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Yacoub(10) **Pub. No.: US 2010/0199643 A1**(43) **Pub. Date: Aug. 12, 2010**(54) **EXHAUST GAS PURIFICATION SYSTEM****Publication Classification**(76) Inventor: **Yasser Mohamed Sayed Yacoub,**
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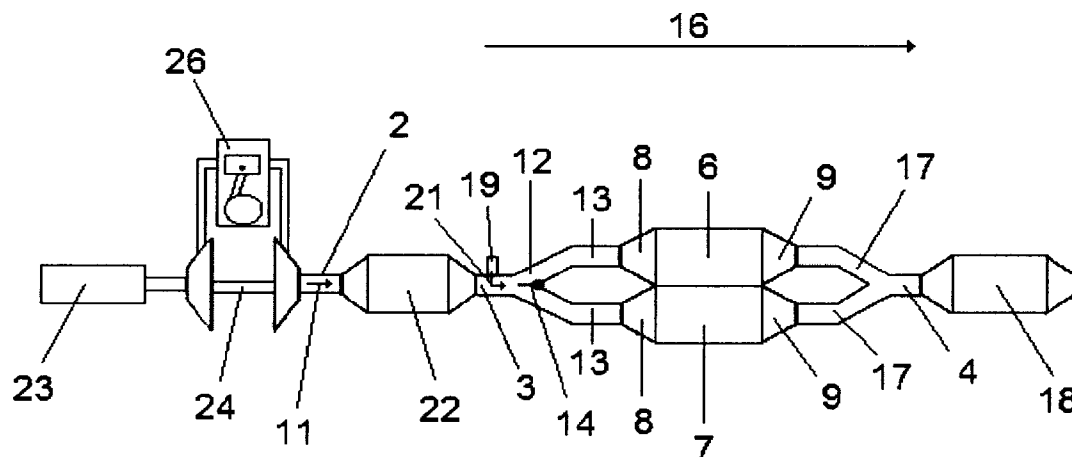
Correspondence Address:

FORD GLOBAL TECHNOLOGIES, LLC
FAIRLANE PLAZA SOUTH, SUITE 800, 330
TOWN CENTER DRIVE
DEARBORN, MI 48126 (US)(57) **ABSTRACT**

The invention relates to an exhaust gas purification system (1) for exhaust gases from an internal combustion engine, in particular from a diesel engine, said system being arranged in an exhaust tract (2) which has a primary exhaust gas treatment system (22) and an inlet line (3) with a metering device (19). In order to achieve higher efficiency in nitrogen conversion, it is proposed that the inlet line (3) together with the metering device (19) be arranged downstream of the exhaust gas treatment system (22) and that the inlet line (3) be divided downstream by the metering device (19) into two catalyst lines (13) which lead the exhaust gas stream from the internal combustion engine in each case to a catalyst element (6, 7), the exhaust gas stream being steerable into the first catalyst element (6) or the second catalyst element (7) by means of a control valve (14).

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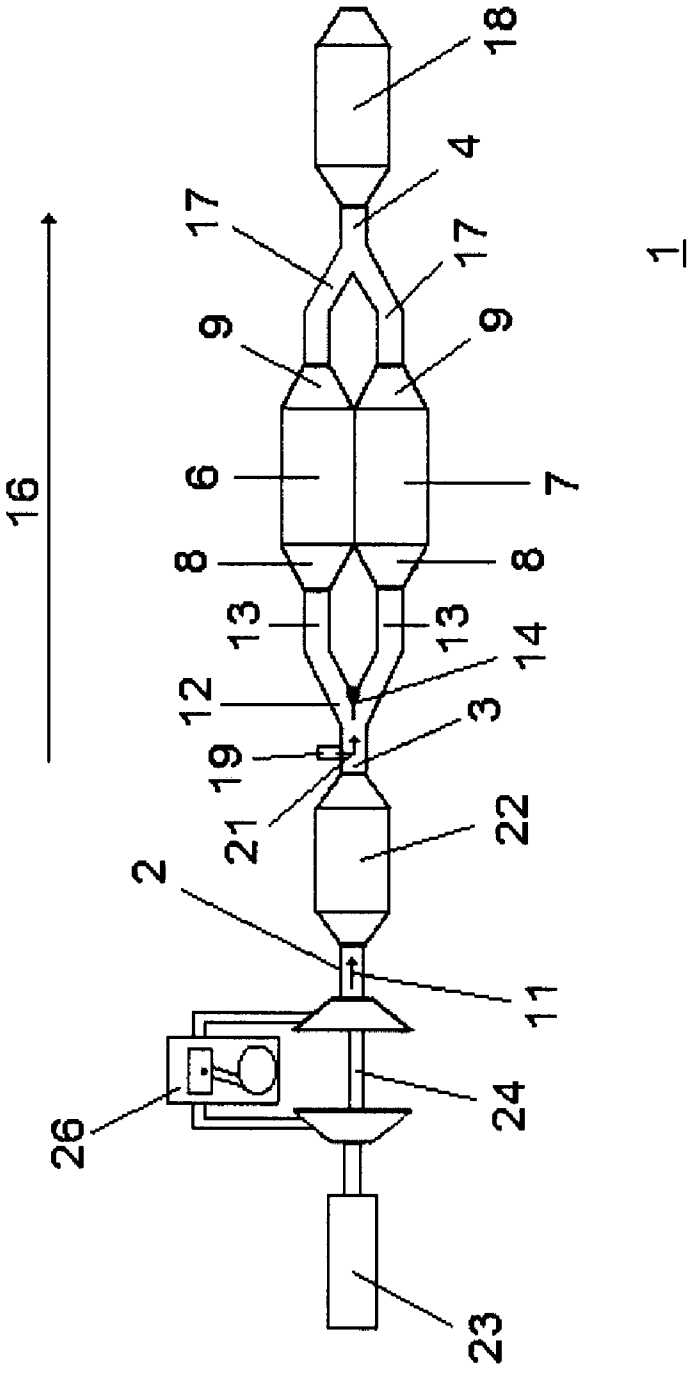


Fig. 1

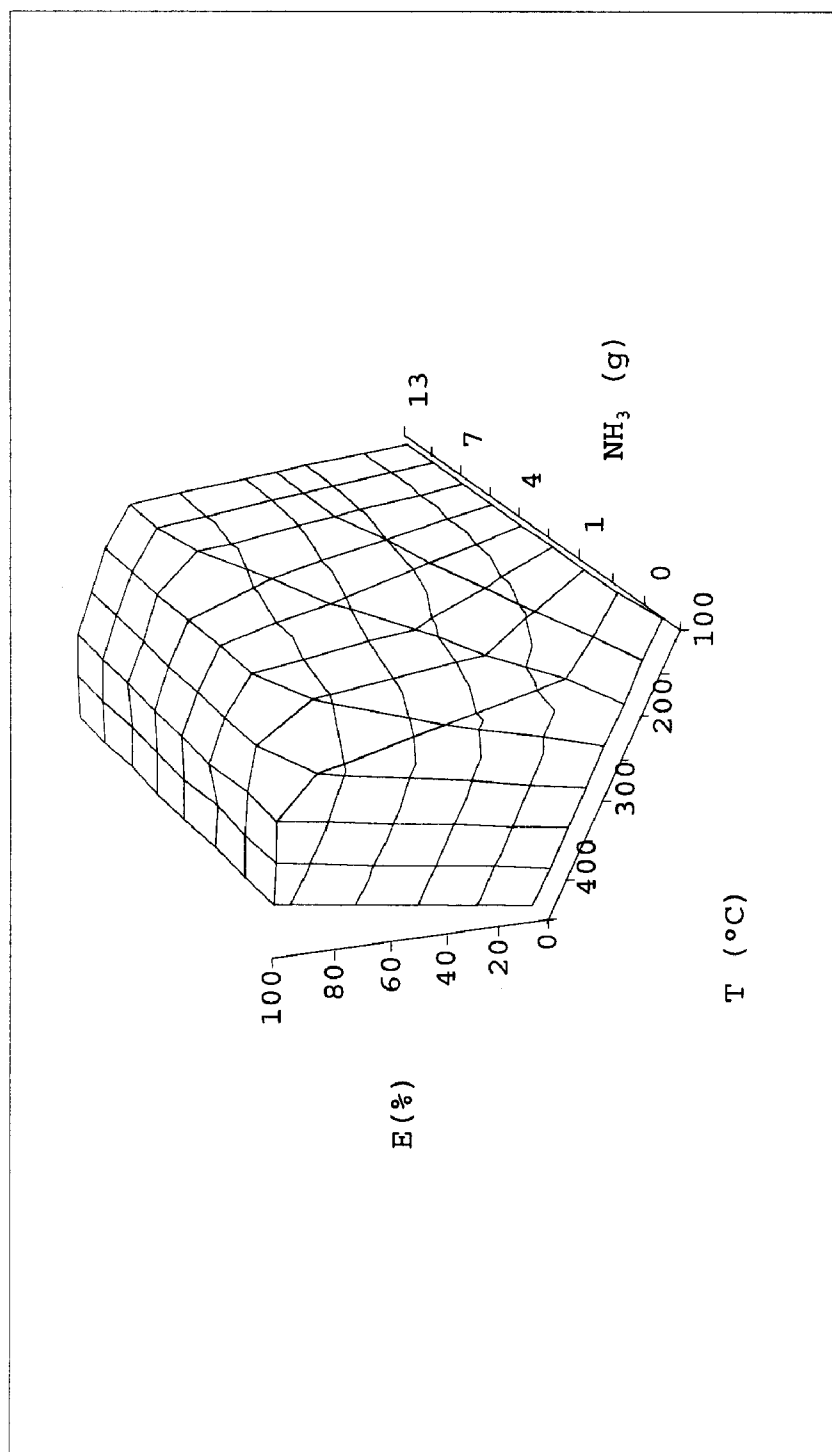


Fig. 2

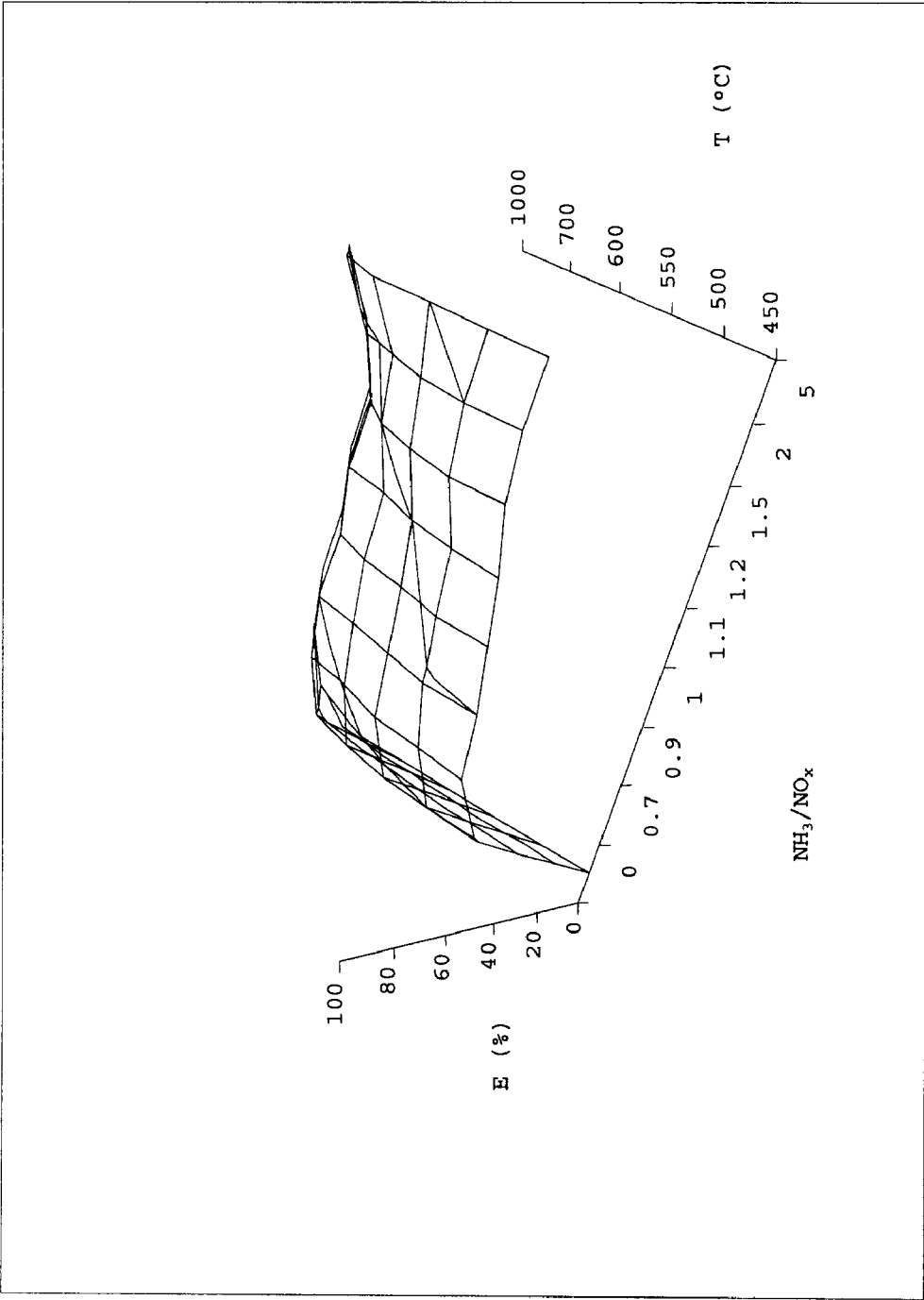


Fig. 3

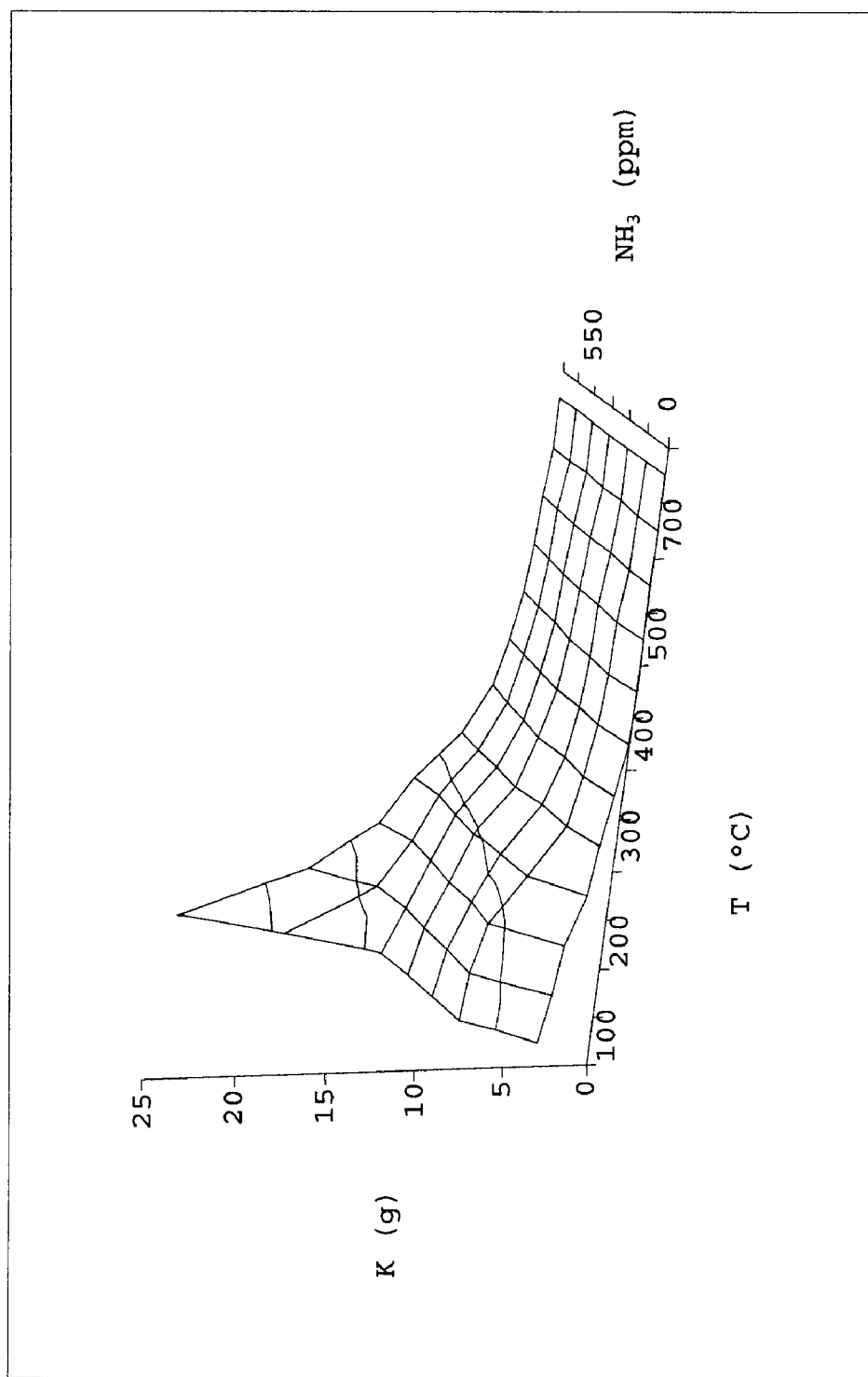


Fig. 4

EXHAUST GAS PURIFICATION SYSTEM

[0001] The disclosure relates to an exhaust gas purification system for exhaust gases from an internal combustion engine, in particular from a diesel engine, said system being arranged in an exhaust tract which has a primary exhaust gas treatment system and an inlet line with a metering device.

[0002] The disclosure relates, furthermore, to a method for nitrogen oxide reduction in an exhaust gas purification system.

BACKGROUND AND SUMMARY

[0003] US 2008/0127635 A1 discloses an exhaust gas purification system with a housing with a dividing element creating a plurality of air. At least one catalytic converter and one particle filter are arranged in the housing. The at least one dividing element is arranged such as to form two chambers which lie one above the other and are connected opposite to the exhaust gas inlet, so that the exhaust gas stream is deflected out of one chamber into the other chamber. An exhaust gas purification apparatus having a reduced longitudinal extent is thereby to be made available, since the two chambers are arranged so as to lay one above the other. The exhaust gas stream therefore flows in succession through the purification elements arranged in the housing, these being connected virtually in series.

[0004] WO 2006/021337 A1 teaches a catalytically coated particle filter having a first and a second end face and an axial length. The particle filter, commencing from its first end face, is coated on a fraction of its length with a first catalyst and thereafter with a second catalyst. The first catalyst has platinum and palladium on the first carrier material, the second catalyst containing platinum and, if appropriate, palladium on the second carrier materials. The particle filter to that extent has two catalyst coatings lying in series with respect to the exhaust gas stream. Filters of this type possess a high thermal mass and heat up only slowly, which is why an increased concentration of noble metal in the entry region of the filter is provided.

[0005] WO 2006/021338 A1 discloses a method for coating a wall flow filter. Wall flow filters have two end faces and a multiplicity of flow ducts running parallel with respect to the cylinder axis. To generate the filter action, the flow ducts are closed alternately on the first and the second end face. On its way through the filter, the exhaust gas has to change over from the inlet ducts through the duct walls between the inlet and outlet ducts into the outlet ducts of the filter.

[0006] DE 602 22 826 T2 (=part WO 03/068362) discloses a filter for exhaust gas treatment. The filter has a plurality of axially running flow ducts which are closed alternately at least in a second filter portion. The cylindrical filter is a filter role consisting of folded filter medium which is spirally wound from a web. In a first throughflow portion, exhaust gas flows through, unfiltered. The first throughflow portion is a middle inner portion which is surrounded by the annularly designed second filter portion. The middle inner portion is merely a throughflow portion with open flow ducts. The filter portion has a catalyst portion and a particle filter portion which are arranged in succession. In one embodiment, part of the exhaust gas stream flows through the filter portion and another part flows, unfiltered, through the inner portion. However, because of this, some of the exhaust gases are not purified at all. For the overall exhaust gas stream to undergo

purification, an exhaust pipe is connected to the inner throughflow portion, so that the overall exhaust gas stream flows through the throughflow portion and flows, unfiltered, into a rear chamber. In this, the exhaust gas stream is forced to flow back to the inlet side through the filter portion in which the catalyst portion and the filter portion are successively arranged in a similar way to the version of WO 2006/021338 A1.

[0007] WO 2004/027230 discloses a device for the reduction of emissions, which consist of two parallel exhaust gas paths and two regeneratable emission-reducing elements, the first emission-reducing element having a higher emission-reducing capacity than the second. The exhaust gas stream is conducted primarily through the first emission-reducing element. To regenerate the first emission-reducing element, a valve arranged upstream of this element is closed and a second valve arranged upstream of the second emission-reducing element is opened, so that the exhaust gas stream is conducted through the second emission-reducing element.

[0008] In order to treat exhaust gases from an internal combustion engine, in particular from a diesel engine, therefore, it is known to arrange a catalyst element and a filter element, in particular a particle filter, in an exhaust tract of the internal combustion engine. In this case, the catalyst element is arranged either upstream of the particle filter or downstream of the particle filter, both components being capable of being arranged in one common housing. The two components may, of course, also be arranged successively in separate housings in the exhaust tract.

[0009] If the particle filter is arranged upstream of the catalyst element, soot combustion (regeneration) can be carried out more quickly, since the exhaust gas stream still contains sufficient nitrogen oxides. The disadvantage, however, because of the high thermal mass of the (diesel) particle filter, is that the temperature in the catalyst element rises very slowly, thus leading to reduced nitrogen oxide conversion of the catalyst. On the other hand, the catalyst or the catalyst element reaches operating temperature more quickly if it is arranged upstream of the (diesel) particle filter, thus leading to a higher nitrogen oxide conversion. However, this leads to reduced soot combustion because of a reduced nitrogen oxide concentration in the exhaust gas, where both active and passive regeneration are concerned. Both combinations therefore have just as many advantages as disadvantages.

[0010] This disclosure therefore, is directed to teaching an improved exhaust gas purification system such that exhaust gases, in particular diesel exhaust gases, can be purified more efficiently, and, in particular, the efficiency of the nitrogen oxide conversion is increased.

[0011] Accordingly, a system for treating an exhaust gas from an internal combustion engine is presented, the system including a primary exhaust gas treatment system; a first catalyst coupled downstream of said primary exhaust gas treatment system; a second catalyst coupled downstream of said primary exhaust gas treatment system; an inlet line connecting said primary exhaust gas aftertreatment system to said first catalyst and said second catalyst, said inlet line having a valve and a reductant metering device; and a controller adjusting said valve to direct said exhaust gas either into said first catalyst element or into said second catalyst element based on a temperature of said exhaust gas.

[0012] In an exemplary embodiment, the two catalysts are arranged such that the engine exhaust gas stream, depending on its properties (exhaust gas temperature, etc.), is directed

via a control valve into one of two catalysts where nitrogen oxide conversion (NO_x conversion) takes place.

[0013] Arranged in the exhaust tract are a plurality of sensors which serve for detecting the temperature, the molecular ratio of NH_3 and NO_x , and the oxygen, nitrogen oxide and/or ammonia content in the exhaust gas stream and/or in the catalyst element and which are connected to a control unit. A plurality of the functions mentioned may also be integrated in a single sensor.

[0014] The first and second catalysts are preferably SCR catalysts (SCR: selective catalytic reduction). In this case, the nitrogen oxides are reacted with ammonia (NH_3) and oxygen (O_2) to form elementary nitrogen (N_2) and water (H_2O). Furthermore, an SCR catalyst is capable of storing at low temperatures the ammonia which is used and which is then desorbed at higher temperatures.

[0015] Preferably, the ammonia required for the reaction in the SCR catalyst is not used in pure form, but, instead, as an aqueous urea solution (urea: $(\text{NH}_2)_2\text{CO}$). This aqueous solution is sprayed, upstream of the SCR catalysis, into the exhaust tract, and, as a result of a hydrolysis reaction, carbon dioxide (CO_2) and the required ammonia are formed.

[0016] Preferably, a reducing reagent can be injected into the exhaust gas stream, upstream of the catalysts, through the metering device. Preferably, further, the reducing reagent is ammonia. The ammonia is required for nitrogen oxide conversion, as described above.

[0017] The control valve preferably conducts the exhaust gas stream either into the first catalyst or into the second catalyst as a function of the ratio between the exhaust gas temperature and stored ammonia at low temperatures or the ratio between the exhaust gas temperature and the NH_3/NO_x ratio at the inlet of the catalyst, the first catalyst being suitable for nitrogen oxide conversion at low exhaust gas temperatures, and the second catalyst being suitable for nitrogen oxide conversion at high exhaust gas temperatures.

[0018] The switchable control valve is arranged in the exhaust gas stream and is used for conducting the exhaust gas stream either into a first catalyst or a second catalyst. Into which of the systems the exhaust gas stream is conducted is determined from the function of the exhaust gas temperature and of the quantity of ammonia stored in the first and second catalysts and from the function of the exhaust gas temperature and the molecular ratio between the ammonia and nitrogen oxide at the inlet line by a controller connected to the control valve.

[0019] Preferably, an exhaust gas stream having a low exhaust gas temperature is conducted into a first catalyst in which the content of stored ammonia is maintained near the maximum storage capacity, while an exhaust gas stream having a high exhaust gas temperature is conducted into a second catalyst in which the content of the stored ammonia is maintained low and ammonia is injected directly into the exhaust gas stream.

[0020] Preferably, at low exhaust gas temperatures, the control valve is switched such that the largest part of the exhaust gas runs through the first catalyst when the ammonia storage content in the first catalyst is near the desired threshold.

[0021] In the event of low ammonia storage content in the first catalyst, the control valve is set such that most exhaust gases are conducted through the second catalyst, with ammonia being injected directly. The remaining exhaust gases are conducted into the first catalyst, mainly in order to fill the first

catalyst with ammonia. When first catalyst has stored the desired ammonia content, the control valve is changed over in order to conduct most exhaust gases having a low temperature through the first catalyst.

[0022] Preferably, for exhaust gas streams having high temperatures, the control valve is set such that exhaust gases are conducted through the second catalyst which is then used in order to convert the NO_x exhaust gas emissions by setting the quantity of the directly injected ammonia.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] FIG. 1 shows an embodiment of an exhaust gas purification system according to the present disclosure;

[0024] FIG. 2 shows a graph in which the efficiency of nitrogen oxide conversion is illustrated as a function of the catalyst temperature (exhaust gas temperature) and stored ammonia;

[0025] FIG. 3 shows a graph in which the efficiency of nitrogen oxide conversion is illustrated as a function of the catalyst temperature (exhaust gas temperature) and molecular ratio of ammonia to the oxides of the nitrogen at the inlet to an SCR catalyst; and

[0026] FIG. 4 shows a graph in which the ammonia storage capacity is illustrated as a function of the catalyst temperature and ammonia concentration at the inlet to an SCR catalyst.

DESCRIPTION OF PREFERRED EMBODIMENT(S)

[0027] FIG. 1 shows a diagrammatic set-up of an exhaust gas purification system 1 according to the invention for exhaust gases from an internal combustion engine, in particular from a diesel engine, said system being arranged in an exhaust tract 2. The exhaust tract 2 has an inlet line 3 and an outlet line 4. The exhaust gas purification system 1 according to the invention has two exhaust gas treatment elements which are designed as catalysts 6, 7.

[0028] Both catalysts 6, 7 have in each case an entry side 8 and an exit side 9 lying opposite this.

[0029] The inlet line 3 conducts exhaust gases coming from the internal combustion engine in the direction of the exhaust gas purification system 1 (arrow 11). On the inlet side, the inlet line 3 has a branch 12 which divides the inlet line 3 into two catalyst lines 13. Arranged in the branch 12 is a control valve 14. The control valve 14 is controlled by a controller, not shown in the figure. The controller evaluates the data measured by sensors (not shown in the figure), such as, for example, the ammonia content, NO_x content, exhaust gas temperature or catalyst temperature, ratio of ammonia to NO_x at the inlet to the catalyst elements 6, 7, etc., and, by adjusting the position of the control valve 14 fastened in the exhaust gas stream, controls the amount of the exhaust gas supplied to catalysts 6, 7, one of the two catalyst elements 6, 7 being designed as a low-temperature SCR catalyst and the other as a high-temperature SCR catalyst. The catalyst lines 13 are connected in each case to the entry side 8 of one of the two catalyst elements 6, 7.

[0030] The exhaust gases flowing into the respective catalysts 6, 7 flow through the respective catalysts 6, 7 with respect to a main flow direction (arrow 16).

[0031] On the outlet side, the respective catalysts 6, 7 have connecting elements 17 for connection to the outlet line 4.

[0032] Downstream, the outlet line 4 may be connected, for example, to a muffler system 18.

[0033] Upstream of the branch 12, a metering device 19 is arranged for supplying a reducing reagent into the exhaust gas stream, such as, for example, ammonia, or urea for ammonia production (arrow 21).

[0034] A primary exhaust gas treatment system 22 may be arranged upstream of the inlet line. The primary exhaust gas treatment system 22 may, for example, contain an oxidation catalyst, a particle filter, an NO_x trap and/or an SCR catalyst.

[0035] An oxidation catalyst serves for increasing the NO_2/NO ratio in the exhaust gas stream. The efficiency of the catalysts 6, 7 can thereby be increased further, since NO_2 reacts more quickly in the SCR catalysts 6, 7 than NO .

[0036] Arranged upstream of the primary exhaust gas treatment system 22 are, for example, a (primary) air filter 23, a turbocharger 24 and an engine system 26 (internal combustion engine). The engine system 26 may, for example contain a charge air cooler, an intake manifold, a combustion system and/or an exhaust manifold.

[0037] In an exemplary embodiment, as shown in FIG. 1, two SCR catalysts 6, 7 are used in parallel. The first catalyst 6 serves for nitrogen oxide conversion at low exhaust gas temperatures and with a low consumption of ammonia. The second catalyst 7 is arranged on a path parallel to the first catalyst element 6 and is designed for high exhaust gas temperatures with a high consumption of ammonia. In the first catalyst 6 (lower-temperature SCR catalyst), the content of the stored ammonia is maintained near the maximum storage capacity (89-90%), in order to achieve as high an efficiency as possible in the nitrogen oxide conversion. Also, both the connecting pipe and the size and capacity of the first SCR catalyst 6 are optimized for nitrogen oxide conversions at low temperatures which would normally lead to a small SCR catalyst because low space velocities are expected.

[0038] In the second SCR catalyst 7, the content of the stored ammonia is maintained low, and the size and capacity of the second catalyst element 7 are optimized for space velocities and exhaust gas temperatures which would normally lead to a somewhat larger SCR catalyst.

[0039] FIG. 2 shows a graph in which the efficiency of nitrogen oxide conversion (E in %) is illustrated as a function of the exhaust gas temperature (T in ° C.) and of the stored ammonia (NH_3 in g).

[0040] As will be gathered from FIG. 2, the efficiency of an SCR catalyst at lower temperatures (up to 400° C.) is dependent both on the exhaust gas temperature and on the quantity of the stored ammonia.

[0041] The efficiency of nitrogen oxide conversion at higher exhaust gas temperatures is influenced mainly by the molecular ratio of NH_3 to NO_x at the inlet of the SCR catalysts 6, 7 (see FIG. 3).

[0042] FIG. 3 shows a graph in which the efficiency of nitrogen oxide conversion (E in %) is illustrated as a function of the exhaust gas temperature (T in ° C.) and of the molecular ratio of ammonia to the oxides of nitrogen at the inlet of the SCR catalyst element 6, 7 (mol ratio of NH_3/NO_x).

[0043] In order to obtain efficient nitrogen oxide conversion when an SCR-based treatment system is in operation, it is necessary to achieve a compromise. When such a system is operating at low exhaust a temperature, that is to say with a low consumption of ammonia, a large quantity of the stored ammonia remains in the catalyst. At high exhaust gas temperatures, the maximum storage capacity of the catalyst is reduced. In order to obtain the desired molecular ratio of

ammonia to NO_x at the inlet of the SCR catalyst 7, the quantity of ammonia stored in the catalyst 7 must be reduced to a lower limit, so that nitrogen oxide conversion is controlled mainly by the direct injection of ammonia.

[0044] FIG. 4 shows a graph in which the ammonia storage capacity (K in g) is illustrated as a function of the catalyst temperature (T in ° C.) and ammonia concentration at the inlet of the SCR catalysts 6, 7 (NH_3 in ppm).

[0045] As shown in FIG. 4, the ammonia storage capacity is significantly reduced at higher exhaust gas temperatures. It has therefore been assumed hitherto that a sudden rise in the catalyst temperature where there is a high content of stored ammonia leads to a sudden desorption of the stored ammonia which in turn leads to a direct ammonia slip. The ammonia slip is ammonia which was overdosed in relation to the NO_x fraction or did not possess the temperature required for a reaction.

1. A system for treating an exhaust gas from an internal combustion engine, comprising:

- a primary exhaust gas treatment system;
- a first catalyst coupled downstream of said primary exhaust gas treatment system;
- a second catalyst coupled downstream of said primary exhaust gas treatment system; an inlet line connecting said primary exhaust gas aftertreatment system to said first catalyst and said second catalyst, said inlet line having a valve and a reductant metering device; and
- a controller adjusting said valve to control an amount of said exhaust gas entering said first catalyst and said second catalyst based on a temperature of said exhaust gas.

2. The system as claimed in claim 1, wherein the engine is a diesel engine.

3. The system as claimed in claim 2, wherein said first catalyst and said second catalyst are SCR catalysts.

4. The system as claimed in claim 3, wherein said reductant metering device injects urea into the exhaust gas stream.

5. The system as claimed in claim 4 wherein said controller further controls an amount of said exhaust gas entering said first catalyst and said second catalyst based on a ratio of NH_3 to NO_x at said inlet line.

6. The system as claimed in claim 5 wherein said controller adjusts said valve such that a major portion of total exhaust gas flow is directed to said first catalyst when said temperature of said exhaust gas is below a first predetermined threshold and an amount of ammonia stored in said first catalyst is above a second predetermined threshold.

7. The system as claimed in claim 5 wherein said controller adjusts said valve such that a major portion of total exhaust gas flow is directed to said second catalyst when said temperature of said exhaust gas is above said first predetermined threshold.

8. The system as claimed in claim 5 wherein when said temperature of said exhaust gas is below said predetermined threshold and said amount of ammonia stored in said first catalyst is below a second predetermined threshold, said controller adjusts said valve such that a major portion of total exhaust gas flow is directed to said second catalyst; said controller further controls said reductant metering device to allow said amount of ammonia stores in said first catalyst to reach said first predetermined threshold.

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