[0005] Several published studies have demonstrated that turbocharger use, engine design, engine coatings, piston shape, fuel choice, and/or engine oil additives may contribute 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, at least 0.3 wt.% of an overbased detergent having a total base number (TBN) greater than 225 mg KOH/g, and at least 0.2 wt.% of a low-based/neutral detergent having a TBN less than or equal to 175 mg KOH/g, wherein a total amount of calcium from the overbased and 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. The lubricating oil composition may be effective to reduce low-speed pre-ignition events in the boosted internal combustion engine lubricated with the lubricating oil composition.

[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;

at least 0.3 wt.% of an overbased detergent having a total base number of greater than 225 mg KOH/g, measured by the method of ASTM D-2896, and

at least 0.2 wt.% of a low-based/neutral detergent having a total base number of up to 175 mg KOH/g, measured by the method of ASTM D-2896, wherein a total amount of calcium from the overbased and 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 a total amount of calcium from the overbased detergent is from

900 ppm to no more than 1800 ppm by weight, based on the total weight of the lubricating oil composition; and

a ratio of the ppm of calcium, by weight, provided to the lubricating oil composition by the low-based/neutral detergent to the ppm of calcium, by weight, provided to the lubricating oil composition by the overbased calcium detergent, is from 0.08 to 0.4.

[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;

at least 0.3 wt.% of an overbased detergent having a total base number of greater than 225 mg KOH/g, measured by the method of ASTM D-2896; and

at least 0.2 wt.% of a low-based/neutral detergent having a total base number of up to 175 mg KOH/g, measured by the method of ASTM D-2896; wherein a total amount of calcium from the overbased and 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

a total amount of calcium from the overbased detergent is from 900 ppm to no more than 1800 ppm by weight, based on the total weight of the lubricating oil composition; and

a ratio of the ppm of calcium, by weight, provided to the lubricating oil composition by the low-based/neutral detergent to the ppm of calcium, by weight, provided to the lubricating oil composition by the overbased calcium detergent, is from 0.08 to 0.4;

operating the engine lubricated with the lubricating oil composition.

[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 a step of lubricating the boosted internal combustion engine with a lubricating oil composition including greater than 50 wt.% of a base oil of lubricating viscosity, at least 0.3 wt.% of an overbased detergent having a TBN greater than 225 mg KOH/g, and at least 0.2 wt.% of a low-based/neutral detergent having a TBN up to 175 mg KOH/g. A total amount of calcium from the overbased and 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. The boosted internal combustion engine is operated and lubricated with the lubricating oil composition whereby the low-speed pre-ignition events in the engine lubricated with the lubricating oil composition may be reduced.

What is claimed is:

1. A lubricating oil composition comprising:

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

at least 0.3 wt.% of an overbased detergent having a total base number of greater than 225 mg KOH/g, measured by the method of ASTM D-2896, and

at least 0.2 wt.% of a low-based/neutral detergent having a total base number of up to 175 mg KOH/g, measured by the method of ASTM D-2896, wherein a total amount of calcium from the overbased and 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 a total amount of calcium from the overbased detergent is from 900 ppm to no more than 1800 ppm by weight, based on the total weight of the lubricating oil composition; and

a ratio of the ppm of calcium, by weight, provided to the lubricating oil composition by the low-based/neutral detergent to the ppm of calcium, by weight, provided to the lubricating oil composition by the overbased calcium detergent, is from 0.08 to 0.4.

2. The lubricating oil composition of claim 1, wherein the overbased calcium-containing detergent comprises a compound selected from an overbased calcium sulfonate detergent, and an overbased calcium phenate detergent.

3. The lubricating oil composition of claim 1, wherein the reduction of LSPI events is a 75% 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 18,000 kPa.

4. The lubricating oil composition of claim 1, wherein the low-based/neutral detergent comprises a detergent selected from the group consisting of: a calcium sulfonate detergent and a calcium phenate detergent.

5. The lubricating oil composition of claim 1, wherein the lubricating oil composition has a ratio of a total mmol metal in the lubricating oil composition to a total base number of the lubricating oil composition ranging from greater than 4.5 to 10.0.

6. The lubricating oil composition of claim 1, wherein the lubricating oil composition is effective to pass a TEOST 33 bench oxidation test.

7. 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.

8. The lubricating oil composition of claim 1, wherein the greater than 50% 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 the greater than 50 wt.% of base oil is other than diluent oils that arise from provision of additive components or viscosity index improvers in the composition.

9. The lubricating oil composition of claim 1, wherein a ratio of mmol total metal in the lubricating oil composition to TBN of lubricant is greater than 8 to less than 10 and the lubricating oil composition comprises at least 0.25 wt. % of the low-based/neutral detergent.

10. The lubricating oil composition of claim 1, wherein the total calcium provided to the lubricating oil composition by the one or more overbased detergents is from 1100 ppm to 1800 ppm, by weight, based on the total weight of the lubricating oil composition.

11. The lubricating oil composition of claim 1, wherein the total calcium provided to the lubricating oil composition by the one or more low-based/neutral calcium-containing detergents is from 50 ppm to 1000 ppm, by weight, based on the total weight of the lubricating oil composition.

12. 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.

13. 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;

at least 0.3 wt.% of an overbased detergent having a total base number of greater than 225 mg KOH/g, measured by the method of ASTM D-2896; and

at least 0.2 wt.% of a low-based/neutral detergent having a total base number of up to 175 mg KOH/g, measured by the method of ASTM D-2896; wherein a total amount of calcium from the overbased and 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,

a total amount of calcium from the overbased detergent is from 900 ppm to no more than 1800 ppm by weight, based on the total weight of the lubricating oil composition; and

a ratio of the ppm of calcium, by weight, provided to the lubricating oil composition by the low-based/neutral detergent to the ppm of calcium, by weight, provided to the lubricating oil composition by the overbased calcium detergent, is from 0.08 to 0.4; and

operating the engine lubricated with the lubricating oil composition.

14. The method of claim 13, wherein the lubricant composition passes a TEOST 33 bench oxidation test.

15. The method of claim 14, wherein LSPI events are based on LSPI counts during 25,000 engine cycles, wherein the engine is operated at 2000 revolutions per minute (RPM) with brake mean effective pressure (BMEP) of 18,000 kPa and 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 reference lubricating oil R-1.

16. The method of claim 15, 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.

17. The method of claim 15, further comprising a step of measuring low speed pre-ignition events of the internal combustion engine lubricated with the lubricating oil.