PHOSPHORUS ANTIWEAR SYSTEM FOR IMPROVED GEAR PROTECTION

TECHNICAL FIELD

[0001] The present disclosure relates to lubricating compositions for transmissions and gearboxes.

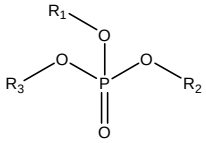
BACKGROUND

[0002] Transmissions and gearboxes are often subjected to pressures and loads over time that may cause wear to various gear surfaces in the driveline. Lubricants can be used to minimize and prevent wear damage. This is most often achieved using phosphorus-based antiwear compounds as lubricant additives. Newer transmission lubricants are expected to be of lower viscosity to improve efficiency and fuel economy while having longer drain intervals to save on equipment maintenance costs. Thus, newer lubricants are required to protect gear systems longer and under more severe conditions.

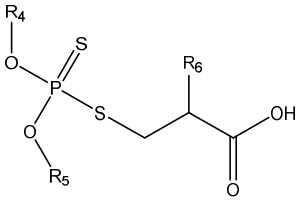
[0003] Transmission gear wear is generally understood to be damage to an individual gear tooth surface, which involves progressive loss of material over time due to contact motion between individual gear teeth. There are, of course, different types of component wear that need to be eliminated. Two relevant wear mechanisms in the context of transmission gears include abrasive wear as measured pursuant to ASTM D4172 and adhesive wear as measured pursuant to CEC L-84. Achieving passing performance in both wear mechanisms in lower viscosity fluids has been challenging because selecting fluid additives to achieve good abrasive wear does not necessarily lead to acceptable adhesive wear, and vice versa.

SUMMARY

[0004] In one approach or example, a transmission or gearbox lubricating composition is provided herein. In examples, the lubricating composition includes (i) a base oil of lubricating viscosity; (ii) a first phosphorus compound comprising a trialkyl phosphate ester of Formula I:



(Formula I) wherein R_1, R_2, and R_3 are, independently, a C4 to C8 linear or branched alkyl group; (iii) a second phosphorus compound comprising an ashless, dialkyl dithiophosphate of Formula II, or a salt thereof:

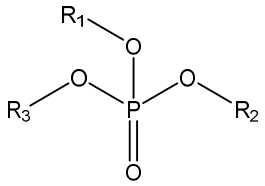


(Formula II) wherein R_4 and R_5 are, independently, a C3 to C8 linear or branched alkyl group, and R_6 is -H or $-CH_3$; (iv) a third phosphorus compound prepared by reacting an O,O-di (4-methyl-2-pentyl) phosphorodithioic acid with ethylene and/or propylene oxide to provide a first reaction product and further reacting said first reaction product with phosphorus pentoxide to provide a second reaction product and neutralizing said second reaction product with one or more tertiary aliphatic primary amines to obtain or provide said third phosphorus compound; and wherein said first, second, and third phosphorus compounds provide a total of about 800 to about 2000 ppm phosphorus to the lubricating composition.

[0004a] In one aspect, the present disclosure refers to a transmission or gearbox lubricating composition comprising:

(i) a base oil of lubricating viscosity;

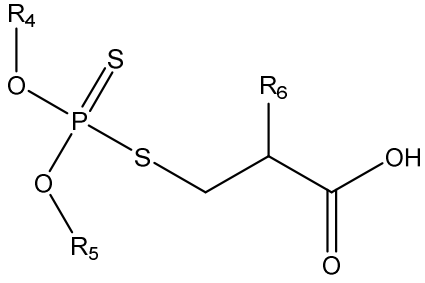
(ii) a first phosphorus compound comprising a trialkyl phosphate ester of Formula I:



(Formula I)

wherein R_1, R_2, and R_3 are, independently, a C4 to C8 linear or branched alkyl group;

(iii) a second phosphorus compound comprising an ashless, dialkyl dithiophosphate of Formula II, or a salt thereof:



(Formula II)

wherein R_4 and R_5 are, independently, a C3 to C8 linear or branched alkyl group, and R_6 is -H or $-CH_3$;

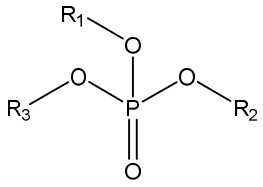
(iv) a third phosphorus compound prepared by reacting an O,O-di (4-methyl-2-pentyl) phosphorodithioic acid with ethylene and/or propylene oxide to provide a first reaction product and further reacting said first reaction product with phosphorus pentoxide to provide a second reaction product and neutralizing said second reaction product with one or more tertiary aliphatic primary amines to provide said third phosphorus compound; and

wherein said first, second, and third phosphorus compounds provide a total of 800 to 2000 ppm phosphorus to the lubricating composition, wherein the first phosphorus compound provides 280 ppm to 840 ppm of phosphorus to the lubricating composition, wherein the second phosphorus compound provides 90 to 450 ppm of phosphorus to the lubricating composition, and wherein the third phosphorus compound provides 80 to 600 ppm of phosphorus to the lubricating composition.

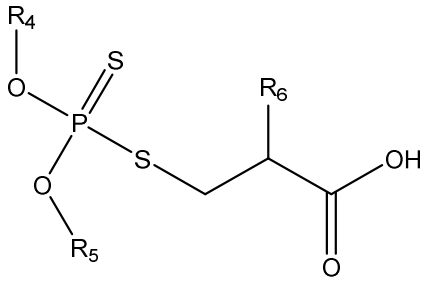
[0005] In other approaches or examples, the lubricating composition of the previous paragraph may be combined with one or more optional features in any combination. Such optional features include one or more of the following: wherein the first phosphorus compound is tris (2-ethylhexyl) phosphate; and/or wherein the first phosphorus compound provides about 280 ppm to about 840 ppm of phosphorus to the lubricating composition; and/or wherein the second phosphorus compound is 3-[[bis(2-methylpropoxy) phosphinothioyl]thio]-2-methyl-propanoic acid; and/or wherein the second phosphorus compound provides about 90 to about 450 ppm of phosphorus to the lubricating composition; and/or wherein the third phosphorus compound provides about 80 to about 600 ppm of phosphorus to the lubricating composition; and/or wherein the first phosphorus compound provides about 280 ppm to about 840 ppm of phosphorus to the lubricating composition, the second phosphorus compound provides about 90 to about 450 ppm of phosphorus to the lubricating composition, and the third phosphorus compound provides about 180 to about 600 ppm of phosphorus to the lubricating composition; and/or wherein the lubricating composition exhibits a wear scar of about 0.5 mm or less pursuant to ASTM D4172 (40kgf) and has a fail load stage rating of 10 or higher pursuant to CEC L-84 at 90ºC; and/or wherein about 30 to about 60 weight percent of the total phosphorus is provided by the first phosphorus compound, about 12 to about 35 weight percent of the total phosphorus is provided by the second phosphorus compound, and about 20 to about 35 weight percent of the total phosphorus is provided by the third phosphorus compound; and/or wherein the lubricating composition has a KV100 of about 4 to about 15 cSt; and/or wherein the lubricating composition

includes more of the first phosphorus compound, in terms of phosphorus content, than the second and third phosphorus compounds combined.

[0006] In other examples or approaches, a method of lubricating a transmission or gearbox is provided herein. In examples, the method includes lubricating a transmission or gearbox component with a lubricating composition; and wherein the lubricating composition includes (i) a base oil of lubricating viscosity; and (ii) a first phosphorus compound comprising a trialkyl phosphate ester of Formula I:



(Formula I) wherein R_1, R_2, and R_3 are, independently, a C4 to C8 linear or branched alkyl group, (iii) a second phosphorus compound comprising an ashless, dialkyl dithiophosphate of Formula II, or a salt thereof:



(Formula II) wherein R_4 and R_5 are, independently, a C3 to C8 linear or branched alkyl group, and R_6 is -H or $-CH_3$, and (iv) a third phosphorus compound prepared by reacting an O,O-di (4-methyl-2-pentyl) phosphorodithioic acid with ethylene and/or propylene oxide to provide a first reaction product and further reacting said first reaction product with phosphorus pentoxide to provide a second reaction product and neutralizing said second reaction product with one or more tertiary aliphatic primary amines to obtain or provide said third phosphorus compound; and wherein said first, second, and third phosphorus compounds provide a total of about 800 to about 2000 ppm phosphorus to the lubricating composition.

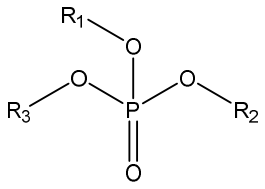
[0006a] In one aspect, the present disclosure refers to a method of lubricating a transmission or gearbox, the method comprising:

lubricating a transmission or gearbox component with a lubricating composition; and

wherein the lubricating composition includes

(i) a base oil of lubricating viscosity; and

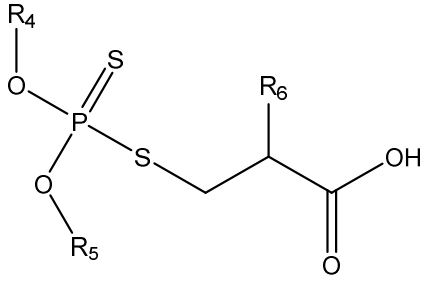
(ii) a first phosphorus compound comprising a trialkyl phosphate ester of Formula I:



(Formula I)

wherein R_1, R_2, and R_3 are, independently, a C4 to C8 linear or branched alkyl group,

(iii) a second phosphorus compound comprising an ashless, dialkyl dithiophosphate of Formula II, or a salt thereof:



(Formula II)

wherein R_4 and R_5 are, independently, a C3 to C8 linear or branched alkyl group, and R_6 is -H or $-CH_3$, and

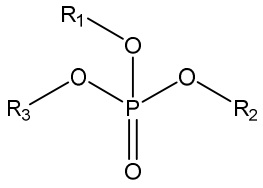
(iv) a third phosphorus compound prepared by reacting an O,O-di (4-methyl-2-pentyl) phosphorodithioic acid with ethylene and/or propylene oxide to provide a first reaction product and further reacting said first reaction product with phosphorus pentoxide to provide a second reaction product and neutralizing said second reaction product with one or more tertiary aliphatic primary amines to provide said third phosphorus compound; and wherein said first, second, and third phosphorus compounds provide a total of 800 to 2000 ppm phosphorus to the lubricating composition, and

wherein 30 to 60 weight percent of the total phosphorus is provided by the first phosphorus compound, 12 to 35 weight percent of the total phosphorus is provided by the second phosphorus compound, and 20 to 35 weight percent of the total phosphorus is provided by the third phosphorus compound.

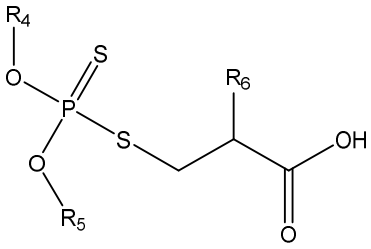
[0007] In other approaches or examples, the method examples of the previous paragraph may be combined with one or more optional features, steps, or limitations in any combination. These optional features, steps, or limitations including one or more of the following: wherein the first phosphorus compound is tris (2-ethylhexyl) phosphate; and/or wherein the first phosphorus compound provides about 280 ppm to about 840 ppm of

phosphorus to the lubricating composition; and/or wherein the second phosphorus compound is 3-[[bis(2-methylpropoxy) phosphinothioyl]thio]-2-methyl-propanoic acid; and/or wherein the second phosphorus compound provides about 90 to about 450 ppm of phosphorus to the lubricating composition; and/or wherein the third phosphorus compound provides about 180 to about 600 ppm of phosphorus to the lubricating composition; and/or wherein the lubricating composition exhibits a wear scar of about 0.5 mm or less pursuant to ASTM D4172 (40kgf) and has a fail load stage rating of 10 or higher pursuant to CEC L-84 at 90ºC; and/or wherein about 30 to about 60 weight percent of the total phosphorus is provided by the first phosphorus compound, about 12 to about 35 weight percent of the total phosphorus is provided by the second phosphorus compound, and about 20 to about 35 weight percent of the total phosphorus is provided by the third phosphorus compound; and/or wherein the lubricating composition has a KV100 of about 4 to about 10 cSt; and/or wherein the lubricating composition includes more of the first phosphorus compound, in terms of phosphorus content, than the second and third phosphorus compounds combined; and/or wherein the first phosphorus compound provides about 280 ppm to about 840 ppm of phosphorus to the lubricating composition; the second phosphorus compound provides about 90 to about 450 ppm of phosphorus to the lubricating composition, and the third phosphorus compound provides about 180 to about 600 ppm of phosphorus to the lubricating composition.

[0008] In yet other approaches or examples, the use of a first phosphorus compound, a second phosphorus compound, and a third phosphorus compound to provide lubricant, preferably in a driveline, exhibiting a wear scar of about 0.5 mm or less pursuant to ASTM D4172 (40kgf) and a fail load stage rating of 10 or higher pursuant to CEC L-84 at 90ºC is provided herein wherein the first phosphorus compound comprises a trialkyl phosphate ester of Formula I:



(Formula I) wherein R_1, R_2, and R_3 are, independently, a C4 to C8 linear or branched alkyl group, (iii) the second phosphorus compound comprises an ashless, dialkyl dithiophosphate of Formula II, or a salt thereof:



(Formula II) wherein R_4 and R_5 are, independently, a C3 to C8 linear or branched alkyl group, and R_6 is -H or -CH_3, and (iv) the third phosphorus compound is prepared by reacting an O,O-di (4-methyl-2-pentyl) phosphorodithioic acid with ethylene and/or propylene oxide to provide a first reaction product and further reacting said first reaction product with phosphorus pentoxide to obtain or provide a second reaction product and neutralizing said second reaction product with one or more tertiary aliphatic primary amines to provide said third phosphorus compound.

[0009] In yet further examples, a driveline apparatus is provided herein wherein the driveline includes a lubricating composition including any example herein of the first phosphorus compound, the second phosphorus compound, and the third phosphorus compound.

[00010] Other examples of the present disclosure will be apparent to those skilled in the art from consideration of the specification and practice of the disclosure disclosed herein. The following definitions of terms are provided in order to clarify the meanings of certain terms as used herein.

[00011] The terms “gear oil,” “gear fluid,” “gear lubricant,” “base gear lubricant,” “lubricating oil,” “lubricant composition,” “lubricating composition,” “lubricant” and “lubricating fluid” refer to a finished lubrication product comprising a major amount of a base oil plus a minor amount of an additive composition as discussed herein. Such gear fluids are for use in extreme pressure situations such as for transmissions and gear drive components having metal-on-metal contact situations, for instance, in a transmission and/or a limited-slip differential.

[00012] 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 the molecule and having a predominantly hydrocarbon character. Each hydrocarbyl group is independently selected from hydrocarbon substituents, and substituted hydrocarbon substituents containing one or more of halo groups, hydroxyl groups, alkoxy groups, mercapto groups, nitro groups, nitroso groups,

amino groups, pyridyl groups, furyl groups, imidazolyl groups, oxygen and nitrogen, and wherein no more than two non-hydrocarbon substituents are present for every ten carbon atoms in the hydrocarbyl group.

[00013] As used herein, the term "percent by weight" or “wt%”, unless expressly stated otherwise, means the percentage the recited component represents to the weight of the entire composition. All percent numbers herein, unless specified otherwise, is weight percent.

[00014] The terms "soluble," "oil-soluble," or "dispersible" used herein may, but does not necessarily, indicate that the compounds or additives are soluble, dissolvable, miscible, or capable of being suspended in the oil in all proportions. The foregoing terms do mean, however, that they are, for instance, soluble, suspendable, dissolvable, or stably dispersible in oil to an extent sufficient to exert their intended effect in the environment in which the oil is employed. Moreover, the additional incorporation of other additives may also permit incorporation of higher levels of a particular additive, if desired.

[00015] The term "alkyl" as employed herein refers to straight, branched, cyclic, and/or substituted saturated chain moieties from about 1 to about 200 carbon atoms. The term "alkenyl" as employed herein refers to straight, branched, cyclic, and/or substituted unsaturated chain moieties from about 3 to about 30 carbon atoms. The term “aryl” as employed herein refers to single and multi-ring aromatic compounds that may include alkyl, alkenyl, alkylaryl, amino, hydroxyl, alkoxy, halo substituents, and/or heteroatoms including, but not limited to, nitrogen, and oxygen.

[00016] As used herein, the molecular weight is determined by gel permeation chromatography (GPC) using commercially available polystyrene standards (with a Mn of about 180 to about 18,000 as the calibration reference). The molecular weight (Mn) for any example herein may be determined with a gel permeation chromatography (GPC) instrument obtained from Waters or the like instrument and the data processed with Waters Empower Software or the like software. The GPC instrument may be equipped with a Waters Separations Module and Waters Refractive Index detector (or the like optional equipment). The GPC operating conditions may include a guard column, 4 Agilent PLgel columns (length of 300×7.5 mm; particle size of 5 µ, and pore size ranging from 100-10000 Å) with the column temperature at about 40 °C. Un-stabilized HPLC grade tetrahydrofuran (THF) may be used as solvent, at a flow rate of 1.0 mL/min. The GPC instrument may be calibrated with commercially available

polystyrene (PS) standards having a narrow molecular weight distribution ranging from 500 – 380,000 g/mol. The calibration curve can be extrapolated for samples having a mass less than 500 g/mol. Samples and PS standards can be in dissolved in THF and prepared at concentration of 0.1-0.5 weight percent and used without filtration. GPC measurements are also described in US 5,266,223, which is incorporated herein by reference. The GPC method additionally provides molecular weight distribution information; *see, for example,* W. W. Yau, J. J. Kirkland and D. D. Bly, "Modern Size Exclusion Liquid Chromatography", John Wiley and Sons, New York, 1979, also incorporated herein by reference.

[00017] It is to be understood that throughout the present disclosure, the terms "comprises," "includes," "contains," etc. are considered open-ended and include any element, step, or ingredient not explicitly listed. The phrase "consists essentially of" is meant to include any expressly listed element, step, or ingredient and any additional elements, steps, or ingredients that do not materially affect the basic and novel aspects of the disclosure. The present disclosure also contemplates that any composition described using the terms, "comprises," "includes," "contains," is also to be interpreted as including a disclosure of the same composition "consisting essentially of" or "consisting of" the specifically listed components thereof.

DETAILED DESCRIPTION

[00018] Disclosed herein are lubricating compositions suitable for gear fluids, transmission fluids, power transmission fluids, and/or driveline applications that achieve good performance in both abrasive wear as measured pursuant to ASTM D4172 and adhesive wear as measured pursuant to CEC L-84. In one approach or embodiment, the lubricating compositions herein include a base oil of lubricating viscosity and a trio of phosphorus-containing antiwear compounds to achieve the passing adhesive wear and abrasive wear. In approaches, the trio of phosphorus containing compounds provide a total of about 800 ppm to about 2000 ppm phosphorus to the lubricating composition. In one aspect, the phosphorus-containing antiwear compounds include a first phosphorus compound of a trialkyl phosphate ester; a second phosphorus compound of an ashless, dialkyl dithiophosphate; and a third phosphorus compound of a dithiophosphate ester amine or salt thereof.

[00019] In approaches or embodiments, the first phosphorus compound is a trialkyl phosphate ester of Formula I:

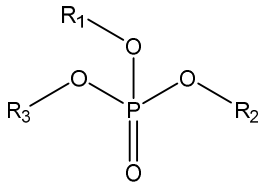
CLAIMS

WHAT IS CLAIMED IS

1. A transmission or gearbox lubricating composition comprising:

(i) a base oil of lubricating viscosity;

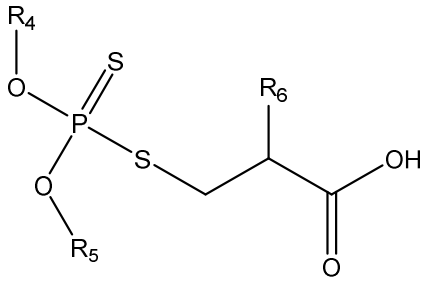
(ii) a first phosphorus compound comprising a trialkyl phosphate ester of Formula I:



(Formula I)

wherein R_1, R_2, and R_3 are, independently, a C4 to C8 linear or branched alkyl group;

(iii) a second phosphorus compound comprising an ashless, dialkyl dithiophosphate of Formula II, or a salt thereof:



(Formula II)

wherein R_4 and R_5 are, independently, a C3 to C8 linear or branched alkyl group, and R_6 is -H or $-CH_3$;

(iv) a third phosphorus compound prepared by reacting an O,O-di (4-methyl-2-pentyl) phosphorodithioic acid with ethylene and/or propylene oxide to provide a first reaction product and further reacting said first reaction product with phosphorus pentoxide to provide a second reaction product and neutralizing said second reaction product with one or more tertiary aliphatic primary amines to provide said third phosphorus compound; and

wherein said first, second, and third phosphorus compounds provide a total of 800 to 2000 ppm phosphorus to the lubricating composition, wherein the first phosphorus compound provides 280 ppm to 840 ppm of phosphorus to the lubricating composition, wherein the second phosphorus compound provides 90 to 450 ppm of phosphorus to the lubricating composition, and wherein the third phosphorus compound provides 80 to 600 ppm of phosphorus to the lubricating composition.

2. The lubricating composition of claim 1, wherein the first phosphorus compound is tris (2-ethylhexyl) phosphate.

3. The lubricating composition of claim 1, wherein the second phosphorus compound is 3-[[bis(2-methylpropoxy) phosphinothioyl]thio]-2-methyl-propanoic acid.

4. The lubricating composition of claim 1, wherein the first phosphorus compound provides 280 ppm to 840 ppm of phosphorus to the lubricating composition; the second phosphorus compound provides 90 to 450 ppm of phosphorus to the lubricating composition, and the third phosphorus compound provides 180 to 600 ppm of phosphorus to the lubricating composition.

5. The lubricating composition of claim 1, wherein the lubricating composition exhibits a wear scar of about 0.5 mm or less pursuant to ASTM D4172 (40 kgf) and has a fail load stage rating of 10 or higher pursuant to CEC L-84 at 90º C.

6. The lubricating composition of claim 1, wherein 30 to 60 weight percent of the total phosphorus is provided by the first phosphorus compound, 12 to 35 weight percent of the total phosphorus is provided by the second phosphorus compound, and 20 to 35 weight percent of the total phosphorus is provided by the third phosphorus compound.

7. The lubricating composition of claim 1, wherein the lubricating composition has a KV100 of 4 to 10 cSt.

8. The lubricating composition of claim 1, wherein the lubricating composition includes more of the first phosphorus compound than the second and third phosphorus compounds combined.

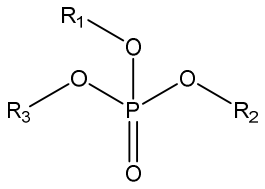
9. A method of lubricating a transmission or gearbox, the method comprising:

lubricating a transmission or gearbox component with a lubricating composition; and

wherein the lubricating composition includes

(i) a base oil of lubricating viscosity; and

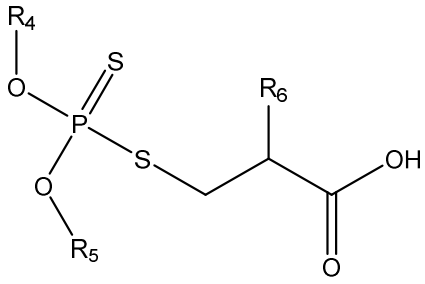
(ii) a first phosphorus compound comprising a trialkyl phosphate ester of Formula I:



(Formula I)

wherein R_1, R_2, and R_3 are, independently, a C4 to C8 linear or branched alkyl group,

(iii) a second phosphorus compound comprising an ashless, dialkyl dithiophosphate of Formula II, or a salt thereof:



(Formula II)

wherein R_4 and R_5 are, independently, a C3 to C8 linear or branched alkyl group, and R_6 is -H or -CH_3, and

(iv) a third phosphorus compound prepared by reacting an O,O-di (4-methyl-2-pentyl) phosphorodithioic acid with ethylene and/or propylene oxide to provide a first reaction product and further reacting said first reaction product with phosphorus pentoxide to provide a second reaction product and neutralizing said second reaction product with one or more tertiary aliphatic primary amines to provide said third phosphorus compound; and wherein said first, second, and third phosphorus compounds provide a total of 800 to 2000 ppm phosphorus to the lubricating composition, and

wherein 30 to 60 weight percent of the total phosphorus is provided by the first phosphorus compound, 12 to 35 weight percent of the total phosphorus is provided by the second phosphorus compound, and 20 to 35 weight percent of the total phosphorus is provided by the third phosphorus compound.

10. The method of claim 9, wherein the first phosphorus compound is tris (2-ethylhexyl) phosphate.

11. The method of claim 9, wherein the first phosphorus compound provides 280 ppm to 840 ppm of phosphorus to the lubricating composition.

12. The method of claim 9, wherein the second phosphorus compound is 3-[[bis(2-methylpropoxy) phosphinothioyl]thio]-2-methyl-propanoic acid.

13. The method of claim 9, wherein the second phosphorus compound provides 90 to 450 ppm of phosphorus to the lubricating composition.

14. The method of claim 9, wherein the third phosphorus compound provides 180 to 600 ppm of phosphorus to the lubricating composition.

15. The method of claim 9, wherein the lubricating composition exhibits a wear scar of about 0.5 mm or less pursuant to ASTM D4172 (40 kgf) and has a fail load stage rating of 10 or higher pursuant to CEC L-84 at 90º C.

16. The method of claim 9, wherein the lubricating composition has a KV100 of 4 to 10 cSt.

17. The method of claim 9, wherein the lubricating composition includes more of the first phosphorus compound than the second and third phosphorus compounds combined.

18. The method of claim 9, wherein the first phosphorus compound provides 280 ppm to 840 ppm of phosphorus to the lubricating composition; the second phosphorus compound provides 90 to 450 ppm of phosphorus to the lubricating composition, and the third phosphorus compound provides 180 to 600 ppm of phosphorus to the lubricating composition.