The invention relates to an exhaust line of an internal combustion engine comprising: a pipe receiving exhaust gases, and a particulate filter impregnated with a first catalytic coating forming a reduction catalyst for nitrogen oxides (NOx), and with a second catalytic coating forming a first oxidation catalyst for carbon monoxide (CO) and hydrocarbons (HC). The line comprises an additional filter housed in the pipe downstream of the particulate filter and impregnated with a catalytic coating forming a second reduction catalyst for nitrogen oxides (NOx). And, the additional filter has an internal structure such that the additional filter creates a pressure drop which is less than the pressure drop created by the same volume of particulate filter impregnated with the same quantity of the same catalytic coating.
INTERNAL COMBUSTION ENGINE EXHAUST LINE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present invention is the US national stage under 35 U.S.C. §371 of International Application No. PCT/FR2011/052878, which was filed on Dec. 6, 2011 and which claims the priority of application FR 1150211 filed on Jan. 11, 2011 the content of which (text, drawings and claims) is incorporated here by reference in its entirety.

FIELD

[0002] The invention relates to an exhaust line for an internal combustion engine. The invention also relates to a drive assembly comprising the exhaust line. Finally, the invention relates to a vehicle equipped with the drive assembly.

BACKGROUND

[0003] The exhaust gases emitted from an internal combustion engine contain pollutants whose release into the atmosphere it is desirable to reduce. "Pollutants" designates, more particularly, nitrogen oxides NOx (N2O, NO and NO2), carbon monoxide (CO), unburned hydrocarbons (HC) and soot particles. In order to limit emissions of pollutants, it is known to carry out post-processing of exhaust gases flowing through an internal combustion engine exhaust line. Typically, the exhaust line of an internal combustion engine comprises:

[0004] a pipe receiving the exhaust gases from the engine,
[0005] a particulate filter for retaining and burning the soot particles contained in the gases,
[0006] an oxidation catalyst to convert carbon monoxides (CO) and hydrocarbons (HC) into carbon dioxide (CO2) and water (H2O), and
[0007] a reduction catalyst to convert nitrogen oxides (NOx) into nitrogen (N2) and water (H2O).

[0008] In order to minimize the overall size of the exhaust line, the oxidation catalyst and the reduction catalyst can be included inside the particulate filter to form a filter particle called "bi-catalyzed".

[0009] A bi-catalyzed particulate filter comprises generally a honeycomb structure. The filter comprises an inlet face for the entry of exhaust gases inside the filter and an outlet face for the evacuation of exhaust gases from the filter. The filter comprises, between the inlet and outlet faces, a set of channels or ducts adjacent to axes parallel to one another, separated by porous filtering walls. The ducts are closed off at one or the other of their ends to delimit intake ducts leading only to the inlet face and exhaust ducts leading only to the outlet face. The ducts are alternately closed off in an order such that the exhaust gases, while passing through the filter, are forced to pass through the side walls of the intake ducts to reach the exhaust ducts. In this way, the soot particles are deposited and accumulate on the porous walls of the filter. These inner walls of the particulate filter are impregnated with catalytic coatings to form the reduction catalyst and the oxidation catalyst.

[0010] Typically, the particulate filter is made of silicon carbide.

[0011] A first drawback of this type of bi-catalyzed particulate filter is that, in order to ensure the regulatory decontamination of exhaust gas, it is necessary that the amount of impregnated catalytic coating on the walls be greater than a minimum threshold.

[0012] If the amount of impregnated catalytic coating on the walls is excessive, the pores of the porous walls of the filter get clogged up. In such case, during operation of the engine, the exhaust gases pass through the filter with more difficulty. Consequently, the pressure of the exhaust gases in the pipe increases at the inlet of the particulate filter. Indirectly, an obstruction of the gases results in an increase in the fuel consumption of the engine.

[0013] A known solution is to increase the volume of the particulate filter so that more catalytic coating can be deposited without clogging the pores of the filter. However, this solution is to be avoided as it increases the overall size of the exhaust line.

[0014] A second drawback is that the reduction of nitrogen oxides (NOx) requires that the temperature of the exhaust gases be greater than a threshold temperature in order to take place. The lower the temperature of the exhaust gases, the lower the amount of reduced nitrogen oxides. The filter being made of silicon carbide, it dissipates the heat of the exhaust gas passing through this filter and therefore decreases the amount of the reduced nitrogen oxides. Under these conditions, it is known to increase the amount of catalyst in the particulate filter in order to maintain a satisfactory amount of reduced nitrogen oxides at low temperature. However, that amount of catalyst (typically precious materials) is often significant. Such addition of catalyst is costly to the filter manufacturer.

[0015] A third drawback is that, in order to allow the reduction of nitrogen oxides (NOx), a reducing agent, typically urea, is injected into the pipe upstream of the filter. In the exhaust lines known to the applicant, it is necessary to inject the reducing agent far upstream of the particulate filter to allow time for the urea to break down into ammonia (NH3) as a result of the heat from the exhaust gases. This is problematic for small vehicles in which the pipe is short.

SUMMARY

[0016] The invention aims to overcome one or more of these drawbacks.

[0017] The invention relates to an exhaust line for an internal combustion engine, this exhaust line comprising:

[0018] a pipe receiving the exhaust gases, and
[0019] a particulate filter housed inside the pipe impregnated with:

[0020] a first catalytic coating forming a first reduction catalyst of nitrogen oxides (NOx), and
[0021] a second catalytic coating forming an oxidation catalyst for carbon monoxides (CO) and hydrocarbons (HC),
[0022] an additional filter, housed in the pipe upstream of the particulate filter, and impregnated with a catalytic coating forming a second reduction catalyst for nitrogen oxides (NOx), and
[0023] the additional filter comprises an internal structure such that the additional filter creates a pressure drop lower than the pressure drop created by the same volume of the particulate filter impregnated with the same amount of the same catalytic coating.

[0024] In the exhaust line presented above, the additional filter can be impregnated with an amount of first catalytic coating per unit volume greater than the particulate filter.
Thus, in order to increase the amount of the catalytic coating in the exhaust line, while not clogging the pores of the particulate filter, it is less cumbersome to add the additional filter to the exhaust line than to lengthen the particulate filter. Moreover, the additional filter creates a pressure drop lower than the pressure drop that would be created by the same volume of the particulate filter impregnated with the same amount of catalytic coating as the additional filter. Thus, the consumption of the engine is not worsened compared to that with a lengthened particulate filter.

The embodiments of this exhaust line can include one or more of the following characteristics:

- an exhaust line, wherein:
- the particulate filter comprises:
- intake ducts leading only to an inlet face for the exhaust gases, and
- exhaust ducts leading only to an outlet face for the exhaust gases, and
- porous walls for fluidly connecting the intake ducts and the exhaust ducts,
- the additional filter comprises ducts leading to an inlet face and to an outlet face, the diameter of these ducts being greater than the pore diameter of the porous walls of the particulate filter,
- the specific heat capacity of the material of which the additional filter is made is lower than the specific heat capacity of the material of which the particulate filter is made,
- the line comprises a reducing agent which decomposes when heated to produce a reagent which intervenes in the reduction of nitrogen oxides by the first catalytic coating and an injector for injecting the reducing agent into the pipe upstream of the additional filter,
- the catalytic coating of which the additional filter is impregnated comprises zeolites in order to accelerate the decomposition of the reducing agent,
- the additional filter is made of cordierite and/or the particulate filter is made of silicon carbide, and
- an exhaust line, wherein:
- the intake ducts of the particulate filter are only impregnated with the first catalytic coating, and
- the exhaust ducts are only impregnated with the second catalytic coating.

The embodiments of this exhaust line include the following additional benefits:

- when the diameter of the ducts of the additional filter is greater than the pore diameter of the particulate filter, it is possible to impregnate the additional filter with an amount of catalytic coating per unit volume greater than for the particulate filter while creating a lower pressure drop,
- when the specific heat capacity of the additional filter is lower than the specific heat capacity of the particulate filter, the additional filter temperature rises faster than that of the particulate filter which allows starting the reduction of nitrogen oxides at a lower temperature when starting the engine,
- when the catalytic coating of the additional filter comprises zeolites, the decomposition of the reducing agent is accelerated by the additional filter which indirectly allows shortening the length of the pipe upstream of the additional filter, and
- when the intake ducts are only impregnated with the first catalytic coating, and the exhaust ducts are only impregnated with the second catalytic coating, the amount of ammonia, entrapped in the first coating and oxidized by the second coating to form nitrogen oxides NOx, is limited.

The invention also relates to a drive assembly, the assembly comprising:

- an internal combustion engine, and
- an exhaust line as described above.

The invention finally relates to an engine vehicle equipped with the drive assembly.

DRAWINGS

Other features and advantages of the invention will become clearly apparent from the description which is given below, as an indication in no way restrictive, with reference to FIG. 1. FIG. 1 is a partial schematic illustration of a vehicle equipped with a drive assembly comprising an exhaust line, in accordance with various embodiments of the invention.

DETAILED DESCRIPTION

In the remainder of this description, the features and functions well known to those skilled in the art are not described in detail.

FIG. 1 shows a vehicle 2 such as an automobile. For example, vehicle 2 is a car. This vehicle 2 is equipped with a drive assembly 4. The assembly 4 comprises an internal combustion engine 6 and an exhaust line 8.

The engine 6 is capable of rotating the drive wheels 10 of the vehicle 2. In various embodiments, the engine 6 is a diesel engine. During operation, the engine 6 is discharging exhaust gases which, before being expelled to the outside of the vehicle 2, are received by the exhaust line 8 capable of processing these gases.

The exhaust line 8 comprises a pipe 12 receiving the exhaust gases through an opening 13 in an exhaust manifold of engine 6. For example, the pipe 12 is a cylindrical tube of circular section. In various embodiments, the pipe 12 is made of steel.

The exhaust line 8 includes a particulate filter 14 (also known as FAP) able to retain the soot particles contained in the exhaust gases and burn these particles. In various embodiments, the filter 14 is adapted to retain particles of a diameter greater than, or equal to 23 nm. The filter 14 is housed inside the pipe 12.

In various embodiments, the filter 14 is advantageously made of silicon carbide. In various embodiments, the filter 14 includes a honeycomb structure. In this example, the internal structure of the filter 14 is known per se. It has already been presented in the introduction, so it is not described in detail. Hereafter, reference 16 and 18 designate, respectively, the inlet face and the outlet face of the filter 14.

The filter 14 includes a plurality of intake and exhaust ducts. In order to simplify FIG. 1, only one intake duct 20 leading to the inlet face 16, and one exhaust duct 22 leading to the outlet face 18, are shown. In various embodiments, the ducts 20 and 22 are bonded to each other by means of cement. Typically, this cement can comprise one or more of the following chemical species: cordierite, SiC, B2O3, Si3N4, BN, AlN, ZrO2, mullite, Al2O3, ZrB2, and/or SiAlon (an alloy of silicon, aluminium, oxygen and nitride).

In various embodiments the length of the filter 14 is between 5 cm and 75 cm. For example, the length can be between 18 cm and 25 cm.
The filter 14 is a bi-catalyzed filter. For this purpose, the porous walls of the ducts are impregnated with two catalytic coatings.

In various embodiments, the porous walls of the intake ducts 20 are only impregnated with a catalytic coating $R_{cat}$, The coating $R_{cat}$ forms a selective reduction catalyst (also known as SCR). This selective reduction catalyst is capable of converting the nitrogen oxides (NOx) contained in exhaust gases passing through the filter 14 into nitrogen (N2) and water (H2O).

The exhaust line 8 also includes an additional filter 30. The filter 30 is adapted to carry out the reduction of nitrogen oxides (NOx) contained in the exhaust gases into nitrogen (N2) and water (H2O).

The filter 30 comprises ducts 33 passing through the filter 30 from end to end. The ducts 33 lead to an inlet face 32 and an outlet face 34. To simplify FIG. 1, only two ducts 33 are shown. The ducts 33 are separated by inner walls 35. In various embodiments, these walls 35 are less porous than the walls of the filter 14.

The inner walls 35 of the filter 30 separating the ducts 33 are impregnated with a catalytic coating $R_{cat}$ forming a reduction catalyst. In various embodiments, the $R_{cat}$ and $R_{cat}$ coatings have the same chemical composition with the exception that the $R_{cat}$ coating contains zeolites so that when the exhaust gases pass through the ducts 33, the $R_{cat}$ coating accelerates the decomposition of urea into ammonia.

Under these conditions, a longer length of the pipe 12, between the injector 28 and the filter 14, so that the exhaust gases remain long enough in contact with the urea to bring it to the decomposition temperature, is no longer necessary. The length of the pipe 12 upstream of the filter 14 can then be shortened.

Furthermore, the internal structure of the filter 30 is such that, at equal volume with the filter 14, the filter 30 is adapted to be impregnated with an amount of $R_{cat}$ coating per unit of volume greater than the filter 14, while creating a pressure drop lower than the pressure drop created by the same volume of the particulate filter 14. To this end, in various embodiments, the diameter of the ducts 33 is greater than the pore diameter of the inner walls of the particulate filter 14.

Indeed, the ducts 33 passing through the filter 30 from end to end, and the wall 35 having low porosity, the pressure drop generated by the filter 30 depends on the length of the filter 30, the amount of coating impregnated in the walls 35 and the diameter of the ducts 33. In contrast, the ducts 20 and 22 being closed off at one face of the filter 14, the pressure drop generated by the filter 14 depends on the length of the filter 14, the amount of impregnated coating, and the size of the pores of the porous walls.

The additional filter 30 is housed in the pipe 12 between the injector 28 and the particulate filter 14. In various embodiments, the distance between the filters 14 and 30 is less than 20 millimeters, for example less than 10 mm.

In the remainder of this description, the term “specific heat capacity of a material” means the energy that must be brought to a mass of 1 kg of that material to increase its temperature by one Kelvin. The heat capacity is expressed in Joule. Kelv $^{-1}$. The specific heat capacity of a material defines the ability of this material to absorb and release heat.

Advantageously, the heat capacity of the material of which the additional filter 30 is made is lower than the heat capacity of the material of which the particulate filter 14 is made. Under these conditions, during operation of the engine 6, the temperature inside the filter 30 reaches the temperature of “light-off” faster than the filter 14. Temperature of “light-off” means the starting temperature at which 50% of nitrogen oxides (NOx) contained in the exhaust gases are reduced by the reduction catalyst coating. In these conditions, reduction of nitrogen oxides (NOx) is carried out faster in the filter 30 than in the filter 14, which allows cleaning the exhaust gases sooner when starting the engine 6.

Furthermore, in various embodiments, in order to allow the additional filter 30 to warm up quickly, the length of the filter 30 is advantageously between 2 cm and 10 cm, for example, between 5 cm and 10 cm.

The exhaust line 8 also includes a reservoir 26. The reservoir 26 contains a reducing agent for reducing the nitrogen oxides (NOx) contained in exhaust gases into nitrogen (N2) and water (H2O). Typically, the reducing agent is urea. Under the effect of heat, the urea is decomposed into ammonia (NH3) which reacts with the NO in the reduction catalysts coatings to reduce NOx. The reducing agent is injected into the pipe 12 upstream of the particulate filter 14 through an injector 28. In the example, the injector 28 injects urea downstream of a turbo-compressor (not shown). Also in various embodiments, the injector 28 comprises a temperature sensor for the exhaust gases upstream of the particulate filter 14.

In this description, the terms “downstream” and “upstream” are defined relative to the direction of flow of exhaust gases in the pipe 12. The direction of flow of the exhaust gases in the pipe 12 is represented by arrows in FIG. 1.
In various embodiments, the filter 30 is a cordierite monolith.

The exhaust line 8 also comprises sensors 36 and 38 for the amount of NOx contained in the exhaust gases, respectively, upstream of the filter 30 and downstream of the filter 14.

The exhaust line 8 finally includes a calculating unit 40 that is structured and operable to:

obtain measurements from the sensors 36 and 38, and

control the quantity of urea injected by the injector 28 in the pipe 12 according to the measurements obtained.

For example, in various embodiments, the unit 40 is made from a programmable electronic calculator capable of executing instructions stored on a data recording medium 42. For this purpose, the unit 40 is connected to the data recording medium 42 containing instructions for the execution of a control method of the sensors 36, 38 and the injection 28.

Other embodiments are possible. For example, the filters can include one or more of the following: cordierite, SiC, B4C, Si3N4, BN, AlN, Al2O3, ZrO2, mullite, Al titanate, ZrB2, and Silicon.

The Rcat1 coating can also be acid.

In the Rcat1 and Rcat2 coatings, the catalyst does not necessarily include a material from the platinum group. Other catalysts can be used in addition to, or replacement. For example, the catalyst can be one of the following precious metals: gold (Au), and/or silver (Ag). The catalyst can also include alkaline metals, alkaline earth metals, lanthanide metals, actinide metals, transition metals, and/or perovskites. A transition metal can be scandium (Sc), titanium (Ti), vanadium (V), chromium (Cr), manganese (Mn), iron (Fe), cobalt (Co), nickel (Ni), copper (Cu) or zinc (Zn).

In Rcat2 coatings, the catalyst does not necessarily include a material from the platinum group. In various embodiments, other catalysts can be used in addition to, or replacement. For example, the catalyst can be one of the following precious metals: gold (Au), and/or silver (Ag). The catalyst can also comprise transition metals, alkali metals, alkaline earth metals, lanthanide metals, hydrocarbon traps such as zeolites or clay, actinide metals, and/or perovskites.

In various embodiments, the injector can be placed upstream of the turbocharger.

In various embodiments, reducing agents other than urea can be used.

In various embodiments, the catalytic coatings Rcat1 and Rcat2 can be of the same chemical composition.

In various embodiments, the sensors 36, 38 can be omitted. In such instances, the unit 40 can control the injector 28 from pre-stored formulas or tables.

The engine is not necessarily a diesel type engine. The engine can be a gasoline type engine. In such embodiments, the particulate filter 14 can be impregnated in order to implement the functions of a three-way catalyst.

1.-10. (canceled)

11. An exhaust line for an internal combustion engine, said exhaust line comprising:

a pipe structured and operable for receiving exhaust gases;
a particulate filter, housed inside the pipe and impregnated with:

a first catalytic coating forming a first reduction catalyst of nitrogen oxides (NOx), and

an additional filter, housed in the pipe upstream of the particulate filter, and impregnated with a catalytic coating forming a second reduction catalyst for nitrogen oxides (NOx), the additional filter comprising an internal structure such that the additional filter creates a pressure drop lower than the pressure drop created by the same volume of the particulate filter impregnated with the same amount of the same catalytic coating.

12. The exhaust line according to claim 11, wherein:

the particulate filter includes:

intake ducts only leading to an inlet face for the exhaust gases,

porous walls for fluidly connecting the intake ducts and the exhaust ducts, and

the additional filter further comprises ducts leading to an inlet face and to an outlet face, wherein the diameter of the ducts is greater than the pore diameter of the porous walls of the particulate filter.

13. The exhaust line according to claim 11, wherein the specific heat capacity of the material of which the additional filter is made is lower than the specific heat capacity of the material of which the particulate filter is made.

14. The exhaust line according to claim 13 further comprises a reducing agent which decomposes when heated to produce a reagent which intervenes in the reduction of nitrogen oxides by the first catalytic coating, and an injector for injecting the reducing agent into the pipe upstream of the additional filter.

15. The exhaust line according to claim 11, wherein the catalytic coating with which the additional filter is impregnated comprises zeolites so as to accelerate the decomposition of the reducing agent.

16. The exhaust line according to claim 11, wherein at least one of:

the additional filter is made of cordierite, and

the particulate filter is made of silicon carbide.

17. The exhaust line according to claim 12, wherein the intake ducts of the particulate filter are impregnated with only the first catalytic coating, and the exhaust ducts are impregnated with only the second catalytic coating.

18. A vehicle drive assembly, said assembly comprising:

an internal combustion engine; and

an exhaust line, the exhaust line comprising:

a pipe structured and operable for receiving exhaust gases;
a particulate filter, housed inside the pipe and impregnated with:

a first catalytic coating forming a first reduction catalyst of nitrogen oxides (NOx), and

an additional filter, housed in the pipe upstream of the particulate filter, and impregnated with a catalytic coating forming a second reduction catalyst for nitrogen oxides (NOx), the additional filter comprising an internal structure such that the additional filter creates a pressure drop lower than the pressure drop created by the same volume of the particulate filter impregnated with the same amount of the same catalytic coating.

19. The vehicle drive assembly according to claim 18, wherein:

the particulate filter comprises:

a ceramic body, and

the additional filter comprises:

a metal substrate.
by the same volume of the particulate filter impregnated with the same amount of the same catalytic coating.

19. The assembly according to claim 18, wherein the engine is a diesel type engine.

20. A vehicle comprising:
   a vehicle drive assembly, said assembly comprising:
   an internal combustion engine; and
   an exhaust line, the exhaust line comprising:
   a pipe structured and operable for receiving exhaust gases;
   a particulate filter, housed inside the pipe and impregnated with:
   a first catalytic coating forming a first reduction catalyst of nitrogen oxides (NOx), and
   a second catalytic coating forming an oxidation catalyst for carbon monoxides (CO) and hydrocarbons (HC); and
   an additional filter, housed in the pipe upstream of the particulate filter, and impregnated with a catalytic coating forming a second reduction catalyst for nitrogen oxides (NOx), the additional filter comprising an internal structure such that the additional filter creates a pressure drop lower than the pressure drop created by the same volume of the particulate filter impregnated with the same amount of the same catalytic coating.

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