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(54) **Title**: INTERNAL COMBUSTION ENGINE EQUIPPED WITH TWO TURBOCHARGERS

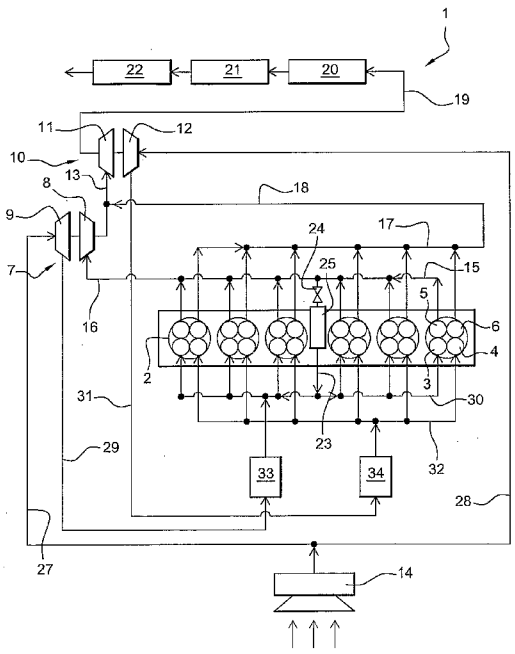

Fig. 1

(57) **Abstract**: The internal combustion engine comprises: a plurality of cylinders (2), each cylinder having at least a first and a second inlet valves (3, 4) and at least a first and a second exhaust valves (5, 6), the lift of said exhaust valves (5, 6) and/or intake valves (3, 4) being independently controlled; a high pressure turbocharger (7) having a high pressure turbine (8) and a high pressure compressor (9), and a low pressure turbocharger (10) having a low pressure turbine (11) and a low pressure compressor (12), the high pressure turbine outlet being connected to the low pressure turbine inlet; at least one intake line (27, 28, 35) capable of carrying intake air compressed by at least one of said high pressure and/or low pressure compressors (9, 12) towards at least one engine intake manifold (30, 32, 43); a first engine exhaust manifold (15) capable of collecting exhaust gas from said first exhaust valves (5) and of carrying it towards said high pressure turbine (8) and then to said low pressure turbine (11); and a second engine exhaust manifold (17) capable of collecting exhaust gas from said second exhaust valves (6) and of carrying it towards said low pressure turbine (11).

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INTERNAL COMBUSTION ENGINE EQUIPPED WITH TWO TURBOCHARGERS

Field of the invention

The present invention relates to an internal combustion engine for an automotive vehicle, especially an industrial vehicle. More specifically, the invention relates to an internal combustion engine equipped with two turbochargers.

Technological background

In order to improve engine efficiency, it is well known to provide engines equipped with at least one turbocharger having a turbine driven by the exhaust gas, said turbine driving a compressor capable of compressing intake air.

Providing a dual stage turbocharger can further improve engine efficiency. It is then necessary to regulate the flow of exhaust gas passing through high pressure and low pressure turbines, so that the turbochargers output can be optimized whatever the engine speed and load.

Said regulation is generally achieved by means of valves or wastegates, which are capable of directing an appropriate portion of the exhaust gas going out from the exhaust valves of each cylinder towards one or two turbines.

Such valves or wastegates are greatly stressed in use, and may be quickly worn. Their reliability is often difficult to control. Furthermore, it implies the use of an additional component, which increases the global cost of the engine.

It therefore appears that, from several standpoints, there is room for improvement in internal combustion engines.

Summary of the invention

It is an object of the present invention to provide an improved internal combustion engine, especially for an industrial vehicle, which can overcome the drawbacks encountered in conventional engines.

Another object of the present invention is to provide an internal combustion engine equipped with two turbochargers in which the flow of exhaust gas passing through each turbine is regulated depending on the engine speed and load.

According to the invention such an internal combustion engine comprises:

- a plurality of cylinders, each cylinder having at least one inlet valve and at least a first and a second exhaust valves, the lift of said exhaust valves being independently controlled;
- a high pressure turbocharger having a high pressure turbine and a high pressure compressor, and a low pressure turbocharger having a low pressure turbine and a low pressure compressor, the high pressure turbine outlet being connected to the low pressure turbine inlet;
- at least one intake line capable of carrying intake air compressed by at least one of said high pressure and/or low pressure compressors towards at least one engine intake manifold;
- a first engine exhaust manifold capable of collecting exhaust gas from said first exhaust valves and of carrying it towards said high pressure turbine and then to said low pressure turbine; and
- a second engine exhaust manifold capable of collecting exhaust gas from said second exhaust valves and of carrying it towards said low pressure turbine.

In concrete terms, the invention makes it possible, by means of the valves lift independent regulation, to direct the exhaust gas flow to the low pressure turbine only, or to the high pressure turbine only (the exhaust gas then flowing to the low pressure turbine arranged in series), or to both low pressure and high pressure turbines.

Typically, the high pressure turbine is used alone at low to mid engine speeds for transient response purpose, whereas the low pressure turbine becomes active at high engine speeds and loads to ensure the requested flow through the engine.

According to an embodiment of the invention, the internal combustion engine can comprise:

- a first intake line capable of carrying intake air towards said high pressure compressor and then towards a first engine intake manifold connected to first inlet valves;

- a second intake line capable of carrying intake air towards said low pressure compressor and then towards a second engine intake manifold connected to second inlet valves;

the high pressure and low pressure compressors being arranged in parallel.

In this embodiment, intake air is carried towards the engine through first intake line or second intake line, and goes through only one compressor (high pressure or low pressure compressor; part of the air through the high pressure compressor and part of the air through the low pressure compressor).

According to another embodiment of the invention, the low pressure compressor outlet is connected to the high pressure compressor inlet, so that at least part of the intake air can be compressed by said two compressors. The compressors are then arranged in series (when considering the flow of intake air).

In this embodiment, according to a variant, the internal combustion engine can comprise a single intake line capable of carrying all of the intake air through low pressure compressor and then through high pressure compressor, and towards a single intake manifold connected to first and second inlet valves. Then all of the intake air is compressed twice. There may be provided a cooler located between said low pressure compressor and said high pressure compressor and/or a cooler located between said high pressure compressor and said intake manifold.

Alternatively, according to another variant, the internal combustion engine can comprise:

- a single main intake line capable of carrying all of the intake air through low pressure compressor;
- a first intake line capable of carrying intake air compressed by said low pressure compressor towards a first intake manifold connected to first inlet valves;
- a branch deviating from said first intake line, capable of carrying part of the intake air compressed by said low pressure compressor towards said high pressure compressor;
- a second intake line capable of carrying intake air compressed by said high pressure compressor towards a second intake manifold connected to second inlet valves.

In other words, according to this variant, part of the intake air is only compressed once, and the other part of the air is compressed twice.

In this variant, there may be provided a cooler located in the first intake line, upstream from the point from which the branch deviates from said intake line and/or a cooler located in the second intake line, between said high pressure compressor and said second intake manifold.

In an implementation of the invention, the internal combustion engine comprises a camless valve control system, the lift of the valves being controlled by actuators. However, other engine arrangements can be envisaged, provided the lift of the exhaust valves can be independently controlled.

Besides, the internal combustion engine can for example comprise an exhaust gas recirculation (EGR) line rerouting a portion of the engine's exhaust gas into the at least one intake manifold.

These and other advantages will become apparent upon reading the following description in view of the drawing attached hereto representing, as non-limiting examples, embodiments of a vehicle according to the invention.

Brief description of the drawing

The following detailed description of several embodiments of the invention is better understood when read in conjunction with the appended drawing being understood, however, that the invention is not limited to the specific embodiments disclosed. In the drawing,

Figure 1 is a schematic drawing of an internal combustion engine according to a first embodiment of the invention;

Figure 2 is a schematic drawing of an internal combustion engine according to a second embodiment of the invention;

Figure 3 is a schematic drawing of an internal combustion engine according to a third embodiment of the invention.

Detailed description of the invention

As this is illustrated in the figures, the invention relates to an internal combustion engine 1 which comprises a plurality of cylinders 2 (here

six cylinders), each cylinder having a first and a second inlet valves 3, 4 and a first and a second exhaust valves 5, 6.

An important feature of the invention is that the lifts of at least the exhaust valves 5, 6 are controlled independently. This can be achieved by a camless valve control system, in which electromagnetic or hydraulic actuators control the valves lifts. It can also be achieved with the use of an elaborate variable cam system.

In the example shown in Figure 1, the intake valves 3, 4 are also preferably controlled independently.

The engine 1 also comprises two turbochargers, namely a high pressure turbocharger 7 having a high pressure turbine 8 and a high pressure compressor 9 driven by said high pressure turbine 8; and a low pressure turbocharger 10 having a low pressure turbine 11 and a low pressure compressor 12 driven by said low pressure turbine 11. The high pressure turbine outlet is connected to the low pressure turbine inlet by a connecting line 13. In other words, said turbines 8, 11 are arranged in series when considering the flow of exhaust gas.

Whatever the embodiment of the invention, the general operation of the engine 1 is the following:

- intake air passes through an air filter 14 and is carried towards the inlet valves 3, 4 of the engine 1, passing through at least one of the high pressure compressor 9 and the low pressure compressor 12;
- exhaust gases from every first exhaust valves 5 are collected by a first engine exhaust manifold 15, and are carried by a first exhaust line 16 towards the high pressure turbine 8 and then to the low pressure turbine 11 by the connecting line 13.
- exhaust gases from every second exhaust valves 6 are collected by a second engine exhaust manifold 17, and are carried by a second exhaust line 18 towards the connecting line 13.

Thus, the low pressure turbine 11 is driven by the exhaust gases of the first exhaust valves 5 which come from the high pressure turbine 8, mixed with the exhaust gases of the second exhaust valves 6 which come from the second exhaust manifold 17.

Finally, a main exhaust line 19 carries the exhaust gas coming out of the low pressure turbine 11 towards the atmosphere. Preferably, one or more after treatment devices are provided on the main exhaust line 19, such as

a device 20 for the treatment of unburned HC (hydrocarbon) and CO (carbon monoxide), and/or a particulate filter 21, before a muffler 22 in which a device for the treatment of NOx (nitrogen oxide and nitrogen dioxide) can be installed.

The engine 1 can further comprise an exhaust gas recirculation (EGR) line 23 rerouting a portion of the engine's exhaust gas towards the first inlet valves 3 and/or the second inlet valves 4. Said EGR line 23 deviates from the first exhaust manifold 15 and includes an EGR valve 24 and an EGR cooler 25.

Various embodiments of the invention will now be described.

Figure 1 shows a first embodiment of the invention.

In this embodiment, the engine 1 comprises, after the air filter 14, a first intake line 27 capable of carrying intake air towards the high pressure compressor 9, and a separate second intake line 28 capable of carrying intake air towards the low pressure compressor 12.

The outlet of the high pressure compressor 9 is connected by a first line 29 to a first engine intake manifold 30 connected to every first inlet valves 3. The outlet of the low pressure compressor 12 is connected by a second line 31, separate from the first line 29, to a second engine intake manifold 32 connected to every second inlet valves 4. Said first line 29 and second line 31 are each provided with a cooler 33, 34. Besides, the EGR line 23 is connected to the first intake manifold 30.

In this embodiment, the high pressure and low pressure compressors 9, 12 are arranged in parallel. The intake air entering the inlet valves 3, 4 has passed through only one of said compressors 9, 12 (part of the air through high pressure compressor 9 and part of the air through low pressure compressor 12).

According to a second embodiment of the invention, shown in Figure 2, a single main intake line 35 is provided downstream from the air filter 14, to carry all of the intake air through low pressure compressor 12.

Air compressed by said low pressure compressor 12 is then carried by a first intake line 36 towards a first intake manifold 30 connected to every first inlet valves 3.

A branch 37 deviating from said first intake line 36 carries part of the intake air compressed by the low pressure compressor 12 towards the high pressure compressor 9. Then, a second intake line 38 carries the intake air

compressed by the high pressure compressor 9 towards a second intake manifold 32 connected to every second inlet valves 4.

A cooler 33 is provided on the first intake line 36, upstream from the point from which the branch 37 deviates from said intake line. Another cooler 34 is provided on the second intake line 38 between the high pressure compressor 9 and the second intake manifold 32.

Besides, the EGR line 23 is connected to the first intake manifold 30.

In this embodiment, part of the intake air is only compressed once (by the low pressure compressor 12) and enters the first inlet valves 3 through the first intake manifold 30, whereas the other part of the air is compressed twice (by the low pressure compressor 12 and then the high pressure compressor 9) and enters the second inlet valves 4 through the second intake manifold 32. The compressors 9, 12 are arranged in a layout which is a combination of the series and of the parallel layouts.

Figure 3 shows a third embodiment of the invention.

In this embodiment, a single main intake line 35 is provided downstream from the air filter 14, to carry all of the intake air through low pressure compressor 12. The low pressure compressor outlet is connected to the high pressure compressor inlet, so that all of the air compressed by the low pressure compressor 12 is carried towards the high pressure compressor 9 by a line 39 provided with a cooler 40. Finally, all of the air going out of the high pressure compressor 9 is carried by a line 41 equipped with a cooler 42 towards a single intake manifold 43 connected to every first and second inlet valves 3, 4.

With the compressors arranged in series, in this embodiment, all of the intake air is compressed by said two compressors. It has to be noted that, in this embodiment, there could be only one intake valve per cylinder, or in case, there are two intake valves per cylinder, they could be jointly controlled instead of being independently controlled.

By regulating (for example by means of a camless valve control system) the lift of each exhaust valve, it is possible to regulate the exhaust flow of gas coming from said exhaust valves. Moreover, by providing two exhaust manifolds each connected to part of the exhaust valves, and connecting said exhaust manifolds to the high pressure turbine, respectively the low pressure turbine, the invention makes it possible to easily and more efficiently control the

exhaust flow entering each turbine. As a result, the operation of the turbines is optimized, whatever the engine load.

The regulation of the exhaust valve lifts can be used to direct the exhaust gas flow to only the high pressure turbine (the gas then flowing to said low pressure turbine), to only the low pressure turbine, or to both turbines.

With the turbines arranged in series, it is possible to recover some energy on the low pressure turbine from the exhaust gas that have been expanded in the high pressure turbine.

These advantages of the invention are achieved without the necessity to provide valves or wastegates for the regulation, at least for the high pressure turbine.

Of course, the invention is not restricted to the embodiment described above by way of non-limiting example, but on the contrary it encompasses all embodiments thereof.

CLAIMS

1. An internal combustion engine, comprising:

- a plurality of cylinders (2), each cylinder having at least one inlet valve (3, 4) and at least a first and a second exhaust valves (5, 6), the lift of said exhaust valves (5, 6) being independently controlled;
- a high pressure turbocharger (7) having a high pressure turbine (8) and a high pressure compressor (9), and a low pressure turbocharger (10) having a low pressure turbine (11) and a low pressure compressor (12), the high pressure turbine outlet being connected to the low pressure turbine inlet;
- at least one intake line (27, 28, 35) capable of carrying intake air compressed by at least one of said high pressure and/or low pressure compressors (9, 12) towards at least one engine intake manifold (30, 32, 43);
- a first engine exhaust manifold (15) capable of collecting exhaust gas from said first exhaust valves (5) and of carrying it towards said high pressure turbine (8) and then to said low pressure turbine (11); and
- a second engine exhaust manifold (17) capable of collecting exhaust gas from said second exhaust valves (6) and of carrying it towards said low pressure turbine (11).

2. The internal combustion engine according to claim 1, characterized in that it comprises:

- a first intake line (27) capable of carrying intake air towards said high pressure compressor (9) and then towards a first engine intake manifold (30) connected to first inlet valves (3);
- a second intake line (28) capable of carrying intake air towards said low pressure compressor (12) and then towards a second engine intake manifold (32) connected to second inlet valves (4);

the high pressure and low pressure compressors (9, 12) being arranged in parallel.

3. The internal combustion engine according to claim 1, characterized in that the low pressure compressor outlet is connected to the high pressure compressor inlet, so that at least part of the intake air can be compressed by said two compressors (9, 12).

4. The internal combustion engine according to claim 3, characterized in that it comprises a single intake line (35) capable of carrying all of the intake air through low pressure compressor (12) and then through high pressure compressor (9), and towards a single intake manifold (43) connected to first and second inlet valves (3, 4).

5. The internal combustion engine according to claim 4, characterized in that it comprises a cooler (40) located between said low pressure compressor and said high pressure compressor.

6. The internal combustion engine according to claim 4 or 5, characterized in that it comprises a cooler (42) located between said high pressure compressor (9) and said intake manifold (43).

7. The internal combustion engine according to claim 3, characterized in that it comprises:

- a single main intake line (35) capable of carrying all of the intake air through low pressure compressor (12);
- a first intake line (36) capable of carrying intake air compressed by said low pressure compressor (12) towards a first intake manifold (30) connected to first inlet valves (3);
- a branch (37) deviating from said first intake line (36), capable of carrying part of the intake air compressed by said low pressure compressor (12) towards said high pressure compressor (9);
- a second intake line (38) capable of carrying intake air compressed by said high pressure compressor (9) towards a second intake manifold (32) connected to second inlet valves (4).

8. The internal combustion engine according to claim 7, characterized in that it comprises a cooler (33) located in the first intake line (36), upstream from the point from which the branch (37) deviates from said intake line (36).

9. The internal combustion engine according to claim 7 or 8, characterized in that it comprises a cooler (34) located in the second intake

line (38), between said high pressure compressor (9) and said second intake manifold (32).

10. The internal combustion engine according to any one of claims 1 to 9, characterized in that it comprises a camless valve control system, the lift of the valves being controlled by actuators.

11. The internal combustion engine according to any one of claims 1 to 10, characterized in that it comprises an exhaust gas recirculation (EGR) line (23) rerouting a portion of the engine's exhaust gas into the at least one intake manifold (30, 43).

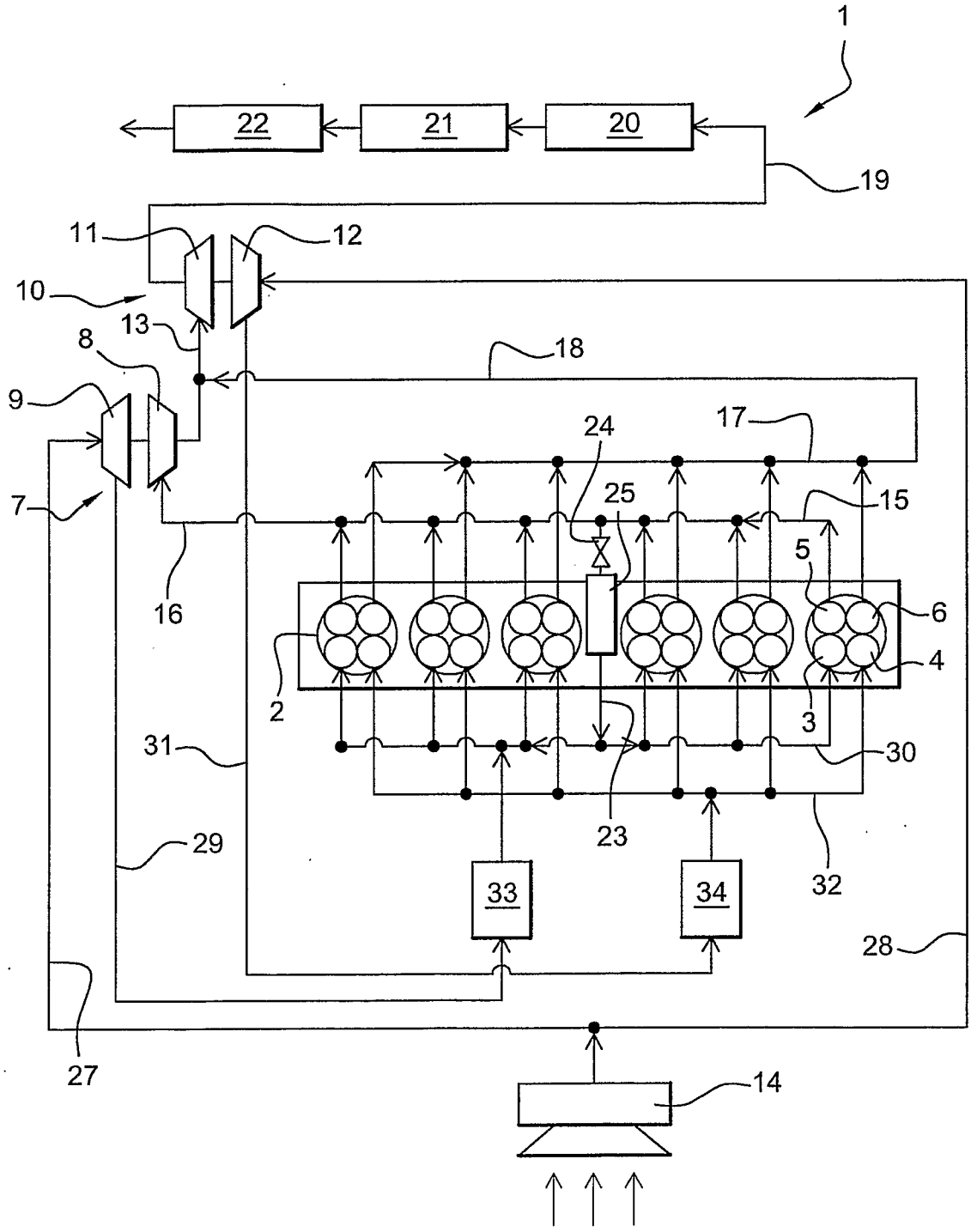
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Fig. 1

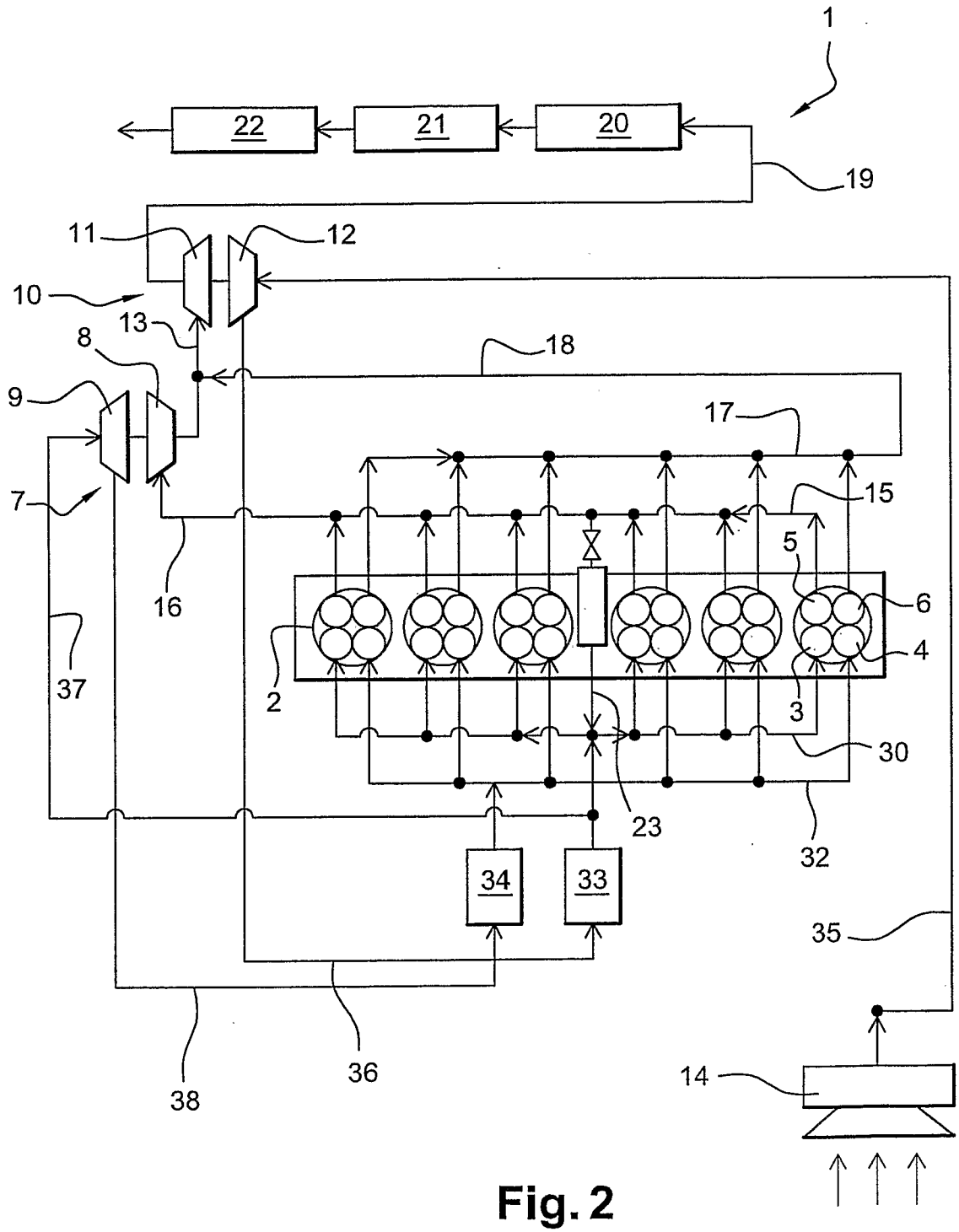
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Fig. 2

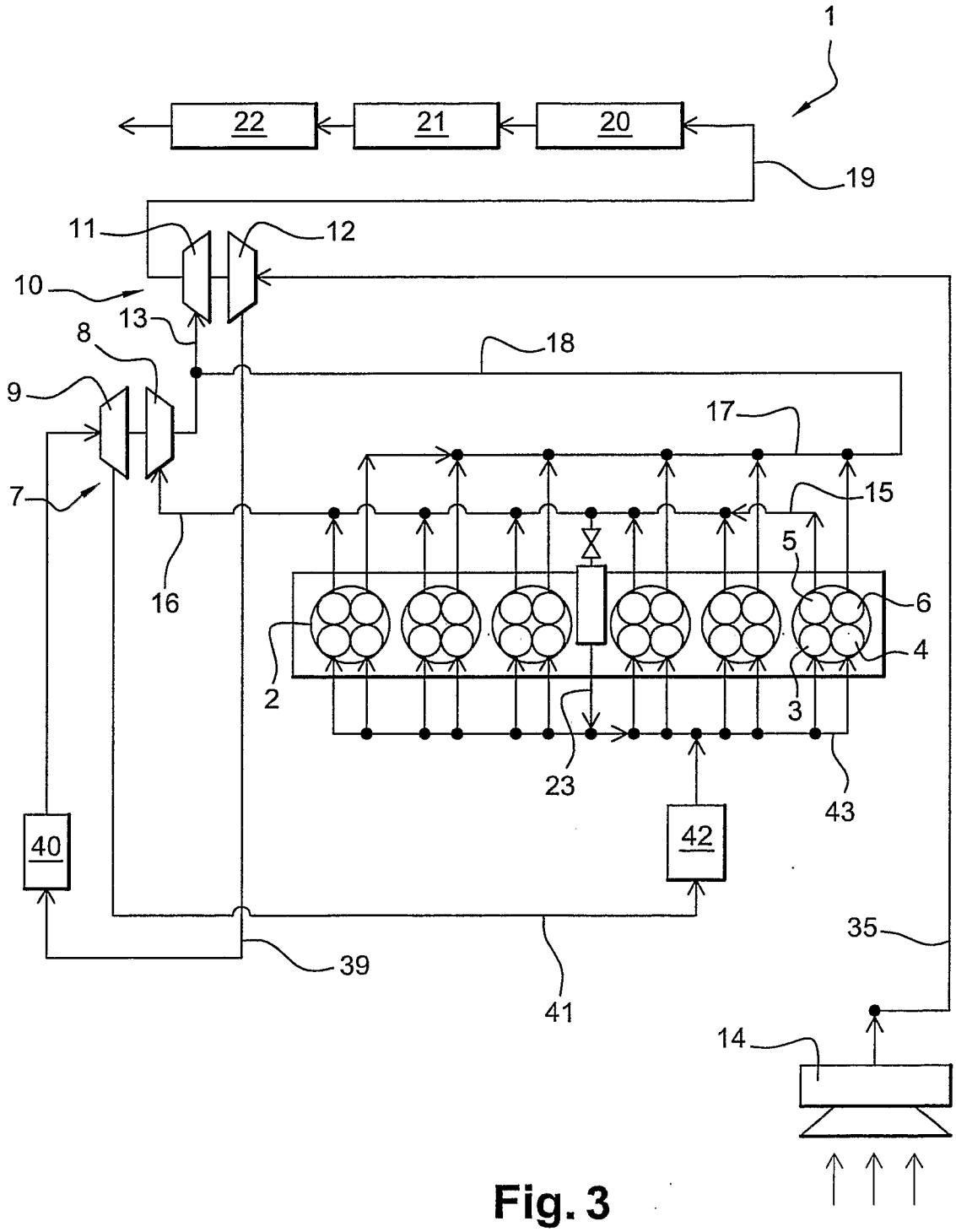

Fig. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2008/003807

A. CLASSIFICATION OF SUBJECT MATTER
INV. F02B37/007 F02B37/013 F02D23/00 F02D13/02
ADD. F02B29/04 F02B37/12 F02B37/16 F02M25/07 F01N7/10

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F02B F02D F02M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP 61 164039 A (NISSAN MOTOR) 24 July 1986 (1986-07-24) figures 1-7	1 2-11
Y	WO 2005/068802 A (LOTUS CAR [GB]; TURNER JAMES WILLIAM GRIFFITH [GB]) 28 July 2005 (2005-07-28) figures 1,2	2-11
X	FR 2 884 866 A (RENAULT SAS [FR]) 27 October 2006 (2006-10-27) figures 1-3	1

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search	Date of mailing of the international search report
8 September 2009	15/09/2009

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2008/003807

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 61164039 A	24-07-1986	NONE	
WO 2005068802 A	28-07-2005	AT 358230 T	15-04-2007
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