combustion chamber from the piston crevice (the space between the piston ring pack and cylinder liner) may be one cause of LSPI events. Accordingly, there is a need for engine oil additive components and/or combinations that are effective to reduce or eliminate LSPI in boosted internal combustion engines.

Some studies are exploring the options of lowering calcium sulfonate detergent concentrations to help suppress LSPI, however this reduction adversely affects the performance of the lubricating oil in other areas, such as corrosion (e.g., rust) protection. Magnesium sulfonates have also been evaluated as an alternative to calcium sulfonate detergents to provide corrosion protection while improving LSPI performance. Unfortunately, this may also lead to debits in performance in other areas such as fuel economy.

US 2018/0237718 relates to lubricating oil compositions for improving low speed pre-ignition in direct injection spark-ignited internal combustion engines. The lubricating oil compositions include a detergent comprising an overbased calcium detergent having a total base number of at least 150. The lubricating oil composition has a calcium content of at least 0.08 wt.% and a silicon content of at least 12 ppmw of by weight, based on the total weight of the lubricating oil composition.

US 2019/0360383 relates to lubricating oil compositions for improving low speed pre-ignition in direct injection spark-ignited internal combustion engines. The lubricating oil compositions may include a detergent in combination with at least one silane-containing compound,

The present disclosure is directed to providing particular lubricating oil compositions and methods of using such lubricating oil compositions which result in a significant benefit in reduction of LSPI events, while still providing other desirable properties that are important for lubrication of direct injection spark-ignited internal composition engines.

SUMMARY AND TERMS

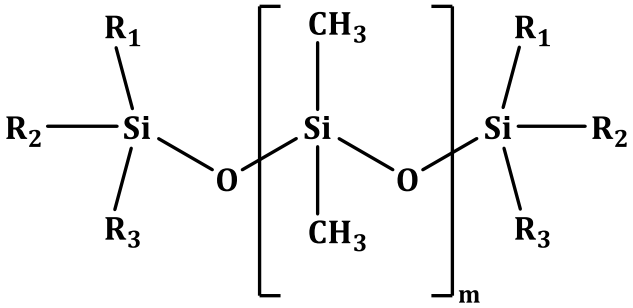
The present disclosure relates to a lubricating oil composition including greater than 50 wt.% of a base oil of lubricating viscosity, and an additive composition prepared by mixing a calcium-containing detergent, and a silicon-containing compound.

In a first aspect of the present disclosure, there is provided a lubricating oil composition formulated for use in a turbocharged gasoline direct-injection engine comprising:

greater than 50 wt.% of a base oil of lubricating viscosity, based on a total weight of the lubricating oil composition, and an additive composition prepared by mixing:

a) an amount of one or more overbased calcium sulfonate detergents to provide at least 1200 ppmw to 2400 ppmw of calcium to the lubricating oil composition, based on the total weight of the lubricating oil composition, and

b) an amount of one or more silicon-containing compound(s) of formula (IA) to provide at least 170 ppmw to 550 ppmw of silicon to the lubricating oil composition, based on the total weight of the lubricating oil composition



(IA)

wherein R_1, R_2, R_3, are each independently selected from an alkyl group comprising from 1 to 20 carbon atoms, m is an integer from 1 to less than 50; and

wherein a ratio of ppmw of silicon provided by the one or more silicon-containing compound(s) to the lubricating oil composition to the ppmw of calcium provided by the one or more calcium-containing detergent(s) to the lubricating oil composition is at least 0.027 to 1; and

the lubricating oil composition is devoid of a calcium salicylate detergent.

In another aspect of the present disclosure, there is provided a method for reducing low-speed pre-ignition (LSPI) events in a turbocharged gasoline direct-injection engine comprising lubricating the engine with the lubricating oil composition as disclosed herein, wherein the number of low-speed pre-ignition (LSPI) events is reduced relative to a number of low speed pre-ignition events in the same engine lubricated with the same lubricating oil composition absent the additive composition.

In a further aspect of the present disclosure, there is provided a method for providing corrosion protection, comprising lubricating an engine with the lubricating oil composition as disclosed herein.

The following sentences describe some examples of the present disclosure.

1. In a first example, the present disclosure relates to a lubricating oil composition comprising:

32. The lubricating oil composition of any one of sentences 1-31, wherein the lubricating oil composition may be effective to reduce the number of low-speed pre-ignition events relative to the number of low-speed pre-ignition events in the same engine lubricated with the same lubricating oil composition absent the additive composition, as determined in a GM 2.0 Liter, 4 cylinder Ecotec turbocharged gasoline direct injection engine operated at an engine speed of 2,000 rpm and a brake mean effective pressure (BMEP) of about 18 bar for 6 segments of 25,000 cycles per segment.

33. In a second example, the present disclosure relates to a method for reducing low-speed pre-ignition (LSPI) events in a turbocharged gasoline direct-injection engine comprising lubricating the engine with the lubricating oil composition of any one of sentences 1-32.

34. The method of sentence 33, wherein the number of low-speed pre-ignition (LSPI) events may be reduced relative to a number of low speed pre-ignition events in the same engine lubricated with the same lubricating oil composition absent the additive composition.

35. In a third example, the present disclosure relates to a method for providing corrosion protection, comprising lubricating an engine with the lubricating oil composition of any one of sentences 1-32.

36. In a fourth example, the present disclosure relates to a method of preparing a silicon-containing detergent comprising the steps of:

mixing a) and b) to form a mixture:

a) one or more calcium-containing detergent(s); and

b) one or more silicon-containing compound(s) selected from the group consisting of:

38. The method of any one of sentences 36 to 37, wherein the heating step may be carried out at a temperature of from about 35ºC to about 80ºC, or from about 40ºC to about 70ºC, or from about 45ºC to about 65ºC for a period of 30 minutes to 10 hours, or from 1 hour to 8 hours.

39. The method of any one of sentences 36 to 38, wherein the silicon-containing compound may be a compound according to Formula (I).

40. The method of any one of sentences 36 to 38, wherein the silicon-containing compound may be a compound according to Formula (III).

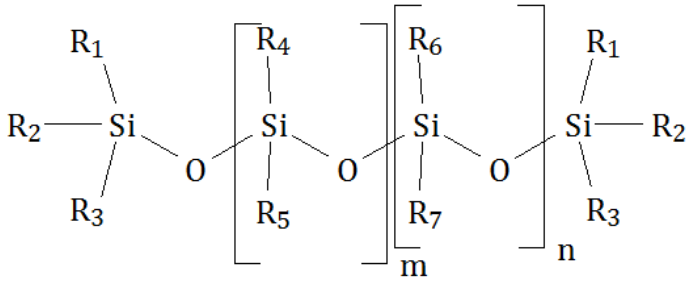
41. The method of any one of sentences 36 to 38, wherein the silicon-containing compound may be a silica and/or silicon-containing nanoparticle.

42. In a fifth example, the present disclosure relates to a silicon containing-detergent prepared by mixing:

a) one or more calcium-containing detergent(s); and

b) one or more silicon-containing compound(s) selected from the group consisting of:

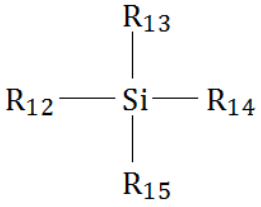
i) siloxanes according to the Formula (I):



(I)

wherein R_1, R_2, R_3, are each independently selected from an alkyl group comprising from 1 to 20 carbon atoms, R_4 and R_6 are each independently selected from an alkyl group comprising from 1 to 20 carbon atoms and an aryl group comprising from 6 to 16 carbon atoms, R_5 and R_7 are each independently selected from an alkyl group comprising from 1 to 3 carbon atoms, m is an integer from 0 to 50, n is an integer from 0 to 50, and $m + n < 50$;

ii) silicon-containing compounds according to Formula (III):



(III)

wherein R_{12}, R_{13}, R_{14}, and R_{15} are each independently selected from an alkyl group comprising from 1 to 20 carbon atoms and an alkoxy group comprising from 1 to 20 carbon atoms; and

iii) silica and/or silicon-containing nanoparticles, wherein the nanoparticles have a size of from 1 to 500 nm, as measured by Dynamic Light Scattering;

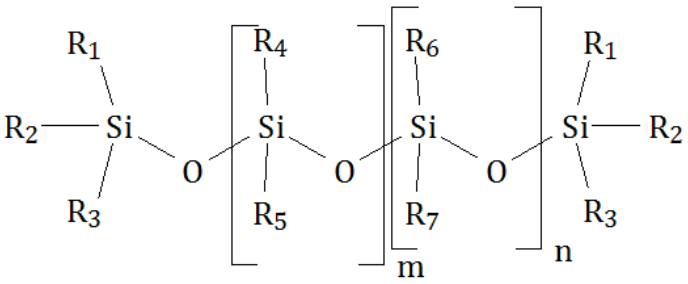
wherein a ratio of ppmw of silicon provided by the one or more silicon-containing compound(s) to the silicon-containing detergent to the ppmw of calcium provided by the one or more calcium-containing detergent(s) to the silicon-containing detergent is from 0.02 to 1.

43. In a sixth example, the present disclosure relates to a silicon containing-detergent prepared by the reaction of:

a) one or more calcium-containing detergent(s); and

b) one or more silicon-containing compound(s) selected from the group consisting of:

i) siloxanes according to the Formula (I):

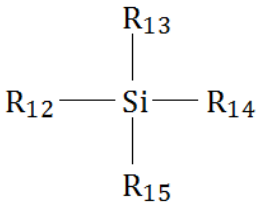


(I)

wherein R_1, R_2, R_3, are each independently selected from an alkyl group comprising from 1 to 20 carbon atoms, R_4 and R_6 are each independently selected from an alkyl group comprising from 1 to 20 carbon atoms and an aryl group comprising from 6 to 16 carbon atoms, R_5 and R_7

are each independently selected from an alkyl group comprising from 1 to 3 carbon atoms, m is an integer of from 0 to 50, n is integer of from 0 to 50, and m + n < 50;

ii) silicon-containing compounds according to Formula (III):



(III)

wherein R_{12}, R_{13}, R_{14}, and R_{15} are each independently selected from an alkyl group comprising from 1 to 20 carbon atoms and an alkoxy group comprising from 1 to 20 carbon atoms; and

iii) silica and/or silicon-containing nanoparticles, wherein the nanoparticles have a size of from 1 to 500 nm, as measured by Dynamic Light Scattering;

wherein a ratio of ppmw of silicon provided by the one or more silicon-containing compound(s) to the silicon-containing detergent to the ppmw of calcium provided by the one or more calcium-containing detergent(s) to the silicon-containing detergent is from 0.02 to 1.

44. In a seventh example, the present disclosure relates to a lubricating oil composition comprising:

greater than 50 wt.% of a base oil of lubricating viscosity, based on a total weight of the lubricating oil composition, and an amount of one or more silicon-containing detergents as claimed in any one of sentences 42-43, wherein the one or more silicon-containing detergents is present in an amount to provide at least 50 ppmw of silicon, based on the total weight of the lubricating oil composition.

45. In an eighth example, the present disclosure relates to a method for reducing low-speed pre-ignition (LSPI) events in a turbocharged gasoline direct-injection engine comprising lubricating the engine with the lubricating oil composition of sentence 44, wherein the number of low-speed pre-ignition (LSPI) events is reduced relative to a number of low speed pre-ignition events in the same engine lubricated with the same lubricating oil composition absent the one or more silicon-containing detergents.

46. In a ninth example, the present disclosure relates to a method for providing corrosion protection, comprising lubricating an engine with the lubricating oil composition of sentence 44.

The following definitions of terms are provided in order to clarify the meanings of certain terms as used herein.

The terms “oil composition,” “lubrication composition,” “lubricating oil composition,” “lubricating oil,” “lubricant composition,” “lubricating composition,” “fully formulated lubricant composition,” “lubricant,” “crankcase oil,” “crankcase lubricant,” “engine oil,” “engine lubricant,” “motor oil,” and “motor lubricant” are considered synonymous, fully interchangeable terminology referring to the finished lubrication product comprising a major amount of a base oil plus a minor amount of an additive composition.

As used herein, the terms “additive package,” “additive concentrate,” “additive composition,” “engine oil additive package,” “engine oil additive concentrate,” “crankcase additive package,” “crankcase additive concentrate,” “motor oil additive package,” “motor oil concentrate,” are considered synonymous, fully interchangeable terminology referring the portion of the lubricating oil composition excluding the major amount of base oil stock mixture. The additive package may or may not include the viscosity index improver or pour point depressant.

The term “overbased” relates to metal salts, such as metal salts of sulfonates, carboxylates, salicylates, and/or phenates, wherein the amount of metal present exceeds the stoichiometric amount. Such salts may have a conversion level in excess of 100% (i.e., they may comprise more than 100% of the theoretical amount of metal needed to convert the acid to its “normal,” “neutral” salt). The expression “metal ratio,” often abbreviated as MR, is used to designate the ratio of total chemical equivalents of metal in the overbased salt to chemical equivalents of the metal in a neutral salt according to known chemical reactivity and stoichiometry. In a normal or neutral salt, the metal ratio is one and in an overbased salt, MR, is greater than one. They are commonly referred to as overbased, hyperbased, or superbased salts and may be salts of organic sulfur acids, carboxylic acids, salicylates, and/or phenols. In the present disclosure, the overbased detergent has a TBN of greater than 225 mg KOH/g. The overbased detergent may be a combination of two or more overbased detergents each having a TBN of greater than 225 mg KOH/g, as measured by the method of ASTM D2896.

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

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, oxygen, and sulfur.

Lubricants, combinations of components, or individual components of the present description may be suitable for use in various types of internal combustion engines. Suitable engine types may include, but are not limited to heavy duty diesel, passenger car, light duty diesel, medium speed diesel, or marine engines. An internal combustion engine may be a diesel fueled engine, a gasoline fueled engine, a natural gas fueled engine, a bio-fueled engine, a mixed diesel/biofuel fueled engine, a mixed gasoline/biofuel fueled engine, an alcohol fueled engine, a mixed gasoline/alcohol fueled engine, a compressed natural gas (CNG) fueled engine, or mixtures thereof. A diesel engine may be a compression ignited engine. A gasoline engine may be a spark-ignited engine. An internal combustion engine may also be used in combination with an electrical or battery source of power. An engine so configured is commonly known as a hybrid engine. The internal combustion engine may be a 2-stroke, 4-stroke, or rotary engine. Suitable internal combustion engines include marine diesel engines (such as inland marine), aviation piston engines, low-load diesel engines, and motorcycle, automobile, locomotive, and truck engines.

The internal combustion engine may contain components of one or more of an aluminum-alloy, lead, tin, copper, cast iron, magnesium, ceramics, stainless steel, composites, and/or mixtures thereof. The components may be coated, for example, with a diamond-like carbon coating, a lubrited coating, a phosphorus-containing coating, molybdenum-containing coating, a graphite coating, a nano-particle-containing coating, and/or mixtures thereof. The aluminum-alloy may include aluminum silicates, aluminum oxides, or other ceramic materials. In one example the aluminum-alloy is an aluminum-silicate surface. As used herein, the term “aluminum alloy” is intended to be synonymous with “aluminum composite” and to describe a component or surface comprising aluminum and another component intermixed or reacted on a microscopic or nearly microscopic level, regardless of the detailed structure thereof. This would include any conventional alloys with metals other than aluminum as well as composite or alloy-like structures with non-metallic elements or compounds such with ceramic-like materials.

The lubricating oil composition for an internal combustion engine may be suitable for any engine lubricant irrespective of the sulfur, phosphorus, or sulfated ash (ASTM D-874) content. The sulfur content of the engine oil lubricant may be about 1 wt% or less, or about 0.8 wt% or

less, or about 0.5 wt% or less, or about 0.4 wt% or less, or about 0.3 wt% or less, or about 0.2 wt% or less. In one example the sulfur content may be in the range of about 0.001 wt% to about 0.5 wt%, or about 0.01 wt% to about 0.3 wt%. The phosphorus content may be about 0.2 wt% or less, or about 0.1 wt% or less, or about 0.085 wt% or less, or about 0.08 wt% or less, or even about 0.06 wt% or less, about 0.055 wt% or less, or about 0.05 wt% or less. In one example the phosphorus content may be about 50 ppmw to about 1000 ppmw, or about 325 ppmw to about 850 ppmw. The total sulfated ash content may be about 2 wt% or less, or about 1.5 wt% or less, or about 1.1 wt% or less, or about 1 wt% or less, or about 0.8 wt% or less, or about 0.5 wt% or less. In one example the sulfated ash content may be about 0.05 wt% to about 0.9 wt%, or about 0.1 wt% or about 0.2 wt% to about 0.45 wt%. In another example, the sulfur content may be about 0.4 wt% or less, the phosphorus content may be about 0.08 wt% or less, and the sulfated ash is about 1 wt% or less. In yet another example the sulfur content may be about 0.3 wt% or less, the phosphorus content is about 0.05 wt% or less, and the sulfated ash may be about 0.8 wt% or less.

In one example the lubricating oil composition is an engine oil, wherein the lubricating oil composition may have (i) a sulfur content of about 0.5 wt% or less, (ii) a phosphorus content of about 0.1 wt% or less, and (iii) a sulfated ash content of about 1.5 wt% or less.

In some examples, the lubricating oil composition is suitable for use with engines powered by low sulfur fuels, such as fuels containing about 1 to about 5% sulfur. Highway vehicle fuels contain about 15 ppmw sulfur (or about 0.0015% sulfur). The lubricating oil composition is suitable for use with boosted internal combustion engines including turbocharged or supercharged internal combustion engines.

Further, lubricants of the present description may be suitable to meet one or more industry specification requirements such as ILSAC GF-3, GF-4, GF-5, GF-6, PC-11, CF, CF-4, CH-4, CK-4, FA-4, CJ-4, CI-4 Plus, CI-4, API SG, SJ, SL, SM, SN, ACEA A1/B1, A2/B2, A3/B3, A3/B4, A5/B5, C1, C2, C3, C4, C5, E4/E6/E7/E9, Euro 5/6,JASO DL-1, Low SAPS, Mid SAPS, or original equipment manufacturer specifications such as DexosTM 1, DexosTM 2, MB-Approval 229.1, 229.3, 229.5, 229.51/229.31, 229.52, 229.6, 229.71, 226.5, 226.51, 228.0/.1, 228.2/.3, 228.31, 228.5, 228.51, 228.61, VW 501.01, 502.00, 503.00/503.01, 504.00, 505.00, 505.01, 506.00/506.01, 507.00, 508.00, 509.00, 508.88, 509.99, BMW Longlife-01, Longlife-01 FE, Longlife-04, Longlife-12 FE, Longlife-14 FE+, Longlife-17 FE+, Porsche A40,

C30, Peugeot Citroën Automobiles B71 2290, B71 2294, B71 2295, B71 2296, B71 2297, B71 2300, B71 2302, B71 2312, B71 2007, B71 2008, Renault RN0700, RN0710, RN0720, Ford WSS-M2C153-H, WSS-M2C930-A, WSS-M2C945-A, WSS-M2C913A, WSS-M2C913-B, WSS-M2C913-C, WSS-M2C913-D, WSS-M2C948-B, WSS-M2C948-A, GM 6094-M, Chrysler MS-6395, Fiat 9.55535 G1, G2, M2, N1, N2, Z2, S1, S2, S3, S4, T2, DS1, DSX, GH2, GS1, GSX, CR1, Jaguar Land Rover STJLR.03.5003, STJLR.03.5004, STJLR.03.5005, STJLR.03.5006, STJLR.03.5007, STJLR.51.5122 or any past or future PCMO or HDD specifications not mentioned herein. In some examples for passenger car motor oil (PCMO) applications, the amount of phosphorus in the finished fluid is 1000 ppmw or less or 900 ppmw or less or 800 ppmw or less.

Other hardware may not be suitable for use with the disclosed lubricant. A "functional fluid" is a term which encompasses a variety of fluids including but not limited to tractor hydraulic fluids, power transmission fluids including automatic transmission fluids, continuously variable transmission fluids and manual transmission fluids, hydraulic fluids, including tractor hydraulic fluids, some gear oils, power steering fluids, fluids used in wind turbines, compressors, some industrial fluids, and fluids related to power train components. It should be noted that within each of these fluids such as, for example, automatic transmission fluids, there are a variety of different types of fluids due to the various transmissions having different designs which have led to the need for fluids of markedly different functional characteristics. This is contrasted by the term "lubricating fluid" which is not used to generate or transfer power.

With respect to tractor hydraulic fluids, for example, these fluids are all-purpose products used for all lubricant applications in a tractor except for lubricating the engine. These lubricating applications may include lubrication of gearboxes, power take-off and clutch(es), rear axles, reduction gears, wet brakes, and hydraulic accessories.

When the functional fluid is an automatic transmission fluid, the automatic transmission fluids must have enough friction for the clutch plates to transfer power. However, the friction coefficient of fluids has a tendency to decline due to the temperature effects as the fluid heats up during operation. It is important that the tractor hydraulic fluid or automatic transmission fluid maintain its high friction coefficient at elevated temperatures, otherwise brake systems or automatic transmissions may fail. This is not a function of an engine oil.

Tractor fluids, and for example Super Tractor Universal Oils (STUOs) or Universal Tractor Transmission Oils (UTTOs), may combine the performance of engine oils with

transmissions, differentials, final-drive planetary gears, wet-brakes, and hydraulic performance. While many of the additives used to formulate a UTTO or a STUO fluid are similar in functionality, they may have deleterious effect if not incorporated properly. For example, some anti-wear and extreme pressure additives used in engine oils can be extremely corrosive to the copper components in hydraulic pumps. Detergents and dispersants used for gasoline or diesel engine performance may be detrimental to wet brake performance. Friction modifiers specific to quiet wet brake noise, may lack the thermal stability required for engine oil performance. Each of these fluids, whether functional, tractor, or lubricating, are designed to meet specific and stringent manufacturer requirements.

The present disclosure provides novel lubricating oil blends formulated for use as automotive crankcase lubricants. Examples of the present disclosure may provide lubricating oils suitable for crankcase applications and having improvements in the following characteristics: air entrainment, alcohol fuel compatibility, antioxidancy, antiwear performance, biofuel compatibility, foam reducing properties, friction reduction, fuel economy, pre-ignition prevention, rust inhibition, sludge and/or soot dispersability, piston cleanliness, deposit formation, and water tolerance.

Engine oils of the present disclosure may be formulated by the addition of one or more additives, as described in detail below, to an appropriate base oil formulation. The additives may be pre-mixed and then combined with a base oil in the form of an additive package (or concentrate) or, alternatively, may be mixed by being combined individually or in any combination with a base oil (or a mixture of both). The fully formulated engine oil may exhibit improved performance properties, based on the additives added and their respective proportions.

Additional details and advantages of the disclosure will be set forth in part in the description which follows, and/or may be learned by practice of the disclosure. The details and advantages of the disclosure may be realized and attained by means of the elements and combinations particularly pointed out in the appended claims. It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the disclosure, as claimed.

BRIEF DESCRIPTION OF THE DRAWING

Figure 1 shows the High Frequency Reciprocating Rig (HFRR) test results for a lubricating oil composition containing a silicon-containing detergent.

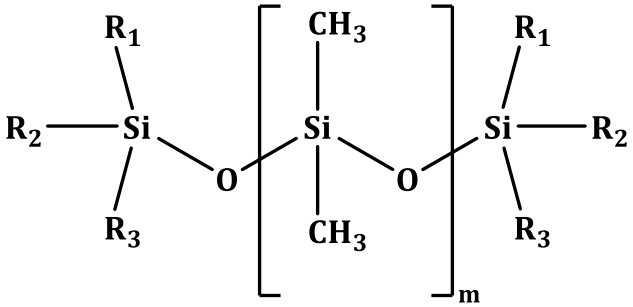
What is Claimed is:

1. A lubricating oil composition formulated for use in a turbocharged gasoline direct-injection engine comprising:

greater than 50 wt.% of a base oil of lubricating viscosity, based on a total weight of the lubricating oil composition, and an additive composition prepared by mixing:

a) an amount of one or more overbased calcium sulfonate detergents to provide at least 1200 ppmw to 2400 ppmw of calcium to the lubricating oil composition, based on the total weight of the lubricating oil composition, and

b) an amount of one or more silicon-containing compound(s) of formula (IA) to provide at least 170 ppmw to 550 ppmw of silicon to the lubricating oil composition, based on the total weight of the lubricating oil composition



(IA)

wherein R_1, R_2, R_3, are each independently selected from an alkyl group comprising from 1 to 20 carbon atoms, m is an integer from 1 to less than 50; and

wherein a ratio of ppmw of silicon provided by the one or more silicon-containing compound(s) to the lubricating oil composition to the ppmw of calcium provided by the one or more calcium-containing detergent(s) to the lubricating oil composition is at least 0.027 to 1; and

the lubricating oil composition is devoid of a calcium salicylate detergent.

2. The lubricating oil composition of claim 1, wherein R_1, R_2 and R_3 are methyl groups.

3. The lubricating oil composition of claim 1, wherein the compound of the Formula (IA) is a polydimethylsiloxane.

4. The lubricating oil composition of claim 1, wherein the compound of the Formula (IA) has a number average molecular weight of from 100 g/mol to 1,000 g/mol, or from 125 g/mol to 800 g/mol, or from 150 g/mol to 600 g/mol, as determined by gel permeation chromatography.

5. The lubricating oil composition of claim 1, wherein the compound of the Formula (IA) has a number average molecular weight of at least 1,000 g/mol, or from 1,000 g/mol to 5,000 g/mol, or from 1,000 g/mol to less than 3866 g/mol, as determined by gel permeation chromatography.

6. The lubricating oil composition of claim 1, wherein the compound of the Formula (IA) has a kinematic viscosity of from 1 cSt to 299 cSt, or from 1 to 50 cSt, or from 1 to 30 cSt, or from 1 to 10 cSt, or from 1 to less than 10 cSt, at 25ºC, as measured according to ASTM-445-19.

7. The lubricating oil composition of claim 1, wherein the compound of Formula (IA) has an elemental ratio of hydrogen atoms to silicon atoms of from 6.115 to 9.

8. The lubricating oil composition of claim 1, wherein the compound of Formula (IA) has an elemental ratio of carbon atoms to silicon atoms of from 2.038 to 3.

9. The lubricating oil composition of claim 1, wherein the compound of Formula (IA) has an elemental ratio of silicon atoms to oxygen atoms of from 1.019 to 2.

10. The lubricating oil composition of any one of claims 1-9, wherein the ratio of the ppmw of silicon provided by the one or more silicon-containing compound(s) to the lubricating oil composition to the ppmw of calcium provided by the one or more calcium-containing detergent(s) to the lubricating oil composition is from 0.027 to 0.75, or from 0.035 to 0.5, or from 0.0375 to 0.45.

11. The lubricating oil composition of any one of claims 1-10, wherein the calcium-containing detergent is present in an amount to provide 1.0 wt% to 10 wt%, or 1.0 wt% to 8 wt%, or 1.0 wt% to 4.0 wt%, or greater than 4 wt% to 8 wt%, based on the total weight of the lubricating oil composition.

12. The lubricating oil composition of any one of claims 1-11, wherein the one or more calcium-containing detergents is an overbased calcium-containing detergent having a TBN of greater than 225 mg KOH/g, or greater than 250 mg KOH/g, or greater than 275 mg KOH/g, or at least 300 mg KOH/g, as measured by ASTM-2896.

13. The lubricating oil composition of any one of claims 1-12, wherein the lubricating oil composition is devoid of detergents selected from the group consisting of phenate-containing detergents.

14. The lubricating oil composition of any one of claims 1-13, wherein the lubricating oil composition provides acceptable stability.

15. The lubricating oil composition of any one of claims 1-14, wherein the lubricating oil composition provides corrosion protection, according to ASTM D6557.

16. The lubricating oil composition of any one of claims 1-15, wherein the lubricating oil composition has a total sulfated ash content of 2 wt% or less, or 1.5 wt% or less, or 1.1 wt% or less, or 1 wt% or less, or 0.8 wt% or less, or 0.5 wt% or less, based on the total weight of the lubricating oil composition.

17. The lubricating oil composition of any one of claims 1-16, wherein the lubricating oil composition is effective to reduce the number of low-speed pre-ignition events relative to the number of low-speed pre-ignition events in the same engine lubricated with the same lubricating oil composition absent the additive composition, as determined in a GM 2.0 Liter, 4 cylinder Ecotec turbocharged gasoline direct injection engine operated at an engine speed of 2,000 rpm and a brake mean effective pressure (BMEP) of 18 bar for 6 segments of 25,000 cycles per segment.

18. A method for reducing low-speed pre-ignition (LSPI) events in a turbocharged gasoline direct-injection engine comprising lubricating the engine with the lubricating oil composition of any one of claims 1-17, wherein the number of low-speed pre-ignition (LSPI) events is reduced relative to a number of low speed pre-ignition events in the same engine lubricated with the same lubricating oil composition absent the additive composition.

19. A method for providing corrosion protection, comprising lubricating an engine with the lubricating oil composition of any one of claims 1-17.

20. The lubricating oil composition of claim 1, wherein the overbased calcium sulfonate detergent is present in an amount sufficient to provide from 1200 ppmw to 2000 ppmw of calcium, based on the total weight of the lubricating oil composition.