



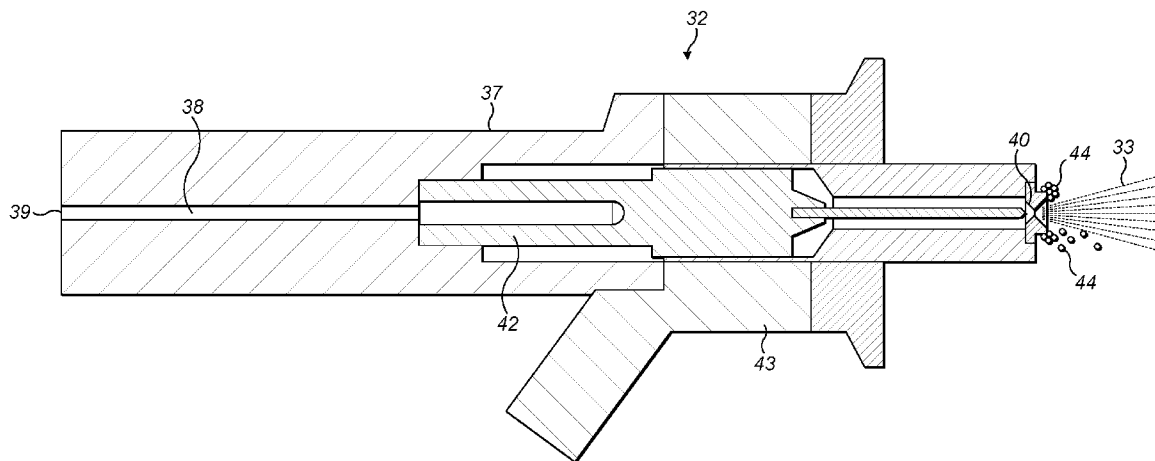
US 20160298515A1

(19) **United States**(12) **Patent Application Publication**
Gharpure et al.(10) **Pub. No.: US 2016/0298515 A1**(43) **Pub. Date: Oct. 13, 2016**(54) **METHOD OF CONTROLLING AN ENGINE SYSTEM**(71) Applicant: **Perkins Engines Company Limited,**
Peterborough (GB)(72) Inventors: **Siddharth Subhash Gharpure,**
Peterborough (GB); **Andrew Cawdery,**
Lincolnshire (GB)(73) Assignee: **Perkins Engines Company Limited,**
Peterborough (GB)(21) Appl. No.: **15/094,313**(22) Filed: **Apr. 8, 2016**(30) **Foreign Application Priority Data**

Apr. 13, 2015 (GB) 1506247.4

Publication Classification(51) **Int. Cl.**
F01N 3/20 (2006.01)(52) **U.S. Cl.**CPC **F01N 3/208** (2013.01); **F01N 2570/14**
(2013.01); **F01N 2900/04** (2013.01); **F01N**
2900/1404 (2013.01)(57) **ABSTRACT**

The present disclosure is directed towards a method of controlling an engine system comprising an exhaust after-treatment module and a controller. The exhaust aftertreatment module is for receiving exhaust gas from an internal combustion engine and comprises a reductant injector selectively operable to inject a reductant fluid from an injector outlet. The controller is configured to control injection of reductant fluid in one of a plurality of different regimes. A first regime comprises injecting reductant fluid in accordance with a first set of injection parameters for reacting with, and substantially reducing, one or more components of the exhaust gas in the exhaust aftertreatment module. A second regime comprises injecting reductant fluid in accordance with a second set of injection parameters for expelling solid reductant deposits formed over the injector outlet. The method comprises determining which of the plurality of regimes to implement. The first regime is implemented when the exhaust gas temperature is above a threshold temperature and the second regime is implemented when the exhaust gas temperature is below the threshold temperature.



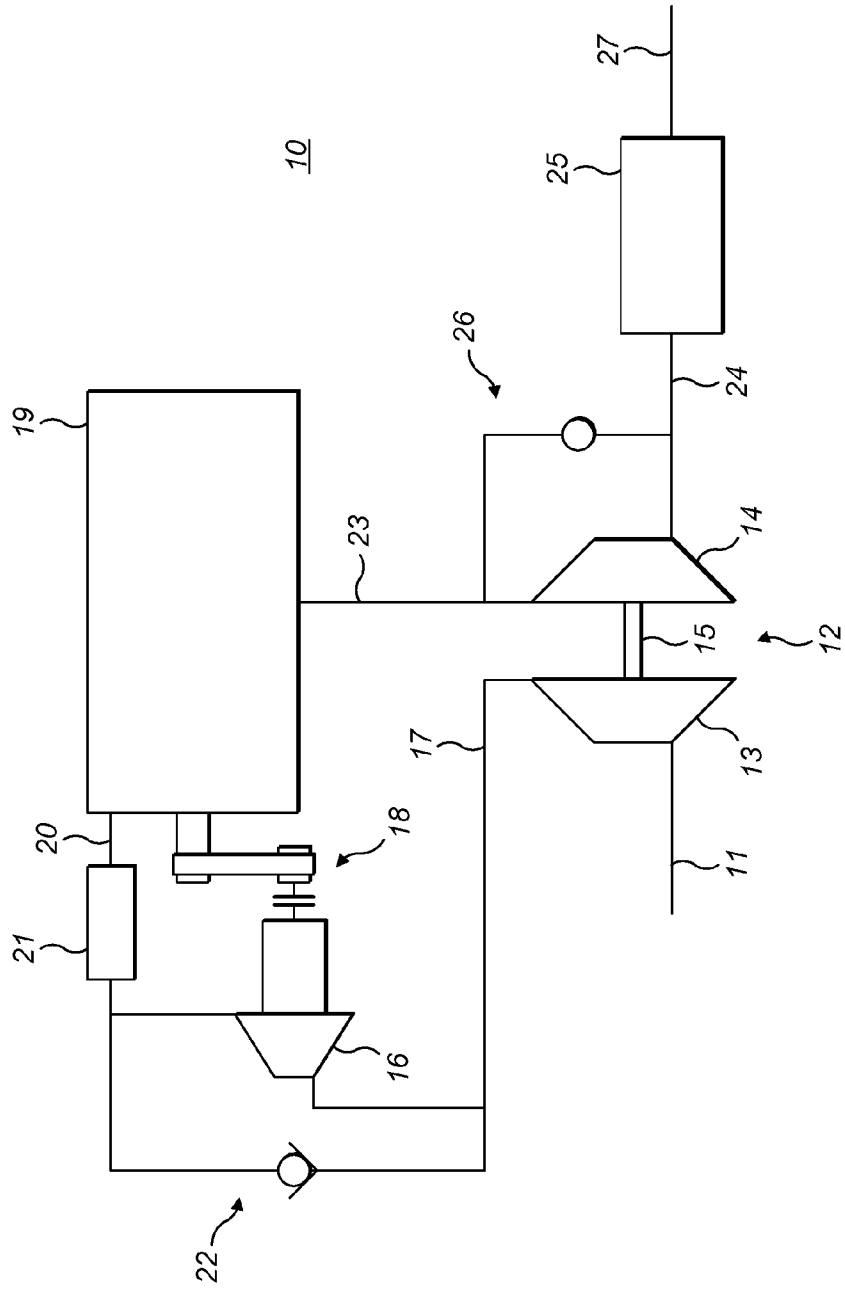


FIG. 1

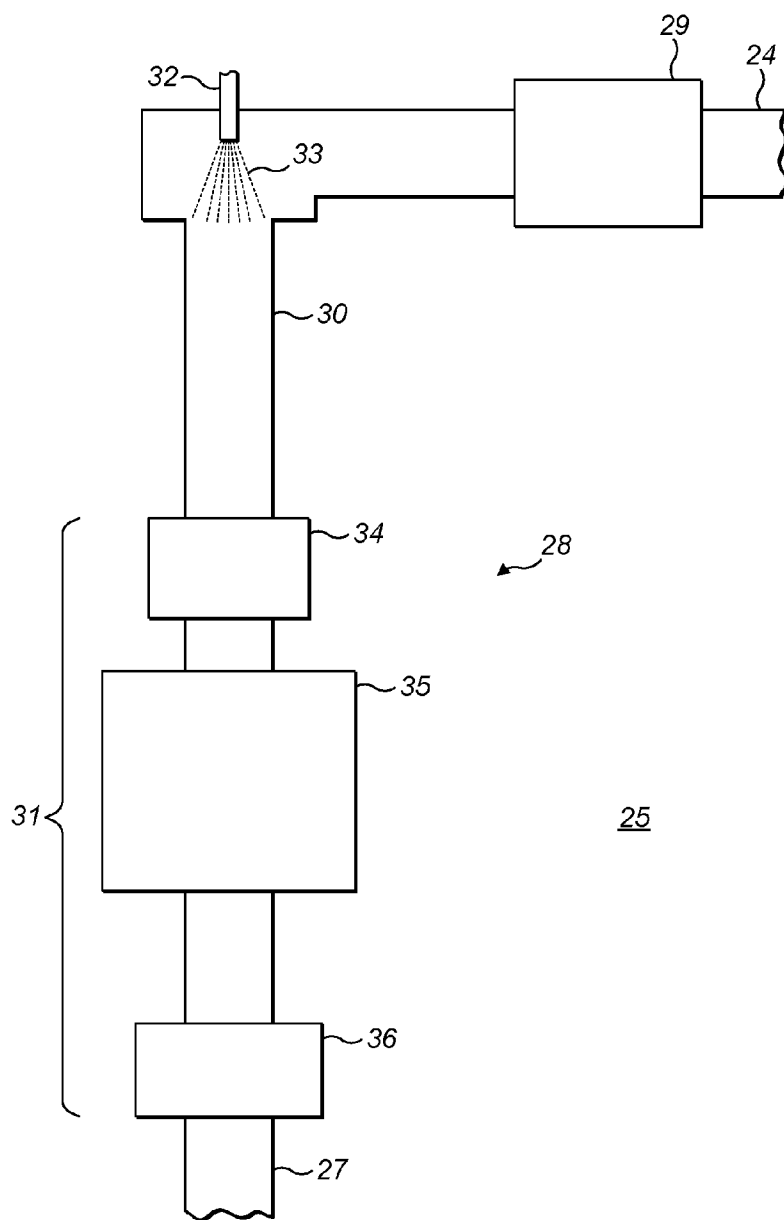
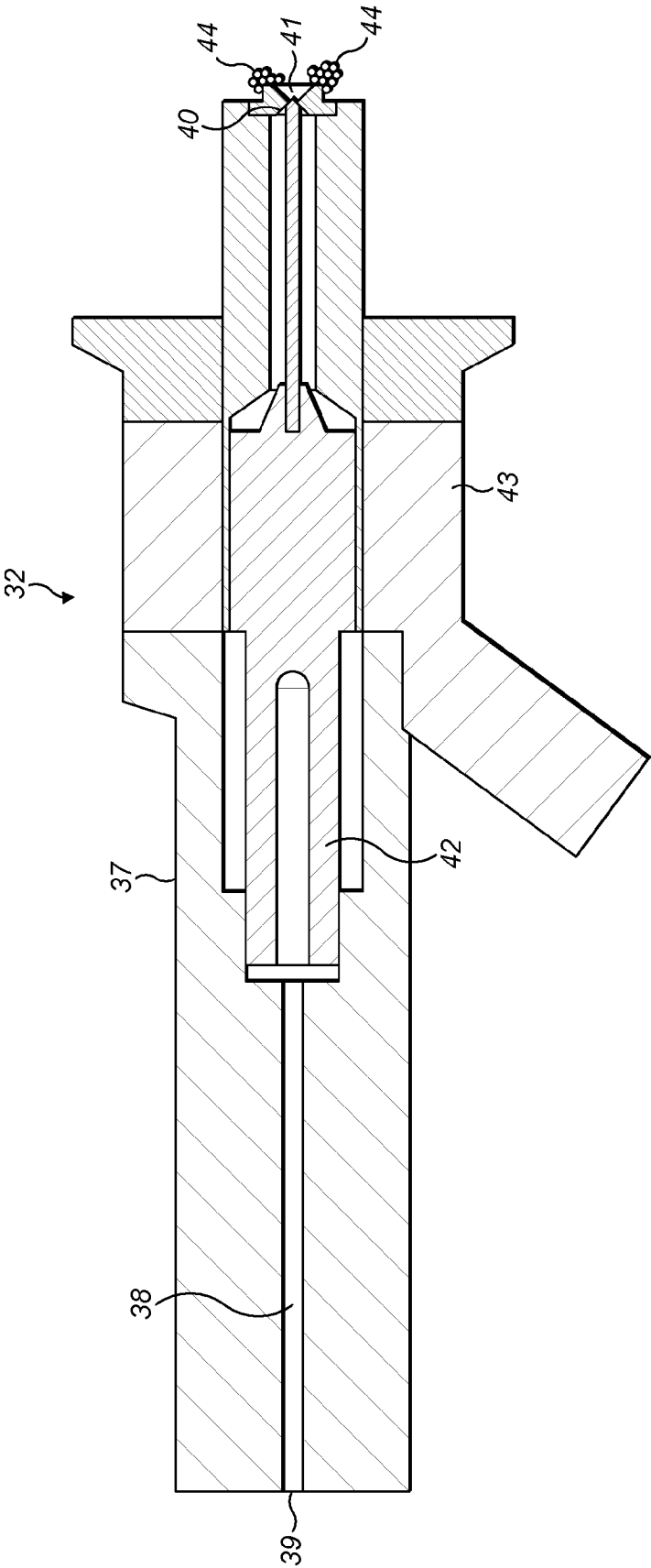


FIG. 2



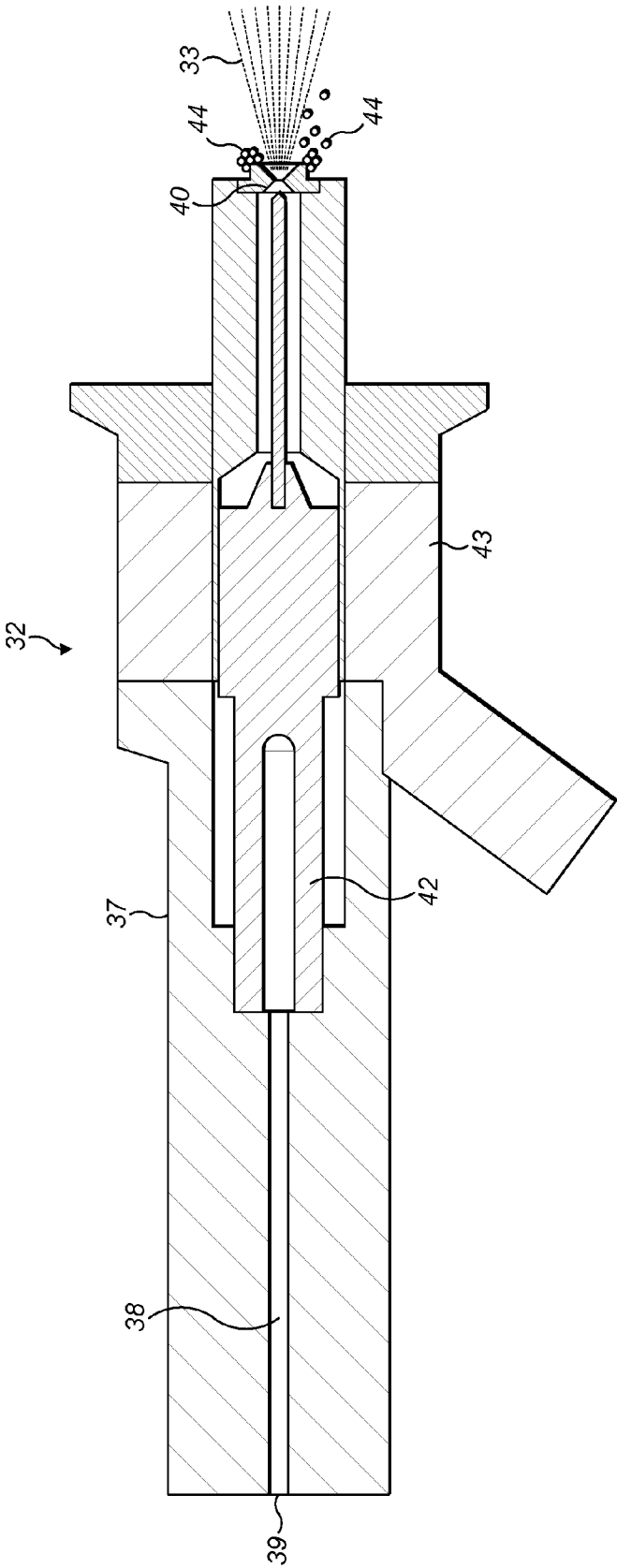


FIG. 4

METHOD OF CONTROLLING AN ENGINE SYSTEM

TECHNICAL FIELD

[0001] This disclosure is directed towards a method of controlling an engine system having an aftertreatment module and a reductant injector therein. The injection of a reductant fluid by the reductant injector is controlled to reduce the formation of solid reductant deposits on the reductant injector during low duty cycles.

BACKGROUND

[0002] Engine systems for vehicles and the like may comprise an aftertreatment module for removing unwanted gaseous emissions or pollutants from the exhaust gases of an internal combustion engine. In particular, a selective catalytic reduction system (SCR) may be provided in the exhaust gas stream for removing nitrogen oxides (NO_x). An SCR system may comprise a reductant injector located upstream of a catalyst and the reductant injector may inject a liquid reductant into the exhaust gases before they contact the catalyst. Suitable liquid reductants may include anhydrous ammonia, aqueous ammonia and urea. The high temperature of the exhaust gases may evaporate the liquid reductant and upon contact with the catalyst, the gaseous reductant may react with the NO_x in the exhaust gas to form nitrogen and water.

[0003] However, if the exhaust gas temperature is too low, such as during low engine load conditions and in low duty cycles, the reductant may be deposited as solid compounds on components of the SCR system. In particular, the reductant may be deposited on or around an outlet nozzle of the reductant injector when eddy currents in the exhaust gas flow redirect injected reductant back onto the outlet nozzle. In addition, the reductant injector may undesirably leak small volumes of reductant, particularly when it is fully pressurised, onto the outlet nozzle. Since the outlet nozzle may have a relatively low surface temperature due to the low exhaust gas temperature, the redirected and leaked reductant may condense on it and the liquid components of the reductant may evaporate. Solid reductant deposits may subsequently be left on the outlet nozzle, which may therefore become partially or fully blocked. This may lead to increased reductant deposit growth and cause poor SCR system conversion efficiency. Furthermore, the reductant injector may be purged with exhaust gas to remove any residual reductant fluid from the reductant injector and its reductant fluid supply. Partial or full blockages may reduce the efficiency of the purge cycles such that residual reductant fluid may freeze or crystallise within the reductant injector.

[0004] Engine systems may therefore be designed to reduce solid reductant deposition during low engine loads and low duty cycles. For example, the exhaust gas temperature may be kept relatively high to prevent the surface of the reductant injector from being too low. Furthermore, the engine system may be arranged to have a high exhaust gas flow rate and/or the conduits within the engine system may be optimised to prevent eddy currents from forming. The design of the reductant injector may also be optimised to prevent leakage of the reductant fluid. However, an engine system needs to be designed to work over whole range of

duty cycles and engine loads and such designs of engine systems may not be suitable at medium and heavy duty cycles.

SUMMARY

[0005] The present disclosure provides a method of controlling an engine system, the engine system comprising: an exhaust aftertreatment module for receiving exhaust gas from an internal combustion engine, the exhaust aftertreatment module comprising a reductant injector selectively operable to inject a reductant fluid from an injector outlet into the exhaust aftertreatment module; and a controller configured to control injection of reductant fluid from the reductant injector in one of a plurality of different regimes, the plurality of different regimes comprising: a first regime comprising injecting reductant fluid in accordance with a first set of injection parameters for reacting with, and substantially reducing, one or more components of the exhaust gas in the exhaust aftertreatment module; and a second regime comprising injecting reductant fluid in accordance with a second set of injection parameters for expelling solid reductant deposits formed over the injector outlet, wherein the method comprises: determining which of the plurality of regimes to implement, the first regime being implemented when the exhaust gas temperature is above a threshold temperature and the second regime being implemented when the exhaust gas temperature is below the threshold temperature.

[0006] The present disclosure further provides computer program comprising program instructions that, when executed on a computer comprising at least one memory and at least one processor, cause the computer to perform the aforementioned method. The present disclosure further provides a computer-readable medium carrying such a computer program. The present disclosure further provides a computer programmed to perform the aforementioned method.

[0007] The present disclosure further provides an engine system comprising: an exhaust aftertreatment module for receiving exhaust gas from an internal combustion engine, the exhaust aftertreatment module comprising a reductant injector selectively operable to inject a reductant fluid from an injector outlet into the exhaust aftertreatment module; and a controller in communication with the reductant injector and programmed to: store a first and a second set of injection parameters; inject reductant fluid from the reductant injector in one of a plurality of different regimes, the plurality of different regimes comprising: a first regime comprising injecting reductant fluid in accordance with the first set of injection parameters for reacting with, and substantially reducing, one or more components of the exhaust gas in the exhaust aftertreatment module; and a second regime comprising injecting reductant fluid in accordance with the second set of injection parameters for expelling solid reductant deposits formed over the injector outlet; and determine which of the plurality of regimes to implement, the first regime being implemented when the exhaust gas temperature is above a threshold temperature and the second regime being implemented when the exhaust gas temperature is below the threshold temperature.

[0008] The present disclosure further provides a method of controlling a reductant injector for injecting a reductant fluid from an injector outlet into an exhaust gas, the method comprising: determining which of a plurality of different

regimes to implement, the plurality of different regimes comprising: a first regime comprising injecting reductant fluid in accordance with a first set of injection parameters for reacting with, and substantially reducing, one or more components of the exhaust gas; and a second regime comprising injecting reductant fluid in accordance with a second set of injection parameters for expelling solid reductant deposits formed over the injector outlet; wherein implementation of the first regime is determined when the exhaust gas temperature is above a threshold temperature and implementation of the second regime is determined when the exhaust gas temperature is below the threshold temperature. [0009] By way of example only, embodiments of a method of controlling an engine system are now described with reference to, and as shown in, the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. 1 is a schematic of an engine system suitable for implementing the method of the present disclosure;

[0011] FIG. 2 is a schematic of an exhaust aftertreatment module of the engine system of FIG. 1;

[0012] FIG. 3 is a schematic of a reductant injector of the exhaust aftertreatment module of FIG. 2 when in a closed position; and

[0013] FIG. 4 is a schematic of the reductant injector of FIG. 3 when in an open position and reductant fluid is being injected.

DETAILED DESCRIPTION

[0014] The present disclosure is generally directed towards a method of controlling an engine system having an aftertreatment module within which a reductant injector is located. The reductant injector may be controlled to inject reductant fluid to expel solid reductant deposits formed on the reductant injector. The reductant fluid may be injected when an exhaust gas temperature is below a threshold temperature associated with the effective operation of the aftertreatment module. The reductant fluid may be injected periodically.

[0015] FIG. 1 illustrates an exemplary embodiment of an engine system 10 which may be suitable for implementing the method of the present disclosure. The engine system 10 may comprise a first conduit 11 for directing intake gas, such as atmospheric air, to a turbocharger 12. The turbocharger 12 may comprise a turbocharger compressor 13 connected to the first conduit 11 and arranged to be driven by a turbine 14 via a shaft 15. The engine system 10 may further comprise a supercharger 16 for receiving intake gas from the turbocharger compressor 13 via a second conduit 17. A supercharger drive arrangement 18 may be provided for selectively driving the supercharger 16. An engine 19 may be arranged to provide power to the supercharger 16 mechanically via the supercharger drive arrangement 18. The engine system 10 may further comprise a third conduit 20 for directing the intake gas from the supercharger 16 to a cooler 21. The engine system 10 may further comprise a supercharger bypass arrangement 22 for selectively allowing intake gas to bypass the supercharger 16.

[0016] The engine 19 may be an internal combustion engine, such as a compression-ignition or spark-ignition engine. Fuel, such as diesel, petrol or natural gas, may be selectively provided to engine cylinders in the engine 19 to combust with the intake gas and drive the pistons, thereby

rotating a crankshaft and providing an engine output torque and power. The by-product of the combustion process is exhaust gas, which may be directed from the engine cylinders along a fifth conduit 23 of the engine system 10 for example, via an exhaust manifold. The exhaust gas may comprise unwanted gaseous emissions or pollutants, such as nitrogen oxides (NOx), particulate matter (such as soot), sulphur oxides, carbon monoxide, unburnt hydrocarbons and/or other organic compounds. As is known in the art, the temperature of the exhaust gas may depend upon the intake gas temperature and the engine load. The fifth conduit 23 may direct exhaust gas from the engine 19 to the turbine 14 of the turbocharger 12. The engine system 10 may further comprise a sixth conduit 24 for directing exhaust gas from the turbine 14 to an exhaust aftertreatment module 25. A turbine bypass arrangement 26 may be provided for selectively allowing exhaust gas to bypass the turbine 14.

[0017] The exhaust aftertreatment module 25 may receive and treat the exhaust gas to remove pollutants prior to directing the exhaust gas to atmosphere via a seventh conduit 27. As illustrated in further detail in FIG. 2, the exhaust aftertreatment module 25 may comprise a selective catalytic reduction or SCR system 28 and may comprise a diesel oxidation catalyst 29. The diesel oxidation catalyst 29 may be arranged to receive exhaust gases from the sixth conduit 24 and located upstream of the SCR system 28. The SCR system 28 may comprise an SCR conduit 30 leading from the diesel oxidation catalyst 29 to an SCR catalyst arrangement 31. A reductant injector 32 may be located in the SCR conduit 30 for selectively injecting reductant fluid 33 into the SCR conduit 30 upstream of the SCR catalyst arrangement 31. The reductant fluid 33 may comprise aqueous urea, aqueous ammonia or the like. In particular, the reductant fluid 33 may be diesel exhaust fluid (DEF) and the DEF may meet the ISO22241 standard and comprise from 31.8% to 33.2% urea by weight.

[0018] The SCR catalyst arrangement 31 may comprise, in the direction of exhaust gas flow, a mixer 34, a catalyst substrate 35 and a further oxidation catalyst or AMOx 36. The reductant injector 32 may selectively inject the reductant fluid 33, preferably as a liquid, into the stream of exhaust gas to provide a dose of reductant fluid 33 to the SCR catalyst arrangement 31. The high exhaust gas temperature may cause the reductant fluid 33 to evaporate and the resulting combination of gases may contact the catalyst substrate 35. The reductant fluid 33 may react with the NOx in the exhaust gas to reduce it to nitrogen and water, which may pass out of the engine system 10 via the seventh conduit 27. The catalyst substrate 35 may comprise zeolites, vanadium or the like.

[0019] The mixer 34 may promote even distribution and conversion of the reductant fluid 33 upon entry into the catalyst substrate 35. During operation of engine system 10, it may be possible for too much reductant fluid 33 to be injected into the exhaust (i.e. urea in excess of that required for appropriate NOx reduction). In the case of the reductant fluid 33 comprising urea this situation is known as “ammonia slip”, and some amount of ammonia may pass through catalyst substrate 35 to the atmosphere, if not otherwise accounted for. To minimize the magnitude of ammonia slip, the AMOx 36 may be located downstream of the catalyst substrate 35. The AMOx 36 may include a substrate coated with a catalyst that oxidizes residual ammonia in the exhaust to form water and elemental nitrogen.

[0020] The engine system 10 may further comprise at least one sensor arranged to sense one or more parameters relating to one or more of the components of the engine system 10 and send signals relating thereto to a controller. In particular, the engine system 10 may comprise a temperature sensor in communication with the controller for determining the exhaust gas temperature at the outlet of the engine 19 and/or in the exhaust aftertreatment module 25. The controller may be able to determine the exhaust gas temperature in any way known in the art, for example via engine maps or algorithms based upon the intake gas temperature and the engine load. The controller may also be in communication with one or more actuators for controlling the operation of the engine 19. In particular, the controller may be operable to control the turbocharger 12, the supercharger 16, the rate of fuel injection to the engine 19 and the injection of the reductant fluid 33 by the reductant injector 32. The controller may be a computer and may be operable to store and implement one or more computer programs and may comprise at least one memory, at least one processing unit and at least one communication means. The controller may be an engine controller (ECU).

[0021] An exemplary reductant injector 32 suitable for such an engine system 10 is illustrated in FIGS. 3 and 4. The reductant injector 32 may comprise a housing 37 for mounting in the SCR system 28, particularly in the wall of the SCR conduit 30, upstream of the SCR catalyst arrangement 31. Inside the housing 37 a passageway 38 may lead from a reductant fluid inlet 39 to a nozzle 40 and injector outlet 41. The reductant fluid inlet 39 may be in fluid communication with a reductant fluid supply system. The reductant fluid supply system may comprise a reservoir of reductant fluid 33 and a pump for selectively directing reductant fluid 33 via fluid conduits from the reservoir to the reductant fluid inlet 39. The pump may be controlled by the controller. A valve member 42 may be located within the passageway 38 and may be moveable by an actuator 43 between an open position and a closed position. The actuator 43 may be an electrically activated solenoid or the like. The actuator 43 may be in electronic communication with the controller such that the controller may control its movement between the open and closed positions. The closed position is illustrated in FIG. 3, in which the injector outlet 41 is closed and reductant fluid 33 cannot pass therethrough. The open position is illustrated in FIG. 4, in which the injector outlet 41 is open and reductant fluid 33 can pass through.

[0022] During operation of the engine system 10 the controller controls the injection of reductant fluid 33 in order to control the reduction of NOx by the SCR system 28. The SCR system 28 may be more effective when the exhaust gas temperature is above a threshold temperature. The threshold temperature may be associated with the exhaust aftertreatment module 25. The threshold temperature may be the minimum temperature at which a chemical reaction can reliably take place between the reductant fluid 33 and the NOx. The threshold temperature may be in the range of from 80° C. to 250° C. and more particularly may be approximately 210° C. If the exhaust gas temperature is below the threshold temperature, then upon injection of reductant fluid 33 ammonia slip may increase and unwanted compounds, such as ammonium hydrogen sulphate, may form and degrade the performance of the exhaust aftertreatment mod-

ule 25. Therefore, the SCR system 28 may be operated only when the exhaust gas temperature is above the threshold temperature.

[0023] The SCR system 28 may have a preferred NOx conversion efficiency of at least 90% when the exhaust gas temperature is above the threshold temperature. The NOx conversion efficiency may be determined by locating a first NOx sensor upstream of the SCR system 28 and a second NOx sensor downstream of the SCR system. A NOx conversion efficiency of at least 90% may indicate that the amount of NOx in the exhaust gas has been reduced by at least 90% between the first and second NOx sensors by the SCR system 28.

[0024] The controller may operate the engine system 10 in one of a plurality of regimes. In particular, the one or more computer programs may comprise program instructions that, when executed on the controller, cause the controller to determine which of the plurality of regimes to implement and to subsequently operate the engine system 10 in one of the plurality of regimes. The plurality of regimes may comprise a first, a second, a third and a fourth regime. When the exhaust gas temperature is above the threshold temperature the controller may implement the first regime to inject one or more doses of reductant fluid 33 from the reductant injector 32 with a first set of injection parameters. The first regime may inject the reductant fluid 33 for reacting with, and substantially reducing, one or more components of the exhaust gas in the exhaust aftertreatment module 25 and more particularly for reducing the NOx in the exhaust gas. The first set of injection parameters may comprise a dosing time period and a dosing rate. The dosing time period may be the time period in which the exhaust gas temperature is above the threshold temperature. The dosing rates may be based upon, for example, the exhaust gas temperature, the amount of NOx in the exhaust gas and the exhaust gas flow rate and, for example, the dosing rates may be in the range from 40 ml/hr to 8000 ml/hr. When the exhaust gas temperature is below the threshold temperature of the SCR system 28 the controller may not operate the reductant injector 32 in the first regime in order to avoid ammonia slip.

[0025] In the fourth regime the controller may purge the reductant injector 32 and reductant fluid supply system to remove any residual reductant fluid 33 therein. In particular, the controller may control the pump of the reductant fluid supply system to draw the reductant injector 32 out of the passageway 38. This may prevent hard freezing and/or crystallisation of the residual reductant fluid 33. The fourth regime may be implemented after the shutdown of the engine 19.

[0026] However, after the implementation of the fourth regime the reductant injector 32 may not be filled with reductant fluid 33. Therefore, the third regime may be implemented in which the reductant injector 32 is primed by having the passageway 38 refilled with reductant fluid 33. After the reductant injector 32 has been primed it may be actuated by the controller to provide a small priming dose of reductant fluid 33 and/or air (if there is no reductant fluid 33 adjacent the injector outlet 41 after priming) to check that the reductant injector 32 is operating normally. In particular, a pressure sensor may be located in the reductant fluid supply system and the controller may determine that the priming dose has been provided and that the reductant injector 32 is operating normally by detecting a small change in the pressure output of the pressure sensor during

the small priming dose. The reductant injector 32 may, for example, inject the priming dose for less than 50 ms. The reductant injector 32 may be considered by the controller to be in the primed state after the small priming dose has been injected.

[0027] The third regime may not result in the reductant injector 32 being instantaneously ready to inject reductant fluid 33 and thus the controller may be unable to immediately implement the first regime once the exhaust gas temperature has reached the threshold temperature. For example, the third regime may require approximately 5 seconds to 120 seconds to reach the primed state due to the length of the fluid conduits in the reductant fluid supply system. The controller may therefore implement the third regime when at least one priming parameters have been met. The at least one priming parameters may comprises a predetermined priming temperature and the third regime may be implemented when the exhaust gas temperature is below the threshold temperature but above a predetermined priming temperature. The predetermined priming temperature may be selected based upon the time taken for the third regime to be implemented, referred to as the priming time, and the threshold temperature. In particular, the predetermined priming temperature may be selected such that the priming time is the same as the time taken for the exhaust gas temperature to rise from the predetermined priming temperature to the dosing temperature during engine 19 warm-up. For example, the predetermined priming temperature may be in the range of from approximately 80° C. to approximately 250° C. or from approximately 80° C. to approximately 120° C. and more particularly may be 110° C. The controller may not operate the reductant injector 32 to inject reductant fluid 33 when the exhaust gas temperature is below the predetermined priming temperature.

[0028] During injection in the first or third regime, reductant fluid 33 may be directed back onto the nozzle 40 after injection by eddy currents in exhaust gases travelling through the SCR conduit 30. When the reductant injector 32 is in the closed position reductant fluid 33 may leak through the injector outlet 41 due to the high pressure of the reductant fluid 33 in the passageway 38. Leakage of reductant fluid 33 may be particularly likely in aged and worn reductant injectors 32. The leaked reductant fluid 33 may cause reductant fluid 33 to deposit on the nozzle 40. The amount leaked and deposited may be increased if the reductant injector 32 is not opened for a prolonged period of time, such as after an implementation of the third regime but before an implementation of the first regime. The nozzle 40 may typically have a relatively low surface temperature, such as around 200° C., such that the reductant fluid 33 on the nozzle 40 may condense. The liquid components of the reductant fluid 33 may subsequently evaporate and solid reductant deposits 44 may remain on the nozzle 40. FIG. 3 illustrates the reductant injector 32 in the closed position with solid reductant deposits 44 formed on the nozzle 40 partially blocking the injector outlet 41. The interruption of flow of the reductant fluid 33 from the reductant injector 32 may reduce the conversion efficiency of the SCR system 28. If these solid reductant deposits 44 build up further they may fully block the injector outlet 41. Partial or full blockages may reduce the efficiency of the purging of the reductant injector 32 in the fourth regime such that residual reductant fluid 33 may freeze or crystallise within the reductant injector 32.

[0029] As illustrated in FIG. 4, the solid reductant deposits 44 may be removed from blocking the injector outlet 41 by opening the reductant injector 32 and injecting reductant fluid 33 into the SCR system 28. As the reductant fluid 33 passes out of the injector outlet 41 the solid reductant deposits 44 partially blocking the injector outlet 41 are expelled away from the nozzle 40. During low duty cycles, when the exhaust gas temperature is below the threshold temperature such that the first regime is infrequently implemented, the solid reductant deposits 44 may build up in and around the injector outlet 41 and nozzle 40.

[0030] The controller may therefore implement the second regime in which reductant fluid 33 is injected by the reductant injector 32 for expelling and/or reducing the formation of solid reductant deposits 44 on the nozzle 40 and over the injector outlet 41. In particular, the controller may operate the reductant injector 32 whilst the exhaust gas temperature is below the threshold temperature of the SCR system 28 and the reductant fluid 33 may not be injected to reduce the amount of NOx in the exhaust gas. In particular, the second regime may be implemented when the SCR system 28 has a NOx conversion efficiency of less than 90%. The second regime may be implemented whilst the engine 19 is operated in low engine load conditions and/or low duty cycles when implementation of the first regime is not required.

[0031] The controller may implement the second regime periodically and may implement the second regime after a predetermined time period has passed since a previous implementation of the first regime or a previous implementation of the third regime. The second regime may therefore be implemented to provide a dose to the SCR system 28 when the exhaust gas temperature is between the predetermined priming temperature and the threshold temperature. This may occur if the engine system 10 has been started and the exhaust gas temperature has risen above the predetermined priming temperature (i.e. such that the third regime has been implemented) but, since starting, the engine system 10 has been operated at low engine loads or in a low duty cycle such that the exhaust gas temperature has not reached the threshold temperature. Alternatively, this may occur if the first regime was previously implemented and the exhaust gas temperature subsequently falls below the threshold temperature for the predetermined time period.

[0032] The predetermined time period may depend upon the specific arrangement of the engine system 10 and is selected to prevent a sufficiently large amount of solid reductant deposits 44 forming such that the injector outlet 41 is fully blocked. The predetermined time period may be at least 10 minutes, at least 20 minutes or at least 30 minutes. The predetermined time period may be in the range from 10 minutes to 10 hours. The predetermined time period may be approximately 60 minutes.

[0033] In the second regime the controller may operate the reductant injector 32 to inject reductant fluid 33 in accordance with a second set of injection parameters. The second set of injection parameters may comprise a predetermined injection rate and a predetermined dosing time period. The predetermined injection rate may be selected to raise as high a pressure behind the solid reductant deposits 44 as possible to expel them from the injector outlet 41 in a single dose. Therefore, the predetermined injection rate may be substantially higher the dosing rate of the first regime. The predetermined dosing period may be substantially shorter than the dosing time period of the first regime.

[0034] The predetermined dosing time period may be in the range from 1 second to 120 seconds. In particular, the predetermined dosing time period may be approximately 2 seconds. The predetermined injection rate may be a maximum injection rate of the reductant injector 32. The predetermined injection rate may be between approximately 10 ml/hr and approximately 12 l/hr or between approximately 40 ml/hr and approximately 8 l/hr. In particular, the predetermined injection rate may be approximately 8 l/hr.

[0035] In a particularly suitable embodiment the predetermined time period is approximately 60 minutes, the predetermined dosing time period is approximately 2 seconds and the predetermined injection rate is approximately 8 litres per hour. Thus in a single dose approximately 4.5 ml of reductant fluid 33 is injected into the SCR system 28.

[0036] The present disclosure is applicable to any suitable engine system 10 comprising an exhaust aftertreatment module 25 having a reductant injector 32. In particular, the engine system 10 may comprise an internal combustion engine 19 of any suitable type. The engine system 10 may comprise just one of, or both, a turbocharger 12 and a supercharger 16. The controller of the engine system 10 may be programmed to implement any of the plurality of regimes.

INDUSTRIAL APPLICABILITY

[0037] The method of the present disclosure may ensure that the solid reductant deposits 44 do not form blockages over the injector outlet 41 during periods in which reductant fluid 33 is not injected into the SCR system 28 by the reductant injector 32 during the first regime. The reduced growth of solid reductant deposits 44 prevents a reduction in SCR system conversion efficiency. Furthermore, the efficiency of the purging of the reductant injector 32 in the fourth regime may be maintained and the freezing or crystallisation of residual reductant fluid 33 remaining inside the reductant injector 32 may be avoided.

[0038] As a result, the method may avoid the formation of solid reductant deposits 44 during low duty cycles of the engine system 10 and when very little power or energy output from the engine 19 is required and exhaust gas temperatures are relatively low. The engine system 10 may therefore be designed to operate effectively across medium and high duty cycles without needing to compromise efficiency for the sake of avoiding the formation of solid reductant deposits 44 in low duty cycles. In particular, exhaust gas flow paths and temperature can be controlled independently of the need to avoid the formation of solid reductant deposits 44.

[0039] The engine system 10 and method of operation of the present disclosure may therefore be particularly suitable for work machines which need to be operated most efficiently at medium and high duty cycles, in which the first regime may be implemented, but which may be operated for prolonged periods at low duty cycles, in which the second and third regimes may be implemented. Suitable work machines may include backhoe loaders, excavators, wheel loaders, bulldozers and the like which may comprise work tools, such as backhoes and excavators. The work machines may operate at medium and high duty cycles when travelling at a relatively high speed and/or during operation of the work tools. The work machines may operate at low duty cycles when the work tools are not being used, the work

machines are travelling at low speeds and/or the engine system 10 of the work machines is idling.

1. A method of controlling an engine system, the engine system comprising:

an exhaust aftertreatment module for receiving exhaust gas from an internal combustion engine, the exhaust aftertreatment module comprising a reductant injector selectively operable to inject a reductant fluid from an injector outlet into the exhaust aftertreatment module; and

a controller configured to control injection of reductant fluid from the reductant injector in one of a plurality of different regimes, the plurality of different regimes comprising:

a first regime comprising injecting reductant fluid in accordance with a first set of injection parameters for reacting with, and substantially reducing, one or more components of the exhaust gas in the exhaust aftertreatment module; and

a second regime comprising injecting reductant fluid in accordance with a second set of injection parameters for expelling solid reductant deposits formed over the injector outlet,

wherein the method comprises:

determining which of the plurality of regimes to implement, the first regime being implemented when the exhaust gas temperature is above a threshold temperature and the second regime being implemented when the exhaust gas temperature is below the threshold temperature.

2. A method as claimed in claim 1 wherein a dosing rate of the first set of injection parameters is higher than a predetermined injection rate of the second set of injection parameters.

3. A method as claimed in claim 1 wherein the exhaust aftertreatment module comprises a selective catalytic reduction (SCR) system having an SCR catalyst arrangement downstream of the reductant injector.

4. A method as claimed in claim 3 wherein in the first regime the SCR system has a NO_x conversion efficiency of at least 90% and in the second regime the SCR system has a NO_x conversion efficiency of below 90%.

5. A method as claimed in claim 1 wherein:

the plurality of different regimes further comprises a third regime comprising filling the reductant injector with reductant fluid such that the reductant injector is in a primed state ready to inject reductant fluid;

the third regime is implemented when at least one priming parameters has been met and the exhaust gas temperature below the threshold temperature, and

the first or second regime is implemented after the third regime has been implemented.

6. A method as claimed in claim 5 wherein the third regime further comprises:

operating the reductant injector after it has been filled to inject a priming dose of reductant fluid;

detecting a reduction in pressure in the reductant injector during the priming dose; and

refilling the reductant injector with reductant fluid such that the reductant injector is in the primed state.

7. A method as claimed in claim 5 further comprising implementing the second regime a predetermined time period after an implementation of the third regime.

8. A method as claimed in claim 1 comprising implementing the second regime a predetermined time period after an implementation of the first regime.

9. A method as claimed in claim 7 wherein the predetermined time period is at least 10 minutes, at least 20 minutes or at least 30 minutes, or the predetermined time period is in the range from approximately 10 minutes to approximately 1 hour, or the predetermined time period is approximately 60 minutes.

10. A method as claimed in claim 1 wherein the second set of injection parameters comprises a predetermined injection rate and a predetermined dosing time period, each being selected for raising a sufficiently high pressure behind solid reductant deposits formed over the injector outlet so as to expel them from the injector outlet.

11. A method as claimed in claim 10 wherein the predetermined injection rate is the maximum injection rate of the reductant injector.

12. A method as claimed in claim 10 wherein the predetermined injection rate is between approximately 10 ml/hr and approximately 12 l/hr or between approximately 40 ml/hr and approximately 8 l/hr.

13. A method as claimed in claim 10 wherein the predetermined dosing time period is in a range from approximately 1 second to approximately 120 seconds.

14. A computer program comprising program instructions that, when executed on a computer comprising at least one memory and at least one processor, cause the computer to perform the method of claim 1.

15. An engine system comprising:

an exhaust aftertreatment module for receiving exhaust gas from an internal combustion engine, the exhaust aftertreatment module comprising a reductant injector selectively operable to inject a reductant fluid from an injector outlet into the exhaust aftertreatment module; and

a controller in communication with the reductant injector and programmed to:

store a first and a second set of injection parameters; inject reductant fluid from the reductant injector in one of a plurality of different regimes, the plurality of different regimes comprising:

a first regime comprising injecting reductant fluid in accordance with the first set of injection parameters for reacting with, and substantially reducing, one or more components of the exhaust gas in the exhaust aftertreatment module; and

a second regime comprising injecting reductant fluid in accordance with the second set of injection parameters for expelling solid reductant deposits formed over the injector outlet; and

determine which of the plurality of regimes to implement, the first regime being implemented when the exhaust gas temperature is above a threshold temperature and the second regime being implemented when the exhaust gas temperature is below the threshold temperature.

* * * * *