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JP 500149136 A

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(54) Abstract Title: **ENGINE INTERNAL GAS TRANSFER METHOD**

(57) An internal gas transfer method for operating an engine with at least a first and a second intake port controlled by respective first and second poppet valves normally timed to open and close during the intake period of the engine cycle. Variable valve timing is provided for at least the second poppet valve, and a non-return valve is mounted in the second intake port positioned such that the valve automatically shuts in the flow direction away from the engine cylinder when the said port and the non-return valve are subjected to a pressure higher than the intake air supply pressure. An auxiliary chamber is provided which communicates with the cylinder via the second intake port and downstream of the non-return valve. When internal gas transfer is required, the second poppet valve is moved in timing to open and close during a period other than the air intake period of the engine cycle, thus briefly connecting the second intake port and non-return valve with the engine cylinder, shutting the said non-return valve, and permitting transfer of gas between the cylinder and the auxiliary chamber during the power conversion phase of the engine cycle.

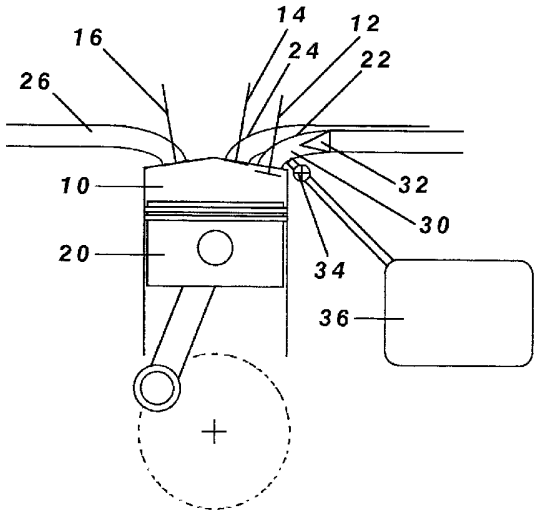

Fig.1

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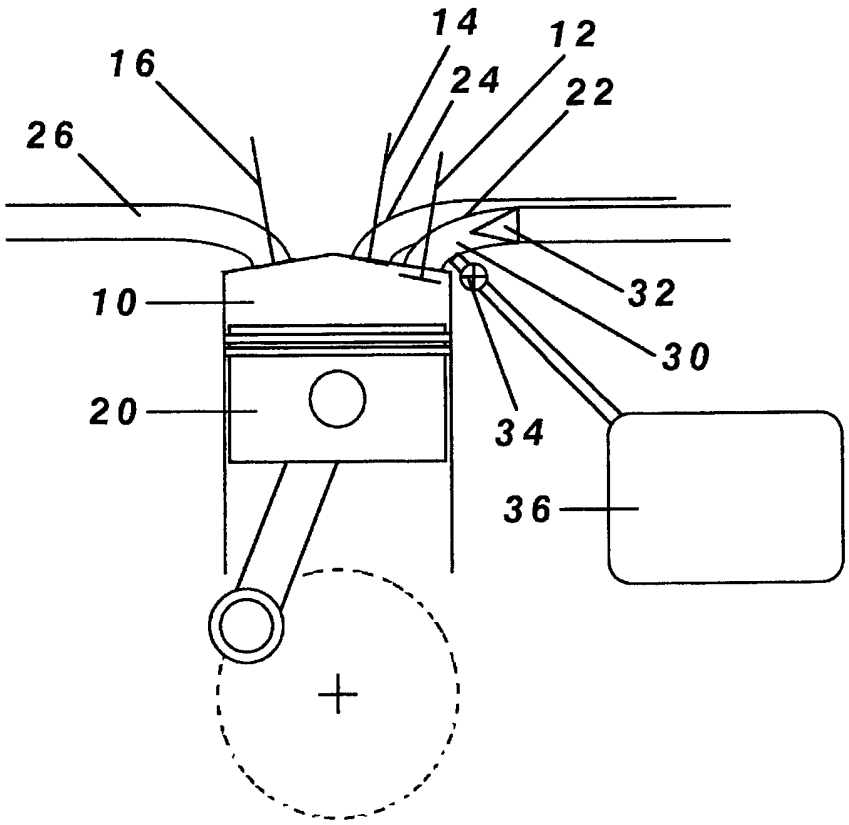

Fig.1

ENGINE INTERNAL GAS TRANSFER METHOD

Field of the invention

The present invention relates to a method enabling the power conversion process in an internal combustion engine to be influenced.

Background of the invention

It is known to provide an auxiliary chamber which is connected and disconnected with the engine cylinder during the compression or expansion period of the engine cycle in order to influence the compression or expansion process. EP0095252 proposed using an auxiliary chamber to trap a variable fraction of the cylinder charge during compression in order to vary the effective compression ratio of the engine. Pending patent application PCT/GB2004/001018 proposed using an auxiliary chamber as a buffer chamber in an air hybrid engine vehicle to transfer compressed gases in two steps via the auxiliary chamber to a compressed gas reservoir when the engine is operating as a gas compressor thereby assisting deceleration of the vehicle, and to expand the compressed gases in two steps from the compressed gas reservoir via the auxiliary chamber when the engine is operated as a gas expander thereby assisting acceleration of the vehicle. Another pending patent application GB0405828.5 proposed using an auxiliary chamber to vary the compression temperature of the cylinder charge in order to achieve CAI/HCCI combustion and influence the auto-ignition timing. In applying the above proposed concepts, a dedicated auxiliary chamber and a dedicated control valve are provided connecting with the engine cylinder at the appropriate timing in order to vary the internal gas transfer. Such a system however adds cost and complexity, and is difficult to install in the limited space of the combustion chamber of the engine.

Summary of the invention

With a view of mitigating at least some of the above problems, there is provided an internal gas transfer method for operating an internal combustion engine having at least a first and a second intake port controlled by respective first and second poppet valves normally timed to open and close during the intake period of the engine cycle with variable valve timing provided for at least the second poppet valve, and a non-return valve mounted in the second intake port positioned such that the valve automatically shuts in the flow direction away from the engine cylinder when the said port and the non-return valve are subjected to a pressure higher than the intake air supply pressure, the method characterised in that when internal gas transfer is required, the second poppet valve is moved in timing to open and close during a period other than the ambient air intake period of the engine cycle, thus briefly connecting the said second intake port and the said non-return valve with the engine cylinder at a pressure higher than the intake air supply pressure, shutting the said non-return valve, isolating the said port to form a sealed auxiliary chamber, and permitting transfer of gases internally between the engine cylinder and the said auxiliary chamber during the power conversion phase of the engine cycle.

The ambient air intake period of the engine cycle is herein defined as the period during which there is a through-flow of air from the ambient atmosphere directly into the engine cylinder. This includes naturally aspirated air, and boosted air from a turbocharger or supercharger drawing air from the ambient atmosphere and forcing it into the engine.

It should be noted that when the second poppet valve is timed to open and close during the ambient air intake period of the engine cycle, the said non-return valve will be

subjected to a suction pressure from the engine cylinder and will automatically open to permit through-flow of ambient air in the direction towards the engine cylinder. On the other hand, when internal gas transfer is required and the second poppet valve is moved in timing to open and close during the compression, expansion or exhaust period of the engine cycle, the second intake port will cease to function as an ambient air flow port during the intake period of the engine cycle but the engine will continue to operate with at least the first intake port and its associated poppet valve fully functional as an ambient air flow port so that there is no adverse effect in the running of the engine other than a possible reduction in the volumetric efficiency of the engine.

In the invention, by transforming the said second intake port into a sealed auxiliary chamber, no extra space is required in the combustion chamber to include this provision, and there will be cost saving in not duplicating the connecting valve and the associated variable valve actuation system for the auxiliary chamber by making use of the existing poppet valve and its variable actuation system.

The provision of an auxiliary chamber makes it possible to apply the patent proposal described in EP0095252 for a variable compression ratio engine adapted to operate according to the internal gas transfer method of the present invention.

Thus the engine may be switched to serve as a variable compression ratio engine by following the method steps of briefly connecting the said auxiliary chamber with the engine cylinder by moving the opening and closing timings of the second poppet valve to the compression period of the engine cycle thereby trapping a variable fraction of the compressed charge in the auxiliary chamber in order to vary the effective compression ratio of the engine.

By varying the effective compression ratio, the internal gas transfer method of the present invention may then be used in applying the patent proposal described in GB0405828.5 to vary the compression temperature of the cylinder charge in order to achieve CAI/HCCI combustion and influence the auto-ignition timing.

In another application of the present invention, after the auxiliary chamber is briefly connected with the engine cylinder by moving the opening and closing timings of the second poppet valve to predetermined times during the said period other than the ambient air intake period of the engine cycle, the then sealed auxiliary chamber is further briefly connected with an external compressed gas reservoir during the remaining period of the engine cycle by way of a timed on/off valve provided between the said auxiliary chamber and the said compressed gas reservoir.

The above provision of further timed connection of the then sealed auxiliary chamber with an external compressor gas reservoir makes it possible to apply the patent proposal described in PCT/GB2004/001018 for an air hybrid engine adapted to operate according to the gas transfer switching method of the present invention.

Thus the engine may be switched to serve at times as a gas compressor for absorbing power during a non-firing engine cycle in the absence of fuel by following the method steps of briefly connecting the said auxiliary chamber with the engine cylinder by moving the opening and closing timings of the second poppet valve to predetermined times during the compression period of the engine cycle thereby forcing some compressed gases into the auxiliary chamber, followed by briefly connecting the then sealed auxiliary chamber with the compressed gas reservoir by the said on/off valve during the remaining period of the said engine cycle

thereby transferring and storing some of the compressed gases into the compressed gas reservoir.

The engine may also be switched to serve at other times as a gas expander for producing power during a non-firing engine cycle in the absence of fuel by following the method steps of briefly connecting the said auxiliary chamber with the engine cylinder by moving the opening and closing timings of the poppet valve to predetermined times during the expansion period of the engine cycle thereby allowing some compressed gases in the auxiliary chamber to expand into the engine cylinder, followed by briefly connecting the then sealed auxiliary chamber with the compressed gas reservoir by the said on/off valve during the remaining period of the said engine cycle thereby transferring some compressed gases into the auxiliary chamber to replenish the chamber.

In this way, the engine may be used in an air hybrid vehicle where the cylinders of the engine may be switched to serve as gas compressors for absorbing power and storing it in the compressed gas reservoir when the vehicle is decelerating or coasting, and as gas expanders for producing power by extracting it from the compressed gas reservoir when the vehicle in accelerating or cruising.

Finally, the engine may at any time be switched back to operate with two through-flow intake ports for maximum volumetric efficiency by moving the opening and closing timings of the second poppet valve back to the intake period of the engine cycle. In this case, the non-return valve will be subjected to a suction pressure from the engine cylinder and will automatically open to permit through-flow of air in the direction towards the engine cylinder.

Brief description of the drawing

The invention will now be described further, by way of example, with reference to a single drawing showing a schematic view of an internal combustion engine with first and second intake ports and with the second intake port having a non-return valve, used in the internal gas transfer method of the present invention.

Detailed description of the preferred embodiment

Figure 1 shows an internal combustion engine having a first and a second intake port 24, 22 working in conjunction with an exhaust port 26 in each cylinder in which each port is controlled by an associated poppet valve 14, 12, 16 timed to open and close during the intake or exhaust period of the engine cycle in order to control the breathing of the engine. A non-return reed valve 32 is additionally provided in the second intake port 22 positioned such that the valve 32 automatically shuts in the flow direction away from the engine cylinder 10 when the port 22 and the non-return valve 32 are subjected to a pressure higher than the intake air supply pressure. The engine also includes a fuel system and an ignition system which are not shown.

In the above engine, a variable valve actuation system (not shown) is provided at least for the second poppet valve 12 controlling the second intake port 22. This may be fully variable as in an electronic controlled camless valve actuation system. It may be a cam actuation system with variable phasing of the camshaft, or with switchable tappets to select from more than one discrete cam profiles with different timing positions.

The second poppet valve 12 is normally timed to open and close during the ambient air intake period of the engine cycle during which the non-return valve 32 is subjected to a

suction pressure from the engine cylinder 10 and will automatically open to permit through-flow of air in the flow direction towards the engine cylinder 10. When internal gas transfer is required and the second poppet valve 12 is moved in timing to open and close during the compression, expansion or exhaust period of the engine cycle, the second intake port 22 and the non-return valve 32 will be subjected to a pressure higher than the intake air supply pressure when connected with the engine cylinder, causing the non-return valve 32 to shut automatically thus isolating the second intake port 22 to form a sealed auxiliary chamber 30 while permitting transfer of gases internally between the engine cylinder 10 and the auxiliary chamber 30 during the power conversion phase of the engine cycle.

The non-return reed valve 32 is designed to have fast response and good sealing against a high pressure within the auxiliary chamber 30. It is also designed to permit a high air flow when there is a suction pressure in the auxiliary chamber 30.

In Figure 1, the engine is shown at a time when the engine cycle is undergoing compression or expansion with the poppet valves 14, 16 of the intake and exhaust ports 24, 26 in the fully closed position. On the other hand, the poppet valve 12 of the port 22 is shown at this time in the open position, connecting the auxiliary chamber 30 with the engine cylinder 10 and permitting gas transfer internally between the engine cylinder 10 and the auxiliary chamber 30.

It should be noted that in the above case, the second intake port 22 will cease to function as an ambient air flow port during the intake period of the engine cycle but the engine will continue to operate with the first intake port 24 and its associated poppet valve 14 fully functional as an ambient air flow port so that there is no adverse effect in

the running of the engine other than a possible reduction in the volumetric efficiency of the engine.

The internal gas transfer method of the present invention may be used to influence the power conversion process of the engine cycle in a variety of ways described in the following in several examples.

In a first example according to EP0095252, the engine is switched to serve as a variable compression ratio engine for optimising the combustion process during a firing engine cycle by following the method steps of briefly connecting the auxiliary chamber 30 with the engine cylinder 10 by moving the opening and closing timings of the poppet valve 12 to predetermined times during the compression period of the engine cycle thereby trapping a variable fraction of the compressed charge in the auxiliary chamber 30 in order to vary the effective compression ratio of the engine.

In a second example according to pending patent application GB0405828.5, the effective compression ratio of the engine is varied using the auxiliary chamber 30 thereby varying the compression temperature of the cylinder charge in order to achieve CAI/HCCI combustion and influence the auto-ignition timing.

In a third example according to pending patent application PCT/GB2004/001018, the engine is used in an air hybrid vehicle where some cylinders of the engine are switched to serve as gas compressors for absorbing power and storing it in a compressed gas reservoir when the vehicle is decelerating or coasting, and as gas expanders for producing power by extracting it from the compressed gas reservoir when the vehicle in accelerating or cruising.

In this example, after the auxiliary chamber 30 is briefly connected with the engine cylinder 10 by moving the

opening and closing timings of the poppet valve 12 to predetermined times during the period other than the ambient air intake period of the engine cycle, the then sealed auxiliary chamber 30 is further briefly connected with an external compressed gas reservoir 36 during the remaining periods of the engine cycle by way of a timed on/off valve 34.

Thus according to PCT/GB2004/001018, the engine may be switched to serve at times as a gas compressor for absorbing power during a non-firing engine cycle in the absence of fuel by following the method steps of briefly connecting the auxiliary chamber 30 with the engine cylinder 10 by moving the opening and closing timings of the poppet valve 12 to predetermined times during the compression period of the engine cycle thereby forcing some compressed gases into the auxiliary chamber 30, followed by briefly connecting the then sealed auxiliary chamber 30 with the compressed gas reservoir 36 by the shut-off valve 34 during the remaining period of the engine cycle thereby transferring and storing some of the compressed gases into the compressed gas reservoir 36.

The engine may also be switched to serve at other times as a gas expander for producing power during a non-firing engine cycle in the absence of fuel by following the method steps of briefly connecting the auxiliary chamber 30 with the engine cylinder 10 by moving the opening and closing timings of the poppet valve 12 to predetermined times during the expansion period of the engine cycle thereby allowing some compressed gases in the auxiliary chamber 30 to expand into the engine cylinder 10, followed by briefly connecting the then sealed auxiliary chamber 30 with the compressed gas reservoir 36 by the shut-off valve 34 during the remaining period of the engine cycle thereby transferring some compressed gases into the auxiliary chamber 30 to replenish the chamber 30.

In the above air hybrid engine, the compressed gas reservoir 36 containing compressed air may further be used as a temporary source of high pressure air for briefly supercharging the engine under firing conditions with fuel. In a first such example, the present invention may be used to improve the transient torque response of the engine during brisk acceleration by following the method steps of briefly connecting the auxiliary chamber 30 with the engine cylinder 10 by moving the opening and closing timings of the poppet valve 14 to predetermined times during the early phase of the compression period of the engine cycle thereby allowing some compressed air in the auxiliary chamber 30 to further fill the engine cylinder 10 in addition to the ambient air intake charge, followed by briefly connecting the then sealed auxiliary chamber 30 with the compressed air reservoir 36 by the shut-off valve 34 during the remaining period of the engine cycle thereby transferring some compressed air into the auxiliary chamber 30 to replenish the chamber 30.

In a second such example, the present invention may be used to increase the engine torque very significantly by following the method steps of disabling the first intake valve 14 with a valve de-activation system (not shown), and briefly connecting the auxiliary chamber 30 with the compressed air reservoir 36 by opening and closing the on/off valve 34 while briefly connecting the auxiliary chamber 30 with the engine cylinder 10 by opening and closing the poppet valve 12 at respective predetermined timings relative to one another such that there is a variable overlap period during which the on/off valve 34 and the poppet valve 12 are both open connecting the compressed air reservoir 36 directly with the engine cylinder 10 at a predetermined time during the nominal intake period of the engine cycle, thereby permitting only stored air at high pressure from the compressed air reservoir 36 to fill the engine cylinder 10 while producing motoring work on the

piston 20. In this case, no ambient air is drawn into the engine during the nominal intake period of the engine cycle and the engine is run entirely with the stored air supplied from the compressed air reservoir 36. Depending on the available air pressure in the compressed air reservoir 36, the engine may be supercharged to a very high boost of many bars of air pressure at least for a brief period of time.

Both of these examples may be used to advantage in a turbocharged engine, which not only eliminates the response delay and sudden smoke emission typically experienced during rapid acceleration due to turbo-lag, but also enhances the drive feel of engine with a short burst of very high torque in excess of the expected torque from the turbocharger.

Going back to the second example, an air hybrid engine using the present invention may be created with a cam profile switching system (not shown) for each of the first and second intake valve 14, 12. Such cam profile switching system is conventionally used offering the choice of two discrete cam profiles which can be selectively connected to each valve by a switchable cam follower. Thus the second intake valve 12 may have a first cam profile phased for the ambient air intake period and a second cam profile phased for the internal gas transfer period. The first intake valve 14 may have a first cam profile phased for the ambient air intake period and a second cam profile of zero lift for completely disabling the valve 14. By selecting the appropriate cam profiles in different combinations for the first and second intake valves 14, 12, the air hybrid engine may be operated as an air compressor, as a power booster with compressed air producing motoring work during the intake strokes and as a normal combustion engine. This represents a low cost air hybrid engine using cam actuation valve components which are well developed with proven reliability.

Thus in the invention, by transforming the second intake port 22 into a sealed auxiliary chamber 30, no extra space is required in the combustion chamber to include this provision, and there is considerable saving in cost and complexity in not duplicating the connecting valve and the associated variable valve actuation system for the auxiliary chamber 30 by making use of the existing poppet valve 12 and its variable actuation system. This enables the auxiliary chamber 30 to be used in a variety of ways for achieving internal gas transfer in the engine thereby influencing the power conversion processes in the engine according to many known concepts which can now be realised cost-effectively as a consequence.

CLAIMS

1. An internal gas transfer method for operating an internal combustion engine having at least a first and a second intake port controlled by respective first and second poppet valves normally timed to open and close during the intake period of the engine cycle with variable valve timing provided for at least the second poppet valve, and a non-return valve mounted in the second intake port positioned such that the valve automatically shuts in the flow direction away from the engine cylinder when the said port and the non-return valve are subjected to a pressure higher than the intake air supply pressure, the method characterised in that when internal gas transfer is required, the second poppet valve is moved in timing to open and close during a period other than the ambient air intake period of the engine cycle, thus briefly connecting the said second intake port and the said non-return valve with the engine cylinder at a pressure higher than the intake air supply pressure, shutting the said non-return valve, isolating the said port to form a sealed auxiliary chamber, and permitting transfer of gases internally between the engine cylinder and the said auxiliary chamber during the power conversion phase of the engine cycle.

2. An internal gas transfer method as claimed in claim 1, wherein the said second poppet valve of the said second intake port is actuated by a fully variable valve actuation system.

3. An internal gas transfer method as claimed in claim 1 or 2, wherein the said non-return valve in the said second intake port is a reed valve.

4. An internal gas transfer method as claimed in any preceding claim, wherein when the said second poppet valve is moved in timing to open and close during the said period

other than the ambient air intake period of the engine cycle, the engine continues to operate with at least the first intake port and its associated poppet valve fully functional as an ambient air flow port.

5. An internal gas transfer method as claimed in any preceding claim, wherein the said engine is switched to serve as a variable compression ratio engine for optimising the combustion process during a firing engine cycle by following the method steps of briefly connecting the said auxiliary chamber with the engine cylinder by moving the opening and closing timing of the said second poppet valve to predetermined times during the compression period of the said engine cycle thereby trapping a variable fraction of the compressed charge in the auxiliary chamber in order to vary the effective compression ratio of the engine.

6. An internal gas transfer method as claimed in claim 5, used to vary the compression temperature of the cylinder charge in order to achieve CAI/HCCI combustion and influence the auto-ignition timing.

7. An internal gas transfer method as claimed in any one of claims 1 to 3, wherein after the said auxiliary chamber is briefly connected with the engine cylinder by moving the opening and closing timings of the said second poppet valve to predetermined times during the said period other than the ambient air intake period of the engine cycle, the then sealed auxiliary chamber is further briefly connected with an external compressed gas reservoir during the remaining period of the engine cycle by way of a timed on/off valve.

8. An internal gas transfer method as claimed in claims 4 and 7, wherein the said engine is switched to serve as a gas compressor for absorbing power during a non-firing engine cycle in the absence of fuel by following the method

steps of briefly connecting the said auxiliary chamber with the engine cylinder by moving the opening and closing timings of the said second poppet valve to predetermined times during the compression period of the said engine cycle thereby forcing some compressed gases into the auxiliary chamber, followed by briefly connecting the then sealed auxiliary chamber with the said compressed gas reservoir by the said on/off valve during the remaining period of the said engine cycle thereby transferring and storing some of the compressed gases into the compressed gas reservoir.

9. An internal gas transfer method as claimed in claims 4 and 7, wherein the said engine is switched to serve as a gas expander for producing power during a non-firing engine cycle in the absence of fuel by following the method steps of briefly connecting the said auxiliary chamber with the engine cylinder by moving the opening and closing timings of the said second poppet valve to predetermined times during the expansion period of the said engine cycle thereby allowing some compressed gases in the auxiliary chamber to expand into the engine cylinder, followed by briefly connecting the then sealed auxiliary chamber with the said compressed gas reservoir by the said on/off valve during the remaining period of the said engine cycle thereby transferring some compressed gases into the auxiliary chamber to replenish the chamber.

10. An internal gas transfer method as claimed in claims 8 and 9, wherein the said engine is used in an air hybrid vehicle and wherein some cylinders of the engine are switched to serve as gas compressors for absorbing power and storing it in the compressed gas reservoir when the vehicle is decelerating or coasting, and as gas expanders for producing power by extracting it from the compressed gas reservoir when the vehicle in accelerating or cruising.

11. An internal gas transfer method as claimed in claims 4 and 7, wherein the said compressed gas reservoir containing compressed air is used as a temporary source of high pressure air for supercharging the engine under firing conditions with fuel by following the method steps of briefly connecting the said auxiliary chamber with the engine cylinder by moving the opening and closing timings of the said second poppet valve to predetermined times during the early phase of the compression period of the said engine cycle thereby allowing some compressed air in the said auxiliary chamber to further fill the engine cylinder, followed by briefly connecting the then sealed auxiliary chamber with the said compressed air reservoir by the said shut-off valve during the remaining period of the said engine cycle thereby transferring some compressed air into the said auxiliary chamber to replenish the chamber.

12. An internal gas transfer method as claimed in claims 1 and 7, wherein the said compressed gas reservoir containing compressed air is used as a temporary source of high pressure air for supercharging the engine under firing conditions with fuel by following the method steps of disabling the said first intake valve with a valve de-activation system, and briefly connecting the said auxiliary chamber with the said compressed air reservoir by opening and closing the said on/off valve while briefly connecting the said auxiliary chamber with the engine cylinder by opening and closing the said second poppet valve at respective predetermined timings relative to one another such that there is a variable overlap period during which the said on/off valve and the said second poppet valve are both open connecting the said compressed air reservoir directly with the engine cylinder at a predetermined time during the nominal intake period of the engine cycle, thereby permitting only stored air at high pressure from the said compressed air reservoir to fill the engine cylinder while producing motoring work in the cylinder.

Application No:	GB0415421.7	**Examiner:**	Catherine Allen
Claims searched:	1 to 12	**Date of search:**	15 November 2004

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
A	-	FR2836181 A PEUGEOT CITROEN AUTOMOBILES SA
A	-	EP0953744 A1 INST FRANCAIS DU PETROL
A	-	JP50149136 A MAZDA MOTOR

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X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
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&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{W} :

F1B

Worldwide search of patent documents classified in the following areas of the IPC^{07}

F02B; F02D; F02M

The following online and other databases have been used in the preparation of this search report

EPODOC, JAPIO, WPI