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(56) Documents Cited:
GB 2210930 A **GB 2000551 A**
US 5024184 A **US 4890585 A**
US 4516537 A **US 20030097998 A1**

(58) Field of Search:
INT CL **F02B**
Other: **EPODOC, WPI, TXTA**

(54) Title of the Invention: **An engine assembly and method**
Abstract Title: **An engine assembly with a variable volume chamber and method of control**

(57) An engine assembly 2 comprises a cylinder, a piston 14 reciprocating between a maximum volume, when the piston is in a bottom dead centre position 14', and a clearance volume when the piston is in a top dead centre position 14", and a variable volume chamber 20 in fluid communication with the cylinder and configured to selectively vary the clearance volume of the cylinder. Communication between the cylinder the variable volume chamber may be via an opening and passage 18. A moveable element 24 preferably varies the volume in the variable volume chamber which may be driven by an actuator 26 and / or could be controlled by a controller with determination of an engine running speed and / or power. The engine assembly may have a compression ratio that differs from an expansion ratio. A method of operating and a vehicle comprising the engine assembly are also claimed.

Fig. 1

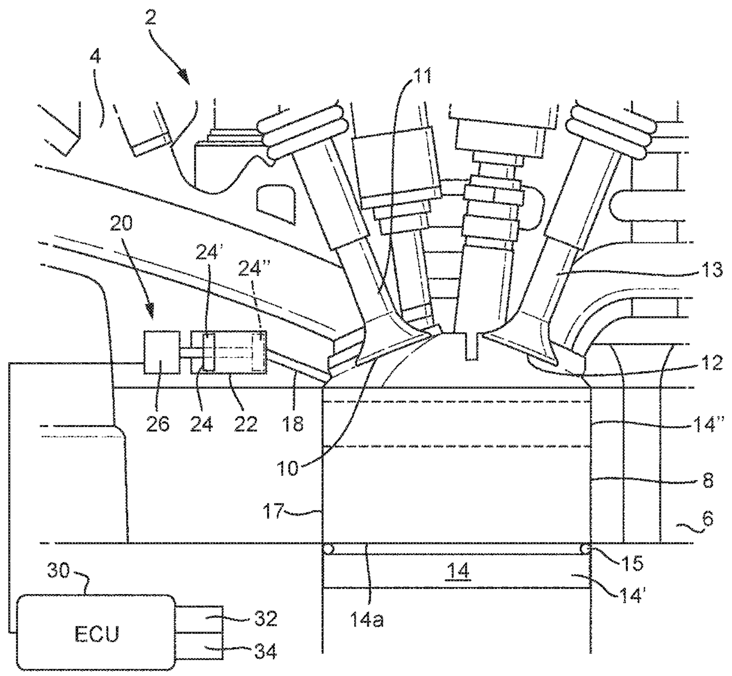

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Fig. 1

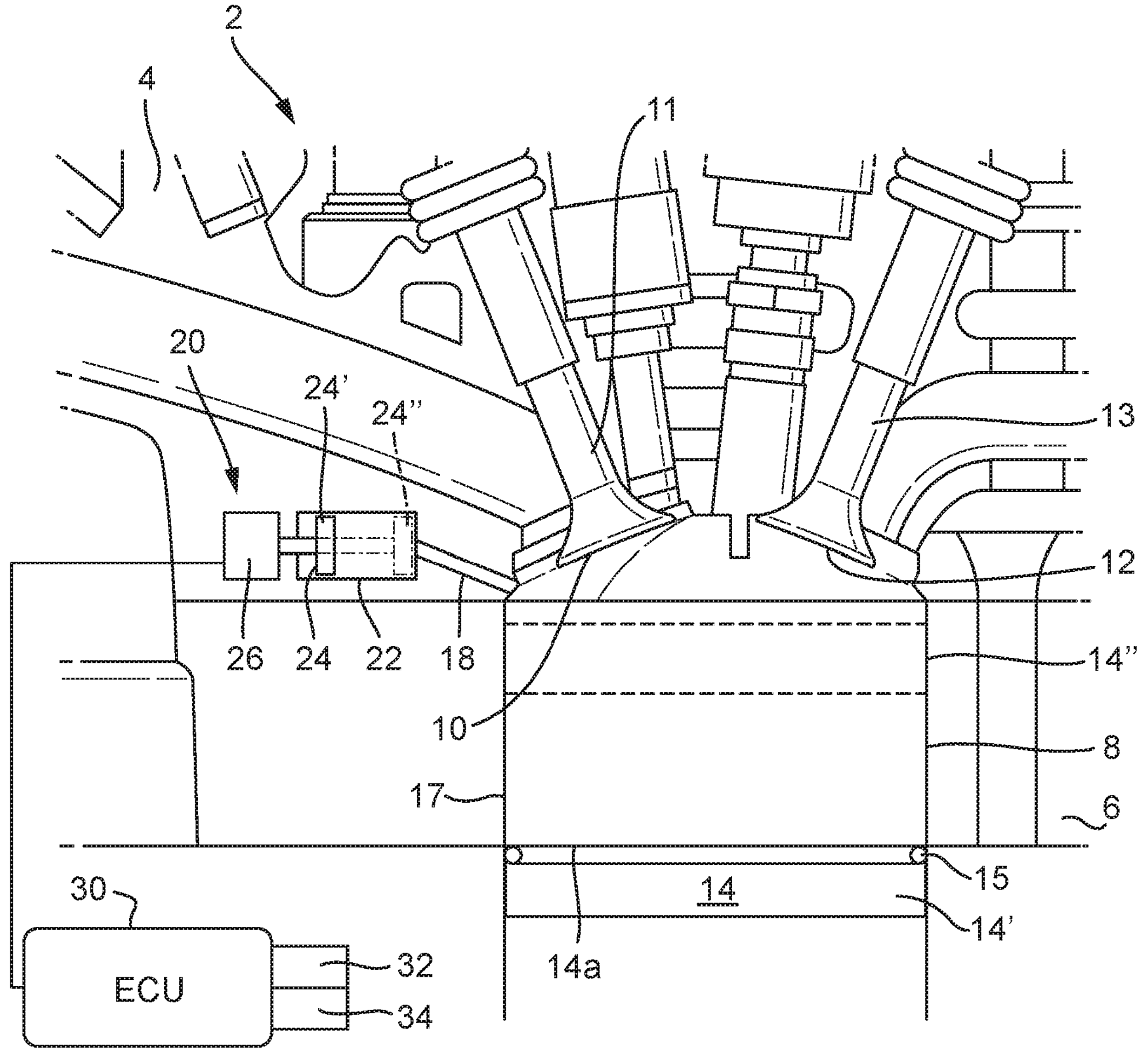


Fig. 2

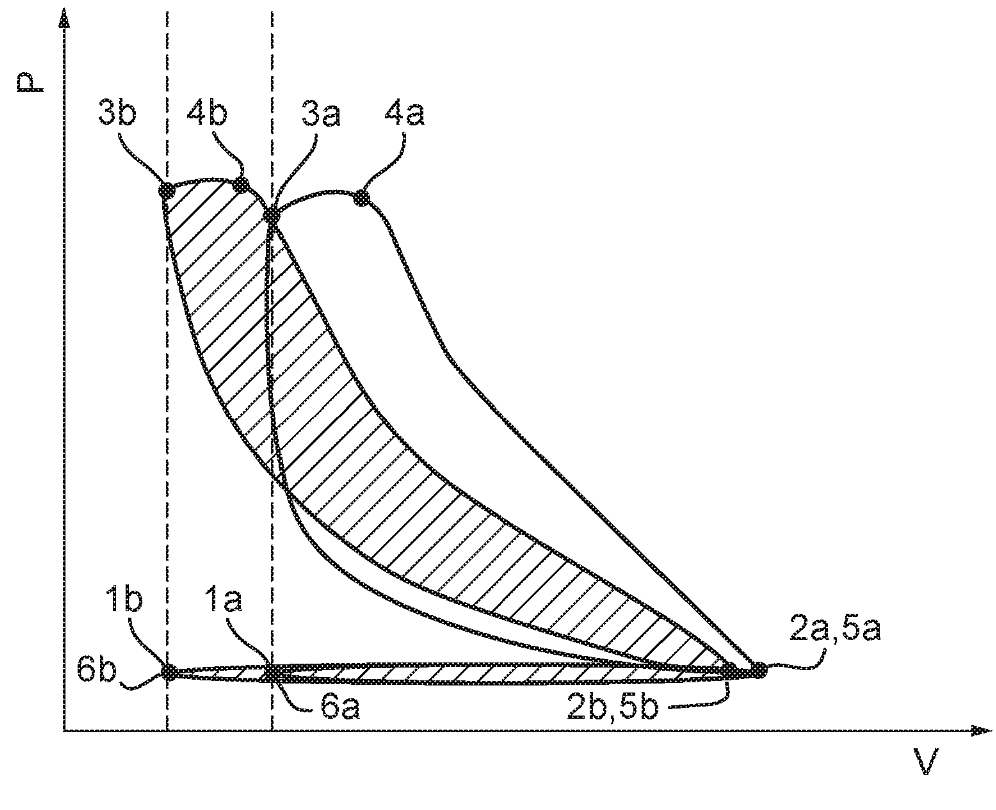


Fig. 3a

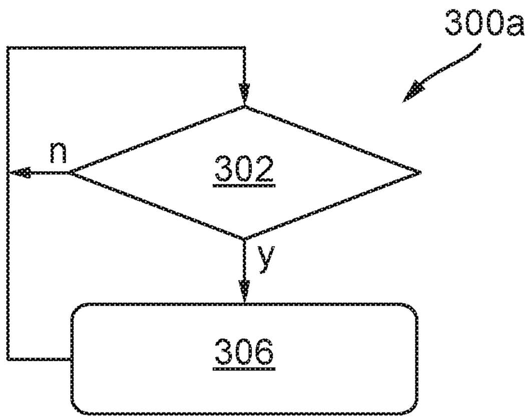
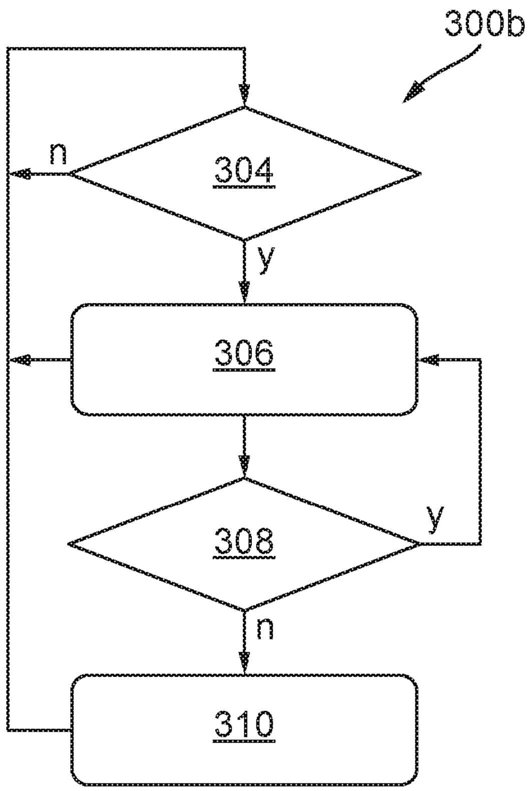


Fig. 3b



An engine assembly and method

Technical Field

The present disclosure relates to an engine assembly and is particularly, although not exclusively, concerned with an engine assembly having increased efficiency.

Background

It is desirable for the efficiency of an internal combustion engine to be increased. One option for increasing thermodynamic efficiency of an engine is to increase the compression ratio of the engine. However, increasing the compression ratio may lead to knocking or pre-ignition events. During such events fuel is not combusted in a desirable manner within the engine cylinders, particularly when the engine is operating at high power. Knocking and pre-ignition may reduce the maximum power and/or torque output available from the engine.

When the internal combustion engine is provided on a motor vehicle, it is also desirable to reduce the weight of the engine and to make the engine more compact. Reducing the size of an engine may reduce the total power output available from the engine. Hence, for engines with reduced size, it may be undesirable to improve efficiency by increasing the engine compression ratio, which may further reduce the maximum power and or torque provided by the engine.

It is therefore desirable to provide and engine assembly with improved efficiency in such a way that does not reduce the peak power or torque available from the engine.

Statements of Invention

According to an aspect of the present disclosure, there is provided an engine assembly, such as an internal combustion engine, comprising: a cylinder; a piston configured to reciprocate within the cylinder in order to vary an operative volume of the cylinder between a maximum volume, when the piston is in a bottom dead centre position, and a clearance volume when the piston is in a top dead centre position; and a variable volume chamber in fluid communication with the cylinder and configured to selectively vary the clearance volume of the cylinder.

The variable volume chamber may be in fluid communication with the cylinder via an opening above the top dead centre position of the piston.

The engine assembly may comprise a cylinder block. The cylinder may be at least partially defined by the cylinder block. The engine assembly may further comprise a cylinder head. The cylinder head may comprise the variable volume chamber. For example, the variable volume chamber may be formed within the cylinder head.

The engine assembly may further comprise a movable element configured to vary a volume of the variable volume chamber that is in fluid communication with the cylinder, e.g. an operative volume of the variable volume chamber.

The engine assembly may further comprise an actuator configured to vary the position of the movable element. The actuator may be a hydraulic, pneumatic or electrically driven actuator.

The position of the movable element may be controlled at least partially according to an engine running speed and/or engine power.

The engine assembly further comprises a controller. The controller may be configured to determine an engine running speed and/or engine power. The controller may be configured to adjust the position of the movable element at least partially according to the engine running speed and/or engine power.

The controller may be provided within an engine control system and/or power electronics system. For example, the controller may be an engine control unit or a powertrain control unit.

The engine assembly may be configured such that a compression ratio of the engine assembly differs from an expansion ratio of the engine assembly. For example, the engine assembly may be a Miller cycle or Atkinson cycle engine.

According to another aspect of the present disclosure, there is provided, an engine assembly comprising: a cylinder; a piston configured to reciprocate within the cylinder between a bottom dead centre position and a top dead centre position; and a variable volume chamber in fluid communication with the cylinder at a position above the top dead centre position of the piston and configured to selectively vary a volume of the cylinder, in order to vary the compression ratio of the engine.

The variable volume chamber may be configured to vary a clearance volume of the cylinder, e.g. an effective volume of the cylinder when the piston is in the top dead centre position.

A vehicle, such as a motor vehicle, may comprise the above-mentioned engine assembly.

According to another aspect of the present disclosure, there is provided a method of operating an engine assembly, the engine assembly comprising: a cylinder; a piston configured to reciprocate within the cylinder in order to vary an operative volume of the cylinder between a maximum volume, when the piston is in a bottom dead centre position, and a clearance volume when the piston is in a top dead centre position; and a variable volume chamber in fluid communication with the cylinder and configured to selectively vary the clearance volume of the cylinder, wherein the method comprises: adjusting the clearance volume of the cylinder using the variable volume cylinder in order to vary a compression ratio of the engine assembly.

According to another aspect of the present disclosure, there is provided a method of operating an engine assembly, the engine assembly comprising: a cylinder; a piston configured to reciprocate within the cylinder in order to vary an operative volume of the cylinder between a maximum volume, when the piston is in a bottom dead centre position, and a clearance volume when the piston is in a top dead centre position; and a variable volume chamber in fluid communication with the cylinder, wherein the method comprises: adjusting an operative volume of the variable volume chamber in order to vary the clearance volume of the cylinder.

The method may comprise determining an engine running speed and/or engine power. The method may further comprise adjusting the operative volume at least partially according to the engine running speed and/or engine power.

The method may comprise detecting a pre-ignition or knocking event of the engine. The method may further comprise adjusting the operative volume of the variable volume chamber to increase the clearance volume following detection of the pre-ignition or knocking event.

To avoid unnecessary duplication of effort and repetition of text in the specification, certain features are described in relation to only one or several aspects or embodiments of the invention. However, it is to be understood that, where it is technically possible, features described in relation to any aspect or embodiment of the invention may also be used with any other aspect or embodiment of the invention.

Brief Description of the Drawings

For a better understanding of the present invention, and to show more clearly how it may be carried into effect, reference will now be made, by way of example, to the accompanying drawings in which:

Figure 1 is a partial schematic view of an engine assembly according to arrangements of the present disclosure;

Figure 2 is a plot illustrating changes in pressure and volume during a cycle of the engine assembly; and

Figures 3a and 3b show methods of operating an engine assembly according to arrangements of the present disclosure.

Detailed Description

With reference to Figure 1, an engine assembly 2 for a motor vehicle comprises a cylinder head 4 and a cylinder block 6. The cylinder block 6 may define a cylinder 8 of the engine. The cylinder head 4 may define one or more inlet ports 10 and one or more outlet ports 12 configured to allow air and exhaust gases to flow into and out of the cylinder respectively. Inlets and outlet valves 11 and 13 may be provided within the inlet and outlet ports in order to control the flow of inlet air and exhaust gases. As depicted, the cylinder head 4 and cylinder block 6 may be separate components or they may be unitary.

The engine assembly 2 further comprises a piston 14 provided within the cylinder 8. The piston 14 is configured to reciprocate within the cylinder between a bottom dead centre position 14' and a top dead centre position 14''. When the piston 14 is in the bottom dead centre position 14', the operative volume of the cylinder, e.g. the volume of the cylinder 8 able to receive inlet air via the inlet port 10, may be at a maximum. When the piston 14 is in the top dead centre position 14'', the operative volume of the piston may be at a minimum, which may be referred to as a clearance volume.

The maximum operative volume of the cylinder 8 may be equal to a sum of the clearance volume and a displacement volume, e.g. a volume swept by the piston 14 as it moves between the bottom dead centre 14' and top dead centre 14'' positions. A ratio of the maximum volume of the cylinder to the clearance volume may define a compression ratio of the engine assembly 2.

The piston 14 may further comprise one or more piston rings 15, provided at or towards a distal end 14a of the piston. The piston rings 15 may be configured to create a seal between the piston 14 and the cylinder 8 and thereby prevent inlet air and/or exhaust gases from leaking past the piston 14.

The engine assembly 2 further comprises a variable volume chamber 20, in fluid communication with the cylinder 8. The variable volume chamber 20 may comprise a cavity 22, a movable element 24 provided within the cavity 22 and an actuator 26 coupled to the movable element 24. The actuator 26 may be configured to move the movable element within the cavity 22 between a first position 24' and a second position 24''. When the movable element 24 is in the first position 24', an operative volume of the variable volume chamber 20, e.g. a volume of the variable volume chamber that is in fluid communication with the cylinder 8, may be at a maximum. When the movable element is in the second position 24'', the operative volume of the variable volume chamber 20 may be at a minimum. As depicted in Figure 1, the movable element may comprise a piston that is slidably disposed within the cavity 22. The operative volume of the variable volume chamber 20, may be defined by one side of the piston and the cavity walls.

The variable volume chamber 20 may be in fluid communication with the cylinder 8, e.g. via an opening 17 in the cylinder walls, at a position above the top dead centre position 14" of the piston. In other words, the variable volume chamber 20 may be in fluid communication with the cylinder 8 at a position between the piston 14, e.g. the piston rings 15 of the piston, and the inlet and/or outlet ports 10, 12, when the piston 14 is in the top dead centre position.

A passage 18 may extend from the variable volume chamber 20 to the cylinder 8. The passage 18 may be formed in the cylinder head and/or the cylinder block. For example, the passage 18 may be formed during a casting process of the cylinder head 4 and/or block 6. The passage 18 may open out into the cylinder 8 at the opening 17.

As the variable volume chamber 20 is in fluid communication with the cylinder 8 at a position above the top dead centre position of the piston 14, by varying the operative volume of the variable volume chamber 20, the clearance volume of the cylinder may be varied. The clearance volume may comprise the operative volume of the variable volume chamber 20 and the volume of the passage 18, together with the volume of the cylinder 8 above the piston 14 at top dead centre.

As depicted in Figure 1, the variable volume chamber 20 may be provided on the cylinder head 4 of the engine assembly 2. In some arrangements, the variable volume chamber 20 may be formed within the cylinder head 4. For example, the cavity 22 may be defined by the cylinder head 4. Alternatively, the variable volume chamber may be provided on or formed within the cylinder block 6.

The engine assembly 2 may further comprise a controller 30. The controller may be provided within an engine control system and/or power electronics system of the engine assembly. For example, the controller 30 may be an engine control unit or a powertrain control unit. The controller 30 may be configured to control the operation of the actuator 26 to vary the operative volume of the variable volume chamber that is in fluid communication with the cylinder 8. For example, according to the method 300 described below.

The engine assembly 2 may further comprise one or more sensors, such as an engine speed sensor 32 and/or a manifold air pressure sensor 34, configured to determine the pressure of air within an inlet manifold (not shown) of the engine assembly 2. The sensors may be coupled to the controller 30, which may use measurements from the sensors to determine the power and/or running speed of the engine assembly 2.

With reference to Figure 2, a combustion cycle of the engine assembly 2 will now be described. When the movable element 24 is in the first position, the combustion cycle may be defined by a first set of points 1a, 2a, 3a, 4a, 5a, 6a. When the movable element is in the second position, the combustion cycle may be defined by a second set of points 1b, 2b, 3b, 4b, 5b, 6b.

The position of the movable element 24 may vary between the first and second positions at any stage during the combustion cycle, e.g. during any of the stages of the combustion cycle described below, such that the cycle progresses from a point within the first set of points to a point within the second set, or an intermediate point, or vice versa. Furthermore, it will be appreciated that at intermediate positions of the movable element 24, the combustion cycle may be defined by points located between corresponding points of the first and second sets of points.

The combustion cycle may begin at a first point 1a, 1b of either of the set points, e.g. according to the position of the movable element 24. At the first point 1a, 1b, the piston 14 is in the top dead centre position 14", the inlet valve 11 is open and the exhaust valve 13 is closed. As described above, when the piston 14 is in the top dead centre position 14", the volume of the cylinder 8 above the piston together with the volume of the passage 18 and the operative volume of the variable volume chamber 20 is equal to the clearance volume. Hence, point 1a may be at a smaller volume than point 1b, e.g. by an amount equal to the change in the operative volume of the variable volume chamber 20.

An intake stroke may be performed between the first point 1a, 1b and a corresponding second point 2a, 2b, in which inlet air is drawn into the cylinder 8. During the intake stroke the operative volume of the cylinder 8 may increase by an amount equal to the displacement of piston 14. The displacement of the piston 14 is not affected by the variable volume chamber and hence, point 2a may also be at a smaller volume than point 2b.

At or around the second point 2a, 2b, the inlet valve 11 may be closed. A compression stroke may be performed between the second point 2a, 2b and a corresponding third point 3a, 3b. At the third point 3a, 3b, the piston may once again be in the top dead centre positon and hence, the operative volume of the cylinder may be equal to the clearance volume.

When the movable element 24 is in the first position 24’, e.g. when the clearance volume is at a maximum, the ratio of maximum cylinder volume to clearance volume may be less than when the movable element is in the first position. When the movable element is in the first position 24’, the compression ratio of the engine assembly may therefore be lower than when the movable element is in the second position 24’’.

An expansion stroke of the piston may begin at the third point 3a, 3b. Between the third point 3a, 3b and a fourth point 4a, 4b fuel may be combusted within the cylinder 8. The expansion stroke may continue to a fifth point 5a, 5b, at which the piston 14 reaches the bottom dead centre positon 14’. The pressure of exhaust gases within the cylinder 8 following the expansion stroke, e.g. at the fifth point 5a, 5b, may be substantially the same regardless of whether the movable element 24 is in the first position 24’ or the second position 24’’, e.g. regardless of the operative volume of the variable volume chamber 20.

At or around the fifth point 5a, 5b, the exhaust valve 13 may open. An exhaust stroke may be performed between the fifth point 5a, 5b and a corresponding sixth point 6a, 6b, during which exhaust gases may be ejected from the cylinder 8 via the exhaust port 12.

As described above, when the clearance volume is at a maximum and the combustion cycle is defined by the second set of points 1b, 2b, 3b, 4b, 5b, 6b, the compression ratio of the engine may be reduced compared to when the clearance volume is at a minimum. When the engine is configured in this way, the efficiency of the engine may also be reduced. However, the power output by the engine may be substantially the same regardless of the clearance volume, e.g. regardless of the position of the movable element. Furthermore, since the compression ratio has been reduced, the likelihood of knocking or pre-ignition occurring may be reduced. Increasing the clearance volume may therefore allow the maximum power provided by the engine to be increased.

With reference to Figures 3a and 4b, the engine assembly 2 may be operated according to a method 300a and/or 300b. The methods 300a and 300b comprise an adjustment step 306, in which the operative volume of the variable volume chamber 22 is adjusted in order to vary the clearance volume of the cylinder.

When the engine is operating at high loads and/or at high engine speeds, adjusting, e.g. increasing, the clearance volume may reduce the likelihood of knocking and/or pre-ignition, which may allow the maximum power provided by the engine to be increased. However, increasing the clearance volume may reduce the compression ratio of the engine which may reduce the efficiency of the engine. Hence, when the engine is operating at a low engine running speed and/or load, it may not be desirable to increase the clearance volume.

With reference to Figure 3a, the method 300a may comprise a determination step 302 in which the engine running speed and/or engine power may be determined. The operative volume of the variable volume chamber 20 may be adjusted at least partially according to the engine running speed and/or engine power. For example, if the engine running speed and/or engine power is at or above a threshold value, the operative volume of the variable volume chamber that is in fluid communication with the cylinder may be increased, in order to increase the clearance volume. Alternatively, if the engine running speed and/or power is below the threshold value, the operative volume of the variable volume chamber 20 may be reduced, in order to reduce the clearance volume.

By adjusting the operative volume of the variable volume chamber according to engine running speed and/or engine power, the engine assembly may be controlled such that engine efficiency is maximised when the engine assembly is operating at running speeds and/or powers below the threshold value whilst the peak engine power and torque that the engine is able to provide may be maximised.

Additionally or alternatively, the operative volume of the variable volume chamber may be adjusted in response to a knocking or pre-ignition event of the engine. As depicted in Figure 3b, the method 300b may include a detection step 304 in which a knocking and/or pre-ignition event is detected. The operative volume of the variable volume chamber may be adjusted following detection of the pre-ignition or knocking event to increase the clearance volume.

The operative volume of the variable volume chamber 20 may be adjusted until substantially no pre-ignition or knocking events are detected. For example, as shown in Figure 3b, following detection of a knocking or pre-ignition event, the operative volume of the variable volume chamber 20 may be increased in the adjustment step 306. If, in a step 308, no knocking or pre-ignition events are detected within a predetermined period of time following the increase in the operative volume, the operative volume may be returned to a pre-adjustment level in a further adjustment step 310. Alternatively, if in the step 308, a knocking or pre-ignition event is detected, the operative volume of the method may return the adjustment step 306 and the operative volume may be increased further.

The methods 300a and 300b may be performed as alternatives to one another or may be performed together, e.g. simultaneously.

The present disclosure may apply to both spark ignition, e.g. Otto cycle, engines and compression ignition, e.g. Diesel cycle, engines. Additionally, in some arrangements of the present disclosure, the engine assembly 2 may be configured such that a compression ratio of the engine is not the same as an expansion ratio of the engine assembly 2. In other words, the engine may be configured such that the ratio between the maximum volume and the clearance volume of the cylinder 8 is different during the compression and expansion strokes of the piston 14. For example, the engine may be a Miller cycle engine, in which one or more of the inlet valves 10 remains open during a portion of the compression stroke, causing the compression ratio to be reduced relative to the expansion ratio, or an Atkinson cycle engine.

It will be appreciated by those skilled in the art that although the invention has been described by way of example, with reference to one or more exemplary examples, it is not limited to the disclosed examples and that alternative examples could be constructed without departing from the scope of the invention as defined by the appended claims.

Claims

1. An engine assembly comprising:

a cylinder;

a piston configured to reciprocate within the cylinder in order to vary an operative volume of the cylinder between a maximum volume, when the piston is in a bottom dead centre position, and a clearance volume when the piston is in a top dead centre position; and

a variable volume chamber in fluid communication with the cylinder and configured to selectively vary the clearance volume of the cylinder.

2. The engine assembly of claim 1, wherein the variable volume chamber is in fluid communication with the cylinder via an opening above the top dead centre position of the piston.

3. The engine assembly of claim 1 or 2, wherein the engine assembly comprises a cylinder block, the cylinder being at least partially defined by the cylinder block; and

wherein the engine assembly further comprises a cylinder head, wherein the cylinder head comprises the variable volume chamber.

4. The engine assembly of any of the preceding claims, wherein the engine assembly further comprises a movable element configured to vary a volume of the variable volume chamber that is in fluid communication with the cylinder.

5. The engine assembly of claim 4, wherein the engine assembly further comprises an actuator configured to vary the position of the movable element.

6. The engine assembly of claim 4 or 5, wherein the position of the movable element is controlled at least partially according to an engine running speed and/or engine power.

7. The engine assembly of any of claims 4 to 6, wherein the engine assembly further comprises a controller, the controller being configured to:

determine an engine running speed and/or engine power; and

adjust the position of the movable element at least partially according to the engine running speed and/or engine power.

8. The engine assembly of any of the preceding claims, wherein the engine assembly is configured such that a compression ratio of the engine assembly differs from an expansion ratio of the engine assembly.

9. A method of operating an engine assembly, the engine assembly comprising:

a cylinder;

a piston configured to reciprocate within the cylinder in order to vary an operative volume of the cylinder between a maximum volume, when the piston is in a bottom dead centre position, and a clearance volume when the piston is in a top dead centre position; and

a variable volume chamber in fluid communication with the cylinder, wherein the method comprises:

adjusting an operative volume of the variable volume chamber in order to vary the clearance volume of the cylinder.

10. The method of claim 9, wherein the method further comprises:

determining an engine running speed and/or engine power; and

adjusting the operative volume at least partially according to the engine running speed and/or engine power.

11. The method of claim 9 or 10, wherein the method comprises:

detecting a pre-ignition or knocking event of the engine; and

adjusting the operative volume to increase the clearance volume following detection of the pre-ignition or knocking event.

12. A vehicle comprising the engine assembly according to any of claims 1 to 8.

13. An engine assembly, vehicle or method of operating an engine assembly substantially as describe herein, with reference to and as shown in the accompanying drawings.

Application No: GB1615998.0 **Examiner:** Mr Mat Smith

Claims searched: 1-13 **Date of search:** 23 February 2017

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
X	1-11	GB 2210930 A (MORIKAWA) figures and page 5, line 19 - page 14, line 11. In particular adjusting piston 10, sub-chamber (variable volume chamber) 1c and actuator 11.
X	1-11	US 4516537 A (NAKAHARA et al) figures and columns 6-15. In particular sub-piston 17 and sub-cylinder (variable volume chamber) 15.
X	1-10, 12	US 2003/097998 A1 (GRAY) figure 1 and paragraphs [0006]-[0023]. In particular head chamber (variable chamber) 15, piston 17, noting hydraulic actuation.
X	1-10	US 5024184 A (NAGANO et al) figures and columns 3-8. In particular auxiliary cylinder (variable volume chamber) 8, auxiliary piston 7 and actuator motor 24.
X	1-10	GB 2000551 A (AUDOUX) figure 1 and pages 1 & 2. In particular auxiliary piston 9, cavity (variable volume chamber) 8 and depression box (actuator) 34.
X	1-10	US 4890585 A (HAWTHORN) figures and columns 3-6. In particular auxiliary piston 22, auxiliary chamber (variable volume chamber) 20 and actuation motor 50.

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

F02B

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

EPODOC, WPI, TXTA

International Classification:

Subclass	Subgroup	Valid From
F02D	0015/04	01/01/2006
F02B	0075/04	01/01/2006
F02B	0075/06	01/01/2006