and foreign application EP2290041, disclose additive formulations or methods to address oxidation and deposits within the engine due to the influence of biodiesel.

SUMMARY OF THE INVENTION

Provided herein are lubricating oil compositions that can inhibit the viscosity increase of the lubricant. In one aspect, the present disclosure is directed to a lubricating oil composition contaminated with at least about 0.3 wt% of a biodiesel fuel or a decomposition product thereof, based on the total weight of the lubricating oil composition, comprising a major amount of base oil of lubricating viscosity; and a polysaccharide dispersant, said dispersant prepared by the process which comprises reacting

(A) at least one of the following copolymers:

(i) a copolymer obtained by free radical copolymerization of components comprising:

(a) at least one monoethylenically unsaturated C_3-C_{28} monocarboxylic acid or ester thereof, or C_4-C_{28} dicarboxylic acid, anhydride or ester thereof;

(b) at least one 1-olefin comprising about 2 to 40 carbon atoms or at least one polyolefin comprising about 4 to 360 carbon atoms and having a terminal copolymerizable group in the form of a vinyl, vinylidene or alkyl vinylidene group or mixtures thereof; and

(c) at least one monoolefin compound which is copolymerizable with the monomers of (a) and (b) and is selected from the group consisting of:

(1) an alkyl vinyl ether and an allyl alkyl ether where the alkyl group is hydroxyl, amino, dialkylamino or alkoxy substituted or is unsubstituted, and containing 1 to 40 carbon atoms;

(2) an alkyl amine and an N-alkylamide of a monoethylenically unsaturated mono- or dicarboxylic acid of 3 to 10 carbon atoms wherein the alkyl substituent contains 1 to 40 carbon atoms;

(3) a N-vinylcarboxamide of carboxylic acids of 1 to 8 carbon atoms;

(4) a N-vinyl substituted nitrogen-containing heterocyclic compound; and

(5) at least one 1-olefin comprising about 2 to 40 carbon atoms or at least one polyolefin comprising about 4 to about 360 carbon atoms and having a terminal copolymerizable group in the form of a vinyl, vinylidene or alkyl vinylidene group or mixtures thereof, provided that the olefin employed is not the same as the olefin employed in (i)(b);

(ii) a copolymer obtained by reacting compound (i)(a) and compound(i)(b) in the presence of a free radical initiator;

(iii) a copolymer obtained by (a) reacting compound (i)(a) with compound (i)(b) or (i)(c) in a non-free radical catalyzed reaction in the presence of copolymer (i) or copolymer (ii) or both; or by (b) contacting copolymer (i) or copolymer (ii) or both with the non-free radical catalyzed reaction product of compound (i)(a) and compound (i)(b) or (i)(c); with

(B) at least one ether compound selected from the group consisting of an ether polyamine, a polyether polyamine, a polyether amino alcohol, a polyether amino thiol, and a polyether polyol; and

(C) at least one aromatic amine; and

wherein the amount of said dispersant present in the lubricating oil composition is at least about 2 wt.% actives, based on the total weight of the lubricating oil composition.

Also provided herein are methods of lubricating an engine with a lubricating oil composition that can inhibit the viscosity increase in an engine. In one aspect, the methods comprise a method of lubricating a diesel engine fueled at least in part with a biodiesel fuel which comprises operating the engine with a lubricating oil composition contaminated with at least about 0.3 wt% of a biodiesel fuel or a decomposition product thereof, based on the total weight of the lubricating oil composition, wherein the lubricating oil composition comprises a major amount of base oil of lubricating viscosity; and a polysuccinimide dispersant, said dispersant prepared by the process which comprises reacting

(A) at least one of the following copolymers:

(i) a copolymer obtained by free radical copolymerization of components comprising:

(C) at least one aromatic amine; and

wherein the amount of said dispersant present in the lubricating oil composition is at least about 2 wt.% actives, based on the total weight of the lubricating oil composition.

In another aspect of the present disclosure, there is provided a method for inhibiting viscosity increase in a diesel engine fueled at least in part with a biodiesel fuel which comprises operating the engine with a lubricating oil composition contaminated with at least about 0.3 wt% of a biodiesel fuel or a decomposition product thereof, based on the total weight of the lubricating oil composition, wherein the lubricating oil composition comprises: comprising a major amount of base oil of lubricating viscosity; and a polysuccinimide dispersant, said dispersant prepared by the process which comprises reacting

(A) at least one of the following copolymers:

(i) a copolymer obtained by free radical copolymerization of components comprising:

(a) at least one monoethylenically unsaturated C_3-C_{28} monocarboxylic acid or ester thereof, or C_4-C_{28} dicarboxylic acid, anhydride or ester thereof;

(b) at least one 1-olefin comprising about 2 to 40 carbon atoms or at least one polyolefin comprising about 4 to 360 carbon atoms and having a terminal copolymerizable group in the form of a vinyl, vinylidene or alkyl vinylidene group or mixtures thereof; and

(c) at least one monoolefin compound which is copolymerizable with the monomers of (a) and (b) and is selected from the group consisting of:

(1) an alkyl vinyl ether and an allyl alkyl ether where the alkyl group is hydroxyl, amino, dialkylamino or alkoxy substituted or is unsubstituted, and containing 1 to 40 carbon atoms;

(2) an alkyl amine and an N-alkylamide of a monoethylenically unsaturated mono- or dicarboxylic acid of 3 to 10 carbon atoms wherein the alkyl substituent contains 1 to 40 carbon atoms;

(3) a N-vinylcarboxamide of carboxylic acids of 1 to 8 carbon atoms;

(4) a N-vinyl substituted nitrogen-containing heterocyclic compound; and

(5) at least one 1-olefin comprising about 2 to 40 carbon atoms or at least one polyolefin comprising about 4 to about 360 carbon atoms and having a terminal copolymerizable group in the form of a vinyl, vinylidene or alkyl vinylidene group or mixtures thereof, provided that the olefin employed is not the same as the olefin employed in (i)(b);

(ii) a copolymer obtained by reacting compound (i)(a) and compound(i)(b) in the presence of a free radical initiator;

(iii) a copolymer obtained by (a) reacting compound (i)(a) with compound (i)(b) or (i)(c) in a non-free radical catalyzed reaction in the presence of copolymer (i) or copolymer (ii) or both; or by (b) contacting copolymer (i) or copolymer (ii) or both with the non-free radical catalyzed reaction product of compound (i)(a) and compound (i)(b) or (i)(c); with

(B) at least one ether compound selected from the group consisting of an ether polyamine, a polyether polyamine, a polyether amino alcohol, a polyether amino thiol, and a polyether polyol; and

(C) at least one aromatic amine; and

wherein the amount of said dispersant present in the lubricating oil composition is at least about 2 wt.% actives, based on the total weight of the lubricating oil composition.

In some embodiments, the lubricating oil composition disclosed herein is substantially free of a vegetable oil or animal oil. In other embodiments, the lubricating oil composition disclosed herein is free of a vegetable oil or animal oil.

In certain embodiments, the lubricating oil composition disclosed herein further comprises at least one additive selected from the group consisting of antioxidants, antiwear agents, detergents, rust inhibitors, demulsifiers, friction modifiers, multi-functional additives, viscosity index improvers, pour point depressants, foam inhibitors, metal deactivators, dispersants, corrosion inhibitors, lubricity improvers, thermal stability improvers, anti-haze additives, icing inhibitors, dyes, markers, static dissipaters, biocides and combinations thereof. In other embodiments, the at least one additive is at least one antiwear agent. In further embodiments, the at least one antiwear agent comprises a zinc dialkyl dithiophosphate compound. In still further embodiments, the phosphorous content derived from the zinc dialkyldithiophosphate compound is from about 0.001 wt.% to about 0.5 wt.%, from about

0.01 wt.% to about 0.08 wt.%, or from about 0.01 wt.% to about 0.12 wt.%,, based on the total weight of the lubricating oil composition.

In some embodiments, the sulfated ash content of the lubricating oil composition disclosed herein is at most about 2.0, 1.5, 1.0, or 0.5 wt.%, based on the total weight of the lubricating oil composition.

In certain embodiments, the biodiesel fuel of the lubricating oil composition disclosed herein comprises an alkyl ester of a long chain fatty acid. In further embodiments, the long chain fatty acid comprises from about 12 carbon atoms to about 30 carbon atoms.

In certain embodiments, the amount of the biodiesel fuel is from at least 0.3 wt.%, or from about 0.3 to 20 wt.%, 1 wt.% to about 20 wt.%, 1 wt.% to about 15 wt.%, 1 wt.% to about 10 wt.%, 1 wt.% to about 9 wt.%, 1 wt.% to about 8 wt.%, 1 wt.% to about 7 wt.%, 4 wt.% to about 8 wt.%, or from 1 wt.%, 2 wt.%, 3 wt.%, 4 wt.%, 5 wt.%, 6 wt.%, 7 wt.%, 8 wt.%, or 9 wt.%, based on the total weight of the lubricating oil composition.

CLAIMS

What is claimed is:

1. A lubricating oil composition contaminated with at least about 0.3 wt% of a biodiesel fuel or a decomposition product thereof, based on the total weight of the lubricating oil composition, comprising a major amount of base oil of lubricating viscosity; and a polysuccinimide dispersant, said dispersant prepared by the process which comprises reacting

(A) at least one of the following copolymers:

(i) a copolymer obtained by free radical copolymerization of components comprising:

(a) at least one monoethylenically unsaturated C_3-C_{28} monocarboxylic acid or ester thereof, or C_4-C_{28} dicarboxylic acid, anhydride or ester thereof;

(b) at least one 1-olefin comprising about 2 to 40 carbon atoms or at least one polyolefin comprising about 4 to 360 carbon atoms and having a terminal copolymerizable group in the form of a vinyl, vinylidene or alkyl vinylidene group or mixtures thereof; and

(c) at least one monoolefin compound which is copolymerizable with the monomers of (a) and (b) and is selected from the group consisting of:

(1) an alkyl vinyl ether and an allyl alkyl ether where the alkyl group is hydroxyl, amino, dialkylamino or alkoxy substituted or is unsubstituted, and containing 1 to 40 carbon atoms;

(2) an alkyl amine and an N-alkylamide of a monoethylenically unsaturated mono- or dicarboxylic acid of 3 to 10 carbon atoms wherein the alkyl substituent contains 1 to 40 carbon atoms;

(3) a N-vinylcarboxamide of carboxylic acids of 1 to 8 carbon atoms;

(4) a N-vinyl substituted nitrogen-containing heterocyclic compound; and

(5) at least one 1-olefin comprising about 2 to 40 carbon atoms or at least one polyolefin comprising about 4 to about 360 carbon atoms and having a terminal copolymerizable group in the form of a vinyl, vinylidene or alkyl vinylidene group or mixtures

thereof, provided that the olefin employed is not the same as the olefin employed in (i)(b);

(ii) a copolymer obtained by reacting compound (i)(a) and compound(i)(b) in the presence of a free radical initiator;

(iii) a copolymer obtained by (a) reacting compound (i)(a) with compound (i)(b) or (i)(c) in a non-free radical catalyzed reaction in the presence of copolymer (i) or copolymer (ii) or both; or by (b) contacting copolymer (i) or copolymer (ii) or both with the non-free radical catalyzed reaction product of compound (i)(a) and compound (i)(b) or (i)(c); with

(B) at least one ether compound selected from the group consisting of an ether polyamine, a polyether polyamine, a polyether amino alcohol, a polyether amino thiol, and a polyether polyol; and

(C) at least one aromatic amine; and

wherein the amount of said dispersant present in the lubricating oil composition is at least about 2 wt.% actives, based on the total weight of the lubricating oil composition.

2. The lubricating oil composition of claim 1 further comprising at least one additive selected from the group consisting of antioxidants, antiwear agents, detergents, rust inhibitors, demulsifiers, friction modifiers, multi-functional additives, viscosity index improvers, pour point depressants, foam inhibitors, metal deactivators, dispersants, corrosion inhibitors, lubricity improvers, thermal stability improvers, anti-haze additives, icing inhibitors, dyes, markers, static dissipaters, biocides and combinations thereof.

3. The lubricating oil composition of claim 1, wherein the sulfated ash content of the lubricating oil composition is at most about 2.0 wt.%, based on the total weight of the lubricating oil composition.

4. The lubricating oil composition of claim 1, wherein the biodiesel fuel comprises an alkyl ester of a long chain fatty acid.

5. The lubricating oil composition of claim 4, wherein the long chain fatty acid comprises from about 12 carbon atoms to about 30 carbon atoms.

6. The lubricating oil composition of claim 1, wherein the amount of the biodiesel fuel or decomposition products thereof is present in the lubricating oil

composition at from 0.3 wt.% to 20 wt.%, based on the total weight of the lubricating oil composition.

7. The lubricating oil composition of claim 6, wherein the amount of the biodiesel fuel or decomposition products thereof is present in the lubricating oil composition at about 1 wt. % to about 10 wt. %, based on the total weight of the lubricating oil composition.

8. The lubricating oil composition of claim 1, wherein the amount of the dispersant present in the lubricating oil composition is from about 2 to 10 wt.% actives, based on the total weight of the lubricating oil composition.

9. The lubricating oil composition of claim 1, wherein the amount of the dispersant present in the lubricating oil composition is from about 2 to 6 wt. % actives, based on the total weight of the lubricating oil composition.

10. The lubricating oil composition of claim 1, wherein the base oil has a kinematic viscosity from about 4 cSt to about 20 cSt at 100 °C.

11. A method of lubricating a diesel engine fueled at least in part with a biodiesel fuel which comprises operating the engine with a lubricating oil composition contaminated with at least about 0.3 wt% of a biodiesel fuel or a decomposition product thereof, based on the total weight of the lubricating oil composition, wherein the lubricating oil composition comprises: comprising a major amount of base oil of lubricating viscosity; and a polysuccinimide dispersant, said dispersant prepared by the process which comprises reacting

(A) at least one of the following copolymers:

(i) a copolymer obtained by free radical copolymerization of components comprising:

(a) at least one monoethylenically unsaturated C_3-C_{28} monocarboxylic acid or ester thereof, or C_4-C_{28} dicarboxylic acid, anhydride or ester thereof;

(b) at least one 1-olefin comprising about 2 to 40 carbon atoms or at least one polyolefin comprising about 4 to 360 carbon atoms and having a terminal copolymerizable group in the form of a vinyl, vinylidene or alkyl vinylidene group or mixtures thereof; and

(c) at least one monoolefin compound which is copolymerizable with the monomers of (a) and (b) and is selected from the group consisting of:

(1) an alkyl vinyl ether and an allyl alkyl ether where the alkyl group is hydroxyl, amino, dialkylamino or alkoxy substituted or is unsubstituted, and containing 1 to 40 carbon atoms;

(2) an alkyl amine and an N-alkylamide of a monoethylenically unsaturated mono- or dicarboxylic acid of 3 to 10 carbon atoms wherein the alkyl substituent contains 1 to 40 carbon atoms;

(3) a N-vinylcarboxamide of carboxylic acids of 1 to 8 carbon atoms;

(4) a N-vinyl substituted nitrogen-containing heterocyclic compound; and

(5) at least one 1-olefin comprising about 2 to 40 carbon atoms or at least one polyolefin comprising about 4 to about 360 carbon atoms and having a terminal copolymerizable group in the form of a vinyl, vinylidene or alkyl vinylidene group or mixtures thereof, provided that the olefin employed is not the same as the olefin employed in (i)(b);

(ii) a copolymer obtained by reacting compound (i)(a) and compound(i)(b) in the presence of a free radical initiator;

(iii) a copolymer obtained by (a) reacting compound (i)(a) with compound (i)(b) or (i)(c) in a non-free radical catalyzed reaction in the presence of copolymer (i) or copolymer (ii) or both; or by (b) contacting copolymer (i) or copolymer (ii) or both with the non-free radical catalyzed reaction product of compound (i)(a) and compound (i)(b) or (i)(c); with

(B) at least one ether compound selected from the group consisting of an ether polyamine, a polyether polyamine, a polyether amino alcohol, a polyether amino thiol, and a polyether polyol; and

(C) at least one aromatic amine; and

wherein the amount of said dispersant present in the lubricating oil composition is at least about 2 wt.% actives, based on the total weight of the lubricating oil composition.

12. The method of claim 11 further comprising at least one additive selected from the group consisting of antioxidants, antiwear agents, detergents, rust inhibitors, demulsifiers, friction modifiers, multi-functional additives, viscosity index improvers, pour point depressants, foam inhibitors, metal deactivators, dispersants, corrosion inhibitors, lubricity improvers, thermal stability improvers, anti-haze additives, icing inhibitors, dyes, markers, static dissipaters, biocides and combinations thereof.

13. The method of claim 11, wherein the sulfated ash content of the lubricating oil composition is at most about 2.0 wt.%, based on the total weight of the lubricating oil composition.

14. The method of claim 11, wherein the biodiesel fuel comprises an alkyl ester of a long chain fatty acid.

15. The method of claim 14, wherein the long chain fatty acid comprises from about 12 carbon atoms to about 30 carbon atoms.

16. The method of claim 11, wherein the base oil has a kinematic viscosity from about 4 cSt to about 20 cSt at 100 °C.

17. The method of claim 1, wherein the amount of the biodiesel fuel or decomposition products thereof is present in the lubricating oil composition at from about 0.3 wt.% to about 20 wt.%, based on the total weight of the lubricating oil composition.

18. The method of claim 1, wherein the amount of the dispersant present in the lubricating oil composition is from 2 to 10 wt.% actives, based on the total weight of the lubricating oil composition.

19. A method for inhibiting viscosity increase in a diesel engine fueled at least in part with a biodiesel fuel which comprises operating the engine with a lubricating oil composition contaminated with at least about 0.3 wt% of a biodiesel fuel or a decomposition product thereof, based on the total weight of the lubricating oil composition, wherein the lubricating oil composition comprises: comprising a major amount of base oil of lubricating viscosity; and a polysuccinimide dispersant, said dispersant prepared by the process which comprises reacting

(A) at least one of the following copolymers:

(i) a copolymer obtained by free radical copolymerization of components comprising:

(a) at least one monoethylenically unsaturated C_3-C_{28} monocarboxylic acid or ester thereof, or C_4-C_{28} dicarboxylic acid, anhydride or ester thereof;

(b) at least one 1-olefin comprising about 2 to 40 carbon atoms or at least one polyolefin comprising about 4 to 360 carbon atoms and having a terminal copolymerizable group in the form of a vinyl, vinylidene or alkyl vinylidene group or mixtures thereof; and

(c) at least one monoolefin compound which is copolymerizable with the monomers of (a) and (b) and is selected from the group consisting of:

(1) an alkyl vinyl ether and an allyl alkyl ether where the alkyl group is hydroxyl, amino, dialkylamino or alkoxy substituted or is unsubstituted, and containing 1 to 40 carbon atoms;

(2) an alkyl amine and an N-alkylamide of a monoethylenically unsaturated mono- or dicarboxylic acid of 3 to 10 carbon atoms wherein the alkyl substituent contains 1 to 40 carbon atoms;

(3) a N-vinylcarboxamide of carboxylic acids of 1 to 8 carbon atoms;

(4) a N-vinyl substituted nitrogen-containing heterocyclic compound; and

(5) at least one 1-olefin comprising about 2 to 40 carbon atoms or at least one polyolefin comprising about 4 to about 360 carbon atoms and having a terminal copolymerizable group in the form of a vinyl, vinylidene or alkyl vinylidene group or mixtures thereof, provided that the olefin employed is not the same as the olefin employed in (i)(b);

(ii) a copolymer obtained by reacting compound (i)(a) and compound(i)(b) in the presence of a free radical initiator;

(iii) a copolymer obtained by (a) reacting compound (i)(a) with compound (i)(b) or (i)(c) in a non-free radical catalyzed reaction in the presence of copolymer (i) or copolymer (ii) or both; or by (b) contacting copolymer (i) or copolymer (ii) or both with the non-free radical catalyzed reaction product of compound (i)(a) and compound (i)(b) or (i)(c); with

(B) at least one ether compound selected from the group consisting of an ether polyamine, a polyether polyamine, a polyether amino alcohol, a polyether amino thiol, and a polyether polyol; and

(C) at least one aromatic amine; and

wherein the amount of said dispersant present in the lubricating oil composition is at least about 2 wt.% actives, based on the total weight of the lubricating oil composition.

20. The method of claim 19 further comprising at least one additive selected from the group consisting of antioxidants, antiwear agents, detergents, rust inhibitors, demulsifiers, friction modifiers, multi-functional additives, viscosity index improvers,

pour point depressants, foam inhibitors, metal deactivators, dispersants, corrosion inhibitors, lubricity improvers, thermal stability improvers, anti-haze additives, icing inhibitors, dyes, markers, static dissipaters, biocides and combinations thereof.

21. The method of claim 19, wherein the sulfated ash content of the lubricating oil composition is at most about 2.0 wt.%, based on the total weight of the lubricating oil composition.

22. The method of claim 19, wherein the biodiesel fuel comprises an alkyl ester of a long chain fatty acid.

23. The method of claim 22, wherein the long chain fatty acid comprises from 12 carbon atoms to about 30 carbon atoms.

24. The method of claim 19, wherein the base oil has a kinematic viscosity from about 4 cSt to about 20 cSt at 100 °C.

25. The method of claim 19, wherein the amount of the biodiesel fuel or decomposition products thereof is present in the lubricating oil composition at from about 0.3 wt.% to about 20 wt.%, based on the total weight of the lubricating oil composition.

26. The method of claim 19, wherein the amount of the dispersant present in the lubricating oil composition is from about 2 to 10 wt.% actives, based on the total weight of the lubricating oil composition.