



(11) **EP 3 168 444 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
17.05.2017 Bulletin 2017/20

(51) Int Cl.:
F02D 17/02 (2006.01) **F02D 41/00** (2006.01)
F02D 15/00 (2006.01) **F02B 73/00** (2006.01)

(21) Application number: **16198544.5**

(22) Date of filing: **11.11.2016**

(84) Designated Contracting States:
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO
PL PT RO RS SE SI SK SM TR**
Designated Extension States:
BA ME
Designated Validation States:
MA MD

(71) Applicant: **FPT Industrial S.p.A.**
10156 Torino (IT)

(72) Inventor: **D'EPIRO, Clino**
10091 ALPIGNANO (IT)

(74) Representative: **Fiume, Orazio et al**
Studio Torta S.p.A.
Via Viotti, 9
10121 Torino (IT)

(30) Priority: **11.11.2015 IT UB20155457**

(54) **INTERNAL COMBUSTION ENGINE AND METHOD FOR CONTROLLING THE SAME**

(57) Internal combustion engine comprising a plurality of cylinders with relative pistons, connected to a relative common drive shaft, said multitude of cylinders being divided into a first group and a second group of cylinders, in which consecutive ignition cycles alternate between the two groups of cylinders, the first group of cyl-

inders being controlled to be always active, and the second group of cylinders being controlled to be active on request, the engine being characterised in that said first group of cylinders has a compression ratio different from a compression ratio of said second group of cylinders.

EP 3 168 444 A1

Description

Technical field of the invention

[0001] The invention relates to the field of internal combustion engines, for example Diesel cycle or Otto cycle engines, and to a method for controlling the same.

State of the art

[0002] For a long time, the so-called cylinder deactivation technique has been known, which involves cutting off some of the cylinders of an internal combustion engine, so as to offer a greater load to the active cylinders, thus saving fuel but with the same power delivered.

[0003] Depending on the type of implementation, this can lead to simple operations to be carried out on the supply, but also to actual changes in the way in which the valves are controlled, so as to forbid the circulation of air through the deactivated cylinders. In particular, in petrol engines, owing to the stoichiometric supply and the three-way catalyst for controlling emissions, practice requires the elimination of the air flow in the deactivated cylinder, thus forcing manufacturers, given a limited reduction of pumping losses, to use the expensive variable valve control system. As a matter of fact, the reduction of the number of active cylinders, given the same power delivered, leads to an increase of the load acting upon the remaining cylinders. This load increase causes a greater opening of the supply control throttle, with a reduction of the intake depression, which generates known pumping losses. This reduction leads to a limited reduction of consumptions, which, anyway, only relates to highly choked loads.

[0004] In Diesel engines, which, unlike petrol engines, are not affected by pumping losses, there are no significant advantages in terms of consumptions.

[0005] Generally speaking, though, this practice is anyway associated with operating limitations concerning the duration of the deactivation, as the trapped gas tends to escape through the segments of the pistons, thus creating a vacuum, which causes oil to flow to the combustion chamber and cools down the deactivated cylinder, which then does not burn well during the following activation. Therefore, the current practice comprises the periodic activation of the deactivated cylinders, thus limiting application possibilities.

[0006] For this reason, we think that the cylinder deactivation technique can be improved.

Summary of the invention

[0007] The object of the invention is to overcome all the aforesaid drawbacks and to provide an internal combustion engine that is capable of further reducing fuel consumptions, though leaving unchanged - or even improving - the performances of an engine of the prior art.

[0008] In the description below you will read about a

first group of cylinders and a second group of cylinders, even if one of said first or second group comprises one single cylinder. However, the two groups preferably have the same number of cylinders, e.g. 2+2, 3+3, etc.

[0009] In other words, we are dealing with one single internal combustion engine with two groups of cylinders sharing the same cylinder block, the same drive shaft and, preferably, even the same fuel injection system and engine control unit; therefore, the engine, as a whole, can be a V engine or an in-line engine.

[0010] The idea on which the invention is based is not only that of using the controlled deactivation of a second group of cylinders, but also that of changing the functional features of the first group of cylinders so as to better adjust to the cruising speed of the vehicle in which the resisting load is remarkably smaller than the maximum power that the engine is capable of delivering. Typically, said resisting load at the cruising speed is less than a third of the maximum power.

[0011] The engine is preferably provided with one single and common drive shaft, to which the pistons of the first and second group of cylinders are connected, so that, when the two groups are both active, the Diesel or Otto thermodynamic cycles are alternately divided between the two groups of cylinders. This implies obtaining the burning of the mixture alternately between the two groups of cylinders.

[0012] According to the invention, the first group of cylinders is always active and has a first compression ratio that is greater than the compression ratio of the second group of cylinders.

[0013] Preferably, the first group of cylinders has a fuel injection timing advance that is lower than a fuel injection timing advance of the second group of cylinders.

[0014] Advantageously, the first group of cylinder, with a greater compression ratio, ensures high efficiency at small loads and, therefore, according to the invention, it is always used.

[0015] Since, at a constant cruising speed, which ranges from 90 to 130 km/h, the power supplied by the engine is approximately 1/3 of the nominal power, this implies not only doubling the load on said first group of cylinders, relative to a conventional engine, but also having optimized said first group of cylinders so as to consume as little as possible in those operating conditions.

[0016] Said first group of cylinders preferably has a specific power that is smaller than the maximum one that would be possible with a smaller compression ratio and, hence, a power that is preferably smaller than the second group of cylinders.

[0017] On the contrary, the second group of cylinders has a smaller compression ratio and, preferably, a higher fuel injection timing advance, thus ensuring greater efficiency at high loads, namely during the acceleration phases of the vehicle, when the second group of cylinders is asked to deliver power as well.

[0018] Advantageously, during transient phases, i.e. during the accelerations of the vehicle, the second group

of cylinders, working with a higher injection timing advance, ensures a better mixing between air and fuel, having a greater ignition delay; therefore, the temperature cycle turns out to be lower with a smaller production of NOx. According to a preferred embodiment of the invention, the first group of cylinders is associated with a first turbocompressor, whereas the second group of cylinders is associated with a second turbocompressor, wherein the first turbocompressor is set so as to offer a lower boost than the second turbocompressor, so as to make sure that the peak combustion pressure - PCP is not exceeded despite the high compression ratio.

[0019] According to a second preferred variant of the invention, regardless of the presence of two separate supercharging groups, the first group of cylinders has an intake manifold and an exhaust manifold, which are respectively separate from the intake manifold and from the exhaust manifold of the second group of cylinders.

[0020] Preferably, recirculation means connect the exhaust manifold or a point downstream of the first turbocompressor and/or of the power turbine, if available, of the first group of cylinders to the intake manifold of the second group of cylinders and said recirculation means are active when the second group of cylinders is deactivated, so as to prevent fresh air from reaching, flowing through the second group of cylinders, the exhaust gas after-treatment system (ATS), thus cooling it down and worsening the efficiency, especially if the engine is a Diesel cycle engine. This practice is particularly advantageous especially when the engine is a stoichiometric Otto cycle engine for the operation of the three-way-catalyst, but it has also proven to be advantageous for Diesel cycle engines in order to keep the ATS hot, as, at a certain temperature, its stops functioning in an efficient manner (light-off temperature). According to a further preferred embodiment of the invention, the first group of cylinders supplies a power turbine, i.e. a turbine that is mechanically connected to the drive shaft of the engine, and/or the second group of cylinders is associated with at least one first supercharging stage of the turbocompressor type and, if necessary, with a second supercharging stage, always of the turbocompressor type.

[0021] According to another preferred variant of the invention, deriving from the previous one, the first group of cylinders, besides supplying a power turbine, also comprises a supercharging stage of the turbocompressor type.

[0022] According to a further preferred variant of the invention, regardless of the presence of the power turbine and of the aforesaid recirculation means, the supercharging stage of the first group of cylinders comprises a wastegate valve to bypass the relative turbine, but exhaust gases, rather than being directly directed towards the ATS, are directed towards a turbine of the first and/or second stage, if different supercharging stages are available, of the second group of cylinders, so as to help said stage achieve a faster transient, thus improving the dynamic reaction of the supercharging stage/s of the sec-

ond group of cylinders. Preferably, the valve control system is shared by both groups of cylinders, even if the opening and/or closing angles of the first group of valves, belonging to the first group of cylinders, can be different from the second group of valves belonging to the second group of cylinders. Furthermore, preferably, there is no particular strategy for controlling the valves of the second group of cylinders, which means that the valves invariably continue the relative opening cycles both when said second group is active and when it is not active.

[0023] It is a subject-matter of the invention an internal combustion engine according to claim 1.

[0024] Another subject-matter of the invention is a method for controlling the internal combustion engine.

[0025] A further subject-matter of the invention is a terrestrial vehicle or a fixed installation implementing said internal combustion engine.

[0026] The claims describe preferred embodiments of the invention, thus forming an integral part of the description.

Brief description of the figures

[0027] Further objects and advantages of the invention will be best understood upon perusal of the following detailed description of an embodiment thereof (and of relative variants) with reference to the accompanying drawings merely showing non-limiting examples, wherein figures 1 - 5 and 7 show preferred diagrams implementing preferred variants of the invention, whereas figures 6a and 6b show some components that are typically implemented in the devices used to reduce pollutants in exhaust gases of Diesel engines.

[0028] In the figures, the same numbers and the same reference letters indicate the same elements or components.

[0029] For the purposes of the invention, the term "second" component does not imply the presence of a "first" component. As a matter of fact, these terms are only used for greater clarity and should not be interpreted in a limiting manner.

Detailed description of embodiments

[0030] According to the invention, an internal combustion engine E comprises a plurality of cylinders C1, C2 with relative pistons, which are connected to a relative common drive shaft (not shown). The multitude of cylinders is divided into a first group C1 and a second group of cylinders C2, in which consecutive ignition cycles alternate between the two groups of cylinders when both groups are active. By so doing, there is always the ignition of a cylinder belonging to the first group C1 followed, immediately after, by the ignition of a cylinder belonging to the second group C2 and then another cylinder belonging to the first group C2, etc..

[0031] The first group of cylinders is controlled to be always active, whereas the second group of cylinders is

controlled to be active on demand.

[0032] In particular, the first group of cylinders has a compression ratio that is different from a compression ratio of the second group of cylinders.

[0033] In a Diesel cycle engine, the first group of cylinders preferably has a compression ratio up to 21, whereas in a Otto cycle engine the compression ratio is up to 15.

[0034] If the engine is a Diesel cycle engine, the second group of cylinders preferably has a compression ratio up to 13 and even up to 11 or less in case of pre-heating of the feeding air. On the other hand, if the engine is an Otto cycle engine, in the presence of a strong supercharging, a compression ratio of 8 is sufficiently low to enable very high specific powers.

[0035] Therefore, the difference of the compression ratios preferably is at least 3, with an optimal value of 7 both for a Diesel cycle engine and for an Otto cycle engine.

[0036] The engine, as a whole, regardless of the division into groups of cylinders, is a Diesel cycle engine or an Otto cycle engine and, furthermore, the cylinders can have an "in-line" or a V arrangement. In the last case, each bank defines said first or second group of cylinders.

[0037] By compression ratio we can mean both the geometric compression ratio, given by the ratio of the volumes when the piston respectively is in the bottom dead centre and in the top dead centre, and the actual compression ratio, which can take into account particular opening and/or closing angles of the intake valves. As a matter of fact, an early or delayed closing thereof determines a smaller charge volume in the cylinder, with a lower actual compression ratio. This difference does not affect the invention.

[0038] Preferably, the compression ratio of the first group of cylinders C1 is greater than the compression ratio of the second group of cylinders C2.

[0039] Advantageously, the first group of cylinders has an especially economic operation at low and medium loads, which basically means when the vehicle moves at a cruising speed.

[0040] Vice versa, the second group of cylinders, with a smaller compression ratio, is capable of expressing a better efficiency at high loads, which means in transient states, during the accelerations of the vehicles, and at maximum power.

[0041] As explained more in detail below, the first group of cylinders can have a different power compared to the second group of cylinders.

[0042] The engine preferably comprises a fuel injection system (not shown) for supplying the first and second group of cylinders, wherein a fuel injection regulation relative to the first group of cylinders is different from a fuel injection regulation relative to the second group of cylinders.

[0043] A different injection mapping between the two groups of cylinders can be provided not only in static terms, but also in dynamic terms, which means that, as

the groups are substantially different in terms of maps of specific consumption (BSFC), given a predefined rotation speed and a predefined power level requested, as a whole, to the engine, the two groups of cylinders are fed in such a way that the actual global consumption of the engine is minimised. This implies that, at the same predefined rotation speed, the feeding maps of the two groups of cylinders can drastically vary so as to minimise the consumption of the entire engine. In other words, this is about solving a linear programming method, an example thereof being the simplex method, or according to other methods, among which there are the Fourier methods. Furthermore, this regulation of the injection can be differentiated also in terms of injection timing advance relative to the top dead centre. As a matter of fact, there preferably is a higher injection timing advance for the second group of cylinders, compared to the injection timing advance of the first group of cylinders.

[0044] The first group of cylinders and the second group of cylinders preferably have separate intake and/or exhaust manifolds.

[0045] According to the preferred variants shown in the figures, the first group of cylinders has an intake manifold IT1, called "first manifold", and the second group of cylinders has a respective intake manifold IT2, called "second manifold", so that said first and second manifold are mutually separate from each other. Preferably, the engine also comprises a first supercharging device TC1 operatively connected to the first intake manifold and/or a second supercharging device operatively connected to the second intake manifold.

[0046] They can be volumetric compressors guided by the drive shaft and/or turbocompressors.

[0047] The engine can comprise one single supercharging device TC1/TC2 connected to both intake manifolds, or it can be connected only to a group of cylinders, preferably the one having a smaller compression ratio (C2), so as to develop a greater specific power, which is useful during transient states.

[0048] Furthermore, the engine can comprise a first TC1 and a second supercharging device TC2, and wherein said first supercharging device TC1 is calibrated to provide a supercharging pressure lower than said second supercharging device TC2. In this case, it turns out that it is particularly useful to have the intake manifolds IT1 and IT2 and the exhaust manifolds EX1 and EX2, of the first group C1 and of the second group C2 respectively, mutually separate from each other.

[0049] Regardless of the number of supercharging devices used, it is advantageous to have the intake manifolds and, preferably, also the exhaust manifolds separate between the two groups of cylinders also for another reason. According to a preferred variant of the invention, which can be combined with the previous ones, the engine E comprises first bypass means B1 for connecting said first exhaust manifold, preferably in a point downstream of one or more turbines, to said second intake manifold IT2, and wherein said bypass means B1 are

configured, by means of a valve V1, to cut in when said second group of cylinders is not active, so as to circulate exhaust gas, produced by the first group of cylinders C1, through the second group of cylinders C2. Since the first bypass means are active when the second group of cylinders is not active, we are not dealing with exhaust gas recirculation as it is known, because the aim is not that of reducing NOx, but that of preventing the second group of cylinders from pumping fresh air, which then reaches and cools down the pollutant reduction devices generally indicated with ATS (After Treatment System), especially when the engine is a Diesel cycle engine.

[0050] By so doing, the first bypass means are made in such a way that, when the second group of cylinders is not active, they can only and exclusively ingest exhaust gases, possible excess exhaust gases are directly sent to the ATS. When the engine is a petrol engine, the advantage is that of preventing oxygen from being introduced into the ATS, which would lead to a fault thereof.

[0051] Furthermore, especially when the engine is a petrol engine, a cooler can be arranged on the bypass line connecting the exhaust manifold of the first group of cylinders to the intake manifold of the second group of cylinders, activated at high loads, while the second group of cylinders is not active, so as to limit temperatures in the second group of cylinders and in the three-way catalyst.

[0052] According to a preferred variant of the invention, which can be combined with the previous one, the bypass point is obtained not only downstream of said one or more turbines, but also downstream of the ATS, similarly to a low-pressure EGR, in which the exhaust gas ingested by the second group of cylinders is equal to 100% of the respective overall charge.

[0053] According to another preferred variant of the invention, which can be combined with the previous ones, the exhaust lines of the two groups of cylinders are separate from each other with respective separate turbines, which are properly calibrated based on the features of the two groups of cylinders. In this case, again, the first bypass means are preferably connected downstream of the turbine/s of the first group of cylinders.

[0054] In the accompanying figures, the exhaust lines of the two groups of cylinders EL1, EL2 converge in a common ATS, but the principle described herein applies also in case of two distinct after treatment systems for each group of cylinders.

[0055] Similarly, both intake lines IL1 and IL2 can branch off from a common air filter or from separate and independent filters.

[0056] The expressions "downstream" and "upstream" take into account the circulation of exhaust gases, when they are referred to the exhaust lines EL1 and EL2, and the circulation of fresh air, when they are referred to the intake lines IL1 and IL2.

[0057] Furthermore, as to the point of connection of the first bypass means B1, the turbine (T1, T2, T3, PT) or turbines mentioned above can be groups of turbocom-

pressors (T1, T2, T3) or "compound" turbines also known as "power turbines" (PT), as they have an axis that is operatively connected to the drive shaft.

[0058] According to a further preferred variant of the invention, which can be combined with the previous ones, the engine further comprises second bypass means B2 to connect an inlet to a respective outlet of a respective compressor CP2 of said second supercharging device TC2, through a relative valve V2, and wherein said second bypass means are active when said first bypass means are also active and vice versa, so as to prevent the respective second turbine of the second turbocompressor from having the chance, by dragging the relative compressor that compresses air, of offering resistance to the passage of the exhaust gases produced by the first group of cylinders and recirculated through the second group of cylinders. Alternatively, the second turbine T2 comprises relative fourth bypass means B4 with a relative Wastegate valve WG2 arranged on said bypass means and said valve can be controlled to completely bypass the turbine T2 of the second supercharging device TC2 when the second group of cylinders is not active. The aim is that of avoiding offering resistance to the passage of the exhaust gases coming from the second group of cylinders due to the - useless - pumping work that would be carried out by the relative compressor CP2 belonging to the second turbocompressor TC2.

[0059] The first valve V1 can be a three-way valve alternatively connecting the first exhaust manifold EX1 or the second intake line IL2 to the second intake manifold IT2.

[0060] If both groups of cylinders are supercharged, then both intake lines IL1 and IL2, as shown on figure 1, can each comprise an intercooler to cool down the compressed fresh air. Preferably, the intercooler of the first group of cylinders CAC1 is an air/liquid intercooler, whereas the intercooler CAC2 of the second group of cylinders C2 is a water/liquid intercooler, wherein by water we mean both the cooling water of the engine or a carrier fluid of an exchange circuit that is independent from the engine water cooling system.

[0061] According to a preferred variant of the invention, which can be combined with all the variants in which both groups of cylinders are supercharged, the first turbine T1 of the first supercharging device TC1 of the first group of cylinders also comprises a Wastegate valve WG1 mounted on relative bypass means B3. The bypass means B3, according to a preferred variant of the invention, connect a point upstream of the first turbine CP1 to a point downstream of the second turbine CP2, by means of an ejection device EJ, which is better shown in figure 2.

[0062] The effect obtained is that of determining a depression downstream of the second turbine, which helps it start. To this regard, we would like to take into consideration a condition in which only the first group of cylinders is active and a drive power is requested that is such as to determine the activation of the second group of cylinders. According to this preferred variant of the in-

vention, before activating the second group of cylinders, the first Wastegate valve WG1 is calibrated/controlled to open so as to support the activation of the second turbine CP2, so that, upon activation of the second group of cylinders, the latter does not suffer from the so-called "turbolag".

[0063] The solution of figure 3 is substantially identical to the solution of figure 1 except for two aspects:

- There are no second bypass means B2 of the compressor CP2, which, as already mentioned above, can be avoided through proper measures to be taken on the Wastegate valve WG2 so as to avoid any resistance to the passage of exhaust gases produced by the first group of cylinders and circulated through the second group of cylinders,
- There is not the ejection system EJ shown in figure 1, but the turbine T2 of the second supercharging device TC2 is an asymmetrical twin-scroll turbine and the third bypass means B3, controlled through the first Wastegate valve WG1 of the turbine T1, are operatively connected upstream of the relatively smaller scroll of the asymmetrical twin-scroll turbine, whereas the relatively larger scroll is connected to the exhaust manifold of the second group of cylinders.

[0064] It is known that twin-scroll turbines have two separate inlets.

[0065] Figure 4 shows a further preferred variant of the invention, in which the second group of cylinders is provided not only with a first supercharging stage defined by the second turbocompressor TC2, but also with a second supercharging stage in cascade with the first one defined by the third turbocompressor TC3.

[0066] There is also the chance of a variant in which the first group of cylinders is not supercharged, whereas the second one comprises both a first and a second supercharging stage.

[0067] As you can see in figure 4, the intercoolers CAC1, CAC2, CAC3 are air/air intercoolers, but this does not exclude that one or more of them can be air/water intercoolers, as described above.

[0068] The solution of figure 5 differs from the other variants described above because of the fact that the exhaust gas of the first group of cylinders C1 is led to a power turbine PT.

[0069] When the first group of cylinders is provided with a supercharging stage TC1, then the power turbine PT preferably is arranged downstream of the turbine T1 of the single supercharging stage, if present.

[0070] Figure 5 shows, furthermore:

- EGR means - this time used to reduce NO_x - which connect the exhaust manifold EX1 of the first group of cylinders C1 to the relative intake manifold IT1, the recirculation pipe can comprise a cooler for the exhaust gases recirculated,

- fifth bypass means B5, with a relative control valve V5, to bypass the possible first supercharging stage TC1 in favour of the operation of the power turbine.

[0071] Both these technical detail can be implemented in any of the previous variants.

[0072] The comparison between figure 6a and figure 6b explains that the ATS according to a preferred variant of the invention, which can be combined with any one of the variants described above, comprises a DOC (Diesel Oxidation Cat), a diesel particulate filter (DPF), a SCR (Selective Catalyst Reduction) and a CUC (Clean Up Catalyst), in the hypothesis that the engine, as a whole, is a Diesel cycle engine. The invention can also be implemented in Otto cycle engines.

[0073] The diagram of figure 7 shows a variant that is particularly suited for petrol engines. In particular, not only there is a TWC (three-way-catalyst), but, in case you wanted to implement the aforesaid first bypass means B1/V1, you should preferably also insert a cooler, for example an air/water cooler, to cool down the exhaust gases produced by the first group of cylinders and introduced into the second one, so as to avoid damaging the engine due to the high temperatures reached.

[0074] Figure 6 shows an actual EGR for the first group of cylinders and figure 1 shows the ejection system schematically represented in figure 2 for the purposes described above. It should be clear that these details can be left out.

[0075] As to the controlling of an internal combustion engine according to any one of the variants described above, the method according to the invention comprises a step of acquiring a power value to be delivered and controlling a feeding of said first group of cylinders and said second group of cylinders according to respective specific consumption maps so as to minimise the overall specific consumption of the engine.

[0076] Furthermore, the method comprises a further step of deactivating said second group of cylinders when, given a requested power value, the overall specific consumption of the engine is minimised maintaining active only said first group of cylinders. And when, in transient conditions, said second group of cylinders is not active and a required power value entails activation also of the second group of cylinders, the following steps are performed:

- increase of the fuel injected into the first group of cylinders up to a predefined torque level and subsequent
- opening of a respective Wastegate valve of said first supercharging device with directing of the exhaust gases expelled from said Wastegate valve towards said second supercharging device so as to facilitate activation thereof in rotation and
- activation of the second group of cylinders.

[0077] The opening of the valve WG1 can be prior or

simultaneous to the activation of the second group of cylinders.

[0078] According to the preferred variants of the invention, this facilitation is obtained either by means of the ejection system according to figures 1, 2 and 7 or by means of an asymmetrical twin-scroll turbine T2, for example shown in figures 3 - 5.

[0079] When the engine is provided with power turbines and with bypass means B5/V5 for bypassing the first turbine T1 in favour of the power turbine, the valve V5 is controlled so as to close before or during the opening of the valve WG1, which then allows the turbine or turbines of the second group of cylinders to achieve a faster transient.

[0080] This invention can be advantageously implemented by means of a computer program comprising coding means for carrying out one or more steps of the method, when the program is executed by a computer. Therefore, the scope of protection is extended to said computer program and, furthermore, to means that can be read by a computer and comprises a recorded message, said means that can be read by a computer comprising coding means for a program for carrying out one or more steps of the method, when the program is executed by a computer.

[0081] The non-limiting example described above can be subjected to variations, without for this reason going beyond the scope of protection of the invention, comprising all equivalent embodiments for a person skilled in the art. When reading the description above, a skilled person can carry out the subject-matter of the invention without introducing further manufacturing details. The elements and features contained in the different preferred embodiments, drawings included, can be combined with one another, without for this reason going beyond the scope of protection of this patent application. The information contained in the part concerning the state of art only serves the purpose of better understanding the invention and does not represent a declaration of existence of the items described. Furthermore, if not specifically excluded by the detailed description, the information contained in the part concerning the state of art can be considered as combined with the features of the invention, thus forming an integral part of the invention. None of the features of the different variants is essential and, therefore, the single features of each preferred variant or drawing can be individually combined with the other variants.

Claims

1. Internal combustion engine (E) comprising a plurality of cylinders (C1, C2) with relative pistons, connected to a relative common drive shaft, said multitude of cylinders being divided into a first group (C1) and a second group of cylinders (C2), in which consecutive ignition cycles alternate between the two groups of cylinders when both groups of cylinders are active,

the first group of cylinders being controlled to be always active, and the second group of cylinders being controlled to be active on demand, the engine being **characterised in that** said first group of cylinders has a compression ratio different from a compression ratio of said second group of cylinders.

2. Engine according to claim 1, wherein the compression ratio of said first group of cylinders is greater than the compression ratio of the second group of cylinders.
3. Engine according to one of the preceding claims 1 or 2, wherein said engine comprises a fuel injection system for supplying said first and second group of cylinders wherein a fuel injection regulation relative to said first group of cylinders is different from a fuel injection regulation relative to said second group of cylinders.
4. Engine according to claim 3, wherein said regulation comprises making a fuel injection timing advance relative to said first group of cylinders lower than an injection timing advance relative to said second group of cylinders.
5. Engine according to any one of the preceding claims 1 - 4, wherein said first group of cylinders and said second group of cylinders have respectively a first intake manifold and a second intake manifold mutually separate from each other, or wherein said first group of cylinders and said second group of cylinders have respectively a first intake manifold and a second intake manifold mutually separate from each other and wherein the engine comprises a first supercharging device operatively connected to said first intake manifold and/or a second supercharging device operatively connected to said second intake manifold.
6. Engine according to claim 5, wherein said first and second supercharging device are present together and wherein said first supercharging device is calibrated to provide a supercharging pressure lower than said second supercharging device.
7. Engine according to any one of the preceding claims, further comprising an exhaust line, and wherein said first group of cylinders has a first intake manifold and said second group of cylinders has a second intake manifold, which is distinct and separated from said first intake manifold, and wherein the engine comprises first bypass means for connecting a point of said exhaust line to said second intake manifold and wherein said bypass means are configured to cut in when said second group of cylinders is not active and cut out when said second group of cylinders is active.

8. Engine according to claim 7, wherein said second supercharging device is of the turbo compressor type and wherein the engine further comprises second bypass means to connect an inlet with a respective outlet of a respective compressor of said second supercharging device, and wherein said second bypass means are active when said first bypass means are also active. 5
9. Engine according to any one of the preceding claims, wherein said first group of cylinders has a first exhaust manifold and said second group of cylinders has a second exhaust manifold separate from said first exhaust manifold; the engine further comprises a power turbine (PT) having a relative axis of rotation operatively connected with said drive shaft of the engine, and wherein said power turbine is fed only by said first exhaust manifold. 10 15
10. Engine according to any one of the preceding claims from 6 to 9, wherein said first and second supercharging device are of the turbo compressor type, wherein a first turbine of said first turbo compressor comprises a Wastegate valve with relative bypass means, and wherein said bypass means are connected downstream of a second turbine of said second turbo compressor, by means of an ejection system, so as to generate a depression downstream of said second turbine to help said second turbo compressor to achieve a faster transient. 20 25 30
11. Engine according to any one of the preceding claims from 6 to 9, wherein said engine further comprises a third supercharging device operatively connected in series to said second supercharging device and wherein said first, second and/or third supercharging device are of the turbo compressor type, wherein a first turbine of said first turbo compressor comprises a Wastegate valve with relative bypass means, and wherein said bypass means are connected downstream of a second and/or third turbine of said second turbo compressor, by means of an ejection system, so as to generate a depression downstream of said second and/or third turbine to help said second and/or third turbo compressor to achieve a faster transient. 35 40 45
12. Engine according to any one of the preceding claims from 3 to 10, wherein a cooler (CAC1/CAC2) is connected to at least one of said first or second intake manifolds to cool fresh air coming into the engine or wherein a cooler (CAC1/CAC2) is connected to at least one of said first or second intake manifolds to cool fresh air coming into the engine and wherein said at least one cooler is an air/air or air/coolant liquid exchanger or wherein a cooler (CAC1) is connected to said first manifold intake, to cool the fresh air coming into the first group of cylinders, of the air/air type and wherein a second cooler (CAC2) is connected to said second manifold intake, to cool the fresh air coming into the second group of cylinders, of the air/coolant liquid type, and wherein said coolant liquid belongs to a circuit independent of the engine cooling circuit or said coolant liquid coincides with the engine coolant liquid. 50
13. Engine according to any one of the preceding claims, wherein said first group of cylinders has a first intake manifold and a first exhaust manifold, both respectively separated by a second intake manifold and a second exhaust manifold of said second group of cylinders, and wherein said first group of cylinders comprises EGR means adapted to connect said first intake manifold (IT1) to said first exhaust manifold (EX1) to recirculate exhaust gases generated by said first group of cylinders. 55
14. Method for controlling an internal combustion engine according to any one of the preceding claims comprising a step of acquiring a power value to be delivered and controlling a feeding of said first group of cylinders and said second group of cylinders according to respective specific consumption maps so as to minimise the overall specific consumption of the engine.
15. Method according to claim 14, further comprising a further step of deactivating said second group of cylinders when, given a requested power value, the overall specific consumption of the engine is minimised maintaining active only said first group of cylinders.
16. Method according to one of the preceding claims, wherein when said engine corresponds to one of the claims from 6 to 13, and when, in transient conditions, said second group of cylinders is not active and a required engine power value entails activation also of the second group of cylinders, the following steps are performed:
- increase of the fuel injected into the first group of cylinders up to a predefined torque level and subsequently
 - opening of a respective Wastegate valve of said first supercharging device with directing of the exhaust gases expelled from said Wastegate valve towards said second supercharging device so as to facilitate activation thereof in rotation and
 - activation of the second group of cylinders.
17. Computer program which comprises program coding means adapted to carry out all the steps of any

one of the claims from 14 to 16, when said program is run on a computer.

- 18.** Means readable by computer comprising a recorded program, said means readable by computer comprising program coding means adapted to carry out all the steps of any one of the claims from 14 to 16, when said program is run on a computer.

10

15

20

25

30

35

40

45

50

55

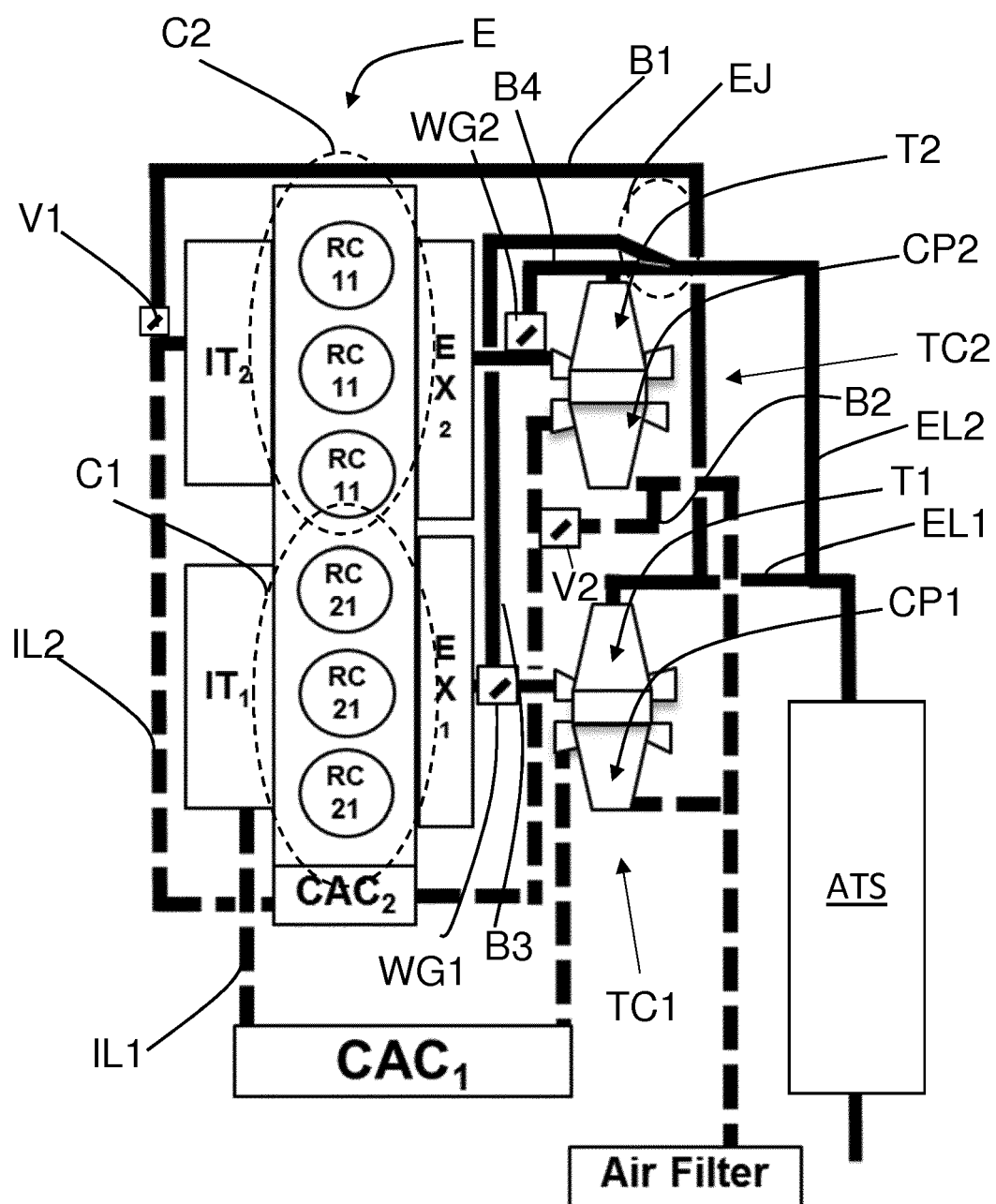
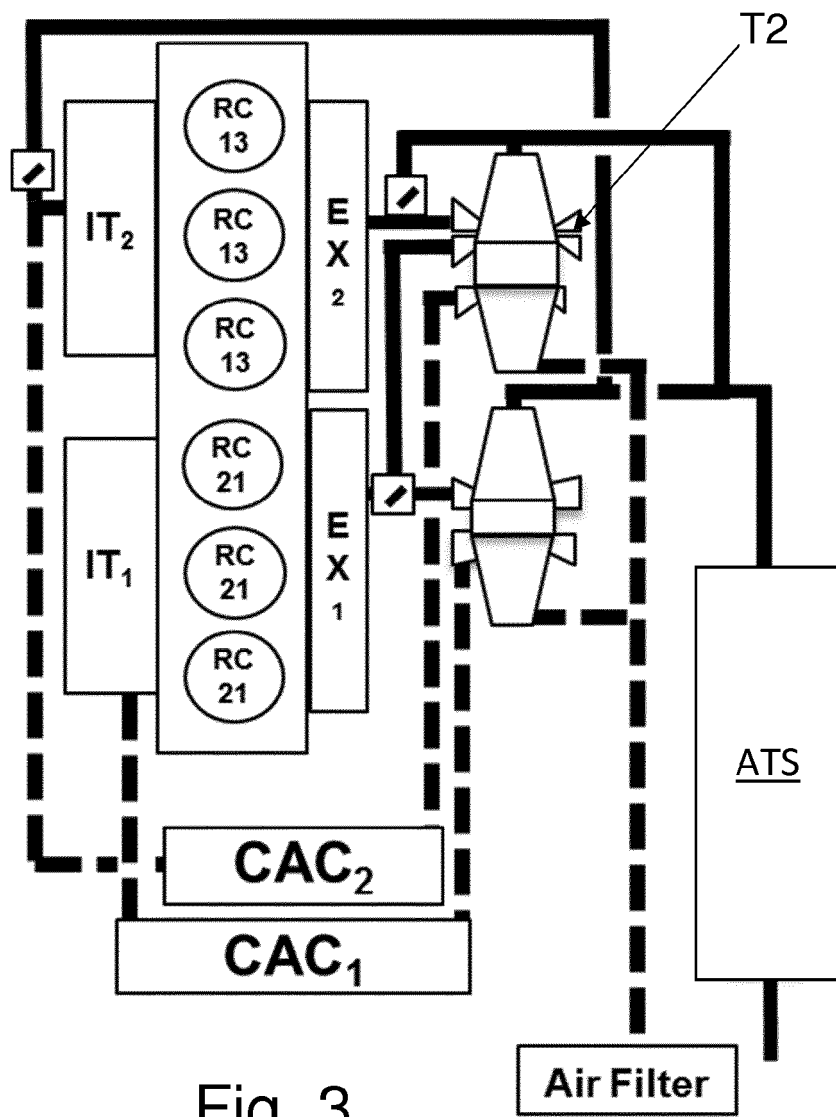
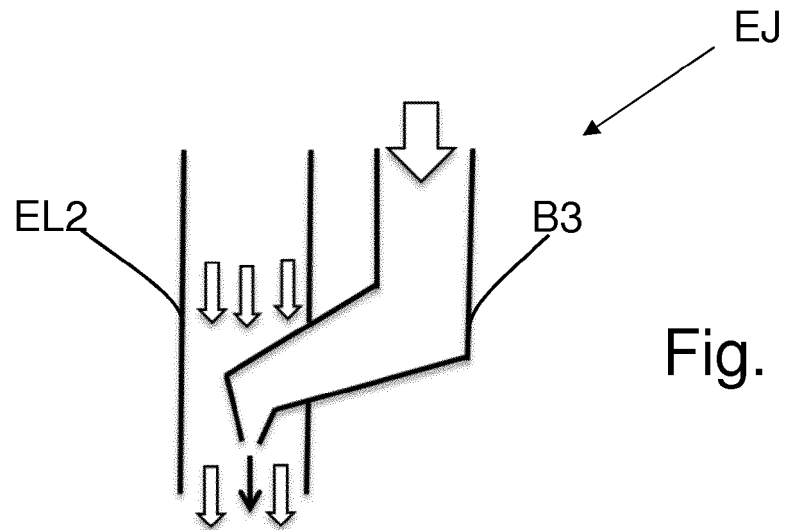


Fig. 1



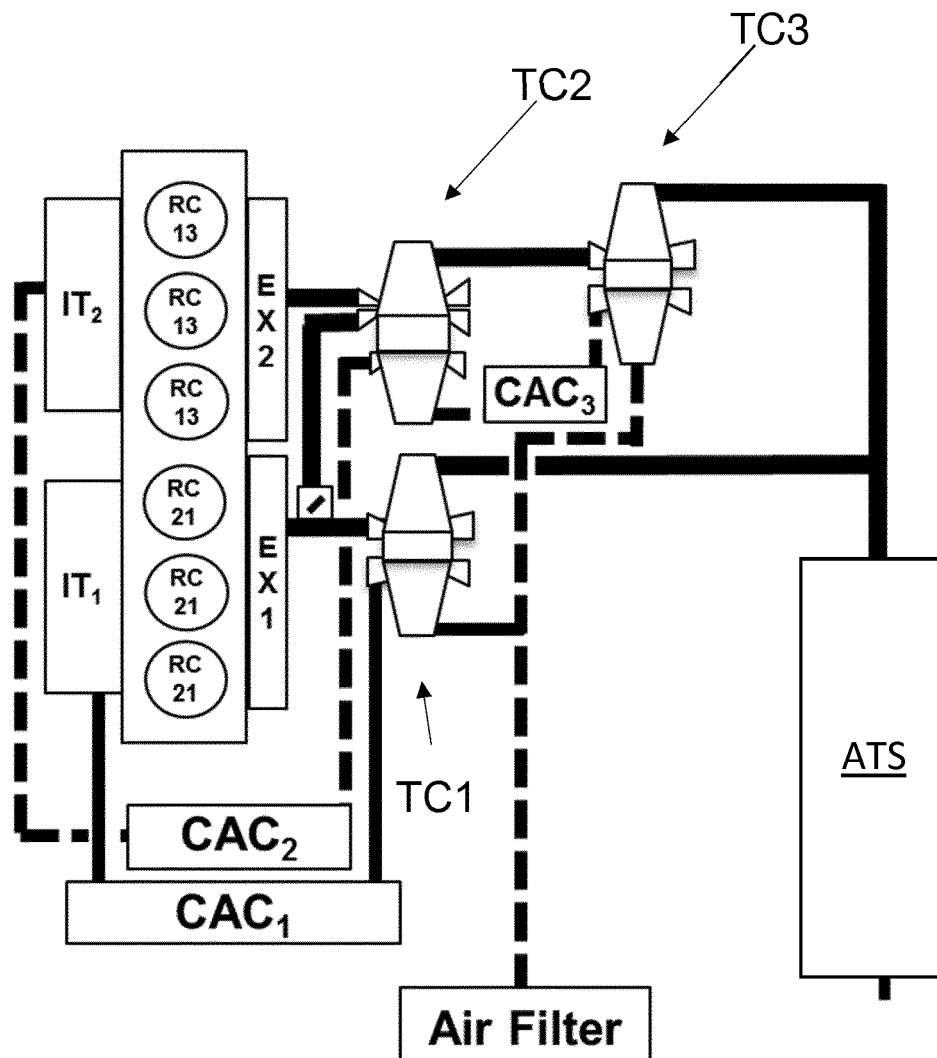
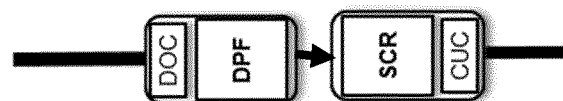
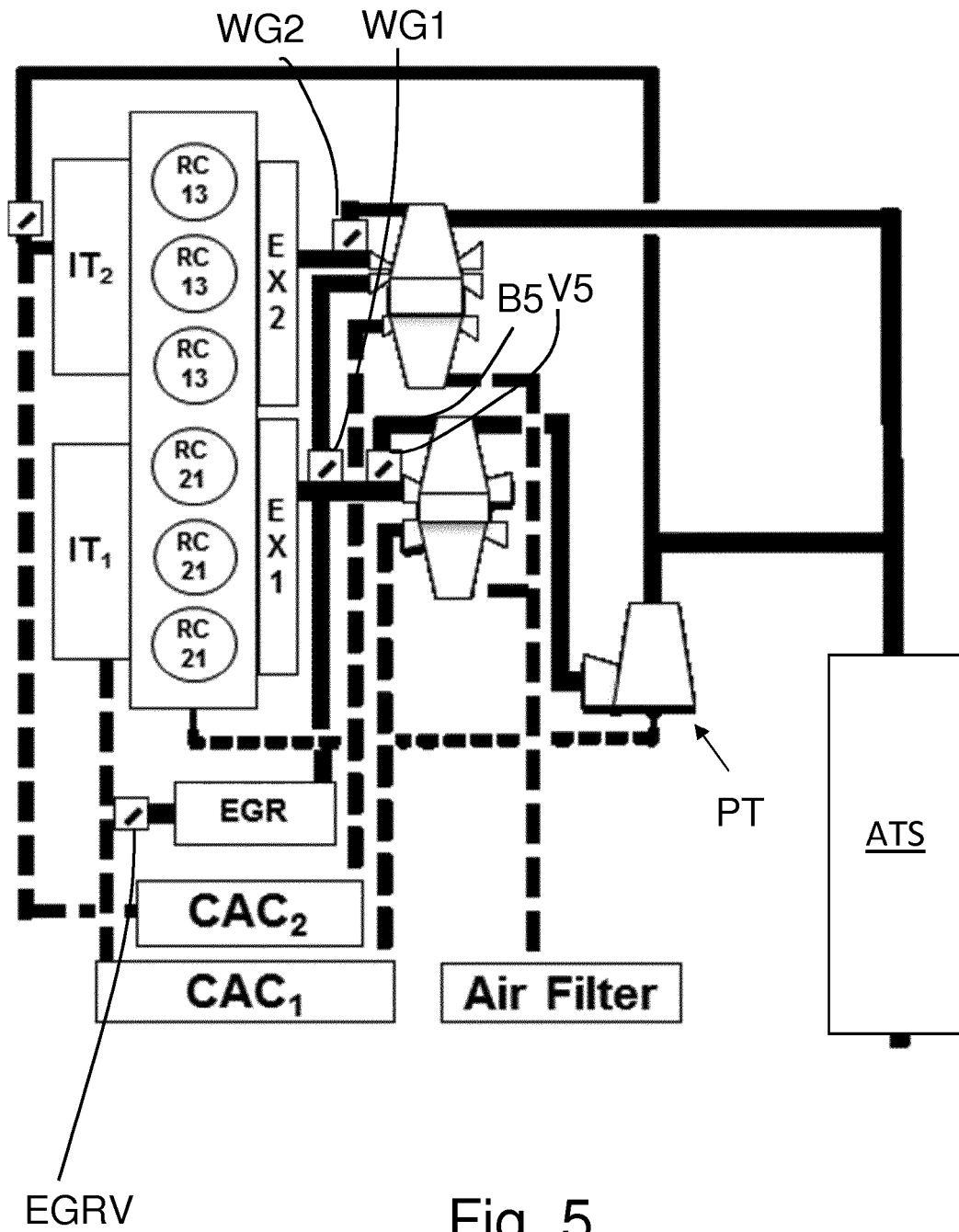


Fig. 4



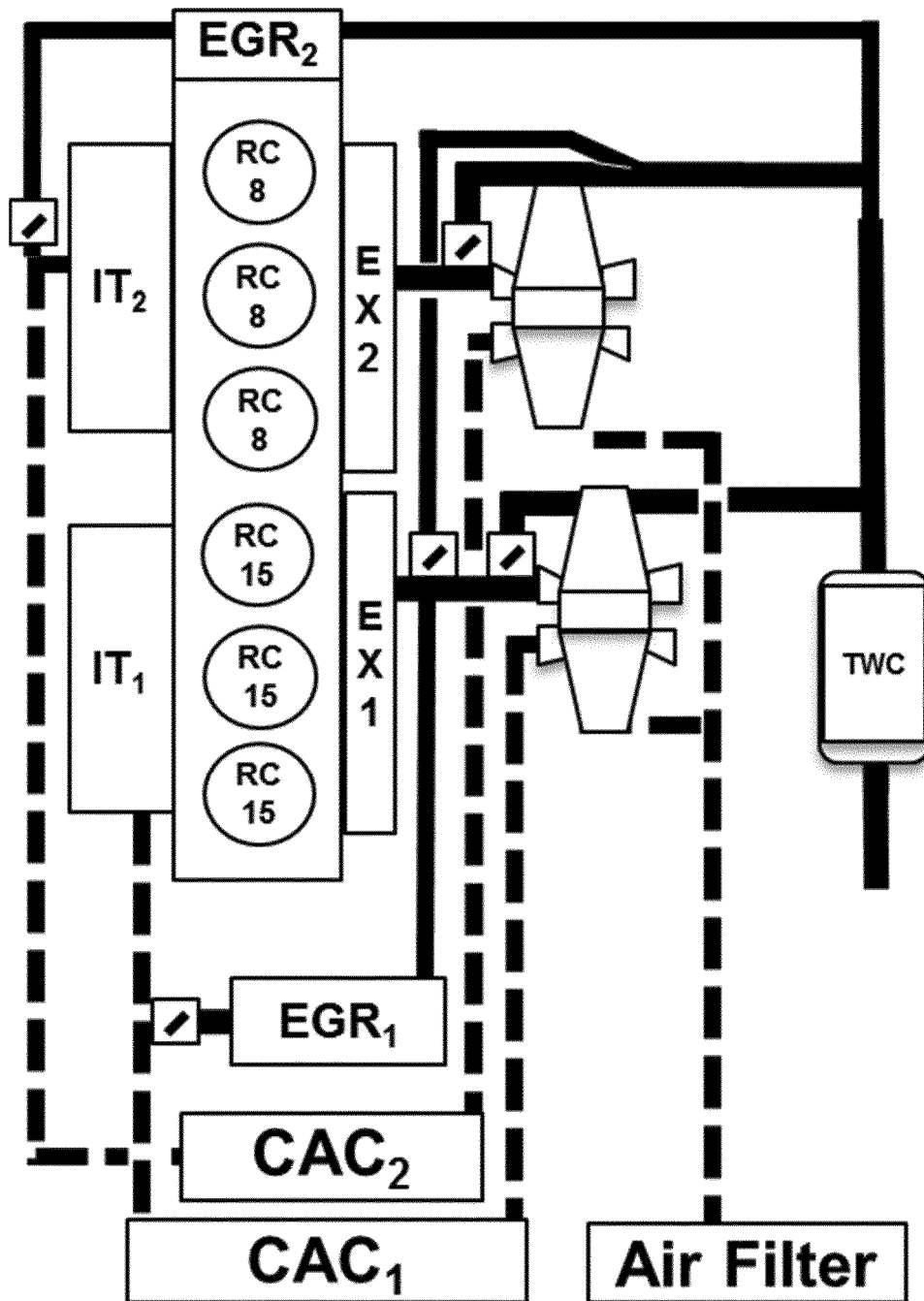


Fig. 7



EUROPEAN SEARCH REPORT

Application Number
EP 16 19 8544

5

10

15

20

25

30

35

40

45

50

55

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	DE 10 2012 221743 A1 (BOSCH GMBH ROBERT [DE]) 28 May 2014 (2014-05-28) * paragraphs [0003] - [0015] * * pages 35-39 * * claims 1-8 * * figure 1 *	1-18	INV. F02D17/02 F02D41/00 F02D15/00 F02B73/00
X	GB 2 115 874 A (ALFA ROMEO AUTO SPA) 14 September 1983 (1983-09-14) * page 1, line 1 - page 3, line 35 * * claims 1-3 * * figure 1 *	1-18	
X	WO 03/067059 A1 (DAIMLER CHRYSLER AG [DE]; BETZ THOMAS [DE]; DUVINAGE FRANK [DE]; PFAFF) 14 August 2003 (2003-08-14) * page 1, line 19 - page 3, line 2 * * page 5, lines 10-26 * * claims 1-3 * * figure 1 *	1-18	
A	DE 31 21 302 A1 (DROESCHEL HELMUT) 30 December 1982 (1982-12-30) * page 2, lines 1-3 * * page 3, lines 25-28 * * page 4, lines 12-22 * * page 5, lines 8-16,21,22 * * figures 1,5 *	1-18	TECHNICAL FIELDS SEARCHED (IPC) F02D F02B
A	GB 2 478 718 A (GM GLOBAL TECH OPERATIONS INC [US]) 21 September 2011 (2011-09-21) * page 2, lines 2-5 * * page 4, lines 7-17 * * page 4, line 32 - page 5, line 4 * * page 5, lines 15-28 * * pages 65-12, lines 25-33; figure 4 *	1-18	
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 13 March 2017	Examiner Calabrese, Nunziante
CATEGORY OF CITED DOCUMENTS 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 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 & : member of the same patent family, corresponding document			

EPO FORM 1503 03.82 (P04C01)

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

EP 16 19 8544

5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

13-03-2017

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 102012221743 A1	28-05-2014	NONE	
GB 2115874 A	14-09-1983	DE 3306350 A1	15-09-1983
		DE 8305073 U1	07-02-1985
		FR 2522365 A1	02-09-1983
		GB 2115874 A	14-09-1983
		IT 1149700 B	03-12-1986
		JP H0345223 B2	10-07-1991
		JP S58158349 A	20-09-1983
		US 4455984 A	26-06-1984
WO 03067059 A1	14-08-2003	DE 10204482 A1	14-08-2003
		EP 1472448 A1	03-11-2004
		JP 2005517115 A	09-06-2005
		US 2005034701 A1	17-02-2005
		WO 03067059 A1	14-08-2003
DE 3121302 A1	30-12-1982	NONE	
GB 2478718 A	21-09-2011	NONE	