

LUBRICATING OIL COMPOSITION

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 63/535,648, filed August 31, 2023, which is hereby incorporated by reference in its entirety.

FIELD OF THE DISCLOSURE

[0002] The present disclosure relates to lubricant additive compositions and lubricating oil compositions containing the same. More particularly, the compositions provide improved gear wear performance (e.g., anti-scuff, anti-seizure) performance for electric vehicles.

BACKGROUND

[0003] Dimercapthothiadiazoles (DMTD) have various broad uses as metal chelators as well as potential uses as antiwear, anticorrosion or antirust agents. The inclusion of DMTD or related compounds in lubricating oils has been limited due to solubility challenges. Accordingly, DMTD or related compounds often require premixing with another additive (e.g., dispersant) before addition into a lubricant additive package or lubricating oil.

[0004] Thus, there exists a need to develop lubricating oil formulations that can improve the compatibility of DMTD and related compounds in lubricating oils to take advantage of the potential benefits. There is also potential to utilize DMTD and related compounds in emerging lubricating oils such as electric drive fluids.

SUMMARY OF THE INVENTION

[0005] The present disclosure provides an additive for a lubricating oil composition, or a driveline lubricating oil composition, which provides improved solubility of DMTD and derivatives thereof while providing improved antiwear (i.e. antiscuff) performance at low sulfur levels.

[0006] In one aspect, this disclosure relates to a lubricating oil composition comprising: a major amount of an oil of lubricating viscosity; a phosphorus-containing additive; and at least one sulfur-containing additive, wherein the sulfur-containing additive is thiadiazole, dithiadiazole, dimercaptodithiadiazole, dimercaptodithiadiazole oligomer, or derivative thereof, or analog thereof.

[0007] In another aspect, this disclosure relates to a method of improving the wear performance of a motor featuring an electric driveline, the method comprising lubricating the motor with a lubricating oil composition comprising: a major amount of an oil of lubricating viscosity; a phosphorus-containing additive; and at least one sulfur-containing additive, wherein the sulfur-containing additive is thiadiazole, dithiadiazole, dimercaptodithiadiazole, dimercaptodithiadiazole oligomer, or derivative thereof, or analog thereof.

DETAILED DESCRIPTION

[0008] The term “a major amount” of a base oil refers to where the amount of the base oil is at least 40 wt. % of the lubricating oil composition. In some embodiments, “a major amount” of a base oil refers to an amount of the base oil more than 50 wt. %, more than 60 wt. %, more than 70 wt. %, more than 80 wt. %, or more than 90 wt. % of the lubricating oil composition.

[0009] The term “hydrocarbyl” refers to a moiety that includes both carbon and hydrogen atoms. In some embodiments, hydrocarbyl may refer to hydrocarbon comprising heteroatoms (e.g., sulfur,

nitrogen, oxygen, etc.). Hydrocarbyl may refer to saturated or unsaturated moieties, aliphatic or aromatic moieties, branched or unbranched moieties.

[0010] As used herein, an Electric Drive Fluid or Electric Driveline Fluid (EDF) refers to a lubricating oil used in electric vehicles equipped with EV motors. Electric drive fluids are analogous to transmission fluids (used in conventional vehicles) but with, usually, one or more added functionalities (e.g., acting as a coolant for the EV motor, providing improved electrical resistivity, improved yellow metal compatibility, etc.). The one or more added functionalities can provide unique challenges to formulating EV fluids.

[0011] The present disclosure relates to a synergistic combination of lubricant additive compositions and/or lubricating oil composition containing the same. Without being limited by theory, it is believed that the synergistic combination of additives provides increased compatibility of thiadiazole or thiadiazole-like compounds in lubricating oil compositions and improved resistance against scuffing. The synergistic combination is particularly suitable for use in a vehicle equipped with an electric driveline (i.e., vehicle equipped with an electric motor such as electric vehicles, hybrid vehicles, or plug-in hybrid vehicles).

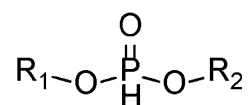
[0012] This disclosure is related to lubricating oil composition comprising: a) a major amount of an oil of lubricating viscosity; b) a hydrocarbyl phosphite or phosphonate; and c) at least one sulfur-containing additive as described herein.

Phosphorus-containing Additive

[0013] The lubricating oil composition of this disclosure include one or more phosphorus containing additive. The phosphorus containing additive may be a hydrocarbyl phosphite, a hydrocarbyl phosphonate, a hydrocarbyl thiophosphite, a phosphonic acid, a hydrocarbyl phosphate ester, or a polymeric polyphosphite.

[0014] More particularly, the hydrocarbyl phosphite/phosphonate compounds compatible with the present disclosure include dihydrocarbyl phosphites/phosphonates and trihydrocarbyl phosphites/phosphonates.

[0015] Dihydrocarbyl phosphites (Structure I) of this disclosure can be defined as follows:



Structure I

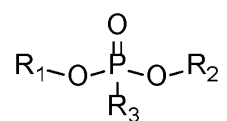
wherein R₁ and R₂ are independently C1 to C24 hydrocarbyl groups. The hydrocarbyl groups may be saturated or unsaturated, aromatic or aliphatic, or include heteroatoms such as O, N, or S (e.g., alkoxylated).

[0016] In some embodiments, R₁ and R₂ are independently C1 to C22 hydrocarbyl groups, C1 to C20 hydrocarbyl groups, C1 to C18 hydrocarbyl groups, C1 to C16 hydrocarbyl groups, C1 to C14 hydrocarbyl groups, C1 to C12 hydrocarbyl groups, C1 to C10 hydrocarbyl groups, C1 to C8 hydrocarbyl groups, C1 to C6 hydrocarbyl groups, C1 to C4 hydrocarbyl groups, C2 to C24 hydrocarbyl groups, C2 to C22 hydrocarbyl groups, C2 to C20 hydrocarbyl groups, C2 to C18 hydrocarbyl groups, C2 to C16 hydrocarbyl groups, C2 to C14 hydrocarbyl groups, C2 to C12 hydrocarbyl groups, C2 to C10 hydrocarbyl groups, C2 to C8 hydrocarbyl groups, C2 to C6 hydrocarbyl groups, C2 to C4 hydrocarbyl groups, C4 to C22 hydrocarbyl groups, C4 to C20 hydrocarbyl groups, C4 to C18 hydrocarbyl groups, C4 to C16 hydrocarbyl groups, C4 to C14 hydrocarbyl groups, C4 to C12 alkyl groups, C4 to C10 hydrocarbyl groups, C4 to C8 hydrocarbyl groups, C4 to C6 hydrocarbyl groups, C6 to C24 hydrocarbyl groups, C6 to C22 hydrocarbyl groups, C6 to C20 hydrocarbyl groups, C6 to C18 hydrocarbyl groups, C6 to C16 hydrocarbyl

groups, C6 to C14 hydrocarbyl groups, C6 to C12 hydrocarbyl groups, C6 to C10 hydrocarbyl groups, C6 to C8 hydrocarbyl groups, C8 to C24 hydrocarbyl groups, C8 to C22 hydrocarbyl groups, C8 to C20 hydrocarbyl groups, C8 to C18 hydrocarbyl groups, C8 to C16 hydrocarbyl groups, C8 to C14 hydrocarbyl groups, C8 to C12 hydrocarbyl groups, C8 to C10 hydrocarbyl groups, C10 to C24 hydrocarbyl groups, C10 to C22 hydrocarbyl groups, C10 to C20 hydrocarbyl groups, C10 to C18 hydrocarbyl groups, C10 to C16 hydrocarbyl groups, C10 to C14 hydrocarbyl groups, C10 to C12 hydrocarbyl groups, C12 to C24 hydrocarbyl groups, C12 to C22 hydrocarbyl groups, C12 to C20 hydrocarbyl groups, C12 to C18 hydrocarbyl groups, C12 to C16 hydrocarbyl groups, C12 to C14 hydrocarbyl groups, C14 to C24 hydrocarbyl groups, C14 to C22 hydrocarbyl groups, C14 to C20 hydrocarbyl groups, C14 to C18 hydrocarbyl groups, C14 to C16 hydrocarbyl groups, C16 to C24 hydrocarbyl groups, C16 to C22 hydrocarbyl groups, C16 to C20 hydrocarbyl groups, C16 to C18 hydrocarbyl groups, C18 to C24 hydrocarbyl groups, C18 to C22 hydrocarbyl groups, C18 to C20 hydrocarbyl groups, C20 to C24 hydrocarbyl groups, C20 to C22 hydrocarbyl groups, or C22 to C24 hydrocarbyl groups.

[0017] Representative dihydrocarbyl phosphites include, but are not limited to, dibutyl phosphite, dihexyl phosphite, dioctyl phosphite, didecyl phosphite, dilauryl phosphite, and dioleyl phosphite.

[0018] Dihydrocarbyl phosphonate (Structure II) of this disclosure can be represented as follows:



Structure II

wherein R₁ and R₂ are independently C1 to C24 hydrocarbyl groups, and R₃ is hydrogen or C1 to C24 hydrocarbyl group. The hydrocarbyl groups may be saturated or unsaturated, aromatic or

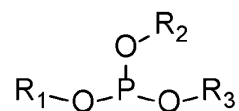
aliphatic, or include heteroatoms (e.g., alkoxyated). A commercially available dihydrocarbyl phosphonate is dimethyl octadecylphosphonate, which is Duraphos® 100 from Solvay.

[0019] In some embodiments, R_1 , R_2 , and R_3 are independently C1 to C22 hydrocarbyl groups, C1 to C20 hydrocarbyl groups, C1 to C18 hydrocarbyl groups, C1 to C16 hydrocarbyl groups, C1 to C14 hydrocarbyl groups, C1 to C12 hydrocarbyl groups, C1 to C10 hydrocarbyl groups, C1 to C8 hydrocarbyl groups, C1 to C6 hydrocarbyl groups, C1 to C4 hydrocarbyl groups, C2 to C24 hydrocarbyl groups, C2 to C22 hydrocarbyl groups, C2 to C20 hydrocarbyl groups, C2 to C18 hydrocarbyl groups, C2 to C16 hydrocarbyl groups, C2 to C14 hydrocarbyl groups, C2 to C12 hydrocarbyl groups, C2 to C10 hydrocarbyl groups, C2 to C8 hydrocarbyl groups, C2 to C6 hydrocarbyl groups, C2 to C4 hydrocarbyl groups, C4 to C22 hydrocarbyl groups, C4 to C20 hydrocarbyl groups, C4 to C18 hydrocarbyl groups, C4 to C16 hydrocarbyl groups, C4 to C14 hydrocarbyl groups, C4 to C12 alkyl groups, C4 to C10 hydrocarbyl groups, C4 to C8 hydrocarbyl groups, C4 to C6 hydrocarbyl groups, C6 to C24 hydrocarbyl groups, C6 to C22 hydrocarbyl groups, C6 to C20 hydrocarbyl groups, C6 to C18 hydrocarbyl groups, C6 to C16 hydrocarbyl groups, C6 to C14 hydrocarbyl groups, C6 to C12 hydrocarbyl groups, C6 to C10 hydrocarbyl groups, C6 to C8 hydrocarbyl groups, C8 to C24 hydrocarbyl groups, C8 to C22 hydrocarbyl groups, C8 to C20 hydrocarbyl groups, C8 to C18 hydrocarbyl groups, C8 to C16 hydrocarbyl groups, C8 to C14 hydrocarbyl groups, C8 to C12 hydrocarbyl groups, C8 to C10 hydrocarbyl groups, C10 to C24 hydrocarbyl groups, C10 to C22 hydrocarbyl groups, C10 to C20 hydrocarbyl groups, C10 to C18 hydrocarbyl groups, C10 to C16 hydrocarbyl groups, C10 to C14 hydrocarbyl groups, C10 to C12 hydrocarbyl groups, C12 to C24 hydrocarbyl groups, C12 to C22 hydrocarbyl groups, C12 to C20 hydrocarbyl groups, C12 to C18 hydrocarbyl groups, C12 to C16 hydrocarbyl groups, C12 to C14 hydrocarbyl groups, C14 to C24 hydrocarbyl groups, C14 to C22 hydrocarbyl

groups, C14 to C20 hydrocarbyl groups, C14 to C18 hydrocarbyl groups, C14 to C16 hydrocarbyl groups, C16 to C24 hydrocarbyl groups, C16 to C22 hydrocarbyl groups, C16 to C20 hydrocarbyl groups, C16 to C18 hydrocarbyl groups, C18 to C24 hydrocarbyl groups, C18 to C22 hydrocarbyl groups, C18 to C20 hydrocarbyl groups, C20 to C24 hydrocarbyl groups, C20 to C22 hydrocarbyl groups, or C22 to C24 hydrocarbyl groups.

[0020] Representative dihydrocarbyl phosphonates include, but are not limited to, dibutyl phosphonates, dihexyl phosphonates, dioctyl phosphonates, didecyl phosphonates, dilauryl phosphonates, and dioleyl phosphonates.

[0021] Trihydrocarbyl phosphite (Structure III) of this disclosure can have the following generalized structure:



Structure III

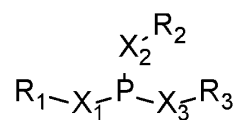
where R₁, R₂, and R₃ are independently C1 to C24 hydrocarbyl groups. The hydrocarbyl groups may be saturated or unsaturated, aromatic or aliphatic, or include heteroatoms (e.g., alkoxyated).

[0022] In some embodiments, R₁, R₂, and R₃ are independently C1 to C22 hydrocarbyl groups, C1 to C20 hydrocarbyl groups, C1 to C18 hydrocarbyl groups, C1 to C16 hydrocarbyl groups, C1 to C14 hydrocarbyl groups, C1 to C12 hydrocarbyl groups, C1 to C10 hydrocarbyl groups, C1 to C8 hydrocarbyl groups, C1 to C6 hydrocarbyl groups, C1 to C4 hydrocarbyl groups, C2 to C24 hydrocarbyl groups, C2 to C22 hydrocarbyl groups, C2 to C20 hydrocarbyl groups, C2 to C18 hydrocarbyl groups, C2 to C16 hydrocarbyl groups, C2 to C14 hydrocarbyl groups, C2 to C12 hydrocarbyl groups, C2 to C10 hydrocarbyl groups, C2 to C8 hydrocarbyl groups, C2 to C6 hydrocarbyl groups, C2 to C4 hydrocarbyl groups, C4 to C22 hydrocarbyl groups, C4 to C20

hydrocarbyl groups, C4 to C18 hydrocarbyl groups, C4 to C16 hydrocarbyl groups, C4 to C14 hydrocarbyl groups, C4 to C12 alkyl groups, C4 to C10 hydrocarbyl groups, C4 to C8 hydrocarbyl groups, C4 to C6 hydrocarbyl groups, C6 to C24 hydrocarbyl groups, C6 to C22 hydrocarbyl groups, C6 to C20 hydrocarbyl groups, C6 to C18 hydrocarbyl groups, C6 to C16 hydrocarbyl groups, C6 to C14 hydrocarbyl groups, C6 to C12 hydrocarbyl groups, C6 to C10 hydrocarbyl groups, C6 to C8 hydrocarbyl groups, C8 to C24 hydrocarbyl groups, C8 to C22 hydrocarbyl groups, C8 to C20 hydrocarbyl groups, C8 to C18 hydrocarbyl groups, C8 to C16 hydrocarbyl groups, C8 to C14 hydrocarbyl groups, C8 to C12 hydrocarbyl groups, C8 to C10 hydrocarbyl groups, C10 to C24 hydrocarbyl groups, C10 to C22 hydrocarbyl groups, C10 to C20 hydrocarbyl groups, C10 to C18 hydrocarbyl groups, C10 to C16 hydrocarbyl groups, C10 to C14 hydrocarbyl groups, C10 to C12 hydrocarbyl groups, C12 to C24 hydrocarbyl groups, C12 to C22 hydrocarbyl groups, C12 to C20 hydrocarbyl groups, C12 to C18 hydrocarbyl groups, C12 to C16 hydrocarbyl groups, C12 to C14 hydrocarbyl groups, C14 to C24 hydrocarbyl groups, C14 to C22 hydrocarbyl groups, C14 to C20 hydrocarbyl groups, C14 to C18 hydrocarbyl groups, C14 to C16 hydrocarbyl groups, C16 to C24 hydrocarbyl groups, C16 to C22 hydrocarbyl groups, C16 to C20 hydrocarbyl groups, C16 to C18 hydrocarbyl groups, C18 to C24 hydrocarbyl groups, C18 to C22 hydrocarbyl groups, C18 to C20 hydrocarbyl groups, C20 to C24 hydrocarbyl groups, C20 to C22 hydrocarbyl groups, or C22 to C24 hydrocarbyl groups.

[0023] Representative trialkyl phosphites include, but are not limited to, tributyl phosphite, trihexyl phosphite, trioctyl phosphite, tridecyl phosphite, trilauryl phosphite and trioleyl phosphite.

[0024] Hydrocarbyl thiophosphite (Structure IV) of this disclosure can have the following generalized structure:



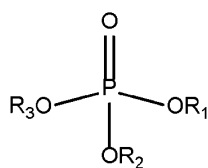
Structure IV

where R₁, R₂, and R₃ are independently C1 to C24 hydrocarbyl groups and wherein X₁, X₂, and X₃ are independently sulfur or oxygen atoms, wherein at least one of X₁, X₂, and X₃ is a sulfur atom. The hydrocarbyl groups may be saturated or unsaturated, aromatic or aliphatic, or include heteroatoms (e.g., alkoxyated).

[0025] In some embodiments, R₁, R₂, and R₃ are independently C1 to C22 hydrocarbyl groups, C1 to C20 hydrocarbyl groups, C1 to C18 hydrocarbyl groups, C1 to C16 hydrocarbyl groups, C1 to C14 hydrocarbyl groups, C1 to C12 hydrocarbyl groups, C1 to C10 hydrocarbyl groups, C1 to C8 hydrocarbyl groups, C1 to C6 hydrocarbyl groups, C1 to C4 hydrocarbyl groups, C2 to C24 hydrocarbyl groups, C2 to C22 hydrocarbyl groups, C2 to C20 hydrocarbyl groups, C2 to C18 hydrocarbyl groups, C2 to C16 hydrocarbyl groups, C2 to C14 hydrocarbyl groups, C2 to C12 hydrocarbyl groups, C2 to C10 hydrocarbyl groups, C2 to C8 hydrocarbyl groups, C2 to C6 hydrocarbyl groups, C2 to C4 hydrocarbyl groups, C4 to C22 hydrocarbyl groups, C4 to C20 hydrocarbyl groups, C4 to C18 hydrocarbyl groups, C4 to C16 hydrocarbyl groups, C4 to C14 hydrocarbyl groups, C4 to C12 alkyl groups, C4 to C10 hydrocarbyl groups, C4 to C8 hydrocarbyl groups, C4 to C6 hydrocarbyl groups, C6 to C24 hydrocarbyl groups, C6 to C22 hydrocarbyl groups, C6 to C20 hydrocarbyl groups, C6 to C18 hydrocarbyl groups, C6 to C16 hydrocarbyl groups, C6 to C14 hydrocarbyl groups, C6 to C12 hydrocarbyl groups, C6 to C10 hydrocarbyl groups, C6 to C8 hydrocarbyl groups, C8 to C24 hydrocarbyl groups, C8 to C22 hydrocarbyl groups, C8 to C20 hydrocarbyl groups, C8 to C18 hydrocarbyl groups, C8 to C16 hydrocarbyl groups, C8 to C14 hydrocarbyl groups, C8 to C12 hydrocarbyl groups, C8 to C10 hydrocarbyl

groups, C10 to C24 hydrocarbyl groups, C10 to C22 hydrocarbyl groups, C10 to C20 hydrocarbyl groups, C10 to C18 hydrocarbyl groups, C10 to C16 hydrocarbyl groups, C10 to C14 hydrocarbyl groups, C10 to C12 hydrocarbyl groups, C12 to C24 hydrocarbyl groups, C12 to C22 hydrocarbyl groups, C12 to C20 hydrocarbyl groups, C12 to C18 hydrocarbyl groups, C12 to C16 hydrocarbyl groups, C12 to C14 hydrocarbyl groups, C14 to C24 hydrocarbyl groups, C14 to C22 hydrocarbyl groups, C14 to C20 hydrocarbyl groups, C14 to C18 hydrocarbyl groups, C14 to C16 hydrocarbyl groups, C16 to C24 hydrocarbyl groups, C16 to C22 hydrocarbyl groups, C16 to C20 hydrocarbyl groups, C16 to C18 hydrocarbyl groups, C18 to C24 hydrocarbyl groups, C18 to C22 hydrocarbyl groups, C18 to C20 hydrocarbyl groups, C20 to C24 hydrocarbyl groups, C20 to C22 hydrocarbyl groups, or C22 to C24 hydrocarbyl groups.

[0026] Hydrocarbyl phosphate ester (Structure V) of this disclosure can have the generalized structure:



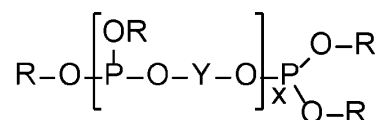
Structure V

wherein R₁, R₂, and R₃ are independently H or C1-C24 hydrocarbyl group, wherein at least one of R₁, R₂, and R₃ is a hydrocarbyl group. The hydrocarbyl groups may be saturated or unsaturated, aromatic or aliphatic, or include heteroatoms (e.g., alkoxy). A more detailed discussion of phosphate esters can be found in US2022/0119727, which is hereby incorporated by reference.

[0027] In some embodiments, R₁, R₂, and R₃ are independently C1 to C22 hydrocarbyl groups, C1 to C20 hydrocarbyl groups, C1 to C18 hydrocarbyl groups, C1 to C16 hydrocarbyl groups, C1 to C14 hydrocarbyl groups, C1 to C12 hydrocarbyl groups, C1 to C10 hydrocarbyl groups, C1 to C8

hydrocarbyl groups, C1 to C6 hydrocarbyl groups, C1 to C4 hydrocarbyl groups, C2 to C24 hydrocarbyl groups, C2 to C22 hydrocarbyl groups, C2 to C20 hydrocarbyl groups, C2 to C18 hydrocarbyl groups, C2 to C16 hydrocarbyl groups, C2 to C14 hydrocarbyl groups, C2 to C12 hydrocarbyl groups, C2 to C10 hydrocarbyl groups, C2 to C8 hydrocarbyl groups, C2 to C6 hydrocarbyl groups, C2 to C4 hydrocarbyl groups, C4 to C22 hydrocarbyl groups, C4 to C20 hydrocarbyl groups, C4 to C18 hydrocarbyl groups, C4 to C16 hydrocarbyl groups, C4 to C14 hydrocarbyl groups, C4 to C12 alkyl groups, C4 to C10 hydrocarbyl groups, C4 to C8 hydrocarbyl groups, C4 to C6 hydrocarbyl groups, C6 to C24 hydrocarbyl groups, C6 to C22 hydrocarbyl groups, C6 to C20 hydrocarbyl groups, C6 to C18 hydrocarbyl groups, C6 to C16 hydrocarbyl groups, C6 to C14 hydrocarbyl groups, C6 to C12 hydrocarbyl groups, C6 to C10 hydrocarbyl groups, C6 to C8 hydrocarbyl groups, C8 to C24 hydrocarbyl groups, C8 to C22 hydrocarbyl groups, C8 to C20 hydrocarbyl groups, C8 to C18 hydrocarbyl groups, C8 to C16 hydrocarbyl groups, C8 to C14 hydrocarbyl groups, C8 to C12 hydrocarbyl groups, C8 to C10 hydrocarbyl groups, C10 to C24 hydrocarbyl groups, C10 to C22 hydrocarbyl groups, C10 to C20 hydrocarbyl groups, C10 to C18 hydrocarbyl groups, C10 to C16 hydrocarbyl groups, C10 to C14 hydrocarbyl groups, C10 to C12 hydrocarbyl groups, C12 to C24 hydrocarbyl groups, C12 to C22 hydrocarbyl groups, C12 to C20 hydrocarbyl groups, C12 to C18 hydrocarbyl groups, C12 to C16 hydrocarbyl groups, C12 to C14 hydrocarbyl groups, C14 to C24 hydrocarbyl groups, C14 to C22 hydrocarbyl groups, C14 to C20 hydrocarbyl groups, C14 to C18 hydrocarbyl groups, C14 to C16 hydrocarbyl groups, C16 to C24 hydrocarbyl groups, C16 to C22 hydrocarbyl groups, C16 to C20 hydrocarbyl groups, C16 to C18 hydrocarbyl groups, C18 to C24 hydrocarbyl groups, C18 to C22 hydrocarbyl groups, C18 to C20 hydrocarbyl groups, C20 to C24 hydrocarbyl groups, C20 to C22 hydrocarbyl groups, or C22 to C24 hydrocarbyl groups.

[0028] Polymeric polyphosphites (Structure VII) of this disclosure can have the following generalized structure:



Structure VII

wherein each R is independently a C10-C40 hydrocarbyl group, Y is a C2-C40 hydrocarbyl group, C2-C40 hydrocarbyl glycol ether, C2-C40 hydrocarbyl lactone, and wherein X is a integer ranging from 2 to 1000. A more detailed discussion of polymeric polyphosphites can be found in US2016/0340493, which is hereby incorporated by reference.

[0029] The exact amount of phosphorus-containing additive based on the total lubricating oil composition may vary. In some embodiments, the amount phosphorus-containing additive is at least about 0.001 wt.% based on the total lubricating oil composition, such as at least about 0.05 wt.%, at least about 0.1 wt.%, at least about 0.3 wt.%, at least about 0.4 wt.%, at least about 0.5 wt.%, at least about 0.75 wt.%, or at least about 1.0 wt. %.

[0030] In some embodiments, the amount of phosphorus-containing additive is up to about 5.0 wt.% based on the total lubricating oil composition, such as up to about 4.5 wt.%, up to about 4.0 wt.%, up to about 3.5 wt.%, up to about 3.0 wt.%, up to about 2.5 wt.%, up to about 2.0 wt.%, up to about 1.5 wt.%, up to about 1.25, up to about 1.0, up to about 0.9, or up to about 0.8 wt. % based on the total weight of the lubricating oil composition.

Sulfur-Containing Additive

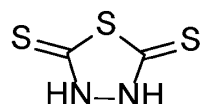
[0031] The lubricating oil composition of this disclosure includes at least one sulfur-containing additive. More particularly, the sulfur-containing additive is a heterocyclic compound that

includes both sulfur and nitrogen. In some embodiments, the sulfur-containing is non-alkylated (i.e., no R groups are present only H atoms).

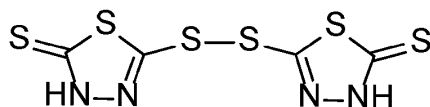
[0032] In accordance with the present disclosure, the sulfur-containing additive is generally a thiadiazole. In some embodiments, the sulfur-containing additive may be polycyclic compound.

[0033] Suitable sulfur-containing compounds include, for example, dimercaptodithiadiazoles, dimercaptodithiadiazole oligomers (trimer, tetramer, pentamer), thiadiazoles, dithiadiazoles, or salts thereof, or derivatives thereof or analogs thereof.

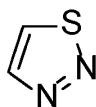
[0034] Non-limiting examples sulfur-containing additives, derivatives thereof, or analogs thereof, are shown below.



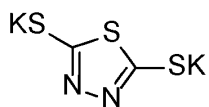
(i) 2,5-Dimercapto-1,3,4-thiadiazole



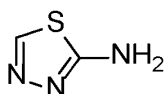
(ii) 5,5'-dithiodi-1,3,4-thiadiazole-2(3H)-thione



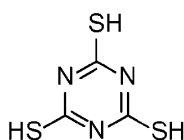
(iii) 1,2,3-Thiadiazole



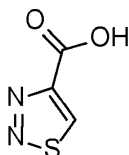
(iv) potassium thiadiazole-bis(thiolate)



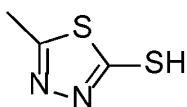
(v) 2-Amino-1,3,4-thiadiazole



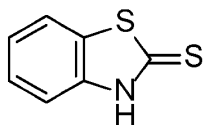
(vi) 1,3,5-Triazine-2,4,6-trithiol



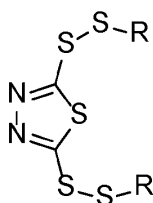
(vii) 1,2,3-thiadiazole-4-carboxylic acid



(viii) 5-Methyl-1,3,4-thiadiazole-2-thiol



(ix) 2-Mercaptobenzothiazole



(x) bis(hydrocarbylthio)-substituted dimercaptothiadiazoled

R = H or C1-C6 hydrocarbyl group

[0035] The exact amount of the sulfur-containing additive based on the total lubricating oil composition may vary. In some embodiments, the amount of sulfur-containing additive is at least about 0.001 wt.% based on the total lubricating oil composition, such as at least about 0.05 wt.%, at least about 0.1 wt.%, at least about 0.3 wt.%, at least about 0.4 wt.%, at least about 0.5 wt.%, at least about 0.75 wt.%, or at least about 1.0 wt. %.

[0036] In some embodiments, the amount of sulfur-containing additive is up to about 5.0 wt.% based on the total lubricating oil composition, such as up to about 4.5 wt.%, up to about 4.0 wt.%, up to about 3.5 wt.%, up to about 3.0 wt.%, up to about 2.5 wt.%, up to about 2.0 wt.%, up to about 1.5 wt.%, up to about 1.25, up to about 1.0, up to about 0.9 wt.%, or up to about 0.8 wt. % based on the total weight of the lubricating oil composition.

[0037] In some embodiments, the lubricating oil composition contains low amounts of sulfur, such as less than about 2000 ppm of sulfur based on total weight of the lubricating oil composition, such

as less than about 1950 ppm of sulfur, less than about 1900 ppm of sulfur, less than about 1850 ppm of sulfur, less than about 1800 ppm of sulfur, less than about 1750 ppm of sulfur, less than about 1700 ppm of sulfur, less than about 1650 ppm of sulfur, less than about 1600 ppm of sulfur, less than about 1550 ppm of sulfur, less than about 1500 ppm of sulfur, less than about 1450 ppm of sulfur, less than about 1400 ppm of sulfur, less than about 1350 ppm of sulfur, less than about 1300 ppm of sulfur, less than about 1250 ppm of sulfur, less than about 1200 ppm of sulfur, less than about 1150 ppm of sulfur, less than about 1100 ppm of sulfur, less than about 1050 ppm of sulfur, less than about 1000 ppm of sulfur, less than about 950 ppm of sulfur, less than about 900 ppm of sulfur, less than about 850 ppm of sulfur, less than about 800 ppm of sulfur, less than about 750 ppm of sulfur, less than about 700 ppm of sulfur, less than about 650 ppm of sulfur, less than about 600 ppm of sulfur, less than about 550 ppm of sulfur, less than about 500 ppm of sulfur, or less than about 450 ppm of sulfur.

Other Additives

[0038] Optionally, the lubricating oil composition may further comprise at least an additive or a modifier (hereinafter designated as "additive") that can impart or improve any desirable property of the lubricating oil composition. Any additive known to a person of ordinary skill in the art may be used in the lubricating oil compositions disclosed herein. Some suitable additives have been described in Mortier et al., "Chemistry and Technology of Lubricants," 2nd Edition. London, Springer, (1996); and Leslie R. Rudnick, "Lubricant Additives: Chemistry and Applications," New York, Marcel Dekker (2003), both of which are incorporated herein by reference. In some embodiments, the additive can be selected from the group consisting of antioxidants, antiwear agents, detergents, rust inhibitors, demulsifiers, friction modifiers, multi-functional additives, viscosity index improvers, pour point depressants, foam inhibitors, metal deactivators, dispersants,

corrosion inhibitors, lubricity improvers, thermal stability improvers, anti-haze additives, icing inhibitors, dyes, markers, static dissipaters, biocides and combinations thereof.

[0039] In general, the concentration of each of the additives in the lubricating oil composition, when used, may range from about 0.001 wt. % to about 10 wt. %, from about 0.01 wt. % to about 5 wt. %, or from about 0.1 wt. % to about 2.5 wt. %, based on the total weight of the lubricating oil composition. Further, the total amount of the additives in the lubricating oil composition may range from about 0.001 wt. % to about 20 wt. %, from about 0.01 wt. % to about 10 wt. %, or from about 0.1 wt. % to about 5 wt. %, based on the total weight of the lubricating oil composition.

[0040] In some embodiments, the lubricating oil composition is substantially free of sulfur-containing zinc compounds such as zinc dialkyl dithiophosphate. In some embodiments, the sulfur-containing zinc compound is present in an amount that contributes 100 ppm or less of zinc by total weight of the lubricating oil composition. In some embodiments, the lubricating oil composition contains less than 100 ppm of zinc by total weight of the lubricating oil composition.

The Oil of Lubricating Viscosity

[0041] The lubricating oil compositions disclosed herein generally comprise at least one oil of lubricating viscosity. Any base oil known to a skilled artisan can be used as the oil of lubricating viscosity disclosed herein. Some base oils suitable for preparing the lubricating oil compositions have been described in Mortier et al., "Chemistry and Technology of Lubricants," 2nd Edition, London, Springer, Chapters 1 and 2 (1996); and A. Sequeria, Jr., "Lubricant Base Oil and Wax Processing," New York, Marcel Decker, Chapter 6, (1994); and D. V. Brock, Lubrication Engineering, Vol. 43, pages 184-5, (1987), all of which are incorporated herein by reference. Generally, the amount of the base oil in the lubricating oil composition may be from about 70 to about 99.5 wt. %, based on the total weight of the lubricating oil composition. In some

embodiments, the amount of the base oil in the lubricating oil composition is from about 75 to about 99 wt. %, from about 80 to about 98.5 wt. %, or from about 80 to about 98 wt. %, based on the total weight of the lubricating oil composition.

[0042] In certain embodiments, the base oil is or comprises any natural or synthetic lubricating base oil fraction. Some non-limiting examples of synthetic oils include oils, such as polyalphaolefins or PAOs, prepared from the polymerization of at least one alpha-olefin, such as ethylene, or from hydrocarbon synthesis procedures using carbon monoxide and hydrogen gases, such as the Fisher-Tropsch process. In certain embodiments, the base oil comprises less than about 10 wt. % of one or more heavy fractions, based on the total weight of the base oil. A heavy fraction refers to a lube oil fraction having a viscosity of at least about 20 cSt at 100° C. In certain embodiments, the heavy fraction has a viscosity of at least about 25 cSt or at least about 30 cSt at 100° C. In further embodiments, the amount of the one or more heavy fractions in the base oil is less than about 10 wt. %, less than about 5 wt. %, less than about 2.5 wt. %, less than about 1 wt. %, or less than about 0.1 wt. %, based on the total weight of the base oil. In still further embodiments, the base oil comprises no heavy fraction.

[0043] In certain embodiments, the lubricating oil compositions comprise a major amount of a base oil of lubricating viscosity. In some embodiments, the base oil has a kinematic viscosity at 100° C. from about 2.5 centistokes (cSt) to about 20 cSt, from about 4 centistokes (cSt) to about 20 cSt, or from about 5 cSt to about 16 cSt. The kinematic viscosity of the base oils or the lubricating oil compositions disclosed herein can be measured according to ASTM D 445, which is incorporated herein by reference.

[0044] In other embodiments, the base oil is or comprises a base stock or blend of base stocks. In further embodiments, the base stocks are manufactured using a variety of different processes

including, but not limited to, distillation, solvent refining, hydrogen processing, oligomerization, esterification, and rerefining. In some embodiments, the base stocks comprise a rerefined stock. In further embodiments, the rerefined stock shall be substantially free from materials introduced through manufacturing, contamination, or previous use.

[0045] In some embodiments, the base oil comprises one or more of the base stocks in one or more of Groups I-V as specified in the American Petroleum Institute (API) Publication 1509, Fourteen Edition, December 1996 (i.e., API Base Oil Interchangeability Guidelines for Passenger Car Motor Oils and Diesel Engine Oils), which is incorporated herein by reference. The API guideline defines a base stock as a lubricant component that may be manufactured using a variety of different processes. Groups I, II and III base stocks are mineral oils, each with specific ranges of the amount of saturates, sulfur content and viscosity index. Group IV base stocks are polyalphaolefins (PAO). Group V base stocks include all other base stocks not included in Group I, II, III, or IV.

[0046] In some embodiments, the base oil comprises one or more of the base stocks in Group I, II, III, IV, V or a combination thereof. In other embodiments, the base oil comprises one or more of the base stocks in Group II, III, IV or a combination thereof. In further embodiments, the base oil comprises one or more of the base stocks in Group II, III, IV or a combination thereof wherein the base oil has a kinematic viscosity from about 2.5 centistokes (cSt) to about 20 cSt, from about 4 cSt to about 20 cSt, or from about 5 cSt to about 16 cSt at 100° C.

[0047] The base oil may be selected from the group consisting of natural oils of lubricating viscosity, synthetic oils of lubricating viscosity and mixtures thereof. In some embodiments, the base oil includes base stocks obtained by isomerization of synthetic wax and slack wax, as well as hydrocrackate base stocks produced by hydrocracking (rather than solvent extracting) the aromatic and polar components of the crude. In other embodiments, the base oil of lubricating viscosity

includes natural oils, such as animal oils, vegetable oils, mineral oils (e.g., liquid petroleum oils and solvent treated or acid-treated mineral oils of the paraffinic, naphthenic or mixed paraffinic-naphthenic types), oils derived from coal or shale, and combinations thereof. Some non-limiting examples of animal oils include bone oil, lanolin, fish oil, lard oil, dolphin oil, seal oil, shark oil, tallow oil, and whale oil. Some non-limiting examples of vegetable oils include castor oil, olive oil, peanut oil, rapeseed oil, corn oil, sesame oil, cottonseed oil, soybean oil, sunflower oil, safflower oil, hemp oil, linseed oil, tung oil, oiticica oil, jojoba oil, and meadow foam oil. Such oils may be partially or fully hydrogenated.

[0048] In some embodiments, the synthetic oils of lubricating viscosity include hydrocarbon oils and halo-substituted hydrocarbon oils such as polymerized and inter-polymerized olefins, alkylbenzenes, polyphenyls, alkylated diphenyl ethers, alkylated diphenyl sulfides, as well as their derivatives, analogues and homologues thereof, and the like. In other embodiments, the synthetic oils include alkylene oxide polymers, interpolymers, copolymers and derivatives thereof wherein the terminal hydroxyl groups can be modified by esterification, etherification, and the like. In further embodiments, the synthetic oils include the esters of dicarboxylic acids with a variety of alcohols. In certain embodiments, the synthetic oils include esters made from C₅ to C₁₂ monocarboxylic acids and polyols and polyol ethers. In further embodiments, the synthetic oils include tri-alkyl phosphate ester oils, such as tri-n-butyl phosphate and tri-iso-butyl phosphate.

[0049] In some embodiments, the synthetic oils of lubricating viscosity include silicon-based oils (such as the polyakyl-, polyaryl-, polyalkoxy-, polyaryloxy-siloxane oils and silicate oils). In other embodiments, the synthetic oils include liquid esters of phosphorus-containing acids, polymeric tetrahydrofurans, polyalphaolefins, and the like.

[0050] Base oil derived from the hydroisomerization of wax may also be used, either alone or in combination with the aforesaid natural and/or synthetic base oil. Such wax isomerase oil is produced by the hydroisomerization of natural or synthetic waxes or mixtures thereof over a hydroisomerization catalyst.

[0051] In further embodiments, the base oil comprises a poly-alpha-olefin (PAO). In general, the poly-alpha-olefins may be derived from an alpha-olefin having from about 2 to about 30, from about 4 to about 20, or from about 6 to about 16 carbon atoms. Non-limiting examples of suitable poly-alpha-olefins include those derived from octene, decene, mixtures thereof, and the like. These poly-alpha-olefins may have a viscosity from about 2 to about 15, from about 3 to about 12, or from about 4 to about 8 centistokes at 100° C. In some instances, the poly-alpha-olefins may be used together with other base oils such as mineral oils.

[0052] In further embodiments, the base oil comprises a polyalkylene glycol or a polyalkylene glycol derivative, where the terminal hydroxyl groups of the polyalkylene glycol may be modified by esterification, etherification, acetylation and the like. Non-limiting examples of suitable polyalkylene glycols include polyethylene glycol, polypropylene glycol, polyisopropylene glycol, and combinations thereof. Non-limiting examples of suitable polyalkylene glycol derivatives include ethers of polyalkylene glycols (e.g., methyl ether of polyisopropylene glycol, diphenyl ether of polyethylene glycol, diethyl ether of polypropylene glycol, etc.), mono- and polycarboxylic esters of polyalkylene glycols, and combinations thereof. In some instances, the polyalkylene glycol or polyalkylene glycol derivative may be used together with other base oils such as poly-alpha-olefins and mineral oils.

[0053] In further embodiments, the base oil comprises any of the esters of dicarboxylic acids (e.g., phthalic acid, succinic acid, alkyl succinic acids, alkenyl succinic acids, maleic acid, azelaic acid,

suberic acid, sebacic acid, fumaric acid, adipic acid, linoleic acid dimer, malonic acid, alkyl malonic acids, alkenyl malonic acids, and the like) with a variety of alcohols (e.g., butyl alcohol, hexyl alcohol, dodecyl alcohol, 2-ethylhexyl alcohol, ethylene glycol, diethylene glycol monoether, propylene glycol, and the like). Non-limiting examples of these esters include dibutyl adipate, di(2-ethylhexyl) sebacate, di-n-hexyl fumarate, dioctyl sebacate, diisooctyl azelate, diisodecyl azelate, dioctyl phthalate, didecyl phthalate, dieicosyl sebacate, the 2-ethylhexyl diester of linoleic acid dimer, and the like.

[0054] In further embodiments, the base oil comprises a hydrocarbon prepared by the Fischer-Tropsch process. The Fischer-Tropsch process prepares hydrocarbons from gases containing hydrogen and carbon monoxide using a Fischer-Tropsch catalyst. These hydrocarbons may require further processing in order to be useful as base oils. For example, the hydrocarbons may be dewaxed, hydroisomerized, and/or hydrocracked using processes known to a person of ordinary skill in the art.

[0055] In further embodiments, the base oil comprises an unrefined oil, a refined oil, a rerefined oil, or a mixture thereof. Unrefined oils are those obtained directly from a natural or synthetic source without further purification treatment. Non-limiting examples of unrefined oils include shale oils obtained directly from retorting operations, petroleum oils obtained directly from primary distillation, and ester oils obtained directly from an esterification process and used without further treatment. Refined oils are similar to the unrefined oils except the former have been further treated by one or more purification processes to improve one or more properties. Many such purification processes are known to those skilled in the art such as solvent extraction, secondary distillation, acid or base extraction, filtration, percolation, and the like. Rerefined oils are obtained by applying to refined oils processes similar to those used to obtain refined oils. Such rerefined

oils are also known as reclaimed or reprocessed oils and often are additionally treated by processes directed to removal of spent additives and oil breakdown products.

[0056] The following examples are presented to exemplify embodiments but are not intended to limit the application to the specific embodiments set forth. Unless indicated to the contrary, all parts and percentages are by weight. All numerical values are approximate. When numerical ranges are given, it should be understood that embodiments outside the stated ranges may still fall within the scope of the application. Specific details described in each example should not be construed as necessary features.

EXAMPLES

[0057] The following examples are intended for illustrative purposes only and do not limit in any way the scope. Inventive and comparative lubricating oil samples were subjected to the following performance tests.

FZG Step Load Test

[0058] The FZG Step Load Test (also known as CEC L-84-02) evaluates the ability of lubricating oils to resist scuffing in reduction gears, transmission gears, hypoid gears, spur gears, or other such gear types. The gear used in the test is a 10mm A10-type pinion with a wheel with a width of 20mm.

[0059] At the start of the test, an initial load is applied. The lubricating oil is heated to an initial temperature of 90 °C, and the motor is run at a wheel rotational speed of 2880 rpm and a circumferential speed of 16.6 m/s for 7 minutes and 30 seconds. After each load stage (12 load stages in total), the gear wheels are inspected visually, and measured for surface damage/wear. If

the measured wear exceeds a certain limit, the test is terminated, and the last load stage is identified as the failure load stage. Higher load stage failures are indicative of lubricant oils of greater scuff-resistance.

[0060] The lubricating oil formulations tested all contained the same additive base package that includes antioxidant, seal swell, and foam inhibitor. The amounts of phosphorus, sulfur, and sulfur-containing phosphorus components are also summarized in Tables 1 and 2. The formulations were tested in finished oils having PAO (polyalphaolefin) base stock with kinematic viscosities at 100 °C of approximately 4.50 cSt. Details of the key components are below:

[0061] Sulfur Component 1 (S-1): Di-tert-butyl polysulfide with an average polysulfide chain length of 4 containing approximately 54 wt% sulfur.

[0062] Sulfur Component 2 (S-2): Bishydrocarbylthio-substituted dimercaptothiadiazole and derivatives thereof containing approximately 28 wt% sulfur.

[0063] Sulfur Component 3 (S-3): 2,5-Dimercapto-1,3,4-thiadiazole containing approximately 64 wt% sulfur.

[0064] Sulfur Component 4 (S-4): 5,5'-dithiodi-1,3,4-thiadiazole-2(3H)-thione containing approximately 64 wt% sulfur.

[0065] Sulfur Component 5 (S-5): Methylenebis(dibutyldithiocarbamate) containing approximately 30 wt% sulfur.

[0066] Phosphorus Component 1 (P-1): Trilauryl phosphite containing approximately 5.5 wt% phosphorus.

[0067] Phosphorus Component 2 (P-2): Dioleoyl hydrogen phosphite containing approximately 5.4 wt% phosphorus.

[0068] Sulfur-Containing Phosphorus Component 1 (S/P-1): Mixture of ammonium phosphate and ammonium dithiophosphate containing approximately 6.1 wt% phosphorus and 5.9 wt% sulfur.

[0069] Sulfur-Containing Phosphorus Component 2 (S/P-2): Dialkylphosphoryl alkanoic acid containing approximately 9.3 wt% phosphorus and 19.8 wt% sulfur.

[0070] Sulfur-Containing Phosphorus Component 3 (S/P-3): Triphenyl phosphorothioate containing approximately 9.0 wt% phosphorus and 9.3 wt% sulfur.

[0071] Basic Nitrogen-Containing Dispersant (D-1): Monosuccinimide dispersant prepared from 1000 Mn polyisobutylene containing approximately 3.2 wt% nitrogen.

[0072] Reference 1, Comparative Examples 1-5, Comparative Example 7, and Inventive Examples 1-8 were prepared by blending the components of the admixture as set forth in Tables 1 and 2 to generate finished fluids.

[0073] Comparative Example 6 was prepared by blending the basic nitrogen-containing dispersant component (D-1) with the dimercaptodithiadiazole component (S-3) at 100 °C for 2 hr to yield a homogenous, dark brown liquid. Remaining components of the admixture as set forth in Table 2 were added and blended to generate finished fluids.

[0074] The FZG step load scuffing performance data are shown below in Tables 1 and 2.

Table 1

Component (wt.%)	Ref. 1	Comp. Ex. 1	Comp. Ex. 2	Comp. Ex. 3	Comp. Ex. 4	Comp. Ex. 5	Inv. Ex. 1	Inv. Ex. 2
S-1	0.18	-	-	-	-	-	-	-
S-2	0.02	0.3	0.2	0.2	0.2	0.2	0.2	0.2

S-3	-	-	-	-	-	-	0.05	-
S-4	-	-	-	-	-	-	-	0.05
S-5	-	-	-	-	-	0.1	-	-
P-1	0.05	0.5	0.5	0.5	0.5	0.5	0.5	0.5
S/P - 1	0.05	-	0.5	-	-	-	-	-
S/P - 2	-	-	-	0.15	-	-	-	-
S/P - 3	-	-	-	-	0.15	-	-	-
Viscosity Modifier	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
KV100 (cSt)	4.46	4.43	4.43	4.52	4.52	4.44	4.44	4.44
Sulfur (ppm)	1050	850	920	940	920	950	970	960
FZG Step Load								
Failure Load Stage	4	6	7	7	7	8	11	9

[0075] The FZG step load scuffing results of Inventive Examples 1 and 2 provides a higher failure load stage compared to Comparative Examples 1-5, demonstrating the performance advantage of alkyl phosphite with S-3 (dimercaptothiadiazole monomer) (Inventive Example 1) or S-4 (dimercaptothiadiazole dimer) (Inventive Example 2).

[0076] Although Comparative Examples 1-5 do contain an equivalent amount of S-2 (bishydrocarbylthio-substituted dimercaptothiadiazole) as Inventive Examples 1 and 2, a synergy is observed when trialkyl phosphite (P-1) and S-1 or S-2 are combined. Surprisingly, as evidenced by the data in Table 1, Inventive Examples 1 and 2 (which contain comparable amounts of sulfur as Comparative Examples 1-5) exhibit superior wear performance.

Table 2

Component (wt%)	Comp. Ex. 6	Inv. Ex. 3	Inv. Ex. 4	Inv. Ex. 5	Inv. Ex. 6	Inv. Ex. 7	Inv. Ex. 8	Comp. Ex. 7
S-2	0.2	0.2	0.2	0.2	0.2	0.2	-	0.11
S-3	0.05	0.05	0.05	-	-	-	-	-
S-4	-	-	-	0.05	0.03	0.01	0.05	-
P-1	0.5	0.5	-	-	-	-	-	-
P-2	-	-	0.5	0.5	0.5	0.5	0.25	0.25
D-1	1.0	-	-	-	-	-	-	-
Viscosity Modifier	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
KV100 (cSt)	4.50	4.44	4.45	4.44	4.44	4.40	4.46	4.67
Sulfur (PPM)	970	970	930	960	820	690	330	400
FZG Step Load								
Failure Load Stage	5	11	10	9	10	8	8	4

[0077] Referencing the FZG step load scuffing results of Table 2, Inventive Examples 3 and 4 exhibit higher load stage failures compared to Comparative Example 6, which utilizes a conventional method of a basic dispersant to solubilize S-3. Inventive Examples 3-5 demonstrate the synergy of trihydrocarbyl phosphites (P-1) or dihydrocarbyl phosphites (P-2) with S-3 (dimercaptiothiadiazole monomer) or S-4 (dimercaptiothiadiazole dimer) in which high load stage failures are observed.

[0078] Inventive Examples 5-7 demonstrate the surprising synergy between the alkyl phosphite (P-2) with S-3 (dimercaptothiadiazole monomer) which maintained high load stage failures even as sulfur levels and treat rates of S-4 decreased.

[0079] Comparing Inventive Example 8 versus Comparative Example 7 demonstrates the improved gear wear performance as a result of the synergy between the alkyl phosphite with S-4 (dimercaptothiadiazole dimer). This is particularly evident when compared against conventional S-2 (bishydrocarbylthio-substituted dimercaptothiadiazole).

[0080] Lastly Inventive Example 8 showed suprisingly improved gear wear performance as a result of synergy between the alkyl phosphite with S-4 even in the absence of conventional S-2.

[0081] It will be understood that various modifications may be made to the embodiments disclosed herein. Therefore, the above description should not be construed as limiting, but merely as exemplifications of embodiments of the invention. For example, the functions described above and implemented for operating are for illustration purposes only. Other arrangements and methods may be implemented by those skilled in the art without departing from the scope and spirit of this application. Moreover, those skilled in the art will envision other modifications within the scope and spirit of the claims appended hereto.

CLAIMS

1. A lubricating oil composition comprising:
 - a. a major amount of an oil of lubricating viscosity;
 - b. a phosphorus-containing additive; and
 - c. at least one sulfur-containing additive, wherein the sulfur-containing additive is thiadiazole, dithiadiazole, dimercaptodithiadiazole, dimercaptodithiadiazole oligomer, or derivative thereof, or analog thereof.
2. The lubricating oil composition of claim 1, wherein the lubricating oil composition contains less than 2000 ppm of sulfur based on the total weight of the lubricating oil composition.
3. The lubricating oil composition of claim 1, wherein the phosphorus-containing additive is a hydrocarbyl phosphite, a hydrocarbyl phosphonate, a hydrocarbyl thiophosphite, a phosphonic acid, a hydrocarbyl phosphate ester, or a polymeric polyphosphite.
4. The lubricating oil composition of claim 1, wherein the phosphorus-containing additive is a dihydrocarbyl phosphite, a trihydrocarbyl phosphite, or a dihydrocarbyl phosphonate.
5. The lubricating oil composition of claim 1, wherein the dimercaptodithiadiazole oligomer is a dimer, a trimer, or tetramer.
6. The lubricating oil composition of claim 1, wherein the sulfur-containing additive is a salt.
7. The lubricating oil composition of claim 1, further comprising:
dispersant, detergent, friction modifier, foam inhibitor, seal swell, demulsifier, pour point depressant, metal deactivator, antioxidant, or corrosion inhibitor.
8. A method of improving the wear performance of a motor featuring an electric driveline, the method comprising lubricating the motor with a lubricating oil composition comprising:
 - a. a major amount of an oil of lubricating viscosity;

- b. a phosphorus-containing additive; and
 - c. at least one sulfur-containing additive, wherein the sulfur-containing additive is thiadiazole, dithiadiazole, dimercaptodithiadiazole, dimercaptodithiadiazole oligomer, or derivative thereof, or analog thereof.
9. The method of claim 8, wherein the lubricating oil composition contains less than 2000 ppm of sulfur based on the total weight of the lubricating oil composition.
10. The method of claim 8, wherein the phosphorus-containing additive is a hydrocarbyl phosphite, a hydrocarbyl phosphonate, a hydrocarbyl thiophosphite, a phosphonic acid, a hydrocarbyl phosphate ester, or a polymeric polyphosphite.
11. The method of claim 8, wherein the phosphorus-containing additive is a dihydrocarbyl phosphite, a trihydrocarbyl phosphite, or a dihydrocarbyl phosphonate.
12. The method of claim 8, wherein the dimercaptodithiadiazole oligomer is a dimer, a trimer, or tetramer.
13. The method of claim 8, wherein the sulfur-containing additive is a salt.
14. The method of claim 8, wherein the lubricating oil composition further comprises: dispersant, detergent, friction modifier, foam inhibitor, seal swell, demulsifier, pour point depressant, metal deactivator, antioxidant, or corrosion inhibitor.