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## (54) Internal combustion engine with an exhaust emission aftertreatment device for reducing nitrogen oxides (NOx) emissions and method for controlling such an engine

(57) The present invention relates to a turbocharged direct injection internal combustion engine (10) comprising an intake air manifold (19) in order to feed the engine (10) with fresh air, an exhaust manifold (20) to evacuate the exhaust gases, at least one turbocharger including a turbine (11) and a compressor (12) and at least one $NO_x$ storage catalyst (13) used as exhaust emission aftertreatment device for reducing nitrogen oxides ($NO_x$) emissions and disposed in said exhaust manifold (20) downstream said turbine (11).

It is an object of the present invention to provide an engine (10) of the above mentioned kind, which overcomes the above described problems, in particular an engine which is enabled to elevate the $NO_x$ conversion and limit the HC emissions under the mid to high engine loads and high engine speeds..

With respect to the object an engine (10) is provided, which is characterized in that a first additional pipe (24) is arranged which enables a connection between said intake air manifold (19) and said exhaust manifold (20) in such a manner, that said first additional pipe (24) leads into the exhaust manifold (20) downstream said at least one $NO_x$ storage catalyst (24) and a predetermined amount of intake air can be guided into said exhaust manifold (20) by means of a control valve (18,26) disposed in said first additional pipe (24) bypassing the engine (10).

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## Description

**[0001]** The present invention relates to a turbocharged direct injection internal combustion engine comprising an intake air manifold in order to feed the engine with fresh air, an exhaust manifold to evacuate the exhaust gases, at least one turbocharger including a turbine and a compressor and at least one $NO_x$ storage catalyst used as exhaust emission aftertreatment device for reducing nitrogen oxides ($NO_x$) emissions and disposed in said exhaust manifold downstream said turbine.

**[0002]** A conventional engine arrangement, i.e., a conventional engine setup using an engine 100 of the above mentioned kind is shown in Figure 1. In addition this engine is provided with an exhaust gas recirculation (EGR) 106 comprising an EGR valve 108 for determining the recirculated exhaust gas mass flow and a throttle 105 arranged downstream the compressor 102 in the intake manifold 109 for controlling the air mass flow fed to the engine 100. The pipe for recirculation 107 branchs off upstream the turbine 101 and leads into the intake manifold 109 downstream the compressor 102 and downstream said throttle 105. A cooler 104 is disposed downstream the compressor 102 in order to reduce the temperature of the air charge and by doing this to improve the quality of the gas exchange by increasing the air mass. A $NO_x$ storage catalyst 103 used as exhaust emission aftertreatment device for reducing nitrogen oxides ($NO_x$) emissions is disposed in the exhaust manifold 110 downstream said turbine 101.

**[0003]** Furthermore the invention relates to a method for controlling such an engine.

**[0004]** Internal combustion engines are provided with various types of aftertreatment devices for purifying exhaust gas generated by the combustion and emitted from combustion chambers into the exhaust pipe, i.e., exhaust manifold. For example, devices to filter and trapped the soot particulates contained in the exhaust gas. Such a filter is also known as diesel particulates filter (abbreviated DPF - Diesel Particulate Filter).Within a regenartion phase the particulate filter is regenerated and the trapped particulates are burned by increasing the exhaust gas temperature. Instead of increasing the exhaust gas temperature additives could be added to the exhaust gas for promoting the combustion of the trapped particulates.

**[0005]** For reducing nitrogen oxides ($NO_x$) emissions of an internal combustion engine a $NO_x$ storage catalyst could be disposed in the exhaust pipe. Such a catalyst is also known as $NO_x$ trap or lean $NO_x$ trap (abbreviated LNT - Lean $NO_x$ Trap).

**[0006]** A diesel lean $NO_x$ trap (LNT) absorbs and stores emissions of nitrogen oxides ($NO_x$) during the lean operation of the internal combustion engine. When saturated with $NO_x$ molecules, a rich operation phase is required to purge the trap. This allows the release of the stored $NO_x$ molecules and its reduction into non-polluting components, mainly nitrogen ($N_2$), carbon dioxide ($CO_2$), and water vapor ($H_2O$). The frequency of this purging action is determined by the engine out $NO_x$ emissions and the storage capacity of the LNT which depends on the temperature of the exhaust gas.

**[0007]** A possibility to achieve high conversion efficiency under all engine operating conditions is the usage of multiple LNT bricks. According to a first specific arrangement a close-coupled brick is disposed in the exhaust gas pipe near to the exhaust gas outlet of the combustion engine and an under-floor brick is disposed in the exhaust gas pipe downstream the close-coupled brick, i.e., catalyst. Preferably the closed-coupled catalyst is smaller in size than the under-floor catalyst. This allows $NO_x$ conversion under engine operation with low exhaust gas masses, i.e., under low load and low speeds as well as in cold start conditions using the close-coupled LNT and $NO_x$ conversion under engine operation with high exhaust gas masses, i.e., at high load and high speeds using the under-floor LNT which is bigger in size to accommodate high conversion at high space velocities under these operating conditions. The space velocity correlates to the exhaust gas mass passes through the exhaust gas piping.

**[0008]** Because of its close proximity to the engine exhaust gas outlet and its small size, the close-coupled catalyst will reach the temperature window for high conversion efficiency much faster than the under-floor catalyst. On the other hand, under high engine load, the closed-coupled LNT will suffer low conversion of $NO_x$ because of reaching higher temperatures than its optimal conversion temperature window and quite high space velocities because of its small size. Under high load conditions, the under-floor LNT will be within its optimal conversion window since the exhaust gas cools down in the exhaust gas piping. Moreover, the under-floor LNT is sized large enough to ensure lower space velocity and consequently proper conversion of $NO_x$ emissions under high emission rates (i.e. high exhaust gas masses).

**[0009]** At the same time the storage capacity of the under-floor LNT is large enough to store high amounts of $NO_x$ under operation with high emission rates and therefore this high storage capacity keep the purging fuel consumption penalty caused by the purging of the trap within acceptable limits. Taking into account that the regeneration, i.e. the purging of the LNT requires rich operation mode of the engine as mentioned above, the purging frequency influences the fuel consumption and engine emissions directly.

**[0010]** To deal with the above described problems according to the state of the art an exhaust gas guide mechanism could be disposed in the exhaust pipe upstream the catalysts in such a manner, that by switching the guide mechanism between two operating positions either in a first operating position the first catalyst is disposed upstream the second catalyst or in a second operating position said second catalyst is disposed upstream said first catalyst.

**[0011]** In order to achieve high conversion efficiency, the ability to purge the trap should be guaranteed under all operating conditions during steady state as well as on transient operation.

[0012] In particular the ability to operate the engine in rich mode for purging the trap should be guaranteed under all operating conditions. The rich engine operation mode (rich mode) is limited by several boundary conditions which have to take into account during engine control.

[0013] At low engine load conditions rich mode is limited by combustion stability, neutral torque transition, and HC emissions. Misfirings which result in increased exhaust emissions, in particular HC emissions have to be avoided.

[0014] At high engine loads, low engine speeds, smoke emission could be considered as the most critical drawback with respect to operate the engine in rich mode. Smoke emission leads to a restriction to fuel quantity injected into the combustion chambers and limits rich operation mode.

[0015] At mid engine loads, mid to high engine speeds an increased purge frequency is required because of high engine out $NO_x$ emissions. This results in increased accumulated HC emissions.

[0016] At high engine loads, high engine speeds, rich mode limitation consists in the increase of the exhaust gas temperature which should not exceed the admissable temperature for turbine material. This limits the allowable rich pulse duration and negatively influencing the $NO_x$ conversion especially for typically high engine out $NO_x$ emissions.

[0017] The last mentioned limitation is quite severe since the increased temperature of the exhaust gas is combined with a high mass flow which makes it difficult to achieve the required target lambda value at these conditions. Modifying the fuel path calibration by increasing fuel quantity within a post injection will result for early injection timing in even higher exhaust temperatures and for later injection timing in excessive oil dilution. On the other hand, attempting to modify the air path by reducing the mass flow can only be successful by throttling the intake air which results in excessive high pressure ratio across the compressor resulting in difficulties to achieve stable boost pressure control. Especially during engine transition mode, for example when the exhaust gas temperature has not yet been elevated to its steady values during the rich mode. Moreover, the attempt to aid the reduction in air mass through exhaust gas recirculation is limited by the maximum temperature tolerated by the EGR cooler valve, as well as by the admissable temperature for the material used to form the intake manifold, which is often synthetic material.

[0018] Another restriction could be seen in the non favorable pressure difference across the engine during high engine load/high engine speed operation, i.e., having a higher manifold boost pressure than exhaust pressure is not appropriate for exhaust gas recirculation and in particular such boundary conditions are not appropriate to increase the absolute mass of recirculated exhaust gas. In general higher EGR rates require a low intake manifold pressure and a high pressure in the exhaust manifold upstream the turbine, where the pipe for recirculation branchs off. Furthermore to provide the high air mass flow for high engine speed operation it is intended to guide as much exhaust gas as possible through the turbine in order to generate a respective high boost pressure by means of the compressor. Finally HC emissions tend to be higher for higher EGR rates.

[0019] In summary, using the conventional methods for controlling and the conventional engine arrangements $NO_x$ conversion by means of LNT is limited by temperature limitation at high engine loads, high engine speeds, and accumulated HC emissions at mid to high engine loads and high engine speeds.

[0020] With respect to this it is an object of the present invention to provide an engine according to the preamble of claim 1, which overcomes the above described problems, in particular an engine which is enabled to elevate the $NO_x$ conversion and limit the HC emissions under the mid to high engine loads and high engine speeds.

[0021] Another object of the present invention is to provide a method for controlling such an engine.

[0022] According to the present invention and with respect to the first object a turbocharged direct injection internal combustion engine is provided comprising an intake air manifold in order to feed the engine with fresh air, an exhaust manifold to evacuate the exhaust gases, at least one turbocharger including a turbine and a compressor and at least one $NO_x$ storage catalyst used as exhaust emission aftertreatment device for reducing nitrogen oxides ($NO_x$) emissions and disposed in said exhaust manifold downstream said turbine, and which is characterized in that a first additional pipe is arranged which enables a connection between said intake air manifold and said exhaust manifold in such a manner, that said first additional pipe leads into the exhaust manifold downstream said at least one $NO_x$ storage catalyst and a predetermined amount of intake air can be guided into said exhaust manifold by means of a control valve disposed in said first additional pipe bypassing the engine.

[0023] In contrast to the conventional arrangement shown in Figure 1 the engine according to the invention is modified by providing a first additional pipe which is used to form a direct connection between the intake air manifold and the exhaust manifold in order to guide more or less intake air directly into the exhaust manifold downstream said at least one $NO_x$ storage catalyst. The air conducted through the additional pipe bypasses the engine.

[0024] The advantages of using the inventive additional pipe to reduce the air mass fed into the engine cylinders are the following.

[0025] The pressure ratio across the compressor is much lower than in the case of using conventional throttling. Thus the stability of intake manifold pressure control is improved. This is an advantage in particular during transition from normal engine operation mode, i.e., lean engine operation (lean mode) to rich mode caried out in order to purge the at least one $NO_x$ storage catalyst.

**[0026]** The reduction in fresh air charge flow by means of an additional pipe as described above leads to lower exhaust gas temperatures and allows extending the rich operation period and thus achieving more efficient purges. The use of the inventive engine lowers the exhaust gas temperatures and the exhaust gas mass flow passing through the turbine and the LNT during rich engine operation mode.

**[0027]** Another advantage is the simplicity of the inventive engine arrangement and the simplicity of the associated method for controlling the engine, in particular during engine transition.

**[0028]** A preferred embodiment of the engine is characterized in that an exhaust gas recirculation (EGR) comprising an EGR valve for determining the recirculated exhaust gas mass flow is arranged in such a manner, that a pipe for recirculation branchs off upstream said at least one turbine. Preferably the pipe for recirculation leads into the intake manifold downstream said at least one compressor. An exhaust gas recirculation is an appropriate instrument to reduce emissions of nitrogen oxides ($NO_x$). Furthermore the usage of EGR enables further preferred embodiments of the inventive engine as can be seen below. In particular the EGR valve can be used as control valve.

**[0029]** Another preferred embodiment of the engine is characterized in that a throttling element is arranged downstream said compressor in said intake manifold for controlling the air mass flow, i.e., the intake air pressure. If exhaust gas recirculation is used the pipe for recirculation preferably leads into the intake manifold downstream said throttling element. A throttling element, for example a throttle, can be used for influencing the intake manifold pressure upstream and downstream the throttling element. With respect to the exhaust gas recirculation a throttle is appropriate to control the pressure difference across the engine, i.e., the pressure difference between the exhaust gas manifold and the intake manifold. Consequently the throttle - beside the EGR valve - is useful for controlling the recirculated exhaust gas mass flow.

**[0030]** For engines which are provided with an exhaust gas recirculation embodiments are preferred which are characterized in that said first additional pipe leads to the EGR valve and said EGR valve is designed in such a manner, that by switching said EGR valve between two operating positions either in a first operating position said EGR valve is used to determine the recirculated exhaust gas mass flow or in a second operating position said EGR valve is used to guide a predetermined amount of intake air via said pipe for recirculation, said EGR valve and said first additional pipe into the exhaust manifold.

**[0031]** Starting from a conventional engine arrangement only fewer modifications are required to obtain an inventive engine according to the embodiment in question. Only one additional component, namely said additional first pipe connecting the EGR-valve with the exhaust manifold, has to be arranged. This enhances an effective engine packaging, which is one major goal of the constructers. The EGR valve has two functions and therefore this component is a bit more complex than a conventional EGR valve known from the state of the art. However, all in all only one valve is sufficient and used to determine the recirculated exhaust gas mass and to guide intake air into the exhaust manifold.

**[0032]** Consequently the embodiment is also characterized in that fewer expenses are required for modifications.

**[0033]** For engines which are provided with an exhaust gas recirculation another embodiment is also preferred which is characterized in that said first additional pipe leads to the EGR valve, a second additional pipe is arranged which connects the intake air manifold with the EGR valve and said EGR valve is designed in such a manner, that by switching said EGR valve between two operating positions either in a first operating position said EGR valve is used to determine the recirculated exhaust gas mass flow or in a second operating position said EGR valve is used to guide a predetermined amount of intake air via said second additional pipe, said EGR valve and said first additional pipe into the exhaust manifold. If a throttling element is arranged in the intake manifold said second additional pipe preferably branchs off the intake manifold upstream this throttling element.

**[0034]** In comparison to the before discussed embodiment a second additional pipe instead of the recirculation pipe is used for bypassing the engine. In this case the bypassed air flow is taken upstream the throttle and is injected downstream the LNT. The control strategy has to coordinate the throttle and the EGR valve to achieve the required flow direction, i.e., the throttle will have to be further closed to generate high pressure upstream the throttle and thus to achieve the required pressure difference between the intake manifold and the exhaust manifold.

**[0035]** The opening of the EGR valve can be controlled to achieve a desired pressure setpoint upstream the throttle or a required mass air flow to the exhaust manifold. The advantage of this setup is the ability to control the fresh air flow at mid to low engine speeds and loads which are expected to be beneficial to reduce accumulated HC emissions when used in combination with a downstream oxidation device.

**[0036]** Another preferred embodiment of the engine is characterized in that said first additional pipe branchs off said intake air manifold comprising a second valve for determining the amount of intake air bypassing the engine. The second valve is used as control valve. If a throttling element is arranged in the intake manifold said first additional pipe preferably branchs off the intake manifold upstream this throttling element.

**[0037]** This embodiment allows to operate the engine in rich mode in order to purge the at least one $NO_x$ storage catalyst while simultaneously exhaust gas recirculation can be applied. Contrary to that using the before described embodiments either the engine operates in rich mode or exhaust gas recirculation is applied while the engine is operating in normal (lean) engine operation mode.

**[0038]** For engines equipped with an oxidation catalyst embodiments are preferred which are characterized in that said oxidation catalyst is arranged in the exhaust manifold downstream where the first additional pipe flows into said exhaust manifold. In this case the oxidation catalyst is a low pressure difference aftertreatment device.

**[0039]** The routing of the fresh air in the exhaust manifold improves the oxidation of the exhaust gas, providing the potential to reduce HC emissions.

**[0040]** It should be noted that there is a difference between low pressure difference aftertreatment devices and high pressure difference aftertreatment devices with respect to the arrangement of these catalyst types in the exhaust manifold relative to the at least one $NO_x$ storage catalyst. The brick, i.e., the substrate used to form the catalyst determines if the catalyst belongs to the low pressure difference or to the high pressure difference aftertreatment device type.

**[0041]** High pressure difference aftertreatment devices, i.e., aftertreatment devices which cause a pressure decrease across the catatlyst should be arranged upstream where the first additional pipe flows into the exhaust manifold, while low pressure difference aftertreatment devices could be arranged either upstream or downstream the additional pipe's port.

**[0042]** Therefore, for engines equipped with a diesel particulate filter embodiments are preferred which are characterized in that said diesel particulate filter is arranged in the exhaust manifold upstream where the first additional pipe flows into said exhaust manifold. Usually diesel particulate filters are of the high pressure difference type because the exhaust gases have to flow through the walls of the used substrate resulting in a pressure decrease across the filter.

**[0043]** The $NO_x$ storage catalyst could be of the low pressure difference type or the high pressure difference type. Furthermore embodiments could be created in which the at least one $NO_x$ storage catalyst and the dieselparticulate filter form one component, i.e., one aftertreatment device.

**[0044]** Furthermore a method is provided for controlling an engine according to any of the above described embodiments, which comprises the following steps:

(a) arranging a first additional pipe which leads into the exhaust manifold downstream said at least one $NO_x$ storage catalyst in such a manner, that said exhaust manifold can be connected with said intake air manifold, and

(b) providing said first additional pipe with a control valve in order to guide a predetermined amount of intake air into said exhaust manifold bypassing the engine for purging said at least one $NO_x$ storage catalyst during rich engine operation mode.

**[0045]** A preferred embodiment of the aftertreatment device is characterized in that

(a) connecting said first additional pipe with said EGR valve, and

(b) designing said EGR valve in such a manner, that by switching said EGR valve between two operating positions either in a first operating position said EGR valve is used to determine the recirculated exhaust gas mass flow or in a second operating position said EGR valve is used to guide a predetermined amount of intake air via said pipe for recirculation, said EGR valve and said first additional pipe into the exhaust manifold.

**[0046]** Another preferred embodiment of the aftertreatment device is characterized in that

(a) connecting said first additional pipe with the EGR valve,

(b) arranging a second additional pipe which connects the intake air manifold with said EGR valve,

(c) designing said EGR valve in such a manner, that by switching said EGR valve between two operating positions either in a first operating position said EGR valve is used to determine the recirculated exhaust gas mass flow or in a second operating position said EGR valve is used to guide a predetermined amount of intake air via said pipe for recirculation, said EGR valve and said first additional pipe into the exhaust manifold.

**[0047]** If a throttling element is arranged in the intake manifold said second additional pipe preferably is connected with the intake manifold upstream this throttling element.

**[0048]** Hereby preferably the EGR valve and the throtteling element are controlled in such a way that at low to mid engine loads the throttle is actuated closed looped to control the manifold pressure and the EGR valve is actuated to closed looped to control the recirculated exhaust gas flowing from exhaust to intake manifold as inferred from the measured fresh mass air.

**[0049]** A model-based approach can be used to drive the open loop (feed forward) set-point of the actuators meanwhile a known control approach is used to determine the closed loop correction. Moreover, the use of observer to estimate the percent exhaust gas re-circulated or to estimate the burnt mass fraction in the intake manifold can be utilized to improve the transient performance, for example, through dynamic adaptation of the steady state set point(s) during transients.

**[0050]** According to the inventive method, at mid to high load engine operation, the proposed coordinated control method to operate the engine at rich mode is in such that the temperature upstream the turbine is controlled open looped by mapping the position of the control valve as a function of engine operation. In the presence of a temperature sensor upstream the turbine, the control valve would be adapted closed looped to control the temperature to a predetermined maximum level, once exceeded. Alternatively, the control valve can be adapted closed looped to control the pressure upstream the throttling element downstream the compressor, which is advantageous compared to the limited band width achievable when using slow response temperature sensor upstream the turbine.

**[0051]** Another preferred embodiment of the aftertreatment device is characterized in that

(a) connecting said first additional pipe with the intake manifold, and

(b) providing said first additional pipe with a second valve in order to guide a predetermined amount of intake air into said exhaust manifold bypassing the engine for purging said at least one $NO_x$ storage catalyst during rich engine operation mode.

**[0052]** Embodiments of the present invention will be described below with reference to the drawings:

Figure 1 shows schematically a conventional engine arrangement according to the state of the art,

Figure 2a shows schematically a first embodiment of the engine in a first operating position, i.e., first operating mode,

Figure 2b shows schematically the embodiment illustrated in Figure 2a in a second operating position, i.e., second operating mode

Figure 3a shows schematically a second embodiment of the engine in a second operating position, i.e., second operating mode, and

Figure 3b shows schematically a third embodiment of the engine.

**[0053]** Figure 1 is already described within the introduction in order to point out the conventional engine arrangement according to the state of the art and thus the problems resulting herefrom.

**[0054]** Figure 2a shows schematically a first embodiment of the engine 10 in a first operating position, i.e., first operating mode. Figure 2b shows schematically the same embodiment in a second operating position, i.e., second operating mode.

**[0055]** The combustion engine 10 comprises an intake air manifold 19 in order to feed the engine 10 with fresh air and an exhaust manifold 20 to evacuate the exhaust gases from the engine cylinder's combustion chambers. The engine 10 is turbocharged by means of a turbocharger whose turbine 11 is disposed in the exhaust manifold 20 and whose compressor 12 is disposed in the intake manifold 19.

**[0056]** The engine 10 is equipped with an aftertreatment device for reducing nitrogen oxides ($NO_x$) emissions contained in the exhaust gas, i.e., with a $NO_x$ storage catalyst 13. The catalyst 13 is disposed in the exhaust manifold 20 downstream the turbine 11.

**[0057]** In addition the engine 10 is provided with an exhaust gas recirculation (EGR) 16 comprising an EGR valve 18 for determining the recirculated exhaust gas mass flow and an EGR-cooler to lower the temperature of the refed exhaust gases. A throttle 15 is arranged downstream the compressor 12 in the intake manifold 19 for controlling the air mass flow fed to the engine 10. The pipe for recirculation 17 branchs off upstream the turbine 11 and leads into the intake manifold 19 downstream the throttle 15.

**[0058]** A cooler 14 is disposed downstream the compressor 12 and upstream the throttle 15 reducing the temperature of the air charge.

**[0059]** The engine 10 is provided with a first additional pipe 24 which connects the EGR valve 18 with the exhaust manifold 20 in such a way, that the first additional pipe 24 flows into the exhaust manifold 20 downstream the $NO_x$ storage catalyst 13.

**[0060]** By switching the EGR valve 18 between two operating positions either in a first operating position - see Figure 2a - the EGR valve 18 is used to determine the recirculated exhaust gas mass flow (indicated by arrows) or in a second operating position - see Figure 2b - the EGR valve 18 is used as control valve, i.e., to guide a predetermined amount of intake air via the recirculation pipe 17, the EGR valve 18 and the first additional pipe 24 into the exhaust manifold 20 during bypassing the engine 10 (indicated by arrows).

**[0061]** The engine 10 illustrated in the Figures 2a,2b is equipped with a second aftertreatment device, namley an oxidation catalyst 22 which is arranged in the exhaust manifold 20 downstream where the first additional pipe 24 flows into the exhaust manifold 20. Consequently the oxidation catalyst 22 has to be a low pressure difference aftertreatment device 23 in order to guarantee a low pressure downstream the LNT 13 and upstream the oxidation catalyst 22.

**[0062]** The routing of fresh air via the first additional pipe 24 into the exhaust manifold 20 during rich engine operation mode, i.e., during purging the LNT 13 improves the oxidation of the exhaust gases, in particular the oxidation of unburnt hydrocarbons (HC).

**[0063]** Figure 3a shows schematically a second embodiment of the engine 10 in a second operating position, i.e., in the LNT-purging mode.

**[0064]** Contrary to the engine arrangement described before the embodiment shown in Figure 3a is equipped with a second additional pipe 25 connecting the intake air manifold 19 upstream the throttle 15 with the EGR valve 18.

**[0065]** In a first operating position the EGR valve 18 is used to determine the recirculated exhaust gas mass flow whereas in a second operating position said EGR valve 18 is used as control valve to guide a predetermined amount of intake air via the second additional pipe 25, the EGR valve 18 and the first additional pipe 24 into the exhaust manifold 20 (indicated by arrows).

**[0066]** Figure 3b shows schematically a third embodiment of the engine 10. According to this third embodiment the first additional pipe 24 branchs off upstream the throttle 15 comprising a second valve 26 for determining the amount of intake air bypassing the engine 10. This allows the engine 10 to operate in the rich engine operation mode in order to purge the $NO_x$ storage catalyst 13 while simultaneously exhaust gas recirculation 16 can be applied.

**Reference signs**

**[0067]**

| | |
|---|---|
| 10 | internal combustion engine |
| 11 | turbine |
| 12 | compressor |
| 13 | aftertreatment device, LNT |
| 14 | cooler |
| 15 | throttle |
| 16 | exhaust gas recirculation (EGR) |
| 17 | pipe for recirculation |
| 18 | EGR valve |
| 19 | intake manifold |
| 20 | exhaust manifold |
| 21 | EGR-cooler |
| 22 | oxidation catalyst |
| 23 | low pressure difference aftertreatment device |
| 24 | first additional pipe |
| 25 | second additional pipe |
| 26 | second valve |

State of the art:

**[0068]**

| | |
|---|---|
| 100 | internal combustion engine |
| 101 | turbine |
| 102 | compressor |
| 103 | aftertreatment device, LNT |
| 104 | cooler |
| 105 | throttle |
| 106 | exhaust gas recirculation (EGR) |
| 107 | pipe for recirculation |
| 108 | EGR valve |
| 109 | intake manifold |
| 110 | exhaust manifold |

**Claims**

**1.** A turbocharged direct injection internal combustion engine (10) comprising an intake air manifold (19) in order to feed the engine (10) with fresh air, an exhaust manifold (20) to evacuate the exhaust gases, at least one turbocharger including a turbine (11) and a compressor (12) and at least one $NO_x$ storage catalyst (13) used as exhaust emission aftertreatment device for reducing nitrogen oxides ($NO_x$) emissions and disposed in said exhaust manifold (20) downstream said turbine (11),
**characterized in that**
a first additional pipe (24) is arranged which enables a connection between said intake air manifold (19) and said exhaust manifold (20) in such a manner, that said first additional pipe (24) leads into the exhaust manifold (20) downstream said at least one $NO_x$ storage catalyst (24) and a predetermined amount of intake air can be guided into said exhaust manifold (20) by means of a control valve (18,26) disposed in said first additional pipe (24) bypassing the engine (10).

**2.** A turbocharged direct injection internal combustion engine (10) according to claim 1, **characterized in that** an exhaust gas recirculation (16) comprising an EGR valve (18) for determining the recirculated exhaust gas mass flow is arranged in such a manner, that a pipe for recirculation (17) branchs off upstream said at least one turbine (11).

**3.** A turbocharged direct injection internal combustion engine (10) according to any of the preceding claims, **characterized in that** a throttling element (15) is arranged downstream said compressor (12) in said intake manifold for (19) controlling the air mass flow, i.e., the intake air pressure.

**4.** A turbocharged direct injection internal combustion engine (10) according to claim 2 or 3, **characterized in that** said first additional pipe (24) leads to the EGR valve (18) and said EGR valve (18) is designed in such a manner, that by switching said EGR valve (18) between two operating positions either in a first operating position said EGR valve (18) is used to determine the recirculated exhaust gas mass flow or in a second operating position said EGR valve (18) is used as control valve to guide a predetermined amount of intake air via said pipe for recirculation (17), said EGR valve (18) and said first additional pipe (24) into the exhaust manifold (20).

**5.** A turbocharged direct injection internal combustion engine (10) according to claim 2 or 3, **characterized**

**in that** said first additional pipe (24) leads to the EGR valve (18), a second additional pipe (25) is arranged which connects the intake air manifold (19) with the EGR valve (18) and said EGR valve (18) is designed in such a manner, that by switching said EGR valve (18) between two operating positions either in a first operating position said EGR valve (18) is used to determine the recirculated exhaust gas mass flow or in a second operating position said EGR valve (18) is used as control valve to guide a predetermined amount of intake air via said second additional pipe (25), said EGR valve (18) and said first additional pipe (24) into the exhaust manifold (20).

**6.** A turbocharged direct injection internal combustion engine (10) according to one of the claims 1 to 3, **characterized in that** said first additional pipe (24) branchs off said intake air manifold (19) comprising a second valve (26) for determining the amount of intake air bypassing the engine (10).

**7.** A turbocharged direct injection internal combustion engine (10) according to any of the preceding claims comprising an oxidation catalyst (22), **characterized in that** said oxidation catalyst (22) is arranged in the exhaust manifold (20) downstream where the first additional pipe (24) flows into said exhaust manifold (20).

**8.** A turbocharged direct injection internal combustion engine (10) according to any of the preceding claims comprising a diesel particulate filter, **characterized in that** said diesel particulate filter is arranged in the exhaust manifold (20) upstream where the first additional pipe (24) flows into said exhaust manifold (20).

**9.** A method for controlling an engine (10) according to any of the preceding claims, which comprises the following steps:

(a) arranging a first additional pipe (24) which leads into the exhaust manifold (20) downstream said at least one $NO_x$ storage catalyst (24) in such a manner, that said exhaust manifold (20) can be connected with said intake air manifold (19), and
(b) providing said first additional pipe (24) with a control valve (18,26) in order to guide a predetermined amount of intake air into said exhaust manifold (20) bypassing the engine (10) for purging said at least one $NO_x$ storage catalyst during rich engine operation mode.

**10.** A method according to claim 9 for controlling an engine (10) according to one of the claims 2 to 8, **characterized in that**

(a) connecting said first additional pipe (24) with said EGR valve (18), and
(b) designing said EGR valve (18) in such a manner, that by switching said EGR valve (18) between two operating positions either in a first operating position said EGR valve (18) is used to determine the recirculated exhaust gas mass flow or in a second operating position said EGR valve (18) is used to guide a predetermined amount of intake air via said pipe for recirculation (17), said EGR valve (18) and said first additional pipe (24) into the exhaust manifold (20).

**11.** A method according to claim 9 for controlling an engine (10) according to one of the claims 5 to 8, **characterized in that**

(a) connecting said first additional pipe (24) with the EGR valve (18),
(b) arranging a second additional pipe (25) which connects the intake air manifold (19) with said EGR valve (18),
(c) designing said EGR valve (18) in such a manner, that by switching said EGR valve (18) between two operating positions either in a first operating position said EGR valve (18) is used to determine the recirculated exhaust gas mass flow or in a second operating position said EGR valve (18) is used to guide a predetermined amount of intake air via said pipe for recirculation (17), said EGR valve (18) and said first additional pipe (24) into the exhaust manifold (20).

**12.** A method according to claim 9 for controlling an engine (10) according to one of the claims 6 to 8, which comprises the following steps:

(a) connecting said first additional pipe (24) with the intake manifold (19), and
(b) providing said first additional pipe (24) with a second valve (18,26) in order to guide a predetermined amount of intake air into said exhaust manifold (20) bypassing the engine (10) for purging said at least one $NO_x$ storage catalyst during rich engine operation mode.

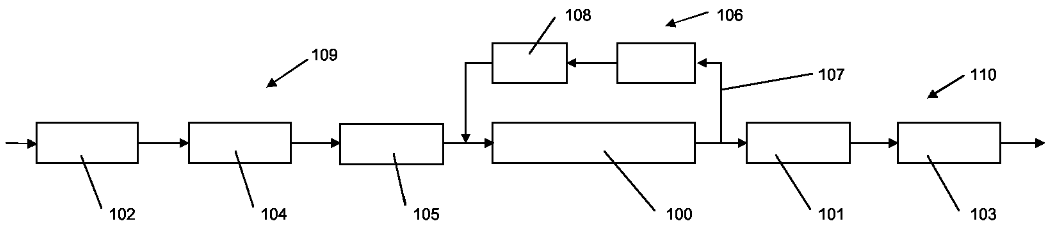


Fig. 1

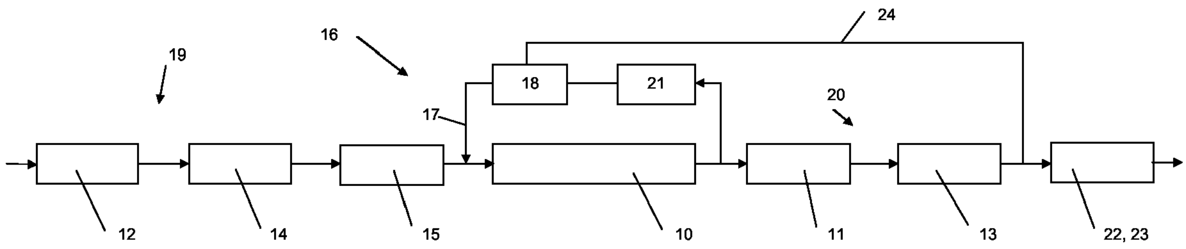


Fig. 2a

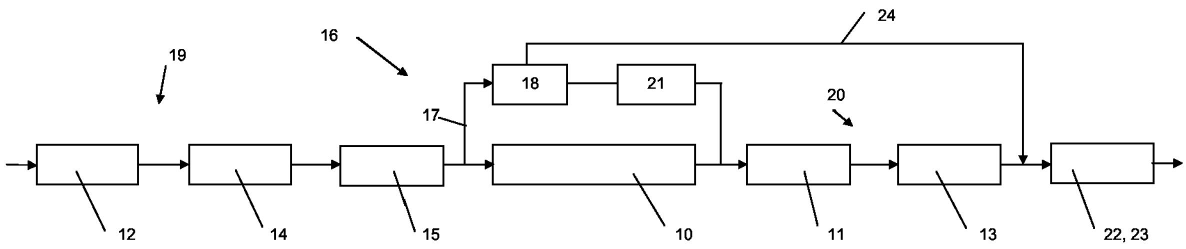


Fig. 2b

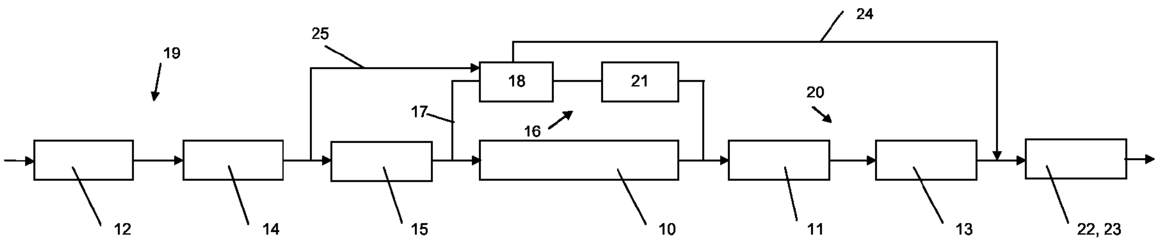
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Fig. 3a

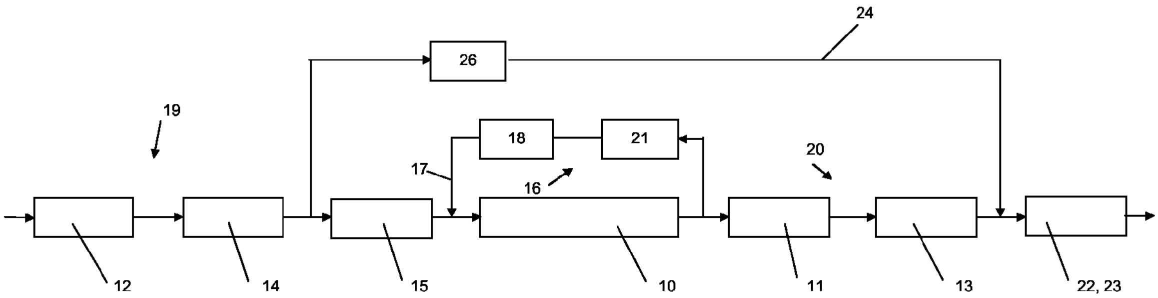
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Fig. 3b

European Patent Office

# EUROPEAN SEARCH REPORT

Application Number
EP 05 10 9065

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| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| The Hague | 7 June 2006 | Raposo, J |

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2

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