Direct Injection Spark Ignition engines do however produce particulates, albeit in a lower concentration than many diesel engines. These particulates are known to be harmful to human health and to have a detrimental environmental impact.

There is thus a need to reduce particulate emissions from spark ignition engines and it is expected that legislation in the coming years will mandate lower particulate emissions.

The present invention seeks to provide means for reducing particulate emissions from direct injection spark ignition engines.

Summary

In one aspect of the present disclosure, there is provided a use of a quaternary ammonium compound as an additive in a gasoline composition to reduce particulate emissions from a direct injection spark ignition engine, wherein the quaternary ammonium compound is the reaction product of a nitrogen-containing species having at least one tertiary amine group and a quaternising agent wherein the nitrogen-containing species having at least one tertiary amine group may be selected from (i) the reaction product of a hydrocarbyl-substituted acylating agent and a compound comprising at least one tertiary amine group and a primary amine, secondary amine or alcohol group; (ii) a Mannich reaction product comprising a tertiary amine group; (iii) a polyalkylene substituted amine having at least one tertiary amine group; (iv) a tertiary amine of formula $R^1R^2R^3N$, wherein each of R^1, R^2 and R^3 is independently an alkyl group or a hydroxyalkyl group; and (v) a cyclic tertiary amine.

In yet another aspect, there is provided a use of a quaternary ammonium compound as an additive in a gasoline fuel composition to improve the performance of a particulate filter fitted to the exhaust of a direct injection spark ignition engine wherein the improvement in performance is selected from increased longevity; an increase in maintenance intervals; and an increase in regeneration intervals; and wherein the quaternary ammonium compound is the reaction product of a nitrogen-containing species having at least one tertiary amine group and a quaternising agent wherein the nitrogen-containing species having at least one tertiary amine group may be selected from: (i) the reaction product of a hydrocarbyl-substituted acylating agent and a compound comprising at least one tertiary amine group and a primary amine, secondary amine or alcohol group; (ii) a Mannich reaction product comprising a tertiary amine group; (iii) a polyalkylene substituted amine having at least one tertiary amine group; (iv) a tertiary amine of formula $R^1R^2R^3N$, wherein each of R^1, R^2 and R^3 is independently an alkyl group or a hydroxyalkyl group; and (v) a cyclic tertiary amine.

Detailed Description

According to a first aspect of the present invention there is provided a method of reducing particulate emissions from a direct injection spark ignition engine, the method comprising combusting in the engine a gasoline composition comprising as an additive a quaternary ammonium compound.

According to a second aspect of the present invention there is provided the use of a quaternary ammonium compound as an additive in a gasoline composition to reduce particulate emissions from a direct injection spark ignition engine.

Preferred features of the first and second aspects of the invention will now be described. Any feature of any aspect may be combined with any feature of any other aspect as appropriate.

The present invention relates to a method and a use involving a quaternary ammonium compound as a fuel additive. The additive may be referred to herein as “the additive of the present invention”, “the quaternary ammonium compound” or as “the quaternary ammonium salt additive”.

The quaternary ammonium salt additive may comprise a single compound. In some embodiments mixtures containing more than one quaternary ammonium compound may be used. References herein to “an additive” of the invention or “the additive” include mixtures comprising two or more such compounds.

The quaternary ammonium salt additive is suitably the reaction product of a nitrogen-containing species having at least one tertiary amine group and a quaternising agent.

The nitrogen-containing species having at least one tertiary amine group may be selected from any compound including a tertiary amine functional group.

Claims

1. The use of a quaternary ammonium compound as an additive in a gasoline composition to reduce particulate emissions from a direct injection spark ignition engine; wherein the quaternary ammonium compound is the reaction product of a nitrogen-containing species having at least one tertiary amine group and a quaternising agent wherein the nitrogen-containing species having at least one tertiary amine group may be selected from:

   (i) the reaction product of a hydrocarbyl-substituted acylating agent and a compound comprising at least one tertiary amine group and a primary amine, secondary amine or alcohol group;

   (ii) a Mannich reaction product comprising a tertiary amine group;

   (iii) a polyalkylene substituted amine having at least one tertiary amine group;

   (iv) a tertiary amine of formula $R^1R^2R^3N$, wherein each of R^1, R^2 and R^3 is independently an alkyl group or a hydroxyalkyl group; and

   (v) a cyclic tertiary amine.

2. A use according to claim 1 wherein the nitrogen-containing species having at least one tertiary amine group is the reaction product of an alcohol or amine including a tertiary amino group and an optionally substituted succinic acid or anhydride thereof, suitably wherein the succinic acid or anhydride thereof is substituted with a polyisobutenyl group having a number average molecular weight of from 170 to 2800, preferably 450 to 1500.

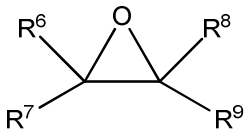
3. A use according to claim 1 or claim 2 wherein the alcohol or amine including a tertiary amino group is selected from dimethylaminopropanol, dimethylaminopropylamine, N,N-diethyl-1,3-diaminopropane, N,N-dimethylethylenediamine, N,N-diethylethylenediamine, N,N-dibutylethylenediamine, or combinations thereof.

4. A use according to any preceding claim wherein the quaternising agent is selected from an ester of a carboxylic acid, epoxides optionally in combination with an acid, dialkyl sulfates, benzyl halides, hydrocarbyl substituted carbonates, alkyl halides, alkyl sulfonates, sultones, hydrocarbyl substituted phosphates, hydrocarbyl substituted borates, alkyl nitrites, alkyl nitrates, hydroxides, N-oxides or mixtures thereof, followed by an anion exchange reaction.

5. A use according to claim 4 wherein the quaternising agent is an ester of formula R^5COOR^0 wherein R^0 is a C_1 to C_7 alkyl group and R^5 is the residue of a carboxylic acid selected from a substituted aromatic carboxylic acid, an α-hydroxycarboxylic acid and a polycarboxylic acid.

6. A use according to claim 5 wherein the quaternising agent is an ester of a carboxylic acid selected from one or more of oxalic acid, phthalic acid, salicylic acid, maleic acid, malonic acid, citric acid, nitrobenzoic acid, aminobenzoic acid and 2, 4, 6-trihydroxybenzoic acid, suitably wherein the quaternising agent is selected from dimethyl oxalate, methyl 2-nitrobenzoate, dimethylphthalate, dimethyltartrate and methyl salicylate.

7. A use according to claim 4 wherein the quaternising agent is selected from epoxides, optionally in combination with an acid, wherein the epoxide has the formula:



wherein each of R^6, R^7, R^8, R^9 is independently selected from hydrogen or an optionally substituted alkyl, alkenyl or aryl group, provided at least one of R^6, R^7, R^8 and R^9 is hydrogen, suitably wherein each of R^6, R^7 and R^8 is hydrogen and R^9 is selected from phenyl, an optionally substituted alkyl or alkenyl group having 1 to 20 carbon atoms, hydrogen, CH_2OR^{10} or CH_2OCOR^{11} wherein each of R^{10} and R^{11} is an optionally substituted alkyl or aryl group having from 1 to 20 carbon atoms.

8. A use according to claim 7 wherein the epoxide is selected from styrene oxide, ethylene oxide, propylene oxide, butylene oxide, stilbene oxide and isopropyl glycidyl ether.

9. A use according to any of claims 4, 7 or 8 wherein the epoxide quaternising agents are used in combination with an acid.

10. A use according to claim 9 wherein the acid is selected from:
    - a small simple acid selected from formic acid, acetic acid, propionic acid and butyric acid;
    - a fatty acid compound; and
    - a hydrocarbyl substituted phthalic acid or succinic acid derivative including a carboxylic functional group.

11. A use according to any preceding claim wherein the gasoline composition further comprises one or more additional components selected from:
    a) carrier oils
    b) acylated nitrogen compounds which are the reaction product of a carboxylic acid-derived acylating agent and an amine
    c) hydrocarbyl-substituted amines wherein the hydrocarbyl substituent is substantially aliphatic and contains at least 8 carbon atoms

d) mannich base additives comprising nitrogen-containing condensates of a phenol, aldehyde and primary or secondary amine; and

e) aromatic esters of a polyalkylphenoxyalkanol.

12. A use according to any preceding claim which reduces the number of particulates emitted per unit volume of exhaust gas and /or the total mass of particulates emitted per unit volume of exhaust gas.

13. The use of a quaternary ammonium compound as an additive in a gasoline fuel composition to improve the performance of a particulate filter fitted to the exhaust of a direct injection spark ignition engine wherein the improvement in performance is selected from:

- increased longevity;
- an increase in maintenance intervals; and
- an increase in regeneration intervals; and wherein the quaternary ammonium compound is the reaction product of a nitrogen-containing species having at least one tertiary amine group and a quaternising agent wherein the nitrogen-containing species having at least one tertiary amine group may be selected from:
- (i) the reaction product of a hydrocarbyl-substituted acylating agent and a compound comprising at least one tertiary amine group and a primary amine, secondary amine or alcohol group;
- (ii) a Mannich reaction product comprising a tertiary amine group;
- (iii) a polyalkylene substituted amine having at least one tertiary amine group;
- (iv) a tertiary amine of formula $R^1R^2R^3N$, wherein each of R^1, R^2 and R^3 is independently an alkyl group or a hydroxyalkyl group; and
- (v) a cyclic tertiary amine.