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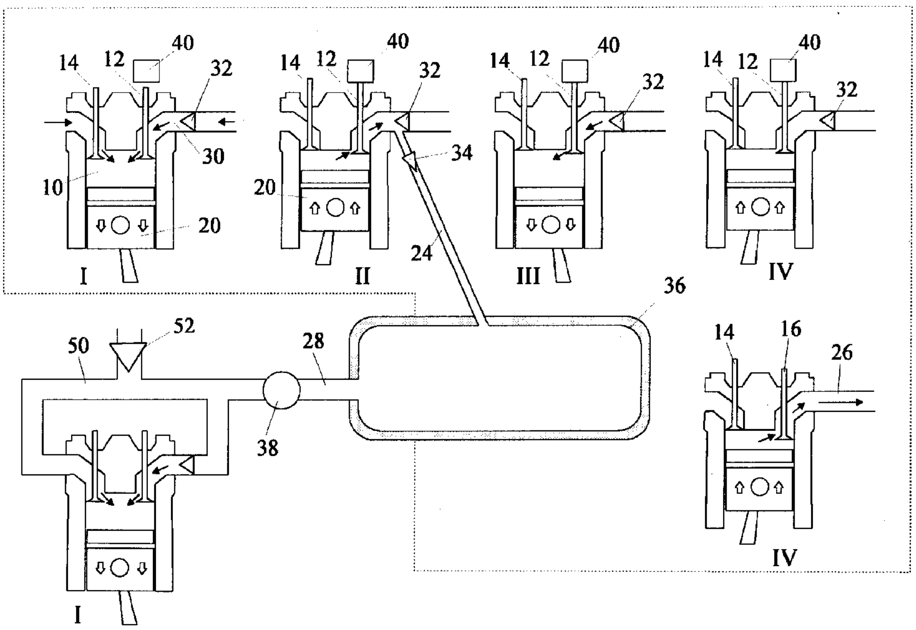
EP 1747351 A

(58) Field of Search:
INT CL **B60K, F01L, F02B, F02D**
Other: **EPODOC, TXTE, WPI**

(54) Abstract Title**: I.c engine air hybrid vehicle**

(57) An air hybrid vehicle is powered by a multi-cylinder internal combustion engine with at least one intake valve 12 per cylinder and a non-return valve 32 located in the intake port for blocking reverse flow. An auxiliary chamber 30 is provided in the intake port between the intake valve 12 and the non-return valve 32 and is connected via a self-sealing valve 34 to a separate air storage tank 36 common to all the cylinders of the engine. The engine has a variable valve engine braking device 40 operable to produce an engine braking cycle during which the intake valve 12 is allowed to open and close normally during the intake stroke but prevented from closing completely during the rest of the engine cycle. During strong engine braking of the vehicle, fuel supply is shut off while the variable valve engine braking device 40 is activated and compressed air is forced past the unclosed gap of the intake valve 12 into the auxiliary chamber 30 and through to the air storage tank 36. During driving of the vehicle, the variable valve engine braking device 40 is deactivated, fuel supply is restored and compressed air from the air storage tank 36 is delivered into the intake manifold 50 for driving the engine as well as supporting combustion in the engine.



At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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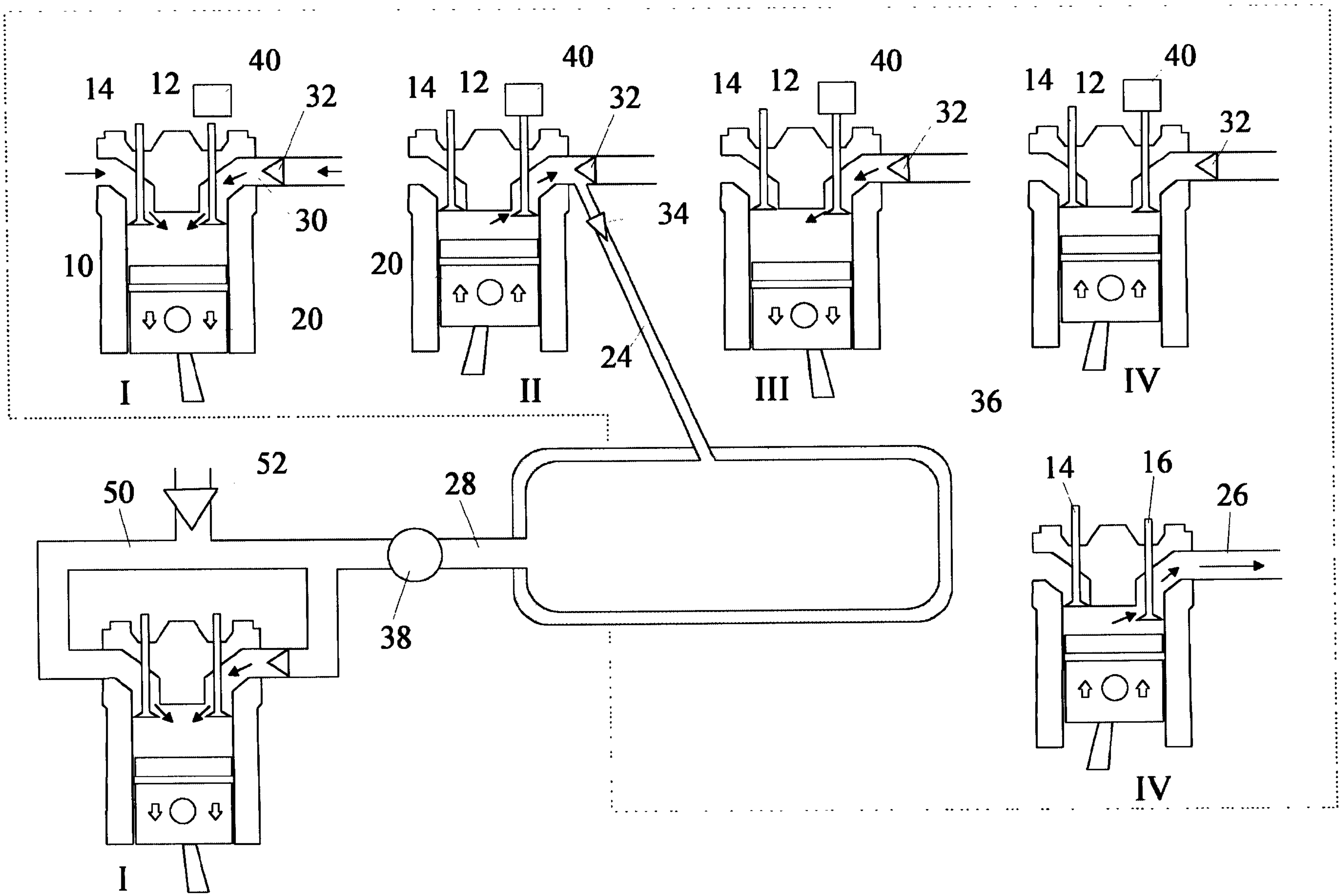

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AIR HYBRID VEHICLE

Field of the invention

The present invention relates to a hybrid vehicle in which regenerative braking is achieved by utilising air energy.

Background of the invention

It is known that a regenerative hybrid vehicle can achieve significant reduction in fuel consumption (hence CO2 reduction) by recovering some of the kinetic energy of the vehicle during deceleration or braking of the vehicle and transforming it into another form of energy which can be stored and later reused. One example is the electric hybrid vehicle in which the braking energy is transformed into electric energy and stored in an electric battery for future use. Another example is the inertia hybrid vehicle in which the braking energy is transformed into inertial energy and stored in a spinning flywheel for future use. A further example is the pneumatic hybrid vehicle in which the braking energy is transformed into pneumatic energy and stored in a compressed air tank for future use.

Summary of the invention

According to the present invention, there is provided an air hybrid vehicle powered by a multi-cylinder internal combustion engine having an intake manifold supplying air to a plurality of cylinders, at least one cylinder having at least one intake port and intake valve per cylinder and a non-return valve located in the intake port for blocking any reverse flow of air in the opposite direction to the normal air flow direction towards the engine defining an auxiliary chamber in the intake port between the intake valve and the non-return valve while the auxiliary chamber is connected via a self-sealing valve to a separate air storage tank in the vehicle common to all the cylinders of the engine, the vehicle characterised in that the engine has a variable valve engine braking device operable when activated to produce a powerful engine braking cycle during which the intake valve is allowed to open and close normally during the intake stroke but prevented from closing completely shut after the intake stroke has passed during the rest of the engine cycle.

The vehicle is operable in one of at least two modes, namely: a) during strong engine braking of the vehicle, the engine fuel supply is shut off while the variable valve engine braking device is activated and compressed air is forced past the unclosed gap of the intake valve into the auxiliary chamber and through to the air storage tank, and b) during driving of the vehicle, the variable valve engine braking device is deactivated while the engine fuel supply is restored and compressed air from the air storage tank is delivered into the intake manifold of the engine for driving the engine as well as supporting combustion in the engine.

The variable valve engine braking device described above is commonly used in the engine of a heavy vehicle capable of producing very high engine braking, but it conventionally acts on the exhaust valve of the engine to produce a powerful engine braking cycle and the air that took part in the braking cycle is discharged into the exhaust system of the engine and is therefore lost. In the present invention, a similar device is used on the intake valve of the engine and a non-return valve is added in the associated intake port of the engine. This results in a similar and equally effective powerful engine braking cycle being produced, with the additional advantage that the air that took part in the braking cycle is transferred at a high compression pressure into a separate air storage tank in the vehicle and this compressed air can be used at a later time for driving the vehicle, thus achieving regenerative braking in the air hybrid vehicle.

The Applicant's earlier EP 1747351, is believed to represent the closest prior art to the present invention and in the ensuing description the differences between the present invention and the latter patent will be discussed in some detail. EP 1747351 describes a method for operating an internal combustion engine with a non-return valve defining an auxiliary chamber in the intake port of the engine while the intake valve timing is altered to open and close during the compression stroke of the engine. However, it fails to disclose the possibility of operating a powerful engine braking cycle by preventing the intake valve from closing completely after completion of the intake stroke. The engine braking cycle of the present invention is more effective in producing a significantly higher braking torque than in the air compressor mode described in EP 1747351 while still achieving the parallel function of generating compressed air for air hybrid operation. Thus the present invention is more effective and especially suitable for application in a heavy vehicle with regenerative braking. Examples of a heavy vehicle include trucks, buses and heavy construction and mining transport equipment.

Preferably in the present invention, a manifold non-return valve is provided guarding the entrance of the intake manifold of the engine so that when the compressed air from the air storage tank is delivered for regenerative use into the intake manifold behind the non-return valve, the non-return valve prevents any compressed air from escaping to the ambient atmosphere through the entrance of the intake manifold.

Brief description of the drawing

The invention will now be described further, by way of example, with reference to the accompanying drawings in which the single figure shows the engine braking and compressed air storage cycle of the present invention.

Detailed description of the preferred embodiment

The five diagrams enclosed within the dash-line box in the accompanying drawing show the sequential sectional views of an engine cylinder going through an engine braking cycle. The cylinder shown in all the diagrams has a combustion chamber 10 and a piston 20 connected in the normal way to a crankshaft (not shown). Air is admitted into the combustion chamber through two intake valves 12 and 14 and is discharged through an exhaust valve 16. The manifold branch leading to the valve 12 contains a non-return valve 32 and a small auxiliary chamber 30 is defined between the seat of the valve 12 and the non-return valve 32. A passage 24 controlled by a self-sealing valve 34 leads from the auxiliary chamber 30 to an air storage tank 36, which is in turn connected by way of a passage 28 containing a valve 38 to the intake manifold 50. A further non-return valve 52 is provided at the entrance of the intake manifold 50 remote from the engine intake ports.

The top four diagrams show the sectional view across the two intake valves 12, 14 and the diagram in the lower right of the drawing shows a different sectional view across the exhaust valve 16. The numeral next to the connecting rod of each diagram indicates the stroke number of the engine braking cycle.

In stroke 1, the intake valves 12 and 14 are opened and closed normally by a camshaft (not shown) while the piston 20 is moving downwards, so that fresh air is drawn into the combustion chamber 10 through the open intake valves 12 and 14. The non-return 32 will be open in the flow direction towards the engine.

In stroke 2, the intake valve 14 is fully closed in the normal way, but the intake valve 12 is prevented from closing completely by activating the variable valve engine braking device 40. The latter device is a hydraulic stopper moved into the path of the closing intake valve 12, arresting the movement of the valve 12 before it reaches its valve seat, thereby maintaining the valve 12 partially open. The engine braking device 40 remains in the stopping position for the rest of the engine cycle and for many engine cycles until it is deactivated. The camshaft of the engine still opens and closes the intake valve 12 normally during the intake stroke of the engine cycle, but the intake valve 12 moves towards and away from the stopping position of the engine braking device 40 instead of the valve seat.

During stroke 2, the piston 20 moves upwards, compressing the full charge of intake air towards TDC (top dead centre) at an effective compression ratio nearly the same as the geometric compression ratio of the engine. This is because only a small amount of air leakage can occur through the partially open intake valve 12. In this context, one should bear in mind that any flow trying to get past the small gap will be choked under sonic flow conditions and the maximum leakage can only occur at the top of compression when the air density is at the highest value. The mass of air passing through the gap is the product of the area of the gap, the velocity of air movement through the gap and the density of the air. As the gap area and flow velocity are restricted, it is only when the air density is high that any substantial mass of air can be withdrawn from the combustion chamber. The presence of the auxiliary chamber 30 thus has little effect on the effective compression ratio because it is substantially isolated from the cylinder 10 by the small unclosed gap in the intake valve 12.

By contrast, in the compression mode of EP 1747351, the intake valve 12 is opened wide and the auxiliary chamber 30 is freely connected to the cylinder 10 so that its volume becomes an integral part of the cylinder volume. As a result, the effective compression ratio is significantly lower than the geometric compression ratio. For example, if the volume of the auxiliary chamber 30 is the same as the clearance volume in the cylinder 10, the effective compression ratio in WO2005113947 will be half of the geometric compression ratio of the engine.

Thus comparing the compression torque produced during stroke 2, the present invention will yield a significantly higher braking torque than in EP 1747351 because of the higher effective compression ratio during stroke 2.

In the meantime, in stroke 2 in the present invention, some air will leak past the unclosed gap in the intake valve 12 into the auxiliary chamber 30, especially when the piston 20 is approaching TDC and the density of the compressed air is increasing to a maximum value at the top of the compression. This air at high compression pressure will then escape from the auxiliary chamber 30 into the air storage tank 30 via the self-sealing valve 34 and the passage 24.

In EP 1747351, some compressed air is also transferred from the auxiliary chamber to the air storage tank but the density of the compressed air is much lower because of the lower effective compression ratio. The total mass of air transferred into the air storage tank over many cycles of operation could be similar or less than that of the present invention, because of the higher pressure and air density that the present invention can attain in the air storage tank 36.

In stroke 3, a high vacuum is generated in the cylinder 10 as the piston 20 moves downwards. The effective expansion ratio during stroke 3 will be slightly lower in the present invention than that in EP 1747351 because of the leakage past the unclosed gap of the intake valve 12, but the two expansion ratios are both substantially the same as the geometric expansion ratio of the engine, so that there is little difference in the negative torque on the piston in the two cases during stroke 3. A small quantity of air may be drawn into the auxiliary chamber 30 through the non-return valve 32 during stroke 3 in the present invention but it will play no significant part in the engine braking cycle.

In stroke 4, as shown in the diagram at the lower right corner of the dash-line box, the exhaust valve 16 is opened normally by the camshaft (not shown) both in the present invention and in EP 1747351. In both cases, the piston will experience the same exhaust back pressure as it moves upwards and the cylinder content is discharged through the exhaust valve 16 and the exhaust pipe 26.

Thus in taking the four strokes of the engine cycle into account, the engine braking cycle of the present invention will produce a significantly higher average braking torque than in the compressor mode of EP 1747351 while the mass of compressed air delivered to the air storage tank during the cycle could be similar. This demonstrates the advantage of the present invention over the method of EP 1747351 by virtue of the more powerful engine braking cycle specified in the present invention in which the intake valve is prevented from closing completely after the intake stroke has passed during the rest of the engine cycle.

The drawing outside the dash-line box in the bottom left corner of Figure 1 shows a sectional view of an engine cylinder across one of the intake valves supplied by the intake manifold 50 which also supplies other cylinders adjacent to this cylinder. The manifold non-return valve 52 guards the entrance of the intake manifold 50 so that when the compressed air from the air storage tank 36 is delivered for regenerative use into the intake manifold 50 behind the non-return valve 52, controlled by the dispensing valve 38, the non-return valve 52 prevents any compressed air from escaping to the ambient atmosphere through the entrance of the intake manifold 50.

Thus the air hybrid vehicle of the present invention is operable in one of at least two modes: a) during strong engine braking of the vehicle, the engine fuel supply is shut off while the variable valve engine braking device 40 is activated and compressed air is forced past the unclosed gap of the intake valve 12 into the auxiliary chamber 30 and through to the air storage tank 36, and b) during driving of the vehicle, the variable valve engine braking device 40 is deactivated while the engine fuel supply is restored and compressed air from the air storage tank 36 is delivered into the intake manifold 50 of the engine for driving the engine as well as supporting combustion in the engine.

The air hybrid vehicle of the present invention is especially suitable for application in a heavy vehicle with regenerative braking. Examples of a heavy vehicle include trucks, buses and heavy construction and mining transport equipment.

CLAIMS

1. An air hybrid vehicle powered by a multi-cylinder internal combustion engine having an intake manifold supplying air to a plurality of cylinders, at least one cylinder having at least one intake port and intake valve per cylinder and a non-return valve located in the intake port for blocking any reverse flow of air in the opposite direction to the normal air flow direction towards the engine defining an auxiliary chamber in the intake port between the intake valve and the non-return valve while the auxiliary chamber is connected via a self-sealing valve to a separate air storage tank in the vehicle common to all the cylinders of the engine, the vehicle characterised in that the engine has a variable valve engine braking device operable when activated to produce a powerful engine braking cycle during which the intake valve is allowed to open and close normally during the intake stroke but prevented from closing completely shut after the intake stroke has passed during the rest of the engine cycle.

2. An air hybrid vehicle as claimed in claim 1, wherein the vehicle is operable in one of at least 2 modes: a) during strong engine braking of the vehicle, the engine fuel supply is shut off while the variable valve engine braking device is activated and compressed air is forced past the unclosed gap of the intake valve into the auxiliary chamber and through to the air storage tank, and b) during driving of the vehicle, the variable valve engine braking device is deactivated while the engine fuel supply is restored and compressed air from the air storage tank is delivered into the intake manifold of the engine for driving the engine as well as supporting combustion in the engine.

3. An air hybrid vehicle as claimed in claim 2, wherein a manifold non-return valve is provided guarding the entrance of the intake manifold of the engine so that when

the compressed air from the air storage tank is delivered into the intake manifold behind the non-return valve, the non-return valve prevents any compressed air from escaping to the ambient atmosphere through the entrance of the intake manifold.

4. An air hybrid vehicle as claimed in any preceding claim, including trucks, buses and heavy vehicles.

Application No: GB0803685.7 **Examiner:** John Twin

Claims searched: 1 to 4 **Date of search:** 12 June 2008

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	-	EP 1747351 A (Brunel University)

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	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^{X} :

Worldwide search of patent documents classified in the following areas of the IPC

B60K; F01L; F02B; F02D

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

EPODOC, TXTE, WPI

International Classification:

Subclass	Subgroup	Valid From
B60K	0006/12	01/01/2006
F01L	0013/06	01/01/2006
F02D	0013/04	01/01/2006
F02D	0013/06	01/01/2006
F02D	0017/02	01/01/2006