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(54) Title: SPARK-IGNITION ENGINE CYLINDER HEAD COMPRISING A SPARK PLUG AND A MOBILE PRE-CHAMBER

(57) Abstract: Cylinder head (3) for spark-ignition engine (2) comprising at least one spark plug shaft (30) under which the cylinder head casting delimits a first volume (300) wherein a spark plug (4) and a mobile pre-chamber (5) are configured for movement in the first volume (300), with respect to the spark plug (4), in order to circulate the drain air flow in the first volume (300) and in an intermediate volume (550) of the pre-chamber (5).

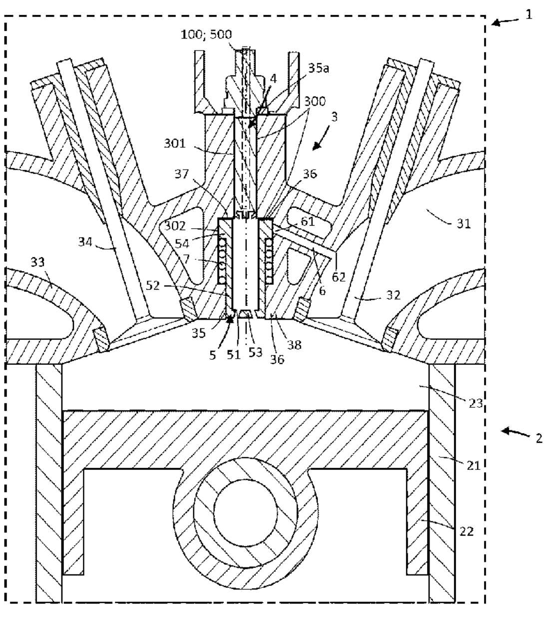

FIG. 1

WO 2024/256566 A1

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DESCRIPTION

SPARK-IGNITION ENGINE CYLINDER HEAD COMPRISING A SPARK PLUG AND A MOBILE PRE-CHAMBER

The invention refers to a spark-ignition engine cylinder head comprising a spark plug. In addition, the invention refers to an engine equipped with said cylinder head. Lastly, the invention refers to an operating method for such an engine.

Increased efficiency of spark-ignition thermal engines is one of the challenges faced by the automotive industry, and boosting the volumetric ratio is a key area for improvement. Nevertheless, boosting the volumetric ratio of a thermal engine entails challenges such as fuel auto-ignition phenomena, also known as knocking, which can potentially damage the engine.

A solution to these challenges is to use pre-chambered spark plugs, more particularly spark plugs with a passive pre-chamber, i.e. one that does not have a fuel injection mechanism operating directly into the pre-chamber. A disadvantage of such spark plugs is the residual-burnt gas, or GBR, that gradually deposits in the pre-chamber until it reaches high proportions, which can impact the fuel mixture's combustion or even render such combustion inefficient.

The invention falls within this context and is intended to offer an alternative to the known cylinder heads, designed to evacuate residual burnt gases that may remain in the pre-chamber after the combustion cycles, in order to guarantee a good quality of the fuel mixture in the pre-chamber before the ignition of the spark plug.

The invention refers to a cylinder head for spark-ignition engines comprising at least one spark plug shaft and a first volume, in particular the first volume being delimited by the cylinder head material below the said shaft, a first end of the said first volume comprising an opening which is designed to open into a cylinder combustion chamber. In addition, the cylinder head comprises at least one spark plug at least in part positioned in the first volume, in particular positioned in the first volume from the shaft, and at least one channel opening into the first volume at the level of at least one orifice and configured to circulate a drain air flow towards the first volume. In addition, the cylinder head comprises a movable pre-chamber comprising at least one hole for the passage of a fuel-air mixture between the combustion chamber and the pre-chamber, the pre-chamber being positioned in the first volume and configured to be moved in the first volume relative to the spark plug, between a first position, wherein it extends opposite to the at least one orifice in order to interrupt the drain air flow to the first volume, and a second position, wherein it extends at a distance to the one or more orifices in order to allow the drain air flow to circulate in the first volume. The cylinder head also comprises a return member designed to move the pre-chamber between the first position and the second position.

In particular, the cylinder head can additionally comprise an intake duct, equipped with an intake valve, and an exhaust duct, equipped with an exhaust valve, where one or more channels are fluidically connected to the intake duct.

Particularly, the pre-chamber:
- may comprise a metallic material, such as steel; and/or
- may be configured to be positioned for translational movement along a first direction within the first volume.

Alternatively, the first volume may comprise a first chamber, comprising at least a part of one or more spark plugs, and a second chamber, comprising the mobile pre-chamber, the first chamber, the second chamber and the opening being fluidically connected.

Alternatively, the return member can be a spring and/or at least one elastically deformable blade.

In particular, the pre-chamber may comprise at least one flange, in addition to which the first volume comprises at least one blocking member designed to stop the one or more flanges in order to limit the movement of the mobile pre-chamber in the first volume.

According to an exemplary embodiment, the cylinder head may have a lower flank comprising the opening. The mobile pre-chamber may then comprise a lower wall containing the one or more holes, the lower flank and the lower wall being positioned towards the combustion chamber. A first side of the lower flank and a first surface of the lower wall can be flush when the mobile pre-chamber is in the first position.

The invention also refers to a spark-ignition engine comprising a cylinder head according to the invention, at least one cylinder delimiting a combustion chamber and a mobile piston positioned in the one or more cylinders, the cylinder head opening and the one or more pre-chamber holes opening into the combustion chamber.

In particular, the engine additionally comprises an intake valve control device for controlling a displacement, in particular a movement delay, of the said valve.

Furthermore, the invention refers to an operating method for a spark-ignition engine according to the invention, which consists of :
- an inlet phase comprising the inlet of an air flow, fuel injection and negative pressure generation into the cylinder designed to shift the mobile pre-chamber into the second position in order to open the one or more orifices and circulate a drain air flow, in particular extracted from the inlet air flow, through one or more channels, the first volume and towards the combustion chamber, the said flow being designed to discharge any residual burnt gases located in the pre-chamber and/or in the first volume; then
- a compression phase comprising an increase in pressure in the cylinder so that a part of an air-fuel mixture is sent to the pre-chamber and further comprising the ignition of said mixture in the pre-chamber; then
- an expansion phase wherein the air-fuel mixture in the cylinder ignites; then
- an exhaust phase comprising the piston being lifted upwards to discharge residual burnt gases contained in the cylinder's combustion chamber towards the mobile pre-chamber.

Any further details, features and advantages shall be evident from the detailed description given below, which is illustrative and non-limiting, with reference to the various exemplary embodiments illustrated in the following figures:

Figure 1 is a schematic representation of a vehicle equipped with a spark-ignition engine comprising a cylinder head, a spark plug and a mobile pre-chamber.
Figure 2 is a schematic representation of a cylinder head equipped with a spark plug and a mobile pre-chamber.
Figure 3 is a schematic representation of engine operation during an intake phase.
Figure 4 is a schematic representation of engine operation during an exhaust phase.

Figure 1 schematically illustrates an exemplary embodiment of a motor vehicle 1 according to the invention. In particular, the motor vehicle 1 is equipped with a spark-ignition engine 2 according to the invention. The spark-ignition engine 2 is a thermal engine of all types. Also, the vehicle 1 could be of any type, for example, a passenger car, a commercial vehicle, a truck or a bus. In particular, the vehicle 1 under consideration may be a connected and/or autonomous vehicle.

The conventional spark-ignition engine 2 comprises at least one cylinder 21, wherein a mobile piston 22 is positioned. One or more cylinders 21 delimit a combustion chamber 23 wherein the piston 22 is moved and wherein an air-fuel mixture is injected.

The engine 2 also comprises a cylinder head 3. In general, the cylinder head 3 according to the invention comprises at least one shaft 30, also referred to as a spark plug shaft, under which the cylinder head 3 casting, or more precisely the cylinder head 3 material, delimits at least one first volume 300, as well as at least one spark plug 4 and a mobile pre-chamber 5, positioned in one or more first volumes 300. The cylinder head 3 also comprises at least one channel 6 opening into the said first volume 300, which is designed to circulate a drain air flow FV towards the first volume 300 and then, by extending, towards the interior of the pre-chamber 5, and a return member 7 designed to shift the mobile pre-chamber 5, as explained in more detail below.

Also, as illustrated, according to an exemplary embodiment, the cylinder head 3 comprises an intake duct 31 equipped with an intake valve 32 and an exhaust duct 33 equipped with an exhaust valve 34. The cylinder head 3 is installed into the engine 2 in order to ensure a fluidic connection between the intake duct 31 and the exhaust duct 33, on one side, and the combustion chamber 23 of one or more cylinders 21, on other side. The inlet valve 32 and the exhaust valve 34 are conventionally mounted mobile and designed to facilitate or hinder the fluidic connection between the duct wherein each valve is installed and the combustion chamber 23.

The following description refers to a cylinder head 3 comprising a shaft 30, a spark plug 4, a first volume 300 and a pre-chamber 5. It is also understood that the description is made with reference to a considered cylinder 21 of the engine 2 and to an associated part of the cylinder head 3. Nevertheless, it extends to a spark-ignition engine 2 comprising a plurality of cylinders 21 each equipped with a piston 22 and, by extending, to a cylinder head 3 comprising a plurality of shafts 30, first volumes 300, spark plugs 4, intake valves 32 and exhaust valves 34.

The cylinder head 3 comprises a first volume 300 wherein one or more spark plugs 4 and a movable pre-chamber 5 are positioned. The first volume 300 is therefore a space delimited by the material of the cylinder head 3. The shaft 30 is open to the first volume 300 and the spark plug 4 is positioned to extend at least partially into the first volume 300. In particular, as illustrated, the spark plug 4 extends partially into the shaft 30 and into the first volume 300, particularly so that a screw thread of the said spark plug 4 extends into the first volume 300. A first end of the said first volume 300 comprising an opening 35 designed to open into the combustion chamber 23 of the associated cylinder 21 when the engine 2 is assembled. A second end of the first volume 300, which is opposite the first end, is connected to the shaft 30 and sealed at least in part, particularly by the spark plug 4, in order to prevent the inflow of liquids and particles which could affect the operation of the spark plug 4.

The conventional spark plug 4 comprising at least one electrically insulating body 41 and an electrically conductive base 42 extending along an extended direction 400. The body 41 is made of an electrically insulating material such as ceramic, especially alumina-based. The base 42 is made of an electrically conductive material, particularly metal. The spark plug 4 is positioned to extend partially into the spark plug shaft 30 of the cylinder head 3, in order to be secured in the cylinder head 3 and at least extend partially into the first volume 300. According to an exemplary embodiment, which is optional but preferable, the spark plug 4 is positioned in a first chamber 301 of one or more first volumes 300. Alternatively, the cylinder head 3 comprises at least one sealing member 35a positioned at the interface between the spark plug 4 and the cylinder head 3, for example positioned around the spark plug 4. In particular, this could be a spark plug joint.

In addition, the spark plug 4 also comprises at least one central electrode 43 and at least one ground electrode 44 separated by an inter-electrode gap, i.e. a gap separating two non-contacting electrodes that is intended to support sparking between the respective electrodes. It is understood that the spark plug 4 may comprise a plurality of ground electrodes 44. Alternatively, the vehicle 1 is equipped with a spark ignition system comprising a spark control unit and a high-voltage electrical circuit designed to supply electrical energy to one or more central electrodes 43 of the spark plug 4. One or more spark plugs 4 are therefore standard and have no integrated pre-chamber.

One or more channels 6 are positioned to supply the first volume 300, and by extending an intermediate volume 550 that is delimited by the mobile pre-chamber 5 and at least partially included in the first volume 300, with a drain air flow FV. The term “drain air flow FV” refers to an air flow circulating through all or part of the first volume 300, in particular through one or more channels 6 and the mobile pre-chamber 5, in order to evacuate any residual burnt gases that may have collected there towards the combustion chamber 23. As explained in more detail below, the drain air flow FV enables the pre-chamber 5 to be cleaned.

One or more channels 6 open into the first volume 300 through at least one orifice 61. According to an exemplary preferred embodiment, one or more channels 6 are fluidically connected to the inlet duct 31 at a divergence point 62. Therefore, one or more channels 6 extend between the inlet duct 31 and the first volume 300. This extracts a part of the intake air flow FA, which flows through intake duct 31 towards combustion chamber 23, and directs it towards first volume 300 and mobile pre-chamber 5. The extracted portion of intake air flow FA then forms drain air flow FV as described above.

Alternatively, an engine intake system, not illustrated, supplying intake air flow FA to the intake duct 31, can be equipped with at least one filter and a flow meter. One or more channels 6 are then preferably connected to the intake duct 31 downstream of said filter and/or said measuring device in the direction of the intake air flow (FA). According to various exemplary embodiments, one or more channels 6 form a passage in the cast material of the cylinder head 3, or a tube connecting various points on the cylinder head 3 to one another, i.e. the bifurcation point 62 and one or more orifices 61.

The mobile pre-chamber 5 is an insert positioned in the first volume 300 within the material of the cylinder head 3. The term “pre-chamber 5” is conventionally taken to refer to a chamber separate from the combustion chamber 23 of one or more cylinders 21 and having a limited volume, in particular a volume more limited than that the combustion chamber 23, into which a fuel mixture, also known as an air-fuel mixture, is injected and then spark ignited. A hot jet of combustion gases is then generated and delivered to an external environment of cylinder head 3, namely to combustion chamber 23 of the cylinder 21. In particular, according to the invention, the pre-chamber 5 is a passive chamber, i.e. a pre-chamber 5 without a fuel supply system, or injector, which would conventionally be used to inject fuel directly into the pre-chamber 5. According to the invention, the pre-chamber 5 is also separate from one or more spark plugs 4.

The mobile pre-chamber 5 conventionally comprises at least one opening 51 designed to facilitate the passage of air-fuel mixture between the combustion chamber 23 and the pre-chamber 5, as described in more detail below with reference to the process according to the invention. The mobile pre-chamber 5 also comprises at least one wall that delimits the intermediate volume 550 of the pre-chamber 5.

According to a non-limiting exemplary embodiment, the mobile pre-chamber 5 comprises a cylindrical or partly cylindrical shape that is at least partially complementary to the first volume 300 wherein it is positioned. For example, the pre-chamber 5 is centered on a main axis 500 and extends along the said axis. In particular, the pre-chamber 5 comprises a side wall 52 or a plurality of side walls 52 that define the cylindrical form of the base. The pre-chamber 5 also comprises a base wall 53, which delimits one side of the pre-chamber 5 more distant from the spark plug 4. In this case, the base wall 53 comprises at least one hole 51. For example, the mobile pre-chamber 5, especially the base wall 53, comprises a plurality of holes 51 designed for fluid connection between the intermediate volume 550, and by extending the first volume 300 comprises the spark plug 4, and the combustion chamber 23 of the cylinder 21.

In addition, the mobile pre-chamber 5 is preferably open on one side, especially on a side which is faced towards the spark plug 4 within the first volume 300 and/or a side which is opposite to the side comprisng at least a hole 51. In the example illustrated, the side opened is an upper side of the mobile pre-chamber 5, which corresponds to an uppermost side of the pre-chamber 5 within the engine 2, in order to facilitate the inlet of drain flow and the spreading of flames.

Alternatively, but preferably, the pre-chamber 5 is made of a metallic material such as steel, in particular a metallic material resistant to temperatures of around 600°C.

According to the exemplary embodiment illustrated, the spark plug 4 is positioned in the first chamber 301 as described above, and the first volume 300 additionally comprises a second chamber 302, wherein the mobile pre-chamber 5 is positioned and can be moved. The first cavity 301, the second cavity 302 and the opening 35 of the cylinder head 3 are then connected fluidically. Alternatively, the spark plug 4 and the mobile pre-chamber 5 could be positioned in the same cavity of the first volume 300, the spark plug 4 being maintained in a fixed position in order to extend at least partially into this cavity, while the pre-chamber 5 would be movable in this cavity.

The mobile pre-chamber 5 is positioned in the first volume 300 and designed for movement within the said volume. Consequently, the mobile pre-chamber 5 is positioned to be displaced with respect to the spark plug 4, which remains in a fixed position within the first volume 300 delimited by the material of the cylinder head 3 under the spark plug well 30.

The mobile pre-chamber 5 is particularly designed for movement between a first position and a second position. The first position is a “closed” configuration wherein the mobile pre-chamber 5 obstructs and closes one or more orifices 61 in order to interrupt the drain air flow FV passing through the one or more channels 6 to the first volume 300. For example, one or more pre-chamber walls seal off at least one orifice 61. In this case, one or more walls is considered to be the side wall 52 or one of the side walls. The term “close” referring to one or more orifices 61 indicates that at least a part of mobile pre-chamber 5 is positioned opposite at least one orifice 61, particularly in contact with a flank that delimits the first volume 300 comprising the said orifice 61, in order to interrupt the fluidic connection between one or more channels and the first volume 300. For example, the flank under consideration is a side flank of the first volume 300. On the other hand, the second position represents an “open” configuration wherein the mobile pre-chamber 5 extends at a non-zero distance from one or more orifices 61 in order to re-establish the fluidic connection between the one or more channels 6 and the first volume 300 and circulate the drain air flow FV in the first volume 300 and the intermediate volume 550 of the pre-chamber 5. One or more orifices 61 are then completely or partially unobstructed.

According to a preferable but optional exemplary embodiment, the mobile pre-chamber 5 is configured to be moved in a translational movement T1, along a first direction 100, within the first volume 300. For example, the first direction 100 is parallel, or substantially parallel, to the direction of extension of the spark plug 4 and/or to the main axis 500 of the pre-chamber 5. In particular, the movement of the mobile pre-chamber 5 is limited to the second cavity 302.

Alternatively, but preferably, the mobile pre-chamber 5 comprises at least one flange 54 to limit its movement. The first volume 300 then comprises at least one blocking member 36 configured to stop the one or more flanges 54 in order to limit the movement of the mobile pre-chamber 5 in the first volume 300, especially in the second cavity 302.

For example, one or more walls, in particular one or more side walls 52, comprise a flange 54. One or more flanges extends from all or part of an external surface of the one or more walls, which faces one or more sides of the first volume 300. According to the illustrated exemplary embodiment, one or more flanges 54 extend along a second direction 200, transverse, especially orthogonal, to the main axis 500 of the pre-chamber and/or to the first direction 100. Preferably, one or more flanges 54 are positioned in an upper half of the pre-chamber 5. One or more flanges 54 extend around all or part of the circumference of the cylindrical shape of the mobile pre-chamber 5. For example, one or more flanges 54 are designed to surround all or part of the external surface of the pre-chamber 5.

The mobile pre-chamber 5 is dimensioned so that it can be displaced within the first volume 300. Also, a first dimension of the pre-chamber 5, here defined along the main axis 500, which is strictly smaller than a first dimension of the first volume 300 and/or a first dimension of the second cavity 302 along these same directions. A second dimension of the pre-chamber 5, which is measured along the second direction 200, is strictly smaller than a second dimension of the first volume 300. The second dimension of the pre-chamber 5 corresponds to a diameter or diagonal of the base of the cylindrical shape, for example. Alternatively, one or more flanges can be at least partially in contact with one or more flanks, in particular lateral flanks, of the first volume 300, for example by limiting the displacement of the pre-chamber 5 along the second direction 200.

One or more blocking members 36 are positioned in the first volume 300 and enable, for example, the mobile pre-chamber 5 to be prevented from moving further than the first position and/or the second position. In this case, the first volume 300 comprises a plurality of blocking members 36. A first blocking member 36a comprises an intermediate flank 37 of the first volume 300 that is configured to stop the pre-chamber 5 moving along a first direction 100. A second blocking member 36b comprises a lower flank 38 of the first volume 300 that is configured to stop one or more flanges 54 along a second direction, opposite to the first direction, along the first direction 100. In this case, non-restrictively, the intermediate flank 37 helps to delimit the first cavity 301 and the second cavity 302. Likewise, for example, the lower flank 38 comprises the opening 35 of the first volume 300, with the second blocking member 36 especially comprising an edge of the opening 35.

The return member 7 can move the pre-chamber 5 between the first position and the second position, therefore indirectly controlling the drain air flow FV. In particular, as explained below, the return member 7 can move the mobile pre-chamber 5 from the second position to the first position. It therefore operates together with the mobile pre-chamber 5 during the engine cycle 2. The return member 7 indirectly controls the drain air flow FV according to the position of the mobile pre-chamber 5 as described above. The term “control” is used here to describe the interruption of the fluidic connection between one or more channels 6 and the combustion chamber 23 in such a way as to interrupt the circulation of the said flow, or the enabling of such fluidic connection.

The return member 7 is therefore a passive, non-engine-driven member. The term “passive” refers to control that does not require direct engine-driven actuation. For example, the return member 7 is a spring and/or at least one elastically deformable blade. According to an exemplary embodiment, the return member 7 encloses at least a part of the mobile pre-chamber 5. The return member 7 extends into a space between the mobile pre-chamber 5 and one or more side walls of the first volume 300. In particular, the return member 7 is positioned in contact with a surface of the first volume 300, for example the lower sidewall 38. According to the exemplary, non-limiting embodiment illustrated, the return member 7 is positioned in contact with one or more blocking members 36, in particular the second blocking member 36b. The return member 7 is also positioned in contact with the mobile pre-chamber 5. For example, the return member 7 is positioned in contact with one or more flanges 54. In particular, the return member 7 is interposed, along the first direction 100 and/or the main axis 500, between at least a part of the pre-chamber 5 and at least a part of the first volume 300. In this case, the return member 7 is interposed between at least one flange 54 of the pre-chamber 5 and the lower flank 38 of the first volume 300.

When the pre-chamber is in the first position, in the “open” configuration, the return member is particularly in an initial, or nominal, configuration. As explained in more detail below, with reference to the process according to the invention, the return member 7 is actuated passively, in this case by moving the mobile pre-chamber 5. The movement of mobile pre-chamber 5 initially takes place as a function of a differential pressure defined between a pressure measured in the first volume 300 and a pressure measured in combustion chamber 23.

The mobile pre-chamber 5 is shifted to the second position when a negative pressure is generated in the combustion chamber 23 during an intake phase of the engine cycle 2. In particular, the mobile pre-chamber 5 is aspirated in the second position and therefore moved towards cylinder 21 and combustion chamber 23. The term “negative pressure” is used here to refer to the pressure reduction in combustion chamber 23 to a value strictly below atmospheric pressure. When moved to the second position, the pre-chamber 5 exerts a force on the return member 7. In particular, the return member 7 is pre-tuned in order to present a resistance adapted for such movement of the pre-chamber as a function of a predefined negative pressure level. As a result of the movement of the pre-chamber 5, one or more orifices 61 are exposed and the drain air flow FV circulates in the one or more channels 6, in the first volume 300, particularly through the pre-chamber 5, and is then directed to the combustion chamber 23 of the cylinder 21 through one or more holes 51. The drain air flow FV therefore evacuates all or part of any residual burnt gas accumulation contained in the first volume 300, particularly in the intermediate volume 550 of the pre-chamber 5, towards the combustion chamber 23.

Subsequently, when the pressure differential decreases, the mobile pre-chamber 5 is passively moved to the first position. The return force exerted by the return member 7 then causes the return member 7 to passively return to its initial configuration, and consequently pushes the pre-chamber 5 towards the first position at the contact zones between the pre-chamber 5 and the return member 7. The pre-chamber 5 placed in the first position again obstructs one or more orifices 61 and prevents the circulation of draining air flow FV in the first volume 300. This principle can be observed, for example, when the differential pressure decreases to the point where it is insufficient to hold the pre-chamber 5 in the second position, particularly when the return member 7 is adjusted.

In order to optimize the positioning of mobile pre-chamber 5 in cylinder head 3, and to minimize its impact on the volume of combustion chamber 23, mobile pre-chamber 5 is dimensioned and positioned so that a first surface 531 of lower wall 53 in pre-chamber 5 and a first face 381 of lower flank 38 in first volume 300, configured to face combustion chamber 23 within engine 2, are aligned in the same level when pre-chamber 5 is positioned in the first position. The first surface 531 and the first face 381 are therefore perfectly flush. Alternatively, when the pre-chamber 5 is positioned in the first position, the first surface 531 of the lower wall 53 in the pre-chamber 5 has a position higher than a position of the first face 381 of the lower sidewall 38 in the first volume 300, so that the first face 381 is interposed between the first surface 531 in the pre-chamber 5 and the combustion chamber 23 along the first direction 100 and/or the main axis 500. The mobile pre-chamber 5 does not affect the volume of the combustion chamber 23 or the engine 2 during operation.

The invention also refers to an operating method for the spark-ignition engine 2 according to the invention. This process is implemented during an engine cycle 2, which typically comprises intake, compression, expansion and exhaust phases.

During the intake phase, as illustrated in Figure 3, an intake air flow FA into one or more cylinders 21, the process also comprises the generation of a negative pressure in the cylinder 21, especially in the combustion chamber 23, which can shift the mobile pre-chamber 5 into the second position. As mentioned above, the negative pressure here consists of pressure reduction in the combustion chamber 23 to the value strictly below atmospheric pressure. The negative pressure generated drives the pre-chamber 5 towards the second position, i.e. towards the combustion chamber 23, so that the mobile pre-chamber 5 extends at a non-zero distance from one or more orifices 61. The mobile pre-chamber 5 is therefore in open configuration, at least one orifice 61 is clear and at least one channel 6 is in fluidic connection with the first volume 300 and, by extending, with the combustion chamber 23. The drain air flow FV then circulates through one or more channels 6, into the first volume 300, especially into the intermediate volume 550 of the mobile pre-chamber 5, and then through one or more holes 51 towards the combustion chamber 23.

According to a preferred exemplary implementation of the process under the invention, a negative pressure is generated in the combustion chamber 23 through the implementation of a delayed intake open, or ROA, consisting of maintaining the intake valve 32 closed when the piston 22 is initiated to descend. For example, the intake opening delay is implemented by a control device, not illustrated, for the intake valve 32, which can trigger a shift in an opening law 35 of the said valve in the engine cycle 2. The pressure in one or more cylinders 21 is therefore mechanically lowered to a value strictly lower than atmospheric pressure and strictly lower than the pressure in intake duct 31. As mentioned above, when the negative pressure generated in the combustion chamber 23 is sufficient, the mobile pre-chamber 5 is aspirated towards the combustion chamber 23. It then shifts to the second position and passively releases one or more orifices 61. The mobile pre-chamber 5 is therefore in the “open” configuration, and the drain air flow FV circulates through one or more channels 6, penetrates into the first volume 300 and passes through the pre-chamber 5 and one or more holes 51 before being aspirated into the combustion chamber 23 as a result of the negative pressure. All or part of the residual burnt gases remaining in the first volume 300 and the intermediate volume 550, particularly in the mobile pre-chamber 5, that have accumulated during a previous combustion in an earlier engine cycle 2, are then aspirated towards the cylinder 21. The mobile pre-chamber 5 can therefore be cleaned, also known as “drained”, by passively discharging residual burnt gases, with no need for a tank or motorized system for discharging the drain air flow. Simultaneously, the mobile pre-chamber 5 exerts a force on the return member 7, particularly through the flange 54 as described above. For example, it is lowered so that it extends at least partially into the combustion chamber 23 of cylinder 21.

As indicated above, when one or more channels 6 are connected to the intake duct 31, as shown in Figures 1 to 4, the drain air flow FV is a part of the intake air flow FA diverted from its conventional trajectory, i.e. from the intake duct 31, and redirected to the first volume 300 through one or more channels 6. The preferred bifurcation point 62, for example a tapping point for one or more channels 6 on the intake duct 31, is positioned downstream of the filter and/or the device for measuring the intake air flow rate FA, depending on the circulation of intake air flow FA into intake duct 31. This principle advantageously ensures that the drain air flow FV extracted from the intake air flow FA is free of particles and/or that the quantity of air injected into cylinder 21, which corresponds to a combination of the remaining intake air flow and the drain air flow FV, is well known.

It should be noted that, preferably, the process according to the invention can be implemented to run only during defined operational periods of the engine 2. For example, the process can be performed when engine 2 is running at low load. The process according to the invention can then be inactive and no pre-chamber 5 draining is carried out, when engine 2 is operating in overload.

Subsequently, the intake valve 32 is conventionally opened, the cylinder 21 is filled with a flow of intake air FA from the intake duct 31, and fuel injection is initiated. The atomized fuel is mixed with the moving intake air flow FA to form a fuel-air mixture in the combustion chamber 23.

It should be noted that, when the inlet valve 32 opens, the pressure in the combustion chamber 23 converges towards the pressure prevailing in the inlet duct 31. As a result, the negative pressure initially generated is reduced or even interrupted. For example, in case of a high-load supercharged engine 2, the pressure measured in the intake duct 31 is strictly higher than atmospheric pressure. During this part of the inlet air flow FA phase, the pre-chamber 5 can, according to the engine 2 operation, the pressure measured in the cylinder 21, the pressure measured in the inlet duct 31 and the setting of the return member 7, be moved to the first position or held in the second position. The mobile pre-chamber 5 can be lifted into the first position, or into an intermediate position between the first and second positions, under the control of the return member 7.

As we know, the engine cycle 2 continues with the compression phase. The inlet valve 32 and the exhaust valve 34 are closed. Under the control of the return member 7, the pre-chamber 5 is displaced into the first position, which corresponds to its nominal position, if such movement has not taken place during the intake phase. The mobile pre-chamber 5 is then in a “closed” configuration and obstructs one or more orifices 61, thereby interrupting the fluidic connection between the first volume 300 and the one or more channels 6.

Fuel injection continues, and the fuel mixture is homogenized by the turbulence in the combustion chamber 23 of cylinder 21. The piston 22 retracts into cylinder 21, increasing the pressure in combustion chamber 23 and first volume 300. The pressure in combustion chamber 23 is increased. A part of fuel mixture is then sent to pre-chamber 5 through one or more holes 51. At the end of the compression phase, the spark ignition system triggers a sparkle at spark plug 4, which causes the compressed fuel mixture to burn in pre-chamber 5 and part of intermediate volume 550. As combustion continues, the pressure in mobile pre-chamber 5 increases, expelling the flaming gases into combustion chamber 23 with fire jets.

Subsequently, during the expansion phase of the engine cycle, the flame front spreads out in the combustion chamber 23 into fire jets that constitute a number of ignition points, thereby optimizing the timing of the heat release mechanism and combustion efficiency. The inlet valve 32, the exhaust valve 34 and one or more orifices 61 are then always closed.

Lastly, during the exhaust phase, illustrated in Figure 4, the exhaust valve 34 opens. The piston 22 retracts and simultaneously displaces residual burnt gases remaining in the combustion chamber 23 of cylinder 21 towards exhaust duct 33 and mobile pre-chamber 5. In particular, a majority of residual burnt gases are discharged to the exhaust duct 33, while some are directed to the mobile pre-chamber 5. Some residual burnt gases are therefore discharged from the engine 2 through the exhaust duct 33, while some are collected in the intermediate volume 550 and in the pre-chamber 5. The residual burnt gases therefore collected in the intermediate volume 550, adjacent to one or more spark plugs 4, can be discharged during the intake phase of a subsequent engine cycle 2, as described above.

The cylinder head 3 and the process according to the invention therefore facilitate the passive draining of the mobile pre-chamber 5 positioned in the first volume 300, thereby limiting the residual burnt gases collected around the spark plug 4 through excessive concentration, which could prevent the fuel mixture from initiating combustion. Draining the residual burnt gases that collected during previous combustions and discharged to cylinder 21 during the intake phase, enables the pre-chamber 5 to be cleaned independently before it is refilled with a fuel mixture.

The invention therefore offers an alternative to cylinder heads equipped with spark plugs, in particular pre-chamber spark plugs, for example passive spark plugs. The invention is designed to prevent the collection of residual burnt gases around the spark plug. The proposed solution is advantageously designed to accommodate standard spark plugs without a pre-chamber 5. The integration of mobile pre-chamber

5 advantageously optimizes the volume of said pre-chamber 5 for combustion, while facilitating the passive draining of residual burnt gases with no need for engine-driven intervention directly on the said pre-chamber.

Nevertheless, this invention is not limited to the methods and configurations described and illustrated herein, and it also extends to any equivalent methods or configurations, and any technically effective combination of such methods, insofar as they eventually fulfil the functionalities described and illustrated herein.

CLAIMS

1. Cylinder head (3) for spark-ignition engine (2) comprising at least one spark plug shaft (30) and a first volume (300), the first volume (300) being delimited in particular by the material of the cylinder head (3) below the said shaft (30), a first end of the said first volume (300) comprising an opening (35) configured to open into a combustion chamber (23) of a cylinder (21), the cylinder head (3) also comprising:
- at least one spark plug (4) at least partly positioned in the first volume (300), in particular positioned in the first volume from the shaft (30);
- at least one channel (6) opening into the first volume (300) at the level of at least one orifice (61) and configured to allow the circulation of a drain air flow (FV) towards the first volume (300);
- a mobile pre-chamber (5) comprising at least one hole (51) designed for the passage of a fuel-air mixture between the combustion chamber (23) and the pre-chamber (5), the pre-chamber (5) being positioned in the first volume (300) and configured to be moved in the first volume (300), relative to the spark plug (4), between a first position, wherein it extends opposite the at least one orifice (61) in order to interrupt the circulation of drain air (FV) into the first volume (300), and a second position wherein it extends at a distance from the one or more orifices (61) in order to circulate the drain air flow (FV) in the first volume (300);
- a return member (7) designed to move the pre-chamber (5) between the first position and the second position.

2. Cylinder head (3) according to the preceding claim, further comprising an intake duct (31), equipped with an intake valve (32), and an exhaust duct (33), equipped with an exhaust valve (34), the at least one channel (6) being connected by a fluidic connection to the intake duct (31).

3. Cylinder head (3) according to one of the preceding claims, wherein the pre-chamber (5):
- comprises a metallic material, such as steel; and/or
- is configured to be positioned for translational movement along a first direction (100) within the first volume (300).

4. Cylinder head (3) according to one of the preceding claims, wherein the first volume (300) comprises a first cavity (301), comprising at least a part of one or more spark plugs (4), and a second cavity (302), comprising the mobile pre-chamber (5), the first cavity (301), the second cavity (302) and the opening (35) being in fluidic connection.

5. Cylinder head (3) according to one of the preceding claims, wherein the return member (7) is a spring and/or at least one elastically deformable blade.

6. Cylinder head (3), according to one of the preceding claims, wherein the pre-chamber (5) comprises at least one flange (54), the first volume (300) also comprising at least one blocking member (36) configured to constitute a stop for one or more flanges (54) in order to limit the movement of the pre-chamber (5) which is movable in the first volume (300).

7. Cylinder head (3) according to one of the preceding claims, comprising a lower flank (38) comprising the opening (35) and wherein the mobile pre-chamber (5) comprises a lower wall (53) comprising one or more holes (51), the lower flank (38) and the lower wall (53) being configured to turn towards the combustion chamber (23), a first face (381) of the lower flank (38) and a first surface (531) of the lower wall (53) being flush when the mobile pre-chamber (5) is in first position.

8. A spark-ignition engine (2) comprising a cylinder head (3) according to one of the preceding claims, at least one cylinder (21) delimiting a combustion chamber (23) and a mobile piston (22) positioned in the at least one cylinder (21), the opening (35) of the cylinder head (3) and one or more holes (51) of the pre-chamber (5) opening into the combustion chamber (23).

9. A spark-ignition engine (2) according to the preceding claim, comprising also a device for controlling the intake valve (32), designed to control a movement, in particular a delay in movement, of the said valve.

10. Operating method for a spark-ignition engine (2) according to claim 8 or 9, comprising :
- an inlet phase comprising the inlet of an air flow, fuel injection and negative pressure generation in the cylinder (21) designed to move the mobile pre-

chamber (5) into the second position in order to open one or more orifices (61) and circulate a drain air flow (FV), particularly extracted from the inlet air flow, in at least one channel (6), the first volume (300) and towards the combustion chamber (23), the said flow being used to discharge burnt gases into the combustion chamber (23), the said flow being designed to expel residual burnt gases located in the pre-chamber (5) and/or in the first volume (300); then

- a compression phase comprising a pressure increase in the cylinder so that a part of an air-fuel mixture is sent to the pre-chamber (5) and also comprising the ignition of said mixture in the pre-chamber (5); then
- an expansion phase, wherein the air-fuel mixture in the cylinder (21) ignites; then
- an exhaust phase, comprising the piston (22) being lifted to discharge some of the residual burnt gases contained in the combustion chamber (23) of the cylinder (21) towards the mobile pre-chamber (5).

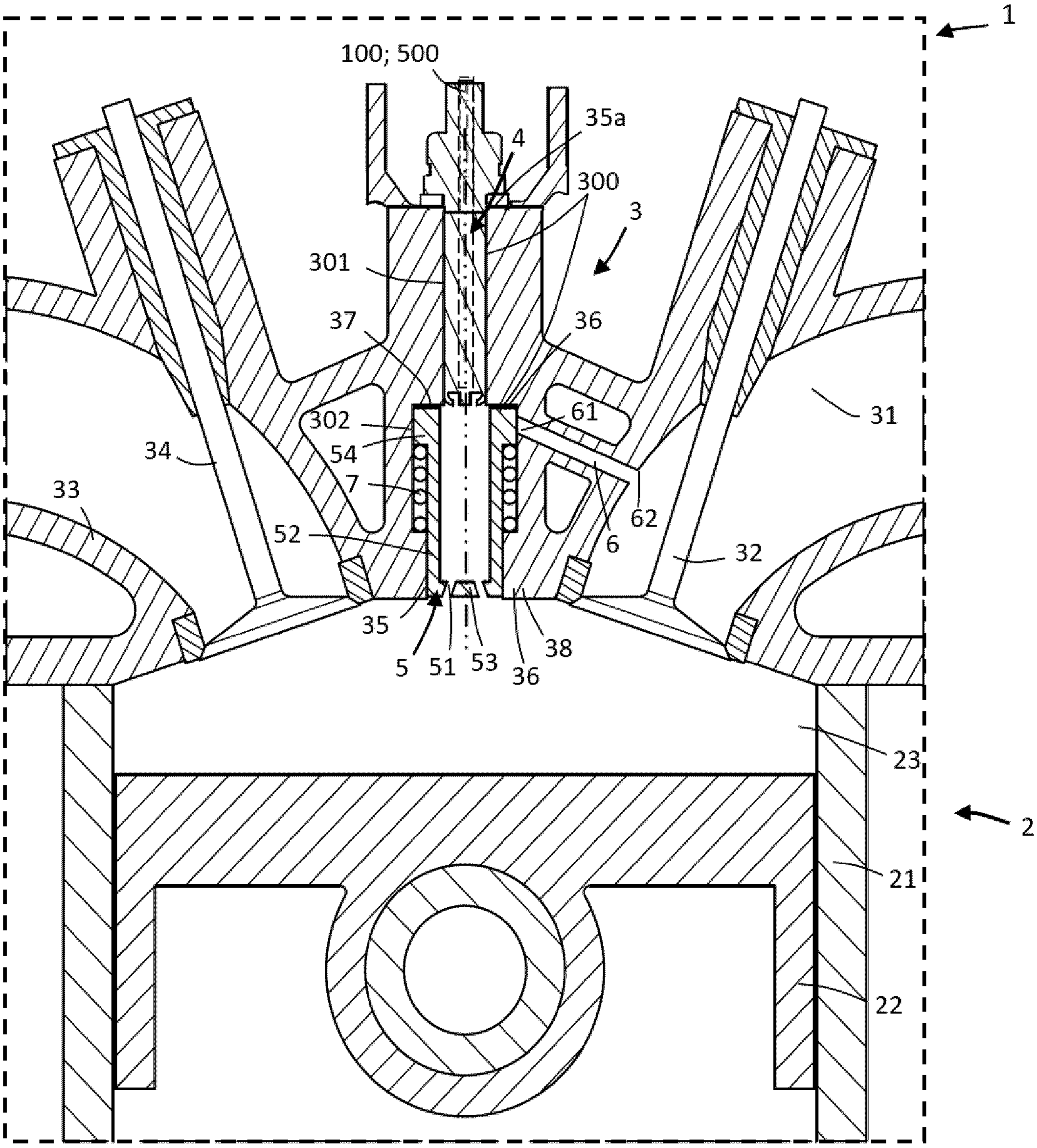
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FIG. 1

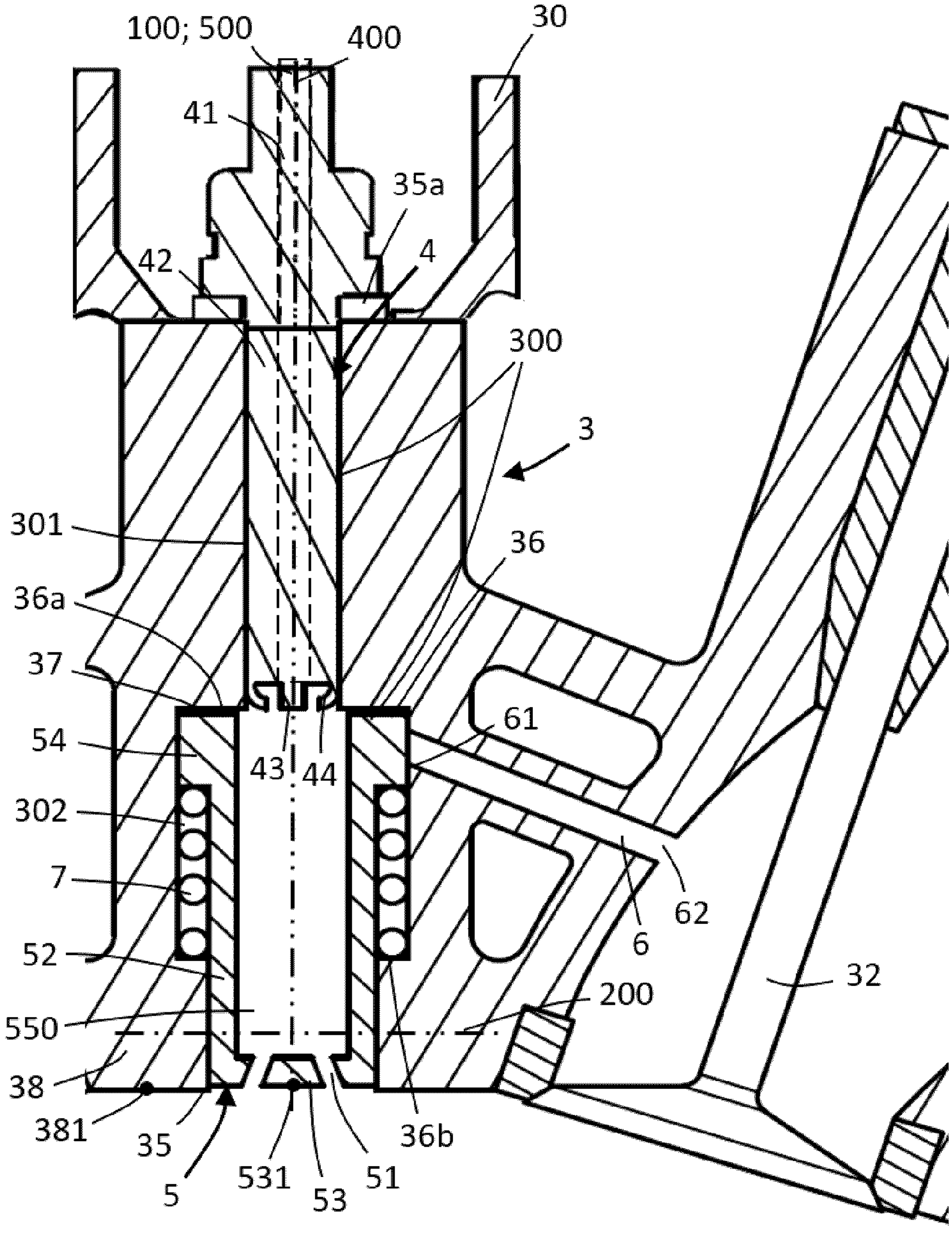
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FIG. 2

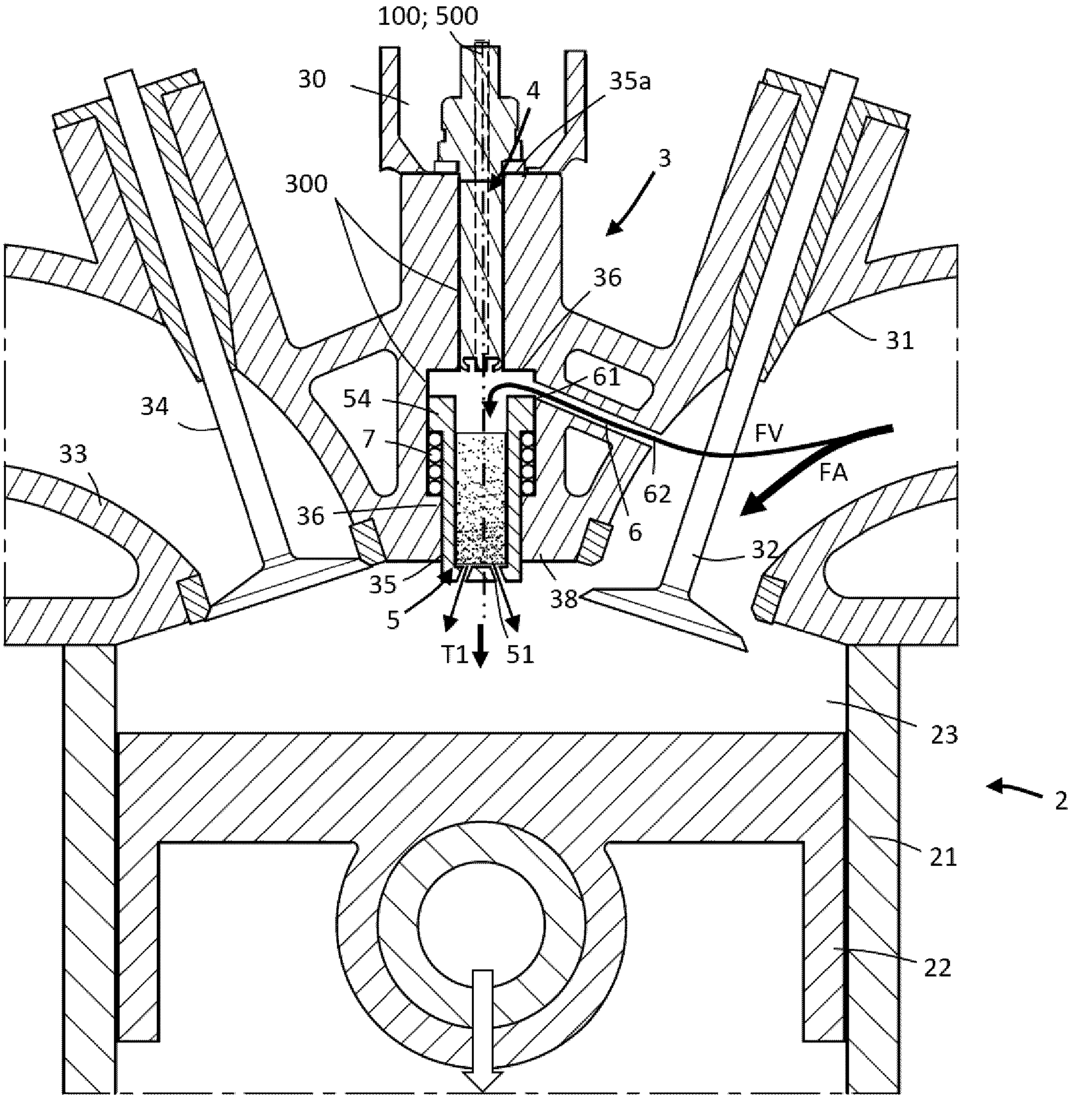
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FIG. 3

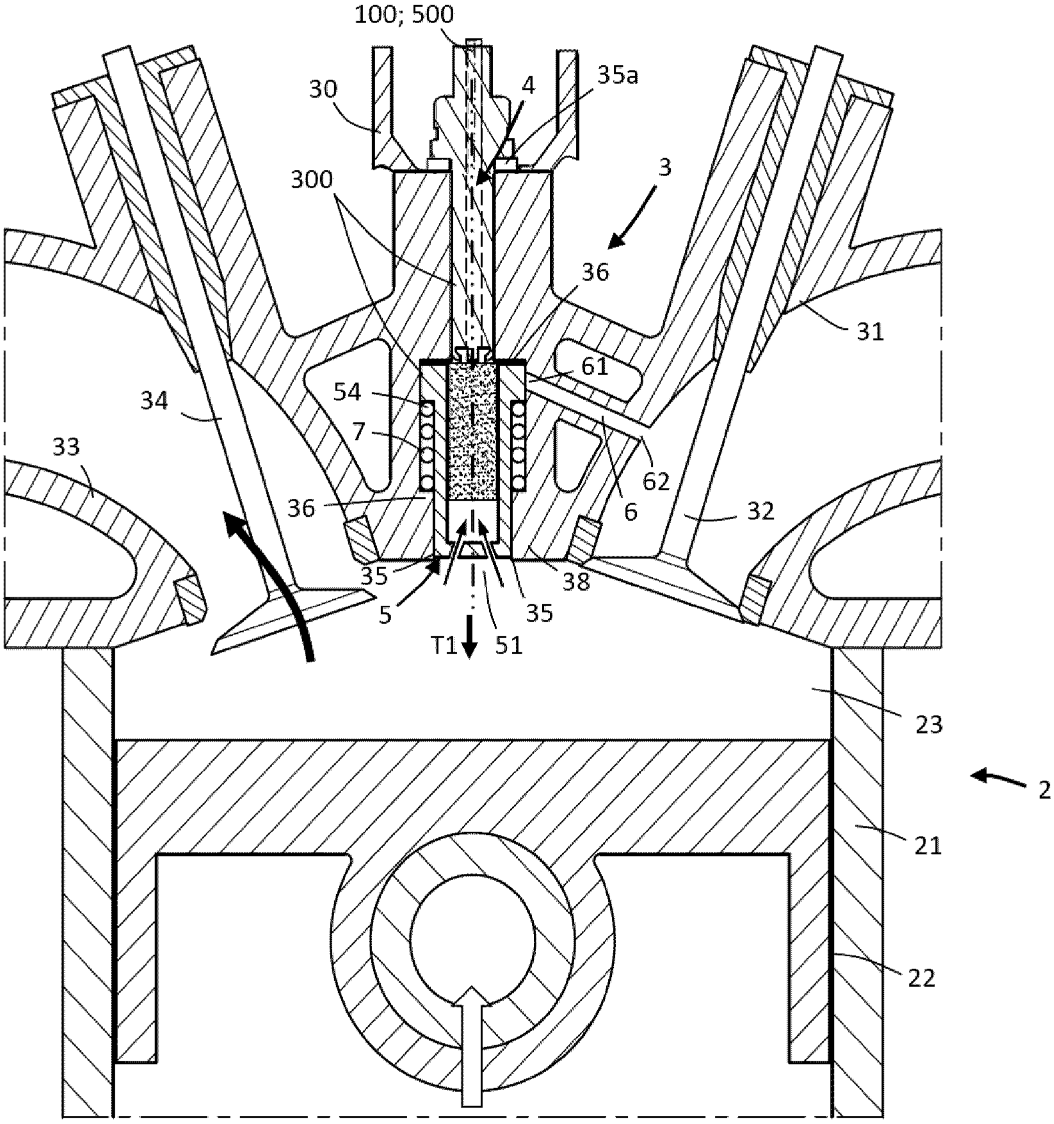
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FIG. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2024/066421

A. CLASSIFICATION OF SUBJECT MATTER
INV. F02B19/12 F02B19/16 F02B25/00 F02D13/02
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F02B F02D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE 10 2015 210669 A1 (MTU FRIEDRICHSHAFEN GMBH [DE]) 15 December 2016 (2016-12-15) abstract -----	1-10
A	US 2021/003066 A1 (KRAEMER FRANK [DE] ET AL) 7 January 2021 (2021-01-07) paragraph [0039]; figure 1 -----	1-10
A	DE 10 2019 208472 A1 (MTU FRIEDRICHSHAFEN GMBH [DE]) 17 December 2020 (2020-12-17) abstract -----	9

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
9 September 2024	25/09/2024

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Torle, Erik

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2024/066421

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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DE 102019208472 A1	17-12-2020	NONE	