to an increase in LSPI events. One theory suggests that auto-ignition of engine oil droplets that enter the engine 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.

SUMMARY AND TERMS

[0006] The present disclosure relates to a lubricating oil composition and method of operating a boosted internal combustion engine. The lubricating oil composition includes greater than 50 wt.% of a base oil of lubricating viscosity, an amount of one or more overbased calcium-containing detergents having a total base number of greater than 225 mg KOH/g, measured by the method of ASTM D-2896 sufficient to provide greater than 900 ppm by weight to less than 2400 ppm by weight of calcium to the lubricating oil composition, based on a total weight of the lubricating oil composition, and a low speed pre-ignition reducing additive composition comprising an amount of one or more titanium-containing compounds sufficient to provide from 10 ppm to 3000 ppm by weight of titanium to the lubricating oil composition and/or an amount of one or more tungsten-containing compounds sufficient to provide from 125 to 3000 ppm of tungsten to the lubricating oil composition, both based on the total weight of the lubricating oil composition. The additive 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 a same lubricating oil composition without the one or more titanium-containing and/or the one or more tungsten-containing compounds.

[0006a] In one aspect of the present disclosure, there is provided a lubricating oil composition comprising:

greater than 50 wt.% of a base oil of lubricating viscosity,

an amount of one or more overbased calcium-containing detergents having a total base number of greater than 225 mg KOH/g, measured by the method of ASTM D-2896 sufficient to provide greater than 900 ppm by weight to 1800 ppm by weight of calcium to the lubricating oil composition, based on a total weight of the lubricating oil composition, and

a low speed pre-ignition reducing additive composition comprising one of the following a), b) or c):

a) an amount of one or more titanium-containing compounds sufficient to provide from 10 ppm to 3000 ppm by weight of titanium to the lubricating oil composition and at least one low-based/neutral calcium-containing detergent having a total base number of up to 175 mg KOH/gram measured by the method of ASTM D-2896 and optionally an amount of one or more tungsten-containing compounds sufficient to provide from 125 to 3000 ppm of tungsten to the lubricating oil composition based on the total weight of the lubricating oil composition;

b) an amount of one or more titanium-containing compounds sufficient to provide from 10 to 3000 ppm by weight of titanium to the lubricating oil composition and optionally an amount of one or more tungsten-containing compounds sufficient to provide from 125 to 3000 ppm of tungsten to the lubricating oil composition based on the total weight of the lubricating oil composition; and

c) an amount of one or more tungsten-containing compounds sufficient to provide from 125 to 3000 ppm of tungsten to the lubricating oil composition, based on the total weight of the lubricating oil composition, and an amount of one or more molybdenum containing components sufficient to provide from 0.5 to 300 ppm by weight of molybdenum to the lubricating oil composition based on the total weight of the lubricating oil composition, and

wherein said additive 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 a same lubricating oil composition without the one or more titanium-containing and/or the one or more tungsten-containing compounds, and the low speed pre-ignition events are low speed pre-ignition counts during 25,000 engine cycles, wherein the engine is operated at 2000 revolutions per minute with a brake mean effective pressure of 18,000 kPa.

[0006b] In another aspect of the present disclosure, there is provided a method for reducing low speed pre-ignition events in a boosted internal combustion engine comprising:

lubricating a boosted internal combustion engine with a lubricating oil composition comprising greater than 50 wt.% of a base oil of lubricating viscosity and an additive composition comprising:

an amount of one or more overbased calcium-containing detergents having a total base number of greater than 225 mg KOH/g, measured by the method of ASTM D-2896 sufficient to provide greater than 900 ppm by weight to 1800 ppm by weight of calcium to the lubricating oil composition, based on a total weight of the lubricating oil composition, and one of the following a), b) or c):

a) an amount of one or more titanium-containing compounds sufficient to provide from 10 ppm to 3000 ppm by weight of titanium to the lubricating oil composition and at least one low-based/neutral calcium-containing detergent having a total base number of up to 175 mg KOH/gram measured by the method of ASTM D-2896 and optionally an amount of one or more tungsten-containing compounds sufficient to provide from 125 to 3000 ppm of tungsten to the lubricating oil composition based on the total weight of the lubricating oil composition;

b) an amount of one or more titanium-containing compounds sufficient to provide from 10 to 3000 ppm by weight of titanium to the lubricating oil composition and optionally an amount of one or more tungsten-containing compounds sufficient to provide from 125 to 3000 ppm of tungsten to the lubricating oil composition based on the total weight of the lubricating oil composition; and

c) an amount of one or more tungsten-containing compounds sufficient to provide from 125 to 3000 ppm of tungsten to the lubricating oil composition, based on the total weight of the lubricating oil composition, and an amount of one or more molybdenum containing components sufficient to provide from 0.5 to 300 ppm by weight of molybdenum to the lubricating oil composition based on the total weight of the lubricating oil composition, and

operating the engine lubricated with the lubricating oil composition whereby the low speed pre-ignition events in the boosted internal combustion engine lubricated with the lubricating oil composition are reduced relative to a number of low speed pre-ignition

events in the same engine lubricated with a same lubricating oil composition without the one or more titanium-containing and/or the one or more tungsten-containing compounds, and the low speed pre-ignition events are low speed pre-ignition counts during 25,000 engine cycles, wherein the engine is operated at 2000 revolutions per minute with a brake mean effective pressure of 18,000 kPa.

[0007] In another embodiment, the disclosure provides a method for reducing low speed pre-ignition events in a boosted internal combustion engine. The method includes lubricating a boosted internal combustion engine with a lubricating oil composition that includes greater than 50 wt.% of a base oil of lubricating viscosity, an amount of one or more overbased calcium-containing detergents having a total base number of greater than 225 mg KOH/g, measured by the method of ASTM D-2896 sufficient to provide greater than 900 ppm by weight to less than 2400 ppm by weight of calcium to the lubricating oil composition, based on a total weight of the lubricating oil composition, and a low speed pre-ignition

What is claimed is:

1. A lubricating oil composition comprising:

greater than 50 wt.% of a base oil of lubricating viscosity,

an amount of one or more overbased calcium-containing detergents having a total base number of greater than 225 mg KOH/g, measured by the method of ASTM D-2896 sufficient to provide greater than 900 ppm by weight to 1800 ppm by weight of calcium to the lubricating oil composition, based on a total weight of the lubricating oil composition, and

a low speed pre-ignition reducing additive composition comprising one of the following a), b) or c):

a) an amount of one or more titanium-containing compounds sufficient to provide from 10 ppm to 3000 ppm by weight of titanium to the lubricating oil composition and at least one low-based/neutral calcium-containing detergent having a total base number of up to 175 mg KOH/gram measured by the method of ASTM D-2896 and optionally an amount of one or more tungsten-containing compounds sufficient to provide from 125 to 3000 ppm of tungsten to the lubricating oil composition based on the total weight of the lubricating oil composition;

b) an amount of one or more titanium-containing compounds sufficient to provide from 10 to 3000 ppm by weight of titanium to the lubricating oil composition and optionally an amount of one or more tungsten-containing compounds sufficient to provide from 125 to 3000 ppm of tungsten to the lubricating oil composition based on the total weight of the lubricating oil composition; and

c) an amount of one or more tungsten-containing compounds sufficient to provide from 125 to 3000 ppm of tungsten to the lubricating oil composition, based on the total weight of the lubricating oil composition, and an amount of one or more molybdenum containing components sufficient to provide from 0.5 to 300 ppm by weight of molybdenum to the lubricating oil composition based on the total weight of the lubricating oil composition, and

wherein said additive 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 a same lubricating oil composition without the one or more titanium-containing and/or the one or more tungsten-containing compounds, and the low speed pre-ignition events are low speed pre-ignition counts during 25,000 engine cycles, wherein the engine is operated at 2000 revolutions per minute with a brake mean effective pressure of 18,000 kPa.

2. The lubricating oil composition of claim 1, wherein the one or more overbased calcium-containing detergents comprise a compound selected from: an overbased calcium sulfonate detergent, an overbased calcium phenate detergent, and an overbased calcium salicylate detergent.

3. The lubricating oil composition of claim 2, wherein the one or more overbased calcium-containing detergents provide from 1100 ppm to less than 1800 ppm by weight calcium to the lubricating oil composition based on the total weight of the lubricating oil composition.

4. The lubricating oil composition of claim 1, wherein the lubricating oil composition

comprises one or more titanium-containing compounds.

5. The lubricating oil composition of claim 4, wherein the one or more titanium-containing compounds is selected from the group consisting of a reaction product of titanium isopropoxide and neodecanoic acid; titanium isopropoxide; a titanium-containing dispersant and mixtures thereof.

6. The lubricating oil composition of claim 4, wherein the one or more titanium-containing compounds provide from 25 ppm to 1000 ppm by weight titanium to the lubricating oil composition based on the total weight of the lubricating oil composition.

7. The lubricating oil composition of claim 1, wherein the lubricating oil composition comprises one or more tungsten-containing compounds.

8. The lubricating oil composition of claim 7, wherein the one or more tungsten-containing compounds is an alkyl or aryl-substituted ammonium tungstate wherein the alkyl and aryl groups each have 6-30 carbon atoms.

9. The lubricating oil composition of claim 1, further comprising one or more components selected from the group consisting of friction modifiers, antiwear agents, dispersants, antioxidants, and viscosity index improvers.

10. The lubricating oil composition of claim 1, wherein the greater than 50 wt.% of base oil is selected from the group consisting of Group II, Group III, Group IV, Group V base oils, and a combination of two or more of the foregoing, and wherein greater than 50 wt.% of the base oil is other than diluent oils that arise from provision of additive components or viscosity index improvers in the composition.

11. The lubricating oil composition of claim 1, wherein the lubricating oil composition has a sulfated ash content less than 1.0 wt.%.

12. The lubricating oil composition of claim 1, wherein the low-based/neutral detergent having a total base number of up to 175 mg KOH/g, measured by the method of ASTM D-2896 is present in an amount of at least 0.2 wt.%, based on the weight of the lubricating oil composition.

13. The lubricating composition of claim 11, wherein the low-based/neutral detergent comprises a calcium sulfonate detergent.

14. A method for reducing low speed pre-ignition events in a boosted internal combustion engine comprising:

lubricating a boosted internal combustion engine with a lubricating oil composition comprising greater than 50 wt.% of a base oil of lubricating viscosity and

an additive composition comprising:

an amount of one or more overbased calcium-containing detergents having a total base number of greater than 225 mg KOH/g, measured by the method of ASTM D-2896 sufficient to provide greater than 900 ppm by weight to 1800 ppm by weight of calcium to the lubricating oil composition, based on a total weight of the lubricating oil composition, and one of the following a), b) or c):

a) an amount of one or more titanium-containing compounds sufficient to provide from 10 ppm to 3000 ppm by weight of titanium to the lubricating oil composition and at least one low-based/neutral calcium-containing detergent having a total base number of up to 175 mg KOH/gram measured by the method of ASTM D-2896 and optionally an amount of one or more tungsten-containing compounds sufficient to provide from 125 to 3000 ppm of tungsten to the lubricating oil composition based on the total weight of the lubricating oil composition;

b) an amount of one or more titanium-containing compounds sufficient to provide from 10 to 3000 ppm by weight of titanium to the lubricating oil composition and optionally an amount of one or more tungsten-containing compounds sufficient to provide from 125 to 3000 ppm of tungsten to the lubricating oil composition based on the total weight of the lubricating oil composition; and

c) an amount of one or more tungsten-containing compounds sufficient to provide from 125 to 3000 ppm of tungsten to the lubricating oil composition, based on the total weight of the lubricating oil composition, and an amount of one or more molybdenum containing components sufficient to provide from 0.5 to 300 ppm by weight of molybdenum to the lubricating oil composition based on the total weight of the lubricating oil composition, and

operating the engine lubricated with the lubricating oil composition whereby the low speed pre-ignition events in the boosted internal combustion engine lubricated with the lubricating oil composition are reduced relative to a number of low speed pre-ignition events in the same engine lubricated with a same lubricating oil composition without the one or more titanium-containing and/or the one or more

tungsten-containing compounds, and the low speed pre-ignition events are low speed pre-ignition counts during 25,000 engine cycles, wherein the engine is operated at 2000 revolutions per minute with a brake mean effective pressure of 18,000 kPa.

15. The method of claim 14, wherein the lubricant composition has a sulfated ash content of less than 1.0 wt.%.

16. The method of claim 14, wherein the one or more overbased calcium-containing detergents comprise a compound selected from: an overbased calcium sulfonate detergent, an overbased calcium phenate detergent, and an overbased calcium salicylate detergent and the one or more overbased calcium-containing detergents provide from 1100 to less than 1800 ppm by weight calcium to the lubricating oil composition based on the total weight of the lubricating oil composition.

17. The method of claim 14, wherein the lubricating oil composition comprises one or more titanium-containing compounds.

18. The method of claim 14, wherein the lubricating oil composition comprises one or more tungsten-containing compounds.

19. The method of claim 14, wherein the additive composition comprises the low-based/neutral detergent having a total base number of up to 175 mg KOH/g, measured by the method of ASTM D-2896, the low-based/neutral detergent comprises a calcium-containing detergent, and a total amount of calcium from the overbased calcium-containing detergent and the low-based/neutral detergent ranges from greater than 1100 ppm by weight to less than 2400 ppm by weight based on a total weight of the lubricating oil composition, and the low-based/neutral detergent comprises at least 0.2 wt.% of the lubricating oil composition.

20. The method of claim 14, wherein the lubricating step lubricates a combustion chamber or

cylinder walls of a spark-ignited direct injection engine or port fuel injected internal combustion engine provided with a turbocharger or a supercharger.

21. The method of claim 14, further comprising a step of measuring low speed pre-ignition events of the internal combustion engine lubricated with the lubricating oil.