(12) UK Patent (19) GB (11) 2578348 (13) B

(45) Date of B Publication 27.04.2022

(54) Title of the Invention: System and method for the control of an internal combustion engine

(51) INT CL: ***F02D 21/04*** (2006.01) ***F01M 13/00*** (2006.01)

(21) Application No: **1910017.1**

(22) Date of Filing: **12.07.2019**

(43) Date of A Publication **06.05.2020**

(56) Documents Cited:
EP 2075444 A1
JP 2004197707 A
US 20160348614 A1
US 20150040878 A1
US 20100076664 A1

(58) Field of Search:
As for published application 2578348 A viz:
INT CL **F01M, F02D**
Other: **WPI, EPODOC**
updated as appropriate

Additional Fields
INT CL **F01M, F02D, F02M**
Other: **WPI, EPODOC**

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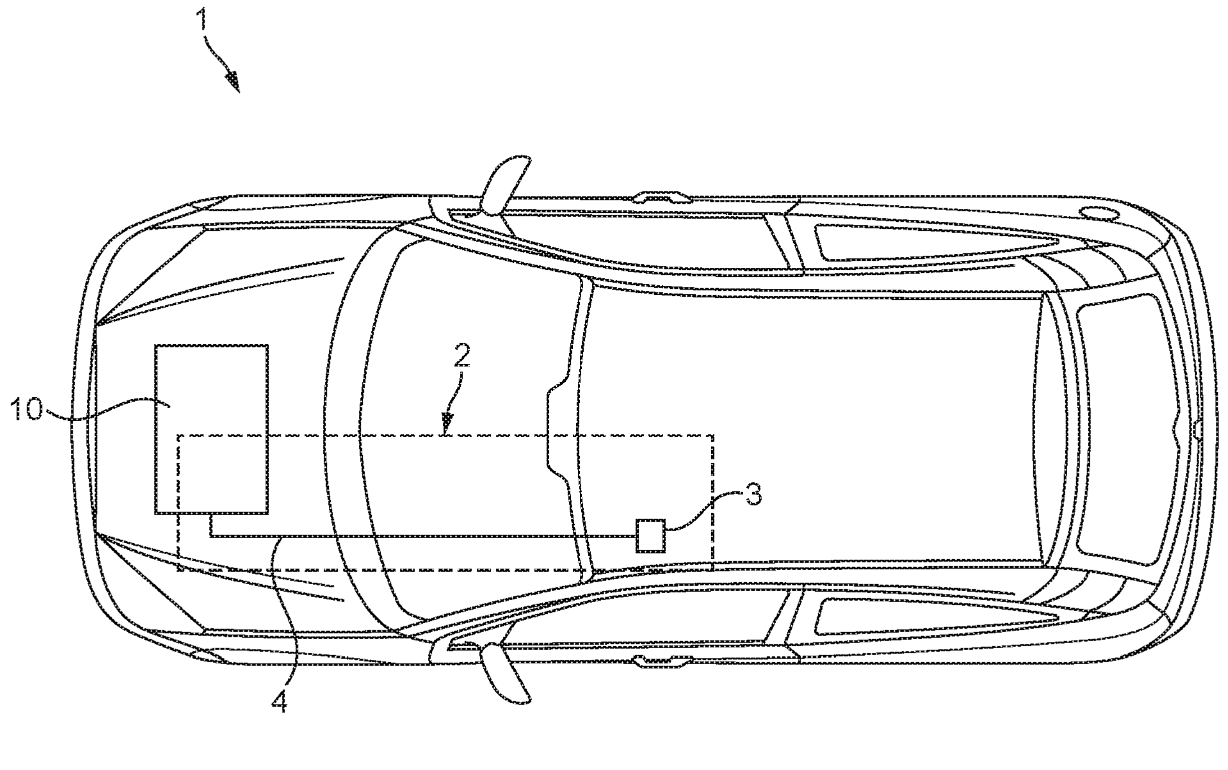

Fig. 1

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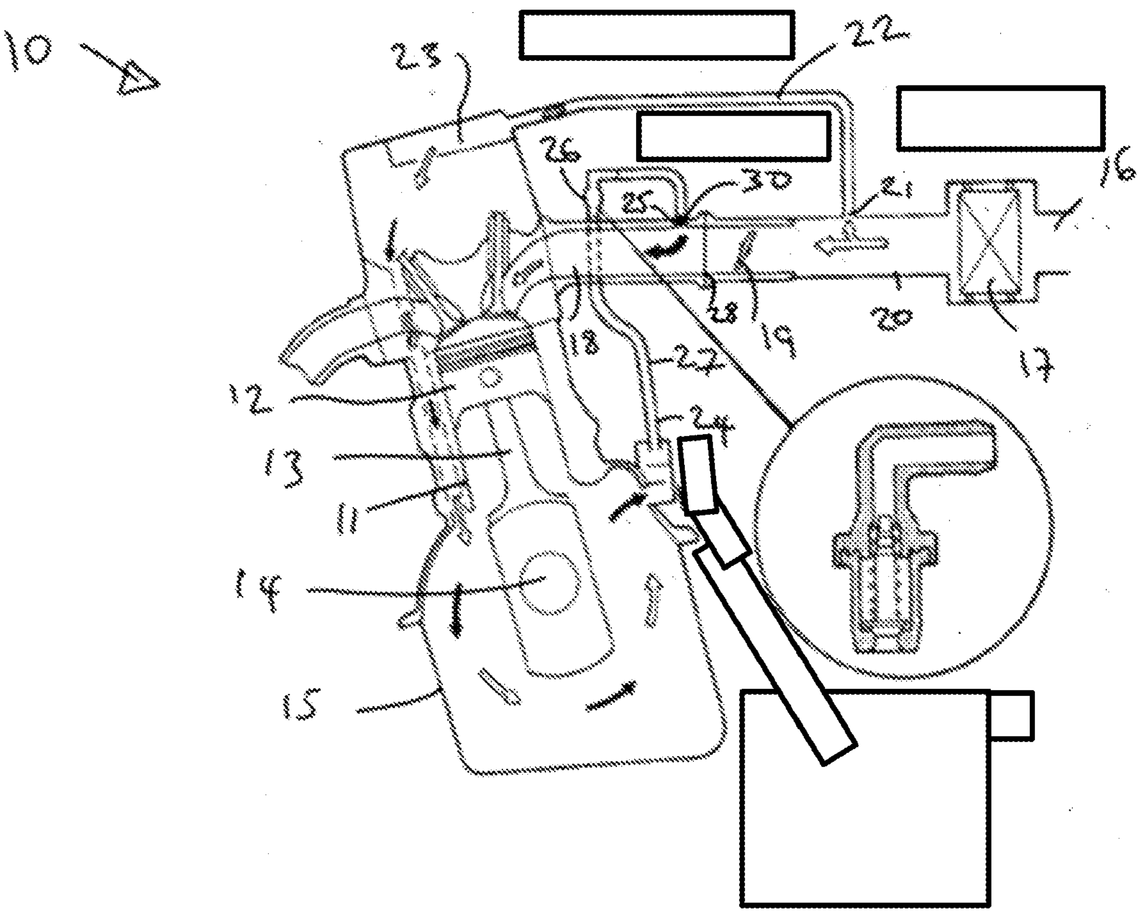

Fig. 2

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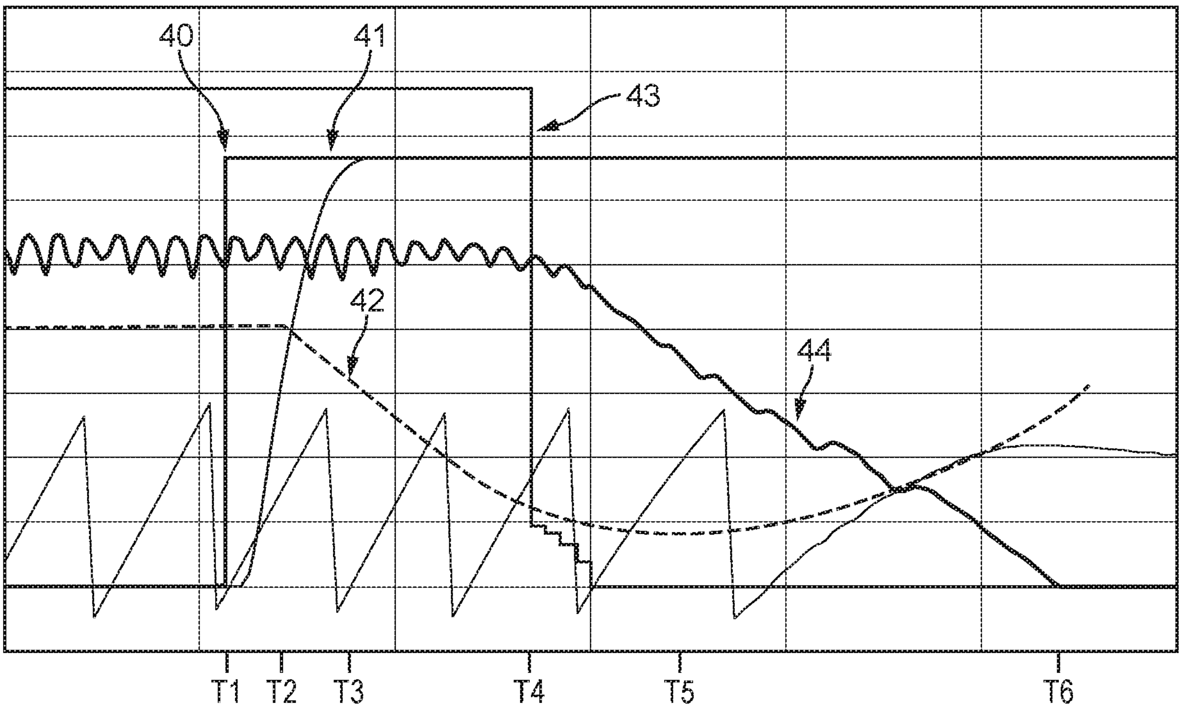

Fig. 3

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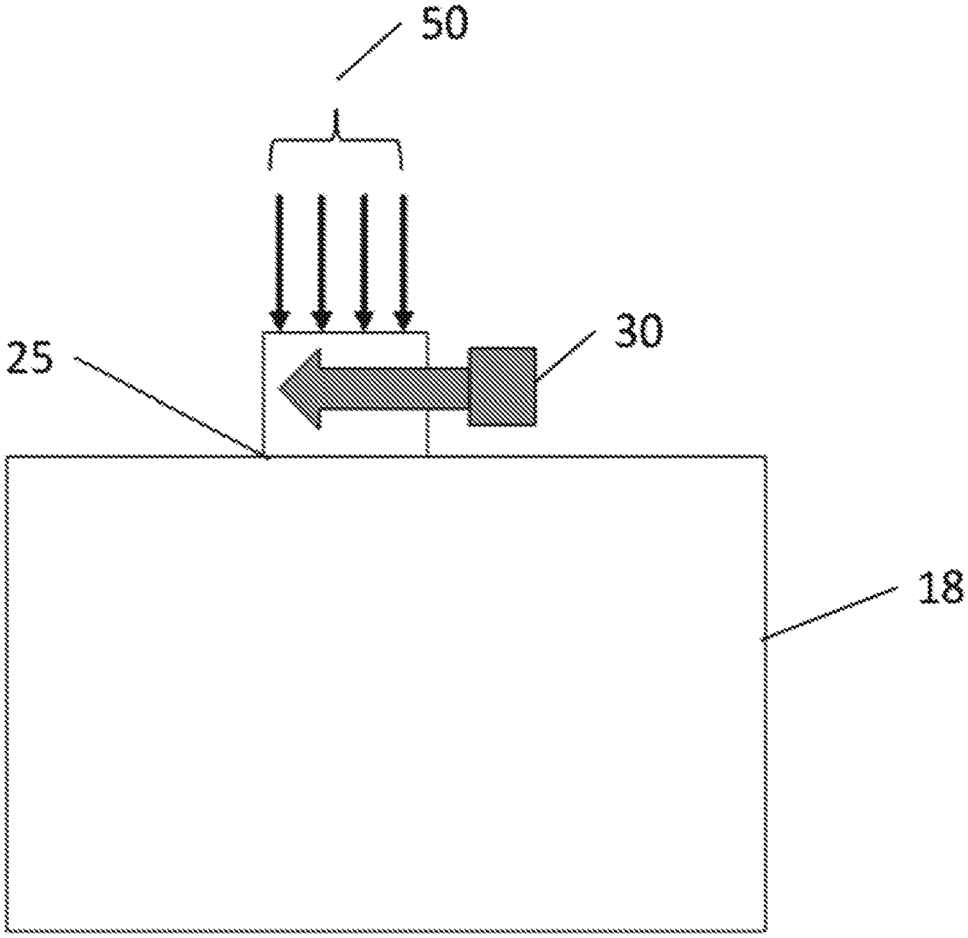

Fig. 4

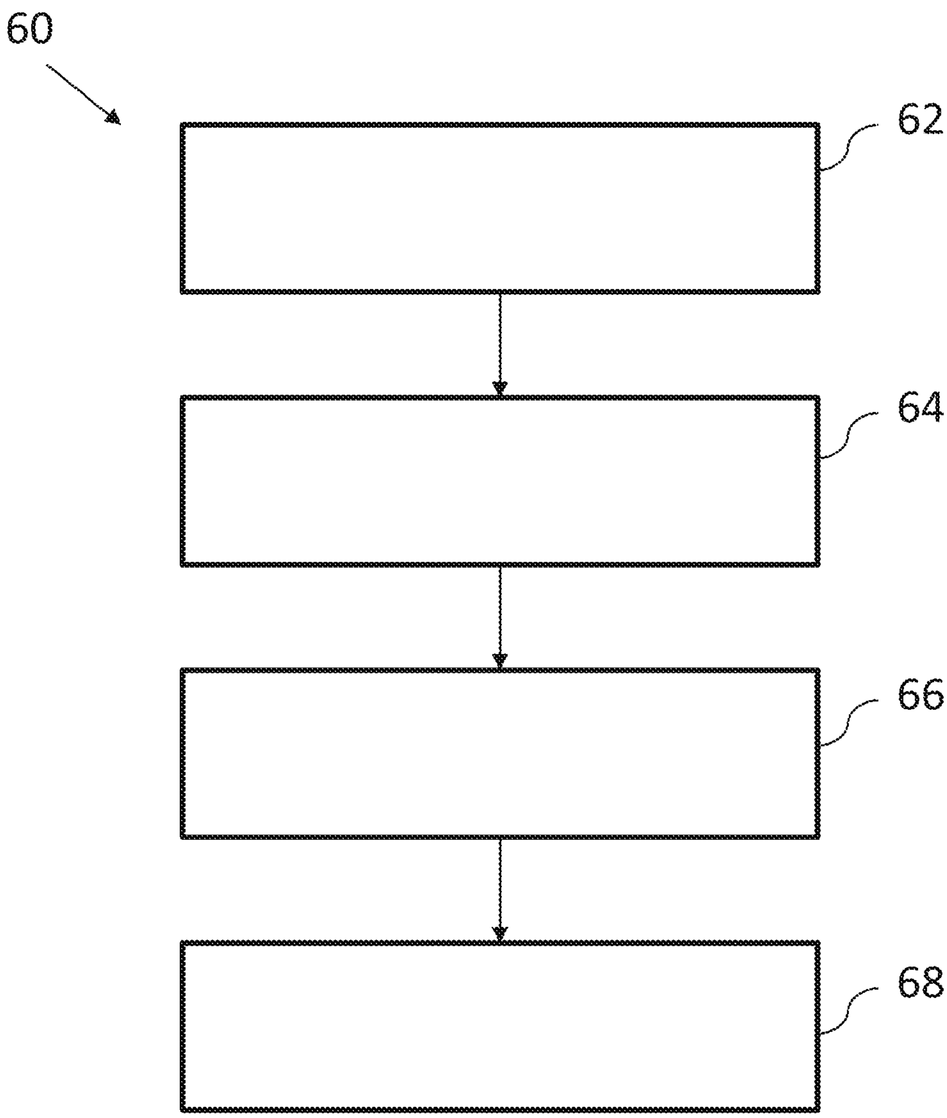

Fig. 5

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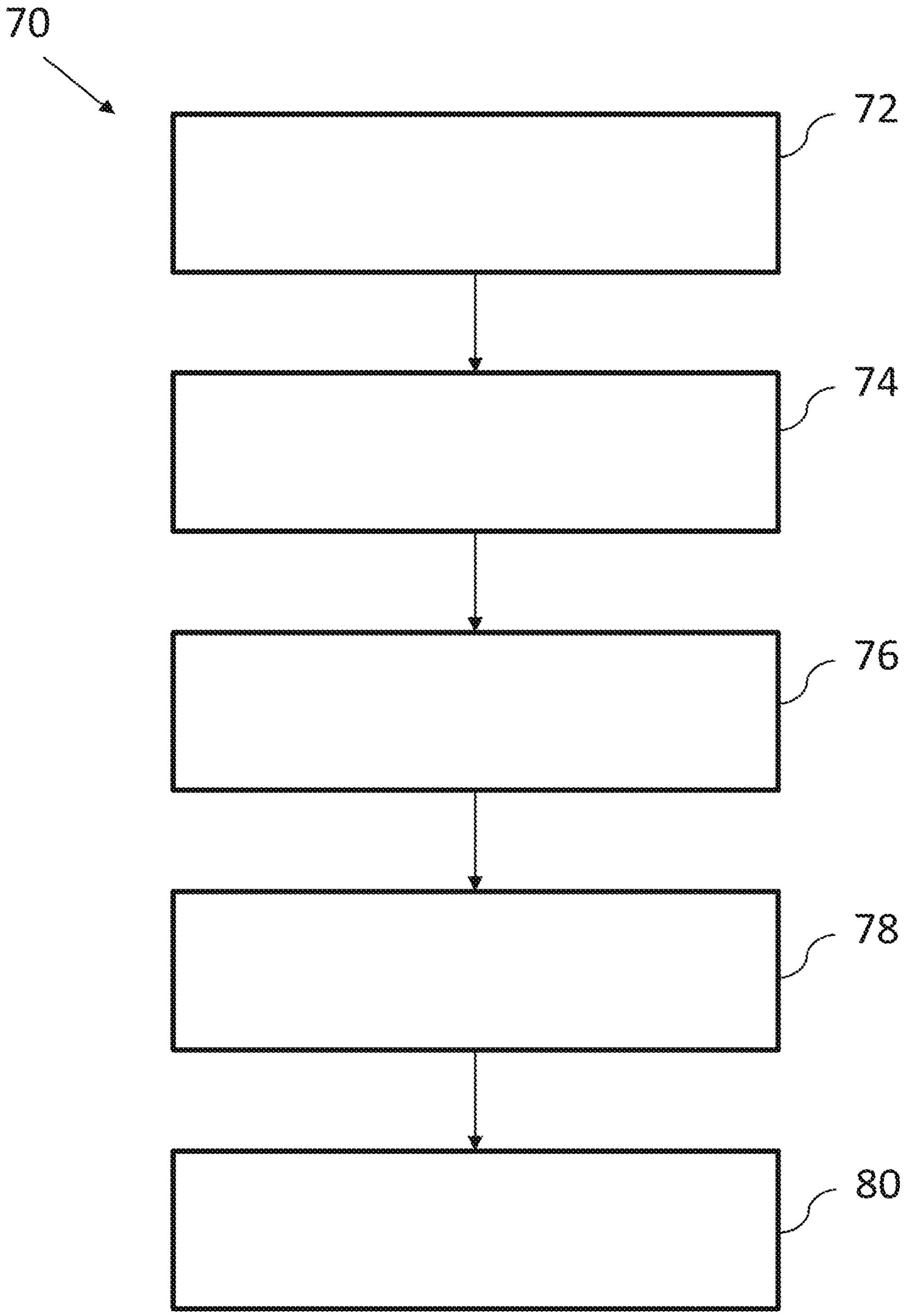

Fig. 6

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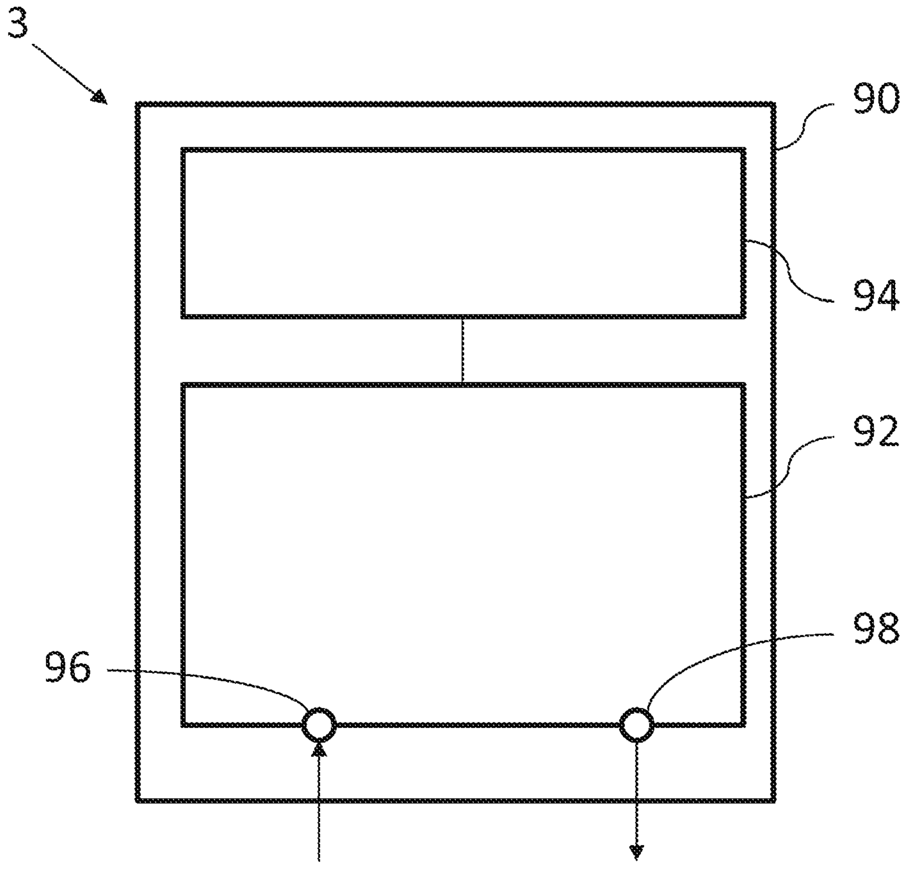

Fig. 7

System and Method for the Control of an Internal Combustion Engine

TECHNICAL FIELD

The present disclosure relates to a system and to a method for the control of an internal combustion engine. Aspects of the invention relate to a valve control system, a valve control apparatus, to an internal combustion engine system, to a method of operating an engine control valve, to a method of shutting down an engine, and to a vehicle comprising the valve control system.

BACKGROUND

It is known that gases in internal combustion engines are able to leak past the pistons and into the crankcase. Such gases, known as blow-by gases, contain air, combustion gases, unburnt fuel and water. The presence of blow-by gases in the crankcase causes the pressure in the crankcase to rise and, if left to build up, the elevated pressure can cause oil to leak from the engine past the crankcase seals. In addition, the blow-by gases can condense and cause the oil to become diluted with unburnt fuel. This reduces the effectiveness of the oil and decreases its serviceable life.

Internal combustion engines may be provided with a positive crankcase ventilation (PCV) system to ventilate the blow-by gases. The PCV system generally comprises a valve, often referred to as a part load breather or PCV valve, located in a flowpath between the crankcase and an ancillary inlet of the intake manifold of the internal combustion engine. The valve stem of the PCV valve is held in the open position, away from the valve seat, by a weak spring. When the pressure at the downstream end of the PCV valve (relative to a direction of gas flow from the crankcase to the intake manifold) is lower than the pressure at the upstream end of the PCV valve, the valve stem is drawn towards the valve seat, causing the flow passage through the PCV valve to become restricted. This may occur when the downstream end of the PCV valve is exposed to a vacuum, i.e. a subatmospheric pressure.

In use, in a typical petrol engine, when the engine is at idle, the throttle or throttle valve is almost closed such that there is a high vacuum, i.e. low absolute pressure, in the intake manifold and a significant pressure difference between the crankcase and the intake manifold. This vacuum causes gases from the crankcase to be drawn towards the intake manifold, via the PCV valve passage, where they can be re-used. In this condition, the PCV valve stem is drawn towards the valve seat by the vacuum and the flow passage through the PCV valve is restricted. This is appropriate as the flow of blow-by-gasses should be restricted proportionally to the flow of air at the intake manifold and the flow of air at the intake manifold is low when the engine is at idle.

Conversely, at high engine load, the throttle opens to a greater extent and the vacuum in the intake manifold is lower, which reduces the pressure difference between the crankcase and the intake manifold. The gases in the crankcase are still drawn towards the intake manifold, where they are re-used, but in this case the valve stem of the PCV valve remains further away from the valve seat. Therefore the PCV valve passage is more open because the pressure difference acting on the PCV valve is not able to overcome the opposing spring force to the same extent as when the intake manifold vacuum is high. This results in a higher gas flow from the crankcase to the intake manifold. Again, this is appropriate as the airflow at the intake manifold and the volume of blow-by gases is higher at higher engine loads and engine speeds.

As the throttle approaches an unthrottled condition, there may be little or no vacuum in the intake manifold. In this condition there is no vacuum to cause the blow-by gases to be drawn towards the ancillary inlet of the intake manifold from the crankcase. In this case, the blow-by gases exit the crankcase via a breather path which ordinarily supplies clean air to the crankcase to help in carrying the blow by gases from the crankcase to the intake manifold for re-use. Although the PCV valve is essentially fully open in this condition, the blow-by gases do not flow through the PCV system to the intake manifold as there is no pressure differential between the crankcase and the ancillary inlet of the intake manifold. The blow-by gasses therefore exit the crankcase, driven by the elevated pressure in the crankcase, via the air breather path. In this case, the blow-by gas flows from the crankcase, along the air breather path, to the upstream side of the throttle where it re-enters the intake manifold via the main inlet of the intake manifold.

In diesel engines the situation is different in that the throttle is substantially open during both idle and higher load engine operation. For example, the throttle may be opened to a position which creates an approximate 5% pressure drop across the throttle. This provides sufficient vacuum in the intake manifold to cause the blow by-gases to be drawn from the crankcase and into the intake manifold for re-use. Whether the engine is running with high or low torque, the blow-by gasses pass through the substantially open PCV valve and into the intake manifold.

If a driver fully depresses the accelerator pedal, thereby requesting maximum torque, the throttle fully opens and there is effectively no vacuum at the intake manifold. In this condition, the blow-by gases exit the crankcase via the air breather path as described above with reference to petrol engine operation. In an alternative example, the PCV system may be omitted from the diesel engine arrangement and the air breather path alone may be relied on for crankcase ventilation.

During engine shutdown, whether in a petrol engine or a diesel engine, the throttle may be closed to stop the supply of fresh intake air and reduce the pressure at the intake manifold, thereby increasing the vacuum as the inertia of the engine dissipates and the supply of fuel is cut-off. However, once the fuel supply is cut-off, air in an engine cylinder acts as a spring that accelerates and decelerates the piston, causing a ‘shaking’ effect that is perceptible by occupants of the vehicle during the final engine cycles.

For example, in a 4-stroke engine, air in the intake manifold is drawn into an engine cylinder during the intake stroke of a particular piston. This volume of air is subsequently compressed and expanded and acts as an air spring. In particular, the air in the engine cylinder resists the motion of the piston towards top dead centre during the compression stroke, yet forces the piston towards bottom dead centre during the subsequent expansion stroke. Thereafter the air is exhausted from the cylinder in the exhaust stroke and another intake of gas is drawn into the engine cylinder during the intake stroke of the next cycle. This process is repeated until the inertia of the engine is lost, but the shaking effects are quite noticeable, particularly during the final compression and expansion strokes.

Notably, the shaking effect is more pronounced if the pressure at the intake manifold is larger when the supply of fuel is cut-off, since more gas enters the cylinders during the subsequent engine cycles, which causes larger forces on the crankshaft and a more pronounced vehicle shake as the engine inertia reduces to zero.

Furthermore, the piston acts to pull gases, via the PCV system, from the crankcase to the ancillary inlet of the intake manifold during engine shut-down. This acts to partially replenish gases in the intake manifold with crankcase gas, even though the supply of fresh air is cut-off by the throttle. Consequently, engine shut-down is prolonged and the intake manifold pressure remains higher as the engine inertia dissipates and the supply of fuel is cut-off. This means that more gas enters the cylinders during the final cycles of the engine, which causes larger forces on the crankshaft and a more pronounced vehicle shake as the engine inertia reduces to zero.

It is an aim of the present invention to address one or more of the disadvantages associated with the prior art.

SUMMARY OF THE INVENTION

Aspects and embodiments of the invention provide a valve control system, an internal combustion engine system, a method of operating an engine control valve, and a vehicle comprising the valve control system as claimed in the appended claims.

According to one implementation there is provided a valve control system comprising a valve located in a flow path between a crankcase and an ancillary inlet of an intake manifold of an internal combustion engine, the valve being operable to selectively restrict flow through the flow path, the control system comprising one or more controllers configured to receive a first request signal indicative of a request to shut down the internal combustion engine; and output a first control signal to cause the valve to restrict flow through the flow path in dependence on receipt of the first request signal.

According to another implementation there is provided a valve control system for a valve located in a flow path between a crankcase and an ancillary inlet of an intake manifold of an internal combustion engine, the valve being operable to selectively restrict flow through the flow path, the control system comprising one or more controllers configured to receive a first request signal indicative that at least one vehicle operation condition has been met selected from: an engine shut-down condition; an engine startup condition; an engine overrun condition; an eco-stop condition; and/or an engine shut-down preparation condition; and output a first control signal to cause the valve to restrict flow through the flow path in dependence on receipt of the first request signal.

The engine shut-down condition is a pre-determined condition, wherein satisfaction of the engine shut-down condition is symptomatic of, or otherwise activates, an engine shut-down procedure. Hence, upon receiving the request signal indicative that the engine shut-down condition has been met, the control system outputs the first control signal to cause the valve to restrict flow through the flow path during the subsequent steps of the engine shut-down procedure.

The engine startup condition is a pre-determined condition, wherein satisfaction of the engine startup condition is symptomatic of, or otherwise activates, an engine startup procedure.

Hence, upon receiving the request signal indicative that the engine startup condition has been met, the control system outputs the first control signal to cause the valve to restrict flow through the flow path during the subsequent steps of the engine startup procedure.

The engine overrun condition is a pre-determined condition, wherein satisfaction of the engine overrun condition is symptomatic of, or otherwise corresponds to the initiation of, a state of the engine operation in which the engine provides negative torque or engine braking. This occurs, for example, when the transmission system drives the operation of the engine or when the wheel speed exceeds the power produced by the engine. For example, this may occur during downhill driving or following a downshift of a connected gearbox. Hence, upon receiving the request signal indicative that the engine overrun condition has been met, the control system outputs the first control signal to cause the valve to restrict flow through the flow path whilst the engine is in the overrun state.

The engine shut-down preparation condition is a pre-determined condition, wherein satisfaction of the engine shut-down preparation condition is symptomatic of, or otherwise activates, a procedure for preparing the engine for shut-down, e.g. performing one or more operations to remove any delay in shutting down the engine upon receiving the request signal indicative of the engine shut-down condition having been met. Hence, upon receiving the request signal indicative that the engine shut-down preparation condition has been met, the control system outputs the first control signal to cause the valve to restrict flow through the flow path prior to receiving the request signal indicative of the engine shut-down condition having been met.

The first control signal may cause the valve to move to a closed position.

Optionally the first control signal causes a throttle of the internal combustion engine to move to a closed position. Alternatively, the control system may be configured to output a second control signal to cause a throttle of the internal combustion engine to move to a closed position in dependence on receipt of the first request signal.

The control system may be configured to output a control signal to cause a fuel supply of the internal combustion engine to be stopped.

The one or more controller(s) may comprise an electronic processor having an electrical input for receiving said first request signal; and an electronic memory device electrically coupled to the electronic processor and having instructions stored therein, the processor being configured to access the memory device and execute the instructions stored therein. For example, the processor being configured to access the memory device and execute the instructions stored therein to output the first control signal in dependence on receiving the first request signal.

According to a further implementation there is provided a valve control apparatus comprising the valve control system, as described in a previous implementation, and a valve located in a flow path between a crankcase and an ancillary inlet of an intake manifold of an internal combustion engine, the valve being operable to selectively restrict flow through the flow path.

The valve may comprise part of a positive crankcase ventilation system of the engine. Alternatively, the valve may be independent of the positive crankcase ventilation system.

Optionally the valve is located downstream of the positive crankcase ventilation system of the engine with respect to a flow direction from the crankcase to the intake manifold.

The valve may be operable to selectively restrict the flow through a plurality of flow paths between the crankcase and the intake manifold of the internal combustion engine.

According to another implementation there is provided an internal combustion engine system comprising the valve control system described above or the valve control apparatus described above.

According to a further implementation there is provided a method of operating a valve, the valve being operable to selectively restrict flow through a flow path between a crankcase and an ancillary inlet of an intake manifold of an internal combustion engine, the method comprising receiving a first request signal indicative of a request to shut down the internal combustion engine; and generating a first control signal in dependence on receipt of the first request signal to cause the valve to restrict flow through the flow path.

According to a further implementation there is provided a method of operating a valve, the valve being operable to selectively restrict flow through a flow path between a crankcase and an ancillary inlet of an intake manifold of an internal combustion engine, the method comprising receiving a first request signal indicative that a vehicle operation condition has been met; and generating a first control signal in dependence on receipt of the first request signal to cause the valve to restrict flow through the flow path.

Optionally, the first request signal is indicative that at least one vehicle operation condition has been met selected from: an engine shut-down condition; an engine startup condition; an engine overrun condition; an eco-stop condition; and/or an engine shut-down preparation condition.

The first control signal may cause the valve to move to a closed position.

Optionally, the first control signal causes a throttle of the internal combustion engine to move to a closed position.

The method may further comprise generating a second control signal to cause a throttle of the internal combustion engine to move to a closed position in dependence on receipt of the first request signal.

Optionally, the method further comprises generating a third control signal to cause a fuel supply of the internal combustion engine to be stopped.

According to a further implementation there is provided a method of shutting down an internal combustion engine, the method comprising issuing a request to shut down the internal combustion engine; closing a throttle located in a flowpath between an air intake and an intake manifold of the internal combustion engine in response to the request to shut down the internal combustion engine; closing a valve located in a flowpath between a crankcase and an ancillary inlet of the intake manifold of the internal combustion engine in response to the request to shut down the internal combustion engine; and stopping a fuel supply of the internal combustion engine in response to the request to shut down the internal combustion engine.

According to a still further implementation there is provided a method of shutting down an internal combustion engine, the method comprising issuing a request indicative that a condition has been met for engine shut-down; closing a first valve located in a flowpath between an air intake and an intake manifold of the internal combustion engine in response to the request; closing a second valve located in a flowpath between a crankcase and an ancillary inlet of the intake manifold of the internal combustion engine in response to the request; and stopping a fuel supply of the internal combustion engine in response to the request.

Optionally, closing the second valve comprises outputting a first control signal, from a control system, to cause the second valve to move to a closed position in dependence on the request.

Optionally, closing the first valve comprises outputting a second control signal, from the control system, to cause the first valve to move to a closed position in dependence on the request.

Optionally, stopping the fuel supply comprises outputting a third control signal, from the control system, to cause the fuel supply of the internal combustion engine to be stopped in dependence on the request.

Optionally the fuel supply may be stopped after the first and second valves have closed.

Optionally the closing of the first and second valves may be initiated at substantially the same time.

Optionally the request is issued when a vehicle in which the internal combustion engine is installed is moving and has a speed below a threshold speed.

The first and or second valve may optionally close while the vehicle is moving.

Optionally the request may be issued as a result of a positive eco-stop condition having been identified. The eco-stop condition may include one or more conditions selected from: the brake being actuated whilst the vehicle is stopped; positive torque not being required, for example, when moving at low speeds or when decelerating to a stop; and/or engine torque not being required, for example, when an electrical machine is used for propulsion in a hybrid vehicle.

According to a further implementation there is provided a vehicle comprising the valve control system as described above, the valve control apparatus as described above or the internal combustion engine system as described above.

Within the scope of this application it is expressly intended that the various aspects, embodiments, examples and alternatives set out in the preceding paragraphs, in the claims and/or in the following description and drawings, and in particular the individual features thereof, may be taken independently or in any combination. That is, all embodiments and/or features of any embodiment can be combined in any way and/or combination, unless such features are incompatible. The applicant reserves the right to change any originally filed claim or file any new claim accordingly, including the right to amend any originally filed claim to depend from and/or incorporate any feature of any other claim although not originally claimed in that manner.

BRIEF DESCRIPTION OF THE DRAWINGS

One or more embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 shows a vehicle in accordance with the present invention;

Figure 2 shows a schematic cross-sectional drawing of an internal combustion engine comprising a valve control apparatus in accordance with the present invention;

Figure 3 shows a chart of a prior art engine shutdown methodology;

Figure 4 shows a schematic representation of an alternative arrangement of the valve control apparatus in accordance with the present invention;

Figure 5 illustrates an embodiment of a method of operating the valve control apparatus, shown in Figure 2, in accordance with the present invention;

Figure 6 illustrates an embodiment of a method of shutting down the internal combustion engine, shown in Figure 2, in accordance with the present invention; and

Figure 7 illustrates an embodiment of a valve control system in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION

A vehicle in accordance with an embodiment of the present invention is described herein with reference to the accompanying Figure 1.

With reference to Figure 1, a schematic representation of a vehicle 1 is shown comprising an internal combustion engine 10, located in an engine bay of the vehicle 1, and a valve control apparatus 2. The valve control apparatus 2 comprises a valve control system 3 located at any suitable position within the vehicle body and an electronically controllable valve 30 (illustrated in Figure 2) located in a PCV system 24 (illustrated in Figure 2) of the engine 10 (described in further detail below). The valve control system 3 comprises one or more controllers which communicate with the electronically controllable valve 30 via a communications bus 4.

It will be understood that the valve control system 3 and communications bus 4 shown in Figure 1 are schematic representations only. The valve control system 3 may form part of a vehicle control unit (VCU) of the vehicle 1, or may be part of an engine control unit (ECU) of the vehicle 1, or any combination thereof. Alternatively or additionally, the valve control system 3 may be separate to either one or both of the VCU and/or ECU. The communications bus 4 may be substituted partially or entirely by a wireless communication system.

For purposes of this disclosure, it is to be understood that the controller(s) described herein can each comprise a control unit or computational device having one or more electronic processors. A vehicle and/or a system thereof may comprise a single control unit or electronic controller or alternatively different functions of the controller(s) may be embodied in, or hosted in, different control units or controllers. A set of instructions could be provided which, when executed, cause said controller(s) or control unit(s) to implement the control techniques described herein (including the described method(s)). The set of instructions may be embedded in one or more electronic processors, or alternatively, the set of instructions could be provided as software to be executed by one or more electronic processor(s). For example, a first controller may be implemented in software run on one or more electronic processors, and one or more other controllers may also be implemented in software run on one or more electronic processors, optionally the same one or more processors as the first controller. It will be appreciated, however, that other arrangements are also useful, and therefore, the present disclosure is not intended to be limited to any particular arrangement. In any event, the set of instructions described above may be embedded in a computer-readable storage medium (e.g., a non-transitory computer-readable storage medium) that may comprise any mechanism for storing information in a form readable by a machine or electronic processors/computational device, including, without limitation: a magnetic storage medium (e.g., floppy diskette); optical storage medium (e.g., CD-ROM); magneto optical storage medium; read only memory (ROM); random access memory (RAM); erasable programmable memory (e.g., EPROM and EEPROM); flash memory; or electrical or other types of medium for storing such information/instructions.

Figure 2 shows a schematic cross-sectional view of the internal combustion engine 10, and shows the electronically controllable valve 30 in situ. In this example, the electronically controllable valve 30 is a solenoid valve which is activated by the application of an electric current as is well known in the art. Any other suitable electronically controllable valve may be used that may, for example, include a stepper motor and/or a moveable flap or panel.

The internal combustion engine 10 comprises a cylinder 11 within which a piston 12 is slideably arranged. A connection rod 13 connects the piston 12 to a crankshaft 14 located within crankcase 15.

Air is supplied to the engine 10 via air intake 16. Air entering the engine 10 passes through an air filter 17 before entering the primary inlet 28 of intake manifold 18. A throttle 19 is located in air inlet pipe 20 upstream of the primary intake manifold inlet 28 relative to a direction of air flow from the air inlet 16 to the intake manifold 18. The air inlet pipe 20 comprises a branch 21 located upstream of the throttle 19. An air breather path 22 connects the branch 21 to a crankcase air inlet 23.

A PCV system 24 connects the interior of the crankcase 15 to an ancillary inlet 25 in the intake manifold 18. A PCV valve 26, such as that described in the introduction above, is located in a conduit 27 of the PCV system 24.

In this example, the electronically controllable valve 30 is located in the PCV system 24 downstream of the PCV valve 26 (relative to a direction of gas flow from the crankcase 15 to the intake manifold 18). However, the electronically controllable valve 30 could be located at any location in the PCV system 24 or at either end of the PCV system 24 such that the electronically controllable valve 30 does not form a part of the PCV system 24 itself. In one example, (not shown) the PCV valve 26 could be, or could comprise, the electronically controllable valve 30.

During engine shutdown, the valve control system 3 receives a request signal indicative that a condition has been met for engine shut-down. For example, a driver of the vehicle may satisfy the condition for engine shut-down by activation of an engine shut-off switch, or the condition may be satisfied by a signal generated by a VCU, or another control system of the vehicle, upon detection of an eco-stop condition. A suitable eco-stop condition may include one or more conditions selected from: the brake being actuated whilst the vehicle is stopped; positive torque not being required, for example, when moving at slow speed; and/or engine torque not being required, for example, when an electrical machine is used for propulsion in a hybrid vehicle.

Upon receipt of the request signal, the valve control system 3 outputs a first control signal to cause the electronically controllable valve 30 to restrict flow through the PCV system 24. In this example, the first control signal is relayed to a valve controller (not shown), which is co-located with the electronically controllable valve 30, via the communications bus 4. Upon receipt of the first control signal, the valve controller causes the electronically controllable valve 30 to restrict flow through the PCV system 24. The valve controller causes the electronically controllable 30 valve to close thereby effectively preventing flow of blow-by gases from the crankcase 15 to the intake manifold 18.

Figure 3 shows a chart of a prior art engine shutdown methodology. At time point T1, an engine shut down request signal 40 is generated. The engine shut down request signal 40 causes the throttle 19 to close. The throttle 19 is fully closed by time point T3 as indicated by the throttle position trace 41. Once the throttle 19 has reached a certain degree of closure at time point T2, the intake manifold pressure begins to decrease, as illustrated by trace 42, as the intake manifold 18 begins to become starved of airflow. Fuel continues to be supplied to the engine 10 until time point T4 when the fuel supply is cut-off, as indicated by trace 43.

The time delay between the generation of the engine stop request signal 40 and the cut-off of the fuel supply is created in order to minimise the pressure at the intake manifold 18 as the inertia of the engine 10 reduces to zero. More specifically, by continuing to supply fuel until a time after the throttle 19 has closed, the piston 12 continues to be driven in the cylinder 11 by the internal combustion process. This helps to maintain the inertia of the engine 10 for more cycles, in order to exhaust more gasses from the intake manifold 18 and lower the pressure at the intake manifold 18 to a greater extent than would otherwise be the case if the fuel supply was cut-off at the same time as the engine stop request signal 40.

The intake manifold 18 reaches its lowest pressure at time point T5. After the fuel supply has been cut-off, the engine speed decreases to zero at time point T6, as indicated by trace 44, and the engine stops.

As discussed previously, the piston 12 acts to pull gases from the crankcase 15, via the PCV system 24, into the intake manifold 18 during the intake strokes of the engine shut-down sequence. This acts to partially replenish gases in the intake manifold 18 with crankcase gas, even though the supply of fresh air is cut-off by the throttle 19. Consequently, engine shut-down is prolonged and the intake manifold pressure remains higher as the engine inertia dissipates. This means that more gas enters the cylinders 11 during the final cycles of the engine, when the supply of fuel is cut-off, which causes larger forces on the crankshaft 14 and a more pronounced vehicle shake as the engine inertia reduces to zero.

The provision of the electronically controllable valve 30, and its control by the valve control system 3, helps to reduce the time it takes for the engine 10 to stop by preventing the replenishment of gases in the intake manifold 18 via the PCV system 24. By closing off the gas supply path from the crankcase 15 to the intake manifold 18, the residual intake manifold pressure decreases more quickly and, as a result, the fuel supply can be shut-off earlier. The engine 10 can therefore be brought to a stop more quickly and fuel can be saved with reduced shake.

In one example, upon issue of a request signal 40 indicative of a condition having been met for engine shut-down, the valve control system 3 outputs a control signal which causes the valve 30 to close and which causes the throttle 19 to close. In an alternative example, upon issue of the engine shut-down request signal 40, the valve control system 3 outputs a first control signal which causes the valve 30 to close and a second control signal which causes the throttle 19 to close. In order to reduce the pressure in the intake manifold 18 as quickly as possible, the closure of the valve 30 and throttle 19 is ideally initiated at the same time by either a single control signal issued by the valve control system 3, or by a plurality of signals issued by the valve controller 3. Alternatively the valve 30 may be closed or restricted before the throttle 19 is closed, for example if the engine has been idling before the engine shut-down request signal is issued.

It will be understood that the request signal 40 indicative of a request to shut down the internal combustion engine might be issued as a result of an eco-stop condition having been identified by the VCU, or another vehicle control system. For the avoidance of doubt, the vehicle 1 need not be at rest when the request signal 40 is issued, nor when the valve control system 3 issues one or more control signals to cause the valve 30 and/or throttle 19 to close.

In an example, the valve control system 3 may be configured to output the first control signal if the valve control system 3 receives a request signal that is indicative that a condition has been met for engine shut-down preparation, i.e. outputting the first control signal before receiving the request signal 40 indicative of a condition having been met for engine shut-down.

For example, if one or more eco-stop conditions are satisfied that form a subset of a plurality of engine shut-down conditions, then the valve control system 3 may output the first control signal to cause the electronically controllable valve 30 to restrict flow through the PCV system 24 before the valve control system 3 receives the request signal 40 indicative of a request to shut down the internal combustion engine 10.

The plurality of engine shut-down conditions may, for example, include a condition that the vehicle is stopped. If the eco-stop conditions are satisfied, then the valve control system 3 may output the first control signal in order to proactively prepare the PCV system 24 for reducing the pressure at the intake manifold 18 when the vehicle is stopped. Thereafter, engine shut-down begins and the valve control system 3 may output the second control signal to close the throttle 19. Advantageously, this example removes any delay in reducing the manifold pressure when the engine shut down request 40 is received such that less or no fuel is required to sufficiently reduce the pressure at the intake manifold 18.

In another example, the valve control system 3 may be configured to output the first control signal if the valve control system 3 receives a request signal that is indicative that a condition has been met for the engine operation in an overrun condition, i.e. upon detecting that the engine is providing negative torque or engine braking.

In this context it should be appreciated that crankcase gases include an unknown mixture of air, combustion gases, unburnt fuel and water that may be combustible when drawn into the engine cylinder 11 and may cause misfires during engine operation in an overrun condition.

To mitigate such issues, the valve control system 3 is configured to output the first control signal to cause the electronically controllable valve 30 to restrict flow through the PCV system 24 during overrun conditions. Such measures advantageously prevent the flow of blow-by gases from the crankcase 15 to the intake manifold 18, which reduces the likelihood of misfires in the engine.

In a further example, the valve control system 3 may be configured to output the first control signal if the valve control system 3 receives a request signal indicative that a condition has been met for engine startup.

On startup, the intake manifold 18 is effectively at full load due to leaks past the throttle 19 whilst the engine 10 is stopped. This full load condition on startup can produce engine flare, in which the engine 10 accelerates to an engine speed that exceeds the current vehicle speed or an idle speed.

To mitigate against this engine flare, it is well-known to shut the throttle 19 and delay the ignition of the engine 10 in order to reduce the load and minimise the pressure of the intake manifold 18 before opening the throttle 19 to the position required for idle engine operation.

However, the PCV valve 26 is ordinarily open on startup because the intake manifold 18 is effectively at full load. Hence, a volume of unknown crankcase gases are present in the intake manifold 18 during engine startup. The unknown chemical makeup entering the cylinder 11 creates unpredictable, and often incomplete, combustion products in the exhaust gases.

By outputting the first control signal to cause the electronically controllable valve 30 to restrict flow through the PCV system 24 on engine startup, the valve control system 3 effectively prevents the flow of blow-by gases from the crankcase 15 to the intake manifold 18, which mitigates such effects and reduces the likelihood of engine misfires.

Figure 4 shows a schematic illustration of an alternative arrangement of the valve control apparatus in accordance with the present invention. In this example, the intake manifold 18 has a plurality of connections 50 to a PCV system 24. The plurality of connections 50 may include connections to the PCV system 24 from one or more of a purge pipe; a brake vacuum pipe; an Exhaust Gas Recirculation (EGR) pipe or any other suitable vacuum operated device. One electronically controllable valve 30 is provided between the connections 50 and the ancillary inlet 25 of the intake manifold 18. In this way, all of the connections 50 may be closed off by actuation of the single valve 30 by the valve control system 3. Alternatively, multiple electronically controllable valves 30 may be provided, each of which is controllable by the valve control system 30 in response to the issue of a control signal to cause the valves 30 to restrict flow through the connections 50.

Figure 5 illustrates an example control method 60 for operating the valve control apparatus 2 in accordance with an embodiment of the invention.

The control method 60 is arranged to control the valve 30 to selectively restrict flow through the flow path 27 between the crankcase 15 and the ancillary inlet 25 of the intake manifold 18. The flow restriction may be applied in dependence on a pre-determined vehicle operation condition having been met, as described in more detail in the description that follows.

In step 62, the vehicle 1 may, for example, be travelling along a path at a constant vehicle speed with the throttle 19 open to produce an unthrottled condition at the intake manifold 18. The valve 30 may be at least partially open at this time to allow ventilation of the crankcase 15 through the ancillary inlet 25 of the intake manifold 18.

In step 64, the valve control system 3 may receive a request signal from one or more vehicle systems (not shown), indicating that the vehicle 1 is operating in a pre-determined condition for which it would be advantageous to restrict flow through the flow path 27. For example, the request signal may indicate that an engine overrun condition has been satisfied, which may occur if the vehicle 1 is driving downhill and the internal combustion engine 10 is providing negative torque or engine braking.

In step 66, following the receipt of the request signal indicating that the vehicle 1 is operating in a manner satisfying one of the pre-determined conditions for operating the valve 30, the valve control system 3 generates a control signal to cause the valve 30 to restrict flow through the flow path 27.

In step 68, the valve control system 3 outputs the control signal to cause the valve 30 to move towards a closed position, restricting the flow through the flow path 27. In this manner, the supply of crankcase gas to the ancillary inlet 25 of the intake manifold 18 is reduced whilst the internal combustion engine 10 is operating in said condition.

By reducing the flow of blow-by gases, from the crankcase 15 to the intake manifold 18, the method may, for example, be utilised to reduce the likelihood of misfires whilst the internal combustion engine 10 is operating in the overrun condition.

For the sake of clarity, it should be appreciated that the control method 60 is merely provided by way of example only and is not intended to limit the control method 60 and/or the valve control system 3. As such, it is understood that any of the steps may be altered, reordered, added, removed or performed sequentially and/or in parallel with any other steps.

Figure 6 illustrates an example control method 70 for shutting down the internal combustion engine 10 in accordance with an embodiment of the invention.

The control method 70 is arranged to control the valve 30 and the throttle 19 in dependence on an engine shut-down condition having been met, as shall become clear in the description that follows.

The valve 30 is controlled to selectively restrict the flow path 27 between the crankcase 15 and the ancillary inlet 25 of the intake manifold 18. The throttle 19 is controlled to selectively restrict the flow path 20 between the air intake 16 and the intake manifold 18 of the internal combustion engine 10.

In step 72, the vehicle 1 may, for example, be decelerating to a stop with the throttle 19 positioned so as to partially throttle the flow path 20. The valve 30 may be at least partially open to allow ventilation of the crankcase 15 through the ancillary inlet 25 of the intake manifold 18.

In step 74, a request 40 is issued indicating that a condition has been met for engine shut-down. For example, an engine shut-off switch may have been activated, which generates the request signal 40.

In step 76, the request signal 40 is received at the valve control system 3 and, in response, a first control signal may be issued to close the throttle 19 and restrict the flow path 20 between the air intake 16 and the intake manifold 18 of the internal combustion engine 10. The throttle 19 is closed to cut-off the supply of air to the intake manifold 18, which is otherwise drawn into the engine cylinders 11 where the air acts as a spring, as described previously.

In step 78, the valve control system 3 may issue a second control signal to close the valve 30 and restrict the flow path 27 between the crankcase 15 and an ancillary inlet 25 of the intake manifold 18. The valve 30 is closed to stop the flow of gas from the crankcase 15 to the intake manifold 18, which would otherwise partially replenish the gases in the intake manifold 18 and increase the intake manifold pressure.

In step 80, a third control signal may be issued to stop a fuel supply of the internal combustion engine 10 in response to the request 40.

The closure of the valve 30 and the throttle 19 may, for example, be initiated at the same time in order to reduce the pressure in the intake manifold 18 as quickly as possible.

As a result, the residual intake manifold pressure decreases faster and the fuel supply can be shut-off earlier in response to the request signal 40. Advantageously, the method can therefore be utilised to reduce the time taken to bring the internal combustion engine 10 to a stop, saving fuel with less perceptible shake.

For the sake of clarity, it should be appreciated that the control method 70 is merely provided by way of example only and is not intended to limit the control method 70. As such, it is understood that any of the steps may be altered, reordered, added, removed or performed sequentially and/or in parallel with any other steps.

Figure 7 illustrates an example valve control system 3 in accordance with an embodiment of the invention. The valve control system 3 includes a controller 90. The controller 90 includes an electronic processor 92 and an electronic memory device 94 electrically coupled to the electronic processor 92. The electronic processor 92 has an electrical input 96 for receiving request signals and an electrical output 98 for outputting control signals to the valve 30 and the throttle 19. The electronic memory device 94 has instructions stored therein for controlling the valve 30 and the throttle 19. In use, the electronic processor 92 is configured to access the electronic memory device 94 and execute the instructions stored therein to control the valve 30 and the throttle 19. The instructions may relate to a method of controlling the valve 30 and/or the throttle 19 in a manner described above.

It will be appreciated that various changes and modifications can be made to the present invention without departing from the scope of the present application.

CLAIMS

1. A valve control system for a valve located in a flow path between a crankcase and an ancillary inlet of an intake manifold of an internal combustion engine, the valve being part of a positive crankcase ventilation system of the engine and operable to selectively restrict flow through the flow path, the control system comprising one or more controllers configured to:

receive a first request signal indicative that an engine shut-down condition has been met;

output a first control signal to cause the valve to move to a closed position in dependence on receipt of the first request signal, wherein the first control signal causes a throttle of the internal combustion engine to move to a closed position; and

thereafter, output a second control signal to cause a fuel supply of the internal combustion engine to be stopped.

2. A valve control apparatus comprising the valve control system according to claim 1 and a further valve located in a flow path between a crankcase and an ancillary inlet of an intake manifold of an internal combustion engine, the further valve being operable to selectively restrict flow through the flow path.

3. A valve control apparatus according to claim 2, wherein the further valve comprises part of a positive crankcase ventilation system of the engine.

4. A valve control apparatus according to claim 2 or claim 3, wherein the valve is operable to selectively restrict the flow through a plurality of flow paths between the crankcase and the intake manifold of the internal combustion engine.

5. An internal combustion engine system comprising the valve control system of claim 1 or the valve control apparatus of any of claims 2 to 4.

6. A method of shutting down an internal combustion engine, the method comprising:

issuing a request indicative that a condition has been met for engine shut-down;

closing a throttle located in a flowpath between an air intake and an intake manifold of the internal combustion engine in response to the request;

closing a valve located in a flowpath between a crankcase and an ancillary inlet of the intake manifold of the internal combustion engine in response to the request, the valve being part of a positive crankcase ventilation system of the engine; and stopping a fuel supply of the internal combustion engine in response to the request, wherein the fuel supply is stopped after the throttle and the valve have closed.

7. A method according to claim 6, comprising initiating the closing of the throttle and the valve at substantially the same time.

8. A method according to claim 6 or claim 7, wherein the request is issued when a vehicle in which the internal combustion engine is installed is moving and has a speed below a threshold speed.

9. A method according to claim 8, wherein the throttle and/or the valve closes while the vehicle is moving.

10. A method according to any one of claims 6 to 9, wherein the request is issued as a result of a positive eco-stop condition having been identified.

11. A vehicle comprising the valve control system according to claim 1, the valve control apparatus according to any of claims 2 to 4 or the internal combustion engine system according to claim 5.