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(54) Title: METHOD FOR OPERATING A FUEL INJECTION SYSTEM

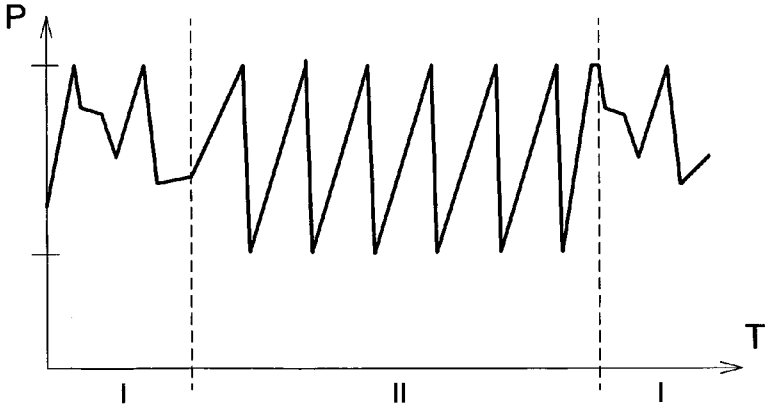

Fig. 3

(57) Abstract: The invention provides for a method for operating an internal combustion engine having a fuel injection system that comprises: - an accumulator where fuel is stored at high pressure by a high pressure pump system, - at least one injector, and - a fuel discharge device for discharging fuel from the accumulator to a fuel discharge circuit, characterized in that the method comprises an energy absorbing mode (II) where the fuel discharge device is allowed to discharge fuel, continuously or from time to time, and where the high pressure pump system is controlled to deliver pressurized fuel to the accumulator so that the fuel pressure in the accumulator either successively increases and decreases several times during the duration of the energy absorbing mode or is substantially maintained at a braking pressure during the energy absorbing mode despite fuel being simultaneously discharged from the accumulator.

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Method for operating a fuel injection system

Field of the invention

The invention concerns a method for improving the braking capabilities of a road vehicle, and more especially of a heavy vehicle such as a truck.

Technological background

When fully loaded, and depending on certain national regulations, a heavy vehicle of the truck type can weigh up to 60 tons.

The capability to slow down and eventually immobilize such a vehicle is therefore critical.

Trucks may thus be equipped with different types of braking systems in addition to the conventional disk or drum friction brakes.

Of course, internal combustion engines all inherently provide some braking power when they are not used in motoring mode, i.e. when no fuel is injected in the engine combustion chambers.

Trucks are commonly fitted with supplemental braking systems which increase the braking power of the engine. Such known systems include exhaust brakes, where the exhaust line of the engine arrangement is more or less obstructed. They also include so-called engine brakes, where dedicated means are used to change the opening/closing of intake and/or exhaust and/or dedicated valves, to increase the total amount of power used by the engine to compress air in the cylinders. In all these cases, the engine may thus have an increased slowing down action on the vehicle drive train. This proves to be a significant addition to the braking power provided by the conventional friction brakes.

However there is a constant need to increase the overall braking capabilities of a vehicle to improve security and/or to increase the vehicle load.

Summary of the invention

In this technical context, an object of the present invention is to increase the braking capability of a vehicle.

The invention concerns a method for operating an internal combustion engine having a fuel injection system that comprises:

A method for operating an internal combustion engine having a fuel injection system that comprises:

- an accumulator where fuel is stored at high pressure by a high pressure pump system, wherein the high pressure in the accumulator may vary between a minimum and a maximum high pressure level,

- at least one injector for injecting fuel from the accumulator into an engine combustion chamber, and

- a fuel discharge device for discharging fuel from the accumulator to a fuel discharge circuit distinct from the engine combustion chamber,

characterized in that the method comprises an energy absorbing mode where the fuel discharge device is allowed to discharge fuel, continuously or from time to time during the duration of the energy absorbing mode, and where the high pressure pump system is controlled to deliver pressurized fuel to the accumulator so that the fuel pressure in the accumulator either successively increases and decreases several times during the duration of the energy absorbing mode or is substantially maintained at a braking pressure during the energy absorbing mode despite fuel being simultaneously discharged from the accumulator.

Thanks to the invention, extra braking capabilities are provided to the engine by letting the high pressure pump system in operation to pressurize fuel, even though such work of the pump system is not required for feeding the engine combustion chambers, because no injection of fuel to the engine combustion is performed, or at least not to a substantial level.

In the most common case where the high pressure pump system is driven mechanically directly or indirectly by the engine crankshaft, the pumping system therefore generates a resistive torque on the crankshaft which is mechanically transmitted to the vehicle driveline and has an additional braking effect which can be estimated in the area of 20 % at low engine speed and around 10 % at high engine speed when compared to the engine braking capacity of a conventional engine.

According to further optional features of the invention:

- the high pressure pump system is controlled to deliver pressurized fuel during substantially the entire duration of the energy absorbing mode;

- during the energy absorbing mode, the fuel pressure in the accumulator either reaches successively or is substantially maintained at a braking pressure;

- the braking pressure may be close to the maximum high pressure level;

- the method may further comprise the step of cooling the fuel that is discharged through the discharge device;

- the energy absorbing mode may be carried out automatically according to one or more vehicular parameters;

- the energy absorbing mode may be carried out upon a driver request; and/or

- during the energy absorbing mode (II), no fuel or substantially no fuel is injected (22) in the engine combustion chamber.

Brief description of the drawings

The following detailed description of an embodiment 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 disclosed embodiment. In the drawings:

Figure 1 shows a simplified fuel injection system.

Figure 2 and 3 are schematic exemplary charts showing possible variations of fuel pressure in the rail accumulator against different vehicle operating modes.

Description of the drawings

The method of the invention is explained in relation to a fuel injection system illustrated in the drawing which is to be used for feeding fuel to a non represented internal combustion engine of a vehicle.

The shown fuel injection system 10 comprises a fuel tank 12, where fuel is stored substantially un-pressurized, and a fuel accumulator 14 where fuel is to be stored at a high pressure before being fed to the engine. The accumulator 14 can be of the well-known common rail type. The fuel pressure in the accumulator can be controlled to vary between a minimum high pressure level and a maximum high pressure level. Typically, the maximum high pressure level for a diesel engine can be

over 1000 bars, or even over 2000 bars in some cases. The minimum high pressure level can be for example 500 bars, but can drop to around 300 bars when the engine is idling.

The fuel is pressurized into the accumulator by a high pressure pump system. In the shown embodiment, the high pressure pump system comprises a low pressure feed pump 16 and a single high pressure pump 18 which are arranged in series. The high pressure pump 18 delivers all the volume of fuel to the accumulator 14. In other embodiments, the fuel system could comprise for example several high pressure pumps for feeding the accumulator, for example as described in document EP-1.902.213. Preferably, at least the high pressure pump system is driven mechanically directly or indirectly by the engine crankshaft.

A pressure sensor 20 may be provided to monitor the fuel pressure in the accumulator

A number of fuel injectors 22 are connected to the accumulator 14 to control the injection of fuel in respective engine combustion chambers. Each injector 22 is for example fitted into the engine cylinder head. The fuel injectors may be electronically controlled.

The accumulator is provided with a discharge device for discharging fuel from the accumulator 14 to a fuel discharge circuit 24, which is to be considered as distinct from the engine combustion chambers. The discharge device may comprise a discharge valve 26. The discharge valve may be a passive valve, such as a spring biased poppet valve which opens automatically when the pressure in the accumulator exceeds a predetermined value. It can be embodied as a safety valve or be distinct from such a safety valve, with a lower predetermined opening pressure than the safety valve. Especially in the latter case, the discharge valve can be a passive valve with a locking function, so that the discharge valve may be disabled in certain operating conditions. Alternatively, the discharge device can comprise an active valve, i.e. an electronically controlled valve whose opening and/or closing is controlled by an electronic control unit. Such active discharge valve may be proportional or not, and it may be embodied as a solenoid valve. The discharge circuit 24 may comprise a simple return conduit to the tank 10. The discharge circuit may be equipped with a cooler 28 for cooling the fuel discharged from the accumulator.

In the shown embodiment, the high pressure pump system, the injectors and the discharge vale 24 are controlled by an electronic control unit 30 that can include a CPU, a ROM (Read Only Memory), and a RAM (Random Access Memory). The control unit 30 can also include other conventional components such as an input interface circuit, an output interface circuit, and the like. The control unit 30 may be connected to one or several sensors such as the pressure sensor 20 for monitoring the fuel pressure in the accumulator 14. It will also be advantageously connected to one or several other control units of the vehicle's electronic system, for example through a CAN-bus. Also, the control unit 30 can be embodied as a single physical entity, but it can also be embodied as several interconnected control units. Thereby, the control unit 30 may have access to various data such as, for example, engine speed, vehicle speed, accelerator pedal position, brake pedal position, status of other supplemental braking systems, etc...

The method of the invention makes it possible to use the injection system 10 as an additional braking means.

When the engine operates in a traction mode or in any mode where no supplemental braking action is required from the fuel injection system, the fuel injection system 10 operates conventionally and stores fuel at high pressure in the accumulator 14. The pressure in the accumulator may vary conventionally between minimum and maximum high pressure levels. The common rail accumulator 14 supplies, in turn, the injectors 22 which deliver the fuel to the engine combustion chambers.

The graphs of Figures 2 and 3 show examples of fuel pressure variation patterns in the accumulator 14 during a traction mode (I). As represented, the fuel pressure may vary according to numerous parameters.

At certain times during the operation of the engine, it becomes adequate for the engine to provide an increased braking power.

According to the invention, the engine fuel system 10 may then be operated under a dedicated energy absorbing mode. Such mode consists essentially in maximising the energy absorption by the high pressure pump system by pumping fuel into the accumulator despite the fact that substantially no fuel or very little fuel is drawn by the injectors to be injected in the combustion chambers. Of course, due to the fact that the accumulator has a limited volume, such pumping would very quickly fill up the accumulator so that no further fuel could be admitted,

Therefore, according to the invention, is provided that, during such energy absorbing mode, the discharge device is allowed to discharge fuel, continuously or from time to time. At the same time, or following a discharge sequence, the high pressure pump system is controlled to deliver pressurized fuel to the accumulator.

Depending on the type of discharge device and how it may be controlled, different pressure variation patterns may be observed. For exemple, if the discharge device is a static valve, which is simply opened at a threshold pressure, a pattern such as shown for period (II) in figure 2 could be observed where the pressures shows very little or no variation and is maintained substantially at the same pressure, which can be called braking pressure. If the discharge valve is not distinct from a safety valve having an opening pressure set for example at the maximum high pressure level of the accumulator, then the braking pressure will be the maximum high pressure level, as shown on figure 2. If the discharge valve is a distinct valve, then it may be advantageous that its opening pressure be lower than maximum high pressure level, so that the accumulator is not maintained too long at its maximum operating pressure. In such a case, the braking pressure may be different from the maximum high pressure, but it is nevertheless preferably close to that maximum high pressure level. In both cases, the pressure pattern may have a wavy form as on Figure 2, for example due to an hysteresis of the valve where its opening and closing pressures are not exactly the same, which could result from internal pressure drops in the valve. At all moments, approximately the same quantity of fuel is discharged from the accumulator than the quantity of fuel which is forced in the accumulator by the fuel pumping system.

If the discharge device is of the active type, then the pattern may be freely controlled by a proper control of both the high pressure pump system and of the discharge device. The pressure variation pattern can for example look more like that shown on figure 3, for period (II), with more a pronounced variation. Here the pressure markedly decreases when the discharge device is open, to a low level, and then increases again as the discharge device is closed. The levels between which this variation of the braking pressure occurs, and the corresponding frequency of this variation, can then be set according to the amount of additional braking power which is to be provided through the fuel injection system.

Of course, it could be possible, with an active valve, to replicate the pressure pattern shown in figure 2. Also, with a proportional valve, a proper feedback control

could be provided so that the amount of fuel discharged through the discharge valve 26 is substantially equal to the volume of fuel introduced in the accumulator 14 by the pump system, leading to an almost constant braking pressure in the accumulator. The level of this braking pressure can then be set according to the amount of additional braking power which is to be provided through the fuel injection system.

As a result, the fuel pressure in the accumulator either successively increases and decreases several times during the duration of the energy absorbing mode or is substantially maintained at a braking pressure during the energy absorbing mode despite fuel being simultaneously discharged from the accumulator.

Therefore, during a given period, the pump system needs to pressurize almost constantly some fuel and therefore absorbs constantly or almost constantly some energy on the engine crankshaft which equals to increased engine braking power.

In a further aspect of the method of the invention, it can be provided to cool down the fuel which is discharged from the accumulator through the discharge circuit. Indeed, when the fuel supply system operates in the energy absorbing mode, fuel is constantly pressurized by the high pressure pump system, which can increase fuel temperature to a level that requires cooling down. This can be achieved by the heat exchanger 28 which may be connected to the vehicle cooling system. According to another possibility, the fuel can be discharged directly into the vehicle fuel tank where heated fuel flowing from the accumulator is mixed with fuel stored in the fuel tank at ambient or near ambient temperature.

The invention has another beneficial effect. As fuel pressure in the accumulator 14 is maintained at a high level, the accumulator is in a suitable position to face a power demand which follows a braking phase. In other words, the fuel pressure within the common rail accumulator remains at a high level; thus, when the engine resumes power operations, the pressurized fuel stored in the accumulator can be immediately used to feed the cylinders. This proves to be of special value in the overall engine efficiency. Indeed, soot level released in exhaust gas is decreased and, as a consequence, fuel consumption is reduced because regeneration of a Diesel Particle Filter is required on a less frequent basis when compared to a traditional fuel injection system where fuel pressure in the common rail accumulator tends to drop during braking mode. Also, thanks to the fact the, after a braking phase, the pressure in the accumulator is high, it can be provided that, upon re-acceleration, the fuel pumping system is deactivated for a short period of time to minimize the

power it takes from the crankshaft, which will help in decreasing the response time of the engine in such transient operation.

It can be provided that the energy absorbing mode of the fuel injection system can be initiated by request of the driver. In such a case, the driver may use a dedicated input device for requesting that mode. The input device can be connected indirectly or indirectly to the control unit 30. In such a case, the control unit may control or not the activation and/or the implementation of the mode requested by the driver. Alternatively or in combination, it can be provided that the energy absorbing mode can be initiated automatically by the control unit 30, according to its analysis, through predefined algorithms, of a number of vehicle operational parameters, such as vehicle speed, braking request, accelerator pedal position, load of the vehicle, operation of other supplemental braking devices, vehicle fluid temperatures, etc...

CLAIMS

1. A method for operating an internal combustion engine having a fuel injection system that comprises:

- an accumulator (14) where fuel is stored at high pressure by a high pressure pump system (16, 18), wherein the high pressure in the accumulator may vary between a minimum and a maximum high pressure level,

- at least one injector (22) for injecting fuel from the accumulator into an engine combustion chamber, and

- a fuel discharge device (26) for discharging fuel from the accumulator to a fuel discharge circuit (24) distinct from the engine combustion chamber,

characterized in that the method comprises an energy absorbing mode (II) where the fuel discharge device (26) is allowed to discharge fuel, continuously or from time to time during the duration of the energy absorbing mode, and where the high pressure pump system (16, 18) is controlled to deliver pressurized fuel to the accumulator (14) so that the fuel pressure in the accumulator either successively increases and decreases several times during the duration of the energy absorbing mode or is substantially maintained at a braking pressure during the energy absorbing mode despite fuel being simultaneously discharged from the accumulator (14).

2. The method according to claim 1, characterized in that the high pressure pump system (16, 18) is controlled to deliver pressurized fuel during substantially the entire duration of the energy absorbing mode (II).

3. The method according to any preceding claim, characterized in that, during the energy absorbing mode (II), the fuel pressure in the accumulator (14) either reaches successively or is substantially maintained at a braking pressure.

4. The method according to claim 3, characterized in that the braking pressure is close to the maximum high pressure level.

5. The method according to any preceding claim, characterized in that the method further comprises the step of cooling (28) the fuel that is discharged through the discharge device (26).

6. The method according to any of claims 1 to 5, characterized in that the energy absorbing mode (II) is carried out automatically according to one or more vehicular parameters.

7. The method according to any of claims 1 to 6, characterized in that the energy absorbing mode (II) is carried out upon a driver request.

8. The method according to any preceding claim, characterized in that during the energy absorbing mode (II), no fuel or substantially no fuel is injected (22) in the engine combustion chamber.

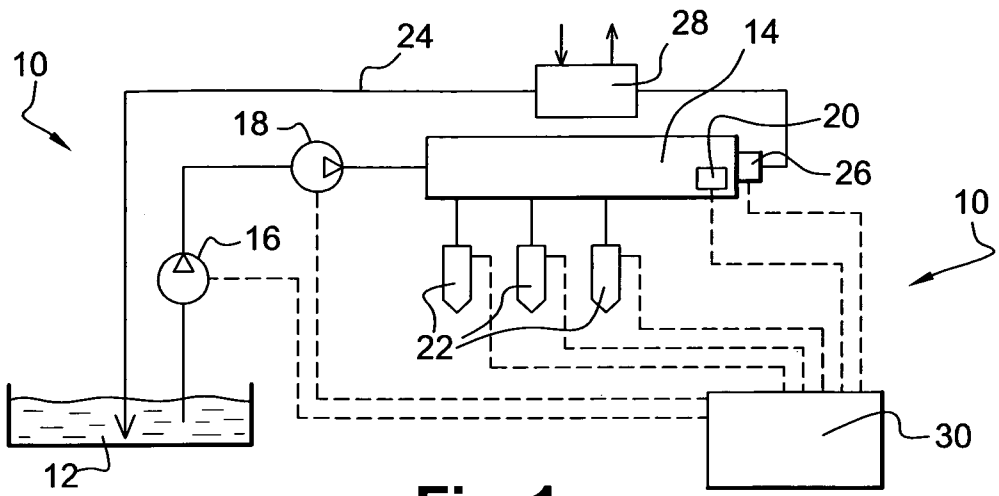

Fig. 1

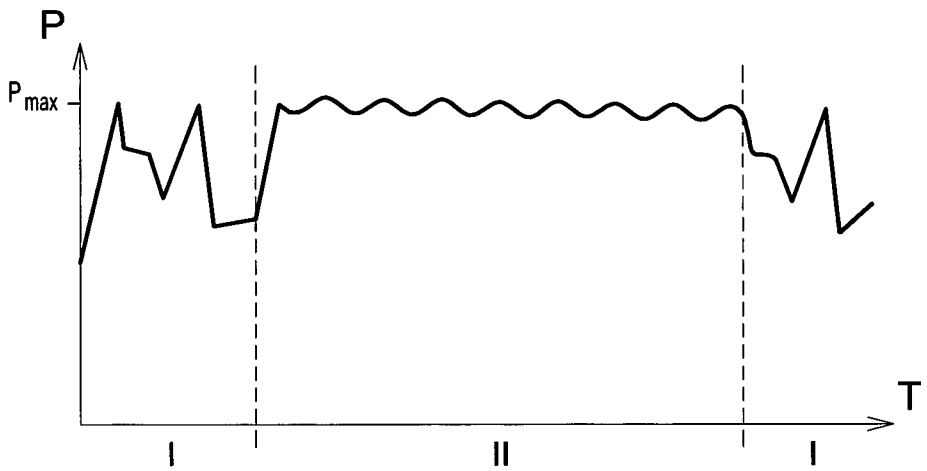

Fig. 2

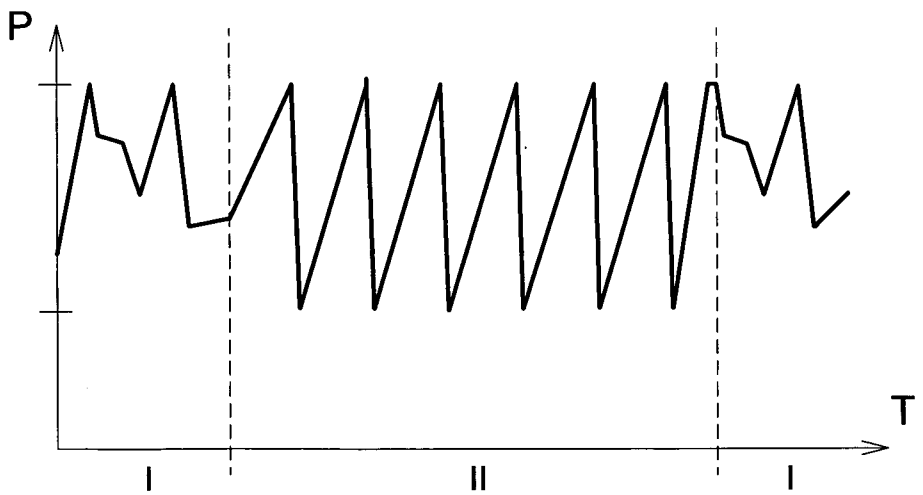

Fig. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2010/001061

A. CLASSIFICATION OF SUBJECT MATTER
INV. F02M63/02 F02D41/38
ADD.

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)
F02M F02D

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	EP 1 990 533 A1 (BOSCH GMBH ROBERT [DE]) 12 November 2008 (2008-11-12) paragraph [0010]; figure 1	1-4,6-8 5
Y	DE 196 52 831 A1 (REXROTH MANNESMANN GMBH [DE]) 25 June 1998 (1998-06-25) column 9, lines 31-37; figure 2	5
Y	US 2007/044767 A1 (KOJIMA SUSUMU [JP] ET AL) 1 March 2007 (2007-03-01) paragraph [0114]; figure 10	5
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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
8 December 2010	17/12/2010

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INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2010/001061

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2004/008010 A1 (BOSCH GMBH ROBERT [DE]; BOEHLAND PETER [DE]; NENTWIG GODEHARD [DE]) 22 January 2004 (2004-01-22) the whole document	1

INTERNATIONAL SEARCH REPORT

Information on patent family members

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