

METHOD FOR CLEANING DEPOSITS FROM TURBOCHARGER AND SUPERCHARGER COMPRESSORS

5

Field of the Invention

The present invention relates to a method for removing turbocharger and supercharger compressor deposits without dismantling the compressor, and allowing for the cleaning of deposits on a running engine without the cleaning fluid
10 being consumed by the engine.

Background of the Invention

Turbochargers, and less commonly, superchargers, are used to increase
15 engine power output by providing higher charge-air density such that more fuel can be burned in each engine cycle, by scavenging airflow to clear the cylinders of combustion products, and by cooling engine parts allowing for power increases. The utilization of a turbocharger with an engine results in increased horsepower output and higher brake mean effective pressure because the higher air density improves
20 engine performance at low loads and permits the engine to operate not only at an optimum efficiency point, but also at reduced speeds and loads. The use of a turbocharger may further act to restore sea level ratings on engines operating at high altitudes by compensating for reduced atmospheric pressures, and may make possible maximum speed acceleration to synchronous speed for fast reliable starts
25 as well as reducing fuel and oil consumption.

Turbocharger and supercharger compressors are very finely machined and run at very high speeds, generally many thousands of revolutions per minute, and therefore are very sensitive to deposit deposition. These deposits are especially

severe in engines equipped with exhaust gas recirculation (EGR) or where crankcase ventilation gases are fed into the intake system of the engine upstream of the compressor.

Previously, compressor deposits had to be removed by removing and
5 dismantling the compressor and cleaning the parts away from the engine. One approach is to use chemical cleaning fluids to dissolve the deposits. One cannot simply spray cleaning fluid into the compressor with the engine turned off, however, as large amounts of cleaning fluid are required which will accumulate and cause puddles in the inlet system. The result of this is that these puddles will be ingested
10 and the engine will “run away” when the engine is turned back on, possibly resulting in dangerous operating conditions and damage to the engine. For the same reason, one cannot simply spray cleaning fluid into the compressor while the output of the compressor is fed into the operating engine. One potential solution to prevent “run away” under these conditions is to install an air restriction valve in the air intake
15 system. However, this would entail significant engineering modification and does not prevent the engine from consuming the cleaning fluid as a non-ideal fuel.

Surprisingly, we have discovered a method for removing turbocharger and supercharger compressor deposits without dismantling the compressor that allows for the cleaning of deposits on a running engine, but without the cleaning fluid being
20 consumed by the engine. Removal of these deposits are important because excessive deposits can cause a restriction of intake airflow, loss of compression, loss of power in the engine, and increased emissions, especially smoke.

Summary

One embodiment of this disclosure is directed to a method for removing deposits from at least one compressor powered by an engine. The method comprises disconnecting, while the engine is turned off, a high pressure downstream side of the compressor from an intercooler, or an air intake manifold for non-intercooled engines, while leaving the compressor attached to a means used in the engine to drive the compressor. The output airflow is diverted from the compressor away from the engine to a disposal or to a means of separating a cleaning fluid from air. A means to inject the cleaning fluid into the air stream is introduced in the low pressure side upstream of said compressor. After starting the engine, and while the engine is running, the cleaning fluid is injected via the aforementioned means for a sufficient time to clean the compressor.

Another embodiment of the disclosure is directed to a method for removing deposits from at least one compressor powered by an engine. The method comprises disconnecting, while the engine is turned off, a high pressure downstream side of the compressor from an intercooler, or an air intake manifold for non-intercooled engines, while leaving said compressor attached to a means used in the engine to drive the compressor. A conduit is attached to the high pressure downstream side of the compressor, and an input to and output from a means for separating a cleaning fluid from air is as also attached. The output airflow is diverted from the compressor to the means for separating the cleaning fluid from air, and further directing the remainder of the airflow to the engine air intake system. A means to inject the cleaning fluid into the air stream is introduced in the low pressure side upstream of the compressor. After starting the engine, and while the engine is

running, the cleaning fluid is injected via the aforementioned means for a sufficient time to clean said compressor.

In a first aspect, there is provided a method for removing deposits from at least one compressor powered by an engine, comprising (a) disconnecting, while said engine is turned off, a high pressure downstream side of said compressor from an intercooler, or an air intake manifold for non-intercooled engines, while leaving said compressor attached to a means used in the engine to drive the compressor, (b) diverting the output airflow from said compressor away from the engine to a disposal or to a means of separating a cleaning fluid from air, (c) starting said engine, (d) introducing a means to inject said cleaning fluid into an air stream in the low pressure side upstream of said compressor; and (e) while said engine is running, injecting said cleaning fluid via the means in step (d) for a sufficient time to clean said compressor, wherein said cleaning fluid comprises (i) a major amount of an aromatic hydrocarbon solvent.

In a second aspect, there is provided a method for removing deposits from at least one compressor powered by an engine, comprising (a) disconnecting, while said engine is turned off, a high pressure downstream side of said compressor from an intercooler, or an air intake manifold for non-intercooled engines, while leaving said compressor attached to a means used in said engine to drive said compressor, (b) attaching a conduit to the high pressure downstream side of said compressor, (c) attaching, an input to and output from, a means for separating a cleaning fluid from air, (d) diverting the output airflow from said compressor to said means for separating said cleaning fluid from air, and further directing the remainder of said airflow to said engine, (e) starting said engine and (f) introducing a means to inject said cleaning fluid into an air

stream in the low pressure side upstream of said compressor; and (g) while said engine is running, injecting said cleaning fluid via the means in step (f) for a sufficient time to clean said compressor.

In a third aspect, there is provided a method for removing deposits from at least one compressor powered by an engine, comprising (a) disconnecting, while said engine is turned off, a high pressure downstream side of said compressor from an intercooler, or an air intake manifold for non-intercooled engines, while leaving said compressor attached to a means used in said engine to drive said compressor, (b) attaching a conduit to the high pressure downstream side of said compressor, (c) attaching, an input to and output from, a means for separating a cleaning fluid from air, (d) diverting the output airflow from said compressor to said means for separating said cleaning fluid from air, and further directing the remainder of said airflow to said engine, (e) starting said engine and (f) introducing a means to inject said cleaning fluid into an air stream in the low pressure side upstream of said compressor; and (g) while said engine is running, injecting said cleaning fluid via the means in step (f) for a sufficient time to clean said compressor, wherein said cleaning fluid comprises (i) a major amount of an aromatic hydrocarbon solvent.

Brief Description of the Drawings

Figure 1 is a block diagram of a standard engine configuration prior to attachment of the cleaning method of this invention

Figure 2 is a block diagram of an engine configuration during turbocharger cleaning with air recirculation

Figure 3 is a block diagram of an engine configuration during turbocharger cleaning without air recirculation

Detailed Description of the Invention

This invention allows for a chemical cleaning method of turbocharger deposits on a running engine without having the cleaning fluid composition be consumed by the engine.

Definitions

The term "hydrocarbon" denotes compounds with purely or predominantly hydrocarbon character, and include the following:

(1) Purely hydrocarbon; that is, aliphatic, (e. g., alkyl or alkenyl), alicyclic (e. g., cycloalkyl or cycloalkenyl), aromatic, aliphatic-and alicyclic-substituted aromatic, aromatic-substituted aliphatic and alicyclic compounds, and the like, as well as cyclic compounds wherein the ring is completed through another portion of the molecule (that is, any two indicated substituents may together form an alicyclic

group). Non-limiting examples include octane, octadecane, cyclohexane, benzene, toluene, etc.

(2) Substituted hydrocarbon; that is, compounds containing non-hydrocarbon substituents which do not alter the predominantly hydrocarbon character of the compound. Those skilled in the art will be aware of suitable substituents. Non-limiting examples of substituents include hydroxy, nitro, cyano, alkoxy, acyl, etc.

(3) Heteroatom compounds; that is, compounds which, while predominantly hydrocarbon in character, contain atoms other than carbon in a chain or ring otherwise composed of carbon atoms. Suitable hetero atoms will be apparent to those skilled in the art and include, for example, nitrogen, oxygen and sulfur.

In general, no more than about three substituents or hetero atoms, and preferably no more than one, will be present for each 10 carbon atoms in the hydrocarbyl group. Preferably, there are no substituents or hetero atoms in the compound.

An "aromatic" compound contains at least one aromatic ring, such as a phenyl or naphthyl ring. An aromatic compound may have substituents on the ring such as alkyl groups, or other substituents such as those named above.

The Cleaning Fluid

The cleaning fluid employed in this invention is preferably composed of a major amount of an aromatic hydrocarbon solvent. The aromatic hydrocarbon solvent of the present invention is present in a "major amount." A "major amount" of an aromatic hydrocarbon solvent refers to a concentration of the solvent within the cleaning solution of at least about 40 vol % aromatics. In some embodiments, "a major amount" of an aromatic solvent refers to a concentration of the solvent within

the cleaning solution of at least about 50 vol % aromatics, at least about 60 vol % aromatics, at least about 70 vol % aromatics, at least about 80 vol % aromatics, or at least about 90 vol % aromatics. The volume % aromatics of a cleaning solution can be measured by any convenient method, such as by ASTM D 1319, or by gas chromatography.

The Aromatic Hydrocarbon Solvent

For reasons of solubility of deposits, compatibility with engine parts and engine fuels, safety, and cost, aromatic hydrocarbon solvents are the preferred solvents for this invention. Suitable aromatic solvents include benzene, toluene, xylene or higher boiling aromatics or aromatic thinners, such as a C₉ aromatic solvent. A preferred solvent for use in the present invention is a C₉ aromatic solvent. This includes mixtures of C₉ aromatics such as trimethyl benzene and ethyl toluene or propyl benzene which exhibit good solvency and compatibility with fuels. Other aromatic petroleum distillates may also be used, and preferably they are not classified as volatile organic compounds. Preferred aromatic petroleum distillates are naphthalene depleted (i.e. contain less than about 1% by weight naphthalene) since naphthalene may be classified as a hazardous air pollutant. Suitable aromatic petroleum distillates are commercially available as AROMATIC 100, 150, 200 from ExxonMobil Chemical Company and Aromatic 150 type Caromax 20ND from Petrochem Carless.

The aromatic hydrocarbon solvent will preferably contain at least 70 vol% aromatics by ASTM D 1319; more preferably at least 80 vol% aromatics; more preferably at least 90 vol% aromatics; even more preferably at least about 95 vol% aromatics by ASTM D 1319. The solvent will preferably have an end boiling point

by ASTM D 86 of less than 300 °C; more preferably less than 250 °C; more preferably less than 180 °C. For safety reasons, it is preferred that the aromatic hydrocarbon solvent have a flash point of at least 15 °C; more preferably 35 °C. Preferably, the viscosity of the aromatic hydrocarbon solvent is less than 4 cSt @ 25 °C.

Other solvents, such as aliphatic hydrocarbon or oxygenated solvents, may be used in the invention, as long as the concentration of such solvents is low enough not to change the overall aromatic nature of the cleaning solution. Suitable aliphatic solvents include dearomatized solvents, such as Exxsol D40 and D60, available from ExxonMobil, other aliphatic solvents, such as D15-20 Naphtha, D115-145 Naphtha and D31-35 Naphtha, also available from ExxonMobil, and nonaromatic mineral spirits, and the like. Oxygenated solvents include mono and polyalcohols; glycol ethers such as ethylene glycol butyl ethers; polyoxyalkylene compounds such as phenoxy mono- or poly(oxyalkylene) alcohols; and other ethers and ketones.

The Nitrogen-containing Detergent Additive

The cleaning composition employed in the present invention may optionally also contain at least one nitrogen-containing detergent additive. Generally speaking, a detergent additive is a fuel-soluble polar compound added to gasoline and diesel fuels, especially automotive fuels, which is used to clean deposits or keep deposits from forming in at least one area of a fuel intake system. Areas of deposit formation in gasoline engines include fuel injectors, carburetors and intake valves. Areas of deposit formation in diesel engines include the fuel pumps and injectors, in particular the injector nozzles and pump plungers. Suitable detergent additives for

use in this invention include, for example, aliphatic hydrocarbyl amines, hydrocarbyl-substituted poly(oxyalkylene) amines, hydrocarbyl-substituted succinimides, Mannich reaction products, nitro and amino aromatic esters of polyalkylphenoxyalkanois, polyalkylphenoxyaminoalkanes, and mixtures thereof.

5 The aliphatic hydrocarbyl-substituted amines which may be employed in the present invention are typically straight or branched chain hydrocarbyl-substituted amines having at least one basic nitrogen atom and wherein the hydrocarbyl group has a number average molecular weight of about 700 to 3,000. Preferred aliphatic hydrocarbyl-substituted amines include polyisobutenyl and polyisobutyl
10 monoamines and polyamines.

 The aliphatic hydrocarbyl amines employed in this invention are prepared by conventional procedures known in the art. Such aliphatic hydrocarbyl amines and their preparations are described in detail in U.S. Pat. Nos. 3,438,757; 3,565,804; 3,574,576; 3,848,056; 3,960,515; 4,832,702; and 6,203,584, the disclosures of
15 which are incorporated herein by reference in their entirety.

 Another class of detergent additives suitable for use in the present invention are the hydrocarbyl-substituted poly(oxyalkylene) amines, also referred to as polyether amines. Typical hydrocarbyl-substituted poly(oxyalkylene) amines include hydrocarbyl poly(oxyalkylene) monoamines and polyamines wherein the
20 hydrocarbyl group contains from 1 to about 30 carbon atoms, the number of oxyalkylene units will range from about 5 to 100, and the amine moiety is derived from ammonia, a primary alkyl or secondary dialkyl monoamine, or a polyamine having a terminal amino nitrogen atom. Preferably, the oxyalkylene moiety will be oxypropylene or oxybutylene or a mixture thereof. Such hydrocarbyl-substituted
25 poly(oxyalkylene) amines are described, for example, in U.S. Pat. No. 6,217,624,

and U.S. Pat. No. 5,112,364, the disclosures of which are incorporated herein by reference in their entirety.

A preferred type of hydrocarbyl-substituted poly(oxyalkylene) monoamine is an alkylphenyl poly(oxyalkylene)monoamine wherein the poly(oxyalkylene) moiety
5 contains oxypropylene units or oxybutylene units or mixtures of oxypropylene and oxybutylene units. Preferably, the alkyl group on the alkylphenyl moiety is a straight or branched-chain alkyl of 1 to 24 carbon atoms. An especially preferred alkylphenyl moiety is tetrapropenylphenyl, that is, where the alkyl group is a branched-chain alkyl of 12 carbon atoms derived from propylene tetramer.

10 An additional type of hydrocarbyl-substituted poly(oxyalkylene)amine finding use in the present invention are hydrocarbyl-substituted poly(oxyalkylene) aminocarbamates disclosed for example, in U.S. Pat. Nos. 4,288,612; 4,236,020; 4,160,648; 4,191,537; 4,270,930; 4,233,168; 4,197,409; 4,243,798 and 4,881,945, the disclosure of each of which are incorporated herein by reference.

15 These hydrocarbyl poly(oxyalkylene)aminocarbamates contain at least one basic nitrogen atom and have an average molecular weight of about 500 to 10,000, preferably about 500 to 5,000, and more preferably about 1,000 to 3,000. A preferred aminocarbamate is alkylphenyl poly(oxybutylene) aminocarbamate wherein the amine moiety is derived from ethylene diamine or diethylene triamine.

20 A further class of detergent additives suitable for use in the present invention are the hydrocarbyl-substituted succinimides. Typical hydrocarbyl-substituted succinimides include polyalkyl and polyalkenyl succinimides wherein the polyalkyl or polyalkenyl group has an average molecular weight of about 500 to 5,000, and preferably about 700 to 3,000. The hydrocarbyl-substituted succinimides are
25 typically prepared by reacting a hydrocarbyl-substituted succinic anhydride with an

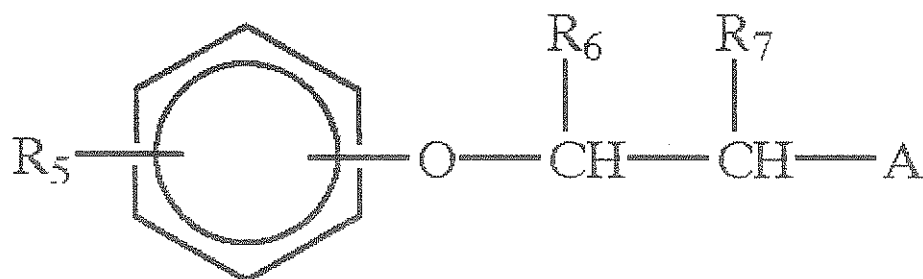
amine or polyamine having at least one reactive hydrogen bonded to an amine nitrogen atom. Preferred hydrocarbyl-substituted succinimides include polyisobutenyl and polyisobutanyl succinimides, and derivatives thereof.

The hydrocarbyl-substituted succinimides finding use in the present invention
5 are described, for example, in U.S. Pat. Nos. 5,393,309; 5,588,973; 5,620,486; 5,916,825; 5,954,843; 5,993,497; and 6,114,542, and British Patent No. 1,486,144, the disclosure of each of which are incorporated herein by reference in their entirety.

Yet another class of detergent additives which may be employed in the present invention are Mannich reaction products which are typically obtained from
10 the Mannich condensation of a high molecular weight alkyl-substituted hydroxyaromatic compound, an amine containing at least one reactive hydrogen, and an aldehyde. The high molecular weight alkyl-substituted hydroxyaromatic compounds are preferably polyalkylphenols, such as polypropylphenol and polybutylphenol, especially polyisobutylphenol, wherein the polyalkyl group has an
15 average molecular weight of about 600 to 3,000. The amine reactant is typically a polyamine, such as alkylene polyamines, especially ethylene or polyethylene polyamines, for example, ethylene diamine, diethylene triamine, triethylene tetramine, and the like. The aldehyde reactant is generally an aliphatic aldehyde, such as formaldehyde, including paraformaldehyde and formalin, and acetaldehyde.
20 A preferred Mannich reaction product is obtained by condensing a polyisobutylphenol with formaldehyde and diethylene triamine, wherein the polyisobutyl group has an average molecular weight of about 1,000.

The Mannich reaction products suitable for use in the present invention are described, for example, in U.S. Pat. Nos. 4,231,759 and 5,697,988, the disclosures
25 of each of which are incorporated herein by reference in their entirety.

A still further class of detergent additive suitable for use in the present invention are polyalkylphenoxyaminoalkanes. Preferred polyalkylphenoxyaminoalkanes include those having the formula (II):



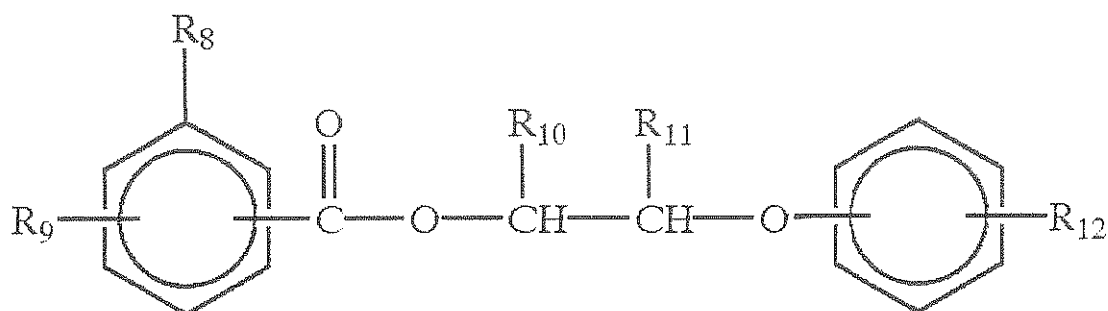
5 wherein R_5 is a polyalkyl group having an average molecular weight in the range of about 600 to 5,000; R_6 and R_7 are independently hydrogen or lower alkyl having 1 to 6 carbon atoms; and A is amino, N-alkyl amino having about 1 to about 20 carbon atoms in the alkyl group, N,N-dialkyl amino having about 1 to about 20 carbon atoms in each alkyl group, or a polyamine moiety having about 2 to about 12 amine
10 nitrogen atoms and about 2 to about 40 carbon atoms.

The polyalkylphenoxyaminoalkanes of Formula II above and their preparations are described in detail in U.S. Pat. No. 5,669,939, the disclosure of which is incorporated herein by reference in its entirety.

Mixtures of polyalkylphenoxyaminoalkanes and poly(oxyalkylene) amines are
15 also suitable for use in the present invention. These mixtures are described in detail in U.S. Pat. No. 5,851,242, the disclosure of which is incorporated herein by reference in its entirety.

A preferred class of detergent additive finding use in the present invention are nitro and amino aromatic esters of polyalkylphenoxyalkanols. Preferred nitro and
20 amino aromatic esters of polyalkylphenoxyalkanols include those having the formula

(III):



wherein R₈ is nitro or $-(CH_2)_n-NR_{13}R_{14}$, wherein R₁₃ and R₁₄ are independently hydrogen or lower alkyl having 1 to 6 carbon atoms and n is 0 or 1; R₉ is hydrogen, hydroxy, nitro or $-NR_{15}R_{16}$, wherein R₁₅ and R₁₆ are independently hydrogen or lower alkyl having 1 to 6 carbon atoms; R₁₀ and R₁₁ are independently hydrogen or lower alkyl having 1 to 6 carbon atoms; and R₁₂ is a polyalkyl group having an average molecular weight in the range of about 450 to 5,000.

The aromatic esters of polyalkylphenoxyalkanols shown in Formula III above and their preparations are described in detail in U.S. Pat. No. 5,618,320, the disclosure of which is incorporated herein by reference in its entirety.

Mixtures of nitro and amino aromatic esters of polyalkylphenoxyalkanols and hydrocarbyl-substituted poly(oxyalkylene) amines are also preferably contemplated for use in the present invention. These mixtures are described in detail in U.S. Pat. No. 5,749,929, the disclosure of which is incorporated herein by reference in its entirety.

Preferred hydrocarbyl-substituted poly(oxyalkylene) amines which may be employed as detergent additives in the present invention include those having the formula (IV):



wherein: R_{17} is a hydrocarbyl group having from about 1 to about 30 carbon atoms; R_{18} and R_{19} are each independently hydrogen or lower alkyl having about 1 to about 6 carbon atoms and each R_{18} and R_{19} is independently selected in each --O--CHR₁₈
 5 --CHR₁₉ -- unit; B is amino, N-alkyl amino having about 1 to about 20 carbon atoms in the alkyl group, N,N-dialkyl amino having about 1 to about 20 carbon atoms in each alkyl group, or a polyamine moiety having about 2 to about 12 amine nitrogen atoms and about 2 to about 40 carbon atoms; and m is an integer from about 5 to about 100.

10 The hydrocarbyl-substituted poly(oxyalkylene) amines of Formula IV above and their preparations are described in detail in U.S. Pat. No. 6,217,624, the disclosure of which is incorporated herein by reference in its entirety.

The hydrocarbyl-substituted poly(oxyalkylene) amines of Formula IV are preferably utilized either by themselves or in combination with other detergent
 15 additives, particularly with the polyalkylphenoxyaminoalkanes of Formula III or the nitro and amino aromatic esters of polyalkylphenoxyalkanois shown in Formula III. More preferably, the detergent additives employed in the present invention will be combinations of the hydrocarbyl-substituted poly(oxyalkylene) amines of Formula IV. A particularly preferred hydrocarbyl-substituted poly(oxyalkylene) amine
 20 detergent additive is dodecylphenoxy poly(oxybutylene) amine and a particularly preferred combination of detergent additives is the combination of dodecylphenoxy poly(oxybutylene) amine and 4-polyisobutylphenoxyethyl para-aminobenzoate.

Preferred Application Tools and Procedures

With reference to the figures, Figure 1 describes a standard engine configuration with a turbocharger prior to attachment of the cleaning method of this invention. The turbocharger 108 is made up of three sections, a compressor 102, and an exhaust turbine 104 on a shared axle 103. The exhaust from the engine 106 flows through an inlet (not shown) causing the exhaust turbine 104 to rotate. This rotation moves the shared axle 103 which drives the compressor 102, which compresses ambient air received via air filter 101. There is a wastegate (not shown) on the exhaust side that regulates how much of the exhaust pressure is applied to the turbocharger 108 and how much bypasses it, and some of this exhaust pressure is directed out through an outlet on exhaust turbine 104. The outlet air from compressor 102 is usually cooled by an intercooler 105, which uses the engine cooling system to reduce the high temperature of the air before it goes into the intake of engine 106.

Figure 2 describes an engine configuration during turbocharger cleaning with air recirculation. The turbocharger 208 is made up of three sections, a compressor 202, and an exhaust turbine 204 on a shared axle 203. In Figure 2, the high pressure side of the compressor 202 is disconnected from the intercooler 206, or air intake manifold for non-intercooled engines, while leaving said compressor 202 attached to a typical means (exhaust) used in the engine to drive compressor 202, and recirculated to the low pressure side to a means for separating a cleaning fluid from air, a non-limiting example of such means is the fluid separation drum 201. All the while, engine 207 is turned off. Preferably, the engine 207 is a compression ignition engine, and the compressor 202 is a turbocharger or

supercharger compressor, and more preferably, a turbocharger compressor. The compressor 202 is disconnected from the intercooler 206 to prevent cleaning fluid-containing intake air from entering the engine 207. This output airflow from compressor 202 can be directed to the fluid separation drum 201 or to a suitable disposal (not shown), non-limiting examples of which include a drain, container, or receptacle. The compressor 202 is powered by the exhaust from the engine 207, which flows through an inlet (not shown) causing the exhaust turbine 204 to rotate. This rotation moves the shared axle 203 which drives the compressor 202. The intake air for operating the engine is not passing the compressor, but instead, taken from the atmosphere, and optionally through air filter 205 and intercooler 206. Also, it is not essential for the air return from the fluid separation drum 201 to be connected to the turbocharger, although this would be preferable.

After starting the engine, a major amount of fresh cleaning fluid 209 is injected into the air stream in the low pressure side of the turbocharger compressor 202. The cleaning fluid 209 is introduced into the compressor through any suitable means, and non-limiting examples include: spraying the cleaning fluid via a common furnace burner injector, and pressurized sources such as aerosols and pumps. It is important, however, that the cleaning fluid introduction means result in a cleaning solution droplet size sufficiently small such that the cleaning fluid is carried essentially quantitatively by the air stream to the turbocharger. Cleaning fluid 209 having passed through the turbocharger compressor 202, having solved and dispersed dirty or used cleaning fluid, will separate/drop out of the air stream due to a lower air velocity in the fluid separation drum 201. An additional air vent (not shown), on top of the fluid separation drum 201 will prevent any pressure or vacuum from building up inside the drum 201. Used cleaning fluid can be drained from the

fluid separation drum after the clean up method and should be disposed of according to local environmental rules.

In Figure 3, an alternative method is shown to separate the cleaning fluid from the intake air in situations where air recirculation is problematic. The turbocharger 308 is made up of three sections, a compressor 302, and an exhaust turbine 304 on a shared axle 303. In these situations where air recirculation is problematic, a means for separating cleaning fluid from air (a non-limiting example of which is the fluid separation drum 305) can be used without air recirculation. A conduit (not shown) is attached to the high pressure downstream side of the compressor 302, and the compressor 302 is disconnected from the intercooler 306, or air intake manifold for non-intercooled engines, all while the engine 307 is turned off. Attached to the fluid separation drum 305 are inputs to (not shown) and outputs from (not shown) the fluid separation drum 305. The output airflow from compressor 302 can be directed the fluid separation drum 305. The fluid separation drum 305 is positioned in between the turbocharger compressor 302 and the intercooler 306, or even bypassing the intercooler 306, directing the remainder of intake air directly from the fluid separation drum 305 to an air inlet manifold (not shown) of engine 307. This cleaning fluid can be drained after cleaning to prevent cleaning fluid from accumulating in the engine. An air restriction valve (not shown) can be placed in the air inlet system for additional safety to prevent engine runaway.

Preferably, the engine 307 is a compression ignition engine, and the compressor 302 is a turbocharger or supercharger compressor, and more preferably, a turbocharger compressor. The compressor 302 is powered by the exhaust from the engine 307, which flows through an inlet (not shown) causing the exhaust turbine 304 to rotate. This rotation moves the shared axle 303 which drives

the compressor 302. The intake air for operating the engine 307 is not passing the compressor 302, but instead, taken from the atmosphere via air filter 301.

After starting the engine, a major amount of fresh cleaning fluid 309 is injected into the air stream in the low pressure side of the turbocharger compressor 302. The cleaning fluid 309 is introduced into the compressor through any suitable means, and non-limiting examples include: spraying the cleaning fluid via a common furnace burner injector, and pressurized sources such as aerosols and pumps.

10

EXAMPLES

Effect of cleaning fluid

An investigation was made into the effect of different cleaning fluids in cleaning field-dirtied turbocharger compressors. The dirty compressors were opened, and a droplet of cleaning fluid was placed on the dirty compressor surface, and the surface was slowly rubbed with a tissue.

Two different classes of cleaning fluids were tested. These classes were oxygenated cleaning fluids similar to the cleaning fluids employed in US Pat. No. 6652667 and US Pat. No. 6616776, which are composed primarily of oxygenated solvents such as 2-phenoxyethanol, 2-butoxyethanol, and propylene carbonate, and also aromatic cleaning fluids based primarily on aromatic solvents, both with and without a common polyalkylene succinimide diesel deposit control additive.

It was found that although oxygenated cleaning fluids were not effective in cleaning turbocharger deposits using the procedure described above, aromatic cleaning fluids with or without deposit control additive were effective in removing the typical turbocharger deposits.

Test procedure

A major advantage of this invention is that it may be implemented with parts
5 commonly found in service garages. The invention was demonstrated in practice
using the equipment described as follows. A dirty BorgWarner Type K29
turbocharger was mounted onto a MAN D2066LF11 Euro IV engine. The conduit
from the air filter to the input of the compressor and the conduit from the output of
the compressor to the intercooler were both disconnected at the turbocharger
10 compressor housing.

A 55-gallon drum was used as a cleaning fluid separation device. Standard
fittings for the drum bungs were used to connect conduits to the air input and output
of the turbocharger compressor housing, with the connections to the housing made
with rubber hose and ring clamps. This achieved a closed system.

15 A commercially available pressurized brake fluid changer equipped with
pressure and flow regulators was used to provide cleaning fluid to the compressor to
be cleaned. A common furnace burner injector was used to spray cleaning fluid into
the input side of the compressor air inlet. The injector was sealed into the
compressor air inlet by removing a sensor, inserting the injector into the sensor
20 housing, and then sealing with elastic hose and ring clamps.

The engine was started, and a cleaning fluid composed of aromatic solvent
with a flash point of 150 °F containing a minor amount of polyalkylene succinimide
was fed to the input side of the compressor at 5 liters/ 30 minutes. Cleaning fluid
was sprayed into the compressor for 30 minutes, and then cleaning fluid addition
25 was discontinued. The engine was run for an additional 5 minutes to further remove
cleaning fluid from the compressor.

The engine was stopped, the cleaning system connections removed, and the turbocharger removed from the engine. Upon disassembly of the turbocharger compressor it was discovered that deposits had been essentially entirely removed from the turbocharger compressor, including both the compressor vanes and the
5 housing.

That which is claimed:

1. A method for removing deposits from at least one compressor powered by an engine, comprising (a) disconnecting, while said engine is turned off, a high
5 pressure downstream side of said compressor from an intercooler, or an air intake manifold for non-intercooled engines, while leaving said compressor attached to a means used in the engine to drive the compressor, (b) diverting the output airflow from said compressor away from the engine to a disposal or to a means of separating a cleaning fluid from air, (c) starting said engine, (d) introducing a means
10 to inject said cleaning fluid into an air stream in the low pressure side upstream of said compressor; and (e) while said engine is running, injecting said cleaning fluid via the means in step (d) for a sufficient time to clean said compressor,
wherein said cleaning fluid comprises (i) a major amount of an aromatic hydrocarbon solvent.
- 15 2. The method of claim 1, wherein said cleaning fluid further comprises (i) at least one nitrogen containing detergent additive.
3. The method of any one of claims 1 or 2, wherein said aromatic hydrocarbon solvent comprises a C₉ aromatic solvent.
4. The method of any one of claims 1 to 3, wherein said aromatic hydrocarbon
20 solvent comprises at least 80 volume percent aromatics.
5. The method of any one of claims 1 to 4, wherein said aromatic hydrocarbon solvent comprises at least 90 volume percent aromatics.
6. The method of any one of the preceding claims wherein said means for separating said cleaning fluid from air in step (c) is a fluid separation drum.

25

7. The method of claim 2 wherein said at least one nitrogen containing detergent additive comprises a hydrocarbyl-substituted succinimide.
8. The method of any one of the preceding claims wherein said engine is a compression ignition engine.
- 5 9. The method of any one of the preceding claims wherein said compressor is a turbocharger compressor.
10. The method of any one of the preceding claims wherein said compressor is a supercharger compressor.
11. A method for removing deposits from at least one compressor powered by an engine, comprising (a) disconnecting, while said engine is turned off, a high pressure downstream side of said compressor from an intercooler, or an air intake manifold for non-intercooled engines, while leaving said compressor attached to a means used in said engine to drive said compressor, (b) attaching a conduit to the high pressure downstream side of said compressor, (c) attaching, an input to and output from, a means for separating a cleaning fluid from air, (d) diverting the output airflow from said compressor to said means for separating said cleaning fluid from air, and further directing the remainder of said airflow to said engine, (e) starting said engine and (f) introducing a means to inject said cleaning fluid into an air stream in the low pressure side upstream of said compressor; and (g) while said engine is running, injecting said cleaning fluid via the means in step (f) for a sufficient time to clean said compressor.
12. The method of claim 11, wherein said cleaning fluid comprises (i) a major amount of an aromatic hydrocarbon solvent.
13. The method of claim 12, wherein said cleaning fluid further comprises (i) at least one nitrogen containing detergent additive.
- 25

14. The method of any one of claims 12 or 13, wherein said aromatic hydrocarbon solvent comprises a C₉ aromatic solvent.
15. The method of any one of claims 12 to 14, wherein said aromatic hydrocarbon solvent comprises at least 80 volume percent aromatics.
16. The method of any one of claims 12 to 15, wherein said aromatic hydrocarbon solvent comprises at least 90 volume percent aromatics.
17. The method of any one of claims 11 to 16, wherein said means for separating said cleaning fluid from air in step (c) is a fluid separation drum
18. The method of claim 13, wherein said at least one nitrogen containing detergent additive comprises a hydrocarbyl-substituted succinimide.
19. The method of any one of claims 11 to 18, wherein said engine is a compression ignition engine.
20. The method of any one of claims 11 to 19, wherein said compressor is a turbocharger compressor.
21. The method of any one of claims 11 to 20, wherein said compressor is a supercharger compressor.
22. A method for removing deposits from at least one compressor powered by an engine, comprising (a) disconnecting, while said engine is turned off, a high pressure downstream side of said compressor from an intercooler, or an air intake manifold for non-intercooled engines, while leaving said compressor attached to a means used in said engine to drive said compressor, (b) attaching a conduit to the high pressure downstream side of said compressor, (c) attaching, an input to and output from, a means for separating a cleaning fluid from air, (d) diverting the output airflow from said compressor to said means for separating said cleaning fluid from air, and further directing the remainder of said airflow to said engine, (e) starting

said engine and (f) introducing a means to inject said cleaning fluid into an air stream in the low pressure side upstream of said compressor; and (g) while said engine is running, injecting said cleaning fluid via the means in step (f) for a sufficient time to clean said compressor, wherein said cleaning fluid comprises (i) a
5 major amount of an aromatic hydrocarbon solvent.

23. The method of claim 22, wherein said cleaning fluid further comprises (i) at least one nitrogen containing detergent additive.

24. The method of any one of claims 22 or 23, wherein said aromatic hydrocarbon solvent comprises a C₉ aromatic solvent.

10 25. The method of any one of claims 22 to 24, wherein said aromatic hydrocarbon solvent comprises at least 80 volume percent aromatics.

26. The method of any one of claims 22 to 25, wherein said aromatic hydrocarbon solvent comprises at least 90 volume percent aromatics.

15 27. The method of any one of claims 22 to 26, wherein said means for separating said cleaning fluid from air in step (c) is a fluid separation drum

28. The method of claim 23, wherein said at least one nitrogen containing detergent additive comprises a hydrocarbyl-substituted succinimide.

29. The method of any one of claims 22 to 28, wherein said engine is a compression ignition engine.

20 30. The method of any one of claims 22 to 29, wherein said compressor is a turbocharger compressor.

31. The method of any one of claims 22 to 30, wherein said compressor is a supercharger compressor.