

DESCRIPTION

TITLE: Engine with low particulate emissions

5 The present invention relates to an engine with low particulate emissions, and particularly a very large turbo diesel engine intended for the propulsion of a ship. It also relates to a method of reducing the particulate emissions from this kind of engine. It also relates to a catalytic device suitable for this kind of engine.

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Very large turbo diesel engines intended for the propulsion of a ship are two-stroke, so-called slow engines, or four-stroke, so-called semi-fast engines. These engines are able to generate a power from 1 MW to almost 100 MW in the case of the largest. They consume liquid fuels, designated by the generic term "fuel oils", including heavy fuel oils (HFO),
15 intermediate fuel oils, known as marine diesel oil (MDO), and light fuel oils, the viscosity and the sulfur content of which are low, these light fuel oils being similar to those used on land for domestic applications. These engines have the disadvantage of emitting components stemming from imperfect combustion, in the form of particles also known as "unburned
20 solids", which contain non-oxidized carbon, referred to in everyday language as soot, and "unburned gases". The former consist of organic particles and in particular ultrafine particles of sooty carbon, more often referred to as "black carbon", varying in size from a few nanometers up to around ten micrometers. The mean size of the particles emitted by this
25 kind of diesel engine is of the order of 100 nm. The gaseous components coming from the "unburned gases" are for their part also of different kinds, including carbon monoxide, unburned hydrocarbons, polycyclic aromatic hydrocarbons, volatile organic compounds, non-methane non-volatile organic compounds. The various emissions mentioned above,
30 stemming from imperfect combustion in the engines, in the form of solid

particles or gaseous components, generate numerous serious effects on human health.

There exist solutions in the automotive sector for treating polluting emissions of solid particle type emitted by engines of small size. They consist in a post-combustion approach, based in particular on the use of filters. However, because of scale and cost factors these filtration solutions are difficult to transpose to all existing engines, in particular the engines for ships mentioned above. These solutions also have the disadvantage of degrading the thermodynamic efficiency of the engine, which leads to excess fuel consumption.

In parallel, one prior art solution in another field is described in the document FR2837214 and recommends on the one hand mixing catalytic vapors of methylcyclopentadienyl manganese tricarbonyl type with the combustion air of a boiler and on the other hand injecting fine droplets of this catalytic agent directly into the fuel, with a view to obtaining a reduction of the sulfur oxides and nitrogen oxides at the outlet of the boiler. This solution makes it possible to obtain a significant reduction of the pollution generated by combustion in a boiler. This document thus concerns the particular field of boilers and teaches that a catalyst can reduce the pollution of the emissions, the targeted emissions being sulfur-containing compounds.

A general object of the invention is to propose a solution enabling improvement of engines, more particularly very large diesel engines for ships, by reducing the noxious particles emitted by these engines.

To this end, the invention is based on an engine for a ship, comprising an intake manifold, characterized in that it comprises a catalytic device using the mixture of a catalyst precursor that comprises an organometallic

compound, notably a methylcyclopentadienyl manganese tricarbonyl component, with a fuel oxidizer, and in that the catalytic device is arranged upstream of a compression device, so that this compression device increases the pressure of the mixture comprising the fuel oxidizer and the catalyst precursor to a value greater than or equal to 2 bar, or even greater than or equal to 4 bar, this pressure value being measured at its entry into the intake manifold.

The engine for a ship may be a turbocharged engine comprising a turboblower, the compression device being the turboblower, and the catalytic device being positioned upstream of the turboblower so that said mixture comprising the fuel oxidizer and the catalyst precursor is conveyed from the outlet of the catalytic device to the turboblower, where it undergoes an increase in pressure, then from the turboblower to the intake manifold.

The engine for a ship may comprise an intercooler heat exchanger disposed between the turboblower and the intake manifold to cool the mixture comprising the fuel oxidizer and the catalyst precursor to a temperature value less than or equal to 50°C, or even less than or equal to 40°C.

The compression device may comprise at least two turbocompressors disposed in series. The engine for a ship may comprise at least one heat exchanger disposed between two turbocompressors to cool the mixture comprising the fuel oxidizer and the catalyst precursor.

This engine may be a turbocharged engine comprising a turboblower and the mixture comprising the fuel oxidizer and the catalyst precursor leaving the catalytic device may be connected to an intake pipe to the intake

manifold via an injection zone disposed downstream of the turboblower and an intercooler exchanger.

5 The injection zone may comprise a diffusion device comprising a hollow metal body pierced by a plurality of cruciform orifices and positioned in a plane perpendicular to the direction of fuel oxidizer flow to enable a mixture of the catalyst precursor vapors with the fuel oxidizer flow to be obtained.

10 The catalytic device may comprise a medium comprising cellulose fibers and/or woven fibers, such as some cottons, onto which the catalyst precursor is injected in liquid form and is evaporated and mixed with a fuel oxidizer in contact with said medium.

15 The catalytic device may comprise a tank of liquid catalyst precursor and may be configured for the at least partial evaporation of said catalyst precursor in the fuel oxidizer.

20 The liquid catalyst precursor may comprise an organometallic compound or methylcyclopentadienyl manganese tricarbonyl concentration greater than or equal to 90% of the total weight of the catalyst precursor.

The engine for a ship may be an engine rated at between 1 MW and 100 MW inclusive.

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The invention also relates to a method of reducing emissions of particles from an engine for a ship, characterized in that it comprises the execution of the following steps:

- mixing a catalyst precursor that comprises an organometallic compound, notably a methylcyclopentadienyl manganese tricarbonyl component, with a fuel oxidizer, then

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- increasing the pressure of said mixture by means of a compression device to a pressure value greater than or equal to 2 bar, or even greater than or equal to 4 bar, then
- injecting said mixture under pressure into an intake manifold for a combustion chamber of an engine.

The invention also relates to a catalytic device for an engine as described above, characterized in that it comprises a tank of liquid catalyst precursor, which comprises an organometallic compound, notably a methylcyclopentadienyl manganese tricarbonyl component, in that it is configured for the mixing and the at least partial evaporation of said catalyst precursor in a fuel oxidizer, and in that it comprises a means of connection with a compression device of an engine for a ship.

These objects, features and advantages of the present invention will be described in detail in the following non-limiting description of one particular embodiment given with reference to the appended figures, in which:

[Fig. 1] Figure 1 represents schematically an engine in accordance with one embodiment of the invention.

[Fig. 2] Figure 2 illustrates, in comparison with a prior art engine, curves of evolution of pressure as a function of the angle of the crankshaft of the engine in accordance with the embodiment of the invention.

[Fig. 3] Figure 3 represents schematically a variant of the engine in accordance with one embodiment of the invention.

It has advantageously been discovered that the use of a liquid catalyst precursor of organometallic type, notably a precursor of a catalyst that comprises methylcyclopentadienyl manganese tricarbonyl, brings about a surprising reduction in the particles emitted by the very large engines of ships, subject to use under particular conditions, whilst improving the

efficiency of such engines. These surprising results were not envisaged following the use of this kind of catalyst in a boiler to reduce sulfur-containing emissions.

- 5 This use will be described in detail hereinafter in the context of one particular embodiment.

Figure 1 represents schematically a very large turbo diesel engine 1 for a ship in accordance with one embodiment of the invention. This engine 1
10 comprises in known manner an intake manifold 2, a combustion chamber (cylinders) 3, an exhaust manifold 4. It further comprises a turboblower 9 for the turbo function actuated by the exhaust gases guided by an exhaust pipe 5 from the exhaust manifold 4 to the turboblower 9. This turboblower makes it possible to increase the pressure of the fuel
15 oxidizer, that is to say of the air in this embodiment, before it arrives in the intake manifold 2 via an intake pipe 6.

In the embodiment, the engine comprises a catalytic device 10 disposed upstream of the turboblower 9. The catalytic device 10 uses the mixture
20 of a precursor of the catalyst mentioned above in the combustion air. This catalytic device 10 is positioned upstream of the turboblower 9 so that the mixture comprising the air (or any other gas provided as fuel oxidizer) and the catalyst precursor is then guided through the turboblower 9.

- 25 The catalytic device 10 may be of the type described in the document FR3059565, enabling evaporation of the liquid catalyst precursor and then its mixing and transportation in the combustion air. At the outlet of the catalytic device 10 the air charged with catalyst precursor is directed via a pipe 7 to the turboblower 9.

In this embodiment the catalytic device 10 comprises a hydraulic sub-assembly, not represented, comprising a tank for storing the catalyst precursor. This tank is mounted above a containment vessel. These two elements are adapted to store a precursor of a catalyst in liquid form, in particular an organometallic precursor as mentioned above. A device for detecting the liquid level, in particular a level detector, is positioned at the top of the tank so that the quantity of catalyst precursor available in the tank is known. In the embodiment shown, the level detector enables triggering of an alert if the stock of catalyst precursor falls below a predefined threshold value. This hydraulic sub-assembly is connected to an aeraulic sub-assembly in which the liquid catalyst precursor can be evaporated and mixed with air. By way of example, a catalyst precursor that comprises methylcyclopentadienyl manganese tricarbonyl becomes an active material at a temperature of the order of 230 to 240°C under the pressure conditions in the engine 1. This operation is advantageously carried out by means of a medium comprising cellulose fibers and/or woven fibers, such as some cottons. Alternatively, this evaporation and this mixing may be obtained by any other means.

In accordance with one advantageous feature of the embodiment, the mixture formed by the air containing the catalyst precursor is then increased in pressure in the turboblower 9 to a relative value of 5 bar, preferably greater than or equal to 2 bar, or even greater than or equal to 4 bar. This pressure is advantageously between 2 and 6 bar inclusive, or even between 4 and 6 bar inclusive. The catalytic device 10 is positioned upstream of the turboblower 9 and the latter forms a device for compressing the mixture comprising the fuel oxidizer and the catalyst precursor. Note that throughout the present description bar units are absolute bar units.

It is also to be understood that throughout the present description there is meant by "compression device" a device having in particular a compression ratio greater than 1.5, or even greater than 4. In particular, in accordance with the values mentioned hereinabove, it enables the pressure of the mixture to be raised from a value close to atmospheric pressure to a pressure greater than or equal to 2 bar, or even greater than or equal to 4 bar.

Another effect of the turboblower is to increase the temperature of the air containing the catalyst to a value that can for example be between 150°C and 200°C inclusive. For this reason, an intercooler exchanger 8 is arranged at the outlet of the turboblower 9, in the intake pipe 6, to reduce this temperature, advantageously to a value below 50°C, or even to a value below 40°C, for example around 30°C.

The pressure and/or temperature conditions obtained in this way enable optimized or even ideal distribution of the catalyst vapors in the fuel, distributing them in a homogeneous manner in the fuel. The catalyst vapors are therefore distributed at a molecular scale. They are atomized to a molecular scale in the fuel oxidizer, which is its transport vector. Prepared in this way, the organometallic precursor offers the best possible specific surface area, the best distribution in the gas medium of the fuel oxidizer. This solution enables it to act in accordance with a "spin" type effect, which renders it hyper-reactive and totally available to be changed to its catalytic form.

This conditioning of the catalyst precursor contributes to releasing the combustion catalyst into the combustion chamber, which becomes the ideal and complementary agent to act with the carbon present in that combustion chamber in all its solid and gaseous forms, so as to perform its almost complete thermal oxidation. This effect leads to destruction of

the unburned particles and gases by gasification thereof, which transforms the available carbon into carbon dioxide. The catalyst conditioned in this way is moreover active throughout its journey from the combustion chamber to the outlet of the exhaust gases to the open air. It is thus possible to achieve the result looked for thanks to the catalyst conditioned in this way.

The engine is moreover advantageously controlled automatically by a control unit, comprising any computer, on the basis of information transmitted by certain sensors of the engine 1. These sensors make it possible for example to take into account the level of load on the engine, including its speed, the engine torque, the cylinder head pressure, etc. This control of the engine advantageously incorporates automatic regulation of the quantity of catalyst used. That quantity is preferably between 5 and 50 decagrams inclusive of catalyst per tonne of fuel.

In particular, for the methylcyclopentadienyl manganese tricarbonyl component, the catalyst precursor amounts to four times the weight of the catalyst, that is to say it comprises for example a volatile fraction of the order of 75% by weight. Also, so as to obtain a quantity of catalyst between 5 and 50 decagrams inclusive per tonne of fuel it will be necessary to inject between 20 and 200 decagrams of catalyst precursor per tonne of fuel.

Measurements at the outlet of the engine 1 in accordance with the embodiment show that the solution makes it possible to eliminate:

- 50 to 99% of carbon-containing particles;
- 70 to 99% of ultrafine particles the size of which is between approximately 30 and 150 nm inclusive;
- 50% to 99% of unburned hydrocarbons resulting from the combustion of heavy fuel oils when their initial concentration is between 200 and

500 ppm inclusive and from 30% to 90% of the hydrocarbons resulting from the combustion of the MDO when the initial concentration thereof is between 1000 and 4500 ppm inclusive.

5 Moreover, for the same level of load on the engine 1, the complete thermal oxidation of the carbon thanks to the advantageous catalyst of the invention and the accelerated kinetics of the chemistry of the combustion because of the catalytic effect generate an increase in the pressure of the gases, which evolves with the number of crankshaft
10 degrees during downstrokes of the piston of the engine. Figure 2 illustrates this phenomenon: the curve 20 represents the pressure of the gases in a prior art engine and the curve 21 represents the pressure of the gases in an identical engine equipped with the catalytic device in accordance with the embodiment of the invention.

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A change to the settings of the engine in the embodiment of the invention makes it possible to benefit from this effect illustrated by figure 2 and to reduce the fuel consumption of the engine whilst maintaining the power and the torque delivered to the shaft. This is reflected in the increased
20 average thermodynamic efficiency of the engine, the specific consumption decreasing to a range from 3 to 12 g/k.W.h, depending on the engine type (two-stroke or four-stroke) and depending on its level of load, between 25% and 100% inclusive.

25 Another, indirect advantage of the elimination of soot from the exhaust of the engine in accordance with the embodiment is to keep the turbines of the turboblowers 9 clean. In fact, the metal surfaces of these turbines are no longer greasy, are no longer soiled. This limits, or even eliminates, preventive and curative maintenance operations and enables an optimum
30 longevity of the blades of the turbine to be assured. Moreover, the

efficiency of the turboblower 9 remains maximal at all times, which contributes to the overall efficiency of the engine 1.

Finally, the engine 1 in accordance with the embodiment of the invention
5 makes it possible not only virtually to eliminate the emissions of pollutant particles but also to improve the efficiency of the engine.

Figure 3 represents a variant of the embodiment of the invention in which the catalytic device 10 is arranged downstream of the turboblower 9 of
10 the engine 1. For simplicity, the same references are used to designate components identical or similar to those in the embodiment described with reference to figure 1.

In this variant embodiment, the catalytic device 10 is therefore positioned
15 downstream of the turboblower 9 and its intercooler exchanger, that is to say that the mixture comprising the fuel oxidizer and the catalyst precursor generated by the catalytic device is injected downstream of the turboblower in an injection zone 16 of the intake pipe 6. A diffusion device
20 may be positioned in a plane perpendicular to the direction of the fuel oxidizer flow in this injection zone 16 to make it possible to obtain a mixture of the catalyst precursor vapors with the fuel oxidizer flow. A diffusion device of this kind may consist of a hollow metal body pierced by several hundred cruciform orifices, each for example of 5 mm² maximum area, with beveled outlet edges, distributed uniformly over all
25 the faces, except on the leading edge for the flow. In this variant embodiment, two turbocompressors 19 are mounted in series between the catalytic device 10 and the injection zone 16. A heat exchanger 18 is moreover disposed between the two turbocompressors 19.

30 The turbocompressors 19 are actuated by some of the exhaust gases. They are designed to operate in their optimum efficiency range whilst

being regulated exclusively by a fraction of the exhaust gases of the engine 1. They can make it possible to shift up to approximately 500 Nm³ of air conveying the catalyst. Alternatively, the compression device could comprise more than two turbocompressors. It could also comprise a plurality of heat exchangers for cooling the fuel oxidizer/catalyst mixture.

The result obtained is substantially to identical that of the figure 1 embodiment. In fact, this configuration makes it possible to increase the pressure in the same ranges of values as before whilst maintaining the temperature below the same threshold value by means of the exchanger 18. In this variant the set of two turbocompressors 19 forms a compression device for the fuel oxidizer/catalyst precursor mixture.

In accordance with a variant embodiment, compatible with the two embodiments from figures 1 and 3, the catalytic device 10 also comprises hardware and/or software elements enabling the automatic or semi-automatic implementation of a method of mixing a precursor of a catalyst to improve the engine 1. The mixing process is implemented by means of electromechanical actuators and sensors supplied with electric power and regulated by means of one or more remotely controlled programmable automatic controllers.

It should be noted that, in all the embodiments envisaged hereinabove, the air used may be replaced by any other gaseous fuel oxidizer or any other vector gas. Moreover, note that the fuel oxidizer charged with a catalyst precursor represents by weight only a fraction of the aeraulic fluid entering into the combustion chamber of the engine.

Finally, in all the embodiments the catalytic device could be of any kind provided that it mixes a catalyst precursor into a fuel oxidizer in a form that enables it to be transported by the fuel oxidizer. Moreover, the device

for compressing said mixture could also take some form other than those described in the embodiments.

The invention also relates to a method of reducing the emissions of particles from an engine, in particular a very large engine for a ship, which comprises the execution of the following steps:

- mixing a catalyst precursor with a fuel oxidizer, then
- increasing the pressure of said mixture to a pressure value greater than or equal to 2 bar, or even greater than or equal to 4 bar, then
- 10 - injecting said mixture under pressure into an intake manifold for a combustion chamber of an engine.

As explained above, the method uses a precursor of a liquid catalyst of organometallic type. One very advantageous application consists in using a precursor of a catalyst that contains methylcyclopentadienyl manganese tricarbonyl or consists entirely of that component. The concentration of the organometallic compound in the catalyst precursor is advantageously greater than or equal to 99% of the total weight of the catalyst precursor.

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This solution does achieve the objectives looked for and makes it possible to reduce or even to eliminate all the emissions of particles from an engine, in particular a very large turbo diesel engine for a ship.

25 The solution described has the advantage of efficient evaporation of the catalyst precursor produced by the fuel oxidizer, which thus becomes the vector transporting the catalyst vapors. Alternatively, the fuel oxidizer is the vector transporting a precursor of a catalyst in liquid form, in particular in droplet form, the catalyst precursor being in particular in whole or in part in the form of droplets, before finally being completely evaporated and ideally distributed into the fuel oxidizer in the compression device.

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In accordance with a third embodiment, illustrated in dashed line in figures 1 and 3 and implemented as an alternative to or in combination with the first or the second embodiment described above, the engine 1 for a ship is characterized in that it comprises the exhaust manifold 4 and at least one catalytic device 10' comprising a compression injection means, in particular using compressed air or water, at least configured to spray in the form of droplets a liquid catalyst precursor consisting of an organometallic compound, in particular a methylcyclopentadienyl manganese tricarbonyl component, and mixing thereof with exhaust gases contained in the exhaust manifold 4.

This kind of spraying under compression, also known as "nebulization" or "atomization", corresponds to the cold transformation of the liquid catalyst precursor into a cloud or mist of droplets. In particular, in accordance with an optional feature, the catalytic device 10' may be configured to produce droplets having a size of the order of 10 to 500 μm , in particular 20 to 100 μm .

As described with reference to figure 1, the engine 1 comprises the intake manifold 2 and the combustion chamber 3 comprising a plurality of cylinders. It further comprises a turboblower 9 that has the compression device function and is actuated by the exhaust gases guided by the exhaust pipe 5 from the exhaust manifold 4 to the turboblower 9. Alternatively, and as described with reference to figure 3, the engine 1 may comprise the two turbocompressors 19 mounted in series and the heat exchanger 18.

In accordance with the present invention, the catalytic device 10' is at least configured to inject the catalyst precursor downstream of the combustion chamber 3.

In accordance with a preferred feature, the catalytic device 10' is configured so as to inject the catalyst precursor directly into the exhaust manifold 4 in at least one injection site 21. In particular, the catalytic device 10' may be configured to inject the catalyst precursor immediately at the outlet of the exhaust gases from at least one of the cylinders of the engine 1.

In accordance with one particular embodiment, not represented, the catalytic device 10' may be configured to inject the catalyst precursor directly into the exhaust manifold 4 at a plurality of injection sites 21. In particular, the engine 1 may comprise as many injection sites 21 as cylinders.

Specifically, the catalytic device 10' may comprise at least one feed pipe 22 configured to circulate the catalytic precursor to the injection site or sites 21.

The objective of an embodiment of this kind is to carry out the post-processing of the exhaust gases at a temperature favorable to the catalytic oxidation capacity of the carbon of the catalyst precursor, which has instantaneously become the catalyst. In particular, the catalytic device 10' may be configured to inject the catalyst precursor in a zone of the exhaust manifold 4 in which the temperature is of the order of 450 to 600°C, in particular in the order of 550 to 600°C, for example around 580°C.

In accordance with one feature of the third embodiment, the injection means of the catalytic device 10' may advantageously comprise at least one injection nozzle, in particular a nebulization nozzle, for the catalyst precursor in the liquid state. An injection nozzle of this kind is disposed in

the at least one injection site 21 in the exhaust manifold 4. As described above, the injection means may comprise a plurality of injection nozzles, for example each disposed in an injection site 21.

- 5 In accordance with one particular embodiment, an injection nozzle of this kind is a dual fluid nozzle configured to inject simultaneously into the exhaust manifold 4 the catalyst precursor and a fluid, in particular compressed air or water.
- 10 The catalyst device 10' may optionally but advantageously comprise a cooling device, not represented, for cooling the injection means, in particular at least the injection nozzle. In accordance with one non-limiting example, this kind of cooling device may cool the injection means by means of a fluid identical to the fluid injected into the exhaust manifold
- 15 4, namely compressed air or water.

This kind of fluid then has, on the one hand, an injection vector function and contributes to the nebulization of the liquid catalyst precursor and, on the other hand, an injection means cooling function. This kind of

20 arrangement advantageously makes it possible to prevent the reaction of the catalyst precursor or its deterioration in the injection means, for example the injection nozzle, and therefore malfunctioning of the latter.

Catalyst precursor in the liquid state is therefore sprayed in the form of

25 droplets by the injection means, which droplets, once in the exhaust manifold 4, are instantaneously vaporized or "flashed" because of the temperature conditions in the exhaust manifold 4 enabling the catalyst precursor to react to form the catalyst.

- 30 The circulation of the exhaust gases in the exhaust manifold 4 then advantageously enables mixing of the exhaust gases and the catalyst as

well as homogenization of said mixture. The same applies to the circulation of this mixture in the turboblower 9, in order to actuate the latter.

- 5 In accordance with a variant of this third embodiment, the engine 1 may comprise in the catalytic device 10, 10':
- a first sub-unit of the catalytic device 10' comprising the compression injection means and configured to spray in the form of droplets a catalyst precursor consisting of an organometallic compound, in particular a
10 methylcyclopentadienyl manganese tricarbonyl component, and mixing thereof with the exhaust gases in the exhaust manifold 4; and/or
 - a second sub-unit of the catalytic device 10, employing the mixture of the catalyst precursor with the fuel oxidizer in gaseous form, arranged upstream of the compression device so that this compression device
15 increases the pressure of the mixture comprising the fuel oxidizer and the catalyst precursor to a value greater than or equal to 2 bar, or even greater than or equal to 4 bar, this pressure value being measured at its entry into the intake manifold 2.
- 20 It should be noted that, although one such particular example of the catalytic device is represented, for clarity, as two sub-units 10, 10' at distinct positions in figures 1 and 3, the latter are contained in the same catalytic device.
- 25 In accordance with a variant of this kind, the second sub-unit of the catalytic device 10 has the features of the catalytic device 10 described above with reference to the first or the second embodiment, and the description of said embodiments thus applies *mutatis mutandis* to the present variant. In particular, this kind of second sub-unit 10 of the
30 catalytic device may, as described above, comprise the hydraulic sub-assembly, not represented, comprising a tank for storing the catalyst

precursor, and the aeraulic sub-assembly, in which the liquid catalyst precursor can be evaporated and mixed into the air.

Specifically, the hydraulic sub-assembly may be common to the first sub-unit 10' and to the second sub-unit 10 of the catalytic device.

In particular, the first sub-unit of the catalytic device 10' may then comprise the feed pipe 22 which connects the hydraulic sub-assembly to at least one of the injection sites 21 and is configured to enable the circulation of the catalyst precursor from the hydraulic sub-assembly to the injection site or sites 21.

As described above, the engine 1 may moreover be controlled automatically by the control unit as a function of information transmitted by the sensors of the engine 1. In particular, such information may relate to the level of load on the engine, to its speed, to the engine torque, to the cylinder head pressure, to the temperature in the exhaust manifold, etc.

Specifically, depending on the embodiment or the variant employed, the engine 1 may be controlled automatically by the control unit so that the catalytic device uses some or all of the following options, as required:

- injection by spraying in droplet form the liquid catalyst precursor consisting of an organometallic compound, in particular a methylcyclopentadienyl manganese tricarbonyl component, and mixing thereof with exhaust gases in the exhaust manifold 4, in particular as described with reference to the third embodiment; and/or
- mixing the catalyst precursor with the fuel oxidizer upstream of the compression device so that the compression device increases the pressure of the mixture comprising the fuel oxidizer and the catalyst precursor to a value greater than or equal to 2 bar, or even greater than

or equal to 4 bar, this pressure value being measured at its entry into the intake manifold 2, as described with reference to the first or second embodiment.

5 The catalytic device 10' may advantageously be configured so as to inject a quantity between 0.5 and 15 milligrams inclusive of catalyst per m³ of exhaust gas. For example, for a catalyst precursor comprising a methylcyclopentadienyl manganese tricarbonyl component, the catalytic device 10' may be configured to inject a quantity of catalyst precursor
10 between 2 and 60 milligrams inclusive per m³ of exhaust gas. Specifically, the control of the engine may incorporate automatic regulation of the quantity of catalyst used and/or of the size of the droplets sprayed.

15 The post-combustion injection of the catalyst precursor thus contributes to carbon present in the exhaust manifold in such a manner as to achieve its almost complete thermal oxidation. This effect leads to destruction of the unburned particles and gases by gasification thereof, transforming the available carbon into carbon dioxide.

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The present invention should nevertheless not be limited to the means and configurations described and illustrated here and extends equally to any configuration and to any technically operative combination of such means to the extent that *in fine* they provide the functionalities described
25 and illustrated in the present document.

CLAIMS

1. An engine (1) for a ship, comprising an intake manifold (2), characterized in that it comprises a catalytic device (10) using the mixture
5 of a catalyst precursor that comprises an organometallic compound, in particular a methylcyclopentadienyl manganese tricarbonyl component, with a fuel oxidizer, and in that the catalytic device (10) is arranged upstream of a compression device, so that this compression device increases the pressure of the mixture comprising the fuel oxidizer and the
10 catalyst precursor to a value greater than or equal to 2 bar, or even greater than or equal to 4 bar, this pressure value being measured at its entry into the intake manifold (2).
2. The engine (1) for a ship as claimed in the preceding claim,
15 characterized in that it is a turbocharged engine comprising a turboblower (9), in that the compression device is the turboblower (9), and in that the catalytic device (10) is positioned upstream of the turboblower (9) so that said mixture comprising the fuel oxidizer and the catalyst precursor is conveyed from the outlet of the catalytic device (10) to the turboblower
20 (9), where it undergoes an increase in pressure, then from the turboblower (9) to the intake manifold (2).
3. The engine (1) for a ship as claimed in the preceding claim, characterized in that it comprises an intercooler heat exchanger (8)
25 disposed between the turboblower (9) and the intake manifold (2) to cool the mixture comprising the fuel oxidizer and the catalyst precursor to a temperature value less than or equal to 50°C, or even less than or equal to 40°C.

4. The engine (1) for a ship as claim in claim 1, characterized in that the compression device comprises at least two turbocompressors (19) disposed in series.
- 5 5. The engine (1) for a ship as claimed in the preceding claim, characterized in that it comprises at least one heat exchanger (18) disposed between two turbocompressors (19) to cool the mixture comprising the fuel oxidizer and the catalyst precursor.
- 10 6. The engine (1) for a ship as claimed in claim 4 or 5, characterized in that it is a turbocharged engine comprising a turboblower (9), in that the mixture comprising the fuel oxidizer and the catalyst precursor leaving the catalytic device is connected to an intake pipe (6) to the intake manifold (2) via an injection zone (16) disposed downstream of the
15 turboblower (9) and an intercooler exchanger (8).
7. The engine (1) for a ship as claimed in the preceding claim, characterized in that the injection zone (16) comprises a diffusion device comprising a hollow metal body pierced by a plurality of cruciform orifices
20 and positioned in a plane perpendicular to the direction of fuel oxidizer flow, to enable a mixture of the catalyst precursor vapors with the fuel oxidizer flow to be obtained.
8. The engine (1) for a ship as claimed in any one of the preceding
25 claims, characterized in that the catalytic device (10) comprises a medium comprising cellulose fibers and/or woven fibers, such as some cottons, onto which the catalyst precursor is injected in liquid form and is evaporated and mixed with a fuel oxidizer in contact with said medium.
- 30 9. The engine (1) for a ship as claimed in any one of the preceding claims, characterized in that the catalytic device (10) comprises a tank of

liquid catalyst precursor and is configured for the at least partial evaporation of said catalyst precursor in the fuel oxidizer.

10. The engine (1) for a ship as claimed in the preceding claim,
5 characterized in that the liquid catalyst precursor comprises an organometallic compound or methylcyclopentadienyl manganese tricarbonyl concentration greater than or equal to 90% of the total weight of the catalyst precursor.

10 11. The engine (1) for a ship as claimed in any one of the preceding claims, characterized in that it is an engine rated at between 1 MW and 100 MW inclusive.

12. A method of reducing emissions of particles from an engine (1) for
15 a ship, characterized in that it comprises the execution of the following steps:

- mixing a catalyst precursor that comprises an organometallic compound, notably a methylcyclopentadienyl manganese tricarbonyl component, with a fuel oxidizer, then
- 20 - increasing the pressure of said mixture by means of a compression device to a pressure value greater than or equal to 2 bar, or even greater than or equal to 4 bar, then
- injecting said mixture under pressure into an intake manifold (2) for a combustion chamber of an engine (1).

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13. A catalytic device (10) for an engine (1) for a ship as claimed in any one of claims 1 to 11, characterized in that it comprises a tank of liquid catalyst precursor, which comprises an organometallic compound, in particular a methylcyclopentadienyl manganese tricarbonyl component,
30 in that it is configured for the mixing and the at least partial evaporation of

said catalyst precursor in a fuel oxidizer, and in that it comprises a means of connection with a compression device of an engine (1) for a ship.