

(19)



(11)

EP 4 741 476 A1

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:
13.05.2026 Bulletin 2026/20

(51) International Patent Classification (IPC):
C10M 169/04 ^(2006.01)

(21) Application number: **24211995.6**

(52) Cooperative Patent Classification (CPC):
C10M 169/04; C10M 2205/0285; C10M 2205/173;
C10M 2207/283; C10M 2207/287; C10M 2207/289;
C10M 2209/109; C10N 2020/02; C10N 2030/02;
C10N 2030/06; C10N 2030/12; C10N 2040/14

(22) Date of filing: **11.11.2024**

(84) Designated Contracting States:
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL
NO PL PT RO RS SE SI SK SM TR**
Designated Extension States:
BA
Designated Validation States:
GE KH MA MD TN

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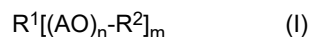
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(54) **LUBRICANT COMPOSITION**

(57) **LUBRICANT COMPOSITION**

This invention provides a lubricating oil composition suitable for use in an electric vehicle, comprising:
a base oil comprising Fischer-Tropsch derived base oils,
poly- α -olefin base oils or mixtures thereof; and in the range of from 0.5 to 12wt% of a friction modifier additive,
wherein the friction modifier additive is a compound of formula (I)



wherein:

R^1 is the residue of a group having at least 2 active hydrogen atoms; m is at least 2;
 AO is an alkylene oxide residue; each n is independently from 0 to 100; and each R^2 is independently H or R^3 , where each
 R^3 is independently a residue of a polyhydroxyalkyl or polyhydroxyalkenyl carboxylic acid, a residue of a hydroxyalkyl or
hydroxyalkenyl carboxylic acid and/or a residue of an oligomer of the hydroxyalkyl or hydroxyalkenyl carboxylic acid; and
on average at least 0.5 of R^2 groups are R^3 ,
wherein the lubricating oil composition has a kinematic viscosity at 100°C in the range of from 2.0 to 5.5 cSt.

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DescriptionField of the Invention

[0001] This invention relates to lubricating oil compositions and, in particular, lubricating oil compositions suitable for e-axle applications.

Background of the invention

[0002] The global electric vehicle (EV) market is growing rapidly, in part due to ever increasing CO₂ emission requirements. Typically, conventional lubricating fluids, designed for use in internal combustion engine vehicles, have been applied in e-drives. However, the development of dedicated fluids comprising e-transmission and e-axle fluids specifically designed to overcome the challenges specific to vehicles with electric motors, including battery electric vehicles (BEVs) and hybrid vehicles, is an important area of research. Critical fluid performance metrics for lubricating oil compositions suitable for EVs include durability, oxidation control, aeration, heat transfer, material compatibility, electrical conductivity and efficiency.

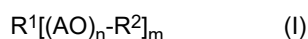
[0003] Energy efficiency is a major challenge across the automotive industry. For an e-axle lubricant composition, low friction has generally been required to improve efficiency. The way to reduce friction must be considered for each lubricating regime. For a hydrodynamic regime, one of the ways to lower friction is to reduce lubricant viscosity. However, as viscosity lowers, anti-wear performance becomes poor. For boundary and mixed lubrication regime, friction modifiers (FMs) may be used to reduce friction by forming adsorption films or tribofilms. However, friction modifiers generally contain reactive polar functional groups, which may promote copper corrosion.

[0004] Lubricating oil compositions for e-axes lubricate both gears and bearings. These are mainly operated in an elastohydrodynamic lubrication regime (EHL). Thus, the technology to reduce friction in an EHL is highly relevant for an e-axle oil. For EHL, low traction base oils are commonly used to reduce friction. A challenge here is that the effect of the base oil to reduce friction is quite limited, so further reduction of EHD friction is required by using a different approach. To solve such challenges, a novel lubricating oil composition must be developed.

Summary of the Invention

[0005] The present invention provides a lubricating oil composition suitable for use in an electric vehicle, comprising:

a base oil comprising Fischer-Tropsch derived base oils, poly- α -olefin base oils or mixtures thereof; and in the range of from 0.5 to 12wt% of a friction modifier additive,
wherein the friction modifier additive is a compound of formula (I)



wherein:

R¹ is the residue of a group having at least 2 active hydrogen atoms; m is at least 2;
AO is an alkylene oxide residue; each n is independently from 0 to 100; and each R² is independently H or R³,
where each R³ is independently a residue of a polyhydroxyalkyl or polyhydroxyalkenyl carboxylic acid, a residue of a hydroxyalkyl or hydroxyalkenyl carboxylic acid and/or a residue of an oligomer of the hydroxyalkyl or hydroxyalkenyl carboxylic acid; and on average at least 0.5 of R² groups are R³,
wherein the lubricating oil composition has a kinematic viscosity at 100°C in the range of from 2.0 to 5.5 cSt.

[0006] The present invention also provides a method for the lubrication of an e-axle said method comprising applying said lubricating oil composition to an e-axle and operating the e-axle, wherein the e-axle is part of a battery electric vehicle or a hybrid electric vehicle.

Detailed Description of the Invention

[0007] One or more specific embodiments of the present disclosure will be described below. These described embodiments are examples of the presently disclosed techniques. Additionally, in an effort to provide a concise description of these embodiments, not all features of an actual implementation may be described in the specification.

[0008] When introducing elements of various embodiments of the present disclosure, the articles "a," "an," and "the" are intended to mean that there are one or more of the elements. The terms "comprising," "including," and "having" are

intended to be inclusive and mean that there may be additional elements other than the listed elements. Additionally, it should be understood that references to "one embodiment" or "an embodiment" of the present disclosure are not intended to be interpreted as excluding the existence of additional embodiments that also incorporate the recited features.

[0009] In the context of the present invention, in a case where a composition comprises two or more components, these components are to be selected in an overall amount not to exceed 100 wt%.

[0010] The present inventors have found that a lubricating oil composition using a certain type of Fischer-Tropsch derived base oil and/or PAO base oil and an ester-based friction modifier, particularly a polymeric ester type friction modifier could overcome the above challenges. The lubricating oil compositions can form adsorption films even under EHL conditions. As well as these characteristics, the compositions described herein give low friction at all regimes and give no harmful impact on wear and copper corrosion.

[0011] Fischer-Tropsch derived base oils are known in the art. By the term "Fischer-Tropsch derived" is meant that a base oil is, or is derived from, a synthesis product of a Fischer-Tropsch process. Fischer-Tropsch derived base oils are often classified by the starting material in the Fischer-Tropsch process, i.e. 'X-to-liquids' or 'XTL', with X standing for said starting material. Biomass-to-liquid (BTL), coal to liquids (CTL), gas-to-liquid (GTL) and power-to-liquid (PTL) processes are some examples of Fischer-Tropsch processes producing base oils. Preferably, the Fischer-Tropsch derived base oil is a GTL (Gas-To-Liquids) base oil.

[0012] Suitable Fischer-Tropsch derived base oils are those as for example disclosed in EP0776959, EP0668342, WO97021788, WO0015736, WO0014188, WO0014187, WO0014183, WO0014179, WO0008115, WO9941332, EP1029029, WO0118156 and WO 0157166.

[0013] A PAO (poly- α -olefin) is an α -olefin homopolymer or copolymer. An α -olefin is a compound with a C-C double bond at the terminal, and specific examples include butene, butadiene, hexene, cyclohexene, methylcyclohexene, octene, nonene, decene, dodecene, tetradecene, hexadecene, octadecene, and eicosene. These can be used alone or in combinations of two or more. These compounds may have any isomeric structure as long as they have a C-C double bond at the terminal and may have a branched structure or a linear structure. These structural isomers and positional isomers with double bonds can be used in combinations of two or more. Among these olefins, a linear olefin having from 6 to 30 carbon atoms is preferred because the flash point is low when the number of carbon atoms is five or less, and the viscosity is high and the olefin impractical when the number of carbon atoms is 31 or higher.

[0014] In embodiments wherein the base oil comprises a Fischer-Tropsch derived base oil, the Fischer-Tropsch derived base oil preferably has a kinematic viscosity at 100°C of at least 1.5 cSt, more preferably at least 1.8 cSt. The kinematic viscosity of the Fischer-Tropsch derived base oil is preferably less than 7.0 cSt, preferably 6.0 cSt or less or 5.0 cSt or less.

[0015] In embodiments wherein the base oil comprises a poly- α -olefin base oil, the poly- α -olefin derived base oil preferably has a kinematic viscosity at 100°C of at least 1.5 cSt. The kinematic viscosity of the poly- α -olefin base oil is preferably less than 7.0 cSt, preferably 6.0 cSt or less or 5.0 cSt or less.

[0016] The amount of base oil comprising Fischer Tropsch derived base oil and/or poly- α -olefin base oil in the lubricating oil composition of the invention is preferably not less than 70 wt% in terms of the total amount of the lubricating oil composition, and more preferably not less than 75 wt%.

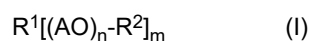
[0017] Preferably, the base oil comprising Fischer Tropsch derived base oil and/or poly- α -olefin base oil contains no less than 75wt%, preferably not less than 90wt%, of Fischer-Tropsch derived base oil and/or poly- α -olefin base oil based on the overall amount of base oil. In one embodiment, the base oil consists substantially of Fischer-Tropsch derived base oil, poly- α -olefin base oil or mixtures thereof.

[0018] Optionally, as well as Fischer-Tropsch derived base oils, poly- α -olefin base oils or mixtures thereof, other base oils may also be incorporated into the lubricating oil composition. In one embodiment of the present invention, an ester base oil is incorporated into the lubricating oil composition. Said ester base oil may be any of monoesters, diesters and partial or total esters of polyhydric alcohols. Suitable monoesters include branched or unbranched, saturated or unsaturated monoesters of fatty acids and alcohols. The fatty acid is preferably a C₆ to C₂₂ branched or unbranched, and saturated or unsaturated, fatty acid. Such fatty acids include, but are not limited to, stearic acid and oleic acid. The alcohol is preferably a C₄ to C₂₀ branched or unbranched, and saturated or unsaturated, alcohol.

[0019] If used in the lubricating oil composition, the ester base oils preferably have a kinematic viscosity at 100°C in the range of from 1.5 to 4.0 cSt, more preferably in the range of from 2.0 to 3.5 cSt.

[0020] Suitably, said ester base oil, if present, is present in an amount in the range of from 1.0 to 20 wt% based on the overall amount of base oil. In this embodiment of the invention, it is preferred that apart from the ester base oil, the remaining base oil consists essentially of Fischer-Tropsch derived base oils, poly- α -olefin base oils or mixtures thereof.

[0021] The lubricating oil composition also comprises a friction modifier additive, which is a compound of formula (I)



wherein:

R¹ is the residue of a group having at least 2 active hydrogen atoms; m is at least 2;

AO is an alkylene oxide residue; each n is independently from 0 to 100; and each R² is independently H or R³, where each R³ is independently a residue of a polyhydroxyalkyl or polyhydroxyalkenyl carboxylic acid, a residue of a hydroxyalkyl or hydroxyalkenyl carboxylic acid and/or a residue of an oligomer of the hydroxyalkyl or hydroxyalkenyl carboxylic acid; and on average at least 0.5 of R² groups are R³.

[0022] The friction modifier additive is at least notionally built up from the group R¹ that can be considered as the "core group" of the compound. This core group is the residue (after removal of m active hydrogen atoms) of a compound containing at least 2 active hydrogen atoms, preferably present in hydroxyl and/or amino groups, and more preferably present in hydroxyl groups only. Preferably the core group is the residue of a substituted hydrocarbyl group, particularly a C3 to C30 substituted hydrocarbyl compound.

[0023] Examples of R¹ core groups include the residues of the following compounds after removal of m active hydrogen atoms:

- 1) glycerol and the polyglycerols, especially diglycerol and triglycerol, the partial esters thereof, or any triglycerides containing multiple hydroxyl groups, for example castor oil;
- 2) tri- and higher polymethylol alkanes such as trimethylol ethane, trimethylol propane, pentaerythritol and dipentaerythritol, and the partial esters thereof;
- 3) sugars, particularly non-reducing sugars such as sorbitol, mannitol, and lactitol, etherified derivatives of sugars such as sorbitan (the cyclic dehydro-ethers of sorbitol), partial alkyl acetals of sugars such as methyl glucose and alkyl (poly-) saccharides, and other oligo-/poly-mers of sugars such as dextrans, partially esterified derivatives of sugars, such as fatty acid esters, for example of lauric, palmitic, oleic, stearic and behenic acid, esters of sorbitan, sorbitol, and sucrose, aminosaccharides such as N-alkylglucamines and their respective N-alkyl-N-alkenoyl glucamides;
- 4) polyhydroxy carboxylic acids especially citric and tartaric acids;
- 5) amines including di- and poly-functional amines, particularly alkylamines including alkyl diamines such as ethylene diamine (1,2-diaminoethane);
- 6) amino-alcohols, particularly the ethanolamines, 2-aminoethanol, di ethanolamine and triethanolamine;
- 7) carboxylic acid amides such as urea, malonamide and succinamide; and
- 8) amido carboxylic acids such as succinamic acid.

[0024] Preferred R¹ core groups are residues of groups having at least three, more preferably in the range from 4 to 10, particularly 5 to 8, and especially 6 free hydroxyl and/or amino groups. The R¹ group preferably has a linear C4 to C7, more preferably C5 chain. The hydroxyl or amino groups are preferably directly bonded to the chain carbon atoms. Hydroxyl groups are preferred.

[0025] R¹ is preferably the residue of an open chain tetraol, pentitol, hexitol or heptitol group or an anhydro, e.g., cycloether anhydro, derivative of such a group. In a particularly preferred embodiment, R¹ is the residue of, or a residue derived from, a sugar, more preferably a monosaccharide such as glucose, fructose or sorbitol, a disaccharide such as maltose, palitose, lactitol or lactose or a higher oligosaccharide. R¹ is preferably the residue of a monosaccharide, more preferably of glucose, fructose, or sorbitol, and particularly of sorbitol.

[0026] The open chain form of R¹ groups is preferred, however groups including internal cyclic ether functionality can be used and may be obtained inadvertently if the synthetic route exposes the group to relatively high temperatures or other conditions, which promote such cyclisation.

[0027] The index m is a measure of the functionality of the R¹ core group and the alkoxylation reactions will replace some, or all, of the active hydrogen atoms (dependent on the molar ratio of core group to alkoxylation group) in the molecule from which the core group is derived. Reaction at a particular site may be restricted or prevented by steric hindrance or suitable protection. The terminating hydroxyl groups of the polyalkylene oxide chains in the resulting compounds are then available for reaction with the above defined acyl compounds. The index m will preferably be at least 3, more preferably in the range from 4 to 10, particularly 5 to 8, and especially 5 to 6. Mixtures may be, and normally are, employed, and therefore m can be an average value and may be non-integral.

[0028] The alkylene oxide groups AO are typically groups of the formula: $-(C_rH_{2r}O)-$ where r is 2, 3 or 4, preferably 2 or 3, i.e., an ethyleneoxy $-(C_2H_4O)-$ or propyleneoxy $-(C_3H_6O)-$ group, and it may represent different groups along the alkylene oxide chain.

[0029] Generally, it is desirable that the chain is a homopolymeric ethylene oxide chain. However, the chain may be a homopolymer chain of propylene glycol residues or a block or random copolymer chain containing both ethylene glycol and propylene glycol residues. Usually, where copolymeric chains of ethylene and propylene oxide units are used the molar proportion of ethylene oxide units used will be at least 50% and more usually at least 700.

[0030] The number of alkylene oxide residues in the (poly)alkylene oxide chains, i.e., the average value of the parameter n, will suitably be in the range from 1 to 50, preferably 2 to 30, more preferably 2 to 20, particularly 2 to 10, and especially 3 to

8.

[0031] The groups are the "terminating groups" of the (poly)alkylene oxide chains. The terminating groups are hydrogen or R^3 , where each R^3 is independently a residue of a polyhydroxyalkyl or polyhydroxyalkenyl carboxylic acid, a residue of a hydroxyalkyl carboxylic acid or hydroxyalkenyl carboxylic acid and/or a residue of an oligomer of the hydroxyalkyl or hydroxyalkenyl carboxylic acid. Preferably each R^A is independently a residue of a polyhydroxyalkyl carboxylic acid, a residue of a hydroxyalkyl carboxylic acid and/or a residue of an oligomer of the hydroxyalkyl carboxylic acid, more preferably a residue of a polyhydroxyalkyl carboxylic acid.

[0032] Suitably at least 1.0, preferably at least 1.5, more preferably at least 2.0, particularly at least 2.2, and especially at least 2.4 of the R^2 groups are R^3 . In addition, suitably up to 6.0, preferably up to 4.0, more preferably up to 3.0, particularly up to 2.7, and especially up to 2.5 of the R^2 groups are R^3 .

[0033] The hydroxyalkyl and hydroxyalkenyl carboxylic acids are of formula $HO-X-COOH$ where X is a divalent saturated or unsaturated, preferably saturated, aliphatic radical containing at least 8 carbon atoms and no more than 20 carbon atoms, typically from 11 to 17 carbons and in which there are at least 4 carbon atoms directly between the hydroxyl and carboxylic acid groups. Desirably the hydroxyalkyl carboxylic acid is 12-hydroxystearic acid. In practice such hydroxyalkyl carboxylic acids are commercially available as mixtures of the hydroxyl acid and the corresponding unsubstituted fatty acid. For example, 12-hydroxystearic acid is typically manufactured by hydrogenation of castor oil fatty acids including the C18 unsaturated hydroxyl acid and the non-substituted fatty acids (oleic and linoleic acids) which on hydrogenation gives a mixture of 12-hydroxystearic and stearic acids. Commercially available 12-hydroxystearic acid typically contains about 5 to 8% of unsubstituted stearic acid.

[0034] The polyhydroxyalkyl or polyhydroxyalkenyl carboxylic acid may be manufactured by polymerizing the above hydroxyalkyl or hydroxyalkenyl carboxylic acid. The presence of the corresponding unsubstituted fatty acid acts as a terminating agent and therefore limits the chain length of the polymer. Desirably the number of hydroxyalkyl or hydroxyalkenyl units is on average from 2 to 12, preferably from 3 to 10, more preferably from 4 to 9, particularly from 5 to 8, and especially 6 to 7. The molecular weight of the polyacid is typically from 600 to 3,000, particularly from 900 to 2,700, more particularly from 1,500 to 2,400 and especially about 2,100.

[0035] The residual acid value for the polyhydroxyalkyl or polyhydroxyalkenyl carboxylic acid typically is less than 50 mgKOH/g and a preferable range is 30 to 35 mgKOH/g. Typically the hydroxyl value for the polyhydroxyalkyl or polyhydroxyalkenyl carboxylic acid is a maximum of 40 mgKOH/g and a preferable range is 20 to 30 mgKOH/g.

[0036] The oligomer of the hydroxyalkyl or hydroxyalkenyl carboxylic acid may differ from the polymer in that termination is not by the unsubstituted corresponding fatty acid. Desirably it is a dimer of the hydroxyalkyl or hydroxyalkenyl carboxylic acid.

[0037] In one preferred embodiment, on average suitably at least 1.0, preferably at least 1.5, more preferably at least 2.0, particularly at least 2.3, and especially at least 2.4 of the

R^2 groups are groups which are polyhydroxyalkyl carboxylic acid residues. In addition, on average suitably up to 4.0, preferably up to 3.5, more preferably up to 3.0, particularly up to 2.7, and especially up to 2.5 of the R^2 groups are R^3 groups which are polyhydroxyalkyl carboxylic acid residues. These polyhydroxyalkyl carboxylic acid residues suitably contain on average from 3 to 10, preferably from 4 to 9, more preferably from 5 to 8, particularly from 6 to 7, and especially 7 hydroxyalkyl monomer units.

[0038] The polyhydroxyalkyl carboxylic acid residues are preferably terminated with an unsubstituted carboxylic acid, more preferably with stearic acid.

[0039] In another preferred embodiment, when the groups comprise hydroxyalkyl carboxylic acid residues, preferably polyhydroxyalkyl carboxylic acid residues, the total number of all of the hydroxyalkyl carboxylic acid residues present in the compound of Formula (I) defined herein is suitably on average in the range from 5 to 30, preferably 8 to 20, more preferably 10 to 17, particularly 12 to 15, and especially 13 to 14 hydroxyalkyl monomer units.

[0040] In a further preferred embodiment, on average suitably at least 2.0, preferably at least 2.5, more preferably at least 3.0, particularly at least 3.3, and especially at least 3.5 of the R^2 groups are H. In addition, on average suitably up to 5.0, preferably up to 4.5, more preferably up to 4.0, particularly up to 3.7, and especially up to 3.6 of the R^2 groups are H.

[0041] When the core group is derived from, for example, pentaerythritol, alkoxylation of the core residue may be evenly distributed over the four available sites from which an active hydrogen can be removed and on esterification of the terminal hydroxyl functions the distribution of acyl groups will be close to the expected random distribution. However, when the core group is derived from compounds, such as sorbitol, where all of the active hydrogen atoms are not equivalent, alkoxylation may give unequal chain lengths for the polyalkyleneoxy chains.

[0042] The friction modifier additive can be made by firstly alkoxyating R^1 core groups containing m active hydrogen atoms, by techniques well known in the art, for example those set out in WO2022251423.

[0043] As well as the base oil and the friction modifier additive, the lubricating oil composition may also contain one or

more further additives. Said additives may be incorporated into the lubricating oil composition as individual additives or a part of a combined additive package. As is known, each additive or additive package may optionally be provided in a diluent fluid, such as a base oil.

[0044] Typical additives in the lubricating oil composition of the present invention include, but are not limited to, extreme pressure additives, anti-wear additives, antioxidants, detergents, dispersants and corrosion inhibitors.

[0045] The lubricating oil composition has a kinematic viscosity at 100°C in the range of from 2.0 to 5.5 cSt. Preferably, the lubricating oil composition has a kinematic viscosity at 100°C in the range of from 2.5 to 5.2 cSt.

[0046] Further, the lubricating oil composition preferably has a phosphorus content of at least 0.030 wt% based on the overall mass of the lubricating oil composition.

[0047] The lubricating oil composition may be used in any suitable application. However, it is preferred that the lubricating oil composition is used as a e-axle oil in an electric vehicle. Said electric vehicle may be a fully battery powered electric vehicle or any form of hybrid electric vehicle wherein at least part of the motive power is provided by an electric motor.

[0048] The invention will now be further illustrated by reference to the following non-limiting examples.

Examples

[0049] A number of lubricant compositions were blended according to Tables 1 to 4 using the following components.

Base Oil 1 - GTL base oil with a KV100 of 1.8 cSt

Base Oil 2 - GTL base oil with a KV100 of 2.7 cSt

Base Oil 3 - GTL base oil with a KV100 of 4.1 cSt

Base Oil 4 - GTL base oil with a KV100 of 7.8 cSt

Base Oil 5 - PAO base oil with a KV100 of 1.7 cSt

Base Oil 6 - mineral oil with a KV100 of 2.1 cSt

Base Oil 7 - mono-ester base oil with a KV100 of 2.8 cSt

Additive packages 1 and 2 - industry standard additive packages suitable for an E-axle

FM 1 - friction modifier of formula $R^1[(AO)_n-R^2]_m$

FM 2 - glycerol monooleate friction modifier

FM 3 - MoDTC friction modifier

FM 4 - polymethacrylate friction modifier (mw = 20,000)

FM 5 - oleylamine friction modifier

VM - styrene diene copolymer viscosity modifier (mw = 140000)

[0050] The following tests were carried out and the results are reported in Tables 1 to 4.

Kinematic viscosity at 40°C (KV40) and 100°C (KV100) were measured according to JIS K 2283.

Viscosity index was measured according to JIS K 2283.

Elemental concentrations are given in wt% and were measured according to JIS 5S 38 (P and Mo), JIS K 2541-4 (S) and JIS K 2609 (N).

MTM EHD traction coefficient was measured at 40°C, Pmax 1.0GPa, Sliding speed 2.0 m/s, steel disc-steel ball (specimen roughness: less than Ra 0.01µm).

MTM boundary coefficient was measured at 40°C, Pmax 1.0GPa, sliding speed 0.01m/s, SRR 500, steel disc-steel ball (specimen roughness: less than Ra 0.01µm).

Cu corrosion is reported as ppm Cu concentration after test measured according to JIS K 2513, Temperature 150°C, Test duration 24 hours.

4 ball wear was measured according to ASTM D 417 Temperature 100°C, Load 392N(40kgf), Rotation speed 1500rpm, Test duration 1h.

[0051] The Examples show that by formulating a lubricating oil composition with a kinematic viscosity in the range of from 2.0 to 5.5 cSt, using Fischer-Tropsch derived base oil or PAO base oil in combination with in the range of amounts of an ester friction modifier as set out in claim 1, a lubricating oil composition with excellent friction and anti-wear characteristics suitable for use as an e-axle oil can be provided.

[0052] The improvement demonstrated by this friction modifier can be shown by comparing any of the inventive examples with comparative Example 1 (Fischer-Tropsch derived base oil and no friction modifier) and comparative Example 7, which contains instead a viscosity modifier. Comparisons with different friction modifiers can be seen in comparative examples 3 to 6, which demonstrate high levels of copper corrosion, poor anti-wear performance and/or raised EHD traction coefficients.

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[0053] The beneficial effect of the combination of Fischer-Tropsch derived base oil or PAO base oil and the friction modifier is shown to start eroding at the high levels of FM used in comparative Example 2.

[0054] Comparative Example 8 which contains a Fischer-Tropsch derived base oil but is a lubricating oil composition with a higher kinematic viscosity at 100°C provides an undesirably high MTM EHD traction coefficient. The use of mineral oils is shown in comparative Example 9 which uses a different type of base oil (mineral oil) and also provides an undesirably high MTM EHD traction coefficient.

Table 1 - Inventive Examples 1 to 6

	1	2	3	4	5	6
Base oil 1	-	-	-	-	89.5	-
Base oil 2	91	89.5	87	82	-	-
Base oil 3						89.5
Additive package 1	8	8	8	8	8	8
FM 1	1	2.5	5	10	2.5	2.5
Total	100.0	100.0	100.0	100.0	100.0	100.0
KV40	12.22	13.45	15.86	22.30	8.23	24.11
KV100	3.191	3.455	3.956	5.195	2.527	5.123
Viscosity index	129	138	153	176	146	148
P	0.037	0.037	0.037	0.037	0.037	0.037
Mo	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
S	0.094	0.094	0.094	0.094	0.094	0.094
N	0.08	0.08	0.08	0.08	0.08	0.08
MTM EHD traction coefficient	0.040	0.040	0.039	0.038	0.034	0.040
MTM boundary friction coefficient	0.09	0.09	0.08	0.08	0.09	0.08
CU corrosion	1	1	1	1	2	1
4 ball wear	0.48	0.46	0.47	0.46	0.45	0.46

Table 2 - Inventive Examples 7 to 11

	7	8	9	10	11
Base oil 2		79.5	88.5	88.5	87
Base oil 5	89.5				
Base oil 7	-	10	-	-	-
Additive package 1	8	8		8	8
Additive package 2	-	-	9	-	-
FM 1	2.5	2.5	2.5	2.5	2.5
FM 2	-	-	-	1	-
FM 4	-	-	-	-	2.5
Total	100.0	100.0	100.0	100.0	100.0
KV4 0	12.81	13.43	13.72	13.78	14.82
KV100	3.343	3.478	3.493	3.486	3.803
Viscosity index	138	142	138	135	156
P	0.037	0.037	0.031	0.037	0.037
Mo	<0.001	<0.001	<0.001	<0.001	<0.001

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(continued)

	7	8	9	10	11
S	0.094	0.094	0.024	0.094	0.094
N	0.08	0.08	0.13	0.08	0.08
MTM EHD traction coefficient	0.039	0.039	0.040	0.039	0.040
MTM boundary friction coefficient	0.09	0.09	0.09	0.09	0.09
CU corrosion	1	2	3	3	2
4 ball wear	0.46	0.48	0.49	0.48	0.47

Table 3 - Comparative Examples 1 to 5

	1	2	3	4	5
Base oil 2	92	77	91	91	89.5
Additive package 1	8	8	8	8	8
FM 1	-	15	-	-	-
FM 2	-	-	1	-	-
FM 3	-	-	-	1	-
FM 4	-	-	-	-	2.5
Total	100.0	100.0	100.0	100.0	100.0
KV4 0	11.48	27.70	12.15	11.53	12.56
KV100	3.025	6.281	3.092	3.034	3.322
Viscosity index	122	188	115	122	141
P	0.037	0.037	0.037	0.037	0.037
Mo	<0.001	<0.001	<0.001	0.042	<0.001
S	0.094	0.094	0.094	0.094	0.094
N	0.08	0.08	0.08	0.08	0.08
MTM EHD traction coefficient	0.042	0.033	0.042	0.042	0.042
MTM boundary friction coefficient	0.11	0.09	0.09	0.09	0.11
CU corrosion	1	50	3	190	2
4 ball wear	0.64	0.45	0.41	0.41	0.61

Table 4 - Comparative Examples 6 to 9

	6	7	8	9
Base oil 2	91	89.5	-	-
Base oil 4	-	-	89.5	-
Base oil 6	-	-	-	89.5
Additive package 1	8	8	8	8
FM 1	-	-	2.5	2.5
FM 5	1	-	-	-
VM	-	2.5	-	-
Total	100.0	100.0	100.0	100.0
KV40	11.69	12.53	52.75	11.75
KV100	3.091	3.262	8.836	3.148

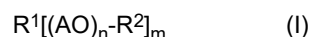
(continued)

	6	7	8	9
Viscosity index	127	132	146	136
P	0.037	0.037	0.037	0.037
Mo	<0.001	<0.001	<0.001	<0.001
S	0.094	0.094	0.094	0.094
N	0.08	0.08	0.08	0.08
MTM EHD traction coefficient	0.041	0.042	0.044	0.046
MTM boundary friction coefficient	0.09	0.11	0.07	0.09
CU corrosion	170	1	2	1
4 ball wear	0.38	0.62	0.45	0.45

Claims

1. A lubricating oil composition suitable for use in an electric vehicle, comprising:

a base oil comprising Fischer-Tropsch derived base oils, poly- α -olefin base oils or mixtures thereof; and in the range of from 0.5 to 12wt% of a friction modifier additive, wherein the friction modifier additive is a compound of formula (I)



wherein:

R^1 is the residue of a group having at least 2 active hydrogen atoms; m is at least 2; AO is an alkylene oxide residue; each n is independently from 0 to 100; and each R^2 is independently H or R^3 , where each R^3 is independently a residue of a polyhydroxyalkyl or polyhydroxyalkenyl carboxylic acid, a residue of a hydroxyalkyl or hydroxyalkenyl carboxylic acid and/or a residue of an oligomer of the hydroxyalkyl or hydroxyalkenyl carboxylic acid; and on average at least 0.5 of R^2 groups are R^3 , wherein the lubricating oil composition has a kinematic viscosity at 100°C in the range of from 2.0 to 5.5 cSt.

2. The lubricating oil composition as claimed in Claim 1, wherein the Fischer-Tropsch derived base oil has a kinematic viscosity at 100°C of at least 1.5 cSt and less than 7.0 cSt.
3. The lubricating oil composition as claimed in Claim 1 or Claim 2, wherein the poly- α -olefin base oil has a kinematic viscosity at 100°C of at least 1.5 cSt and less than 7.0 cSt.
4. The lubricating oil composition as claimed in any one of Claims 1 to 3, wherein the base oil comprising Fischer Tropsch derived base oil and/or poly- α -olefin base oil contains no less than 75wt% of Fischer-Tropsch derived base oil and/or poly- α -olefin base oil based on the overall amount of base oil.
5. The lubricating oil composition as claimed in any one of claims 1 to 4, also comprising in the range of from 1.0 to 20wt% of an ester base oil having a kinematic viscosity at 100°C in the range of from 1.5 to 4.0 cSt.
6. The lubricating oil composition as claimed in any one of claims 1 to 5, wherein the lubricating oil composition has a kinematic viscosity at 100°C in the range of from 2.5 to 5.2 cSt.
7. The lubricating oil composition as claimed in any one of claims 1 to 6, wherein the lubricating oil composition preferably has a phosphorus content of at least 0.030 wt% based on the overall mass of the lubricating oil composition.
8. A method for the lubrication of an e-axle said method comprising applying the lubricating oil composition of any one of claims 1 to 7 to an e-axle and operating the e-axle, wherein the e-axle is part of a battery electric vehicle or a hybrid

electric vehicle.

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