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(54) **An exhaust system and a method for such a system**

(57) The invention relates to an exhaust system providing at least one exhaust path for a vehicle internal combustion engine (2) comprising a particulate filter (5) adapted to store particulate matter, and a nitrogen oxides absorber (4). The nitrogen oxides absorber (4) is located

upstream of the particulate filter (5), and hydrocarbon supply means (6) are adapted to supply hydrocarbon, into at least one of the exhaust paths, upstream of the particulate filter (5) and downstream of the nitrogen oxides absorber (4).

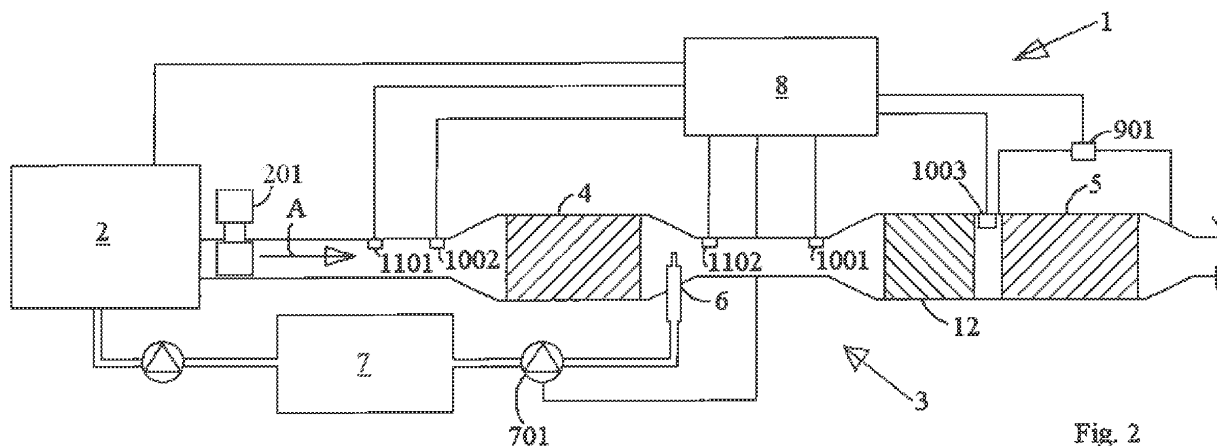


Fig. 2

Description

TECHNICAL FIELD

[0001] The present invention relates to an exhaust system providing at least one exhaust path for a vehicle internal combustion engine comprising a particulate filter adapted to store particulate matter, and a nitrogen oxides adsorber. The invention also relates to a method for such a system.

BACKGROUND

[0002] An exhaust aftertreatment system for a vehicle diesel engine traditionally includes a diesel oxidation catalyst for control of carbon monoxide (CO), hydrocarbons (HC), and soluble organic fractions of particulate matter in the exhaust gases. In addition, a particulate filter, also known as a catalyzed soot filter, diesel particulate filter, carbon trap or carbon particulate filter, adapted to store carbonaceous particulate matter from the exhaust gas, can be provided. In recent years, it has been suggested to replace or complement the diesel oxidation catalyst with a nitrogen oxides (NOx) adsorber, also known as a NOx adsorber catalyst or a lean NOx trap, which is adapted to trap (adsorb) and reduce oxides of nitrogen such as nitrogen monoxide (NO) and nitrogen dioxide (NO₂).

[0003] Below, different types of "regenerations" needed to be performed to maintain the emissions performance of an exhaust aftertreatment system comprising both a NOx adsorber catalyst and a particulate filter, are described briefly.

[0004] A NOx adsorber comprises a catalyst washcoat that chemically adsorbs NO and NO₂ molecules, and when the trap is "full", the NOx adsorber is regenerated or "purged". This type of regeneration will in the following be denoted a "DeNOx regeneration". Such a regeneration can be performed by periodically, temporarily changing the engine operation to provide rich conditions (λ value < 1) in the exhaust gas. Thereby, the trapped NOx molecules will react with CO and hydrocarbons to produce water (H₂O), carbon dioxide (CO₂) and nitrogen gas (N₂). Such a combined release and conversion of trapped NOx molecules by a temporary switch, performed entirely by engine measures to produce rich conditions in the exhaust gas, is here referred to as an "engine control DeNOx regeneration". Alternatively, regeneration of the NOx adsorber can be carried out by injecting fuel into the exhaust path upstream of the NOx adsorber, for example as described in US6745560B2, EP1223312A1 and US2003/0140621A1.

[0005] A well known drawback of NOx adsorbers is their susceptibility to poisoning by sulfur components in the exhaust gas. Sulfur is strongly bound to the NOx adsorber catalyst washcoat, thus reducing the NOx storage capability, and sulfur components are not readily released from the NOx adsorber during DeNOx regenerations. To remove the poisoning sulfur components and

recover the NOx storage capability of the NOx adsorber, a special type of "DeSOx regeneration" must be performed at regular intervals. A DeSOx regeneration requires both rich conditions in the exhaust gas and a high NOx adsorber temperature, generally above e.g. 600-650°C. DeSOx regenerations can be performed entirely by changing the engine operation to provide the required conditions in the exhaust gas.

[0006] A particulate filter needs to be regenerated to avoid overloading of soot. This type of regeneration is in the following denoted a "particulate filter regeneration". It can be performed by periodically changing the engine operation to provide suitable conditions for soot oxidation. As opposed to DeNOx and DeSOx regenerations, a particulate filter regeneration does not require rich conditions in the exhaust gas. For the oxidation of captured soot in the particulate filter, the exhaust gas temperature is raised to e.g. 600°C and lean conditions in the exhaust gas (λ value > 1) are maintained such that the oxygen concentration is sufficient to ensure efficient oxidation of the captured soot particles, also known as soot burnout.

[0007] During particulate filter regeneration there is usually an aim to keep the temperature of the filter at a target filter temperature which is an optimum operating temperature where the soot oxidation rate is sufficiently high, but the temperature is not so high as to cause a significant risk for filter damage due to excessive temperatures within the particulate filter. In known solutions for particulate filter regeneration the target temperature is generally achieved by producing an exotherm across an oxidation catalyst positioned upstream of the particulate filter. A problem occurs where the oxidation catalyst is replaced by a NOx adsorber, since particulate filter regenerations can significantly accelerate the ageing of the NOx adsorber. The catalyst washcoat of a NOx adsorber is significantly more temperature sensitive than that of an oxidation catalyst, and the conditions required for particulate filter regeneration can result in significant thermal ageing through the exothermic reactions taking place in the NOx adsorber. During a particulate filter regeneration, the temperature within the NOx adsorber can come up to 850°C during transient driving conditions, whereas temperatures in excess of e.g. 700°C can be detrimental to the catalyst washcoat of the NOx adsorber.

[0008] Also, in the solution in said US6745560B2, with the NOx adsorber downstream of the particulate filter, the substantial risk of accelerated thermal ageing of the NOx adsorber must be taken into account.

SUMMARY OF THE INVENTION

[0009] It is an object of the invention to provide effective regeneration of a particulate filter in a vehicle exhaust system, while reducing or avoiding risks of causing excessive ageing to a nitrogen oxides adsorber of the exhaust system,

[0010] This object is reached with an exhaust system

of the type mentioned initially, wherein the nitrogen oxides absorber is located upstream of the particulate filter, and hydrocarbon supply means are adapted to supply hydrocarbon, into at least one of the exhaust paths, upstream of the particulate filter and downstream of the nitrogen oxides absorber,

[0011] The supply of hydrocarbon into the exhaust gas can be performed with a low-pressure fuel injector, or with an alternative device for providing finely dispersed or gaseous hydrocarbons into the exhaust gas stream.

[0012] By supplying hydrocarbon upstream of the particulate filter and downstream of the NOx adsorber a temperature increase for particulate filter regeneration, or soot burn-out, of the particulate filter can be produced by an exothermic reaction within the particulate filter itself. Since the hydrocarbon supply takes place downstream of the NOx adsorber, particulate filter regeneration measures will not cause a temperature increase in the NOx adsorber, and the thermal ageing of the latter will be significantly reduced. The hydrocarbon supply can be activated for particulate filter regeneration during all driving conditions, even at low exhaust temperatures, e.g. during low-load and idling driving conditions when the temperature within the NOx adsorber is relatively low, to maintain a target temperature (e.g. 600°C) within the particulate filter.

[0013] During conditions of low exhaust temperatures, the combustion efficiency of the engine may be reduced as to increase the exhaust gas temperature, with the intention of supporting the soot oxidation process during particulate filter regeneration. In this case, a moderate temperature increase may be produced by exothermic reactions within the NOx adsorber, but the temperature should be maintained at such levels as to render the thermal ageing effect on the NOx adsorber negligible.

[0014] In principle, the hydrocarbon type is not limited to any specific compounds; instead the hydrocarbon source can be comprised of a variety of organic compounds based on carbon and hydrogen, the molecular structure of which can vary as is known in the art. Preferably, the hydrocarbon supply means are adapted to supply hydrocarbon by supplying fuel from fuel storage means adapted to store fuel for the engine,

[0015] Preferably, catalytic, oxidation means adapted for hydrocarbon oxidation are provided upstream of the particulate filter and downstream of the hydrocarbon supply means. Thereby, hydrocarbons can be supplied upstream of the catalytic oxidation means so that all, or at least a part of the exothermic reactions take place within the catalytic oxidation means. This will provide for the particulate filter regeneration to be even more effective and will enable a more accurately temperature-controlled particulate filter regeneration process. In addition, the risk for hydrocarbon breakthrough downstream the particulate filter is reduced. The catalytic oxidation means can be provided in the form of an oxidation catalyst, or another type of catalyst with a similar capability of hydrocarbon oxidation, such as a three way catalyst, or a further NOx

adsorber with a hydrocarbon oxidation capacity.

[0016] Preferably, the nitrogen oxides absorber is located directly downstream of a turbocharger of the engine. This means that there is no intermediate device between the NOx adsorber and the turbocharger regardless whether the NOx adsorber is located in the direct vicinity of the turbocharger or at a distance from it. As mentioned below, this can provide a rapid activation of the NOx adsorber after engine start, and also an efficient abatement of CO and hydrocarbon emissions where the NOx adsorber has an oxidizing function.

[0017] The object is also reached with a method according to any of the claims 5-6.

DESCRIPTION OF THE FIGURES

[0018] Below, the invention will be described in detail with reference to the drawings, in which

- fig. 1 shows schematically an engine system with an exhaust system according to an embodiment of the invention, and
- fig. 2 shows schematically an engine system with an exhaust system according to an alternative embodiment of the invention.

DETAILED DESCRIPTION

[0019] Fig. 1 shows an engine system 1 in a vehicle, with an internal combustion engine 2, in the form of a diesel engine 2, and an exhaust system 3 providing an exhaust path, in a direction indicated with an arrow A. for exhaust gases from the engine 2. A turbine of a turbocharger 201 is provided downstream of an exhaust manifold (not shown) of the engine 2. It should be mentioned that the invention is of course also applicable to engines without turbochargers.

[0020] The exhaust system 3 comprises a NOx adsorber 4, and a particulate filter 5 adapted to store particulate matter. The NOx adsorber 4 is located upstream of the particulate filter 5, preferably in a close-coupled position directly downstream the turbocharger 201. In this context, the location of the NOx adsorber 4 in a close-coupled position directly downstream of the turbocharger 201 means that there is no intermediate device between the NOx adsorber 4 and the turbocharger 201. An advantage of placing the NOx adsorber in this position is a rapid heat-up of the NOx adsorber, giving a quick so-called "light-off with activation of the NOx adsorber function rapidly after, engine start. Given that the NOx adsorber has an oxidizing function, its positioning in the close-coupled position also enables efficient abatement of CO and hydrocarbon emissions.

[0021] Hydrocarbon supply means 6 are provided upstream of the particulate filter 5 and downstream of the NOx adsorber 4. The hydrocarbon supply means 6 is adapted to provide into the exhaust, path finely dispersed or gaseous hydrocarbons, in the form of diesel fuel, and

is for this purpose adapted to communicate, via a separate conduit and by means of a fuel pump 701, with fuel storage means, in the form of a fuel tank 7, adapted to store diesel fuel for the engine 2. It should be mentioned that as an alternative, the hydrocarbon supply means 6 can be adapted to communicate with fuel storage means which are separate from the fuel tank for the engine 2. The hydrocarbon supply means 6 could be provided in the form of a fuel evaporation unit as described in EP1369557B1 or EP 1643092A1, or as a part of an agent injection system as described in WO 2006138233A3.

[0022] The engine system comprises an engine control unit 8 adapted to control air flow control means (not shown) and fuel injection means (not shown) of the engine 2 in a manner known in the art. In the exhaust system 3, a differential pressure sensor 901 is connected upstream and downstream, respectively, of the particulate filter 5. An upstream connection pipe to the differential pressure sensor 901 is located downstream of the NOx adsorber 4. The engine control unit 8 is adapted to receive a signal from the differential pressure sensor 901, and to determine based thereon the pressure difference across the particulate filter 5.

[0023] A first temperature sensor 1001 is located in the exhaust system 3 upstream of the particulate filter 5 and downstream of the NOx adsorber 4. Based on the pressure difference, determined by means of the differential pressure sensor 901, and signals from the first temperature sensor 1001, the engine control unit 8 can determine whether accumulated soot amount in the particulate filter 5 has reached a level at which a particulate filter regeneration should be initiated. Alternatively, or in addition, in a particulate filter data model can be used by the control unit 8 to determine whether a particulate filter regeneration should be initiated, and/or particulate filter regeneration can be carried out at predetermined distances covered by the vehicle.

[0024] The engine control unit 8 is adapted to receive signals from a first and second lambda sensor 1101, 1102, located upstream and downstream, respectively, of the NOx adsorber 4. The second lambda sensor 1102 is located upstream of the particulate filter 5. Based on signals from the first and second lambda sensors 1101, 1102, the engine control unit 8 can determine the NOx emissions performance of the NOx adsorber 4 and whether DeNOx or DeSOx regenerations need to be initiated. The signals from the lambda sensors 1101, 1102 can also be used by the engine control unit 8 to determine an appropriate termination time of an activated DeNOx or DeSOx regeneration procedure.

[0025] The engine control unit 8 is adapted to receive signals from a second temperature sensor 1002, located in the exhaust system 3, upstream of the NOx adsorber 4. Based on signals from the temperature sensors 1001, 1002, the engine control unit 8 can estimate the temperature within the NOx adsorber 4, with the objective of avoiding thermal ageing of the latter. The estimated temperature within the NOx adsorber 4 enables the engine

control unit 8 to perform accurate temperature control and avoidance of thermal ageing effects on the NOx adsorber 4 during both DeSOx regenerations and during particulate filter regenerations, in the case that a moderate temperature increase within the NOx adsorber is produced from engine measures.

[0026] The engine control unit 8 can also be adapted to receive signals from a third temperature sensor 1003, located in the exhaust system 3, downstream of the particulate filter 5. Based on the signals from the first and third temperature sensors 1001, 1003, located upstream and downstream, respectively, of the particulate filter 5, the engine control unit 8 can estimate the temperature within the filter during particulate filter regenerations and accordingly adjust the dosing amount of hydrocarbons through hydrocarbon supply 6,

[0027] Fig. 2 shows an engine system 1 with an exhaust system 3 according to an alternative embodiment of the invention. The exhaust system in fig. 2 is similar to the one described above with reference to fig. 1, except for the following features. Catalytic oxidation means in the form of an oxidation catalyst 12 is provided upstream of the particulate filter 5 and downstream of the hydrocarbon supply means 6. As mentioned above, this provides for fuel to be provided upstream of the oxidation catalyst 12, in order to regenerate the particulate filter 5, so that at least a part of the exothermic reactions giving a temperature increase in the particulate filter 5 take place in the oxidation catalyst 12. Preferably, all or a major part of these exothermic reactions take place in the oxidation catalyst 12. As also mentioned above, the catalytic oxidation means 12 can be provided in the form of another type of catalyst with a similar capability of hydrocarbon oxidation.

[0028] In the embodiment shown in fig. 2, a third temperature sensor 1003 is positioned downstream of the oxidation catalyst 12 and upstream of the particulate filter 5. Based on the signals from the temperature sensors 1001, 1003, located upstream and downstream, respectively, of the oxidation catalyst 12, the engine control unit 8 can adjust the dosing amount of hydrocarbons through hydrocarbon supply 6 and estimate the temperature within particulate filter 5 during particulate filter regenerations.

Claims

1. An exhaust system providing at least one exhaust path for a vehicle internal combustion engine (2) comprising a particulate filter (5) adapted to store particulate matter, and a nitrogen oxides absorber (4), **characterized in that** the nitrogen oxides absorber (4) is located upstream of the particulate filter (5), and hydrocarbon supply means (6) are adapted to supply hydrocarbon, into at least one of the exhaust paths, upstream of the particulate filter (5) and downstream of the nitrogen oxides absorber (4).

2. An exhaust system according to claim 1, wherein the hydrocarbon supply means (6) are adapted to supply hydrocarbon by supplying fuel from fuel storage means (7) adapted to store fuel for the engine. 5
3. An exhaust system according to any of the preceding claims, wherein catalytic oxidation means (12) adapted for hydrocarbon oxidation are provided upstream of the particulate filter (5) and downstream of the hydrocarbon supply means (6). 10
4. An exhaust system according to any of the preceding claims, wherein the nitrogen oxides absorber (4) is located directly downstream of a turbocharger (201) of the engine (2), 15
5. A method for an exhaust system providing at least one exhaust path for a vehicle internal combustion engine comprising a particulate filter (5) adapted to store particulate matter, and a nitrogen oxides absorber (4), **characterized in** regenerating the particulate filter (5) by supplying hydrocarbon, into at least one of the exhaust paths, upstream of the particulate filter (5) and downstream of the nitrogen oxides absorber (4). 20 25
6. A method according to claim 5, wherein the hydrocarbon is supplied upstream of catalytic oxidation means (12), adapted for hydrocarbon oxidation and provided upstream of the particulate filter (5). 30

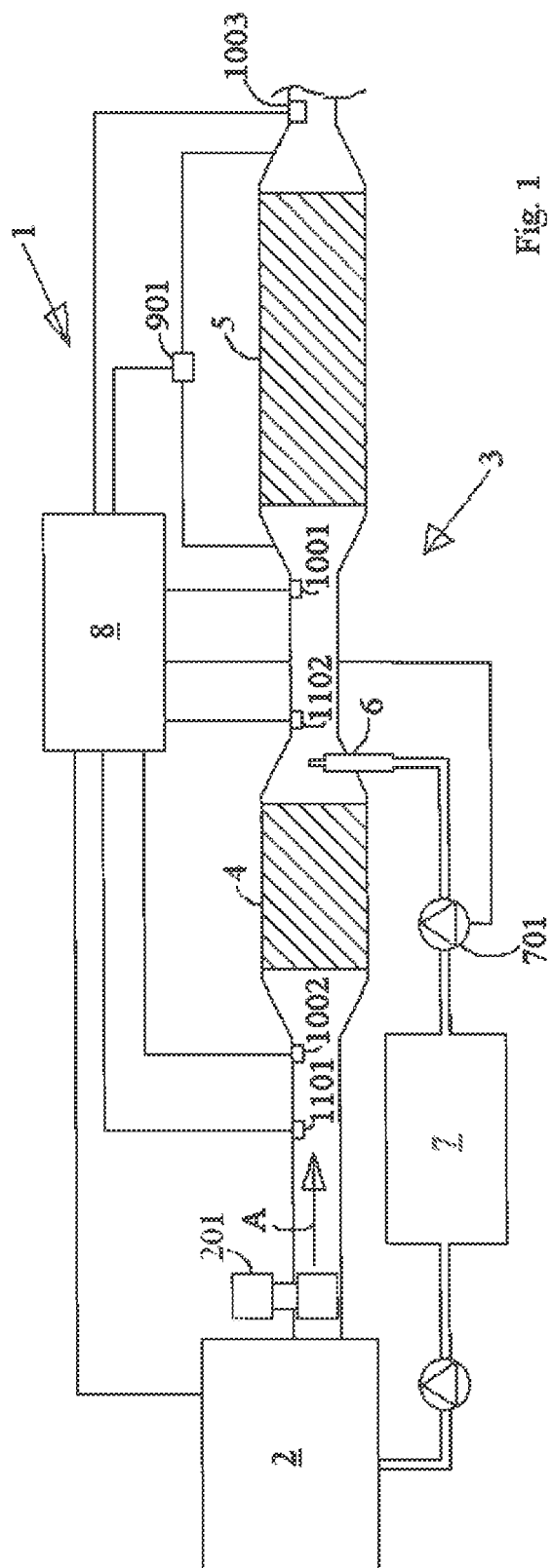
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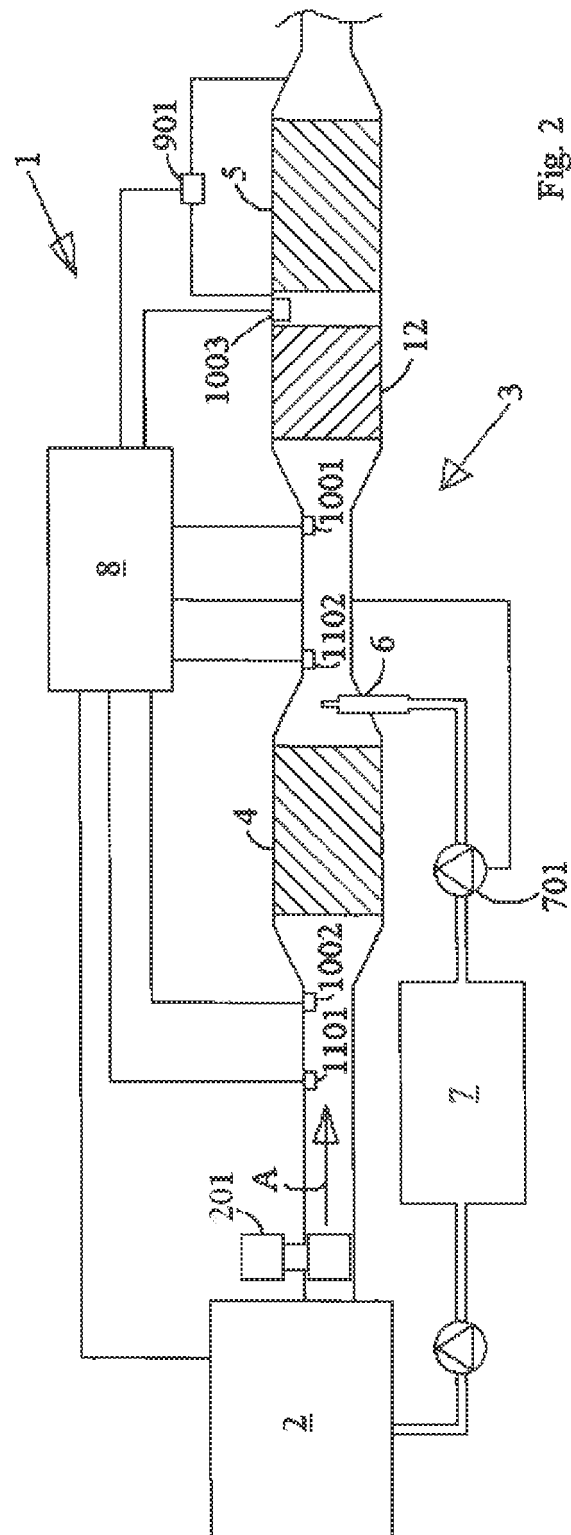


Fig. 2



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 08 15 1791

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	EP 1 321 643 A (BOSCH GMBH ROBERT [DE]) 25 June 2003 (2003-06-25) * paragraph [0010]; figure 1 *	1-6	INV. F01N3/02 F01N3/08
X	WO 2006/066043 A (DONALDSON CO INC [US]; HOU ZHIXIN JASON [US]; WAGNER WAYNE M [US]; ZHA) 22 June 2006 (2006-06-22) * page 18, lines 15-30; figure 4 *	1-3,5,6	
X	WO 2004/079170 A (JOHNSON MATTHEY PLC [GB]; PHILLIPS PAUL RICHARD [GB]; GOERSMANN CLAUS) 16 September 2004 (2004-09-16) * page 11, lines 7-16; figure 1 *	1,2,5	
D,A	EP 1 223 312 A (RENAULT [FR] RENAULT SA [FR]) 17 July 2002 (2002-07-17) * the whole document *	1-6	
The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (IPC)
			F01N
Place of search		Date of completion of the search	Examiner
Munich		21 July 2008	Blanc, Sébastien
<p>CATEGORY OF CITED DOCUMENTS</p> <p>X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document</p> <p>T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons</p> <p>& : member of the same patent family, corresponding document</p>			

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EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 08 15 1791

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21-07-2008

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
EP 1321643	A	25-06-2003	DE 10162383 A1	17-07-2003
WO 2006066043	A	22-06-2006	NONE	
WO 2004079170	A	16-09-2004	CN 1784540 A	07-06-2006
			DE 602004003354 T2	04-10-2007
			EP 1606498 A1	21-12-2005
			JP 2006522272 T	28-09-2006
			KR 20050115274 A	07-12-2005
			US 2006248874 A1	09-11-2006
EP 1223312	A	17-07-2002	DE 60201691 D1	02-12-2004
			DE 60201691 T2	17-03-2005
			ES 2225732 T3	16-03-2005
			FR 2819548 A1	19-07-2002

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 6745560 B2 [0004] [0008]
- EP 1223312 A1 [0004]
- US 20030140621 A1 [0004]
- EP 1369557 B1 [0021]
- EP 1643092 A1 [0021]
- WO 2006138233 A3 [0021]