[0006] Pre-ignition is a form of combustion that results of ignition of the air-fuel mixture in the combustion chamber prior to the desired ignition of the air-fuel mixture by the igniter. Pre-ignition has typically been a problem during high speed engine operation since heat from operation of the engine may heat a part of the combustion chamber to a sufficient temperature to ignite the air-fuel mixture upon contact. This type of pre-ignition is sometimes referred to as hot-spot pre-ignition.

[0007] More recently, intermittent abnormal combustion has been observed in boosted internal combustion engines at low speeds and medium-to-high loads. For example, during operation of the engine at 3,000 rpm or less, under load, with a brake mean effective pressure (BMEP) of at least 1,000 kPa, low-speed pre-ignition (LSPI) may occur in a random and stochastic fashion. During low speed engine operation, the compression stroke time is longest.

[0008] U.S. Application Publication no. 2007/0129266 A1 relates to a lubricating oil composition comprising a base oil and one or more magnesium detergents for the reduction of clogging in a diesel particulate filter.

[0009] U.S. Application Publication no. 2003/182847 A1 relates to fuel additives, lubricating oil additives for diesel engines having diesel particulate filters, comprising molybdenum compounds with a measured sulfated ash content of 1.0 wt% or less, a sulfur content of 0.3 wt% or less, and a molybdenum content of 100 ppm or more.

SUMMARY AND TERMS

[0009a] In a first aspect, the present disclosure refers to a lubricating oil composition comprising:

a) greater than 50 wt.% of a base oil of lubricating viscosity, based on the total weight of the lubricating oil composition;

b) an amount of one or more calcium-containing detergents to provide less than 1700 ppm calcium, based on a total weight of the lubricating oil composition, and the one or more calcium-containing detergents excludes a calcium salicylate detergent,

c) an amount of one or more magnesium-containing detergents to provide less than 450 ppm magnesium, based on the total weight of the lubricating oil composition;

d) an amount of one or more molybdenum-containing compounds to provide less than 450 ppm molybdenum, based on the total weight of the lubricating oil composition;

e) from 700 ppm to 900 ppm of phosphorus, based on the total weight of the lubricating oil composition; and

f) a total measured sulfated ash content of no greater than 1.0 wt.%, as measured by ASTM D874, based on the total weight of the lubricating oil composition; and

a ratio, in ppm, of calcium from the one or more calcium-containing detergents to magnesium from the one or more magnesium-containing detergents of 1:1 or more, and

wherein the lubricating oil composition contains less than 10 ppm of boron, based on the total weight of the lubricating oil composition.

[0009b] In another aspect, the present disclosure refers to a method for reducing clogging in a diesel particulate filter comprising a step of operating an engine equipped with a diesel particulate filter and lubricated with a lubricating oil composition comprising:

a) greater than 50 wt.% of a base oil of lubricating viscosity, based on the total weight of the lubricating oil composition;

b) an amount of one or more calcium-containing detergents to provide less than 1700 ppm calcium, based on a total weight of the lubricating oil composition, and the one or more calcium-containing detergents excludes a calcium salicylate detergent;

c) an amount of one or more magnesium-containing detergents to provide less than 450 ppm magnesium, based on the total weight of the lubricating oil composition;

d) an amount of one or more molybdenum-containing compounds to provide less than 450 ppm molybdenum, based on the total weight of the lubricating oil composition;

e) from 700 ppm to 900 ppm of phosphorus, based on the total weight of the lubricating oil composition; and

f) a total sulfated ash content of no less than 0.5 wt.% and no greater than 1.0 wt.%, as measured by ASTM D874, based on a total weight of the lubricating oil composition; and

a ratio, in ppm, of calcium from the one or more calcium-containing detergents to magnesium from the one or more magnesium-containing detergents of 1:1 or more, and

wherein the lubricating oil composition contains less than 10 ppm of boron, based on the total weight of the lubricating oil composition.

[0010] The present disclosure relates to a lubricating oil composition including a calcium-containing detergent and a magnesium-containing detergent, and methods for reducing clogging in a diesel particulate filter including a step of operating an engine equipped with a diesel particulate filter and lubricated with the lubricating oil composition including a calcium-containing detergent and a magnesium-containing detergent.

[0011] In a first ~~aspect~~example, the present disclosure relates to a lubricating oil composition including one or more calcium-containing detergents and one or more magnesium-containing detergents. The lubricating oil composition of the present disclosure includes greater than 50 wt.% of a base oil of lubricating viscosity, an amount of one or more calcium-containing detergents to provide less than 1700 ppm calcium, an amount of one or more magnesium-containing detergents to provide less than 450 ppm magnesium, an amount of one or more molybdenum-containing compounds to provide less than 450 ppm of molybdenum, from about 700 ppm to about 900 ppm of phosphorus, and a total measured sulfated ash content of no greater than 1.0 wt.%, as measured by ASTM D874, all based on the total weight of the

lubricating oil composition, and a ratio, in ppm, of calcium from the one or more calcium-containing detergents to magnesium from the one or more magnesium-containing detergents of 1:1 or more.

[0012] In the foregoing example~~embodiment~~, the lubricating oil composition may provide a diesel particulate filter delta pressure (ΔP) vs. oil consumption result of 0.6 kPa/kg or less, 0.5 kPa/kg or less or 0.45 kPa/kg or less, as measured in a VW PV 1485 test after 144 hours.

[0013] In each of the foregoing examples~~embodiments~~, the lubricating oil composition may be effective to reduce low speed pre-ignition events in a boosted internal combustion engine lubricated with the lubricating oil composition relative to a number of low speed pre-ignition events in the same engine lubricated with reference lubricating oil R-1; or the reduction of LSPI events may be 50% or greater reduction and the LSPI events are LSPI counts during 25,000 engine cycles, wherein the engine is operated at 2000 revolutions per minute with brake mean effective pressure of 1,800 kPa.

[0014] In each of the foregoing examples~~embodiments~~, the one or more magnesium-containing detergents may provide 440 ppm or less of magnesium, or 430 ppm or less of magnesium, or 420 ppm or less of magnesium, or 410 ppm or less of magnesium, based on a total weight of the lubricating oil composition.

[0015] In each of the foregoing examples~~embodiments~~, the ratio of total calcium from the one or more calcium-containing detergents in ppm to total magnesium from the one or more magnesium-containing detergents may be more than 2.0, or more than 2.5, or more than 3.0, or more than 3.5, or less than 10.0, or less than 9.0, or less than 8.5, or more than 1.0 to less than 10.0.

[0016] In each of the foregoing examples~~embodiments~~, the one or more calcium-containing detergents may be overbased, having a total base number of greater than 200 mg KOH/g, or greater than 225 mg KOH/g, or greater than 250 mg KOH/g, as measured by the method of ASTM D-2896.

[0017] In each of the foregoing examples~~embodiments~~, the one or more calcium-containing detergents may be present in an amount sufficient to provide less than 1670 ppm calcium, or less than 1500 ppm calcium, or less than 1400 ppm calcium, or more than 1350 ppm to less than 1700 ppm calcium to the total weight of the lubricating oil composition.

[0018] In each of the foregoing examples~~embodiments~~, the total measured sulfated ash content may be less than 0.8 wt.%, or more than 0.6 wt.% to less than 1.0 wt.%, or more than 0.6 wt.% to less than 0.8 wt.%, each as measured by ASTM D874.

[0019] In each of the foregoing examples~~embodiments~~, the lubricating oil composition may provide an amount of one or more calcium-containing detergents having a total base number of up to 175 mg KOH/g as measured by the method of ASTM D-2896, if present, provides less than 50 ppm of calcium, or less than 20 ppm of calcium, or less than 5 ppm of calcium, or about 0 ppm of calcium, to the total weight of the lubricating oil composition.

[0020] In each of the foregoing examples~~embodiments~~, the lubricating oil composition may contain less than 100 ppm of boron, or less than 75 ppm of boron, or less than 50 ppm of boron, or less than 10 ppm of boron, or about 0 ppm of boron, based on a total weight of the lubricating oil composition.

[0021] In each of the foregoing examples~~embodiments~~, the lubricating oil composition may have more than 0 ppm of boron and a ratio of total metal in ppm to total boron in ppm of more than 7.5, or more than 50, or more than 75.

[0022] In each of the foregoing examples~~embodiments~~, the lubricating oil composition may contain 0 ppm to less than 100 ppm of boron, or 0 ppm to less than 75 ppm of boron, or 0 ppm to less than 50 ppm of boron, or 0 ppm to less than 10 ppm of boron.

[0023] In each of the foregoing examples~~embodiments~~, the one or more magnesium-containing detergents may be overbased having a total base number of greater than 225 mg KOH/g, or greater than 250 mg KOH/g, or greater than 300 mg KOH/g, or greater than 350 mg KOH/g, or greater than 400 mg KOH/g, as measured by the method of ASTM D-2896.

[0024] In each of the foregoing examples~~embodiments~~, the one or more calcium-containing detergents may optionally exclude a calcium salicylate detergent.

[0025] In each of the foregoing examples~~embodiments~~, the one or more magnesium-containing detergents may be an overbased magnesium sulfonate detergent having a total base number of greater than 225 mg KOH/g, or greater than 250 mg KOH/g, or greater than 300 mg KOH/g, or greater than 350 mg KOH/g, or greater than 400 mg KOH/g, as measured by the method of ASTM D-2896.

[0026] In each of the foregoing examples~~embodiments~~, the lubricating oil composition may be an engine oil composition.

[0027] In a second ~~aspect~~example, the present disclosure relates to a method for reducing clogging in a diesel particulate filter, including a step of operating an engine equipped with a diesel particulate filter and lubricated with a lubricating oil composition comprising greater than 50 wt.% of a base oil of lubricating viscosity, an amount of one or more calcium-containing detergents to provide less than 1700 ppm calcium, an amount of one or more magnesium-containing detergents to provide less than 450 ppm magnesium, an amount of

one or more molybdenum-containing compounds to provide less than 450 ppm of molybdenum, from about 700 ppm to about 900 ppm of phosphorus, and a total measured sulfated ash content of no greater than 1.0 wt.%, as measured by ASTM D874, all based on the total weight of the lubricating oil composition, and a ratio, in ppm, of calcium from the one or more calcium-containing detergents to magnesium from the one or more magnesium-containing detergents of 1:1 or more.

[0028] In this second example~~embodiment~~, the lubricating oil composition may provide a diesel particulate filter delta pressure (ΔP) vs. oil consumption result of 0.6 kPa/kg or less, 0.5 kPa/kg or less or 0.45 kPa/kg or less, as measured in a VW PV 1485 test after 144 hours.

[0029] In each of the foregoing second examples~~embodiments~~, the lubricating oil composition may be effective to reduce low speed pre-ignition events in a boosted internal combustion engine lubricated with the lubricating oil composition relative to a number of low speed pre-ignition events in the same engine lubricated with reference lubricating oil R-1; or the reduction of LSPI events may be 50% or greater reduction and the LSPI events are LSPI counts during 25,000 engine cycles, wherein the engine is operated at 2000 revolutions per minute with brake mean effective pressure of 1,800 kPa.

[0030] In each of the foregoing second examples~~embodiments~~, the one or more magnesium-containing detergents may provide 440 ppm or less of magnesium, or 430 ppm or less of magnesium, or 420 ppm or less of magnesium, or 410 ppm or less of magnesium, based on a total weight of the lubricating oil composition.

[0031] In each of the foregoing second examples~~embodiments~~, the ratio of total calcium from the one or more calcium-containing detergents in ppm to total magnesium from the one or more magnesium-containing detergents may be more than 2.0, or more than 2.5, or more than 3.0, or more than 3.5, or less than 10.0, or less than 9.0, or less than 8.5, or more than 1.0 to less than 10.0.

[0032] In each of the foregoing second examples~~embodiments~~, the one or more calcium-containing detergents may be overbased, having a total base number of greater than 200 mg KOH/g, or greater than 225 mg KOH/g, or greater than 250 mg KOH/g, as measured by the method of ASTM D-2896.

[0033] In each of the foregoing second examples~~embodiments~~, the one or more calcium-containing detergents may be present in an amount sufficient to provide less than 1670 ppm calcium, or less than 1500 ppm calcium, or less than 1400 ppm calcium, or more than 1350 ppm to less than 1700 ppm calcium to the total weight of the lubricating oil composition.

[0034] In each of the foregoing second examples~~embodiments~~, the total measured sulfated ash content may be less than 0.8 wt.%, or more than 0.6 wt.% to less than 1.0 wt.%, each as measured by ASTM D874.

[0035] In each of the foregoing second examples~~embodiments~~, the lubricating oil composition may provide an amount of one or more calcium-containing detergents having a total base number of up to 175 mg KOH/g as measured by the method of ASTM D-2896, if present, provides less than 50 ppm of calcium, or less than 20 ppm of calcium, or less than 5 ppm of calcium, or about 0 ppm of calcium, to the total weight of the lubricating oil composition.

[0036] In each of the foregoing second examples~~embodiments~~, the lubricating oil composition may contain less than 100 ppm of boron, or less than 75 ppm of boron, or less than 50 ppm of boron, or less than 10 ppm of boron, or about 0 ppm of boron, based on a total weight of the lubricating oil composition.

[0037] In each of the foregoing second examples~~embodiments~~, the lubricating oil composition may have more than 0 ppm of boron and a ratio of total metal in ppm to total boron in ppm of more than 7.5, or more than 50, or more than 500.

[0038] In each of the foregoing examples~~embodiments~~, the lubricating oil composition may contain 0 ppm to less than 100 ppm of boron, or 0 ppm to less than 75 ppm of boron, or 0 ppm to less than 50 ppm of boron, or 0 ppm to less than 10 ppm of boron.

[0039] In each of the foregoing second examples~~embodiments~~, the one or more magnesium-containing detergents may be overbased having a total base number of greater than 225 mg KOH/g, or greater than 250 mg KOH/g, or greater than 300 mg KOH/g, or greater than 350 mg KOH/g, or greater than 400 mg KOH/g, as measured by the method of ASTM D-2896.

[0040] In each of the foregoing second examples~~embodiments~~, the one or more calcium-containing detergents may optionally exclude a calcium salicylate detergent.

[0041] In each of the foregoing second examples~~embodiments~~, the one or more magnesium-containing detergents may be an overbased magnesium sulfonate detergent having a total base number of greater than 225 mg KOH/g, or greater than 250 mg KOH/g, or greater than 300 mg KOH/g, or greater than 350 mg KOH/g, or greater than 400 mg KOH/g, as measured by the method of ASTM D-2896.

[0042] In each of the foregoing second examples~~embodiments~~, the lubricating oil composition may be an engine oil composition.

[0043] The following definitions of terms are provided in order to clarify the meanings of certain terms as used herein.

consumption. The diesel particulate filter test measures the increase in backpressure versus oil consumption, after 144 hours of an ash loading phase.

[0056] A reduction in low speed pre-ignition events may be expressed as an "LSPI Ratio." The term, "LSPI Ratio" refers to a ratio of the number of low speed pre-ignition events in a boosted internal combustion engine lubricated with the lubricating oil composition of the present disclosure to a number of low speed pre-ignition events in the same boosted internal combustion engine lubricated with reference lubricating oil R-1 described herein. A lubricating oil composition that reduces the LSPI ratio is effective to reduce low speed pre-ignition events in a boosted internal combustion engine lubricated with the lubricating oil composition relative to a number of low speed pre-ignition events in the same engine lubricated with reference lubricating oil R-1.

[0057] 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 such as a boosted 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.

[0058] Passenger and light-duty vehicles may be equipped with either a compression (diesel) or spark-ignition (gasoline) internal combustion engine. Generally engine oils are specially formulated for use in one or the other. However, it can be beneficial to lubricate a spark-ignition engine with an engine oil formulated for a diesel engine. Further, some diesel engine oils are tested to meet both diesel and gasoline engine oil specifications (i.e., mixed specifications), and, thus are recommend for use with either engine-type. Therefore, an oil that meets both diesel engine and gasoline engine specifications and that can handle each of these diverse engine conditions is desirable.

[0059] 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 ~~embodiment~~ 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.

[0060] The lubricating oil composition for an internal combustion engine may be suitable for any engine lubricant irrespective of the sulfur, phosphorus, or 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 0.3 wt% or less, or about 0.2 wt% or less. In one example ~~embodiment~~ 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 from about 700 ppm to about 900 ppm, or from no more than 850 ppm. The total measured sulfated ash content may be no less than 0.5 wt% to no greater than 1.0 wt%,, or less than 0.8 wt%, or more than 0.5 wt% to less than 1.0 wt%, or more than 0.6 wt% to less than 1.0 wt%, as measured by ASTM D874. In another example~~embodiment~~, the sulfur content may be about 0.4 wt% or less, the phosphorus content may be about 0.08 wt% or less, and the measured sulfated ash is no less than 0.5 wt% to 1 wt% or less. In yet another example ~~embodiment~~ the sulfur content may be about 0.3 wt% or less, the phosphorus content is about 0.05 wt% or less, and the measured sulfated ash may be about 0.8 wt% or less.

[0061] In one example ~~embodiment~~ 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 measured sulfated ash content of no less than 0.5 wt% to no greater than 1.0 wt%.

[0062] In one example~~embodiment~~, the lubricating oil composition contains less than 10 ppm of boron, or less than 50 ppm or boron, or less than 10 ppm or boron, or 0 ppm of boron, based on a total weight of the lubricating oil composition. In another example~~embodiment~~, the

lubricating oil composition has more than 0 ppm of boron and the ratio of total metal in ppm to total boron in ppm is more than 7.5, or more than 50, or more than 500.

[0063] In one example ~~embodiment~~ the lubricating oil composition is suitable for a 2-stroke or a 4-stroke marine diesel internal combustion engine. In one example ~~embodiment~~ the marine diesel combustion engine is a 2-stroke engine. In some examples~~embodiments~~, the lubricating oil composition is not suitable for a 2-stroke or a 4-stroke marine diesel internal combustion engine for one or more reasons, including but not limited to, the high sulfur content of fuel used in powering a marine engine and the high TBN required for a marine-suitable engine oil (e.g., above about 40 TBN in a marine-suitable engine oil).

[0064] In some examples~~embodiments~~, 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 ppm sulfur (or about 0.0015% sulfur).

[0065] Low speed diesel typically refers to marine engines, medium speed diesel typically refers to locomotives, and high speed diesel typically refers to highway vehicles. The lubricating oil composition may be suitable for only one of these types or all.

[0066] 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-5+, GF-6, PC-11, CF, CK-4, FA-4, CF-4, CH-4, CI-4, CJ-4, API SG, SJ, SL, SM, SN, 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 Dexos™ 1, Dexos™ 2, MB-Approval 229.1, 229.3, 229.5, 229.31, 229.51, 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 ~~embodiments~~ examples for passenger car motor oil (PCMO) applications, the amount of phosphorus in the finished fluid is 1000 ppm or less or 900 ppm or less or 800 ppm or less.

[0071] The present disclosure provides novel lubricating oil blends formulated for use as automotive crankcase lubricants. The present disclosure provides novel lubricating oil blends formulated for use as 2T and/or 4T motorcycle crankcase lubricants. ~~Embodiments~~ 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, preignition prevention, rust inhibition, sludge and/or soot dispersability, piston cleanliness, deposit formation, and water tolerance.

[0072] 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 combined with a base oil in the form of an additive package (or concentrate) or, alternatively, may be combined individually 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.

[0073] Additional details and advantages of the present disclosure will be set forth in part in the description which follows, and/or may be learned by practice of the present disclosure. The details and advantages of the present 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 present disclosure, as claimed.

DETAILED DESCRIPTION

[0074] Various embodiments of the disclosure provide a lubricating oil composition and methods for reducing clogging in a diesel particulate filter. The lubricating oil composition may be useful in compression (diesel) engines and/or spark-ignited (gasoline) engines. In particular, engines in which the lubricating oil composition may be employed may include boosted internal combustion engines such as turbocharged and supercharged internal combustion engines. The boosted internal combustion engines include spark-ignited, direct injection and/or port-fuel injection engines. Preferably, the boosted internal combustion engine is a spark-ignited internal combustion engine or a direct injection engine.

[0075] In a first aspect, the present disclosure provides a lubricating oil composition that includes greater than 50 wt.% of a base oil of lubricating viscosity, an amount of one or more calcium-containing detergents to provide less than 1700 ppm calcium, an amount of one

CLAIMS:

1. A lubricating oil composition comprising:
   a) greater than 50 wt.% of a base oil of lubricating viscosity, based on the total weight of the lubricating oil composition;
   b) an amount of one or more calcium-containing detergents to provide less than 1700 ppm calcium, based on a total weight of the lubricating oil composition, and the one or more calcium-containing detergents excludes a calcium salicylate detergent,
   c) an amount of one or more magnesium-containing detergents to provide less than 450 ppm magnesium, based on the total weight of the lubricating oil composition;
   d) an amount of one or more molybdenum-containing compounds to provide less than 450 ppm molybdenum, based on the total weight of the lubricating oil composition;
   e) from ~~about~~ 700 ppm to ~~about~~ 900 ppm of phosphorus, based on the total weight of the lubricating oil composition; and
   f) a total measured sulfated ash content of no greater than 1.0 wt.%, as measured by ASTM D874, based on the total weight of the lubricating oil composition; and
   a ratio, in ppm, of calcium from the one or more calcium-containing detergents to magnesium from the one or more magnesium-containing detergents of 1:1 or more, and
   wherein the lubricating oil composition contains less than 10 ppm of boron, based on the total weight of the lubricating oil composition.

2. The lubricating oil composition of claim 1, wherein the lubricating oil composition provides a diesel particulate filter delta pressure (ΔP) vs. oil consumption result of 0.6 kPa/kg or less, 0.5 kPa/kg or less or 0.45 kPa/kg or less, as measured in a VW PV 1485 test after 144 hours.

3. The lubricating oil composition of claim 1, wherein the lubricating oil composition is effective to reduce low speed pre-ignition events in a boosted internal combustion engine lubricated with the lubricating oil composition relative to a number of low speed pre-ignition events in the same engine lubricated with reference lubricating oil R-1; or the reduction of LSPI events is 50% or greater reduction and the LSPI events

are LSPI counts during 25,000 engine cycles, wherein the engine is operated at 2000 revolutions per minute with brake mean effective pressure of 1,800 kPa, wherein R-1 is formulated from 80.7 wt.% of a Group III base oil, 12.1 wt.% of passenger car motor oil additive package and 7.2 wt.% of a 35 SSI ethylene/propylene copolymer viscosity index improver, and R-1 also showed the following properties and partial elemental analysis:

10.9	Kinematic Viscosity at 100°C, (mm^2/sec)
3.3	TBS, APPARENT_VISCOSITY, cPa
2438	calcium (ppmw)
< 10	magnesium (ppmw)
80	molybdenum (ppmw)
772	phosphorus (ppmw)
855	zinc (ppmw)
9.0	Total Base Number ASTM D-2896 (mg KOH/g)
165	Viscosity Index

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4. The lubricating oil composition of any one of claims 1-3, wherein the one or more magnesium-containing detergents provides 410 ppm or less of magnesium, based on a total weight of the lubricating oil composition

5. The lubricating oil composition of any one of claims 1-4, wherein the ratio of total calcium from the one or more calcium-containing detergents in ppm to total magnesium from the one or more magnesium-containing detergents is more than 2.5; or more than 3.5.

6. The lubricating oil composition of any one of claims 1-5, wherein the one or more calcium-containing detergents is overbased having a total base number of greater than 225 mg KOH/g; or 250 mg KOH/g or more as measured by the method of ASTM D-

2896.

7. The lubricating oil composition of any one of claims 1-6, wherein the one or more calcium-containing detergents is present in an amount sufficient to provide less than 1670 ppm calcium; or less than 1500 ppm calcium; or less than 1400 ppm calcium; or more than 1350 ppm to less than 1700 ppm calcium to the total weight of the lubricating oil composition.

8. The lubricating oil composition of any one of claims 1-7, wherein the total sulfated ash content is less than 0.8 wt.%, or more than 0.6 wt.% to less than 1.0 wt.%, each as measured by ASTM D874.

9. The lubricating oil composition of any one of claims 1-8, wherein one or more calcium-containing detergents having a total base number of up to 175 mg KOH/g as measured by the method of ASTM D-2896, if present, provides less than 50 ppm of calcium, or less than 20 ppm of calcium; or less than 5 ppm of calcium; or ~~about~~ 0 ppm of calcium to the total weight of the lubricating oil composition.

10. The lubricating oil composition of any one of claims 1-9, wherein the lubricating oil composition contains ~~less than 100 ppm of boron; or less than 50 ppm of boron; or less than 10 ppm of boron; or about~~ 0 ppm of boron, based on a total weight of the lubricating oil composition.

11. The lubricating oil composition of any one of claims 1-10, wherein the lubricating oil composition has more than 0 ppm of boron and a ratio of total metal in ppm to total boron in ppm is more than 7.5; or more than 50; or more than 500.

12. The lubricating oil composition of any one of claims 1-11, wherein the one or more magnesium-containing detergents is overbased having a total base number of greater than 225 mg KOH/g; or greater than 250 mg KOH/g or more; or greater than 400 mg KOH/g or more as measured by the method of ASTM D-2896.

~~13. The lubricating oil composition of any one of claims 1-12, wherein the one or more calcium-containing detergents excludes a calcium salicylate detergent.~~

~~14.~~13. The lubricating oil composition of any one of claims 1-~~13~~12, wherein the one or more magnesium-containing detergents is an overbased magnesium sulfonate detergent having a total base number of greater than 225 mg KOH/g, as measured by the method of ASTM D-2896.

~~15.~~14. The lubricating oil composition, of any one of claims 1-~~14~~13, wherein the lubricating oil composition is an engine oil composition.

~~16.~~15. A method for reducing clogging in a diesel particulate filter comprising a step of operating an engine equipped with a diesel particulate filter and lubricated with a lubricating oil composition comprising:

a) greater than 50 wt.% of a base oil of lubricating viscosity, based on the total weight of the lubricating oil composition;

b) an amount of one or more calcium-containing detergents to provide less than 1700 ppm calcium, based on a total weight of the lubricating oil composition, and the one or more calcium-containing detergents excludes a calcium salicylate detergent;

c) an amount of one or more magnesium-containing detergents to provide less than 450 ppm magnesium, based on the total weight of the lubricating oil composition;

d) an amount of one or more molybdenum-containing compounds to provide less than 450 ppm molybdenum, based on the total weight of the lubricating oil composition;

e) from ~~about~~ 700 ppm to ~~about~~ 900 ppm of phosphorus, based on the total weight of the lubricating oil composition; and

f) a total sulfated ash content of no less than 0.5 wt.% and no greater than 1.0 wt.%, as measured by ASTM D874, based on a total weight of the lubricating oil composition; and

a ratio, in ppm, of calcium from the one or more calcium-containing detergents to magnesium from the one or more magnesium-containing detergents of 1:1 or more, and

wherein the lubricating oil composition contains less than 10 ppm of boron, based on the total weight of the lubricating oil composition.

~~17.~~16. The method of claim ~~16~~15, wherein the lubricating oil composition provides a diesel particulate filter delta pressure (ΔP) versus oil consumption result of 0.6 kPa/kg or less, 0.5 kPa/kg or less, or 0.45 kPa/kg or less, as measured in a VW PV 1485 test after 144 hours.

~~18.~~17. The method of claim ~~16~~15, wherein the method is effective to reduce low speed pre-ignition events in a boosted internal combustion engine lubricated with the lubricating oil composition relative to a number of low speed pre-ignition events in the same engine lubricated with reference lubricating oil R-1; or the reduction of LSPI events is 50% or greater reduction and the LSPI events are LSPI counts during 25,000 engine cycles, wherein the engine is operated at 2000 revolutions per minute with brake mean effective pressure of 1,800 kPa, wherein R-1 is formulated from 80.7 wt.% of a Group III base oil, 12.1 wt.% of passenger car motor oil additive package and 7.2 wt.% of a 35 SSI ethylene/propylene copolymer viscosity index improver, and R-1 also showed the following properties and partial elemental analysis:

10.9	Kinematic Viscosity at 100°C, (mm^2/sec)
3.3	TBS, APPARENT_VISCOSITY, cPa
2438	calcium (ppmw)
< 10	magnesium (ppmw)
80	molybdenum (ppmw)
772	phosphorus (ppmw)
855	zinc (ppmw)
9.0	Total Base Number ASTM D-2896 (mg KOH/g)
165	Viscosity Index

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~~19.~~18. The method of any one of claims ~~16~~15-~~18~~17, wherein the one or more magnesium-containing detergents provides 410 ppm or less of magnesium, based on a

total weight of the lubricating oil composition.

~~20.~~19. The method of any one of claims ~~16~~15-~~19~~18, wherein the ratio of total calcium from the one or more calcium-containing detergents in ppm to total magnesium from the one or more magnesium-containing detergents is more than 2.5; or more than 3.5.

~~21.~~20. The method of any one of claims ~~16~~15-~~20~~19, wherein the one or more calcium-containing detergents is overbased having a total base number of greater than 225 mg KOH/g; or greater than 250 mg KOH/g or more as measured by the method of ASTM D-2896.

~~22.~~21. The method of any one of claims ~~16~~15-~~21~~20, wherein the one or more calcium-containing detergents is present in an amount sufficient to provide less than 1670 ppm calcium; or less than 1500 ppm calcium; or less than 1400 ppm calcium; or more than 1350 ppm to less than 1700 ppm calcium to the total weight of the lubricating oil composition.

~~23.~~22. The method of any one of claims ~~16~~15-~~22~~21, wherein the total sulfated ash content is less than 0.8 wt.%, or more than 0.5 wt.% to less than 1.0 wt.%, or more than 0.6 wt.% to less than 1.0 wt.%, each as measured by ASTM D874.

~~24.~~23. The method of any one of claims ~~16~~15-~~23~~22, wherein one or more calcium-containing detergents having a total base number of up to 175 mg KOH/g as measured by the method of ASTM D-2896, if present, provides less than 50 ppm of calcium, or less than 20 ppm of calcium; or less than 5 ppm of calcium; or ~~about~~ 0 ppm of calcium to the total weight of the lubricating oil composition.

~~25.~~24. The method of any one of claims ~~16~~15-~~24~~23, wherein the lubricating oil composition contains ~~less than 100 ppm of boron; or less than 50 ppm of boron; or less than 10 ppm of boron; or about~~ 0 ppm of boron, based on a total weight of the lubricating oil composition.

~~26.~~25. The method of any one of claims ~~16~~15-~~25~~24, wherein the lubricating oil composition has more than 0 ppm of boron and a ratio of total metal in ppm to total

boron in ppm is more than 7.5; or more than 50; or more than 500.

~~27.~~26. The method of any one of claims ~~16~~15-~~26~~25, wherein the one or more magnesium-containing detergents is overbased having a total base number of greater than 225 mg KOH/g; or greater than 250 mg KOH/g or more; or greater than 400 mg KOH/g or more as measured by the method of ASTM D-2896.

~~28. The method of any one of claims 16-27, wherein the one or more calcium-containing detergents exclude a calcium salicylate detergent.~~

~~29.~~27. The method of any one of claims ~~16~~15-~~28~~26, wherein the one or more magnesium-containing detergents is an overbased magnesium sulfonate detergent having a total base number of greater than 225 mg KOH/g, as measured by the method of ASTM D-2896.

~~30.~~28. The method of any one of claims ~~16~~15-~~29~~27, wherein the lubricating oil composition is an engine oil composition.