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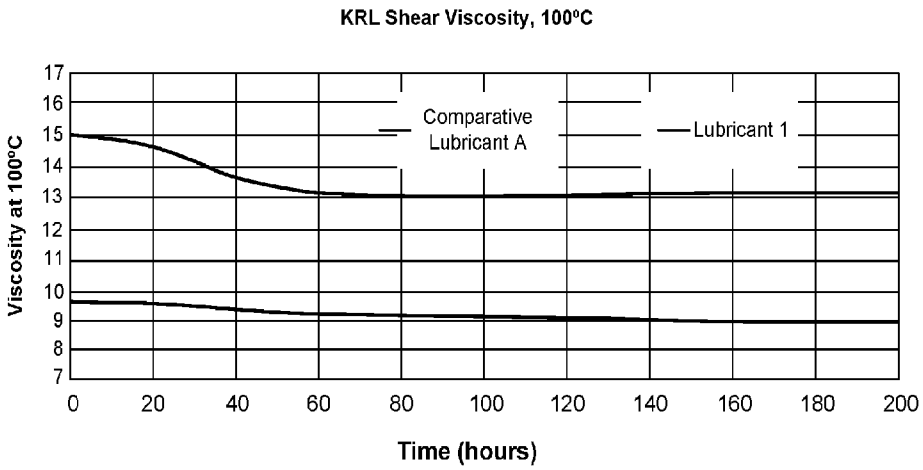

FIG. 5

(57) Abstract: A lubricant composition including a polyalphaolefin base oil component in an amount of about 30 wt.% to about 70 wt.% based on total weight of said lubricant composition and a thickener in an amount up to 30 wt.% based on total weight of said lubricant composition. The lubricant composition has a kinematic viscosity at 100°C of about 5 cSt to about 15 cSt and a kinematic viscosity of at 40°C about 30 cSt to about 70 cSt, each measured in accordance with ASTM D445.

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FUEL EFFICIENT, SHEAR STABLE AXLE LUBRICANT

CROSS REFERENCE TO RELATED APPLICATION(S)

[0001] The present application claims priority to U.S. Provisional Patent Application No. 63/261,970 filed on October 1, 2021, the entire contents of which are incorporated herein.

FIELD OF THE DISCLOSURE

[0002] The present disclosure generally relates to lubricant compositions.

BACKGROUND OF THE DISCLOSURE

[0003] Lubricant compositions are typically required to have a number of performance characteristics associated with the lubricant composition itself and/or with the performance of the equipment in which the lubricant composition is to be used (e.g. vehicles). Recently, market forces and governmental regulations have placed a renewed emphasis on fuel efficiency for vehicles and reduction of Green House Gas (GHG) emissions, *i.e.* CO_2 emissions. Thus, there remains an opportunity to develop a lubricant composition with improved fuel efficiency and reduction in CO_2 emissions.

SUMMARY OF THE DISCLOSURE AND ADVANTAGES

[0003] The present disclosure provides a lubricant composition. The lubricant composition includes a polyalphaolefin base oil component and a thickener. The polyalphaolefin base oil component may be included in an amount from about 30 wt.% to about 70 wt.% based on a total weight of the lubricant composition and a thickener in an amount up to about 30 wt.%, wherein the lubricant composition has a kinematic viscosity at 100°C of about 5 cSt to about 15 cSt and a kinematic viscosity at 40°C of about 30 cSt to about 70 cSt, each measured in accordance with

The lubricant composition may include a second thickener. The lubricant composition may also include a diester. The lubricant composition may also include an additive

package containing at least one additive selected from the group of antioxidants, corrosion inhibitors, foam control additives, extreme pressure additives, anti-wear additives, detergents, and viscosity index improvers, wherein said lubricant composition is essentially free of dispersants. The lubricant composition may be an axle lubricant. The lubricant composition may include a second thickener in an amount up to about 5 wt.%. The second thickener may be a polyisobutene. The lubricant composition may include the ester in an amount up to about 35 wt.%. The lubricant composition may also include an anti-foaming agent in an amount from about 0.001 wt.% to about 1 wt.%.

[0004] The present disclosure also provides an axle lubricant including a polyalphaolefin base oil component and a thickener, wherein the polyalphaolefin base oil component comprises a Type IV base oil, wherein the axle lubricant has a kinematic viscosity at 100°C of about 5 cSt to about 15 cSt and a kinematic viscosity 40°C of about 30 cSt to about 70 cSt, each measured in accordance with ASTM D445. The axle lubricant may have a viscosity index of from about 150 to about 200 as measured in accordance with ASTM D2270. The axle lubricant may include the polyalphaolefin base oil component in an amount of 30 wt.% to about 70 wt.% based on total weight of the axle lubricant. The axle lubricant may include the thickener in an amount up to 30 wt.% based on total weight of the axle lubricant.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] Figure 1 is a bar graph illustrating axle efficiency for certain embodiments of the lubricant composition.

[0006] Figure 2a is a bar graph illustrating greenhouse gas emissions for certain embodiments of the lubricant composition.

[0007] Figure 2b is another bar graph illustrating greenhouse gas consumption for certain embodiments of the lubricant composition.

[0008] Figure 3 is a bar graph illustrating fuel savings for certain embodiments of the lubricant composition.

[0009] Figure 4 is a graph illustrating the shear stability of a lubricant composition of the present application.

[0010] Figure 5 is a graph comparing the shear stability of a lubricant composition of the present application to a commercial composition.

DETAILED DESCRIPTION OF THE DISCLOSURE

[0011] Reference throughout this specification to, for example, "one embodiment," "certain embodiments," "one or more embodiments" or "an embodiment" means that a particular feature, structure, material, or characteristic described in connection with the embodiment is included in at least one embodiment of the invention. Thus, the appearances of the phrases such as "in one or more embodiments," "in certain embodiments," "in one embodiment" or "in an embodiment" in various places throughout this specification are not necessarily referring to the same embodiment of the invention. Furthermore, the particular features, structures, materials, or characteristics may be combined in any suitable manner in one or more embodiments.

[0012] As used herein, the singular forms "a," "an," and "the" include plural references unless the context clearly indicates otherwise. Thus, for example, reference to "an axle" includes an axle as well as more than one axle.

[0013] As used herein, the term "about" in connection with a measured quantity, refers to the normal variations in that measured quantity as expected by one of ordinary skill in the art in making the measurement and exercising a level of care commensurate with the objective of measurement and the precision of the measuring equipment. In certain

embodiments, the term "about" includes the recited number ±10%, such that "about 10" would include from 9 to 11.

[0014] The term "at least about" in connection with a measured quantity refers to the normal variations in the measured quantity, as expected by one of ordinary skill in the art in making the measurement and exercising a level of care commensurate with the objective of measurement and precisions of the measuring equipment and any quantities higher than that. In certain embodiments, the term "at least about" includes the recited number minus 10% and any quantity that is higher such that "at least about 10" would include 9 and anything greater than 9. This term can also be expressed as "about 10 or more." Similarly, the term "less than about" typically includes the recited number plus 10% and any quantity that is lower such that "less than about 10" would include 11 and anything less than 11. This term can also be expressed as "about 10 or less."

[0015] Unless otherwise indicated, all parts and percentages are by weight. Weight percent (wt. %), if not otherwise indicated, is based on an entire composition free of any volatiles, that is, based on dry solids content.

[0016] The present disclosure provides a lubricant composition. The lubricant composition may be utilized in a variety of lubricating applications, and is especially useful as a lubricant for axles, transmissions (manual or automatic), transfer cases, power take off, transaxles, and bearings/wheels. That is, the lubricant composition may be used in both light-duty and heavy-duty axles.

[0017] The lubricant composition includes a polyalphaolefin base oil component. In one or more embodiments, the polyalphaolefin base oil component comprises a Group IV base oil, and is a fully synthetic oil. In other embodiments, the polyalphaolefin base oil component includes a Group I, II, III, IV or V base oil. The polyalphaolefin base oil component may be made through a synthesizing process. During the synthesizing

process, olefins are used to produce the polyalphaolefin base oil. In at least one embodiment, the polyalphaolefin base oil component includes synthetic hydrocarbons.

[0018] In certain embodiments, the lubricant composition includes the polyalphaolefin base oil component in amount of about 30 wt. % to about 70 wt. %, or any individual value or sub-range within this range, based on total weight of the lubricant composition. Alternatively, the lubricant composition includes the polyalphaolefin base oil component in an amount of from about 50 wt. % to about 60 wt. %.

[0019] According to one or more embodiment, the lubricant composition has a kinematic viscosity at 100°C of from about 5 cSt to about 15 cSt when measured in accordance with

American Society for Testing and Materials ("ASTM") D445, alternatively of from about 9 cSt to about 12 cSt. The kinematic viscosity at 100°C may also be about 5 cSt, about 6 cSt, about 7 cSt, about 8 cSt, about 9 cSt, about 10 cSt, about 11 cSt, about 12 cSt, about 13 cSt, about 14 cSt, or about 14 cSt. It is to be understood that for the purpose of this disclosure, any reference to kinematic viscosity is the kinematic viscosity as measured by ASTM D445.

[0020] In one or more embodiments, the lubricant composition also has a kinematic viscosity at 40°C of from about 30 cSt to about 70 cSt when measured in accordance with ASTM D445, alternatively of from about 40 cSt to about 60 cSt. In other embodiments, the kinematic viscosity at 40°C may be about 30 cSt, about 35 cSt, about 40 cSt, about 45 cSt, about 50 cSt, about 55 cSt, about 60 cSt, about 65 cSt, or about 70 cSt.

[0021] The kinematic viscosity of the lubricant composition effects the viscosity index and in turn, the low and high temperature operating range of the product.

[0022] The lubricant composition typically has a viscosity index of from about 150 to about 200 as measured in accordance with ASTM D2270. Alternatively, the lubricant composition may have a viscosity index of from about 160 to about 190, or from about 170 to about 180. It is to be understood that for the purpose of this disclosure, any reference to viscosity index is the viscosity index as measured by ASTM D2270.

[0023] The kinematic viscosity and the viscosity index of the lubricant composition results in the lubricant composition being useful for lubricating an axle of a vehicle, such that the lubricant composition may also be referred to as an axle lubricant. Similarly, the kinematic viscosity and the viscosity index of the lubricant composition results in the lubricant composition being useful for lubricating transmissions (i.e., manual or automatic), transfer cases, transaxles, power take off (PTO), and bearings/wheels. In addition, persons of ordinary skill in the art will also appreciate that the kinematic viscosity of the lubricant composition may make the lubricant composition unsuitable for some applications, such as rotary screw compressor lubricants.

[0024] In one or more embodiments, the lubricant composition has an API gravity of from about 20 to 40 as measured in accordance with ASTM D4052. In at least one embodiment, the lubricant composition may have an API gravity of from about 25 to about 40. In other embodiments, the lubricant composition may have an API gravity of about 20, about 25, about 30, about 35 or about 40.

[0025] In one or more embodiments, the lubricant composition has a Brookfield® viscosity at -40°C of from about 10,000 cP to about 20,000 cP as measured in accordance with ASTM D2983. In at least one embodiment, the lubricant composition may have a Brookfield ® viscosity at -40°C of from about 11,000 cP to about 19,000 cP, from about 12,000 cP to about 18,000 cP, from about 13,000 cP to about 17,000 cP, or from about 14,000 cP to about 16,000 cP.

[0026] In some embodiments, the lubricant composition has a pour point at from about -40 °C to about -55°C, or about -40°C, or about -45°C. In at least one embodiment, the pour point of the lubricant composition is about -42°C.

[0027] The lubricant composition may further include a thickener. The thickener may be included in an amount from about 0 wt. % to about 30 wt. % based on total weight of the composition. In some embodiments, the thickener may be included in an amount from about 1 wt. % to about 25 wt. %, about 5 wt. % to about 20 wt. %, about 7.5 wt. % to about 17.5 wt. %, or about 10 wt.% to about 15 wt. %, or any range, sub range or value herein.

[0028] The thickener may be an olefin copolymer (OCP), polymethacrylate (PMA), polyisobutene (PIB), oil soluble polyalkyl glycol (PAG) (OSP) or high viscosity polyalphaolefin (PAO).

[0029] The thickener may have a kinematic viscosity at 100°C of from about 100 to about 150 cSt, and a kinematic viscosity at 40°C of from about 1000 to about 1200 cSt. The viscosity index of the thickener may be from about 200 to about 250. The density of the thickener may be about 0.9 g/cm^3. In some embodiments, the thickener may have a kinematic viscosity at 100°C of from about 105 to about 145 cSt, about 110 to about 140 cSt, about 115 to about 135 cSt, or about 120 cSt to about 130 cSt; and a kinematic viscosity at 40°C of from about 1050 to about 1150 cSt, or about 1100 to about 1125 cSt, or any range, sub-range or value herein.

[0030] The lubricant composition may further include a second thickener. The second thickener may be included in an amount from about 0 wt.% to about 15 wt.% based on the total weight of the lubricant composition. In some embodiments, the second thickener may be included in an amount of about 1 wt. %, about 2 wt.%, about 3 wt. %, about 4 wt. %, about 5 wt. %, about 6 wt. %, about 7 wt. %, about 8 wt. %, about 9 wt.

%, about 10 wt.%, about 11 wt. %, about 12 wt. %, about 13 wt. %, about 14 wt. %, or about 15 wt. %, based on the total weight of the lubricant composition. The second thickener may be a polyisobutene. The polyisobutene may have a low molecular weight. The molecular weight of the polyisobutene may be about 2,000 g/mol to about 3,000 g/mol. In some embodiments, the molecular weight of the polyisobutene may be about 2,300 g/mol.

[0031] In some embodiments, the lubricant composition may also include an anti-foaming agent. The anti-foaming agent may be a silicon or an ester based anti-foaming agent. The anti-foaming agent may be included in an amount from about 0.001 wt.% to about 1 wt.% based on the total weight of the lubricant composition. In some embodiments, the anti-foaming agent may be included in an amount from about 0.001 wt.% to about 0.75 wt.%, from about 0.001 wt.% to about 0.5 wt.%, or from about 0.01 wt.% to about 0.2 wt.%, based on the total weight of the lubricant composition.

[0032] In some embodiments, the lubricant composition may also include an ester. The ester may be included in an amount from about 0 wt.% to about 40 wt.%, from about 10 wt.% to about 30 wt.%, or from about 15 wt.% to about 25 wt.% based on the total weight of the lubricant composition.

[0033] In some embodiments, the ester may be a dipropylheptanol diester of adipic acid in an amount of from about 15 wt.% to about 25 wt.% based on the total weight of the lubricant composition. In other embodiments, the ester may also be an adipate ester, a polyol ester or a trimethylolpropane ester.

[0034] In some embodiments, the lubricant composition may also include an additive. The additive may be included in an amount from about 0 wt.% to about 15 wt.% based on the total weight of the lubricant composition.

[0035] In the embodiments of the present disclosure, the lubricant composition is generally used to lubricate an axle, transmissions (i.e., manual or automatic), transfer cases, transaxles, power take off (PTO), and/or bearings/wheels of a vehicle while achieving increased fuel efficiency for the vehicle and reducing green house gas emissions. Without being held to any particular theory, it is believed that the combination of the polyalphaolefin base oil component and thickener produce the increased fuel efficiency and reduced green house gas emissions. More specifically, it is believed that the combination of the chemistry and the kinematic viscosity of the lubricant composition impart excellent low and high temperature properties to the lubricant composition, which increases the fuel efficiency of the lubricant composition when the lubricant composition is used to lubricate the above referenced components of the vehicle.

[0036] In certain embodiments, the lubricant composition exhibits improved fuel efficiency in comparison to conventional lubricants. In certain embodiments, the lubricant composition exhibits reduced greenhouse gas emissions when compared to conventional lubricants. In addition, despite demonstrating increased fuel efficiency, the lubricant composition also has good shear stability, among other properties.

[0037] In one or more embodiments, the lubricant composition is an axle lubricant. In this embodiment, the polyalphaolefin base oil component is present in an amount of at least about 50 wt.% based on the total weight of the axle lubricant. Typically, in this embodiment, the polyalphaolefin base oil component is present in an amount of about 50 wt.% to about 60 wt.% based on the total weight of the axle lubricant. Moreover, the axle lubricant of this embodiment is also essentially free of Type I, II, III, and V base oils. Although not required, the axle lubricant of this embodiment may also consist essentially of the components described above and the additive package described below. Without being bound to any particular theory, it is believed that the axle

lubricant of this embodiment increases the fuel efficiency of a vehicle when used to lubricate the axle of the vehicle. More specifically, it is believed that the combination of the chemistry and the kinematic viscosity of the blend of the first and second polyalkylene glycols impart excellent low and high temperature properties to the lubricant composition, which increases the fuel efficiency of the lubricant composition when the lubricant composition is used to lubricate an axle of a vehicle.

[0038] In at least one embodiment, the lubricant composition is a transmission lubricant, a transfer case lubricant, a transaxle lubricant, a power take off lubricant, and/or a bearing/wheel lubricant.

[0039] The lubricating composition may also include an additive package. The additive package includes at least one additive effective to improve at least one property of the lubricant composition and/or the performance of the equipment in which the lubricant composition is to be used. In certain embodiments, the additive package includes one or more additives chosen from antioxidants, corrosion inhibitors, foam control additives, extreme pressure additives, anti-wear additives, detergents, metal passivators, pour point depressant, and viscosity index improvers. Although not required, the additive package and the lubricant composition are generally essentially free of dispersants. In certain embodiments, the additive package, or a portion of the additive package, is commercially available from Afton Chemical under the tradename X-20817 or Lubrizol.

[0040] It is to be appreciated that the individual additives included in the additive package may be combined with one or more other additives prior to being added to the lubricant composition, or in the alternative, the individual additives may be separately added to the lubricant composition. In other words, the additive package does not require that all, or even a portion, of the additives be combined prior to being combined with the polyalphaolefin base oil component.

[0041] When the lubricant composition includes the additive package, the additive package is typically present in an amount of from about 0.001 wt.% to about 20 wt.%, from about 4 wt.% to about 18 wt.%, from about 4 wt.% to about 16 wt.%, from about 4 wt.% to about 14 wt.%, or from about 6 wt.% to about 12 wt.%, based on the total weight of the lubricant composition.

[0042] In regards to the anti-wear additive, any anti-wear additive known in the art may be included. Suitable, non-limiting examples of the anti-wear additive include zinc dialkyl-dithio phosphate ("ZDDP"), zinc dialkyl-dithio phosphates, sulfur- and/or phosphorus- and/or halogen-containing compounds, e.g. sulfurised olefins and vegetable oils, zinc dialkyldithiophosphates, alkylated triphenyl phosphates, tritolyl phosphate, tricresyl phosphate, chlorinated paraffins, alkyl and aryl di- and trisulfides, amine salts of mono- and dialkyl phosphates, amine salts of methylphosphonic acid, diethanolaminomethyltolyltriazole, bis(2-ethylhexyl)aminomethyltolyltriazole, derivatives of 2,5-dimercapto-1,3,4-thiadiazole, ethyl 3-[(diisopropoxyphosphinothioyl)thio]propionate, triphenyl thiophosphate (triphenylphosphorothioate), tris(alkylphenyl) phosphorothioate and mixtures thereof (for example tris(isononylphenyl) phosphorothioate), diphenyl monononylphenyl phosphorothioate, isobutylphenyl diphenyl phosphorothioate, the dodecylamine salt of 3-hydroxy-1,3-thiaphosphetane 3-oxide, trithiophosphoric acid 5,5,5-tris[isooctyl 2-acetate], derivatives of 2-mercaptobenzothiazole such as 1-[N,N-bis (2-ethylhexyl)aminomethyl]-2-mercapto-1H-1,3-benzothiazole, ethoxycarbonyl-5-octyldithio carbamate, ashless anti-wear additives including phosphorous, and/or combinations thereof. In one embodiment, the anti-wear additive is ZDDP.

[0043] If included, the anti-wear additive may be included in the lubricant composition in an amount of from about 0.1 wt.% to about 15 wt.%, alternatively from about 0.1 wt.%

to about 10 wt.%, alternatively from about 0.1 wt.% to about 5 wt.%, alternatively from about 0.1 wt.% to about 4 wt.%, alternatively from about 0.1 wt.% to about 3 wt.%, alternatively from about 0.1 wt.% to about 2 wt.%, alternatively from about 0.1wt.% to about 1 wt.%, alternatively from about 0.1 wt.% to about 0.5 wt.%, based on the total weight of the lubricant composition. The amount of anti-wear additive may vary outside of the ranges above, but is typically both whole and fractional values within these ranges. Further, it is to be appreciated that more than one anti-wear additive may be included in the lubricant composition, in which case the total amount of all the anti-wear additive included is within the above ranges. Further, it is to be appreciated that more than anti-wear additive may be included in the lubricant composition, in which case the total amount of all the anti-wear additives included is within the above ranges.

[0044] Similarly, any pour point depressant known in the art may be included. The pour point depressant is typically selected from polymethacrylate and alkylated naphthalene derivatives, and combinations thereof.

[0045] If present, the pour point depressant may be included in the lubricant composition in an amount of from about 0.001 wt.% to about 1 wt.%, alternatively from about 0.01 wt.% to about 1 wt.%, alternatively from about 0.01 wt.% to about 0.5 wt.%, alternatively from about 0.01 wt.% to about 0.5 wt.%, based on the total weight of the lubricant composition. The amount of pour point depressant may vary outside of the ranges above, but is typically both whole and fractional values within these ranges. Further, it is to be appreciated that more than one pour point depressant may be included in the lubricant composition, in which case the total amount of all the pour point depressant included is within the above ranges.

[0046] In regards to the antifoam agent, any antifoam agent known in the art may be included. The antifoam agent is typically selected from silicone antifoam agents, acrylate copolymer antifoam agents, and combinations thereof.

[0047] If included, the antifoam agent may be included in the lubricant composition in an amount of from about 0.001 wt.% to about 0.5 wt.%, alternatively from about 0.001 wt.% to about 0.25 wt.%, alternatively from about 0.01 wt.% to about 0. wt.%, alternatively from about 0.01 wt.% to about 0.25 wt.%, alternatively from about 0.01 wt.% to about 0.05 wt.%, based on the total weight of the lubricant composition. The amount of antifoam agent may vary outside of the ranges above, but is typically both whole and fractional values within these ranges. Further, it is to be appreciated that more than one antifoam agent may be included in the lubricant composition, in which case the total amount of all the antifoam agent included is within the above ranges.

[0048] If employed, the viscosity index improver may be of various types. Suitable examples of viscosity index improvers include polyacrylates, polymethacrylates, vinylpyrrolidone/methacrylate copolymers, polyvinylpyrrolidones, polybutenes, olefin copolymers, styrene/acrylate copolymers and polyethers, and combinations thereof.

[0049] If employed, the viscosity index improver may be included in various amounts. The viscosity index improver may be present in the lubricant composition in an amount of from about 0.01 wt.% to about 20 wt.%, from about 0.1 wt.% to about 10 wt.%, or from about 0.1 wt.% to about 5 wt.%, from about 1 wt.% to about 15 wt.%, from about 1 wt.% to about 10 wt.%, or from about 1 wt.% to about 5 wt.%, based on the total weight of the lubricant composition. The amount of viscosity index improver may vary outside of the ranges above, but is typically both whole and fractional values within these ranges. Further, it is to be appreciated that more than one viscosity index improver may be

included in the lubricant composition, in which case the total amount of viscosity index improver is within the above ranges.

[0050] If employed, the antioxidant can be of various types. Suitable antioxidants include alkylated monophenols, alkylthiomethylphenols, hydroquinones and alkylated hydroquinones, hydroxylated thiodiphenyl ethers, alkylidenebisphenols, O-, N- and S-benzyl compounds, hydroxybenzylated malonates, triazine compounds, aromatic hydroxybenzyl compounds, benzylphosphonates, acylaminophenols, Esters of [3-(3,5-di-tert-butyl-4-hydroxyphenyl)propionic acid with mono- or polyhydric alcohols, esters of β-(5-tert-butyl-4-hydroxy-3-methylphenyl)-propionic acid with mono- or polyhydric alcohols, aminic antioxidants, aliphatic or aromatic phosphites, esters of thiodipropionic acid or of thiodiacetic acid, salts of dithiocarbamic or dithiophosphoric acid, 2 sulfurized fatty esters, sulfurized fats and sulfurized olefins, and combinations thereof, may be used.

[0051] If included, the antioxidant can be used in various amounts. The antioxidant may be present in the lubricant composition in an amount ranging of from about 0.01wt.% to about 2 wt.% , of from about 0.1 wt.% to about 1 wt. %, or of from about 0.1 wt.% to about 0.5 wt.%, based on total weight of the lubricant composition.

[0052] The present disclosure also provides a method of increasing the fuel efficiency of a vehicle having an axle. The method includes providing the lubricant composition. The method further includes contacting the lubricant composition with the axle of the vehicle to increase the fuel efficiency of the vehicle.

[0053] The present disclosure also provides a method of reducing greenhouse gas emissions of a vehicle having an axle. The method includes providing the lubricant composition. The method further includes contacting the lubricant composition with the axle of the vehicle to reduce the emission of greenhouse gases of the vehicle.

[0054] The present disclosure also provides a method of increasing the fuel efficiency of a vehicle having an axle, transmissions (manual or automatic), transfer cases, transaxles, power take off (PTO), and/or bearings/wheels of a vehicle. The method includes providing the lubricant composition. The method further includes contacting the lubricant composition with at least one component of the vehicle chosen from the group of transmissions (manual or automatic), transfer cases, transaxles, power take offs, bearings/wheels, and combinations thereof to increase the fuel efficiency of the vehicle.

[0055] The present disclosure also provides a method of reducing greenhouse gas emissions of a vehicle having an axle, transmissions (manual or automatic), transfer cases, transaxles, power take off (PTO), and/or bearings/wheels of a vehicle. The method includes providing the lubricant composition. The method further includes contacting the lubricant composition with at least one component of the vehicle chosen from the group of transmissions (manual or automatic), transfer cases, transaxles, power take offs, bearings/wheels, and combinations thereof to reduce emissions of greenhouse gases of the vehicle.

[0056] In one embodiment, the method of the disclosure includes providing the axle lubricant to increase the fuel efficiency of a vehicle having an axle. In this embodiment, the polyalphaolefin base oil component of the axle lubricant is present in an amount of at least about 50 wt.% based on the total weight of the axle lubricant. In addition, the axle lubricant has a kinematic viscosity at 100°C of from about 5 to about 35 cSt and a kinematic viscosity at 40°C of from about 20 to about 300 cSt. The method further includes contacting the lubricant and the axle of the vehicle with the axle lubricant to increase the fuel efficiency of the vehicle.

EXAMPLES

[0057] A lubricant composition within the scope of this disclosure is provided in Table 1 as Lubricant Composition 1. Table 1 also provides two comparative lubricants as Comparative Lubricants A and B. Each individual component for each lubricant in Table 1 is provided in weight percent (wt.%) based on the total weight of the respective lubricant.

Table 1

	Lubricant Composition 1 (Candidate)	Comparative Lubricant A (Commercial 75W-90)	Comparative Lubricant B (Commercial 75W-85)
Base oil	56.46	24.97	46.95
Thickener 1	12.0	-	-
Thickener 2	3.0	-	-
Thickener 3		35.0	
Thickener 4			26.0
Anti-foaming Agent	0.04	0.05	0.05
Ester	20.0	30.0	15.0
Additive	8.5	10.0	10.0
Dispersant	-	-	2.0
Kinematic Vis (100°C) (cSt)	9.8	14.7	12.9
Kinematic Vis (40°C) (cSt)	52.6	98.7	77.2
Viscosity Index	176	156	168
API Gravity	31.1	28.7	32.7
Brookfield Vis (-40°C) (cP)	15,200	65,400	32,000
Pour Point (°C)	-42	-51	-57

Base Oil: polyalphaolefin (PAO7)
Thickener 1: Synative EEB 130
Thickener 2: Glissopal 2300
Thickener 3: Mixture of Polyisobutelene with polyalefaolefin
Thickener 4: High viscosity PAO
Anti-foaming agent: Foam Bam 130B
Ester: DPHA Ester
Additive: Afton X-20817
Dispersant: Market General

[0058] Base Oil is a polyalphaolefin PAO7, having a kinematic viscosity at 100°C of about 7 cSt.

[0059] The physical properties of Lubricant Composition 1 and Comparative Lubricants A-B were measured and are also provided in Table 1. Lubricant Composition 1 was found to have excellent axle efficiency, satisfactory emission of greenhouse gases and improved fuel saving benefits.

[0060] The axle efficiency for Lubricant 1 and Comparative Lubricants A and B was measured using standard test methods. The results for the axle efficiency are provided in Figure 1.

[0061] The emission of greenhouse gases (GHG) was also measured for Lubricant 1 and Comparative Lubricant B. The emission of GHG was measured with a GEM analysis. The results of the GEM analysis is provided in Figures 2a and 2b. As can be seen in these Figures, the emission of GEM emission was improved with Lubricant 1 of the present application.

[0062] The fuel saving benefits of Lubricant Composition 1 and Comparative Example B was also measured and is provided in Figure 3. From this Figure, it can be seen that the Lubricant Composition 1 has improved fuel savings when compared to the commercial lubricant.

[0063] The shear stability of Lubricant 1 was also determined by measuring the kinematic viscosity at 100°C over time 250,000 miles of use in a truck. The shear stability is provided in Figure 4. As can be seen in Figure 4, the shear stability of the viscosity was maintained over the course of 250,000 miles.

[0064] The shear viscosity of Lubricant Composition 1 (Candidate) and Comparative Example A was measured over the course of several hours. The results of which are present in FIG. 5. As can be seen in Figure 5, the Lubricant Composition according to

the present application does not shear over time and maintained the viscosity over the course of 200 hours. In contrast, the Comparative Example A had shear in the beginning of this test. It is preferrable to have as little shear over the course of time because this ensures stability of the lubricant. Thus, the candidate lubricant had improved shear viscosity when compared to commercial lubricants.

[0065] In an embodiment of the present disclosure, a lubricant composition is provided. The lubricant composition may include a polyalphaolefin base oil component in an amount of about 30 wt.% to about 70 wt.% based on total weight of said lubricant composition and a thickener in an amount up to 30 wt.% based on total weight of said lubricant composition, wherein the lubricant composition has a kinematic viscosity at 100°C of about 5 cSt to about 15 cSt and a kinematic viscosity of at 40°C about 30 cSt to about 70 cSt, each measured in accordance with ASTM D445; and/or

wherein the thickener is selected from the group of an olefin copolymer (OCP), polymethylacrylate (PMA), polyisobutene (PIB), oil soluble polyalkyl glycol (PAG) (OSP) high viscosity polyalphaolefin (PAO), and mixtures thereof; and/or

further comprising a second thickener; and/or

further comprising a diester; and/or

further comprising an additive package containing at least one additive selected from the group of antioxidants, corrosion inhibitors, foam control additives, extreme pressure additives, anti-wear additives, detergents, and viscosity index improvers, wherein said lubricant composition is essentially free of dispersants; and/or

wherein the lubricant composition is an axle lubricant; and/or

wherein the polyalphaolefin base oil component is included in an amount of about 50 wt.% to about 60 wt.% based on total weight of said lubricant composition; and/or

wherein the lubricant composition has a kinematic viscosity at 100°C of about 9 cSt to about 12 cSt and a kinematic viscosity of at 40°C about 50 cSt to about 60 cSt, each measured in accordance with ASTM D445; and/or

wherein the second thickener is included in an amount up to about 5 wt.%; and/or

wherein the second thickener is a polyisobutene; and/or

wherein the ester is included in an amount up to about 35 wt.%; and/or

further comprising an anti-foaming agent; and/or wherein the anti-foaming agent is included in an amount from about 0.001 wt.% to about 1 wt.%.

[0066] In another embodiment, an axle lubricant of the present disclosure may include a polyalphaolefin base oil component and a thickener, wherein the polyalphaolefin base oil component comprises a Type IV base oil, wherein said axle lubricant has a kinematic viscosity at 100°C of about 5 to about 15 cSt and a kinematic viscosity at 40°C of about 30 to about 70 cSt, each measured in accordance with ASTM D445; and wherein said axle lubricant has a viscosity index of from about 150 to about 200 as measured in accordance with ASTM D2270; and/or

wherein the polyalphaolefin base oil component is included in an amount of from about 30 wt.% to about 70 wt.% based on total weight of the axle lubricant; and/or

wherein the thickener is included in an amount up to about 30 wt.% based on total weight of the axle lubricant.

[0067] It is to be understood that the appended claims are not limited to express and particular compounds, compositions, or methods described in the detailed description, which may vary between particular embodiments which fall within the scope of the appended claims. With respect to any Markush groups relied upon herein for describing particular features or aspects of various embodiments, different, special, and/or

unexpected results may be obtained from each member of the respective Markush group independent from all other Markush members. Each member of a Markush group may be relied upon individually and or in combination and provides adequate support for specific embodiments within the scope of the appended claims.

[0068] Further, any ranges and subranges relied upon in describing various embodiments of the present disclosure independently and collectively fall within the scope of the appended claims, and are understood to describe and contemplate all ranges including whole and/or fractional values therein, even if such values are not expressly written herein. One of skill in the art readily recognizes that the enumerated ranges and subranges sufficiently describe and enable various embodiments of the present disclosure, and such ranges and subranges may be further delineated into relevant halves, thirds, quarters, fifths, and so on. As just one example, a range "of from 0.1 to 0.9" may be further delineated into a lower third, i.e., from 0.1 to 0.3, a middle third, i.e., from 0.4 to 0.6, and an upper third, i.e., from 0.7 to 0.9, which individually and collectively are within the scope of the appended claims, and may be relied upon individually and/or collectively and provide adequate support for specific embodiments within the scope of the appended claims. In addition, with respect to the language which defines or modifies a range, such as "at least," "greater than," "less than," "no more than," and the like, it is to be understood that such language includes subranges and/or an upper or lower limit. As another example, a range of "at least 10" inherently includes a subrange of from at least 10 to 35, a subrange of from at least 10 to 25, a subrange of from 25 to 35, and so on, and each subrange may be relied upon individually and/or collectively and provides adequate support for specific embodiments within the scope of the appended claims. Finally, an individual number within a disclosed range may be relied upon and provides adequate support for specific embodiments within the scope of

the appended claims. For example, a range "of from 1 to 9" includes various individual integers, such as 3, as well as individual numbers including a decimal point (or fraction), such as 4.1, which may be relied upon and provide adequate support for specific embodiments within the scope of the appended claims. Moreover, the selection of the solvent(s), amount of solvent(s), the choice of polycarboxylate, and both the choice of alkalinity builder(s) and particle size of the alkalinity builder and other solid raw materials, contained within the Formulations generally manipulates the viscosity of the Formulation.

[0069] The present disclosure has been described in an illustrative manner, and it is to be understood that the terminology which has been used is intended to be in the nature of words of description rather than of limitation. Many modifications and variations of the present disclosure are possible in light of the above teachings. The present disclosure may be practiced otherwise than as specifically described. The subject matter of all combinations of independent and dependent claims, both singly and multiply dependent, is herein expressly contemplated.

CLAIMS

1. A lubricant composition comprising:

a polyalphaolefin base oil component in an amount of about 30 wt.% to about 70 wt.% based on total weight of said lubricant composition and

a thickener in an amount up to 30 wt.% based on total weight of said lubricant composition,

wherein the lubricant composition has a kinematic viscosity at 100°C of about 5 cSt to about 15 cSt and a kinematic viscosity of at 40°C about 30 cSt to about 70 cSt, each measured in accordance with ASTM D445.

2. The lubricant composition of claim 1, wherein the thickener is selected from the group of an olefin copolymer (OCP), polymethacrylate (PMA), polyisobutene (PIB), oil soluble polyalkyl glycol (PAG) (OSP),. high viscosity polyalphaolefin (PAO), and mixtures thereof.

3. The lubricant composition of claims 1 or 2, further comprising a second thickener.

4. The lubricant composition in any one of claims 1 through 3, further comprising a diester.

5. The lubricant composition in any one of claims 1 through 4, further comprising an additive package containing at least one additive selected from the group of antioxidants, corrosion inhibitors, foam control additives, extreme pressure additives,

anti-wear additives, detergents, and viscosity index improvers, wherein thelubricant composition is essentially free of dispersants.

6. The lubricant composition as set forth in any one of claims 1 through 5, wherein the lubricant composition is an axle lubricant.

7. The lubricant composition in any of the preceding claims, wherein the polyalphaolefin base oil component is included in an amount of about 50 wt.% to about 60 wt.% based on total weight of said lubricant composition.

8. The lubricant composition in any of the preceding claims, wherein the lubricant composition has a kinematic viscosity at 100°C of about 9 cSt to about 12 cSt and a kinematic viscosity of at 40°C about 50 cSt to about 60 cSt, each measured in accordance with ASTM D445.

9. The lubricant composition of claim 3, wherein the second thickener is included in an amount up to about 5 wt.%.

10. The lubricant composition of claim 3, wherein the second thickener is a polyisobutene.

11. The lubricant composition of claim 4, wherein the ester is included in an amount up to about 35 wt.%.

12. The lubricant composition in any of the preceding claims, further comprising an anti-foaming agent.

13. The lubricant composition of claim 10, wherein the anti-foaming agent is included in an amount from about 0.001 wt.% to about 1 wt.%.

14. An axle lubricant comprising:

a polyalphaolefin base oil component and a thickener, wherein the polyalphaolefin base oil component comprises a Type IV base oil,

wherein said axle lubricant has a kinematic viscosity at 100°C of about 5 to about 15 cSt and a kinematic viscosity at 40°C of about 30 to about 70 cSt, each measured in accordance with ASTM D445; and

wherein said axle lubricant has a viscosity index of from about 150 to about 200 as measured in accordance with ASTM D2270.

15. The axle lubricant of claim 14, wherein the polyalphaolefin base oil component is included in an amount of from about 30 wt.% to about 70 wt.% based on total weight of the axle lubricant.

16. The axle lubricant of claim 14, wherein the thickener is included in an amount up to about 30 wt.% based on total weight of the axle lubricant.

FIG. 1

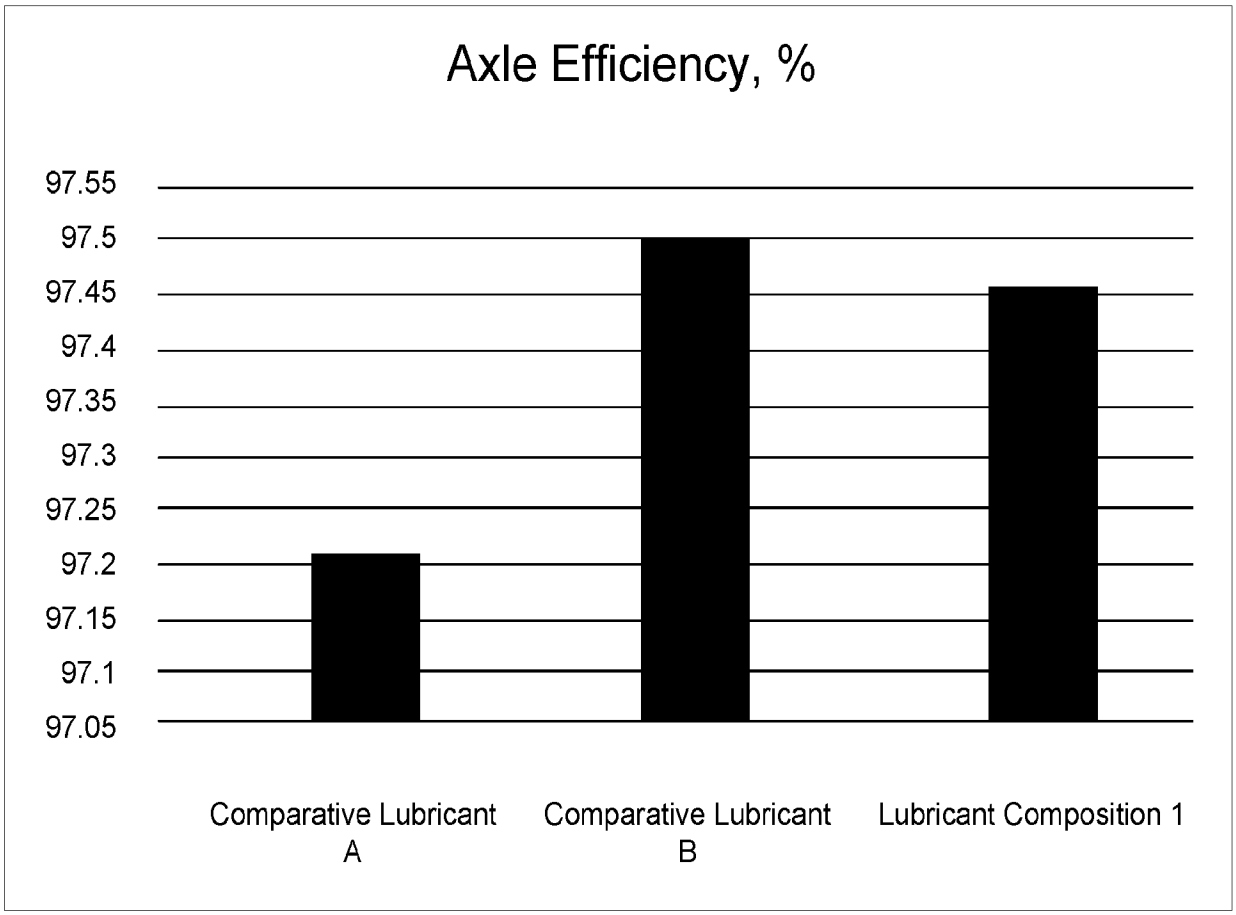

Axle Efficiency, %
97.55
97.5
97.45
97.4
97.35
97.3
97.25
97.2
97.15
97.1
97.05
Comparative Lubricant A
Comparative Lubricant B
Lubricant Composition 1

FIG. 2a

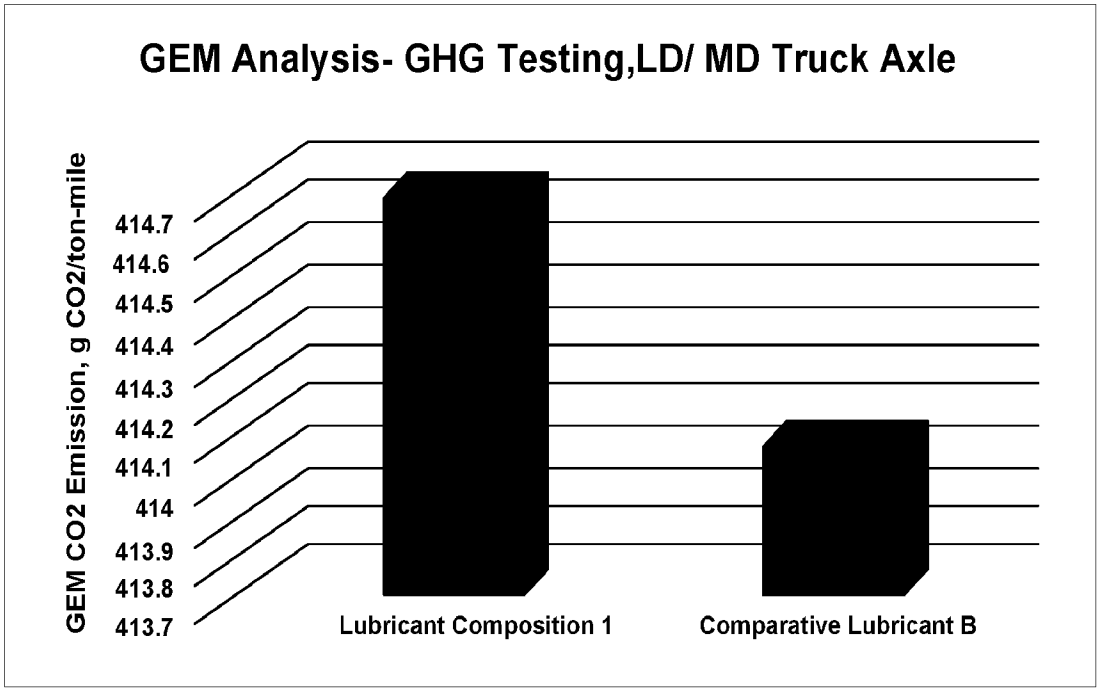

GEM Analysis- GHG Testing,LD/ MD Truck Axle
GEM CO2 Emission, g CO2/ton-mile
414.7
414.6
414.5
414.4
414.3
414.2
414.1
414
413.9
413.8
413.7
Lubricant Composition 1
Comparative Lubricant B

FIG. 2b

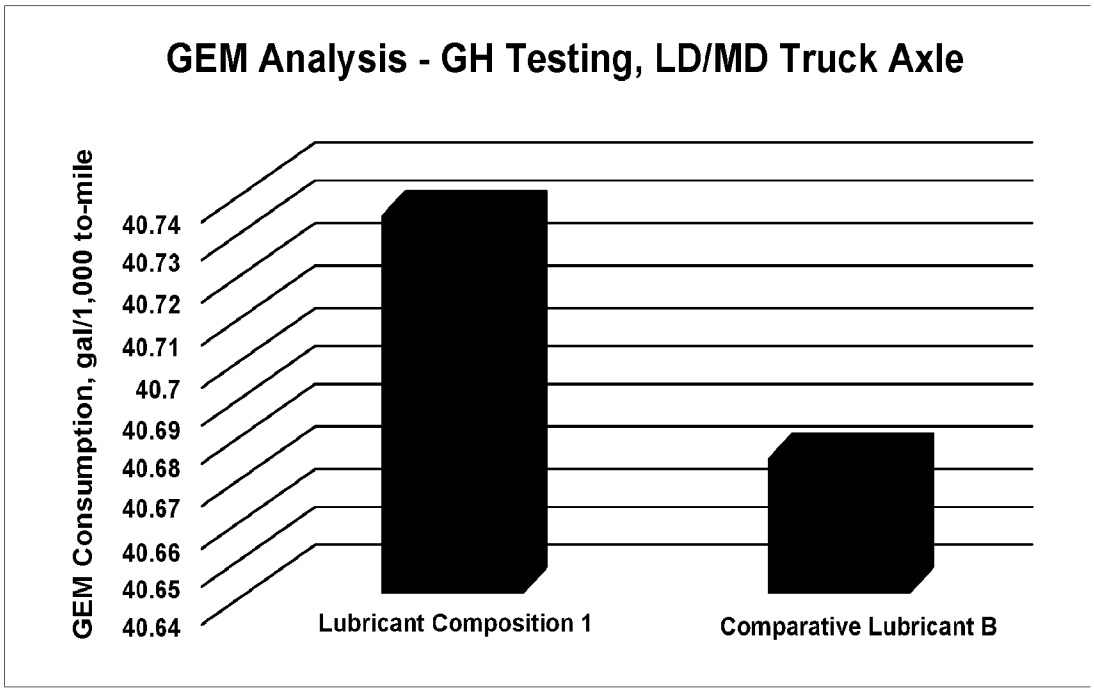

GEM Analysis - GH Testing, LD/MD Truck Axle
GEM Consumption, gal/1,000 to-mile
40.74
40.73
40.72
40.71
40.7
40.69
40.68
40.67
40.66
40.65
40.64
Lubricant Composition 1
Comparative Lubricant B

FIG. 3

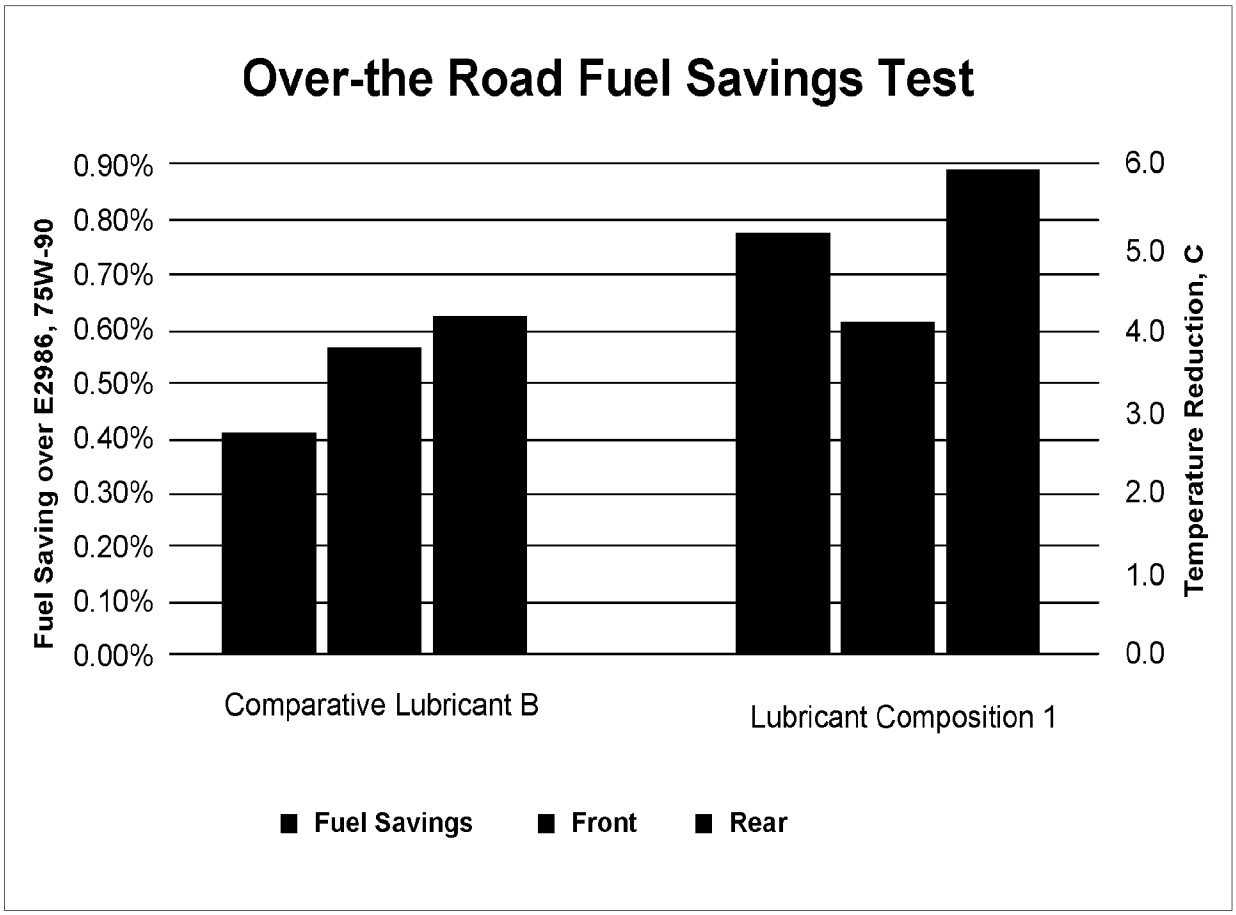

Over-the Road Fuel Savings Test
Fuel Saving over E2986, 75W-90
0.90%
0.80%
0.70%
0.60%
0.50%
0.40%
0.30%
0.20%
0.10%
0.00%
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Temperature Reduction, C
Comparative Lubricant B
Lubricant Composition 1
Fuel Savings
Front
Rear

FIG. 4

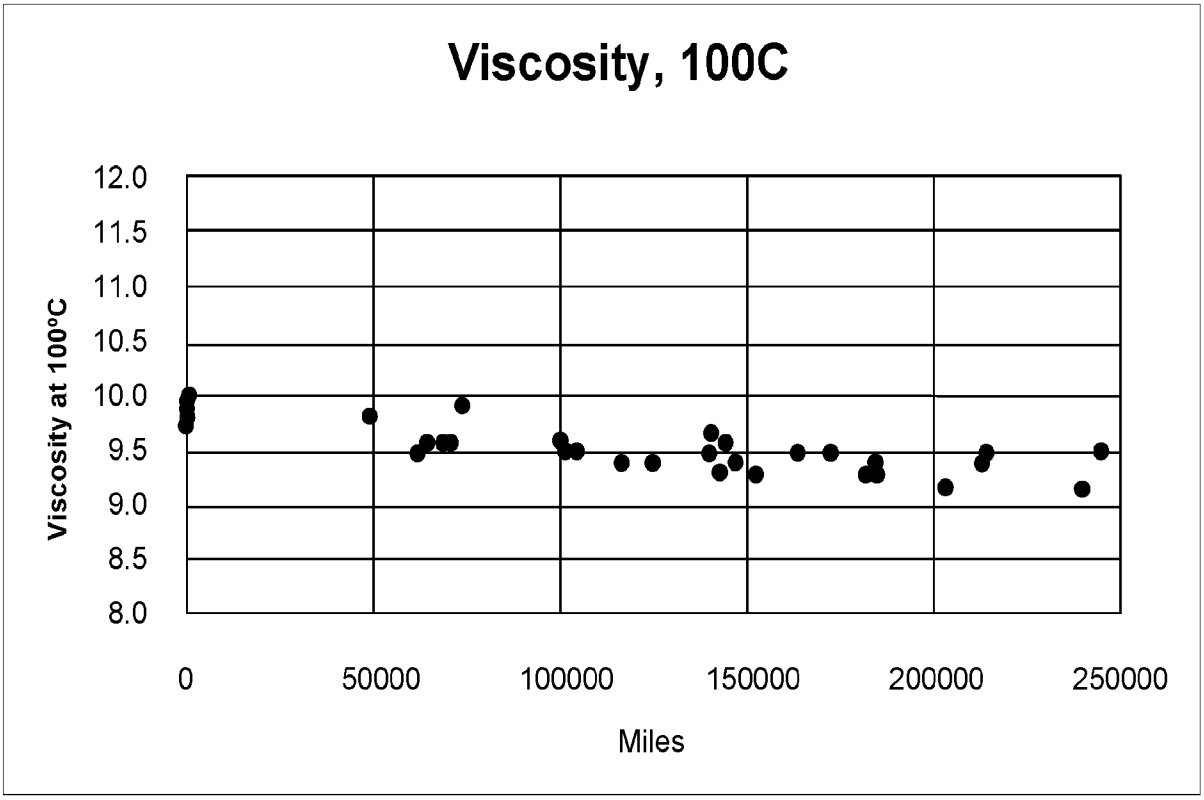
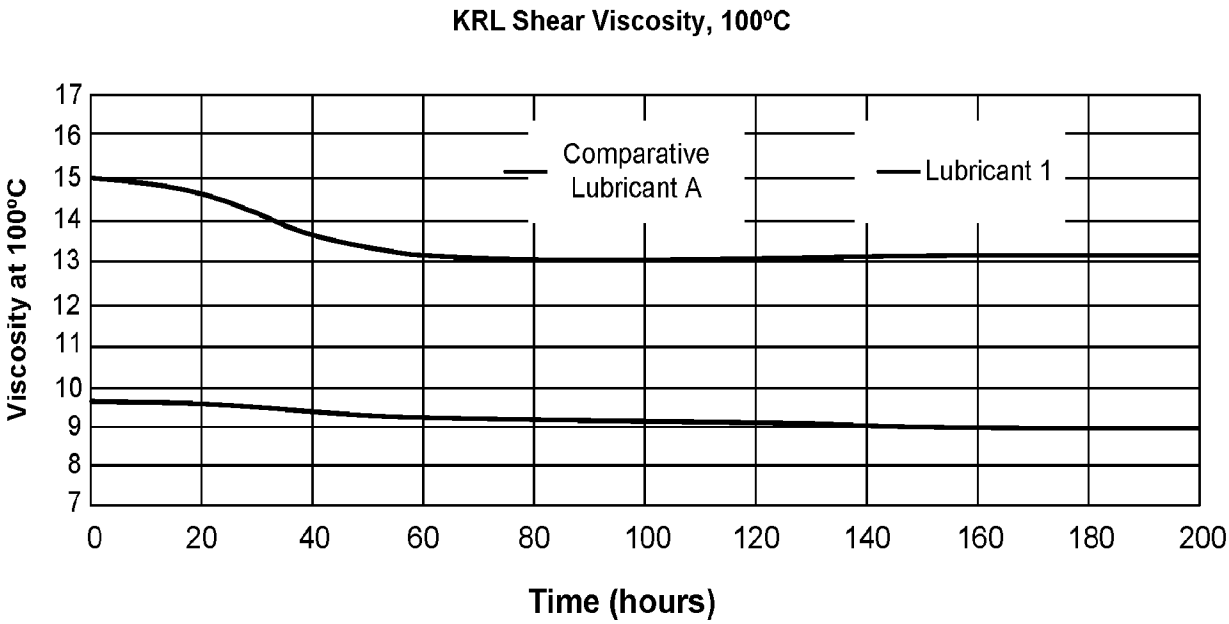

Viscosity, 100C
Viscosity at 100°C
12.0
11.5
11.0
10.5
10.0
9.5
9.0
8.5
8.0
0
50000
100000
150000
200000
250000
Miles

FIG. 5


KRL Shear Viscosity, 100°C
Viscosity at 100°C
17
16
15
14
13
12
11
10
9
8
7
Comparative Lubricant A
Lubricant 1
0
20
40
60
80
100
120
140
160
180
200
Time (hours)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 22/45311

A. CLASSIFICATION OF SUBJECT MATTER

IPC - INV. C10M 107/02, C10M 111/04, C10M 169/04 (2022.01)
ADD. C10M 107/10 (2022.01)

CPC - INV. C10M 107/02, C10M 111/04, C10M 169/04
ADD. C10M 107/10

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
See Search History document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
See Search History document

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2018/0066200 A1 (BASF SE) 8 March 2018 (08.03.2018) Entire document, especially Abstract, para [0002]; [0035]; [0038]; [0108]; [0115]; [0127]; [0137]; [0146]; [0148];	1-3, 9-10, 14-16
A	Profilet. "The Effect of Temperature on Lubricant Viscosity." www.shell.us, Shell USA, Inc., 27 Jan. 2019, https://www.shell.us/business-customers/lubricants-for-business/shell-expertise/our-experts/robert-profilet/effect-of-temperature-on-viscosity.html.	1, 14
A	Dekker. "Differential (Axle) Fluid." My Garage, 27 Mar. 2020, retrieved from http://mygarageairdrie.ca/differential-axle-fluid/.	14
A	US 2006/0196807 A1 (Rosenbaum et al.) 7 September 2006 (07.09.2006) Entire document	1-3, 9-10, 14-16
A	US 2006/0105926 A1 (Hamid) 18 May 2006 (18.05.2006) Entire document	1-3, 9-10, 14-16
A	US 7,129,197 B2 (Song et al.) 31 October 2006 (31.10.2006) Entire document	1-3, 9-10, 14-16
A	US 5,602,086 A (Le et al.) 11 February 1997 (11.02.1997) Entire document	1-3, 9-10, 14-16

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"D" document cited by the applicant in the international application
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
7 December 2022	JAN 25 2023
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer Kari Rodriquez Telephone No. PCT Helpdesk: 571-272-4300

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 22/45311

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☒ Claims Nos.: 4-8, 11-13
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.