compound and carbon disulfide; (c) a borate ester; and (d) optionally a phosphorus-containing compound provided that the phosphorus content of the composition does not exceed about 0.10 wt.%. The '378 patent further discloses that the lubricating oil composition has a boron content of about 30 ppm to about 600 ppm and a molybdenum content of about 25 ppm to about 800 ppm.

[0005] U.S. Patent No. 7,026,273 ("the '273 patent") discloses a lubricating oil composition containing a major amount of oil of lubricating viscosity, and a minor amount of a boron-containing additive, a detergent additive composition and one or more co-additives. The '273 patent further discloses that the lubricating oil composition has a boron content of greater than 150 ppm, a molybdenum content of at most 1000 ppm and less than 4000 ppm by mass of sulfur.

[0006] EP 0 737 735 ("the 735 application") discloses a lubricant composition produced by blending (a) a Mo-containing friction conditioner; and (b) a B-containing compound with a lubricant base oil. The 735 application further discloses that the lubricating oil composition has a boron content of greater than 0.015 wt. % (150 ppm) and a molybdenum content of 100 ppm to 2000 ppm.

[0007] It is desirable to develop improved lubricating oil compositions which exhibit improved wear inhibition when used in an internal combustion engine.

SUMMARY OF THE INVENTION

[0008] In accordance with one embodiment of the present invention, a lubricating oil composition having a sulfur content of up to about 0.4 wt. % and a sulfated ash content of up to about 0.5 wt. % as determined by ASTM D874 is provided which comprises (a) a major amount of an oil of lubricating viscosity; (b) at least one oil-soluble or dispersed oil-stable boron-containing compound having no

more than about 600 ppm of boron, based upon the total mass of the composition; and (c) at least one oil-soluble or dispersed oil-stable molybdenum-containing compound having no more than about 800 ppm of molybdenum, based upon the total mass of the composition; wherein the lubricating oil composition has a ratio of sulfur to molybdenum of about 5:1 to about 500:1.

[0009] In accordance with a second embodiment of the present invention, there is provided a method of operating an internal combustion engine which comprises operating the internal combustion engine with a lubricating oil composition having a sulfur content of up to about 0.4 wt. % and a sulfated ash content of up to about 0.5 wt. % as determined by ASTM D874 and comprising (a) a major amount of an oil of lubricating viscosity; (b) at least one oil-soluble or dispersed oil-stable boron-containing compound having no more than about 600 ppm of boron, based upon the total mass of the composition; and (c) at least one oil-soluble or dispersed oil-stable molybdenum-containing compound having no more than about 800 ppm of molybdenum, based upon the total mass of the composition; wherein the lubricating oil composition has a ratio of sulfur to molybdenum of about 5:1 to about 500:1.

[0010] In accordance with a third embodiment of the present invention, there is provided an internal combustion engine lubricated with a lubricating oil composition having a sulfur content of up to about 0.4 wt. % and a sulfated ash content of up to about 0.5 wt. % as determined by ASTM D874 and comprising (a) a major amount of an oil of lubricating viscosity; (b) at least one oil-soluble or dispersed oil-stable boron-containing compound having no more than about 600 ppm of boron, based upon the total mass of the composition; and (c) at least one oil-soluble or dispersed oil-stable molybdenum-containing compound having no more than about 800 ppm of molybdenum, based upon the total mass of the composition; wherein the

lubricating oil composition has a ratio of sulfur to molybdenum of about 5:1 to about 500:1.

[0011] The low ash lubricating oil compositions of the present invention advantageously provide high wear inhibition when used in an internal combustion engine while employing relatively low levels of boron and molybdenum. In addition, the high wear inhibition can be achieved with the low ash lubricating oil compositions of the present invention while also employing relatively low levels (or substantially free) of any phosphorus and zinc content.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0012] The present invention is directed to a lubricating oil composition having a sulfur content of up to about 0.4 wt. % and a sulfated ash content of up to about 0.5 wt. % as determined by ASTM D874 and containing at least (a) a major amount of an oil of lubricating viscosity; and (b) at least one oil-soluble or dispersed oil-stable boron-containing compound having no more than about 600 ppm of boron, based upon the total mass of the composition; and (c) at least one oil-soluble or dispersed oil-stable molybdenum-containing compound having no more than about 800 ppm of molybdenum, based upon the total mass of the composition; wherein the lubricating oil composition has a ratio of sulfur to molybdenum of about 5:1 to about 500:1. In one embodiment, the lubricating oil composition of the present invention has a sulfur content of up to about 0.3 wt. %, and/or a sulfated ash content of up to about 0.4 wt. % as determined by ASTM D874. The amount of sulfur, boron, molybdenum or phosphorus in the lubricating oil composition of the present invention is measured according to ASTM D4951.

compound and carbon disulfide; (c) a borate ester; and (d) optionally a phosphorus-containing compound provided that the phosphorus content of the composition does not exceed about 0.10 wt.%. The '378 patent further discloses that the lubricating oil composition has a boron content of about 30 ppm to about 600 ppm and a molybdenum content of about 25 ppm to about 800 ppm.

[0005] U.S. Patent No. 7,026,273 ("the '273 patent") discloses a lubricating oil composition containing a major amount of oil of lubricating viscosity, and a minor amount of a boron-containing additive, a detergent additive composition and one or more co-additives. The '273 patent further discloses that the lubricating oil composition has a boron content of greater than 150 ppm, a molybdenum content of at most 1000 ppm and less than 4000 ppm by mass of sulfur.

[0006] EP 0 737 735 ("the 735 application") discloses a lubricant composition produced by blending (a) a Mo-containing friction conditioner; and (b) a B-containing compound with a lubricant base oil. The 735 application further discloses that the lubricating oil composition has a boron content of greater than 0.015 wt. % (150 ppm) and a molybdenum content of 100 ppm to 2000 ppm.

[0007] It is desirable to develop improved lubricating oil compositions which exhibit improved wear inhibition when used in an internal combustion engine.

SUMMARY OF THE INVENTION

[0008] In accordance with one embodiment of the present invention, there is provided a lubricating oil composition having a sulfur content of up to 0.4 wt. % and a sulfated ash content of up to 0.3 wt. % as determined by ASTM D874 and comprising (a) a major amount of an oil of lubricating viscosity; (b) at least one oil-soluble or dispersed oil-stable boron-containing compound having no more than 600 ppm of boron, based upon the total mass of the composition; and (c) at least one oil-soluble or

dispersed oil-stable molybdenum-containing compound having no more than 800 ppm of molybdenum, based upon the total mass of the composition; wherein the lubricating oil composition has a ratio of sulfur to molybdenum of 20:1 to 100:1.

[0009] In accordance with a second embodiment of the present invention, there is provided a lubricating oil composition having a sulfur content of up to 0.4 wt. % and a sulfated ash content of up to 0.5 wt. % as determined by ASTM D874 and comprising (a) a major amount of an oil of lubricating viscosity; (b) at least one oil-soluble or dispersed oil-stable boron-containing compound having no more than 600 ppm of boron, based upon the total mass of the composition; and (c) at least one oil-soluble or dispersed oil-stable molybdenum-containing compound having no more than 800 ppm of molybdenum, based upon the total mass of the composition; wherein the lubricating oil composition has a ratio of sulfur to molybdenum of 20:1 to 100:1, and wherein the lubricating oil composition is free of phosphorus.

[0010] In accordance with a third embodiment of the present invention, there is provided an internal combustion engine lubricated with a lubricating oil composition having a sulfur content of up to about 0.4 wt. % and a sulfated ash content of up to about 0.5 wt. % as determined by ASTM D874 and comprising (a) a major amount of an oil of lubricating viscosity; (b) at least one oil-soluble or dispersed oil-stable boron-containing compound having no more than about 600 ppm of boron, based upon the total mass of the composition; and (c) at least one oil-soluble or dispersed oil-stable molybdenum-containing compound having no more than about 800 ppm of molybdenum, based upon the total mass of the composition; wherein the lubricating oil composition has a ratio of sulfur to molybdenum of about 5:1 to about 500:1.

[0010a] In another embodiment, there is provided a method of operating an internal combustion engine comprising the step of operating the internal combustion

engine with the lubricating oil composition as described herein.

[0010b] In another embodiment, there is provided the use of a lubricating oil composition as described herein for inhibiting wear in an internal combustion engine.

[0011] The low ash lubricating oil compositions of the present invention advantageously provide high wear inhibition when used in an internal combustion engine while employing relatively low levels of boron and molybdenum. In addition, the high wear inhibition can be achieved with the low ash lubricating oil compositions of the present invention while also employing relatively low levels (or substantially free) of any phosphorus and zinc content.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0012] The present invention is directed to a lubricating oil composition having a sulfur content of up to about 0.4 wt. % and a sulfated ash content of up to about 0.5 wt. % as determined by ASTM D874 and containing at least (a) a major amount of an oil of lubricating viscosity; and (b) at least one oil-soluble or dispersed oil-stable boron-containing compound having no more than about 600 ppm of boron, based upon the total mass of the composition; and (c) at least one oil-soluble or dispersed oil-stable molybdenum-containing compound having no more than about 800 ppm of molybdenum, based upon the total mass of the composition; wherein the lubricating oil composition has a ratio of sulfur to molybdenum of about 5:1 to about 500:1. In one embodiment, the lubricating oil composition of the present invention has a sulfur content of up to about 0.3 wt. %, and/or a sulfated ash content of up to about 0.4 wt. % as determined by ASTM D874. The amount of sulfur, boron, molybdenum or phosphorus in the lubricating oil composition of the present invention is measured according to ASTM D4951.

WHAT IS CLAIMED IS:

1. A lubricating oil composition having a sulfur content of up to about 0.4 wt. % and a sulfated ash content of up to about 0.5 wt. % as determined by ASTM D874 and comprising (a) a major amount of an oil of lubricating viscosity; (b) at least one oil-soluble or dispersed oil-stable boron-containing compound having no more than about 600 ppm of boron, based upon the total mass of the composition; and (c) at least one oil-soluble or dispersed oil-stable molybdenum-containing compound having no more than about 800 ppm of molybdenum, based upon the total mass of the composition; wherein the lubricating oil composition has a ratio of sulfur to molybdenum of about 5:1 to about 500:1.

2. The lubricating oil composition of Claim 1, wherein the oil of lubricating viscosity is comprised of a mineral base oil.

3. The lubricating oil composition of Claims 1 or 2, having no more than about 500 ppm of boron.

4. The lubricating oil composition of Claims 1-3, having no more than about 500 ppm of molybdenum.

5. The lubricating oil composition of Claims 1-3, having no more than about 100 ppm of molybdenum.

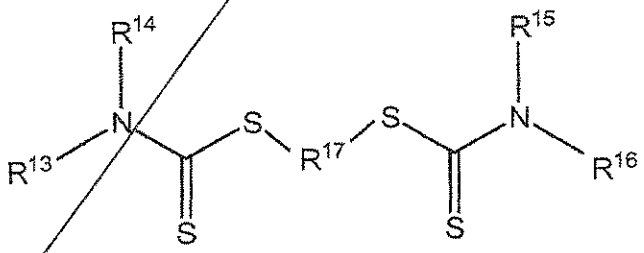
6. The lubricating oil composition of Claim 1, having no more than about 400 ppm of boron and no more than about 100 ppm of molybdenum.

7. The lubricating oil composition of Claims 1-6, having a ratio of sulfur to molybdenum of about 15:1 to about 240:1.

8. The lubricating oil composition of Claims 1-7, having a ratio of sulfur to molybdenum of about 20:1 to about 100:1.

9. The lubricating oil composition of Claims 1-8, wherein the oil-soluble or dispersed oil-stable molybdenum compound is selected from the group consisting of a sulfurized or non-sulfurized molybdenum polyisobutenyl succinimide complex, molybdenum dithiocarbamate, dispersed hydrated molybdenum compound, acidic molybdenum compound or a salt thereof and mixtures thereof.

10. The lubricating oil composition of Claims 1-9, wherein a major amount of the sulfur is derived from a bisdithiocarbamate compound of the Formula:



wherein R^{13}, R^{14}, R^{15}, and R^{16} are the same or different and are aliphatic hydrocarbyl groups having 1 to 13 carbon atoms and R^{17} is an alkylene group having 1 to 8 carbon atoms.

11. The lubricating oil composition of Claims 1-10, having a sulfated ash content of up to about 0.3 wt. % as determined by ASTM D874.

12. The lubricating oil composition of Claims 1-11, which is substantially free of phosphorus.

13. The lubricating oil composition of Claims 1-12, which is substantially free of zinc dialkyl dithiophosphate.

14. The lubricating oil composition of Claims 1-13, further comprising at least one additive selected from the group consisting of metallic detergents, ashless dispersants, friction modifiers, extreme pressure agents, viscosity index improvers and pour point depressants.

15. A method of operating an internal combustion engine comprising the step of operating the internal combustion engine with the lubricating oil composition of Claims 1-14.

WHAT IS CLAIMED IS:

1. A lubricating oil composition having a sulfur content of up to 0.4 wt. % and a sulfated ash content of up to 0.3 wt. % as determined by ASTM D874 and comprising (a) a major amount of an oil of lubricating viscosity; (b) at least one oil-soluble or dispersed oil-stable boron-containing compound having no more than 600 ppm of boron, based upon the total mass of the composition; and (c) at least one oil-soluble or dispersed oil-stable molybdenum-containing compound having no more than 800 ppm of molybdenum, based upon the total mass of the composition; wherein the lubricating oil composition has a ratio of sulfur to molybdenum of 20:1 to 100:1.

2. The lubricating oil composition of Claim 1, wherein the oil of lubricating viscosity is comprised of a mineral base oil.

3. The lubricating oil composition of Claims 1 or 2, having no more than 500 ppm of boron.

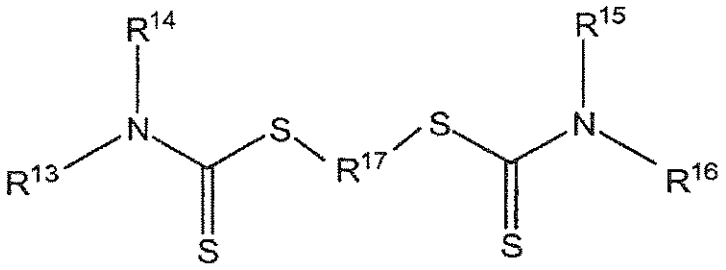
4. The lubricating oil composition of Claims 1-3, having no more than 500 ppm of molybdenum.

5. The lubricating oil composition of Claims 1-3, having no more than 100 ppm of molybdenum.

6. The lubricating oil composition of Claim 1, having no more than 400 ppm of boron and no more than 100 ppm of molybdenum.

7. The lubricating oil composition of Claims 1-6, wherein the oil-soluble or dispersed oil-stable molybdenum compound is selected from the group consisting of a sulfurized or non-sulfurized molybdenum polyisobutenyl succinimide complex, molybdenum dithiocarbamate, dispersed hydrated molybdenum compound, acidic molybdenum compound or a salt thereof and mixtures thereof.

8. The lubricating oil composition of Claims 1-7, wherein a major amount of the sulfur is derived from a bisdithiocarbamate compound of the Formula:



wherein R^{13}, R^{14}, R^{15}, and R^{16} are the same or different and are aliphatic hydrocarbyl groups having 1 to 13 carbon atoms and R^{17} is an alkylene group having 1 to 8 carbon atoms.

9. The lubricating oil composition of Claims 1-8, which is free of phosphorus.

10. The lubricating oil composition of Claims 1-9, which is free of zinc dialkyl dithiophosphate.

11. The lubricating oil composition of Claims 1-10, further comprising at least one additive selected from the group consisting of metallic detergents, ashless dispersants, friction modifiers, extreme pressure agents, viscosity index improvers and pour point depressants.

12. A lubricating oil composition having a sulfur content of up to 0.4 wt. % and a sulfated ash content of up to 0.5 wt. % as determined by ASTM D874 and comprising (a) a major amount of an oil of lubricating viscosity; (b) at least one oil-soluble or dispersed oil-stable boron-containing compound having no more than 600 ppm of boron, based upon the total mass of the composition; and (c) at least one oil-soluble or dispersed oil-stable molybdenum-containing compound having no more than 800 ppm of molybdenum, based upon the total mass of the composition; wherein the lubricating oil composition has a ratio of sulfur to molybdenum of 20:1 to 100:1, and wherein the lubricating oil composition is free of phosphorus.

13. The lubricating oil composition of Claim 12, wherein the oil of lubricating viscosity is comprised of a mineral base oil.

14. The lubricating oil composition of Claims 12 or 13, having no more than 500 ppm of boron.

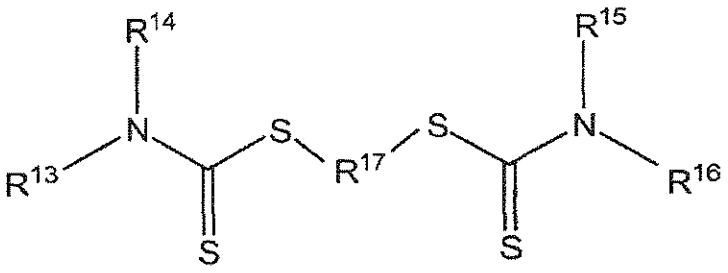
15. The lubricating oil composition of Claims 12-14, having no more than 500 ppm of molybdenum.

16. The lubricating oil composition of Claims 12-14, having no more than 100 ppm of molybdenum.

17. The lubricating oil composition of Claim 12, having no more than 400 ppm of boron and no more than 100 ppm of molybdenum.

18. The lubricating oil composition of Claims 12-17, wherein the oil-soluble or dispersed oil-stable molybdenum compound is selected from the group consisting of a sulfurized or non-sulfurized molybdenum polyisobutenyl succinimide complex, molybdenum dithiocarbamate, dispersed hydrated molybdenum compound, acidic molybdenum compound or a salt thereof and mixtures thereof.

19. The lubricating oil composition of Claims 12-18, wherein a major amount of the sulfur is derived from a bisdithiocarbamate compound of the Formula:



wherein R^{13}, R^{14}, R^{15}, and R^{16} are the same or different and are aliphatic hydrocarbyl groups having 1 to 13 carbon atoms and R^{17} is an alkylene group having 1 to 8 carbon atoms.

20. The lubricating oil composition of Claims 12-19, having a sulfated ash content of up to 0.3 wt. % as determined by ASTM D874.

21. The lubricating oil composition of Claims 12-20, further comprising at least one additive selected from the group consisting of metallic detergents, ashless dispersants, friction modifiers, extreme pressure agents, viscosity index improvers and pour point depressants.

22. A method of operating an internal combustion engine comprising the step of operating the internal combustion engine with the lubricating oil composition of Claims 1-21.

23. Use of a lubricating oil composition according to any one of claims 1-21 for inhibiting wear in an internal combustion engine.

24. Use according to claim 23, wherein said wear is injector screw wear.