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(71) Applicant: Winterthur Gas & Diesel Ltd. 8401 Winterthur (CH)	(74) Representative: Hepp Wenger Ryffel AG Friedtalweg 5 9500 Wil (CH)

(54)

VARIABLE COMPRESSION RATIO (VCR) ENGINE

(57)

The invention relates to a variable compression ratio (VCR) engine and a method for driving a variable compression ratio (VCR) engine. The variable compression ratio (VCR) engine (1), comprises at least one cylinder (2) with a piston (3) movably arranged within the cylinder (2), adapted to perform a predefined piston stroke within the cylinder (2), and a setting unit (4) for setting a preset compression ratio by setting a preset clearance position (11). The VCR-engine (1) further comprises a control unit (5) for setting at least one temporal clearance (15) position different from the preset clearance position (11) and for inducing at least one piston movement with the temporal clearance position (15).

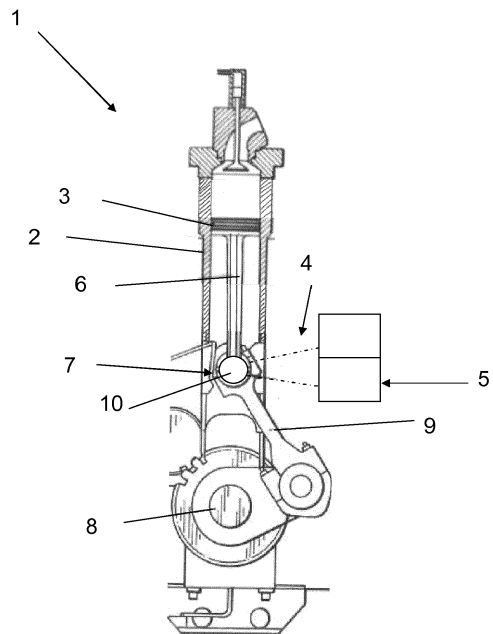


Fig. 1

Description

[0001] The invention relates to a variable compression ratio (VCR) engine and a method for driving a variable compression ratio (VCR) engine.

[0002] In a reciprocating piston combustion engine the compression ratio is an important parameter for the combustion, the thermal efficiency and for the exhaust gas emissions.

[0003] The compression ratio of a combustion engine represents the ratio of the volume of its combustion chamber from its largest capacity to its smallest capacity. In a piston engine it is the ratio between the volume of the cylinder and combustion chamber when the piston is at the bottom of its stroke, and the volume of the combustion chamber when the piston is at the top of its stroke. Hence, the compression ratio may be calculated by the ratio between the sum of the displacement volume and the clearance volume and the clearance volume. The displacement volume is the volume inside the cylinder displaced by the piston from the beginning of the compression stroke to the end of the stroke. The clearance volume is the volume of the space in the cylinder left at the end of the compression stroke.

[0004] The compression ratio is usually chosen to yield the best engine performance. Often the high load engine performance is the most relevant point for the choice. For optimal performance over the whole operating range a variable compression ratio is desirable.

[0005] Different solutions are known for varying the compression ratio in smaller reciprocating piston combustion engines, such as eccentric sleeves around the piston pin or around the main bearing, or eccentric shafts and mechanisms for regulating the distance between the cylinder head and the crankshaft centre line.

[0006] The compression ratio may be changed by allowing the gas to enter an additional volume outside the cylinder as disclosed for example in EP2677141 A1 or by a displaceable exit valve seat as disclosed in JPS61-197731 A.

[0007] Large reciprocating piston combustion engines regularly comprise one or more cylinders equipped with a cylinder liner respectively, one or more pistons movably arranged within the respective cylinder liner, and a crankshaft rotatably arranged in a crankshaft housing, with each piston being connected to a respective crosshead via a piston rod, and with each crosshead being connected to the crankshaft via a connecting rod to drive the crankshaft. The piston rods are typically guided rectilinearly along their longitudinal axis, and the respective crosshead converts the rectilinear movement of the piston rod into a non-rectilinear movement of the connecting rod.

[0008] EP2687707 A2 discloses a large reciprocating piston combustion engine wherein the crosshead and/or the piston may be provided with a control apparatus for controlling the compression ratio of the reciprocating piston combustion engine. For example, the piston rod may

be extended by a hydraulic cylinder sitting in the cross-head pin. Thereby the possible maximum and minimum positions of the piston are changed.

[0009] In combustion engines carbon may build up and wear steps can occur in long time operation above the piston top dead position.

[0010] With a fixed compression ratio this is not a problem since the piston will never reach this area.

[0011] However, when the compression ratio is varied by determining the maximum and the minimum position of the piston in the cylinder, different maximum piston positions of the piston, in particular of the top piston ring, may be achieved.

[0012] If the engine has been operated on a 'low' compression rate with a relatively big clearance volume for a prolonged time and the compression ratio is subsequently increased all of the sudden, the piston rings will pass the area of wear steps and carbonised deposits.

[0013] Thereby reliable piston running performance is not guaranteed and can lead to damages to piston, piston rings and liner of the cylinder. For a reliable engine operation with a variable compression ratio (VCR) engine, managing the carbon build ups and avoid wear steps are essential.

[0014] It is an object of the present invention to avoid the drawbacks of the prior art and in particular to provide an variable compression ratio (VCR) engine and a method of operating an variable compression ratio (VCR) engine with more continuous performance and with a lower need for maintenance than in prior art engines.

[0015] The object is achieved by the variable compression ratio (VCR) engine and the method of operating a variable compression ratio (VCR) engine according to the independent claims.

[0016] The object is achieved by a variable compression ratio (VCR) engine comprising at least one cylinder with a piston movably arranged within the cylinder, adapted to perform a predefined piston stroke within the cylinder. The variable compression ratio (VCR) engine comprises a setting unit for setting a preset compression ratio by setting a preset clearance position.

[0017] The piston moves between the bottom dead center and the top dead center. The distance between these bottom and top positions corresponds to the piston displacement length which may be determined by the length of the crankshaft and the length of the connection rod.

[0018] At the top dead center the piston is in the clearance position.

[0019] The preset clearance position is a preset top position of the piston, in particular the top position of the top ring, and corresponds to a respective clearance volume.

[0020] The top ring is a seal ring positioned in the upper most groove of the piston.

[0021] Since the displacement lengths and thus the displacement volume in most cases cannot be changed for a given piston/cylinder arrangement due to fixed

lengths of the cylinder diameter, the piston, the piston rod, the connecting rod and the crank shaft during movement, the setting of the clearance volume defines the compression ratio.

[0022] Usually there is a highest possible top position in the cylinder which can be reached by the piston which corresponds to a minimal possible clearance volume and to a maximal possible compression ratio.

[0023] To choose a smaller compression ratio the range of movement of the piston within the cylinder may be shifted such that a lower clearance position, a greater clearance volume and hence a smaller compression ratio may be achieved.

[0024] According to the invention the VCR-engine further comprises a control unit for setting at least one temporal clearance position different from the preset clearance position and for inducing at least one piston movement with the temporal clearance position.

[0025] Preferably the temporal clearance position is above the preset clearance position, in other words closer to the highest possible top position as the preset clearance.

[0026] Preferably the control unit is adapted for setting thereafter the preset clearance position again and inducing the piston movements with the preset clearance position.

[0027] A piston movement with the temporal clearance position is a movement between a bottom and top position, wherein the top position corresponds to the temporal clearance position.

[0028] Preferably, a temporal clearance position is chosen which corresponds to the absolute maximum position of the piston and hence to the smallest clearance volume and to the biggest possible compression ratio.

[0029] If a temporal clearance position corresponding to a smaller clearance volume as compared to the preset clearance position is achieved from time to time, carbon build ups may be reduced. The piston cleans the inner wall of the cylinder while moving along the inner wall. Deposits of carbon material which may build up at the inner wall of the cylinder in a region above the clearance position of the piston may be removed when the piston, in particular the top ring, passes this area.

[0030] Preferably the control unit is adapted for inducing at least one piston movement with a temporal clearance position according to at least one predetermined scheme.

[0031] The scheme preferably defines successive values of temporal clearance positions, time intervals or number of strokes for holding temporal clearance positions and/or setting cycles.

[0032] The scheme may induce a repeated setting of a piston movement with a temporal clearance position corresponding to a smaller clearance volume as compared to the preset clearance position after predetermined time intervals or after predetermined piston stroke movements.

[0033] The scheme may provide a curve defining the

clearance positions over time or number of position strokes. The temporal clearance position is changed according to this curve over time or over number of piston strokes. The scheme may define a stepwise change of the temporal clearance positions.

[0034] If the clearance position is changed too fast or by a too large distance change there is the risk that the piston passes an area comprising wear steps, which should be prevented. By moderately changing the clearance position the piston is slowly approaching the area where there may be deposits. The piston may remove more and more of the deposits over the total curve of change.

[0035] Also it may take some time to remove deposits. Hence, the scheme may define the time or the number of piston strokes by which the temporal clearance value is held.

[0036] In an advantageous embodiment of the VCR-engine the control unit is adapted for inducing a piston movement with the temporal clearance position on demand.

[0037] Alternatively or additionally the control unit is adapted for inducing at least one piston movement with a temporal clearance position every 100-5000000 piston strokes.

[0038] Alternatively or additionally the control unit is adapted for inducing at least one piston movement with a temporal clearance position every 1h - 2 months of operating time.

[0039] The VCR engine may comprise at least two cylinders, and the control unit may be adapted for inducing a piston movement with a temporal clearance position for a selected cylinder. The other cylinders may perform predefined piston strokes with a preset clearance position for providing a predefined combustion, a predefined thermal efficiency and a predefined exhaust gas emission. The control unit may be adapted for selecting a respective cylinder according to at least one predetermined scheme.

[0040] The VCR engine may comprise at least two cylinders, and the control unit may be adapted for inducing a piston movement with a temporal clearance position for all cylinder pistons simultaneously or for one cylinder after the other.

[0041] The VCR engine may comprise a number of installed cylinders, the number at least three, and the control unit may be adapted for simultaneously inducing a piston movement with a temporal clearance position for a number of the installed cylinders. The number may be between two and the number of installed cylinders minus one.

[0042] Hence, there are always cylinders performing predefined piston strokes with a preset clearance position.

[0043] In a favourable embodiment of the VCR engine the control unit is adapted for inducing a piston movement with a maximum compression ratio at each start-up and/or shut down of the engine.

[0044] According to an advantageous embodiment the VCR comprises a sensor unit for detecting a value that gives an indication of the presence and/or thickness of the deposits in the area above the piston.

[0045] Deposits may be responsible for a wear step which could cause damage of the position rings.

[0046] The sensor unit may comprise an ultrasound sensor. Alternatively an optical sensor or an electro-magnetically sensor for detecting a resistance or a capacity may be included.

[0047] If a predetermined critical value of an amount of deposit is exceeded a cleaning will be necessary.

[0048] The control unit may be adapted for inducing a piston movement with a temporal clearance position in dependence of the values detected by the sensor unit.

[0049] If a value is detected by the sensor unit which corresponds to a predetermined limit for an acceptable amount of deposits, the control unit may induce a change of the clearance position according to a scheme in order to reduce the deposits on the inside surface off the cylinder wall.

[0050] In a beneficial embodiment the piston is connected to a piston rod and the piston is provided with the setting unit for controlling the compression ratio. In particular the setting unit comprises or is coupled to a mechanism for displacing the top ring of the piston with respect to the piston rod. Preferably the upper part of the piston wearing the top ring is moved with respect to the lower part of the piston and/or the piston rod.

[0051] The piston may comprise two or more parts which are moveable with respect to each other.

[0052] The control unit may comprise or may be coupled to the same mechanism for displacing the top ring of the piston with respect to the piston rod or to a different mechanism for adjusting the temporal clearance position.

[0053] The position of the top ring, preferably together with the upper part of the piston, defines the clearance position and hence the clearance volume. The lengths of the stroke and hence the displacement volume remains the same. Thus, by displacing the top ring the compression ratio may be changed.

[0054] Alternatively or additionally the piston is connected to a crosshead via a piston rod, and the crosshead is connected to a crankshaft via a connecting rod to drive the crankshaft.

[0055] The crosshead may be provided with a mechanism for controlling the compression ratio. In particular the setting unit comprises or is coupled to a mechanism for displacing the piston rod and/or the piston with respect to the crosshead, for example as disclosed in EP2687707A2.

[0056] The control unit may comprise or be coupled to the same mechanism for displacing the piston rod and/or the piston with respect to the crosshead or to a different mechanism for adjusting the temporal clearance position.

[0057] Alternatively or additionally the connecting rod

is provided with a mechanism for controlling the compression ratio. In particular the setting unit comprises or is coupled to a mechanism for displacing the connecting rod with respect to the crankshaft, for example as disclosed in EP2801713 A1. The mechanism may comprise an eccentric tappet at the lower bearing of the at least one connecting rod. The mechanism further may comprise a locking mechanism for locking the eccentric tappet either to the connecting rod or to a corresponding crank pin of the crankshaft to operate the reciprocating piston combustion engine changeably at a first or second compression ratio respectively.

[0058] The control unit may comprise or be coupled to the same mechanism for displacing the connecting rod with respect to the crankshaft or to a different mechanism for adjusting the temporal clearance position.

[0059] Alternatively or additionally the whole piston drive unit may be moveable to change the clearance position of the piston. The control unit and/or the setting unit may comprise or be coupled to a mechanism for moving the whole piston drive unit.

[0060] The present invention preferably relates to a VCR internal combustion engine like a large marine or ship engine or a stationary engine whose cylinders have an inner diameter of at least 200 mm. The engine preferably is a two-stroke engine or a two-stroke cross head engine. The engine can be a diesel or a gas engine, a dual fuel or a multi fuel engine. Burning of liquid and or gaseous fuels in such engines is possible as well as self-igniting or forced igniting.

[0061] The engine has at least one cylinder having a piston therein. The piston is connected to a crankshaft. The piston reciprocates between a top dead center (TDC) and a bottom dead center (BDC) during operation of the engine. The cylinder typically has at least one air passage opening for intake, the air inlet in particular arranged in the liner of the cylinder, and at least one air passage opening for exhaust, the exhaust outlet in particular arranged in the cover of the cylinder.

[0062] The internal combustion engine can be a longitudinally flushed two-stroke engine.

[0063] The term internal combustion engine also refers to large engines which can be operated not only in diesel mode, which is characterized by the self-ignition of the fuel, but also in Otto mode, which is characterized by the positive ignition of the fuel, or in mixtures of the two. Furthermore, the term internal combustion engine includes in particular dual-fuel engines and large engines in which the self-ignition of the fuel is used for the positive ignition of another fuel.

[0064] Engine speed is preferably below 800 RPM (4-stroke) and more preferably below 200 RPM (2-stroke) which indicates the designation of low speed engines.

[0065] Fuel can be diesel or marine diesel oils or heavy fuel oils or emulsions or slurries or methanol or ethanol as well as gases like liquid natural gas (LNG) liquid petrol gas (LPG) and so on.

[0066] Further possible fuels which might be added on

request are: LBG (Liquified Biogas), biological Fuels (e. g. Algae fuel or Seaweed Oil), hydrogen, synthetic fuels from CO₂ (e. g. made by Power-To-Gas or Power-To-Liquid).

[0067] The object is also achieved by a method for driving a variable compression ratio (VCR) engine, comprising at least one cylinder with a moveable piston, adapted to perform a predefined piston stroke within the cylinder. The method comprises the steps of setting a preset compression ratio by setting a preset clearance position, preferably by a setting unit, setting at least one temporal clearance position different from the preset clearance position, preferably by a control unit, and inducing at least one piston movement with the temporal clearance position.

[0068] After setting the clearance positions piston movements are induced with the respective clearance positions, the respective clearance volumes and the respective compression ratios.

[0069] During piston movements with the temporal clearance position the inside wall of the cylinder is cleaned in areas which are not reached by piston movements with the preset clearance position.

[0070] Finally, piston movements are again induced with the preset clearance position.

[0071] Preferably, the piston movement with the temporal clearance position is induced according to at least one predetermined scheme. The scheme preferably defines successive values of temporal clearance positions, time intervals or numbers of strokes for holding temporal clearance positions and/or setting cycles.

[0072] In particular the scheme defines a stepwise rising and/or lowering of temporal clearance positions.

[0073] A piston movement with the temporal clearance position may be induced on demand and/or after a predetermined number of piston strokes and/or after a predetermined operation time.

[0074] For example at least one piston movement with a temporal clearance position may be induced every 100-5000000 piston strokes and/or every 1h - 2 months of operating time.

[0075] For VCR engines comprising at least two cylinders the piston movement with a temporal compression ratio may be induced for all cylinder pistons simultaneously or for one cylinder after the other or simultaneously for a part of the cylinders.

[0076] Advantageously, a piston movement with a temporal clearance position is induced at each start-up and/or shut down of the engine.

[0077] The clearance position may be adapted by displacing the top ring of the piston, preferable the upper part of the piston comprising the top ring, of the piston with respect to the lower part of the piston and/or the piston rod.

[0078] The clearance position may be adapted by displacing a piston rod and/or the piston with respect to a crosshead.

[0079] The clearance position may be adapted by dis-

placing a connecting rod with respect to a crankshaft.

[0080] In a beneficial embodiment of the method a value giving an indication of the thickness of the deposits is detected, for example by an ultrasound sensor.

5 **[0081]** Preferably a piston movement with a temporal clearance position is induced in dependence of values detected by the sensor unit.

10 **[0082]** The object is achieved by a computer program product directly loadable into the internal memory of a digital computer comprising software code portions for performing the steps of a method according as described above, when said product is run on a computer. The scheme according to which the piston movement is induced may also be digitally stored in a memory.

15 **[0083]** In the following, the invention is further explained in embodiments by means of figures:

Figure 1: shows a schematic view of a first example of a combustion engine;

20 Figure 2: shows a schematic view piston in a preset clearance position;

Figure 3: shows a schematic view piston in a temporal clearance position;

25 Figure 4a shows a first typical curve of a temporal clearance position over time;

Figure 4b shows a second typical curve of a temporal clearance position over time.

30 **[0084]** Figure 1 shows a variable compression ratio (VCR) engine 1 comprising a cylinder 2 with a piston 3 movably arranged within the cylinder 2. The piston 3 is adapted to perform a predefined piston stroke within the cylinder 2 between a top dead center and a bottom dead center (not shown in the figure). In the figure the piston 3 is shown in an intermediate position.

35 **[0085]** The piston 3 is connected to a crosshead 7 via a piston rod 6 and the crosshead 7 is connected to a crankshaft 8 via a connecting rod 9 to drive the crankshaft 8.

40 **[0086]** The crosshead 7 is provided with the setting unit 4 setting a preset compression ratio. The setting unit 4 comprises a mechanism for displacing the piston rod 6 and the piston 3 with respect to the crosshead 7.

45 **[0087]** When the piston rod 6 is displaced with respect to the crosshead 7 the movement range of the piston 3 within the cylinder 2 changes and the piston reaches a different top position in the cylinder 2 (not shown in the figure). Hence a new preset clearance position (see figure 2) may be set by the control unit 4.

50 **[0088]** The VCR-engine 1 further comprises a control unit 5 for setting at least one temporal clearance position (see figure 3) different from the preset clearance position 11 and for inducing at least one piston movement with the temporal clearance position 15.

55 **[0089]** The control unit 5 is coupled to the setting unit 4. The mechanism 10 is used for adjusting the preset clearance position and the temporal clearance position.

[0090] Alternatively the control unit 5 may be coupled

to a different mechanism (not shown in the figure) for adapting the temporal clearance position.

[0091] Figure 2 shows a schematic view of a VCR engine 1 with a piston 3 in a preset clearance position 11.

[0092] The distance between crosshead 7 and piston 3 has been set such the piston 3 in the top position is well below the cylinder head 12. Thus, there is an area 13 between the piston 3 and the cylinder head 12, where the inside wall 14 of the cylinder 2 is not stripped off by the piston 3. In this area 13 wear steps and carbonised deposits may occur.

[0093] The VCR engine 1 may comprise a sensor unit 16 for detecting the thickness of the deposits, for example an ultrasound sensor.

[0094] In case there is a layer of carbonised deposits which is thicker than predetermined value the control unit 5 may induce the setting of a temporal clearance position.

[0095] Temporarily the clearance position may be changed by the control unit 5 for example to a temporal clearance position 15 as for example shown in Figure 3.

[0096] When the deposits are removed the control unit 5 may put back the clearance position to the originally preset clearance position 11.

[0097] Figure 4a shows a first typical curve of a clearance position (CP) over time (t), wherein the clearance position is changed from a preset clearance position (PCP) to temporal clearance position (TCP) linearly. Figure 4b shows a second typical curve of a clearance position (CP) over time (t), wherein the clearance position is changed stepwise.

[0098] The time (t) may be measured in time units or in number of piston strokes.

[0099] The temporal clearance position (TCP) may be held constant for a time span t_c .

[0100] Thereafter the clearance position is lowered, for example linearly as shown in figure 4a or stepwise as shown in figure 4b.

[0101] The clearance position may return to the preset clearance position (PCP) it held before the increase or to a different value, as indicated in Figure 4a with dotted lines. Thus a new preset clearance position can be chosen.

[0102] The clearance position typically may be changed in a range of 20 to 200mm.

Claims

1. Variable compression ratio (VCR) engine (1), comprising at least one cylinder (2) with a piston (3) movably arranged within the cylinder (2), adapted to perform a predefined piston stroke within the cylinder (2), and a setting unit (4) for setting a preset compression ratio by setting a preset clearance position (11),
characterized in that
the VCR-engine (1) further comprises a control unit (5) for setting at least one temporal clearance posi-

tion (15) different from the preset clearance position (11) and for inducing at least one piston movement with the temporal clearance position (15).

2. Variable compression ratio (VCR) engine according to claim 1, wherein the control unit (5) is adapted for inducing at least one piston movement with a temporal clearance position (15) according to at least one predetermined scheme, the scheme preferably defining successive values of temporal clearance positions (15), time intervals for holding temporal clearance positions (15) and/or setting cycles.
3. Variable compression ratio (VCR) engine according to claim 1 or 2, wherein the control unit (5) is adapted for inducing a piston movement with a temporal clearance position (15)
 - on demand and/or
 - every 100-5000000 piston strokes and/or
 - every 1h - 2 months of operating time.
4. Variable compression ratio (VCR) engine according to one of the preceding claims, wherein the VCR engine (1) comprises at least two cylinders (2), and the control unit (5) is adapted for inducing a piston movement with a temporal clearance position (15) for a selected cylinder;
or
wherein the VCR engine (1) comprises at least two cylinders (2), and the control unit (5) is adapted for inducing a piston movement with a temporal clearance position (15) for all cylinder pistons (3) simultaneously
or
for one cylinder (2) after the other;
or
wherein the VCR engine (1) comprises a number of installed cylinders (2), the number at least three, and the control unit (5) is adapted for simultaneously inducing a piston movement with a temporal clearance position (15) for two to the number minus one installed cylinders (2).
5. Variable compression ratio (VCR) engine according to one of the preceding claims, wherein the control unit (5) is adapted for inducing a piston movement with temporal clearance position (15), preferably with a maximum compression ratio, at each start-up and/or shut down of the engine.
6. Variable compression ratio (VCR) engine according to one of the preceding claims, wherein the VCR engine (1) comprises a sensor unit (16) for detecting a value that gives an indication of the thickness of the deposits, for example an ultrasound sensor.
7. Variable compression ratio (VCR) engine according

to claim 6, wherein the control unit is adapted for inducing a piston movement with a temporal clearance position (15) in dependence of the values detected by the sensor unit (16).

8. Variable compression ratio (VCR) engine according to one of the preceding claims, wherein the piston (3) is connected to a piston rod (6) and the piston (3) is connected to the setting unit (4) for controlling the compression ratio, the piston (3) in particular comprises a mechanism for displacing a top ring of the piston (3) with respect to the piston rod (6);

and/or

wherein the piston (3) is connected to a crosshead (7) via a piston rod (6), and the crosshead (7) is connected to a crankshaft (8) via a connecting rod (9) to drive the crankshaft (8), and wherein the crosshead (7) is connected to the setting unit (4) for controlling the compression ratio, the crosshead (7) in particular comprises a mechanism (10) for displacing the piston rod (6) and/or the piston (3) with respect to the crosshead (7);

and/or

wherein the piston (3) is connected to a crosshead (7) via a piston rod (6), and the crosshead (7) is connected to a crankshaft (8) via a connecting rod (9) to drive the crankshaft (8), and wherein the connecting rod (9) is connected to the setting unit (4) for controlling the compression ratio, the connecting rod (9) in particular comprises a mechanism for displacing the connecting rod (6) with respect to the crankshaft (8), for example an eccentric tappet at the lower bearing of the at least one connecting rod and comprising a locking mechanism for locking the eccentric tappet either to the connecting rod or to a corresponding crank pin of the crankshaft to operate the VCR-engine changeably at a first or second compression ratio respectively.

9. Variable compression ratio (VCR) engine according to one of the preceding claims wherein the VCR-engine (1) is a large vessel engine with at least one cylinder having an inner diameter of at least 200mm, preferably a two-stroke engine or a two-stroke cross head engine, more preferably a dual fuel or a multi fuel engine.

10. Method for driving a variable compression ratio (VCR) engine, comprising at least one cylinder (2) with a moveable piston (3), adapted to perform a predefined piston stroke within the cylinder (2), comprising the steps of

- setting a preset compression ratio by setting a preset clearance position (11),
- setting at least one temporal clearance position (15) different from the preset clearance position

(11) and

- inducing at least one piston movement with the temporal clearance position (15).

11. Method according to claim 10, wherein the piston movement with the temporal clearance position is induced according to at least one predetermined scheme, the scheme preferably defining successive values of temporal clearance positions, time intervals for holding temporal clearance positions (15) and/or setting cycles.

12. Method according to claim 10 or 11, wherein a piston movement with the temporal clearance position (15) is induced

- on demand and/or
- every 100-5000000 piston strokes and/or
- every 1h - 2 months of operating time

13. Method according to claim 10 to 12, wherein the VCR engine comprises at least two cylinders (2), and the piston movement with a temporal clearance position is induced for all cylinder pistons simultaneously or for one cylinder after the other or simultaneously for a part of the cylinders (2).

14. Method according to one of claims 11 to 13, wherein the piston movement with a temporal clearance position (15) is induced at each start-up and/or shut down of the engine.

15. Method according to one of claims 11 to 14, wherein the clearance position is adapted by

- displacing a top ring of the piston with respect to a piston rod, and/or
- displacing a piston rod and/or the piston with respect to a crosshead and/or
- displacing a connecting rod with respect to a crankshaft.

16. Computer program product directly loadable into the internal memory of a digital computer comprising software code portions for performing the steps of a method according to one of claims 10-15, when said product is run on a computer.

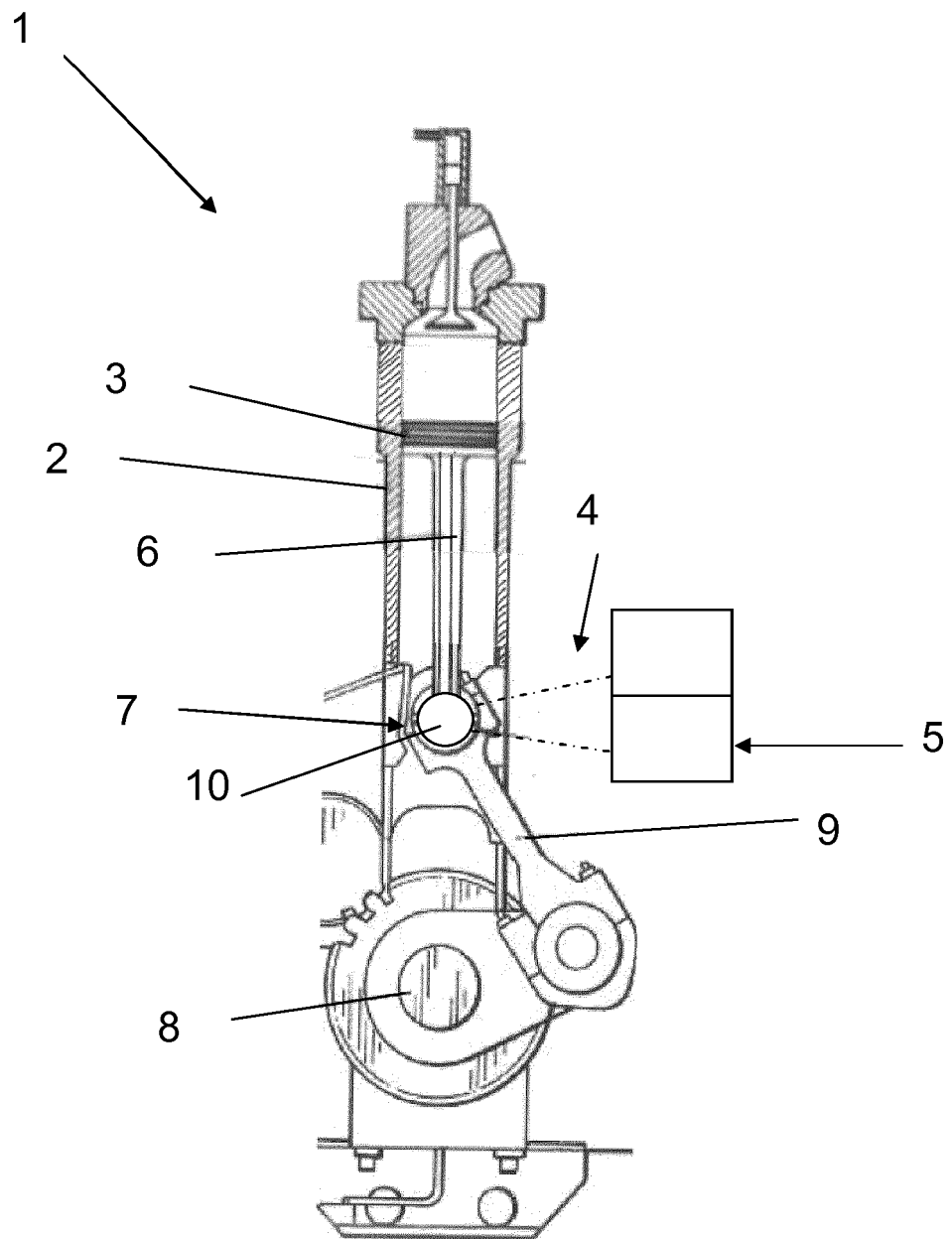


Fig. 1

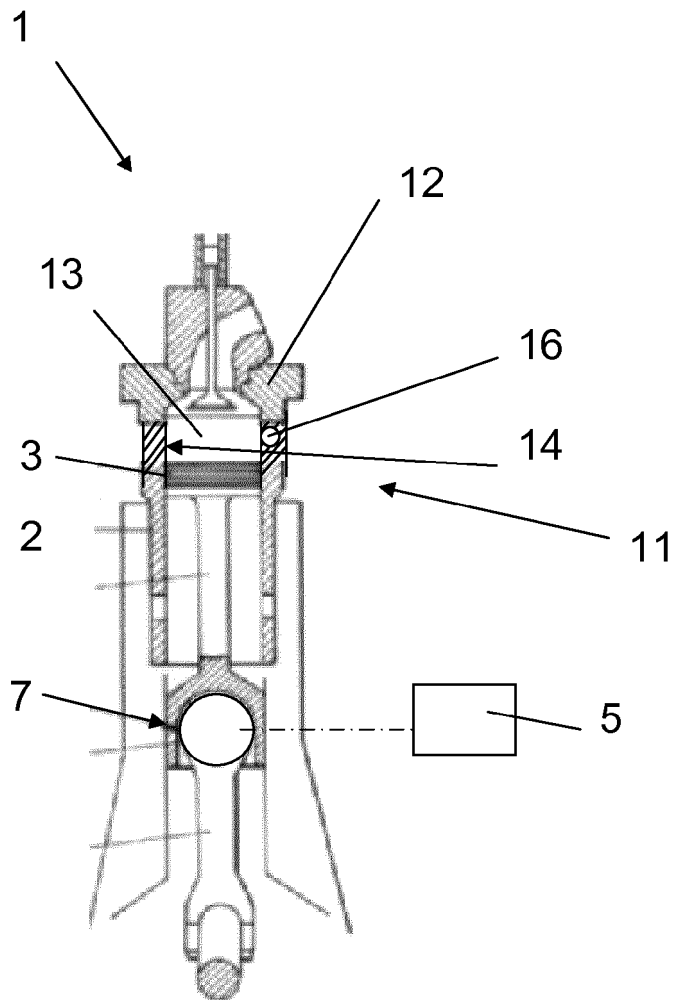


Fig. 2

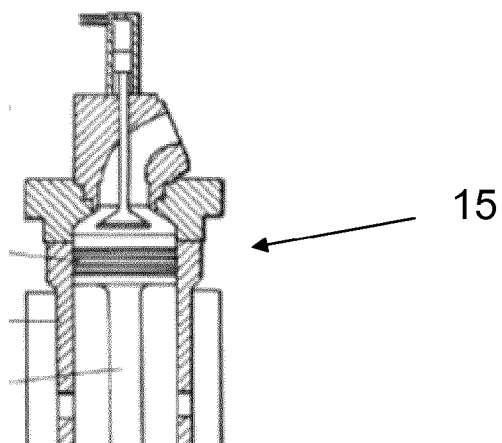


Fig. 3

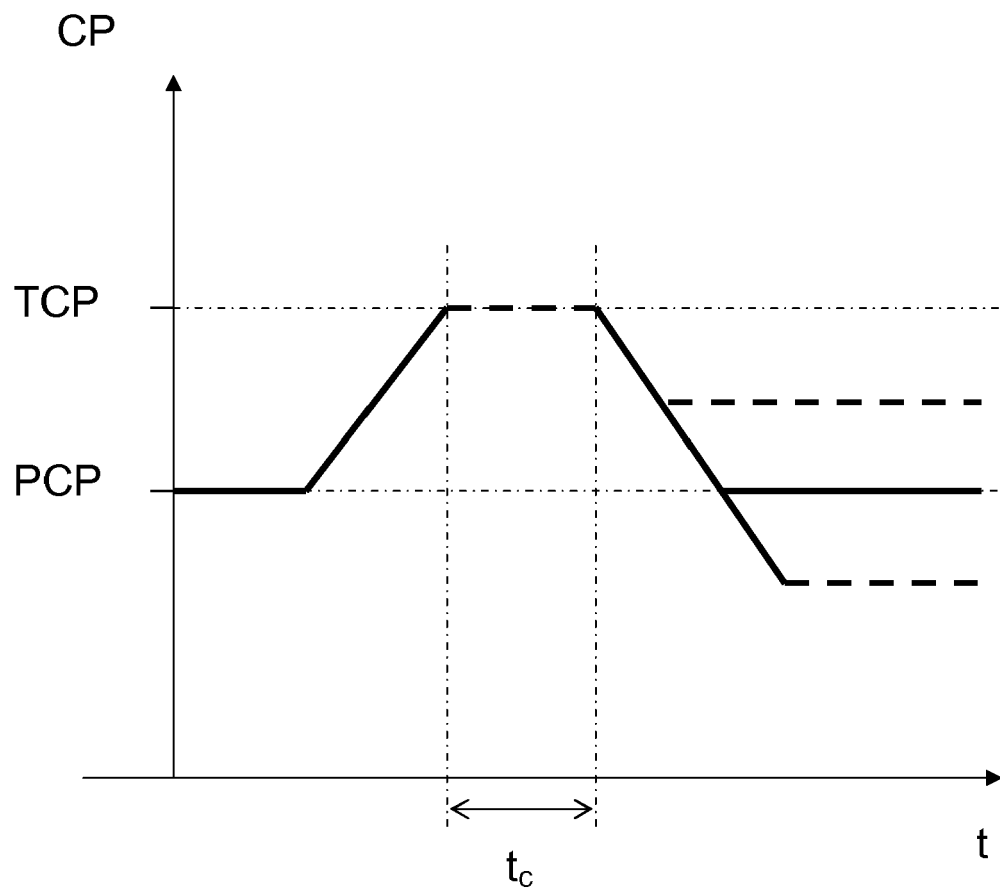


Fig. 4a

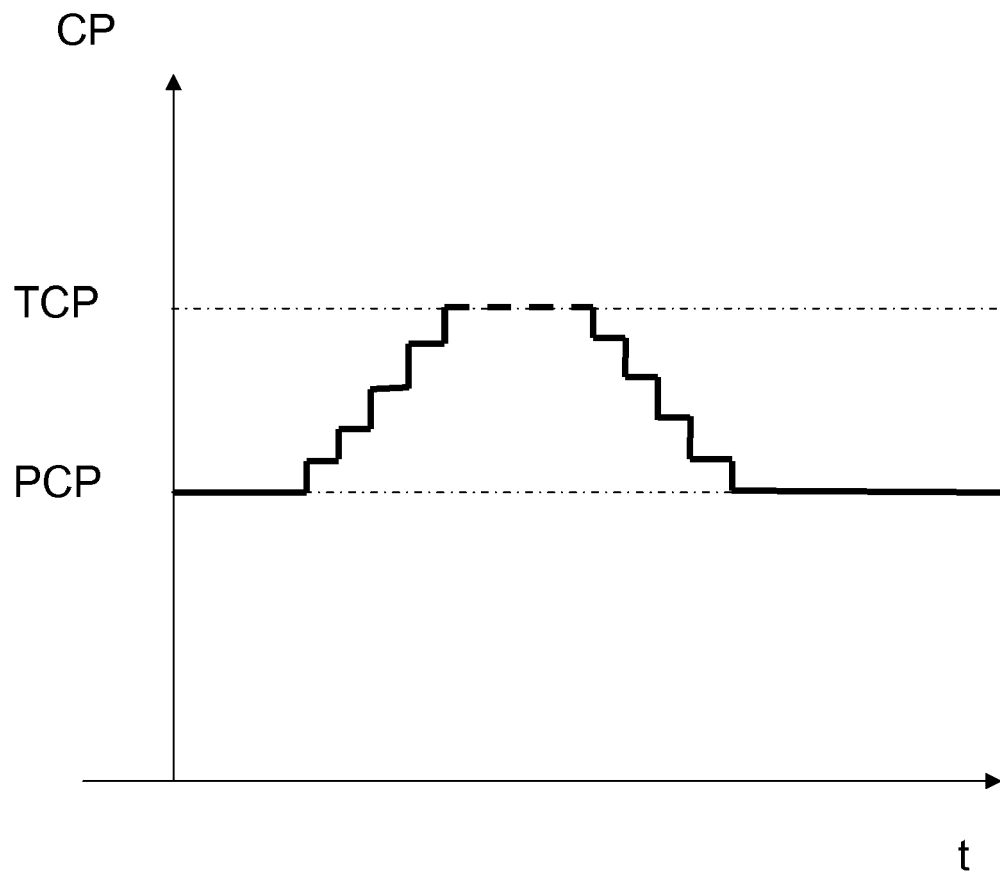


Fig. 4b



EUROPEAN SEARCH REPORT

Application Number
EP 19 17 8942

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	DE 10 2014 220424 A1 (BOSCH GMBH ROBERT [DE]) 14 April 2016 (2016-04-14) * paragraphs [0004], [0005], [0011], [0013], [0015], [0022], [0023]; claim 4 *	1-5,8-16	INV. F02B75/04 F02B77/04 F02D15/00
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