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(54) **PROPULSION SYSTEM, METHOD FOR REDUCING NOX, SHIP COMPRISING A PROPULSION SYSTEM AND CONTROL SYSTEM FOR CONTROLLING THE INJECTION OF A REDUCING AGENT**

(57) Propulsion system comprises a two stroke internal combustion engine, in particular a diesel engine, comprising at least two cylinders, each of them comprising a piston, said piston being arranged in a crosshead configuration. Eeach of the cylinders has an outlet, said outlets being connected to an exhaust gas receiver by connection means, in particular by pipes, providing a connection between each outlet and the exhaust gas receiver. The system comprises a SCR-reactor, which is arranged in or downstream of the exhaust gas receiver and a reservoir comprising a reducing agent, wherein said reducing agent is injectable into the connection means by means of at least two nozzles, preferably one nozzle per connection means. The nozzles are connected to each other by a common rail, wherein between reservoir and nozzles there is provided at least one nozzle valve.

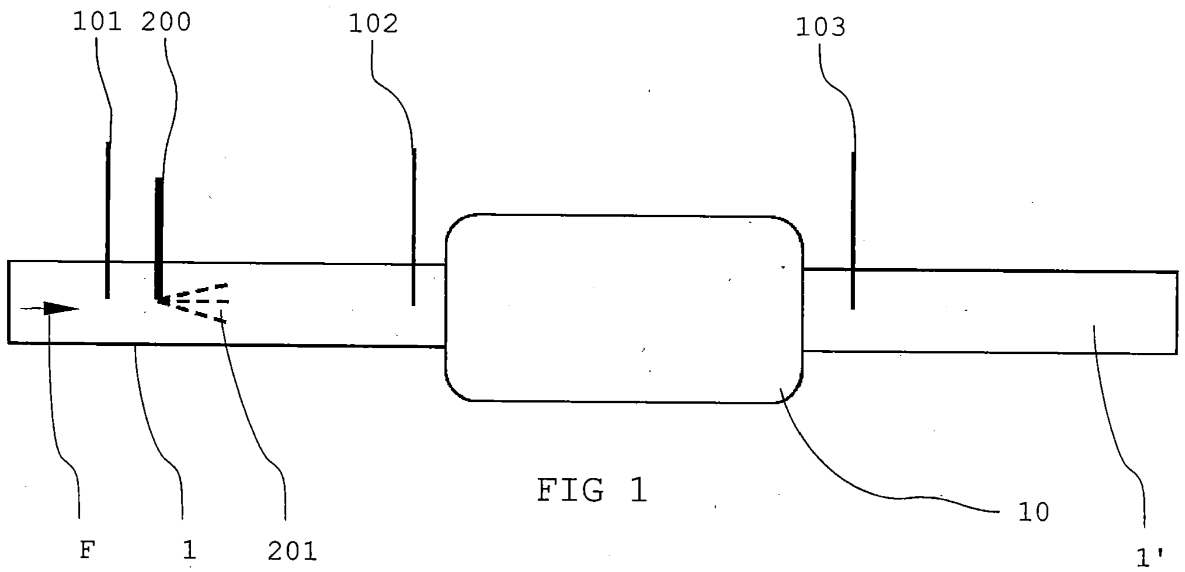

FIG 1

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Description

[0001] The present invention is directed to a propulsion system, a method for reducing NOx, a ship comprising a propulsion system and a control system for controlling the injection of a reducing agent according to the preamble of the independent claims.

[0002] During a combustion process, the fuel and gases in the combustion chamber chemically reacts with each other. As a result of a combustion process, several different residues are present in the exhaust gas, i.e. NOx or particulate matter such as soot.

[0003] Combustion processes typically take place in internal combustion engines. The amounts of those residues differ depending on the combustion engine, in particular, if it is a two or four stroke engine which might be driven with diesel or gasoline.

[0004] In propulsion systems of large ships, typically, two stroke engines of the crosshead type are used. Such engines have at least two cylinders, typically twelve cylinders. Configurations with four, six, eight, ten or more than twelve cylinders may be desirable; additionally, an uneven amount of cylinders might be used.

[0005] As known from the state of the art, NOx might be reduced by using ammonia or urea as a reducing agent. In particular, urea might be injected into the exhaust gas.

[0006] Several systems have been proposed, each of them directed to the reduction of one or more residues.

[0007] DE 197 45 067 A1 discloses a large diesel engine with at least two cylinders. Each of the cylinders is connected to an exhaust gas receiver with an exhaust gas stub. The exhaust gas receiver is connected to a catalytic convertor arrangement. For injecting the reducing agent, each exhaust gas stub comprises an injection valve. Such an arrangement comprises a huge amount of parts and is complicated to fabricate and to run in use.

[0008] EP 2 673 484 B1 discloses an internal combustion engine with an exhaust gas receiver. The exhaust gas receiver is connected to each cylinder of the internal combustion engine through an exhaust inlet. The exhaust inlets are connected to each other by a common rail, providing a reducing agent through nozzles. A supply line for the reducing agent is led through the exhaust gas receiver. Such an arrangement only enables an unprecise injection of reducing agent.

[0009] Furthermore, according to the state of the art, the amount of reducing agent which is used in the chemical reaction is defined based on a so called dosing map. Typically, the dosing map is determined in workshop tests of the engine. Depending on different circumstances, such static determination of the amount of reducing agent which is introduced leads to an undesirable consumption or an insufficient introduction of reducing agent.

[0010] There are several drawbacks in the prior art, for example a huge amount of parts such as separate elements for each exhaust gas stub and/or non-controllable nozzles or undesired amount of injection of reducing agent.

[0011] Aim of the invention is to avoid at least some of the drawbacks of the prior art, in particular, to provide a propulsion system having a simple structure with less parts, and/or which is easy controllable and/or which provides, compared to the state of the art, a higher reduction of NOx and/or enhances lifecycle of the catalytic convertor and/or reduces maintenance. It is an aim to provide also a method for reducing NOx emissions of internal combustion engines, which enables to determine the amount of reducing agent.

[0012] At least some of said objects are accomplished by propulsion system and a method for reducing NOx from an internal combustion engine and a control system for controlling the injection of a reducing agent according to the independent claims.

[0013] In particular, a propulsion system according to the invention comprises a two stroke internal combustion engine, in particular a diesel engine. The internal combustion engine comprises at least two cylinders. Each of them comprises a piston. The pistons are each arranged in a crosshead configuration. The cylinders each have an outlet which is connected to an exhaust gas receiver by connection means, in particular an exhaust gas stub, such as a pipe, providing a connection between each outlet and the exhaust gas receiver. The propulsion system comprises a SCR-reactor, which is arranged in or downstream of the exhaust gas receiver. The propulsion system comprises a reservoir comprising a reducing agent, which reducing agent is injectable into the connection means by means of at least two nozzles. The nozzles are connected to each other by a common rail. Preferably, at least one nozzle is assigned to each connection means. Between reservoir and nozzles, preferably between common rail and nozzles, there is provided at least one nozzle valve. Preferably, each nozzle is assigned to a nozzle valve.

[0014] As known by the skilled person, the degree of rotation of the crankshaft is used to indicate the position of the piston inside the cylinder and/or to indicate the timing of the combustion process.

[0015] Alternative embodiments may also be used in the meaning of this invention, such as common nozzles with an additional, for example separate, dosing valve or with a nozzle and a valve built as a common nozzle valve unit. Alternatively, even a simple opening with a valve which enables opening or closing the opening could be used.

[0016] In context of this invention, the connection means are not part of the exhaust gas receiver. Hence, the nozzles are not connected to the exhaust gas receiver.

[0017] As reducing agents aqueous urea solution, aqueous ammonia solution, and/or pure ammonia, pure ammonia gas, or anhydrous ammonia and other reducing agents are possible.

[0018] For reducing NOx and enabling the catalytic reaction of the reducing agent, the propulsion system comprises a catalytic convertor, in particular an SCR-reactor, which is arranged after injection of the reducing agent, in particular in or downstream the exhaust gas receiver. Furthermore, a turbo charger, through which at least a part of the exhaust gas is led after passing the exhaust gas receiver and/or the catalytic convertor, may be arranged on the propulsion system. The turbocharger may be arranged between the exhaust gas receiver and the catalytic convertor. Hence, the NOx reduction may occur in the low pressure area of the exhaust gas system. Preferably, the turbocharger is arranged downstream of the catalytic convertor such that the NOx reduction occurs in the high pressure area of the exhaust gas system. The exhaust gas may be divided into two flow streams, whereby only one of said streams may be led through the turbocharger and the other stream may be used for exhaust gas recirculation. Each of these two streams may be treated with reducing agent separately, before or after the turbocharger.

[0019] A propulsion engine with a common rail and with distinct nozzles and at least one nozzle valve and which are connected to the connection means enables providing the reducing agent by common rail injection. Hence, a separate pump may be used to provide pressure in the common rail, serving as a high pressure reservoir which is fed by the reducing agent reservoir. The nozzles thus are connected to a high pressure reservoir with a huge pressure elasticity mostly independent of small amounts of reducing agent withdrawn from the high pressure reservoir. Furthermore, nozzle valves are switchable independently. Additionally, through the arrangement of the nozzles on the connection means, each nozzle injects reducing agent into exhaust having high velocity and is therefore distributed optimally. To further optimize reducing agent distribution, there may be provided one nozzle per connection means.

[0020] Alternatively, it may be advantageous to provide a nozzle on every second or third cylinder, i.e. on every second or third connection means. Hence, each nozzle provides reducing agent for the exhaust gas of two or three cylinders respectively.

[0021] The nozzles may be any nozzle as known from the prior art, in particular nozzles including and air stream for vaporizing the reducing agent. The air stream can be connected to an air common rail, so that all nozzles are fed from a common air reservoir.

[0022] The propulsion system may comprise control means for controlling the nozzle valves continuously or intermittently, in particular in an open loop manner depending on the piston position, in particular on the crankshaft rotation. The reducing agent can be injected continuously when the propulsion system is running. This enables a very easy control system. Additionally, or alternatively, the nozzle valves may be controlled depending on exhaust valve timing. The timing of the valves might be dependent on the crankshaft rotation.

[0023] Hence, the injection of the reducing agent may be controlled for each cylinder or a group of cylinders separately. Furthermore, the injection of the reducing agent can be timed to specific periods e.g. only when the connection means of a respective cylinder is filled with exhaust gas or e.g. just before it is filled. Therefore, in particular when the engine is in low load condition or runs on slow speed, such as less than 100rpm, in particular less than 50 rpm,the distribution in the exhaust gas is enhanced since the reducing agent is always mixed up with the exhaust gas.

[0024] Advantageously, the mass flow of the reducing agent though the nozzles may be controllable by the control means in a closed-loop manner.

[0025] Hence, only a specific amount of reducing agent will be introduced. This means, the nozzle valve may be controlled such as to take in a positon between 0% and 100% open. Alternatively, it can be controlled in a binary manner wherein the nozzle valve is switched on and off alternatingly, e.g. such as to provide e.g. a fully open nozzle in 50% of the time and a fully closed nozzle in the rest of the time, resulting in a 50% mass flow over time. These amounts may be varied and may depend on specific engine parameters.

[0026] The nozzles may be arranged inside of the connection means or inside the exhaust gas receiver. Furthermore, they may be formed as multijet nozzles.

[0027] A multijet nozzle can be formed as one nozzle with multiple openings. Multiple single opening nozzles may be arranged together on a grid or on a circle. Hence, they also provide a multijet nozzle. Each of those nozzles may be controlled separately. Alternatively, the nozzles may be controlled in groups. E.g. if the nozzles are arranged on a concentric grid, i.e. on to circles, an inner smaller circle and an outer bigger circle, it may be preferable to switch the nozzle valves in two groups according its respective arrangement.

[0028] Providing of such multijet arrangements enables to distribute the reducing agent in a specific manner. For example, if the connection means are a pipe, the exhaust gas which flows through them will not have a uniform distribution in the cross section of such pipe. Hence, it may not be desired to inject the reducing agent uniformly or with the same amount across said cross section.

[0029] Hence, the distribution is enhanced and may be varied depending on specific structural conditions.

[0030] Alternatively, two or more groups of nozzles may be provided, each of them fed by a respective common rail. Therefore, it is possible to provide e.g. two or more parallel arrangements of common rails, each of them connected through at least one nozzle to each connection means. It is also possible to divide a multicylinder engine in blocks of two or more cylinders, each of them having a separate common rail with respective nozzles for each connection means of one block. The embodiments as herein described may be applied to such configuration also.

[0031] Another or an additional aspect of the invention concerns a method for reducing NOx emissions of an internal combustion engine, in particular a two stroke diesel engine, preferably an internal combustion engine of a propulsion system as previously described . The amount of reducing agent, which is injected through a nozzle into a connection between an outlet of a cylinder and an SCR-reactor, is determined by means of an adjustment parameter. The adjustment parameter is derived from at least one of a direct or an indirect measurement of an engine parameter of the internal combustion engine. Additionally or alternatively, a control parameter of the internal combustion engine may be used to derive the adjustment parameter.

[0032] Hence, the amount of reducing agent can be adapted depending on specific parameters which depend on the actual state of each engine. Such parameters depend e.g. on outside temperature, humidity of the air, workload of the engine, engine load, engine speed, exhaust gas mass flow, firing pressure. The firing pressure is the highest pressure in an engine cylinder during combustion.

[0033] The amount of a reducing agent may be defined by a specific start value, in particular a dosing map. Said specific start value is adjusted by the adjustment parameter.

[0034] By starting with a specific start value, the final adjustment may be derived very fast. Furthermore, by defining a start value, i.e. a dosing map, there are at least some optimized start boundaries to prevent the controller from determining a start value which is not realistic. It is possible to define a maximum deviation average e.g. of 25% compared to the dosing map. If such threshold is exceeded, an alarm signal might be triggered, such that maintenance or human control or a check of the system is necessary.

[0035] The adjustment parameter may be derived from a NOx measurement of a NOx sensor. Said NOx sensor is preferably arranged upstream of the SCR-reactor, in particular upstream of the reducing agent injection.

[0036] Providing a NOx sensor upstream of the SCR reactor enables a direct measurement of the NOx. The exact amount of reducing agent can thus be determined, depending on the NOx which is present in the exhaust gas before the SCR-reactor. A measurement, which is made downstream of the SCR reactor provides a value of NOx which has been left in the exhaust gas. If the SCR reactor does not work properly, the derived NOx value indicates that a higher amount of reducing agent has to be injected. Said amount is increased as long as a desired output value is not reached but won't lead to a lower NOx value.

[0037] Therefore, the amount of reducing agent can be determined exactly based on the amount of NOx. Such a measurement of NOx is also known as a direct measurement. An additional measurement of NOx downstream of the SCR enables to determine if the SCR reactor works properly.

[0038] The adjustment parameter may also be derived from another type of direct measurement. For example, the parameter may be derived from at least one of the following parameters: temperature of scavenge air, scavenge pressure, humidity of scavenge air, temperature of cooling system, temperature of exhaust gas, pressure inside the cylinder, in particular the firing pressure during the combustion or the compression pressure, ambient temperature, ambient pressure, ammonia slip, reducing agent quality, air-fuel ratio (Lambda), fuel amount, sulfur content of the fuel, valve positions, turbocharger speed, engine load, engine speed, exhaust gas mass flow, firing pressure. The exhaust gas flow might be measured directly or indirectly. All of these parameters can be summed as engine parameters. Said parameters can comprise a specific predefined correction factor.

[0039] Therefore, the amount of reducing agent can be determined according to specific circumstances which occur in use of the engine.

[0040] Such measurements can be made for each cylinder separately.

[0041] The amount of reducing agent can thus be determined for each connection means separately.

[0042] Additionally or alternatively, the adjustment parameter can be derived through an indirect measurement. This means, that two values are taken into consideration. These values can be measured or can be values that are in a known correlation to a measured value. Further indirect measurements are measurements, form which measurements a specific parameter is calculated. For example, the exhaust gas flow may be calculated based on measured values of the CO, CO_2 and/or O_2 in the exhaust gas and of measured values of temperature and volume of the exhaust gas flow.

[0043] Accordingly, the adjustment parameter may be derived from a temperature difference of the exhaust gas before and after the SCR reactor. In particular, the adjustment parameter may be derived from a temperature difference of the exhaust gas before the injection of the reducing agent and after the SCR reactor or between or after each of the catalytic elements.

[0044] It is possible, under consideration of the mass flow of the exhaust gas, to determine the activity of the SCR, i.e. to determine how much of the NOx has been reduced. This value can also be compared with the effective value of injected reducing agent. Hence, a qualitative statement on the status of the SCR reactor is available.

[0045] It is understood as well that the herein described direct and indirect measurements can be combined to determine a specific adjustment parameter.

[0046] It is possible to determine the wear and/or the efficiency loss and/or activity deviation and/or fouling of the SCR-reactor if the temperature difference of a first and a second and optionally any subsequent measurement is compared to each other. In case the deviation of the difference exceeds a pre-defined value, such as a mean deviation over time, it can be determined that the SCR-reactor is not working properly any more. Advantageously, those measurements include additional factors such as outside temperature, scavenge air humidity, engine load, engine speed, exhaust gas mass flow, firing pressure, exhaust gas temperature, scavenge air temperature, scavenge air pressure, compression pressure and any other possible influencing factor.

[0047] The measurements as herein described can be continuous measurements or discontinuous measurements. A discontinuous measurement can be repeated according to specific conditions. For example the measurement can be repeated randomly between 100 Hz and once per hour. Alternatively, the discontinuous measurement can be clocked according to the engine revolution i.e. to the revolution of the crankshaft or its multiple. Those measurements can be averaged, e.g. for a specific period or a specific amount of measurements. The periods may be altered depending on the load of the engine, e.g. during acceleration, the period might be shorter than during continuous load while driving on a constant velocity.

[0048] Continuous measurement enables to provide a zero delay controlling, discontinuous measurements enables to reduce energy, in particular relevant for wireless sensors for example, and furthermore, the control system does not react to single measurements which might be flawed. Hence, the system reacts on average measurements only.

[0049] It is understood that for some measurements a continuous measurement is preferred and for other values a discontinuous measurement is preferred. Both methods can be combined.

[0050] According to another aspect of the invention a method for determining the functionality and/or aging of a catalytic reactor in a propulsion system, preferably a propulsion system of a ship, in particular in a propulsion system as previously described, is provided comprising the steps of

- measuring a first exhaust gas temperature upstream of the catalytic reactor
- measuring a second exhaust gas temperature downstream of the catalytic reactor
- determining an activity value of the catalytic reactor from the first and the second exhaust gas temperature.

[0051] By measuring a first and a second exhaust gas temperature, the temperature difference can be determined which gives an indication of the activity of the catalytic reactor. This way the activity can easily be determined.

[0052] Different activity values over time can be compared to determine the aging of the catalytic reactor, in particular under consideration of other status variables such as temperature of scavenge air, scavenge pressure, humidity of scavenge air, temperature of cooling system, temperature of exhaust gas, pressure inside the cylinder, in particular the firing pressure or the compression pressure, ambient temperature, ambient pressure, ammonia slip, reducing agent quality, air-fuel ratio (Lambda), fuel amount, sulfur content of the fuel, valve positions, engine load, engine speed, exhaust gas mass flow.

[0053] This method provides an easy and cost efficient way to determine aging of the catalytic reactor by comparing different activity values over time, in particular under similar conditions.

[0054] Generally, the temperature difference is based on a measurement of temperature difference over the SCR, corrected by a temperature difference caused by hydrolysis in the SCR. The total reaction upstream of the catalytic reactor, comprises a thermolysis and a hydrolysis reaction:

$$\begin{array}{rl} \text{Thermolysis:} & (NH_2)_2CO \rightarrow NH_3 + HNCO \\ \text{Hyd rolysis:} & UNCO + H_2O \rightarrow NH_3 + CO_2 \\ \hline \text{Total reaction:} & (NH_2)_2CO + H_2O \rightarrow 2NH_3 + CO_2 \end{array}$$

[0055] The thermolysis reaction is endotherm, the hydrolysis reaction is exotherm. Since the exact portion of hydrolysis is not known, it is either possible to apply an empiric correction factor to determine the activity of the catalytic converter or to measure the urea mass flow and determine what the deviation of the theoretical temperature difference and the actual temperature difference is. In this case the first temperature difference is measured between a first temperature upstream of the reducing agent injection and a second temperature downstream the reducing agent injection and upstream the catalytic reactor. This difference is used to determine the amount of hydrolysis reaction. Based on this deviation the hydrolysis portion can be calculated and the activity of the catalytic converter can be calculated.

[0056] Alternatively, the activity of the catalytic converter can be determined by

- measuring the urea mass flow, which yields how much water needs to be evaporated, how much urea needs to be thermally dissolved and how much isocyanic acid (HNCO) is present;
- measuring the exhaust mass flow;
- measuring a first temperature upstream of the urea injection;
- measuring a second temperature downstream the catalytic converter;
- calculating the difference between the first and the second temperature;
- adding a temperature amount to the calculated difference, accounting for the temperature by which the exhaust is cooled by evaporation of water;

- deducing an amount accounting for the warming of the exhaust due to hydrolysis of the total amount of isocyanic acid;
- applying a correction factor for side reactions.

[0057] The remaining temperature difference is based on the reaction in the catalytic converter, which can be used for the determination of the activity and/or for DeNOx-determination. The DeNOx is the degree of removal of NOx from the exhaust.

[0058] Another aspect of the invention concerns a ship comprising a propulsion system as herein described.

[0059] The propulsion system can thus be configured according to the intended use of the ship or its size.

[0060] Another aspect of the invention concerns a ship comprising a two stroke internal combustion engine working with a method as herein described.

[0061] Another aspect of the invention concerns a control system for controlling the injection of a reducing agent into a connection, and in particular into connection means, between an outlet of a cylinder and an exhaust gas receiver. Preferably, the control system is for use or used with a propulsion system as previously described. The control system includes at least a first input channel and a first output channel. A specific start value for an amount of reducing agent is adjusted based on an adjustment parameter. The adjustment parameter is derived from at least one of a direct or an indirect measurement of an engine parameter as herein described of the internal combustion engine. The adjustment parameter is received at the first input channel. The altered start value is used to control the injection of a nozzle valve for the reducing agent.

[0062] It might be advantageous to provide an output channel and/or an input channel for each of the nozzle valves.

[0063] The control system might be independently fabricated can be delivered independently with respect to the engine control as such. Hence, such a control system can be used for retrofitting an existing propulsion system.

[0064] Additionally, the control system might have at least a second input channel. The adjustment parameter may be derived from a combination and in particular from a calculated difference of the signals of the at least first and second input channel.

[0065] Hence, independently of outer circumstances, a comparison of two states is possible, e.g. the temperature before and after the SCR. Hence, a statement of a reaction which happened in a section between two measurement points can be made.

[0066] Another or an additional aspect of the invention concerns a propulsion system with a two stroke internal combustion engine, preferably an internal combustion engine as herein described, comprising a control system as herein described with at least one sensor for the measurement of at least one engine parameter, in particular for the measurement of at least one of the following parameters: temperature of scavenge air, scavenge pressure, humidity of scavenge air, temperature of cooling system, temperature of exhaust gas, pressure inside the cylinder, in particular the firing pressure or the compression pressure, ambient temperature, ambient pressure, ammonia slip, urea quality, air-fuel ratio (Lambda), fuel amount, valve positions, turbocharger speed, engine load, engine speed, exhaust gas mass flow.

[0067] Further advantageous aspects of the invention are explained in the following by means of exemplary embodiments and the figures. In the drawings, in a schematic manner:

Figure 1:	shows an SCR-reactor with respective sensors
Figure 2:	shows a common rail with a first arrangement of nozzles
Figure 3:	shows a common rail with a second arrangement of nozzles
Figure 4:	a partial view of an internal combustion engine

[0068] Figure 1 shows an SCR-reactor 10, connected upstream to a (not shown) exhaust gas receiver through an exhaust gas pipe 1. Downstream of the SCR-reactor 10, an exhaust pipe 1' is shown which connects the SCR-reactor 10 to ambient. The stream of the exhaust gas is indicated by the arrow F.

[0069] Upstream of the SCR-reactor 10, two temperature sensors 101 and 102 are arranged. A urea injection device 200 is arranged between said sensors 101 and 102. Downstream of the SCR-reactor, a further temperature sensor 103 is arranged.

[0070] Temperature sensor 101 provides a measurement of the temperature before the injection of urea 201 at the injection device 200. Said measurement is referred as T_{bef_Urea}.

[0071] Temperature sensor 102 provides a measurement of the temperature after the injection of urea 201 at the injection device 200. Said measurement is referred as T_{SCR_IN}.

[0072] Temperature sensor 103 provides a measurement of the temperature downstream of the SCR-reactor. Said measurement is referred as T_{SCR_OUT}.

[0073] The massflow $\dot{m}$ in the exhaust gas pipe 1 may be determined by direct or indirect measurement.

[0074] If $\dot{m}$ is known by measurement (direct or indirect), the heat reduction of the exhaust flow by urea injection can be calculated. From this heat reduction the amount of injected urea solution could be calculated. For providing a reliable result, the exhaust gas pressure and temperature and the temperature of the urea solution before injection is being measured. The urea consumption might also be measured directly by a flow meter. If the amount of urea and the temperature of the exhaust gas is known, also the amount of Isocyanic acid (HNCO) can be determined. With the amount of HNCO known, the temperature rise in the SCR because of the Hydrolysis of HNCO can be calculated. This temperature rise is being subtracted from the measured temp rise (T_{bef_Urea} - T_{SCR_IN}) over the SCR reactor. The remaining temperature difference has to be caused by SCR reaction and side reactions. For each reaction the enthalpies are known. As side reactions are playing a minor role, correction factors can be used for them. After all corrections the remaining amount of temperature rise is caused by SCR reaction and from that the amount of reduced NOx can be calculated. Generally, the temperature difference is based on a measurement of temperature difference over the SCR, corrected by a temperature difference caused by hydrolysis in the SCR. The total reaction upstream of the catalytic reactor, comprises a thermolysis and a hydrolysis reaction:

$$\begin{array}{rl} \text{Thermolysis:} & (NH_2)_2CO \rightarrow NH_3 + HNCO \\ \text{Hydrolysis:} & HNCO + H_2O \rightarrow NH_3 + CO_2 \\ \hline \text{Total reaction:} & (NH_2)_2CO + H_2O \rightarrow 2\,NH_3 + CO_2 \end{array}$$

[0075] The thermolysis reaction is endotherm, the hydrolysis reaction is exotherm. Since the exact portion of hydrolysis is not known, it is either possible to apply an empiric correction factor to determine the activity of the catalytic converter or to measure the urea mass flow and determine what the deviation of the theoretical cooling down and the actual cooling down is. Based on this deviation the hydrolysis portion can be calculated and the activity of the catalytic converter can be calculated.

[0076] Furthermore, it is possible to determine the quality or the wear and/or the efficiency loss and/or activity and/or fouling of the SCR-reactor. A first measurement of the temperature difference, made in the workshop, can be compared to a second and /or subsequent temperature difference in use. If the second temperature deviates for example more than a predetermined threshold value, e.g. 15% from the first temperature difference, this might be an indicator, that the catalytic reactor has to be replaced. Preferably, those measurements are compared under similar conditions, such as scavenge air temperature, scavenge air humidity, exhaust mass flow, engine load, engine speed and/or exhaust gas temperature and/or scavenge air pressure and/or scavenge air temperature and/or other factors

Figure 2 shows a first arrangement of nozzles 201. Said nozzles 201 are connected through a dosing valve 202 to a common rail 205. The common rail 205 comprises reducing agent under pressure. The common rail 205 can be uncoupled through two shut-off valves 203. A drain valve 204 is foreseen. Each of the dosing valves 202 is separately controllable and can be opened from 0% to 100%.

[0077] Figure 3 shows a second arrangement of nozzles 201, similar to the arrangement of figure 2, but comprises additionally a second common rail 206, comprising pressurized air. The second common rail 206 is connected to the nozzles 201 through air dosing valves 208. The air dosing valves 208 can be opened from 0% to 100%. For the sake of simplicity, for the description of the first common rail, reference is made to figure 2 and thus not repeated. The air dosing valves 208 can optionally be controlled independently of the dosing valves 202. The second common rail 206 can be uncoupled through two shut-off valves 207.

[0078] Figure 4 shows a partial view of an internal combustion engine 100 in a schematic manner. For the sake of simplicity, only one of a plurality of same elements is referenced by reference number. The combustion engine 100 comprises four connection means 2, each of them has an inlet which is connected to a cylinder (not shown) and an outlet which is connected to the exhaust gas receiver 11 by an exhaust gas stub, namely a pipe 21. A urea injection device 201 is assigned to each of the pipes 21. The urea injection devices 201 are connected through a common rail 209 to each other and to a reservoir (not shown) comprising a reducing agent, namely urea.

Claims

1. Propulsion system comprising a two stroke internal combustion engine, in particular a diesel engine, comprising at least two cylinders, each of them comprising a piston, said piston being arranged in a crosshead configuration, each of the cylinders having an outlet, said outlets being connected to an exhaust gas receiver by connection means, in particular by pipes, providing a connection between each outlet and the exhaust gas receiver,
an SCR-reactor which is arranged in or downstream of the exhaust gas receiver
a reservoir comprising a reducing agent, wherein said reducing agent is injectable into the connection means by means of at least two nozzles, preferably one nozzle per connection means,
the nozzles are connected to each other by a common rail **characterized in that**
between reservoir and nozzles, preferably between common rail and nozzles, there is provided at least one nozzle valve.

2. The propulsion system according to claim 1 **characterized in that** the mass flow of reducing agent through the nozzles is controllable by the control means in a closed-loop manner.

3. The propulsion system according to one of claims 1 or 2,
wherein the nozzles are arranged inside of the connection means and/or being formed as a multijet nozzle

4. Method for reducing NOx emissions of an internal combustion engine, in particular a two stroke diesel engine, in particular of a propulsion system accord-

ing to one of claims 1 to 3, **characterized in that** the amount of a reducing agent, which is injected into a connection between an outlet of a cylinder and an SCR-reactor through a nozzle is determined by means of an adjustment parameter, said adjustment parameter being derived from at least one of a direct or an indirect measurement of an engine parameter of the internal combustion engine and/or of a control parameter of the internal combustion engine.

5. The method according to claim 4, **characterized in that** the adjustment parameter is derived from a NOx measurement of a NOx sensor, said NOx sensor being preferably arranged upstream of the SCR-reactor.

6. The method according to claim 4, **characterized in that** the adjustment parameter is derived from at least one measurement of the following parameters: temperature of scavenge air, scavenge pressure, humidity of scavenge air, temperature of cooling system, temperature of exhaust gas, pressure inside the cylinder, in particular the firing pressure or the compression pressure, ambient temperature, ambient pressure, ammonia slip, reducing agent quality, air-fuel ratio (Lambda), fuel amount, sulfur content of the fuel, valve positions, engine load, engine speed, exhaust gas mass flow, wherein preferably said measured parameter is modified with a respective predefined correction factor.

7. The method according to claim 4 wherein the adjustment parameter is derived from a combination of the adjustment parameter of at least two of the methods according to claims 5 or 6.

8. The method according to claim 7, wherein at least one of the measurements is a continuous measurement.

9. Method for determining the functionality and/or aging of a catalytic reactor of a propulsion system, preferably a propulsion system of a ship, in particular a propulsion system according to any one of claims 1 to 3, comprising the steps of

- measuring a first exhaust gas temperature upstream of the catalytic reactor
- measuring a second exhaust gas temperature downstream of the catalytic reactor
- determining an activity value of the catalytic reactor from the first and the second exhaust gas temperature.

10. Method according to claim 9 **characterized in that** different activity values over time are compared to determine the aging of the catalytic reactor, in particular under consideration of other status variables such as temperature of scavenge air, scavenge pressure, humidity of scavenge air, temperature of cooling system, temperature of exhaust gas, pressure inside the cylinder, in particular the firing pressure or the compression pressure, ambient temperature, ambient pressure, ammonia slip, reducing agent quality, air-fuel ratio (Lambda), fuel amount, sulfur content of the fuel, valve positions, engine load, engine speed, exhaust gas mass flow.

11. Ship comprising a propulsion system according to one of claims 1 to 3.

12. Ship comprising a two stroke internal combustion engine working with a method according to one of claims 4 to 10.

13. Control system for controlling the injection of a reducing agent into a connection between an outlet of a cylinder and an exhaust gas receiver, in particular a control system for controlling a propulsion system according to one of claims 1 to 3, including at least a first input channel and a first output channel, **characterized in that** a specific start value for an amount of reducing agent is adjusted based on an adjustment parameter which is derived from at least one of a direct or an indirect measurement of an engine parameter of the internal combustion engine which is received at the first input channel, said altered start value is used to control the injection of a nozzle valve for the reducing agent.

14. Control system according to claim 13 comprising at least a second input channel, wherein the adjustment parameter is derived from a combination and in particular from a calculated difference of the signals of the at least first and second input channel.

15. Propulsion system with a two stroke internal combustion engine, in particular a diesel engine, in particular a propulsion system according to one of claims 1 to 3, comprising a control system according to claim 13 or 14 and at least one sensor for measurement of at least one of the following parameters: temperature of scavenge air, scavenge pressure, humidity of scavenge air, temperature of cooling system, temperature of exhaust gas, pressure inside the cylinder, in particular the firing pressure or the compression pressure, ambient temperature, ambient pressure, ammonia slip, urea quality, air-fuel ratio (Lambda), fuel amount, valve positions, turbocharger speed, engine load, engine speed, exhaust gas mass flow.

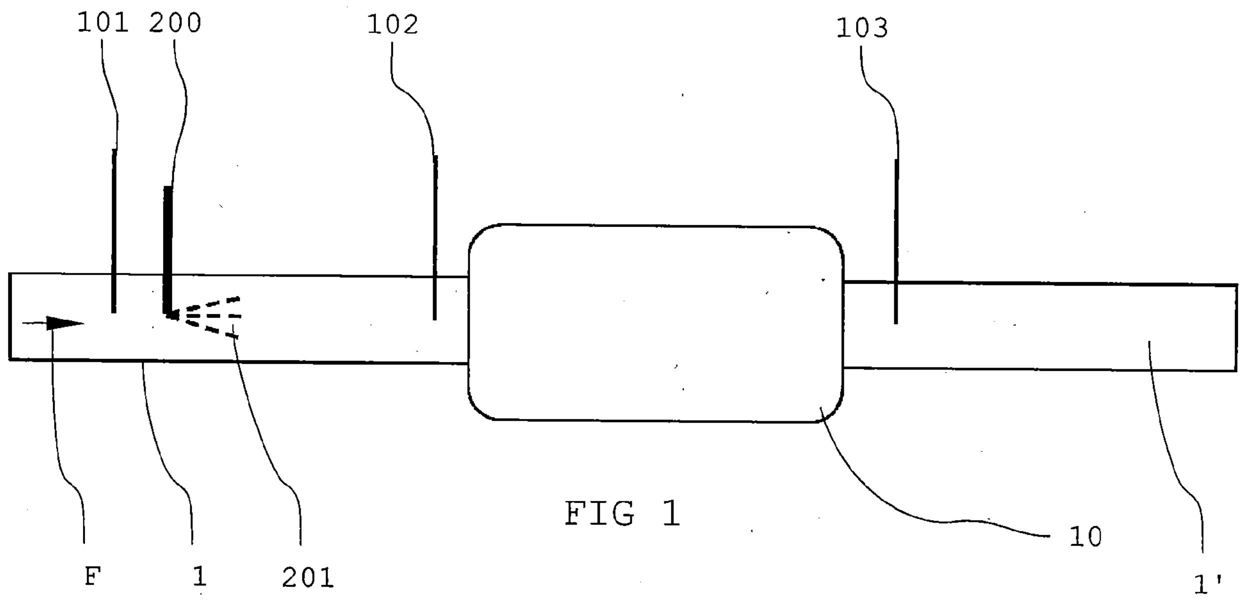

FIG 1

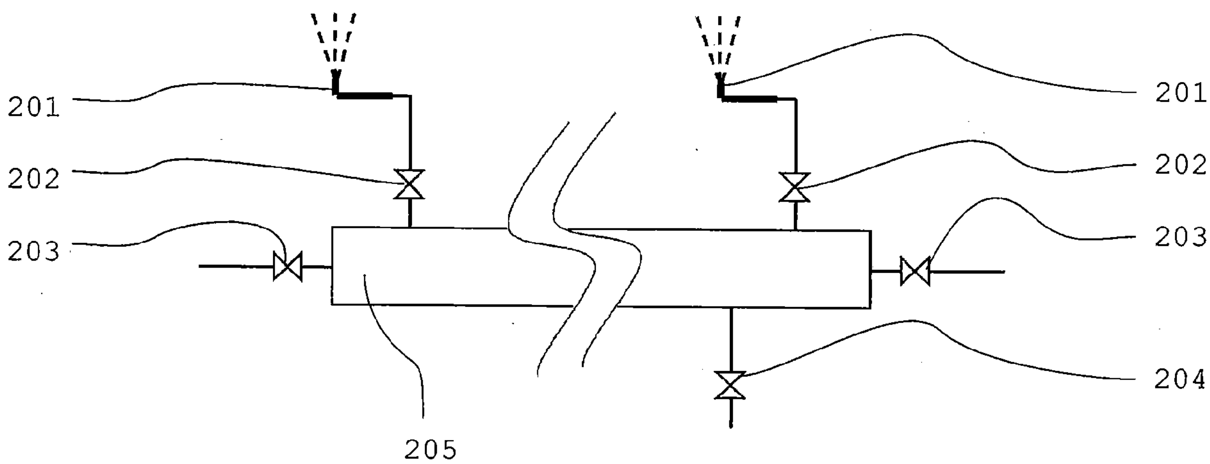

FIG 2

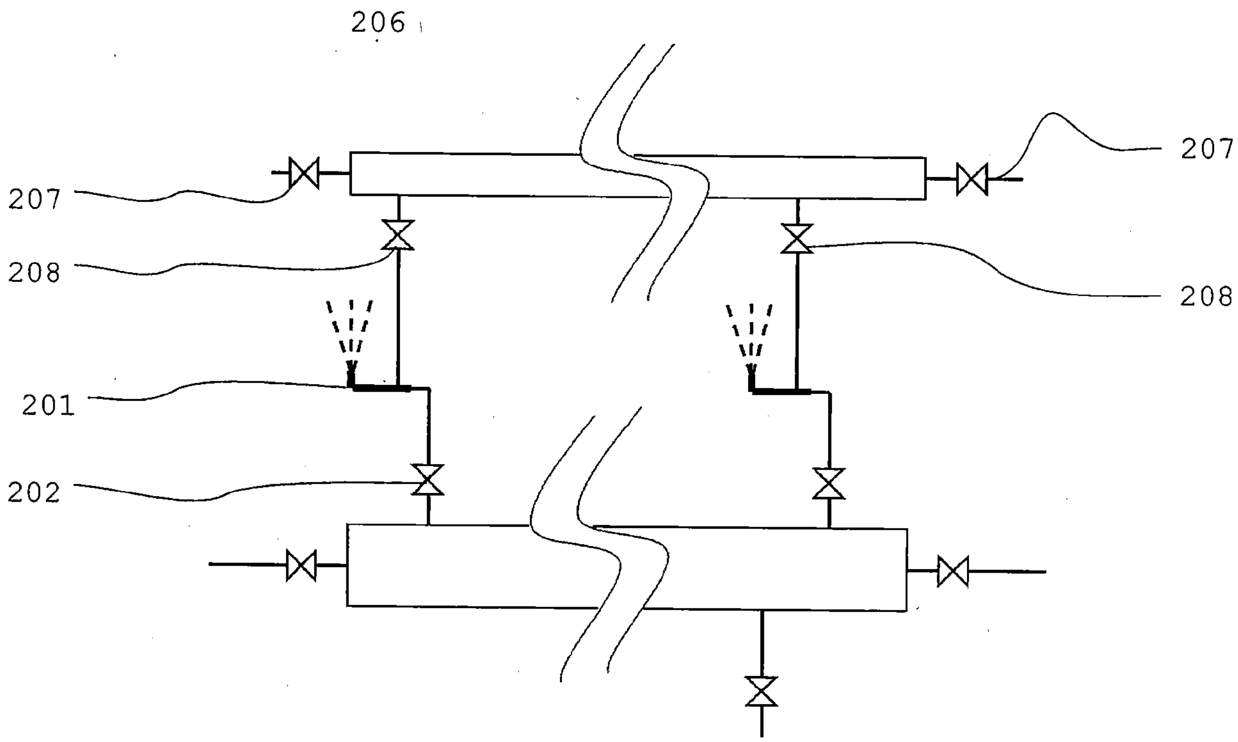

FIG 3

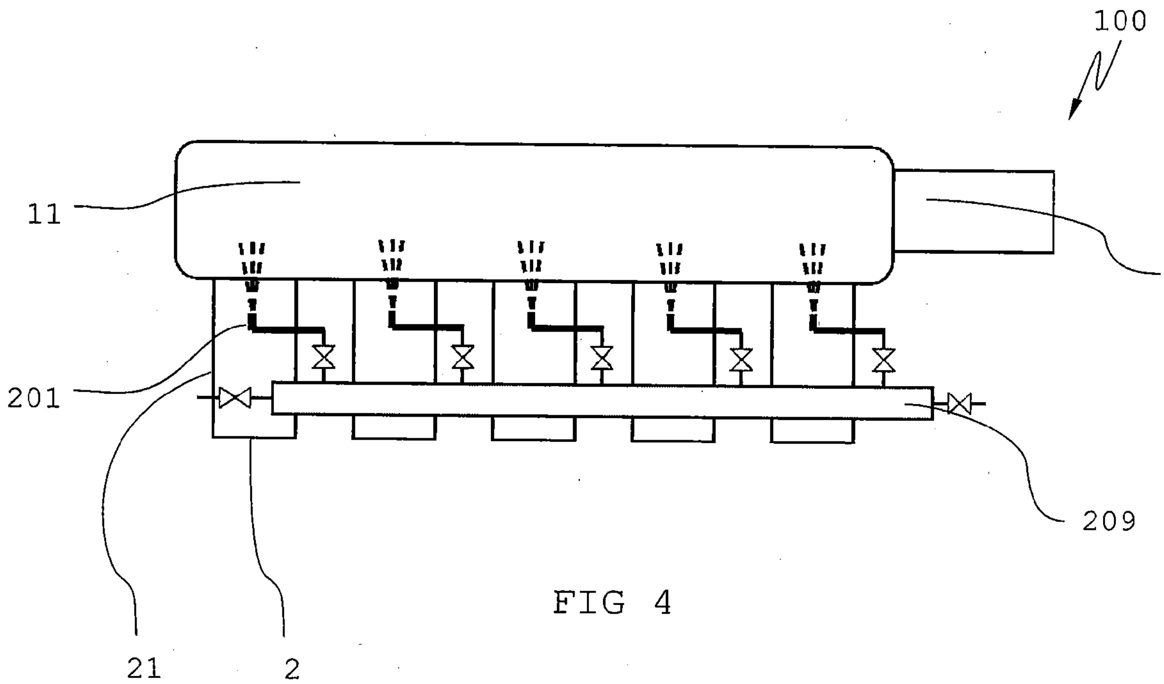

FIG 4

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EUROPEAN SEARCH REPORT

Application Number
EP 17 15 1927

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The present search report has been drawn up for all claims

3

Place of search	Date of completion of the search	Examiner
Munich	16 June 2017	Kolland, Ulrich

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Application Number
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	16 June 2017	Kolland, Ulrich

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CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing claims for which payment was due.

- [ ] Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due and for those claims for which claims fees have been paid, namely claim(s):

- [ ] No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

- [X] All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

- [ ] As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.

- [ ] Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

- [ ] None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

- [ ] The present supplementary European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims (Rule 164 (1) EPC).

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LACK OF UNITY OF INVENTION SHEET B

Application Number
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The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. claims: 1-3, 11

   Propulsion system comprising a two stroke internal combustion engine, wherein a SCR reducing agent is supplied by a common rail, valves and nozzles into the connection means provided between cylinder and an exhaust gas receiver.

   ---

2. claims: 4-8, 13-15(completely); 12(partially)

   Method for reducing NOx emissions of an internal combustion engine the amount of a reducing agent is determined by means of an adjustment parameter which is derived from a measurement or the corresponding control system.

   ---

3. claims: 9, 10(completely); 12(partially)

   Method for determining the functionality and/or aging of a catalytic reactor of a propulsion system, comprising the steps of measuring a first exhaust gas temperature upstream and a second exhaust gas temperature downstream of the catalytic reactor for then determining an activity value of the catalytic reactor.

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 17 15 1927

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