(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
15 December 2016 (15.12.2016)

WIPO | PCT

(10) International Publication Number
WO 2016/198726 A1

(51) International Patent Classification:
F02D 35/02 (2006.01) *F02D 41/00* (2006.01)
F02D 19/02 (2006.01)

(21) International Application Number:
PCT/FI2015/050406

(22) International Filing Date:
10 June 2015 (10.06.2015)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant: **WÄRTSILÄ FINLAND OY** [FI/FI]; Tarhaajantie 2, FI-65380 Vaasa (FI).

(72) Inventor: **LENDORMY, Éric**; c/o Wärtsilä Finland Oy, Tarhaajantie 2, FI-65380 Vaasa (FI).

(74) Agent: **GENIP OY**; Heikinkatu 7, FI-48100 Kotka (FI).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

Published:

— *with international search report (Art. 21(3))*

(54) Title: A METHOD OF OPERATING AN INTERNAL COMBUSTION PISTON ENGINE BY COMBUSTING GASEOUS FUEL IN THE ENGINE AND A CHARGE ADMISSION SYSTEM FOR A SUPERCHARGED INTERNAL COMBUSTION PISTON ENGINE

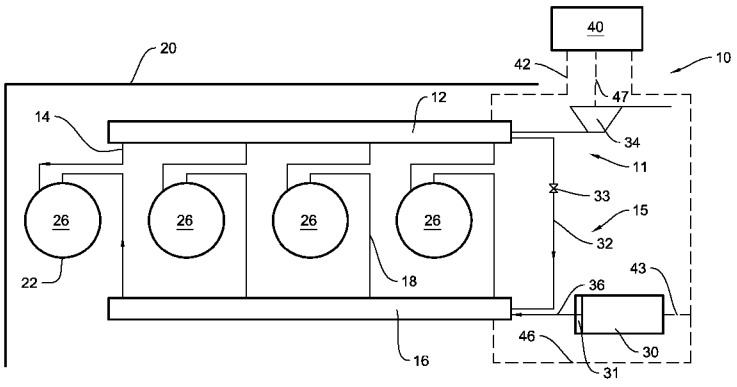

Fig. 1

(57) Abstract: Invention relates to a method of operating an internal combustion piston engine (20), wherein combustion air is pressurized to a first pressure, and gaseous fuel is maintained at a second pressure in a fuel mixing chamber (16) for introducing gaseous fuel directly into the combustion chamber (26) of the engine (20). A first portion of the pressurized air is introduced into the combustion chamber (26) of the engine (20), a second portion of the pressurized air is injected into the fuel mixing chamber (16), and the second portion of the pressurized air injected into the fuel mixing chamber (16) is mixed with the gaseous fuel forming an air-fuel mixture, which is admitted to the combustion chamber (26) of a cylinder (22) of the engine (20) while the piston (24) of the cylinder (22) is at a region of the bottom dead center, and the gaseous fuel is ignited. The invention relates also to a charge admission system (10) for a super-charged internal combustion piston engine (20).

WO 2016/198726 A1

A method of operating an internal combustion piston engine by combusting gaseous fuel in the engine and a charge admission system for a supercharged internal combustion piston engine

Technical field

[001] The present invention relates to a method of operating an internal combustion piston engine by combusting gaseous fuel in the engine according to the preamble of claim 1.

[002] The present invention relates also to a charge admission system for a supercharged internal combustion piston engine.

Background art

[003] Gas fired engines, e.g., natural gas fired engines, may use gas admission valves to admit the natural gas into the intake channel in internal combustion engines. For that purpose in particular solenoid operated gas admission valves (SOGAVs) are used. A SOGAV may be an electrically actuated, high response gas admission valve for in-manifold or port fuel admission. The SOGAV may be designed for use on four-cycle, turbocharged, natural gas or dual-fuel engines. Typically, one SOGAV is required for each cylinder of the engine. Introduction of gaseous fuel into the intake channel brings certain advantages and some challenges.

[004] Publication WO 2011/045026 A1 discloses a gas fuel admission system for a gas fired engines. An engine gas inlet is configured to direct gas into the at least one combustion chamber. An intake air inlet is connected to the combustion chamber. The fuel admission system comprises a gas pressure relief device that is fluidly connected to the gas con-

duit. The gas pressure relief device is configured to relieve overpressure of the gas in the gas supply conduit.

[005] Publication US 2003/0140902 A1 relates to compressed natural gas direct injection into the internal combustion engine. There is shown a controllable device for injecting compressed natural gas. The natural gas is injected between 210° and 90° crank angle before top dead center of the piston. Air is introduced into the combustion chamber via an intake channel when the intake valve is open.

[006] It is well known that compressed natural gas injection system for gaseous fuel engines includes an electronic control unit controlling injection timing to inject compressed gas into cylinders as each piston near its top dead center position.

[007] A problem which may arise in gas fired engines supplied with gas fuel via a gas fuel admission system comprising a gas fuel admission device arranged in connection with a combustion chamber of the engine is that the gaseous fuel and air are not mixed well with each other in the combustion chamber.

[008] An object of the invention is to provide a method of operating an internal combustion piston engine wherein mixing of gaseous fuel and combustion air in the combustion chamber is improved compared to the prior art solutions.

Disclosure of the Invention

[009] An object of the invention is met by a method of operating an internal combustion piston engine by combusting gaseous fuel in the engine, wherein

- combustion air is pressurized to a first pressure, which air is introducible into a combustion chamber of the engine,

- gaseous fuel is maintained at a second pressure in a fuel mixing chamber for introducing gaseous fuel directly into the combustion chamber of the engine.

[0010] It is characteristic to the invention that

- a first portion of the pressurized air is introduced into the combustion chamber of the engine,
- a second portion of the pressurized air is injected into the fuel mixing chamber, and
- the second portion of the pressurized air injected into the fuel mixing chamber is mixed with the gaseous fuel forming an air-fuel mixture,
- the air-fuel mixture is admitted to the combustion chamber of a cylinder of the engine while the piston of the cylinder is at a region of the bottom dead center, and
- the gaseous fuel is ignited and combusted in the combustion chamber of the engine.

[0011] This provides a method of operating an internal combustion piston engine wherein mixing of gaseous fuel and combustion air in the combustion chamber is improved compared to the prior art solutions. This enhances the overall combustion process of the engine, reduces emissions and enhances the safety. Advantageously, the total mass of the injection of the air-fuel mixture is greater than the mass of the injection of gaseous fuel in the prior art solutions. The greater mass generates more turbulence and thus improves the mixing of the gaseous fuel with the air in the combustion chamber compared to prior art solutions.

[0012] The crank angles (CA) referred to herein uses a reference point 0 degrees of CA at piston top dead center during intake stroke applied to a four stoke engine. Thus, a crank angle 180 deg.CA corresponds to the exact bottom dead center of the piston.

[0013] According to an embodiment of the invention the region of the bottom dead center is 45 - 315 deg. CA, and thus the air-fuel mixture is admitted to the combustion chamber of a cylinder of the engine while the piston of the cylinder is at a position of 45 - 315 deg. CA.

[0014] According to an embodiment of the invention, the air-fuel mixture is admitted to the combustion chamber of the cylinder of the engine after an inlet valve of the cylinder has been closed and the piston of the cylinder is at a position of 45 - 315 deg. CA. In other words, the first portion of air is introduced into the combustion chamber prior to the introduction of air-fuel mixture. Particularly since the inlet valve has been closed early before the bottom dead center the pressure in the cylinder decreases and the circumstances for admission the air-fuel mixture into the combustion chamber of a cylinder are favourable.

[0015] According to an advantageous embodiment of the invention, the air-fuel mixture is admitted to the combustion chamber of the cylinder of the engine after an inlet valve of the cylinder has been closed and the piston of the cylinder is at a position of 45 - 315 deg. CA.

[0016] According to an embodiment of the invention, the pressure in the cylinder is determined and the air-fuel mixture is admitted to the combustion chamber of the cylinder during the determined pressure in the cylinder is lower than the second pressure of the gaseous fuel. This way the pressure in the cylinder facilitates for admission of the air-fuel mixture into the combustion chamber.

[0017] According to an embodiment of the invention, the pressure in the cylinder is determined by measuring the pressure with one or more pressure sensors.

[0018] According to an embodiment of the invention, the pressure in the cylinder is determined by estimation based on predetermined engine's control instructions.

[0019] According to an embodiment of the invention, the first pressure is higher than the second pressure. In other words, the pressure in the air receiver is higher than the pressure in the fuel mixing chamber.

[0020] According to an embodiment of the invention, the method comprises a step of controlling an injection of the second portion of the air into the fuel mixing chamber with a valve element.

[0021] According to an embodiment of the invention, the valve element is a check valve wherein back flow is prevented. In other words a flow from the fuel mixing chamber into the air receiver is prevented.

[0022] According to an embodiment of the invention, the method comprises a step of controlling a mass ratio of the air and gaseous fuel in the fuel mixing chamber to be in a range of 1:1 to 10:1.

[0023] According to an embodiment of the invention, the air-fuel mixture is mixed with the first portion of the pressurized air in the combustion chamber.

[0024] Another object of the invention is met by a charge admission system for a supercharged internal combustion piston engine comprising

a. a charge air supply system, comprising
    i. a supercharger unit,
    ii. an air receiver,
    iii. controlling means for controlling the operation of the supercharger unit and thus the pressure in the air receiver, and
    iv. intake channels controllably connecting the air receiver with each combustion chamber of the engine,

b. a gaseous fuel supply system, comprising
   i. at least one fuel mixing chamber being connected to at least one cylinder of the engine,
   ii. means for controlling pressure in the fuel mixing chamber, and
   iii. fuel injection means suitable for introducing a controlled amount of gas from the fuel mixing chamber directly into each combustion chamber of the engine.

[0025] It is characteristic to the invention that the charge air supply system comprises a conduit for introducing a portion of the pressurized air from the air receiver into the fuel mixing chamber so as to form an air-fuel mixture in the fuel mixing chamber.

[0026] This provides a charge admission system which performance is improved for mixing gaseous fuel and combustion air in the combustion chamber compared to the prior art solutions. This enhances the overall combustion process of the engine, reduces emissions and enhances the safety.

[0027] According to an embodiment of the invention, the gaseous fuel supply system comprises only one fuel mixing chamber being common to all cylinders of the engine. Thus the fuel mixing chamber can be called as a gaseous fuel rail.

[0028] According to an embodiment of the invention, each cylinder of the engine is provided with a dedicated fuel mixing chamber. In other words, each cylinder of the engine is provided with its own fuel mixing chamber. Thus a number of fuel mixing chambers equals to a number of cylinders.

[0029] According to an embodiment of the invention, each cylinder of the engine is provided with at least one fuel mixing chamber being common to at least two cylinders of the engine.

[0030] According to an embodiment of the invention, the charge admission system comprises a control unit, which control unit comprises instructions to introduce using a feeding means a portion of the pressurized air from the air receiver via an intake channel into the combustion chamber of the engine.

[0031] According to an embodiment of the invention, the charge admission system comprises the control unit, which control unit comprises instructions to admit the air-fuel mixture from the fuel mixing chamber into the combustion chamber of a cylinder of the engine while a piston of the cylinder is at a position of 45 – 315 deg. CA.

[0032] According to an embodiment of the invention, the control unit comprises the instructions to admit the fuel-air mixture into the combustion chamber of the cylinder of the engine after an inlet valve of the cylinder has been closed and when the piston of the engine is at a position of 45 – 315 deg. CA.

[0033] According to an embodiment of the invention, one or more pressure sensors are arranged to measure pressure in the cylinder.

[0034] According to an embodiment of the invention, the control unit comprises instructions to estimate prevailing pressure in the cylinder.

[0035] According to an embodiment of the invention, the control unit is arranged to control a valve element for controlling an injection of fuel-air mixture into the combustion chamber.

[0036] According to an embodiment of the invention, the conduit for introducing a portion of the pressurized air from the air receiver into the fuel mixing chamber is provided with a valve element for controlling the introduction of the pressurized air into the fuel mixing chamber.

[0037] According to an embodiment of the invention, the conduit for introducing a portion of the pressurized air from the air receiver into the fuel mixing chamber is provided with a valve wherein back flow is prevented.

[0038] According to an embodiment of the invention, the conduit for introducing a portion of the pressurized air from the air receiver into the fuel mixing chamber is provided with a check valve wherein back flow is prevented.

[0039] According to an embodiment of the invention, the control unit comprises instructions to maintain pressure in the fuel mixing chamber depending at least one of a charge pressure, a cylinder pressure or inlet valve timing maps. Advantageously, the inlet valve maps are based on the Miller cycle.

Brief Description of Drawings

[0040] In the following, the invention will be described with reference to the accompanying exemplary, schematic drawings, in which

Figure 1 illustrates a charge admission system of a supercharged internal combustion piston engine according to an embodiment of the invention,

Figure 2 illustrates more in detail the charge admission system of a supercharged internal combustion piston engine according to an embodiment of the invention, and

Figure 3 illustrates a method according to an embodiment of the invention.

Detailed Description of Drawings

[0041] Figure 1 depicts schematically a charge admission system 10 of a supercharged internal combustion piston engine 20. The engine 20 is a gas fired engine and it may comprise one or more combustion chambers 26 supplied with air and combustible gas i.e. gaseous fuel, such as natural gas.

[0042] The charge admission system 10 comprises an air supply system 11, a gaseous fuel supply system 15 and a control unit 40. The charge air supply system 11 comprises an air receiver 12, a supercharger unit 34 and intake channels 14. The gaseous fuel supply system 15 comprises a fuel mixing chamber 16 and means for controlling pressure 31 of the gas in the fuel mixing chamber 16. The gaseous fuel supply system 15 comprises also fuel injection means, such as gas solenoid controlled injectors (not shown) suitable for introducing a controlled amount of gas from the fuel mixing chamber 16 directly into each combustion chamber 26 of the engine 20. The means 31 for controlling the pressure may be a part of a gaseous fuel source 30. The fuel injection means may be a needle valve, a disk valve or any suitable gas admission valve,

[0043] The control unit 40 is arranged to control the operation of the supercharger unit 34 and thus the pressure in the air receiver 12. A signal line 47 depicts schematically an information transfer between the supercharger unit 34 and the control unit 40. The super charger unit 34 is provided with a mechanical actuator system effecting on the performance of the supercharger, known as such. Combustion air is pressurized to a first pressure by means the super charger by controlling the operation of the supercharger 34 accordingly. The intake channels 14 are arranged to connect the air receiver 12 with the each combustion chamber 26 of the engine 20 dependent on the positions of the intake valves. Thus, the

pressurized air is introduced from the air receiver 12 into the combustion chamber 26 of the engine 20.

[0044] According to an embodiment of the invention, the control unit 40 comprises instructions to introduce a first portion of the pressurized air from the air receiver 12 into the combustion chamber 26 of the engine 20. Figure 1 depicts a signal line 42 for transferring a signal or signals from the control unit 40 to the air receiver 12 for controlling the pressure of the air in the receiver and thus the introduction of the air into the combustion chambers 26 of the engine 20.

[0045] The fuel mixing chamber 16 is arranged in flow communication via a conduit 36 with a gaseous fuel source 30 such as a gaseous fuel tank arrangement facilitating the gas supply into the rail. The fuel rail 16 may be a ductwork, or a manifold arranged to distribute the fuel into each cylinder.

[0046] The control unit 40 comprises instructions to control a feed of gaseous fuel from the gaseous fuel source 30 via the conduit 36 into the fuel mixing chamber 16 such that a predetermined second pressure is maintained in the fuel mixing chamber 16. Figure 1 depicts a signal line 43 for transferring a signal or signals from the control unit 40 to gaseous fuel source 30 for feeding an adequate amount of fuel from the gaseous fuel source 30 into the fuel mixing chamber 16.

[0047] There is a conduit 32 arranged extending between the air receiver and the fuel mixing chamber 16. The air receiver 12 is controllably arranged 33 in flow communication via a conduit 32 with the fuel mixing chamber 16 of the gaseous fuel supply system 15. Thus the conduit is provided with a valve 33 for controlling the introduction of the air into the gas in the rail 16. The valve 33 is according to an embodiment of the invention an on/off valve and the flow rate control is accomplished be pressure difference between the air receiver and the fuel mixing chamber

16. According to another embodiment of the invention the valve 33 is a check valve or alike which prevents a back flow from the fuel mixing chamber 16 to the air receiver 12.

[0048] The conduit 32 is arranged to be suitable for introducing a portion of the pressurized air from the air receiver 12 into the fuel mixing chamber 16. Advantageously, the control unit 40 comprises instructions to introduce the second portion of the air from the air receiver 12 into the fuel mixing chamber 16. Thus, an air-fuel mixture is formed in the fuel mixing chamber 16. The air-fuel mixture is maintained at a second pressure in the fuel mixing chamber 16.

[0049] According to an embodiment of the invention a mass ratio of the air and gaseous fuel in the fuel mixing chamber 16 is maintained in a range of 1:1 to 10:1. The control unit 40 comprises instructions to maintain the air-fuel mixture at the second pressure in the fuel mixing chamber 16. A signal line 46 from the gaseous fuel 16 to the control unit 40 indicates information transfer.

[0050] The fuel mixing chamber 16 is further controllably connected to the combustion chambers 26 of each cylinder 22 via a conduit 18. Specifically, each cylinder 22 is provided with its own conduit 18 leading from the combustion chamber 26 to the fuel mixing chamber 16. Thus gaseous fuel- air mixture is introducible from the fuel mixing chamber 16 directly into the combustion chamber 26 of the engine 20. The fuel mixing chamber 16 is common to at least two cylinders 22 of the engine 20, but illustrated here as being common to all the cylinders 22 of the engine.

[0051] The air-fuel mixture is admitted from the fuel mixing chamber 16 into the corresponding combustion chamber 26 of the cylinder 22 while a piston 24 of the cylinder 22 is advantageously at a position range of 45 – 315 crank angle degree. A mass of an injection of air-fuel mixture is increased and thus the mixing is efficient. The air-fuel mixture is mixed

with the first portion of the pressurized air in the combustion chamber 26. Then the gaseous fuel is ignited and combusted in the combustion chamber 26 of the engine 20. The ignition of charge may be accomplished in many ways known as such. Air assists the introduction of the gaseous fuel into the combustion chamber 26 and considerably improves the gaseous fuel to mix with the first portion of the air in the combustion chamber. This enhances the overall combustion process.

[0052] According to an embodiment of the invention, the pressure in the fuel mixing chamber 16 is maintained at lower level than pressure in the cylinder 22 at least when the inlet valve 28 is open and the piston is moving towards the top bottom center.

[0053] Figure 2 illustrates the charge air system 10 of the engine 20 according to Figure 1 in more detailed manner. Same features are shown with same reference characters. The conduit 32 between the air receiver 12 and the fuel mixing chamber 16 is provided with a valve element 33. The control unit 40 is arranged to control the valve element 33. The valve element 33 controls a flow of air from the air receiver 12 into the fuel mixing chamber 16. According to an embodiment of the invention the valve element 33 is an on-off valve by mean of which it is possible to open or close the flow communication between the air receiver 12 and the fuel mixing chamber 16.

[0054] According to another embodiment of the invention the conduit 32 is provided with a check valve 37 whereas the flow from the receiver to the fuel rail is allowed but back flow is prevented. In other words, gaseous fuel or the air-fuel mixture from the fuel mixing chamber 16 is prevented from flowing into the air receiver 16. Only air from the air receiver 12 is allowed to flow into the fuel mixing chamber 16. According to an embodiment of the invention shown in Figure 2, the conduit 32 is provided with two valves: the on-off valve element 33 and the check valve

37.According to another embodiment of the invention, the on-off valve element 33 and the check valve 37 is designed as a single valve element having these two functions (gas quantity control and unidirectional flow for safety). Thus one valve element acts as an on-off valve and a check valve.

[0055] Thus, an adequate pressure is maintained in the fuel mixing chamber 16. In addition, the mass ratio of the air and gaseous fuel i.e. the air-fuel mixture is maintained at an adequate level in the fuel mixing chamber 16 by controlling the pressure ratios between the receiver, the fuel rail and the combustion chamber. Advantageously, the fuel mixing chamber 16 is pressurized to lower pressure than the air receiver 12 whereas the first pressure is higher than the second pressure. The control unit 40 comprises instructions to maintain pressure in the fuel mixing chamber 16 to be lower than that in the air receiver 12. According to an embodiment of the invention, the control unit 40 comprises instructions to maintain pressure in the fuel mixing chamber 16 using a feedback of at least one of a charge pressure, a cylinder pressure or inlet valve timing maps stored or made available to the control unit 40.

[0056] According to an embodiment of the invention, the pressure in the cylinder 22 is determined by means of one or more pressure sensors 50. The control unit 40 comprises instructions to measure the pressure prevailing in the cylinder 22 with the pressure sensor or pressure sensors 50. The pressure sensor 50 communicates with the control unit 40 via a signal line 45. The air-mixture from the fuel mixing chamber 16 is admitted into the combustion chamber 26 of the cylinder 22 during the determined pressure in the cylinder 22 is lower than the pressure of the gaseous fuel.

[0057] The intake channel 14 is provided with an inlet valve 28. The inlet valve 28 controls an introduction of air into the combustion chamber 26. The inlet valve 28 is in its closing position, in Figure 2, that is the air flow

from the air receiver 12 to the combustion chamber 26 is prevented. The control unit 40 is arranged to control an operation of the inlet valve 28 as depicted with a line 48. When the inlet valve 28 is open, the first portion of the pressurized air is introduced from the air receiver 12 into the combustion chamber 26.

[0058] According to an embodiment of the invention, the control unit 40 comprises the instructions to admit the fuel-air mixture from the fuel mixing chamber 16 into the combustion chamber 26 of the cylinder 22 of the engine 20 after the inlet valve 28 of the cylinder 22 has been closed. Advantageously, the air-fuel mixture from the fuel mixing chamber 16 is admitted into the combustion chamber 26 when the piston 24 of the engine is at a position range of 45 – 315 deg. CA. The operation of the inlet valve refers to a so-called Miller cycle. The Miller cycle is disclosed e.g. in US Patent No. 2,670,595 A which is incorporated herein as a reference for operating the inlet valve. In the Miller cycle, the inlet valve 28 is closed before the piston 24 reaches the bottom dead center after the intake stroke. Typically the closing may be activated as early as at 45 deg.CA. After closing the inlet valve 28, the charge or air in the cylinder expands resulting in decreasing the pressure and the temperature or the charge. Advantageously, the air-fuel mixture is fed into the combustion chamber 26 during the Miller timing, i.e. after the inlet valve has been closed and the piston is advancing towards the bottom dead center so as to take advantage of the pressure difference. In other words, after the inlet valve 28 is closed, the air-fuel mixture is introduced into the combustion chamber 26. In the combustion chamber the air-fuel mixture and the first portion of pressurized air is mixed. Then gaseous fuel is ignited and combusted in the combustion chamber 26 of the engine 20.

[0059] According to an embodiment of the invention, the conduit 18 is provided with a fuel injection means19 for injecting the air-fuel mixture into the combustion chamber 26. According to an embodiment of the in-

vention, the fuel injection means 19 is called as a gas admission valve. According to an embodiment of the invention, the fuel injection means 19 is called as an injector. The fuel injection means 19 is arranged to the cylinder head of the engine 20. According to an embodiment of the invention, the fuel injection means 19 is provided with a valve element 38 so as to control an injection of air-fuel mixture into the combustion chamber 26. According to an embodiment of the invention the valve element 38 is a disk valve. The control unit 40 is arranged to control the valve element 38 for controlling an injection of fuel-air mixture into the combustion chamber 26.

[0060] Furthermore, Figure 2 illustrates the piston 24 which is arranged to move in a reciprocating manner in the cylinder 22 of the engine 20. The combustion chamber 26 is delimited by the piston 24, the cylinder 22 and a cylinder head 60. The control unit 40 comprises instructions to detect a crank angle degree as depicted with a signal line 44.

[0061] Figure 2 also illustrates an embodiment of the invention according to which each cylinder is provided with a dedicated air – fuel mixing chamber 16. This way the fuel composition may be controlled more precisely or individually for each cylinder. In other words, each cylinder 22 of the engine 20 is provided with its own fuel mixing chamber 16. Thus a number of fuel mixing chambers 16 equals to a number of cylinders 22. Figure 2 also illustrates an embodiment of the invention according to which each fuel mixing chamber 16 is provided with a dedicated means 31 for controlling the pressure of the gas in the fuel mixing chamber 16. A number of fuel mixing chambers 16 equals to a number of means 31 for controlling the pressure of the gas in the fuel mixing chamber 16. Generally, it should be understood that one fuel mixing chamber may be arranged to serve one or more cylinders of the engine.

[0062] Figure 3 illustrates schematically a method according to an embodiment of the invention. In the figure 3 there is shown the crank angle

in the horizontal axis and pressure in the vertical axis. The crank angles (deg. CA) referred to herein uses a reference point 0 degrees of CA at piston top dead center during intake stroke applied to a four stoke engine. Thus, a crank angle 180 deg.CA corresponds to the exact bottom dead center of the piston and 360 deg.CA relates naturally to the top dead center after compression stroke in a four stroke engine. The curve 58 depicts the pressure in a combustion chamber of a cylinder. During the intake stroke the pressure in the combustion chamber is mainly ruled by the charge air pressure in the receiver 52. In the method at a certain crank angle 54 before the bottom dead center, 180 deg.CA the inlet valve is closed. Since the piston is still moving towards the bottom dead center the pressure in the combustion chamber is decreased. Between certain crank angle range 56 the pressure in the combustion chamber is lower than the charge air pressure, area 55, and according to an embodiment the introduction of the mixture of gaseous fuel and air is introduced to the combustion chamber during the crank angle range 56.

[0063] While the invention has been described herein by way of examples in connection with what are, at present, considered to be the most preferred embodiments, it is to be understood that the invention is not limited to the disclosed embodiments, but is intended to cover various combinations or modifications of its features, and several other applications included within the scope of the invention, as defined in the appended claims. The details mentioned in connection with any embodiment above may be used in connection with another embodiment when such combination is technically feasible.

Claims

1. Method of operating an internal combustion piston engine (20) by combusting gaseous fuel in the engine (20), wherein

- combustion air is pressurized to a first pressure, which air is introducible into a combustion chamber (26) of the engine (20),
- gaseous fuel is maintained at a second pressure in a fuel mixing chamber (16) for introducing gaseous fuel directly into the combustion chamber (26) of the engine (20),

characterized in that

- a first portion of the pressurized air is introduced into the combustion chamber (26) of the engine (20),
- a second portion of the pressurized air is injected into the fuel mixing chamber (16), and
- the second portion of the pressurized air injected into the fuel mixing chamber (16) is mixed with the gaseous fuel forming an air-fuel mixture,
- the air-fuel mixture is admitted to the combustion chamber (26) of a cylinder (22) of the engine (20) while the piston (24) of the cylinder (22) is at a region of the bottom dead center, and
- the gaseous fuel is ignited and combusted in the combustion chamber (26) of the engine (20).

2. Method of operating an internal combustion piston engine (20) by combusting gaseous fuel according to claim 1, **characterized** in that the

air-fuel mixture is admitted to the combustion chamber (26) of the cylinder (22) of the engine (20) after an inlet valve (28) of the cylinder (22) has been closed and the piston (24) of the cylinder (22) is at a position of 45 - 315 deg. CA.

3. Method of operating an internal combustion piston engine (20) by combusting gaseous fuel according to claim 1, **characterized** in that the pressure in the cylinder (22) is determined and the air-fuel mixture is admitted to the combustion chamber (26) of the cylinder (22) during the determined pressure in the cylinder is lower than the second pressure of the gaseous fuel.

4. Method of operating an internal combustion piston engine (20) by combusting gaseous fuel according to claim 3, **characterized** in that the pressure in the cylinder (22) is determined by estimation based on predetermined engine's control instructions.

5. Method of operating an internal combustion piston engine (20) by combusting gaseous fuel according to anyone of claims 1-4, **characterized** in controlling an injection of the second portion of the air into the fuel mixing chamber (16) with a valve element (33).

6. Method of operating an internal combustion piston engine (20) by combusting gaseous fuel according anyone of claims 1-5, **characterized** in that a back flow from the fuel mixing chamber (16) to the air receiver is prevented (33,37).

7. Method of operating an internal combustion piston engine (20) by combusting gaseous fuel according to anyone of claims 1-6, **characterized** in controlling a mass ratio of the air and gaseous fuel in the fuel mixing chamber (16) to be in a range of 1:1 to 10:1.

8. Charge admission system (10) for a supercharged internal combustion piston engine (20) comprising

a. a charge air supply system (11), comprising

i. a supercharger unit (34),

ii. an air receiver (12),

iii. controlling means for controlling the operation of the supercharger unit (34) and thus the pressure in the air receiver (12), and

iv. intake channels (14) controllably connecting the air receiver (12) with each combustion chamber (26) of the engine (20),

b. a gaseous fuel supply system (15), comprising

i. at least one fuel mixing chamber (16) being connected to at least one cylinder (22) of the engine (20),

ii. means for controlling pressure in the fuel mixing chamber (16), and

iii. fuel injection means suitable for introducing a controlled amount of gas from the fuel mixing chamber (16) directly into each combustion chamber (26) of the engine (20),

characterized in that the charge air supply system (11) comprises a conduit (32) for introducing a portion of the pressurized air from the air receiver (12) into the fuel mixing chamber (16) so as to form an air-fuel mixture in the fuel mixing chamber (16).

9. Charge admission system (10) for a supercharged internal combustion piston engine (20) according to claim 8, **characterized** in that the gaseous fuel supply system (15) comprises only one fuel mixing chamber (16) being common to all cylinders (22) of the engine (20).

10. Charge admission system (10) for a supercharged internal combustion piston engine (20) according to claim 8, **characterized** in that the charge admission system (10) comprises a control unit (40), which control unit (40) comprises instructions to introduce using a feeding means a portion of the pressurized air from the air receiver (12) via the intake channel (14) into the combustion chamber (26) of the engine (20).

11. Charge admission system (10) for a supercharged internal combustion piston engine (20) according to anyone of claims 8-10, **characterized** in that the charge admission system (10) comprises the control unit (40), which control unit (40) comprises instructions to admit the air-fuel mixture from the fuel mixing chamber (16) into the combustion chamber (26) of a cylinder (22) of the engine (20) while a piston (24) of the cylinder (22) is at a position of 45 – 315 deg. CA.

12. Charge admission system (10) for a supercharged internal combustion piston engine (20) according to claim 11, **characterized** in that the control unit (40) comprises the instructions to admit the fuel-air mixture into the combustion chamber (26) of the cylinder (22) of the engine (20) after an inlet valve (28) of the cylinder (22) has been closed and when the piston (24) of the cylinder (22) is at a position of 45 – 315 deg. CA.

13. Charge admission system (10) for a supercharged internal combustion piston engine (20) according to anyone of claims 8-12, **characterized** in that the conduit (32) for introducing a portion of the pressurized air from the air receiver (12) into the fuel mixing chamber (16) is

provided with a valve element (33) for controlling the introduction of the pressurized air into the fuel mixing chamber (16).

14. Charge admission system (10) for a supercharged internal combustion piston engine (20) according to anyone of claims 8-13, **characterized** in the conduit (32) for introducing a portion of the pressurized air from the air receiver into the fuel mixing chamber is provided with a valve (33,37) wherein back flow is prevented.

15. Charge admission system (10) for a supercharged internal combustion piston engine (20) according to anyone of claims 8-14, **characterized** in that the control unit (40) comprises instructions to maintain pressure in the fuel mixing chamber (16) depending at least one of a charge pressure, a cylinder pressure or inlet valve timing maps.

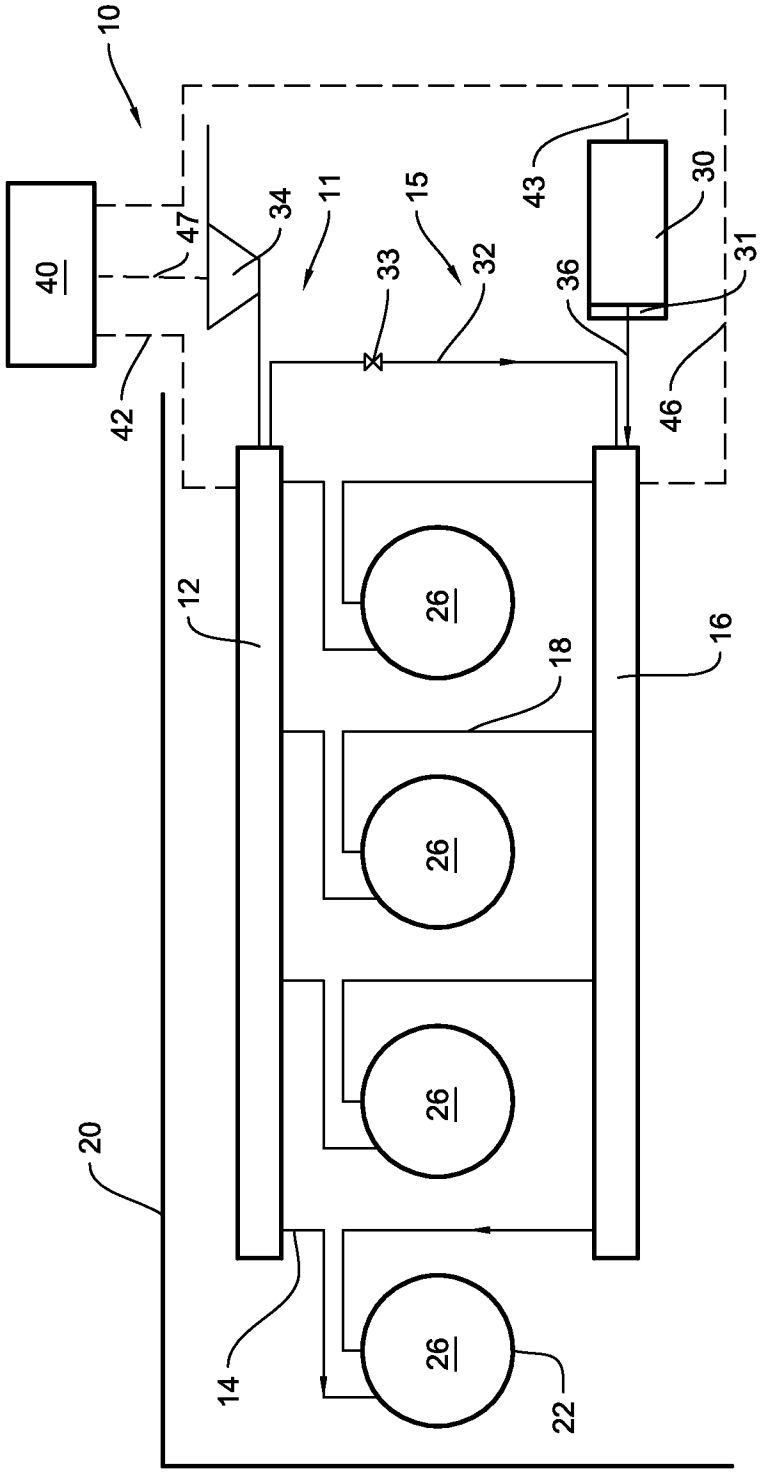

Fig. 1

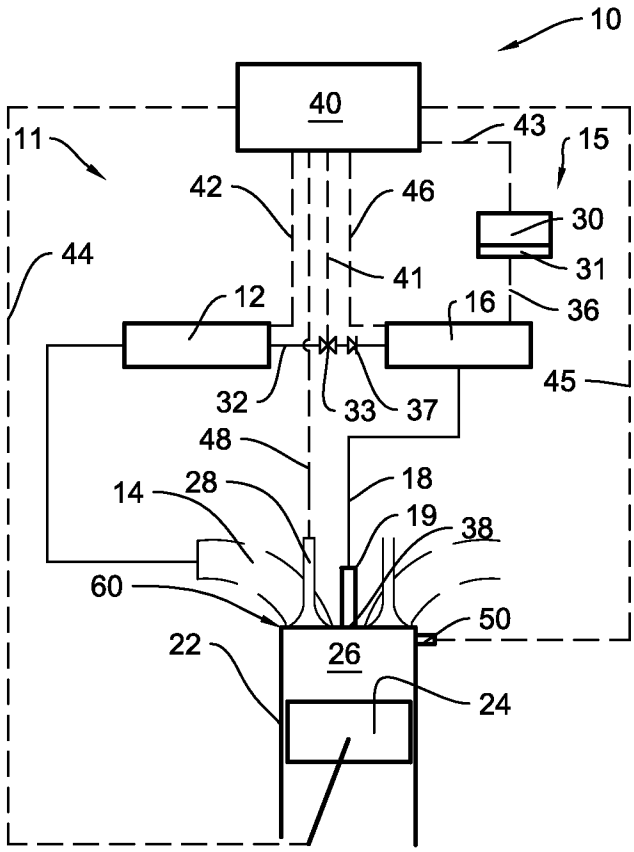
10
40
11
43
15
42
46
30
44
41
31
12
16
36
45
32
33
37
48
18
14
28
19
38
60
50
22
26
24

Fig. 2

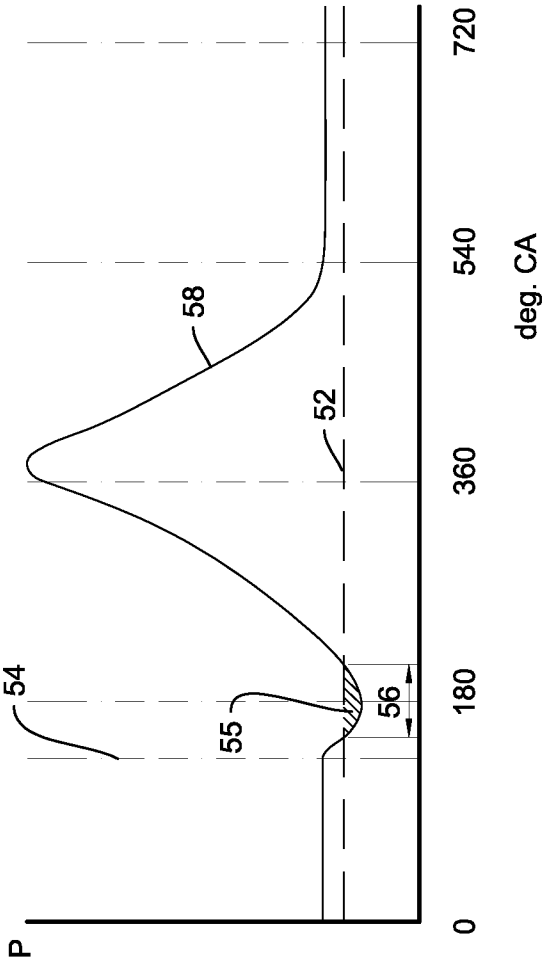

Fig. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/FI2015/050406

A. CLASSIFICATION OF SUBJECT MATTER
INV. F02D35/02 F02D19/02 F02D41/00
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)
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.
X	WO 2014/094154 A1 (WESTPORT POWER INC [CA]) 26 June 2014 (2014-06-26) paragraphs [0001], [0003] paragraphs [0010], [0011] paragraphs [0013] - [0016] paragraphs [0042], [0043] paragraphs [0060] - [0062] figures 16,17 -----	1-15
A	US 2014/102416 A1 (SIVASUBRAMANIAN ARVIND [US] ET AL) 17 April 2014 (2014-04-17) abstract paragraphs [0005], [0006] paragraphs [0011] - [0014] paragraph [0017] paragraphs [0019] - [0023] ----- -/--	1-15

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"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

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
29 January 2016	09/02/2016

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	Wettemann, Mark

1

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/FI2015/050406

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2009/076708 A1 (SHIRAISHI MASATAKA [JP] ET AL) 19 March 2009 (2009-03-19) abstract paragraphs [0022] - [0048]	1,8
A	US 5 150 692 A (TROMBLEY DOUGLASS E [US] ET AL) 29 September 1992 (1992-09-29) abstract column 1, line 6 - line 57 column 2, line 12 - column 3, line 7	1,8

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/FI2015/050406

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2014094154 A1	26-06-2014	CA 2798870 A1	27-02-2013
		CN 104995393 A	21-10-2015
		EP 2932079 A1	21-10-2015
		US 2016017845 A1	21-01-2016
		WO 2014094154 A1	26-06-2014
US 2014102416 A1	17-04-2014	NONE	
US 2009076708 A1	19-03-2009	JP 4599378 B2	15-12-2010
		JP 2009057872 A	19-03-2009
		US 2009076708 A1	19-03-2009
US 5150692 A	29-09-1992	EP 0547649 A1	23-06-1993
		US 5150692 A	29-09-1992