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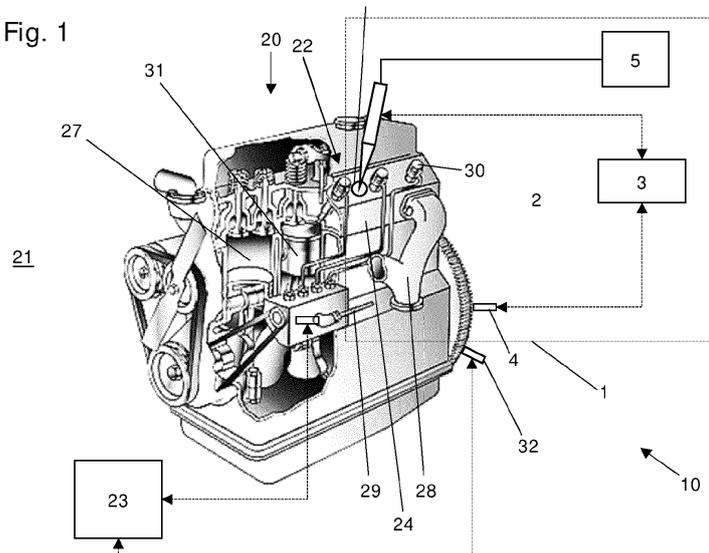
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(54) **A COMBUSTION ENGINE SYSTEM, A RETROFIT SYSTEM FOR RETROFITTING A COMBUSTION ENGINE, AND A METHOD FOR RETROFITTING COMBUSTION ENGINE**

(57) A combustion engine system (10) comprising a combustion engine (20), a retrofit system (1) being retrofitted to the combustion engine (20), and an engine control arrangement, wherein the combustion engine (20) comprises a combustion chamber (27), an inlet channel (28) connected to the combustion chamber (27), a main fuel provision arrangement (22) connected to the inlet channel (28) and/or to the combustion chamber (27) and configured for providing a main fuel into the inlet channel (28) and/or into the combustion chamber (27), and a receiving arrangement (25) arranged in a housing (24) of the combustion engine (20), wherein the receiving arrangement (25) comprises an original opening (26) in the housing (24), the original opening (26) is originally formed into the housing (24) during an original manufacturing process of the combustion engine (20)

and is not subsequently manufactured into the housing (24) after the original manufacturing process was finalized, the original opening (26) is forming a physical pathway between an environment (21) of the combustion engine (20) into the combustion chamber (27), wherein the retrofit system (1) comprises an additional fuel provision arrangement (2), which is configured for providing an additional fuel into the inlet channel (28) and/or into the combustion chamber (27), and wherein the additional fuel provision arrangement (2) is mounted by retrofitting to the receiving arrangement (25), in particular to the original opening (26), of the combustion engine (20), and wherein the engine control arrangement is configured for controlling the main fuel provision arrangement (22) and/or the additional fuel provision arrangement (2).

Fig. 1



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Description

[0001] The invention relates to the technical field of combustion engines and in particular to combustion engines operated in a dual-fuel-operation mode.

[0002] Combustion engines are mainly operated with one single type of fuel, wherein the combustion engine can be operated according to optimum conditions and settings. However, in certain fields bi-fuel operated combustion engines or dual-fuel combustion engines are used.

[0003] Bi-fuel vehicles are vehicles with multi-fuel engines which can be operated with more than one type of fuel. For example, when it comes to combustion engines a first fuel is gasoline or diesel. Bi-fuel vehicles have the ability to switch manually or automatically from gasoline or diesel to the other fuel.

[0004] A diesel engine is a compression ignition engine and has no spark plug. To run a diesel engine on an alternative fuel source such as natural gas, a dual-fuel system is used. Dual-fuel operation means that the engine uses two fuels (gas and diesel) simultaneously, as opposed to bi-fuel, which means that the engine has the option of using one of the two fuels separately.

[0005] WO 2022 247290 A1 discloses a dual-fuel and multi-fuel internal combustion power device.

[0006] CN 114991952 A describes an internal combustion engine fuel supply and discloses a dual-fuel supply system. The dual-fuel supply system comprises a cylinder, a hydrogen supply system, an ammonia supply system, an exhaust gas recirculation system, an air supply system, and an electronic control unit. The hydrogen supply system communicates with the air cylinder and comprises a hydrogen cylinder assembly and a hydrogen heat exchanger which communicate with each other. The electronic control unit is used for sending instructions to the air supply system, the hydrogen supply system, and the ammonia supply system.

[0007] Presently known solutions often come with a complex system, wherein each and every technical detail is specifically adapted for predetermined requirements and for optimizing the output.

[0008] Therefore, there is a need for simplifying combustion engines that can be run on a plurality of fuels, in particular, that can be run by a mixture of different fuels, wherein the application of such operating principle shall be extended.

[0009] Such problem is solved by a combustion engine system according to claim 1, by a combustion engine a retrofit system according to claim 11, and/or by a method for retrofitting a combustion engine according to claim 14. Further embodiments of the invention are described in the dependent claims.

[0010] According to an aspect of the invention a combustion engine system is disclosed. The combustion engine system comprises a retrofit system for retrofitting a combustion engine, a combustion engine, and an engine control arrangement for controlling the main fuel

provision arrangement and/or the additional fuel provision arrangement. The combustion engine comprises a combustion chamber, an inlet channel connected to the combustion chamber, and a main fuel provision arrangement. The main fuel provision arrangement is connected to the inlet channel and/or to the combustion chamber such that a main fuel can be provided into the inlet channel and/or into the combustion chamber for the purpose of combustion. If the combustion engine includes a pre-combustion chamber the term "combustion chamber" may also include the pre-combustion chamber.

[0011] The combustion engine may be a reciprocating combustion engine with internal combustion, and in particular therefore having a piston which transforms expanding combustion gases into a translational movement, which subsequently is transformed into a rotational movement by the use of a crankshaft. The combustion engine may also be a Wankel combustion engine, wherein a rotating combustion and working secondary volume is reciprocating in its absolute size.

[0012] According to the invention, the combustion engine is having a receiving arrangement located in a housing of the combustion engine. The retrofit system comprises an additional fuel provision arrangement which can be arranged by retrofitting into the receiving arrangement. The additional fuel provision arrangement is configured for providing an additional fuel into the inlet channel and/or into the combustion chamber. For example, by this, the combustion engine is enabled to run on dual-fuel, firstly by the main fuel, and additionally by the additional fuel.

[0013] According to an embodiment, the combustion engine is already equipped/adapted to be operated by a plurality of fuel types, in particular according to a dual-fuel and/or bi-fuel configuration. For example, the combustion engine is configured to combust petrol and natural gas. When retrofitting such combustion engine with the additional fuel provision arrangement, the original combustible configuration, in this case petrol and natural gas, is understood as being the "main fuel" provided by the main fuel provision arrangement, regardless if this type of main fuel may comprise two different types of combustible. For example in this case, the retrofitted combustion engine would be a tri-fuel combustion engine.

[0014] The additional fuel is different from the main fuel, or from the types of fuels being originally used by the combustion engine. Preferably, the main fuel is crude oil, heavy fuel oil, marine fuel oil, bunker fuel, furnace oil, gas and oil, heating oil, diesel fuel, or gasoline and similar. The combustion of the additional fuel is more environment-friendly than of the main fuel. That means, when combusted in the combustion engine under normal operating conditions (e.g. the combustion engine is having its operating temperature) the combustion of the main fuel relatively results in a higher number of pollutants than the combustion of the additional fuel. Preferably, the additional fuel is hydrogen.

[0015] The expression "housing of the combustion

engine" may include not only a physical housing of a motor block of the combustion engine but also a housing of the inlet channel or further elements of the combustion engine. Mentioned term may in particular form a boundary between an environment of the combustion engine and an internal combustion pathway of the combustion engine. The internal combustion pathway may include an air filter, and intercooler, air ducts, a compressor, the combustion chamber, an exhaust channel, a turbocharger, a turbine of a turbocharger, and/or a silencer.

[0016] According to an embodiment, the receiving arrangement comprises an original opening in the housing of the combustion engine. The original opening forms a physical pathway between an environment of the combustion engine into the inlet channel and/or in the combustion chamber.

[0017] Specifically, the original opening is originally formed into the housing of the combustion engine during an original manufacturing process. That means, the original opening at least partially forming the receiving arrangement was always in the combustion engine since its manufacturing and has not been manufactured-in into the housing after the finalization of the production of the combustion engine. For example, the original opening is originally arranged in the housing for a specific purpose for example for receiving a glow plaque, spark plug, a temperature measuring device, a pressure measuring device, and/or an optical detection, etc.

[0018] Furthermore, the precedingly described specification of the original opening may include that the original opening is originally pre-formed into the housing of the combustion engine during an original manufacturing process. In this case the pre-formed original opening is only prepared but not finalized during the original manufacturing process. The pre-formed opening was always in the combustion engine since its manufacturing and has not been manufactured-in into the housing after the finalization of the production of the combustion engine. However, for realizing the opening, the original pre-manufactured opening is to be drilled-in or manufactured otherwise. For example, the pre-manufactured but originally closed original opening is originally arranged in the housing for a later specific purpose for example for receiving a temperature measuring device, a pressure measuring device, and/or an optical detection, etc.

[0019] According to an embodiment, the receiving arrangement of the combustion engine is arranged in a cylinder-head of the combustion engine.

[0020] According to an embodiment, the additional fuel provision arrangement is configured such that an interface between the additional fuel provision arrangement and the receiving arrangement is airtight. That means, the additional fuel provision arrangement fits in an airtight and completely off-sealing manner into the receiving arrangement, possibly with the help of sealing elements.

[0021] Furthermore, the airtight configuration of the interface between the additional fuel provision arrangement and the receiving arrangement is/are configured

such that no unwanted additional air can enter the combustion pathway by the receiving arrangement.

[0022] By this, exclusively the additional fuel or a mixture of the additional fuel with oxygen containing air can be provided from the additional fuel provision arrangement into the inlet channel and/or into the combustion chamber via the receiving arrangement. As a result, a combustion engine system partially formed by the retrofit system and the combustion engine, can operate on dual-fuel or multi-fuel. The main fuel is provided according to the original configuration of the combustion engine, for example by injectors injecting the main fuel into the inlet channel and/or into the combustion chamber. The additional fuel is exclusively provided via the original opening of the receiving arrangement by the additional fuel provision arrangement.

[0023] According to an embodiment, the additional fuel provision arrangement comprises pressuring means (e.g. pump) for pressuring the additional fuel. This is for example beneficial if the additional fuel is provided into compressed air within the cylinder during a compression stroke.

[0024] According to an embodiment, the additional fuel provision arrangement may include a so-called pump-injector.

[0025] According to an embodiment, the combustion engine is originally manufactured as a single-fuel-type combustion engine that is adapted to only run on one single fuel. This original combustion engine is not equipped to provide a plurality of types of fuels into the combustion chamber.

[0026] By applying the teaching according to one of the preceding embodiments it is achieved for the first time to obtain a dual-fuel combustion engine out of a single-fuel combustion engine, specifically by applying the retrofit system to the combustion engine. By this, a combustion engine system is obtained which has a high flexibility of application, wherein the operation of the combustion engine system can be aligned according to external requirements and/or to an availability of fuels. For example, the combustion engine system can be operated in a dual-fuel mode if certain environmental regulations require a reduced exhaust pollution. For example, if the combustion engine system is arranged in a ship, the combustion engine can be operated by using two different fuels when being close to a harbor or in an area with more strict pollution regulations. The combustion of the main fuel results relatively in a higher pollution, wherein the additional fuel is a low or non-pollution combustible, for example such as hydrogen.

[0027] Additionally and/or alternatively, the teaching according to one of the preceding embodiments enables the beneficial effect that combustion engines having an original opening can be easily retrofitted and/or updated with an optimized and eco-friendly combustion system without interfering with an original structure of the combustion engine. By this, it is omitted that an original design structure of combustion engine is weakened by adding

an additional and new opening into the housing of the combustion engine. Surprisingly, it was found out that the original opening can be used for this optimization.

[0028] When retrofitting the combustion engine it is explicitly omitted to subsequently manufacturing an additional opening into the housing of the combustion engine since the original opening of the receiving arrangement of the combustion engine is used for applying the additional fuel provision arrangement.

[0029] Additionally and/or alternatively, the teaching according to one of the preceding embodiments enables the beneficial effect that green fuel application in combustion engines is promoted, specifically in originally non-green-fuel designed combustion engines, such as such ship engines.

[0030] Additionally, the teaching according to one of the preceding embodiments enables a widespread application of the dual/multi-fuel combustion in combustion engines by retrofitting a single-fuel combustion engine into a dual-fuel combustion engine. For example, it is possible to retrofit ships having a single-fuel combustion engine, in particular operated with a main fuel as precedingly described.

[0031] It is to be noted that according to the invention the additional fuel is simultaneously combusted with the main fuel in the combustion chamber. Preferably, this must not necessarily be understood that the main fuel and the additional fuel are combusted exactly simultaneously in the very same moment, but the different fuels can be combusted subsequently and/or timely overlapping, but more preferably are combusted in the same working stroke of the of the combustion engine.

[0032] According to an embodiment, the retrofit system comprises an additional engine control device. This additional engine control device is adapted and equipped such that an operational status of the combustion engine, in particular the rotational speed and the rotational position of the crankshaft, and/or the translational position of the piston can be determined. For example, the additional engine control device is equipped and/or connected with a rotation position sensor, in particular having a high resolution. For example, the term "high-resolution" is to be understood as that the rotation position sensor provides at least 5 pulses per 360°-rotation, in particular more than 10 pulses per rotation, preferred more than 50 pulses per rotation, even further preferred at least 180 portals per rotation, particularly further preferred at least 360 portals per rotation. By this, the additional engine control device is well aware of the specific operation condition of the combustion engine. Furthermore, the additional engine control device is configured to use the information about the operational status of the combustion engine such that a predetermined amount of additional fuel can be provided to the inlet channel and/or into the combustion chamber. The term "amount of additional fuel" shall be understood as referring to an amount of energy additionally [Joules (mass of amount by calorific value)] provided to the combustion engine.

[0033] By this, the additional fuel can be added during operation of the combustion engine. Preferably, a main engine control device, and/or an engine control arrangement is configured such, that an amount of main fuel which is provided into the combustion chamber is reduced when a specific amount of additional fuel is additionally provided. For example, the main engine control device and/or the engine control arrangement is adapted to detect an increase of a rotational speed and/or torque due to the additional fuel combusted in the combustion chamber, and consequently the main engine control device and/or engine control arrangement reduces the amount of main fuel in order to maintain a specific operational status of the combustion engine, and vice versa. Furthermore, in particular, the main engine control device and the additional engine control device are configured not to communicate with each other. In particular, there is no data transmission between the main engine control device and the additional engine control device. The consequence of adding the additional fuel into the combustion chamber is detected by the main engine control device and/or by the engine control arrangement solely and exclusively by a change of operation of the combustion engine, in particular by a change of rotational speed and/or torque.

[0034] In other words, the combustion engine and the retrofit system are jointly forming the combustion engine system, but are - at least control-wise, - independent and/or non-/dis-/connected from each other. The main engine control device and/or the engine control arrangement of the combustion engine is/are configured to adjust an amount of main fuel in dependency of an amount of additional fuel provided into the combustion chamber. This results in a non-complex and easy solution to be retrofitted, since control entities/control devices of the original combustion engine are not required to be adapted or manipulated. But simply the retrofit system is applied to the original combustion engine and thereby forming the improved combustion engine system.

[0035] According to an additional and/or alternative aspect of the invention, a retrofit system for retrofitting a combustion engine for forming a combustion engine system is disclosed. The combustion engine system may be embodied according to an embodiment as previously discussed, may comprise a combustion engine as previously discussed, and an engine control arrangement for controlling the main fuel provision arrangement and/or the additional fuel provision arrangement. Positive performance and benefits are achieved mutatis mutandis. Also, details of embodiments as previously described are therefore explicitly disclosed in the context of the aspect of the retrofit system. According to the aspect, the additional fuel provision arrangement is mounted by retrofitting into the receiving arrangement of the combustion engine. Accordingly, the originally existing receiving arrangement is re-used for carrying/supporting/housing the additional fuel provision system. This may also include the embodiment, wherein the opening of the re-

ceiving arrangement is pre-manufactured.

[0036] According to an embodiment of this aspect, the receiving arrangement comprises an original opening in the housing and/or the pre-manufactured opening as precedingly described. The original opening forms a physical pathway between an environment of the combustion engine into the inlet channel and/or into the combustion chamber, wherein the original opening is originally formed ore pre-formed into the housing during an original manufacturing process of the combustion engine and is not subsequently manufactured into the housing after the original manufacturing process was finalized. Further details of disclosure regarding the receiving arrangement are disclosed in the description supra of the preceding embodiment of the retrofit system.

[0037] According to an embodiment, the receiving arrangement of the combustion engine is arranged in a cylinder-head of the combustion engine.

[0038] According to an embodiment, the engine control arrangement comprises a main engine control device, and an additional engine control device, wherein the main engine control device is configured for detecting an operational status of the combustion engine and for controlling the main fuel provision arrangement such that a predetermined amount of main fuel is provided to the inlet channel and/or into the combustion chamber, and wherein the additional engine control device is configured for detecting an operational status of the combustion engine and for controlling the additional fuel provision arrangement such that a predetermined amount of additional fuel is provided into the inlet channel and/or into the combustion chamber.

[0039] According to an embodiment, the additional engine control device is physically separate from the main engine control device, wherein the main engine control device is an original part of the combustion engine and is provided originally in the process of manufacturing the combustion engine, and wherein the additional engine control arrangement is a part of the retrofit system. In particular, the mentioned engine control arrangement is a conceptual, non-physical control instance comprising the main engine control device and the additional engine control device, wherein the engine control arrangement is formed by the retrofitting process of the combustion engine, in particular by applying the main engine control device of the combustion engine and the additional engine control device of the retrofit system together for obtaining the combustion engine system.

[0040] According to an embodiment, the additional engine control device is configured for detecting the operational status such that a precise information of a current rotation position of the combustion engine is determined.

[0041] According to an embodiment, the engine control arrangement and/or the additional engine control device is configured such that a predetermined amount of additional fuel is provided into the combustion chamber prior to a 0°-position of a piston of the combustion engine.

Additionally or alternatively, the predetermined amount of additional fuel is provided during an ongoing combustion of the main fuel in the combustion chamber, and/or, essentially after a combustion of the main fuel in the combustion chamber.

[0042] According to a preferred solution, the engine control arrangement and/or the additional engine control device is/are configured such that a timing of a predetermined amount and/or the predetermined amount per se of additional fuel is provided into the combustion chamber can be adjusted, in particular in dependency of an operational status of the combustion engine.

[0043] According to an embodiment, the engine control arrangement or the additional engine control device is/are configured that firstly an amount of additional fuel to be provided into the combustion chamber is below a certain additional-fuel-limit, and that secondly an amount of the main fuel to be provided into the combustion chamber exceeds a so called self-ignition-limit. By firstly limiting the amount of additional fuel, and secondly by ensuring a minimum-self-ignition-quantity of the main fuel that an ignition (of the main fuel) within the combustion chamber can be self-initiated by environmental conditions (heat, pressure). For example, to initiate the self-ignition no glow plugs, or spark plug is required.

[0044] According to an embodiment, the engine control arrangement and/or the additional engine control device is/are configured such that an amount of additional fuel to be provided into the combustion chamber does not exceed to a predetermined portion of an amount of fuel required by the combustion engine at the detected operational status. In order to obtain this, the additional engine control device may have operational data of the combustion engine, wherein a maximum amount or maximum portion of additional fuel is determined. Additionally or alternatively, the amount of additional fuel is determined by detecting of a minimal fuel rack position of the combustion engine.

[0045] According to an embodiment, the engine control arrangement and/or the main engine control device is/are configured for reducing an amount of main fuel to be provided into the combustion chamber for maintaining the detected operational status of the combustion engine in case of an additional provision of additional fuel. For example, the engine control arrangement and/or the main control device have a control logic for maintaining an operational status of the combustion engine, wherein no communication to the additional engine control device is required and no specific information about an amount of provided additional fuel is required. Preferably, the main engine control device and the additional engine control device work independently from each other, wherein a maximum amount of additional fuel is known by the additional engine control device for a majority of operational status of the combustion engine. In particular that means, the engine control arrangement and/or the main engine control device is/are configured such, when a certain amount of additional fuel is provided into the

combustion chamber, that an amount of main fuel to be provided into the combustion chamber is reduced in order to maintain the detected operational status of the combustion engine, in particular to maintain a detected output power, rotational speed, and/or torque generated by the combustion engine.

[0046] According to an embodiment, the engine control arrangement and/or the additional engine control device is/are configured that an amount of additional fuel is only provided into the combustion chamber if a current output power of the combustion engine does not exceed 95%, preferably does not exceed 90%, more preferably does not exceed 80%, in particular more preferably does not exceed 70% of a maximum output power of the combustion engine. By this it is achieved to mitigate a negative effect on the maximum output power of the combustion engine if the additional fuel having a lower gross caloric value or heating value than the main fuel. Preferably, the engine control arrangement and/or the additional engine control device is configured such that the relative amount of additional fuel is consequently reduced if the output power of the combustion engine is increased and in particular is pushing toward and/or reaching its maximum output.

[0047] According to an embodiment, the engine control arrangement and/or the additional engine control is/are configured such that the relative amount of additional fuel is dependent on the required output power of the combustion engine.

[0048] According to an embodiment, the engine control arrangement and/or the additional engine control is/are configured such that a maximum efficient point control is established for determining a maximum efficiency of the combustion engine system.

[0049] According to an embodiment, the engine control arrangement and/or the additional engine control is/are configured such that knocking (pre-ignition) of the fuel combustion is prevented.

[0050] According to an embodiment, the combustion engine system is equipped with means for detecting a position of a fuel rack of the combustion engine, thus it can be detected and used for controlling the amount of provided additional fuel.

[0051] According to an embodiment, the combustion engine system incorporates common rail injection of the main fuel or uses a fuel pump-injector.

[0052] According to an embodiment, the combustion engine is a combustion engine of a ship.

[0053] According to an embodiment, the combustion engine applies a use of a spark plug or an electric ignition method.

[0054] As an additional or alternative aspect of the invention, a method for retrofitting an internal combustion engine is described. The method comprises the following steps:

providing the combustion engine. The combustion engine is configured according to at least one of the

precedingly described embodiments;

providing and/or opening the receiving arrangement;

5 providing a retrofit system comprising an additional fuel provision arrangement configured for providing an additional fuel into the inlet channel and/or into the combustion chamber. In particular, the retrofit system can be configured according to one of the precedingly described embodiments;

10 mounting the additional fuel provision arrangement to the receiving arrangement in particular such that an interface between the additional fuel provision arrangement and the receiving arrangement is airtight, and in particular that exclusively the additional fuel or a mixture of the additional fuel with oxygen containing air can be provided from the additional fuel provision arrangement into the inlet channel and/or into the combustion chamber via the receiving arrangement;

15 optionally: providing an additional engine control device such, and connecting the additional engine control device to the combustion engine such, that an operational status of the combustion engine (20) can be detected by the additional engine control device.

20 **[0055]** By applying the steps of the described method a combustion engine system, in particular according to one of the preceding embodiments thereof, can be created.

25 **[0056]** The method steps described before can be carried out, if technically reasonable, individually, together, singly, repeatedly, temporally in parallel and/or sequentially in any order.

30 **[0057]** It has to be noted that embodiments of the invention have been described with reference to different subject matters. In particular, some embodiments have been described with reference to apparatus type claims whereas other embodiments have been described with reference to method type claims. However, a person skilled in the art will gather from the above and the following description that, unless other notified, in addition to any combination of features belonging to one type of subject matter also any combination between features relating to different subject matters, in particular between features of the apparatus type claims and features of the method type claims is considered as to be disclosed with this application.

35 **[0058]** Further measures improving the invention will be apparent from the following description of some embodiments of the invention, which are shown schematically in the figures. All features and/or advantages arising from the claims, the description, or the drawings, including constructional details, spatial arrangements, and process steps, may be essential to the invention both individually and in the various combinations. It should be

noted that the figures are descriptive only and are not intended to limit the invention in any way.

[0059] At least one embodiment of the invention will be explained in more detail with reference to the following drawings. In the following figures, identical reference signs are used for the same technical features even of different embodiments.

Fig. 1 shows a combustion engine system according to a first embodiment, and

Fig. 2 depicts a combustion engine system according to a second embodiment.

[0060] In Fig. 1 a first embodiment of a combustion engine system 10 is presented. The combustion engine system 10 comprises a combustion engine 20 and a retrofit system 1.

[0061] The combustion engine 20 is arranged in an environment 21 of the combustion engine 20 and is, at least to the specific embodiment, of a reciprocating engine type having internal combustion. Specifically, a piston 31 together with cylinder walls of the combustion engine 20 delimits a combustion chamber 27, wherein the combustion chamber 27 can be filled by the help of valves with air, wherein a main fuel is provided into the combustion chamber 27 with the help of fuel injectors 30. The combustion engine 20 has a housing 24. Fuel injectors 30 are fed by a central fuel pump 33 of the combustion engine 20. The central fuel pump 33 and the fuel injectors 30 may be referred to as main fuel provision arrangement 22. The amount of main fuel injected into the combustion chamber 27 is controlled by a main engine control device 23. A fuel rack 29 is provided with the main fuel provision arrangement 22.

[0062] The retrofit system 1 is at least formed by an additional fuel provision arrangement 2 and an additional engine control device 3, which are both connected for communication and control purposes. The additional engine control device 3 is configured to control an amount of additional fuel provided by the additional fuel provision arrangement 2 into the combustion chamber 27.

[0063] In Fig. 1 only one the additional fuel provision arrangement 2 is shown in order not to overload the figure; however, such additional fuel provision arrangement 2 is provided to each of the cylinders of the combustion engine 20. The additional fuel provision arrangement 2 is connected to an additional fuel tank 5 and is arranged directly at the housing 24 of the combustion engine 20 for injecting/providing an additional fuel into the non-shown combustion chamber of the third cylinder of the combustion engine 20. For this purpose, the additional fuel provision arrangement 2 is mounted in a receiving arrangement 25, which for example is an original opening 26 or a pre-manufactured opening of the combustion engine 20. For example, the original opening 26 is an inspection opening originally provided in the housing 24 of the combustion engine 20 for applying an

inspection sensor right to the combustion chamber 27.

[0064] In this case, the additional fuel provision arrangement 2 may include pressuring means (e.g. pump) for pressuring the additional fuel. This is for example beneficial if the additional fuel is provided into compressed air within the cylinder during a compression stroke.

[0065] The additional fuel provision arrangement 2 is mounted such into the opening 26 of the receiving arrangement 25 that an interface between the additional fuel provision arrangement 2 and the receiving arrangement 25 is airtight. That means, the additional fuel provision 2 arrangement fits in an airtight and completely off-sealing manner in the receiving arrangement 25.

[0066] The combustion engine 20 can be operated according to two operation modes. First, single-fuel mode, wherein exclusively the main fuel is used and the main fuel provision arrangement 22 is activated. A main engine control device 23 is detecting the rotational speed and position of the combustion engine 20 with the help of a main rotation detection device 32. Hence, the rotational speed is controlled by the main engine control device 23, while the additional fuel provision arrangement 2 and the additional engine control device 3 are inactive.

[0067] When switching the operation of the combustion engine system 10 into a dual-fuel mode the additional fuel provision arrangement 2 and the additional engine control device 3 are activated. Then, depending on the current operational status of the combustion engine 20, the additional engine control device 3 controls the additional fuel provision arrangement 2 such that a predetermined amount of additional fuel is provided into the combustion chamber 27 of the combustion engine 20. Initially, this results in an increased availability of combustible within the combustion chamber 27. As a consequence, the power output (rotational speed, torque) of the combustion engine 20 is increasing. This increase is detected by the main engine control device 23 which subsequently exercises control onto the main fuel provision system 22 such that the amount of provided main fuel is reduced. The reduction of main fuel is determined and executed such that the operational status (rotational speed, torque) of the combustion engine 20 is maintained with respect to the single fuel mode (and vice versa). That means, the amount of main fuel is reduced in dependency of the amount of additional fuel provided. In particular, this control cycle does not require an information exchange between the main engine control device 23 and the additional engine control device 3 but is executed by detecting consequences of the additional fuel availability in the combustion chamber 27.

[0068] Fig. 2 shows an alternative embodiment of the combustion engine system 10. The main difference here with respect to the first embodiment of the combustion engine system 10 is that the additional fuel provision arrangement 2 is mounted to a receiving arrangement 25 located in a structure of the inlet channel 28. Thus, the

additional fuel is provided into the inlet air present in the inlet channel 28. All further details of the second embodiment are similar or even identical to the previously disclosed first embodiment.

Reference numbers

[0069]

- 1 retrofit system
- 2 additional fuel provision arrangement
- 3 additional engine control device
- 4 additional rotation detection device
- 5 additional fuel tank

- 10 combustion engine system

- 20 combustion engine
- 21 environment of the combustion engine
- 22 main fuel provision arrangement
- 23 main engine control device
- 24 housing
- 25 receiving arrangement
- 26 original opening
- 27 combustion chamber
- 28 inlet channel
- 29 fuel rack
- 30 a fuel injector
- 31 piston
- 32 main rotation detection device

Claims

1. A combustion engine system (10) comprising a combustion engine (20), a retrofit system (1) being retrofitted to the combustion engine (20), and an engine control arrangement,

wherein the combustion engine (20) comprises a combustion chamber (27), an inlet channel (28) connected to the combustion chamber (27), a main fuel provision arrangement (22) connected to the inlet channel (28) and/or to the combustion chamber (27) and configured for providing a main fuel into the inlet channel (28) and/or into the combustion chamber (27), and a receiving arrangement (25) arranged in a housing (24) of the combustion engine (20), wherein the receiving arrangement (25) comprises an original opening (26) in the housing (24), the original opening (26) is originally formed into the housing (24) during an original manufacturing process of the combustion engine (20) and is not subsequently manufactured into the housing (24) after the original manufacturing process was finalized, the original opening (26) is forming a physical pathway between an environment (21) of the combustion engine

(20) into the combustion chamber (27), wherein the retrofit system (1) comprises an additional fuel provision arrangement (2),

which is configured for providing an additional fuel into the combustion chamber (27), and

wherein the additional fuel provision arrangement (2) is mounted by retrofitting to the receiving arrangement (25), in particular to the original opening (26), of the combustion engine (20), and

wherein the engine control arrangement is configured for controlling the main fuel provision arrangement (22) and/or the additional fuel provision arrangement (2).

2. The combustion engine system according to claim 1, wherein the original opening (26) is originally configured for receiving a glow plug, a measuring device, and/or a monitoring device.

3. The combustion engine system according to claim 1 or 2, wherein the additional fuel provision arrangement (2) and the receiving arrangement (25) are configured such that an interface between the additional fuel provision arrangement (20) and the original opening (26) is airtight, and that exclusively the additional fuel can be provided from the additional fuel provision arrangement (2) into the combustion chamber (27) via the original opening (26).

4. The combustion engine system according to any of the preceding claims,

wherein the engine control arrangement comprises a main engine control device (23), and an additional engine control device (3), wherein the main engine control device (23) is configured for detecting an operational status of the combustion engine (20) and for controlling the main fuel provision arrangement (22) such that a predetermined amount of main fuel is provided to the inlet channel (28) and/or into the combustion chamber (27), and wherein the additional engine control device (3) is configured for detecting an operational status of the combustion engine (20) and for controlling the additional fuel provision arrangement (2) such that a predetermined amount of additional fuel is provided into the combustion chamber (27).

5. The combustion engine system according to claim 4, wherein the additional engine control device (3)

- is physically separate from the main engine control device (23),
 wherein the main engine control device (23) is an original part of the combustion engine (20) and is provided originally in the process of manufacturing the combustion engine (20), and wherein the additional engine control arrangement (3) is a part of the retrofit system (1).
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6. The combustion engine system according to claim 4 or 5, wherein the additional engine control device (3) is configured for detecting the operational status such that a precise information of a current rotation position of the combustion engine (20) is determined.
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7. The combustion engine system according to any of the preceding claims, wherein the engine control arrangement and/or the additional engine control device (3) is configured such,
 that a predetermined amount of additional fuel is provided into the combustion chamber (20) prior to a 0°-position of a piston of the combustion engine (20), during an ongoing combustion of the main fuel in the combustion chamber (27), and/or, essentially after a combustion of the main fuel in the combustion chamber (27), and/or that a timing of a predetermined amount of additional fuel is provided into the combustion chamber (20) can be adjusted, in particular in dependency of an operational status of the combustion engine (20).
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8. The combustion engine system according to any of the preceding claims, wherein the engine control arrangement, the main engine control device (23), and/or the additional engine control device (3) is configured that
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- an amount of additional fuel to be provided into the combustion chamber (27) is limited such, and
 that an amount of the main fuel to be provided into the combustion chamber (27) exceeds a minimum limit such,
 that an ignition of combustible within the combustion chamber (27) is self-initiated by environmental conditions in the combustion chamber (27), in particular without the support of a glow plug or a spark plug.
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9. The combustion engine system according to any of the preceding claims,
 wherein the engine control arrangement and/or the additional engine control device (3) is/are configured such that an amount of additional fuel to be provided into the combustion chamber (27) does not exceed a predetermined portion of an
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- amount of fuel required by the combustion engine (20) at the detected operational status and/or is determined by detecting of a minimal fuel rack position of the combustion engine (20), and/or
 wherein the engine control arrangement and/or the main engine control device (23) is/are configured such, when an amount of additional fuel is provided into the combustion chamber (27), that an amount of main fuel to be provided into the combustion chamber (27) is reduced in order to maintain the detected operational status of the combustion engine (20), in particular to maintain a detected output power, rotational speed, and/or torque generated by the combustion engine (20).
10. The combustion engine system (10) according to any of the preceding claims, wherein the engine control arrangement and/or the additional engine control device (3) is configured that an amount of additional fuel is only provided into the combustion chamber (27) if a current output power of the combustion engine (20) does not exceed 95%, preferably does not exceed 90%, more preferably does not exceed 80%, in particular more preferably does not exceed 70% of a maximum output power of the combustion engine (20).
11. A retrofit system (1) for retrofitting a combustion engine (20), wherein the combustion engine (20) comprises
 a combustion chamber (27), an inlet channel (28) connected to the combustion chamber (27), a main fuel provision arrangement (22) connected to the inlet channel (28) and/or to the combustion chamber (27), and configured for providing a main fuel into the inlet channel (28) and/or into the combustion chamber (27), and a receiving arrangement (25) arranged in a housing (24) of the combustion engine (20), wherein the receiving arrangement (25) comprises an original opening (26) in the housing (24), wherein the original opening (26) forms a physical pathway between an environment (21) of the combustion engine (20) into the combustion chamber (27), wherein the original opening (26) is originally formed into the housing (24) during an original manufacturing process of the combustion engine (20) and is not subsequently manufactured into the housing (24) after the original manufacturing process was finalized, in particular wherein the original opening (26) is originally configured for receiving a glow plug, a measuring device, and/or a monitoring device, wherein the retrofit system (1) comprises an additional fuel provision arrangement (2) con-

figured

for providing an additional fuel into the combustion chamber (27), and
for being arranged by retrofitting to the receiving arrangement (25) of the combustion engine (20).

- 12.** The retrofit system (1) according to claim 11, comprising an additional engine control device (3) configured for detecting an operational status of the combustion engine (20) and for controlling the additional fuel provision arrangement (2) such that a predetermined amount of additional fuel can be provided into the combustion chamber (27).
- 13.** The retrofit system (1) according to claim 12, wherein the additional fuel provision arrangement (2) is configured such that an interface between the additional fuel provision arrangement (2) and the original opening (26) is airtight, and that exclusively the additional fuel or a mixture of the additional fuel with oxygen containing air can be provided from the additional fuel provision arrangement (2) into the combustion chamber (27) via the original opening (26).
- 14.** A Method for retrofitting an internal combustion engine (20) comprising the steps of:
- providing a combustion engine (20), wherein the combustion engine (20) comprises a combustion chamber (27), an inlet channel (28) connected to the combustion chamber (27), a main fuel provision arrangement (22) connected to the inlet channel (28) and/or to the combustion chamber (27), and configured for providing a main fuel into the inlet channel (28) and/or into the combustion chamber (27), and a receiving arrangement (25) arranged in a housing (24) of the combustion engine (20);
- providing and/or opening the receiving arrangement (25);
- providing a retrofit system (1) comprising an additional fuel provision arrangement (2) configured for providing an additional fuel into the combustion chamber (27);
- mounting the additional fuel provision arrangement (2) to the receiving arrangement (25), in particular such that an interface between the additional fuel provision arrangement (2) and the original opening (26) is airtight, and in particular that exclusively the additional fuel or a mixture of the additional fuel with oxygen containing air can be provided from the additional fuel provision arrangement (2) into the combustion chamber (27) via the original opening (26);
- and
- in particular comprising the steps of providing an

additional engine control device (3) such, and connecting the additional engine control device (3) to the combustion engine (20) such, that an operational status of the combustion engine (20) can be detected by the additional engine control device (3).

- 15.** The method according to claim 14,

wherein the method comprises omitting subsequently manufacturing the original opening (26) into the housing (24) after an original manufacturing process of the combustion engine (20) was finalized, in particular wherein the original opening (26) is originally configured for receiving a glow plug, a measuring device, and/or a monitoring device, and/or

wherein the method does not comprise subsequently manufacturing the original opening (26) into the housing (24) after an original manufacturing process of the combustion engine (20) was finalized, in particular wherein the original opening (26) is originally configured for receiving a glow plug, a measuring device, and/or a monitoring device, and/or

wherein the method comprises originally manufacturing the original opening (26) into the housing (24) exclusively during an original manufacturing process of the combustion engine (20), in particular wherein the original opening (26) is originally configured for receiving a glow plug, a measuring device, and/or a monitoring device.

Fig. 1

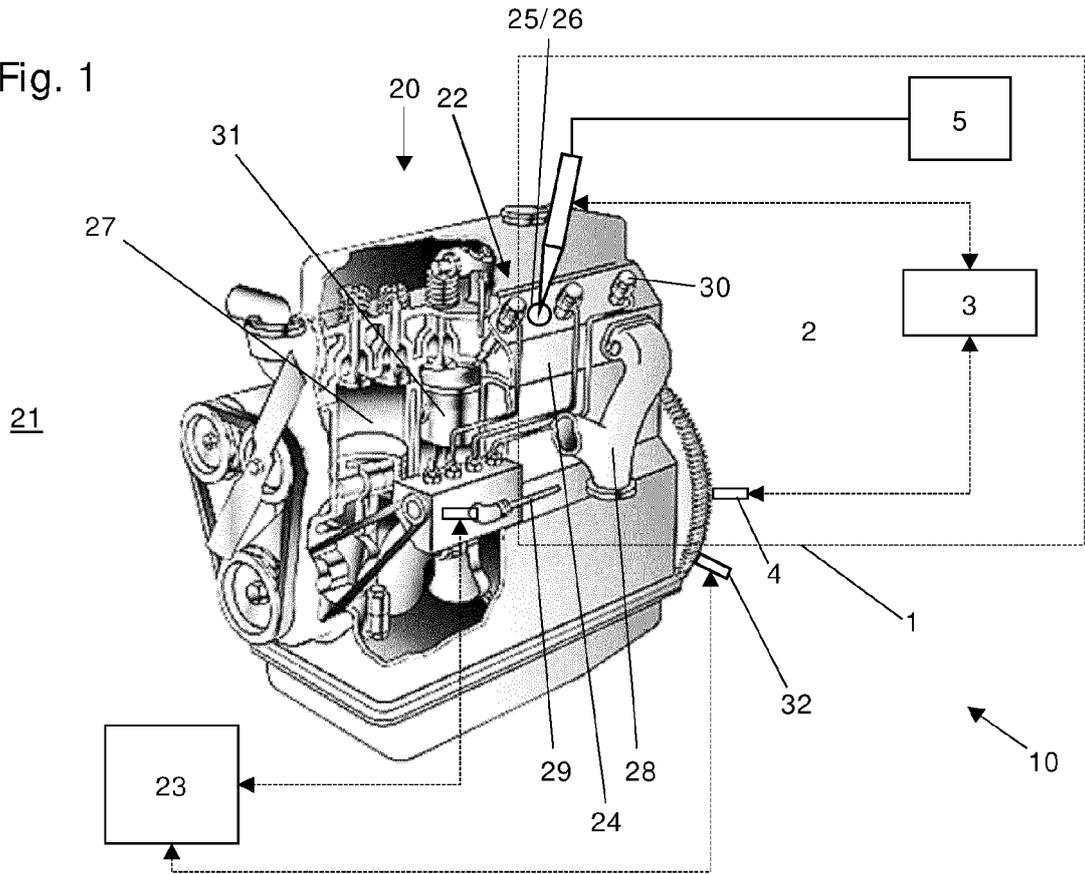
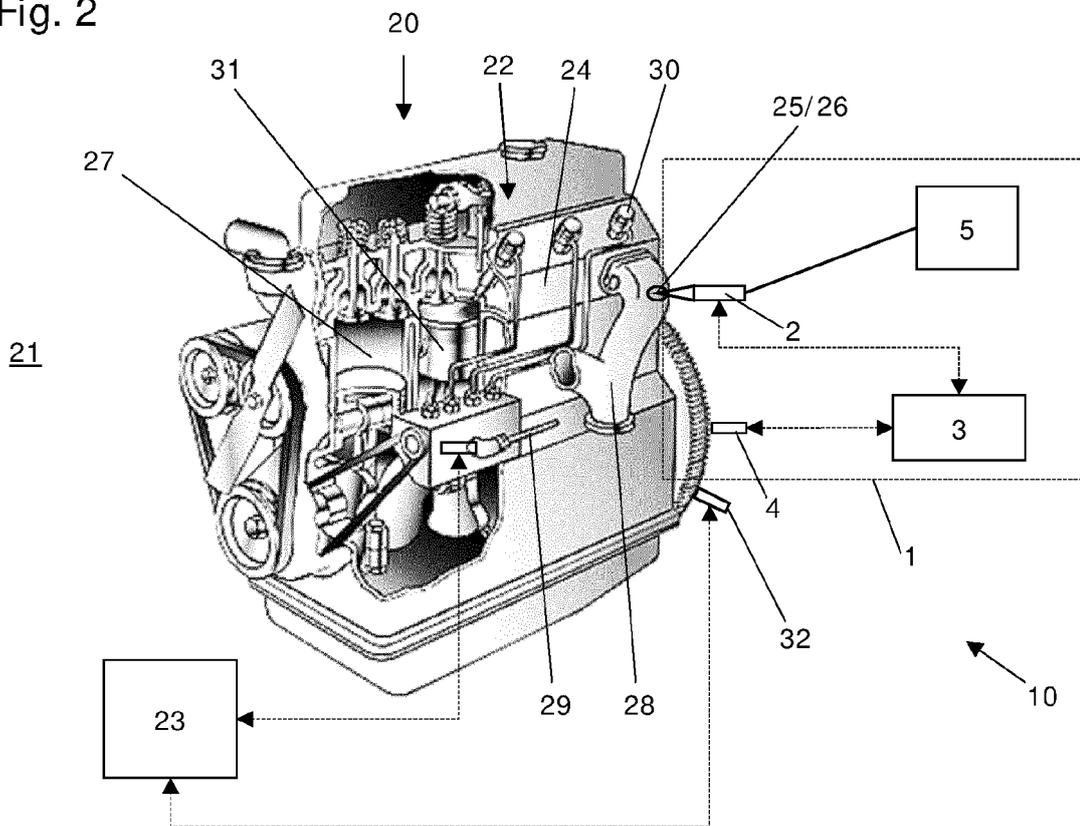


Fig. 2





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Application Number
EP 23 02 0333

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X	<p>US 2019/085776 A1 (TATE JR RAYMON E [US] ET AL) 21 March 2019 (2019-03-21)</p> <p>* paragraph [0036] - paragraph [0038]; figures 1-3 *</p> <p>* paragraph [0049] *</p> <p>-----</p>	1-3, 7-11, 13-15	<p>INV. F02M21</p>
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A	<p>FR 3 099 210 A1 (EURO INVESTISSEMENT [FR]) 29 January 2021 (2021-01-29)</p> <p>* claim 1; figure 4 *</p> <p>-----</p>	1-15	
			<p>TECHNICAL FIELDS SEARCHED (IPC)</p> <p>F02M</p>
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
Munich		13 November 2023	Kolodziejczyk, Piotr
<p>CATEGORY OF CITED DOCUMENTS</p> <p>X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document</p> <p>T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons</p> <p>..... & : member of the same patent family, corresponding document</p>			

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5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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