

(19)



(11)

EP 2 394 035 B1

(12)

EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention
of the grant of the patent:

25.01.2017 Bulletin 2017/04

(51) Int Cl.:

F02B 21/00 ^(2006.01)

F02B 31/08 ^(2006.01)

(86) International application number:

PCT/JP2010/000756

(21) Application number: **10705009.8**

(22) Date of filing: **08.02.2010**

(87) International publication number:

WO 2010/090044 (12.08.2010 Gazette 2010/32)

(54) **EGR DEVICE FOR AN ENGINE**

EGR VORRICHTUNG FÜR EINE BRENNKRAFTMASCHINE

DISPOSITIF EGR POUR UN MOTEUR À COMBUSTION INTERNE

(84) Designated Contracting States:

**AT BE BG CH CY CZ DE DK EE ES FI FR GB GR
HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL
PT RO SE SI SK SM TR**

(30) Priority: **09.02.2009 JP 2009027234**

(43) Date of publication of application:

14.12.2011 Bulletin 2011/50

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Description

TECHNICAL FIELD

5 **[0001]** The present invention relates to a saddle-type vehicle and more specifically to a saddle-type vehicle including a single-cylinder four-cycle engine.

BACKGROUND ART

10 **[0002]** WO2008/013045 (hereinafter referred to as "Patent Document 1") discloses a new exhaust gas re-circulation (hereinafter referred to as "EGR") mechanism different from a conventional external EGR mechanism. The EGR mechanism disclosed by the document includes a gas storage chamber that stores exhaust gas discharged from the combustion chamber of an engine. The EGR mechanism lets exhaust gas come into the gas storage chamber while an exhaust valve is open in an expansion stroke. In an intake stroke, while the exhaust valve is open, the exhaust gas stored in the
15 gas storage chamber is discharged to the combustion chamber. The EGR mechanism reduces nitrogen oxides (NOx) in the exhaust gas and reduces a load generated as the piston reciprocates.

[0003] FR 2 864 166 A1 discloses an engine with a cylinder disposed on the top of a cylinder head for defining a combustion chamber. Air and fuel mixture is supplied to the cylinder through an inlet pipe. Gases from the combustion chamber are conveyed by an exhaust pipe and closed by an exhaust valve. An injection unit and a nozzle are placed
20 in the cylinder head for injecting recycled exhaust gases into the cylinder.

DISCLOSURE OF THE INVENTION

25 **[0004]** In recent years, there have been increasing restrictions on exhaust gas emissions. Therefore, a technique of providing a catalytic device in an exhaust pipe and cleaning exhaust gas has been proposed. However, if a catalytic device is provided in the exhaust pipe of the motorcycle disclosed by Patent Document 1, the pressure difference in exhaust pulsation generated in the exhaust pipe is reduced. Therefore, exhaust gas does not easily come into the combustion chamber from the gas storage chamber. Therefore, the EGR ratio (the amount of exhaust gas entered into the combustion chamber/(the amount of fuel-air mixture entered into the
30 arranged to store the piston so that the piston can reciprocate therein. The cylinder head forms a combustion chamber together with the cylinder block. The cylinder head includes an intake port and an exhaust port. The intake port has an intake opening formed in the combustion chamber and is communicated with the intake pipe. The exhaust port has an exhaust opening formed in the combustion chamber and is communicated with the exhaust pipe. The intake valve opens and closes the intake opening. The exhaust valve opens and closes the exhaust opening. The exhaust gas re-circulation device is communicated with the exhaust port to take in or discharge exhaust gas. The valve driving mechanism raises/lowers the intake valve and the exhaust valve so that a valve overlap period after the top dead center is longer than a valve overlap period before the top dead center. The exhaust gas re-circulation device includes a storage container that stores exhaust gas and a vent pipe arranged to communicate the storage container and the exhaust port. Exhaust gas enters the storage container when the exhaust valve is open in an exhaust stroke and is discharged into the
35 combustion chamber from the storage container when the exhaust valve is open in an intake stroke after the top dead center. Examples of the straddle-type vehicle include ATVs (All Terrain Vehicles) such as a three-wheeled ATV and a four-wheeled ATV other than the motorcycle.

[0005] In the straddle-type vehicle according to the present invention, the exhaust gas re-circulation device discharges exhaust gas to the combustion chamber when the exhaust valve is open in an intake stroke after the top dead center. In the intake stroke after the top dead center, the piston is lowered, so that the pressure in the combustion chamber is reduced. Therefore, the difference between the pressure in the exhaust gas re-circulation device and the pressure in the combustion chamber increases to allow the exhaust gas to come easily into the combustion chamber. Therefore, the fuel efficiency is improved even if a catalytic device is provided. Furthermore, NOx can be reduced.

45 **[0006]** Since the overlap period after the top dead center is long, more exhaust gas is likely to come into the combustion chamber from the EGR device.

50 **[0007]** The storage container preferably has a volume V (mm³) and the vent pipe has a length L (mm) and a sectional area S (mm²). The internal pressure in the storage container fluctuates according to a Helmholtz resonant frequency determined by Expression (1):

55 **Helmholtz resonant frequency = $C \times (S \times V / L)^{1/2} / 2\pi$... (1)**

where C is a sonic speed (mm/s).

[0008] In this way, the exhaust gas re-circulation device takes in/discharges exhaust gas based on the fluctuation of the internal pressure.

[0009] Other features, elements, steps, characteristics and advantages of the present invention will become more apparent from the following detailed description of the preferred embodiments of the present invention with reference to the attached drawings.

Brief Description of Drawings

[0010]

[fig.1]Fig. 1 is a side view of a straddle-type vehicle according to a first preferred embodiment of the present invention.

[fig.2]Fig. 2 is a block diagram of the structure of the periphery of an engine in the straddle-type vehicle shown in Fig. 1.

[fig.3]Fig. 3 is a side view of the engine in Fig. 1.

[fig.4]Fig. 4 is a sectional view of a cylinder head in Fig. 3.

[fig.5]Fig. 5 is a bottom view of the cylinder head shown in Fig. 3.

[fig.6]Fig. 6 is an enlarged view of the vicinity of the exhaust opening end of the cylinder head in Fig. 5.

[fig.7]Fig. 7 is a sectional view of the cylinder head and a cylinder block in Fig. 3.

[fig.8]Fig. 8 is a schematic view of the arrangement of an EGR device and a cylinder 51 when viewed from above the cylinder head 10c.

[fig.9]Fig. 9A is a graph showing the relation between the valve opening degree and the intake and exhaust amounts of the EGR device relative to the crankshaft angle. Fig. 9B is a graph showing the relation between the pressure in a combustion chamber and the internal pressure in the EGR device relative to the crankshaft angle.

[fig.10]Fig. 10 is a view of another cam having a different shape from a cam in Fig. 4;

[fig.11]Fig. 11 is a view of another cam having a different shape from those in Figs. 4 and 10.

[fig.12]Fig. 12 is a graph showing the relation between the valve opening degree and the intake and exhaust amounts of an EGR device relative to the crankshaft angle of an engine in a well-known example.

[fig.13]Fig. 13 is a front view of a cylinder head in an engine according to a second preferred embodiment of the present invention.

Best Mode for Carrying out the Invention

[0011] Now, preferred embodiments of the present invention will be described in conjunction with the accompanying drawings. In the drawings, the same or corresponding portions are designated by the same reference characters and their description will not be repeated.

Overall Structure of Straddle-type vehicle

[0012] Fig. 1 is a side view of a straddle-type vehicle according to a preferred embodiment of the present invention. Referring to Fig. 1, the straddle-type vehicle 1 according to the preferred embodiment is a motorcycle. The straddle-type vehicle 1 includes a head pipe 11, a frame 2, a handle 3, a front fork 4, a front wheel 5, a fuel tank 6, a rear wheel 7, a rear arm 8, and an engine 10.

[0013] The head pipe 11 is provided at the front end of the frame 2. The frame 2 extends backward and obliquely downward from the head pipe 11. The handle 3 is attached rotatably at the upper end of the head pipe 11. The front fork 4 is provided at the lower end of the head pipe 11. The front wheel 5 is attached rotatably at the lower end of the front fork 4.

[0014] The engine 10 is provided under the frame 2. The fuel tank 6 is provided above the frame 2. The rear arm 8 is provided at the rear end of the frame 2. A pivot shaft is provided at the rear end of the frame 2 and the rear arm 8 is supported swingably in the vertical direction around the pivot shaft at its end. The rear wheel 7 is attached rotatably at the rear end of the rear arm 8.

Structure of Periphery of Engine

[0015] Fig. 2 is a diagram of the periphery of the engine. Referring to Fig. 2, the straddle-type vehicle 1 further includes an air cleaner 201, a fuel supply device 202, an intake pipe 203, an exhaust pipe 204, a supply pipe 205, a lead valve 206, catalytic devices 207 and 208, and a silencer 209.

[0016] The intake pipe 203 is provided between the air cleaner 201 and the engine 10 and connected to the air cleaner 201 and the engine 10. The fuel supply device 202 is provided in the intake pipe 203. The fuel supply device 202 receives

liquid fuel supplied from the fuel tank 6 and air supplied from the air cleaner 201. The fuel supply device 202 mixes the liquid fuel with the air to generate fuel-air mixture. The fuel supply device 202 is for example a carburetor or an electronically controlled fuel injection mechanism. The intake pipe 203 guides the fuel-air mixture generated by the fuel supply device 202 to the engine 10.

[0017] The exhaust pipe 204 is provided between the engine 10 and the silencer 209 to connect the engine 10 and the silencer 209. The upstream end of the exhaust pipe 204 is connected to the engine 10. The downstream end of the exhaust pipe 204 is inserted in the silencer 209. The silencer 209 reduces exhaust noise generated when exhaust gas is discharged to the outside.

[0018] The exhaust gas discharged from the engine 10 contains exhaust substances such as nitrogen oxides (NO_x), carbon monoxide (CO), and hydrocarbon (HC). Among them, the CO and HC are unburned components. The exhaust gas is cleaned by the catalytic devices 207 and 208.

[0019] The catalytic devices 207 and 208 are provided in the exhaust pipe 204. The catalytic device 207 is provided more on the upstream side of the exhaust pipe 204 than the catalytic device 208. The catalytic device 207 has a reducing catalyst. The reducing catalyst includes for example a noble metal containing rhodium as a main component. The catalytic device 207 reduces NO_x in the exhaust gas.

[0020] The catalytic device 208 is provided more on the downstream side of exhaust pipe 204 than the catalytic device 207. In this example, the catalytic device 208 is provided on the downstream end of the exhaust pipe 204 inserted in the silencer 209. The catalytic device 208 has an oxidizing catalyst. The oxidizing catalyst includes a noble metal including palladium as a main component. The catalytic device 208 oxidizes unburned components (CO and HC) in the exhaust gas.

[0021] Preferably, the straddle-type vehicle 1 further includes a secondary air supply mechanism. The secondary air supply mechanism includes the air cleaner 201 as a secondary air supply source, the supply pipe 205, and the lead valve 206. The upstream end of the supply pipe 205 is connected to the air cleaner 201. The downstream end of the supply pipe 205 is connected to a part of the exhaust pipe 204 between the catalytic devices 207 and 208. The lead valve 206 is provided in the supply pipe 205. The supply pipe 205 guides air supplied from the air cleaner 201 (herein after referred to as "secondary air") to the exhaust pipe 204 through the lead valve 206. The secondary air is input to the part of the exhaust pipe 204 between the catalytic devices 207 and 208. When the secondary air is introduced, the air fuel ratio in the exhaust pipe 204 between the catalytic devices 207 and 208 becomes lean. Therefore, unburned components (CO and HC) are more easily oxidized in the catalytic device 208.

Structure of Engine 10

[0022] Fig. 3 shows the structure of the engine 10 in Fig. 1. Referring to Fig. 3, the engine 10 is a single-cylinder four-cycle engine. The engine 10 includes a cylinder block 10b and a cylinder head 10c. The engine 10 further includes a crankcase 10a.

[0023] The crankcase 10a is provided under the engine 10. The crankcase 10a stores a crankshaft that is not shown. The cylinder block 10b is attached at the upper end of the front part of the crankcase 10a. The cylinder block 10b has a cylindrical shape and has a cylinder 51 inside. The cylinder 51 stores a piston 52 so that the piston can reciprocate therein. The piston 52 is connected to the crankshaft through a connecting rod 53.

[0024] The cylinder head 10c is provided at the upper end of the cylinder block 10b. The cylinder head 10c forms a combustion chamber 40 together with the cylinder block 10b. In the combustion chamber 40, fuel-air mixture is burned. The cylinder head 10c further has an intake port 21 and an exhaust port 31. The intake port 21 and the exhaust port 31 connect between the combustion chamber 40 and the outside of the cylinder head 10c. The intake port 21 is connected to the intake pipe 203. The exhaust port 31 is connected to the exhaust pipe 204.

[0025] Fig. 4 is an enlarged view of the cylinder head 10c in Fig. 3. Referring to Fig. 4, the intake port 21 is provided between an intake opening 24 formed in the combustion chamber 40 and the intake pipe 203. The exhaust port 31 is provided an exhaust opening 34 formed in the combustion chamber 40 and the exhaust pipe 204. The intake opening 24 and the exhaust opening 34 are each provided with a valve seat.

[0026] The engine 10 further includes an intake valve 22, an exhaust valve 32, and a valve driving mechanism 16. The intake valve 22 is provided at the intake opening 24. The intake valve 22 includes a valve head 22a and a valve stem 22b. The intake valve 22 opens and closes the intake opening 24. A retainer 23c is attached at the upper end of the valve stem 22b. The retainer 23c has a disk shape and is provided coaxially with the valve stem 22b. The cylinder head 10c has a spring seat 23e. A valve spring 23d is provided between the retainer 23c and the spring seat 23e. The valve stem 22b is inserted in the valve spring 23d. The valve spring 23d applies force upon the intake valve 22 in the direction in which the intake valve 22 closes the intake opening 24.

[0027] The exhaust valve 32 is provided at the exhaust opening 34. The exhaust valve 32 includes a valve head 32a and a valve stem 32b. The exhaust valve 32 opens and closes the exhaust opening 34. A retainer 33c is attached at the upper end of the valve stem 32b, and the cylinder head 10c has a spring seat 33e. A valve spring 33d having the valve stem 32b inserted therein is provided between the retainer 33c and the spring seat 33e. The valve spring 33d

applies force upon the exhaust valve 32 in the direction in which exhaust valve 32 closes the exhaust opening 34.

[0028] The valve driving mechanism 16 drives the intake and exhaust valves 22 and 32 and opens/closes the intake and exhaust openings 24 and 34. The valve driving mechanism 16 includes an intake cam 23a and an exhaust cam 33a. The valve driving mechanism further includes two camshafts 23b and 33b. The intake cam 23a is provided on the camshaft 23b. When the camshaft 23b rotates and the intake cam 23a presses the intake valve 22 downward, the intake opening 24 is opened. Similarly, the exhaust cam 33a is provided on the camshaft 33b. When the camshaft 33b rotates and the exhaust cam 33a presses the exhaust valve 32 downward, the exhaust opening 34 is opened. The opening/closing timing for the intake valve 22 and the exhaust valve 32 is determined based on the phases of the intake cam 33a and the exhaust cam 23a relative to the crankshaft.

EGR Device 101

[0029] Fig. 5 is a bottom view of the cylinder head 10c. Referring to Fig. 5, the engine 10 further includes an EGR device 101. The EGR device 101 includes a storage container 100 and a vent pipe 110. The storage container 100 is a rectangular parallelepiped box having a volume V (mm^3). The vent pipe 110 has two opening ends. One opening end is opened into the storage container 100. Referring to Fig. 6, the other opening 110e of the vent pipe 110 is provided in the exhaust port 31 and near the exhaust opening 34. More specifically, the vent pipe 110 is communicated with the exhaust port 31. When the exhaust valve 32 closes the exhaust opening 34, the opening end 110e is positioned apart from the valve head 32a. The vent pipe 110 has a length L (mm) and a sectional area S (mm^2).

[0030] As described above, the EGR device 101 includes the storage container 100 and the vent pipe 110, and its structure is similar to a Helmholtz resonator. Therefore, the internal pressure in the EGR device 101 fluctuates based on a Helmholtz resonant frequency. The Helmholtz resonant frequency F is defined by the following Expression (1):

$$F = C \times (S \times V / L)^{1/2} / 2\pi \quad \dots(1)$$

where C is a sonic speed (mm/s).

[0031] The Helmholtz resonant frequency F can be set as required based on the volume V of the storage container 100 and the sectional area S and the length L of the vent pipe 110.

[0032] The engine 10 is a single-cylinder four-cycle engine. Therefore, the operation of the engine 10 repeatedly carries out an intake stroke, a compression stroke, a combustion and expansion stroke, and an exhaust stroke in the mentioned order. In the exhaust stroke, the exhaust valve 23 is opened. At the time, exhaust gas comes into the exhaust port 31 from the combustion engine 40. The EGR device 101 takes in a part of the exhaust gas and stores the gas in the storage container 100.

[0033] The engine 10 has a valve overlap period. Therefore, in an early stage of the intake stroke, the exhaust valve is still open. As shown in Fig. 7, at the time, the EGR device 101 discharges the exhaust gas stored in the storage container 100 from the opening end 101e to the combustion chamber 40.

[0034] Fig. 8 shows the arrangement of the EGR device and the cylinder 51 when viewed from above the cylinder head 10c. Referring to Fig. 8, the end portion of the vent pipe 110 of the EGR device 101 is directed in the circumferential direction of the cylinder 51. More specifically, the normal D passing the center of the opening surface of the opening end 101e crosses or is preferably orthogonal to a straight line L connecting the central axis AX of the cylinder 51 and the center of the opening surface.

[0035] The end portion of the vent pipe 110 is directed in the circumferential direction of the cylinder 51, so that exhaust gas discharged from the EGR device 101 forms a swirl as shown in Fig. 7. If the engine 10 does not include the EGR device 101, the edge QA of the combustion chamber 40 shown in Fig. 8 is easily cooled. Therefore, flames generated by combustion of fuel-air mixture are easily put out at the edge QA . The edge QA will be referred to as quenching area QA . In the quenching area QA , flames are easily put out, and therefore unburned components (CO and HC) are likely to remain. The EGR device 101 lets the swirled exhaust gas come into the quenching area QA . The exhaust gas is hot and keeps the quenching area QA from being cooled. Therefore, unburned components remaining in the quenching area QA can be reduced. If the amount of the unburned components is reduced, the amount of CO and HC emissions is reduced.

Function of EGR Device 1.01

[0036] The EGR device 101 has internal pressure that fluctuates based on the Helmholtz resonant frequency defined by the above Expression (1). Therefore, the EGR device 101 can take in or discharge exhaust gas depending on the difference between its internal pressure and the pressure in the combustion chamber 40.

[0037] Figs. 9A and 9B shows the relation between the valve opening degree and the intake and exhaust amounts of the EGR device 101 relative to the crankshaft angle. The abscissas in graphs in Figs. 9A and 9B each represent a crankshaft angle (i.e., time). The curve EX denoted by the broken line in Fig. 9A indicates the valve opening degree of the exhaust valve 32, and the curve IN denoted by the broken line indicates the valve opening degree of the intake valve 22. The curve IV denoted by the solid line in Fig. 9A indicates the amount of exhaust gas taken into the EGR device 101. The curve DI denoted by the solid line in Fig. 9A indicates the amount of exhaust gas discharged from the EGR device 101.

[0038] The solid line in Fig. 9B indicates differential pressure DP represented by the following Expression (2):

$$\text{Differential pressure DP} = \text{pressure in exhaust opening 34} - \text{internal pressure in EGR device 101} \dots (2)$$

where the internal pressure in the EGR device 101 is pressure in the storage container 100 in the EGR device 101.

[0039] While the engine 10 is driven, the operation proceeds to the exhaust stroke after the combustion and expansion stroke. In an early stage of the exhaust stroke, the exhaust valve 32 starts to open. In other word, the exhaust valve 32 starts to move downward.

[0040] At the time, the pressure in the combustion chamber 40 is higher than the atmospheric pressure because of the combustion of fuel-air mixture. On the other hand, the pressure in the exhaust port 31 and the internal pressure in the EGR device 101 are equal to the atmospheric pressure. More specifically, the pressure in the combustion chamber 40 is higher than the pressure in the exhaust port 31 and the pressure in the EGR device 101. Therefore, a pressure wave is generated, which advances in the exhaust port 31 and the exhaust pipe 204. At the time, the pressure in the exhaust port 34 is raised, and the differential pressure DP defined by Expression (2) increases.

[0041] The differential pressure DP causes the EGR device 101 to take in exhaust gas in the exhaust port 31 as indicated by the curve IV in Fig. 9A and store the gas in the storage container 100. At the crankshaft angle d10, the differential pressure DP is maximized. Therefore, the amount of exhaust gas taken into the EGR device 101 is maximized at the crankshaft angle d10.

[0042] When the EGR device 101 receives a pressure wave, the internal pressure in the EGR device 101 fluctuates based on the Helmholtz resonant frequency defined by Expression (1) and increases. On the other hand, the pressure in the exhaust opening 34 after the pressure wave passes decreases. Therefore, the differential pressure DP approaches zero as the crankshaft angle increases from d10, and the EGR device 101 stops taking in the exhaust gas.

[0043] When the crankshaft angle is d0, the exhaust valve 32 stops moving downward and starts to rise. In other words, the exhaust valve 32 starts to close. Furthermore, the intake valve 22 starts to open at the crankshaft angle d1 greater than the crankshaft angle d0, and the intake stroke is started. The valve driving mechanism 16 provides a valve overlap period T0 in which the intake valve 22 and the exhaust valve 32 are both open.

[0044] In a valve overlap period T0, the pressure in the combustion chamber 40 is not easily raised. On the other hand, the internal pressure in the EGR device 101 gradually increases based on the Helmholtz resonant frequency according to Expression (1). As a result, in the valve overlap period T0, the differential pressure DP defined by Expression (2) attains a negative value. In other words, the internal pressure in the EGR device 101 is higher than the pressure in the combustion chamber 40. Therefore, the EGR device 101 starts to discharge exhaust gas stored therein to the combustion chamber 40.

[0045] The EGR device 101 discharges the largest amount of exhaust gas at the crankshaft angle d20 at which the differential pressure DP is at the maximum negative value. At the crankshaft angle d20 and higher, the internal pressure in the EGR device 101 gradually decreases. As a result, the differential pressure DP is reduced again. Before the crankshaft angle d3 at which the exhaust valve 32 is closed, the EGR device 101 stops discharging the exhaust gas.

[0046] More specifically, the exhaust gas in the EGR device 101 is discharged to the combustion chamber 40 when the exhaust valve 32 is open in an intake stroke after the top dead center TDC. Stated differently, the exhaust gas in the EGR device 101 is discharged more in a valve overlap period T2 after the top dead center TDC than in a valve overlap period T1 before the top dead center TDC.

[0047] In the valve overlap period T1 before the top dead center TDC, the piston 52 is raised toward the top dead center TDC. At the time, the volume of the combustion chamber 40 is reduced. Therefore, the pressure in the combustion chamber 40 is not easily dropped.

[0048] On the other hand, in the valve overlap period T2 after the top dead center TDC, the piston 52 starts to move downward to the bottom dead center BDC from the top dead center TDC. As the piston 52 is lowered, the volume of the combustion chamber 40 increases. Therefore, the pressure in the combustion chamber 40 is lower than that in the valve overlap period T1 before the top dead center TDC.

[0049] Therefore, in the valve overlap period T2 after the top dead center TDC, more exhaust gas is likely to enter the combustion chamber 40 than in the valve overlap period T1 before the top dead center TDC. As a result, in the engine

10, the point at which the differential pressure DP is negatively maximized is arranged to be included in the valve overlap period T2 after the top dead center TDC.

[0050] Preferably, the internal pressure in the EGR device 101 that fluctuates according to the Helmholtz resonant frequency F defined by Expression (1) is maximized in the valve overlap period T2 after the top dead center TDC. The volume V of the storage container 100 and the length L and the sectional area S of the vent pipe 110 are set according to Expression (1), so that the point at which the internal pressure is maximized can be included in the valve overlap period T2 after the top dead center TDC. When a half cycle of the Helmholtz resonant frequency F is set identical to the period T10 between the crankshaft angle d10 and the crankshaft angle d20 in Fig. 9, the internal pressure in the EGR device 101 is maximized at the crankshaft angle d20. In this way, as shown in Fig. 9, the negative maximum value for the differential pressure DP is included in the valve overlap period T2 after the top dead center TDC.

[0051] As described above, the pressure in the combustion chamber 40 in the valve overlap period T2 after the top dead center TDC is lower than the pressure in the combustion chamber 40 in the valve overlap period T1 before the top dead center TDC. For example, if the point at which the internal pressure in the EGR device 101 that fluctuates according to the Helmholtz resonant frequency F is maximized is included in the valve overlap period T2 after the top dead center TDC, the difference (differential pressure DP) between the internal pressure in the EGR device 101 and the pressure in the exhaust opening 34 is maximized in the valve overlap period T2. In this way, a larger amount of exhaust gas comes into the combustion chamber 40 from the EGR device 101.

Increase of Valve Overlap Period T2 after Top Dead Center TDC

[0052] The valve driving mechanism 16 further drives the intake valve 22 and the exhaust valve 32 so that the valve overlap period T2 after the top dead center TDC becomes longer than the valve overlap period T1 before the top dead center TDC.

[0053] For example as shown in Fig. 7, the valve driving mechanism 16 includes the intake cam 23a and the exhaust cam 33a having the same shape. The phases of the intake cam 23a and the exhaust cam 33a are determined so that the valve overlap period T2 after the top dead center TDC is longer than the valve overlap period T1 before the top dead center TDC. According to the determined phases, the intake cam 23a and the exhaust cam 33a are attached to the cam shafts 23b and 33b. For example, the angle of the exhaust cam shaft 33b is delayed in phase relative to the crankshaft as compared to the case in which the valve overlap period T1 before the top dead center TDC is equal to the valve overlap period T2 after the top dead center TDC.

[0054] As shown in Fig. 10, the valve lift amount LL33 of the exhaust cam 33a is larger than the valve lift amount LL23 of the intake cam 23a, so that the valve overlap period T2 after the top dead center TDC may be longer than the valve overlap period T1 before the top dead center TDC. As shown in Fig. 11, the operation angle A33 of the exhaust cam 33a is set larger than the operation angle A23 of the intake cam 23a, so that the valve overlap period T2 after the top dead center TDC may be longer than the valve overlap period T1 before the top dead center TDC.

[0055] As described above, the pressure in the combustion chamber 40 in the valve overlap period T2 after the top dead center TDC is lower than the pressure in the combustion chamber 40 in the valve overlap period T1 before the top dead center TDC. Therefore, when the valve overlap period T2 after the top dead center TDC is prolonged, more exhaust gas can be entered into the combustion chamber 40 from the EGR device 101.

[0056] As in the foregoing, in the straddle-type vehicle 1 according to the present preferred embodiment, more exhaust gas can be entered into the combustion chamber 40 than the case of using the conventional EGR device. The exhaust gas coming into the combustion chamber 40 from the EGR device 101 lowers the maximum combustion temperature in the combustion chamber 40, so that the generation of NOx is reduced. Since the exhaust gas is returned to the combustion chamber 40, the pumping loss is reduced, and the fuel efficiency improves.

[0057] Fig. 12 shows the relation between the valve opening degree and the intake and exhaust amounts of the EGR device relative to the crankshaft angle in Patent Document 1. The engine disclosed by Patent Document 1 includes an EGR device that has a storage container and a vent pipe similarly to the engine 10. However, in the engine disclosed by Patent Document 1, the valve overlap period T2 after the top dead center TDC is shorter than the valve overlap period T1 before the top dead center TDC. The curve DI indicating the amount of exhaust gas discharged from the EGR device has its peak in the valve overlap period T1.

[0058] In short, in the engine disclosed by Patent Document 1, the exhaust gas comes into the combustion chamber 40 in the valve overlap period T1 before the top dead center TDC. As described above, the pressure in the combustion chamber 40 in the valve overlap period T1 before the top dead center TDC is higher than the pressure in the combustion chamber 40 in the valve overlap period T2 after the top dead center TDC. Therefore, if exhaust gas is discharged from the EGR device in the valve overlap period T1 before the top dead center TDC, the exhaust gas does not easily come into the combustion chamber.

[0059] In the engine disclosed by Patent Document 1, if the shape of the EGR device is adjusted so that exhaust gas is discharged in the valve overlap period T2 after the top dead center TDC, the amount of exhaust gas coming into the

combustion chamber 40 is smaller than that in the engine 10 according to the present preferred embodiment. This is because in the engine disclosed by Patent Document 1, the valve overlap period T2 after the top dead center TDC is shorter than the valve overlap period before the top dead center TDC.

[0060] In the engine 10, exhaust gas is discharged in the valve overlap period T2 after the top dead center TDC and the valve overlap period T2 after the top dead center TDC is longer than the valve overlap period T1 before the top dead center TDC. Therefore, exhaust gas can be discharged in a longer period. As a result, the amount of exhaust gas coming into the combustion chamber 40 increases.

[0061] The engine 10 according to the present preferred embodiment is particularly effectively applied to a straddle-type vehicle including a catalytic device. As shown in Fig. 2, when the catalytic device is provided in the exhaust pipe 204, the pressure in the combustion chamber 40 is not easily lowered because the exhaust gas is less easily let out by the presence of the catalytic device. When the engine disclosed by Patent Document 1 is provided in a straddle-type vehicle including a catalytic device as shown in Fig. 2, the difference between the pressure in the EGR device and the pressure in the combustion chamber is further reduced. This further lowers the EGR ratio.

[0062] On the other hand, if the engine 10 according to the present preferred embodiment includes the catalytic devices 207 and 208, the difference between the pressure in the EGR device 101 and the combustion chamber 40 is still large, and the amount of exhaust gas entered into the combustion chamber 40 increases.

[0063] Preferably, in the straddle-type vehicle according to the present preferred embodiment, the secondary air is supplied to the part of the exhaust pipe between the catalytic devices 207 and 208. A well-known secondary air supply mechanism is arranged to supply secondary air near an exhaust port on the upstream side of a catalytic device. The secondary air supply mechanism promotes oxidizing of the unburned components (CO and HC) in a combustion chamber by the secondary air. Exhaust gas is removed of NO_x by the catalytic device (reducing catalyst) provided on the downstream side. When such a secondary air supply mechanism is combined with the engine 10 according to the present preferred embodiment, secondary air is supplied to the exhaust port 31 near the exhaust valve 32. Therefore, the pressure in the combustion chamber 40 is not easily lowered also in the valve overlap period T2 after the top dead center TDC because of the secondary air.

[0064] In the straddle-type vehicle 1 according to the present preferred embodiment, the downstream end of the supply pipe 205 is connected to the part between the catalytic devices 207 and 208. Therefore, the pressure in the combustion chamber 40 is not easily affected by the secondary air. The difference between the pressure in the EGR device 101 and the pressure in the combustion chamber 40 can be increased.

[0065] In the engine disclosed by Patent Document 1, exhaust gas discharged from the EGR device does not easily come into the combustion chamber 40 and is likely to stay in the exhaust port 31. This is because the exhaust gas is discharged in the valve overlap period T1 before the top dead center TDC. In the valve overlap period T2, a small amount of the exhaust gas remaining in the exhaust port 31 comes into the combustion chamber 40. At the time, the exhaust gas comes into the combustion chamber 40 from the exhaust port 31, not from the opening end of the EGR device and therefore does not form a swirl wave. Therefore, the exhaust gas does not contribute to the reduction of unburned gas in the combustion chamber 40.

[0066] On the other hand, the engine 10 according to the present preferred embodiment discharges exhaust gas from the opening end 101e into the combustion chamber 40 in the valve overlap period T2 after the top dead center TDC. Therefore, the discharged exhaust gas quickly enters the combustion chamber 40 from the opening end 101e and forms a swirl wave as shown in Figs. 7 and 8. Therefore, the engine 10 can reduce more unburned gas remaining in the quenching area QA in the combustion chamber 40 than the engine disclosed by Patent Document 1.

[0067] In an engine without the EGR device 101, a part of exhaust gas in the exhaust port can be returned to the combustion chamber by adjusting the shape and size of the exhaust port or the exhaust pipe as required. However, the shape of the exhaust port or the exhaust pipe is designed in consideration of various factors. Therefore, it would be difficult to design the exhaust port or the exhaust pipe only for the purpose of improving the EGR ratio.

[0068] On the other hand, according to the present preferred embodiment, for example, the timing for returning exhaust gas stored in the EGR device 101 into the combustion chamber 40 can be adjusted readily by adjusting the Helmholtz resonant frequency according to Expression (1). Stated differently, if the shape (volume V, length L, and sectional area S) of the EGR device 101 is adjusted, the Helmholtz resonant frequency can be adjusted readily. Furthermore, the EGR device 101 can be designed only for the purpose of improving the EGR ratio. Therefore, its designing is easier than designing the exhaust port or the exhaust pipe.

[0069] In the engine 10, exhaust gas in the exhaust port 31 does not easily come into the combustion chamber 40. Therefore, the exhaust gas entered into the combustion chamber 40 is less affected by the pressure in the exhaust port 31. Furthermore, the fluctuation cycle (i.e., the Helmholtz resonant frequency defined by Expression (1)) of the internal pressure in the EGR device 101 is lower than the frequency of exhaust pulsation in the exhaust port 31. Therefore, the EGR device 101 is hardly affected by the exhaust pulsation and can discharge exhaust gas stably.

Second Preferred Embodiment

[0070] In Fig. 3, the storage container 100 in the EGR device 101 is formed apart from the cylinder head 10c. However, the storage container 100 may be formed at the cylinder head 10c.

[0071] Fig. 13 is a front view of the cylinder head 10d according to a second preferred embodiment of the present invention. The structure of the straddle-type vehicle according to the second preferred embodiment other than the cylinder head 10d is the same as that of the first preferred embodiment.

[0072] The cylinder head 10d is different from the cylinder head 10c in that it has a new EGR device 151 instead of the EGR device 101. The EGR device 151 includes a storage container 150 and a vent pipe 160.

[0073] The storage container 150 is a rectangular parallelepiped box and provided on the cylinder head 10d. More specifically, the storage container 150 is attached to the cylinder head 10d using bolts. The vent pipe 160 has two opening ends. One of the opening ends is opened into the storage container 150. The vent pipe 160 is communicated with the exhaust port 31 and has its opening end 160e arranged near the intake opening 24 in the exhaust port 31.

[0074] In this way, the storage container 150 is attached to the surface of the cylinder head 10d, so that the engine can be compact.

Third Preferred Embodiment

[0075] The storage container 100 in the EGR device 101 according to the first preferred embodiment has a fixed volume. However, the storage container may have a variable volume. For example, the storage container stores a piston. In this way, the volume of the storage container is changed depending on the movement amount of the piston.

Fourth Preferred Embodiment

[0076] According to the first preferred embodiment, one intake port 21 and one exhaust port 31 are provided. However, a plurality of intake ports 21 and a plurality of exhaust ports 31 may be provided. In this way, the EGR device 101 may be connected to one or more exhaust ports 31.

Fifth Preferred Embodiment

[0077] According to the first preferred embodiment, a plurality of catalytic devices 207 and 208 are provided in the exhaust pipe 204. However, only one catalytic device may be provided in the exhaust pipe 204. In this case, for example, a ternary catalyst may be used as a catalytic device. If only one catalytic device is provided in the exhaust pipe 204, a supply pipe 205 is connected to the part of the exhaust pipe 204 between the engine 10 and the catalytic device.

[0078] If only one catalytic device is provided in the exhaust pipe 204, the straddle-type vehicle may not include the supply pipe 205. In this case, the secondary air is not input to the exhaust pipe 204.

[0079] While preferred embodiments of the present invention have been described above, it is to be understood that variations and modifications will be apparent to those skilled in the art without departing the scope and spirit of the present invention. The scope of the present invention, therefore, is to be determined solely by the following claims.

Claims

1. A saddle-type vehicle (1), comprising:

a single-cylinder four-cycle engine (10);
an intake pipe (203) and an exhaust pipe (204) connected to the engine (10); and
a first catalytic device (207) provided in the exhaust pipe (204),
the engine (10) comprising:

a piston (52);
a cylinder block (10b) having a cylinder (51) arranged to store the piston (52);
a cylinder head (10c) forming a combustion chamber (40) together with the cylinder block (10b) and including
an intake port (21) provided between an intake opening (24) formed in the combustion chamber (40) and
the intake pipe (203) and an exhaust port (31) provided between an exhaust opening (34) formed in the
combustion chamber (40) and the exhaust pipe (204);
an intake valve (22) that opens and closes the intake opening (24);
an exhaust valve (32) that opens and closes the exhaust opening (34);

a valve driving mechanism (16) that provides a valve overlap period in which the intake and exhaust openings (24 and 34) are both open and drives the intake valve (22) and the exhaust valve (32) so that a valve overlap period after the top dead center is longer than a valve overlap period before the top dead center; and
 an exhaust gas re-circulation device (101) communicated with the exhaust port (31) to take in or discharge exhaust gas,
 the exhaust gas re-circulation device (101) comprising:

a storage container (100) that stores the exhaust gas; and
 a vent pipe (110) arranged to communicate the storage container (100) and the exhaust port (31), the vent pipe (110) leading the exhaust gas from the exhaust port (31) into the storage container (100) and discharging the exhaust gas from the storage container (100) into the combustion chamber (40) via the exhaust port (31), the exhaust gas entering the storage container (100) via the vent pipe (110) when the exhaust opening (34) is open in an exhaust stroke and being discharged into the combustion chamber (40) from the storage container (100) via the vent pipe (110) when the exhaust opening (34) is open in an intake stroke after the top dead center.

2. The saddle-type vehicle (1) according to claim 1, wherein a point where the differential pressure obtained by subtracting the pressure in the exhaust opening from the internal pressure in the storage container (100) is maximized is included in the valve overlap period after the top dead center.

3. The saddle-type vehicle (1) according to claim 1, wherein the internal pressure in the storage container (100) is maximized in the valve overlap period after the top dead center.

4. The saddle-type vehicle (1) according to claim 1, further comprising:

a second catalytic device (208) provided in the exhaust pipe (204) on the downstream side of the first catalytic device (207);
 a secondary air supply source; and
 a supply pipe (205) provided between a part of the exhaust pipe (204) between the first catalytic device (207) and the second catalytic device (208) and the supply source to supply secondary air from the supply source to the part of the exhaust pipe (204).

5. The saddle-type vehicle (1) according to claim 1, wherein the valve driving mechanism (16) comprises an intake cam (23a) and an exhaust cam (33a) having the same shape and having their phases set so that the valve overlap period after the top dead center is longer than the valve overlap period before the top dead center.

6. The saddle-type vehicle (1) according to claim 1, wherein the valve driving mechanism (16) comprises:

an intake cam (23a) that raises and lowers the intake valve (22); and
 an exhaust cam (33a) that raises and lowers the exhaust valve (32), the exhaust cam (33a) having an operation angle or a valve lift amount greater than that of the intake cam (23a) so that the valve overlap period after the top dead center is longer than the valve overlap period before the top dead center.

7. The saddle-type vehicle (1) according to claim 1, wherein an end portion of the vent pipe (110) extends in the circumferential direction of the cylinder (51).

8. The saddle-type vehicle (1) according to claim 1, wherein the storage container (100) is provided on the cylinder head (10c).

Patentansprüche

1. Spreizsitz-Fahrzeug (1), das umfasst:

einen Einzylinder-Viertakt-Motor (10);
 ein Einlassrohr (203) und ein Auslassrohr (204), die mit dem Motor (10) verbunden sind; sowie
 eine erste Katalysatorvorrichtung (207), die sich in dem Auslassrohr (204) befindet,

wobei der Motor (10) umfasst:

einen Kolben (52);
 einen Zylinderblock (10b), der einen Zylinder (51) aufweist, der zum Aufnehmen des Kolbens (52) eingerichtet ist;
 einen Zylinderkopf (10c), der zusammen mit dem Zylinderblock (10b) einen Brennraum (40) bildet und einen Einlasskanal (21), der sich zwischen einer in dem Brennraum (40) ausgebildeten Einlassöffnung (24) und dem Einlassrohr (203) befindet, sowie einen Auslasskanal (31) enthält, der sich zwischen einer in dem Brennraum (40) ausgebildeten Auslassöffnung (34) und dem Auslassrohr (204) befindet;
 ein Einlassventil (22), das die Einlassöffnung (24) öffnet und schließt;
 ein Auslassventil (32), das die Auslassöffnung (34) öffnet und schließt;
 einen Ventilbetätigungsmechanismus (16), der eine Ventilüberschneidungszeit bewirkt, in der die Einlass- und die Auslassöffnung (24 und 34) beide offen sind, und der das Einlassventil (22) und das Auslassventil (32) so betätigt, dass eine Ventilüberschneidungszeit nach dem oberen Totpunkt länger ist als eine Ventilüberschneidungszeit vor dem oberen Totpunkt; sowie
 eine Abgasrückführungsvorrichtung (101), die mit dem Auslasskanal (31) in Verbindung steht, um Abgas einzuleiten oder abzuleiten,
 wobei die Abgasrückführungsvorrichtung (101) umfasst:

einen Speicherbehälter (100), der das Abgas speichert; und
 ein Entlüftungrohr (101), das so eingerichtet ist, dass es mit dem Speicherbehälter (100) und dem Auslasskanal (31) in Verbindung steht, wobei das Entlüftungrohr (101) das Abgas aus dem Auslasskanal (31) in den Speicherbehälter (100) einleitet und das Abgas aus dem Speicherbehälter (100) über den Auslasskanal (31) in den Brennraum (40) ableitet, und das Abgas über das Entlüftungrohr (101) in den Speicherbehälter (100) eintritt, wenn die Auslassöffnung (34) bei einem Auslasshub offen ist, und aus dem Speicherbehälter (100) über das Entlüftungrohr (101) in den Brennraum (40) abgeleitet wird, wenn die Auslassöffnung (34) bei einem Einlasshub nach dem oberen Totpunkt offen ist.

2. Spreizsitz-Fahrzeug (1) nach Anspruch 1, wobei ein Punkt, an dem die Druckdifferenz, die ermittelt wird, indem der Druck in der Auslassöffnung von dem Innendruck in dem Speicherbehälter (100) subtrahiert wird, am größten ist, in der Ventilüberschneidungszeit nach dem oberen Totpunkt eingeschlossen ist.

3. Spreizsitz-Fahrzeug (1) nach Anspruch 1, wobei der Innendruck in dem Speicherbehälter (100) in der Ventilüberschneidungszeit nach dem oberen Totpunkt am höchsten ist.

4. Spreizsitz-Fahrzeug (1) nach Anspruch 1, das des Weiteren umfasst:

eine zweite Katalysatorvorrichtung (208), die sich in dem Auslassrohr (204) an der der ersten Katalysatorvorrichtung (207) nachgelagerten Seite befindet;
 eine Sekundärluft-Zuführquelle; und
 ein Zuführrohr (205), das sich zwischen einem Teil des Auslassrohrs (204) zwischen der ersten Katalysatorvorrichtung (207) und der zweiten Katalysatorvorrichtung (208) und der Zuführquelle befindet, um dem Teil des Auslassrohrs (204) Sekundärluft von der Zuführquelle zuzuführen.

5. Spreizsitz-Fahrzeug (1) nach Anspruch 1, wobei der Ventilbetätigungsmechanismus (16) einen Einlassnocken (23a) sowie einen Auslassnocken (33a) umfasst, die die gleiche Form haben und deren Phasen so eingestellt sind, dass die Ventilüberschneidungszeit nach dem oberen Totpunkt länger ist als die Ventilüberschneidungszeit vor dem oberen Totpunkt.

6. Spreizsitz-Fahrzeug (1) nach Anspruch 1, wobei der Ventilbetätigungsmechanismus (16) umfasst:

einen Einlassnocken (23a), der das Einlassventil (22) anhebt und absenkt; und
 einen Auslassnocken (33a), der das Auslassventil (32) anhebt und absenkt, wobei der Auslassnocken (33a) einen Arbeitswinkel oder ein Maß des Ventilhubes hat, der/das größer ist als der/das des Einlassnockens (23a), so dass die Ventilüberschneidungszeit nach dem oberen Totpunkt länger ist als die Ventilüberschneidungszeit vor dem oberen Totpunkt.

7. Spreizsitz-Fahrzeug (1) nach Anspruch 1, wobei sich ein Endabschnitt des Entlüftungrohrs (110) in der Umfangs-

richtung des Zylinders (51) erstreckt.

8. Spreizsitz-Fahrzeug (1) nach Anspruch 1, wobei sich der Speicherbehälter (110) an dem Zylinderkopf (10c) befindet.

5

Revendications

1. Véhicule de type à selle (1) comprenant :

10 un moteur thermique monocylindre quatre temps (10),
une tubulure d'admission (203) et une tubulure d'échappement (204) raccordées au moteur (10), et
un premier dispositif catalytique (207) prévu dans la tubulure d'échappement (204),
le moteur (10) comprenant :

15 un piston (52),
un bloc cylindre (10b) comportant un cylindre (51) agencé pour contenir le piston (52),
une culasse (10c) formant une chambre de combustion (40) avec le bloc cylindre (10b) et incluant un orifice
d'admission (21) prévu entre une lumière d'admission (24) formée dans la chambre de combustion (40) et
la tubulure d'admission (203), ainsi qu'un orifice d'échappement (31) prévu entre une lumière d'échappe-
20 ment (34) formée dans la chambre de combustion (40) et la tubulure d'échappement (204),
une soupape d'admission (22) qui ouvre et ferme la lumière d'admission (24),
une soupape d'échappement (32) qui ouvre et ferme la lumière d'échappement (34),
un mécanisme d'entraînement des soupapes (16) qui procure une période de chevauchement des soupapes
pendant laquelle les lumières d'admission et d'échappement (24 et 34) sont toutes les deux ouvertes et
25 qui entraîne la soupape d'admission (22) et la soupape d'échappement (32) de sorte à ce que la période
de chevauchement des soupapes après le point mort haut soit plus longue que la période de chevauchement
des soupapes avant le point mort haut, et
un dispositif de recirculation des gaz d'échappement (101) en communication avec l'orifice d'échappement
(31) destiné à introduire ou à éjecter les gaz d'échappement,
30 le dispositif de recirculation des gaz d'échappement (101) comprenant :

un réservoir de stockage (100) qui stocke les gaz d'échappement, et
une tubulure de ventilation (110) agencée pour faire communiquer le réservoir de stockage (100) et
l'orifice d'échappement (31), la tubulure de ventilation (110) conduisant les gaz d'échappement de
35 l'orifice d'échappement (31) dans le réservoir de stockage (100) et éjectant les gaz d'échappement du
réservoir de stockage (100) dans la chambre de combustion (40) par l'intermédiaire de l'orifice d'échap-
pement (31), les gaz d'échappement entrant dans le réservoir de stockage (100) via la tubulure de
ventilation (110) lorsque la lumière d'échappement (34) est ouverte pendant la course d'échappement,
et étant éjectés dans la chambre de combustion (40) depuis le réservoir de stockage (100) via la
40 tubulure de ventilation (110) lorsque la lumière d'échappement (34) est ouverte lors de la course
d'admission après le point mort haut.

2. Véhicule de type à selle (1) selon la revendication 1, dans lequel est inclus un point, où est maximisée la pression
différentielle obtenue en soustrayant la pression dans la lumière d'échappement de la pression interne dans le
45 réservoir de stockage (100), lors de la période de chevauchement des soupapes après le point mort haut.

3. Véhicule de type à selle (1) selon la revendication 1, dans lequel la pression interne dans le réservoir de stockage
(100) est maximisée lors de la période de chevauchement des soupapes après le point mort haut.

- 50 4. Véhicule de type à selle (1) selon la revendication 1, comprenant en outre :

un second dispositif catalytique (208) prévu dans la tubulure d'échappement (204) sur le côté aval du premier
dispositif catalytique (207),
une seconde source d'alimentation en air, et
55 une tubulure d'alimentation (205) prévue entre une pièce de la tubulure d'échappement (204), située entre le
premier dispositif catalytique (207) et le second dispositif catalytique (208), et la source d'alimentation pour
fournir de l'air secondaire à partir de la source d'alimentation à la pièce de la tubulure d'échappement (204).

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5. Véhicule de type à selle (1) selon la revendication 1, dans lequel le mécanisme d'entraînement des soupapes (16) comprend une came d'admission (23a) et une came d'échappement (33a) présentant la même forme et dont les phases sont réglées de sorte à ce que la période de chevauchement des soupapes après le point mort haut soit plus longue que la période de chevauchement des soupapes avant le point mort haut.

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6. Véhicule de type à selle (1) selon la revendication 1, dans lequel le mécanisme d'entraînement des soupapes (16) comprend :

10

une came d'admission (23a) qui élève et abaisse la soupape d'admission (22), et
une came d'échappement (33a) qui élève et abaisse la soupape d'échappement (32), la came d'échappement (33a) ayant un angle de fonctionnement ou une valeur de levée de soupape supérieure à celle de la came d'admission (23a) de sorte à ce que la période de chevauchement des soupapes après le point mort haut soit plus longue que la période de chevauchement des soupapes avant le point mort haut.

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7. Véhicule de type à selle (1) selon la revendication 1, dans lequel une extrémité de la tubulure de ventilation (110) s'étend dans la direction circonférentielle du cylindre (51).

20

8. Véhicule de type à selle (1) selon la revendication 1, dans lequel le réservoir de stockage (100) est prévu sur la culasse (10c).

25

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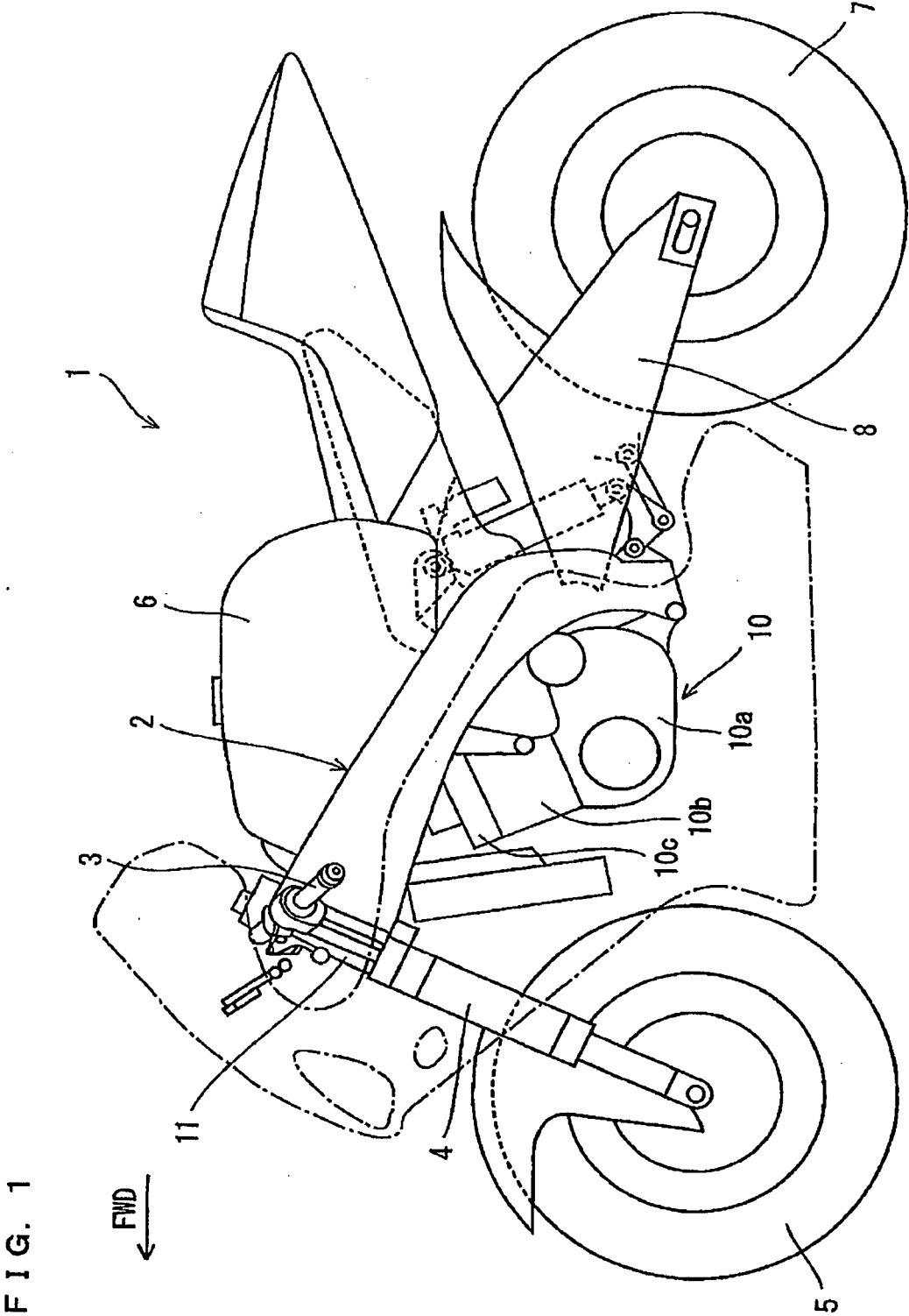
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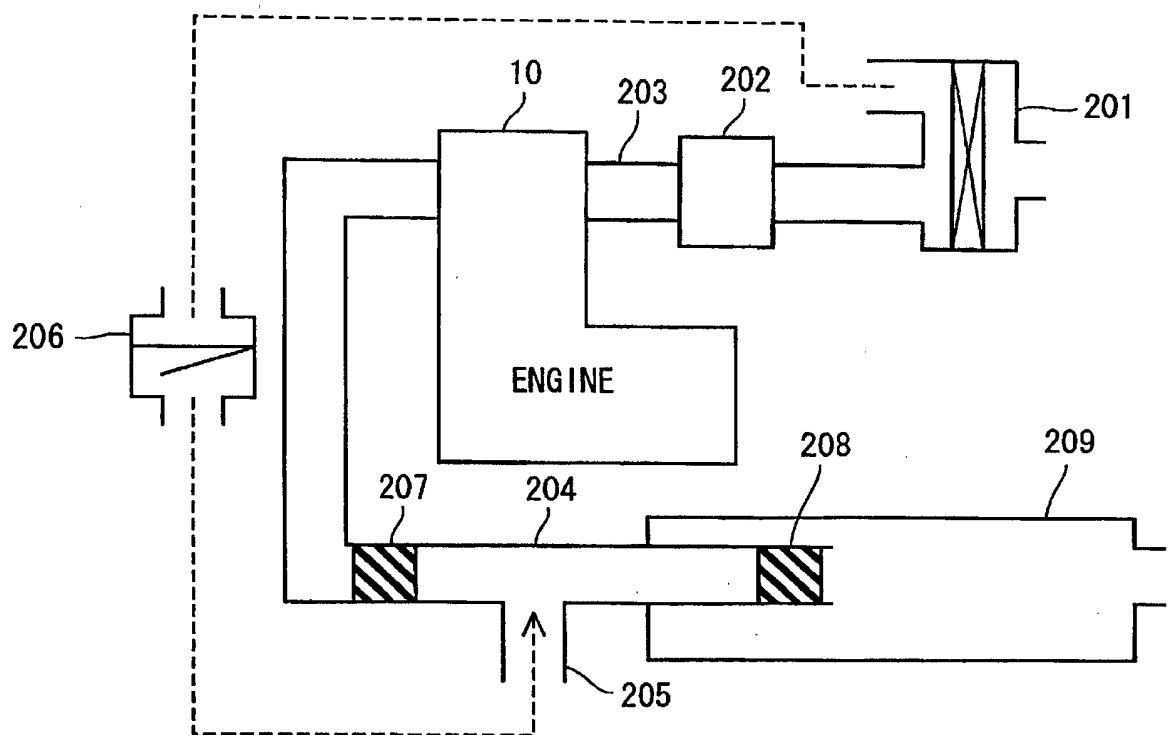
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[Fig. 1]



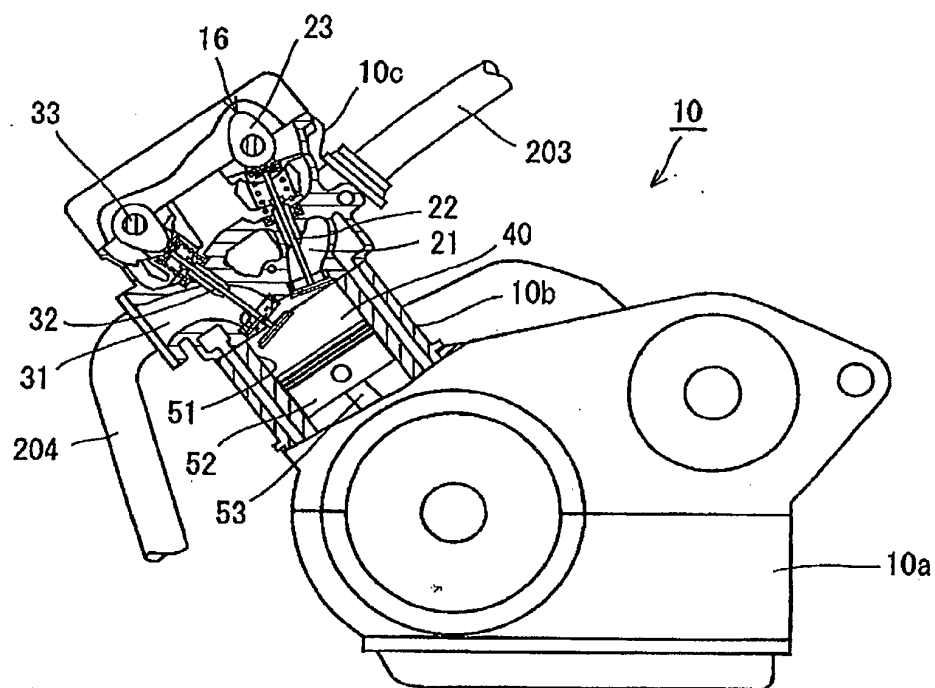
[Fig. 2]

FIG. 2



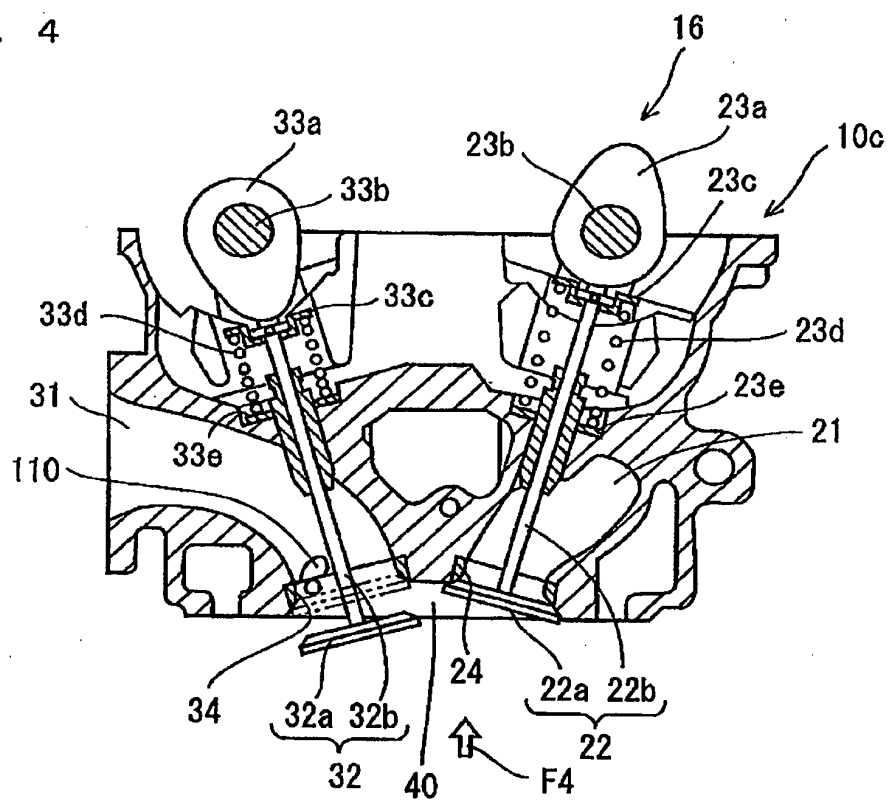
[Fig. 3]

FIG. 3



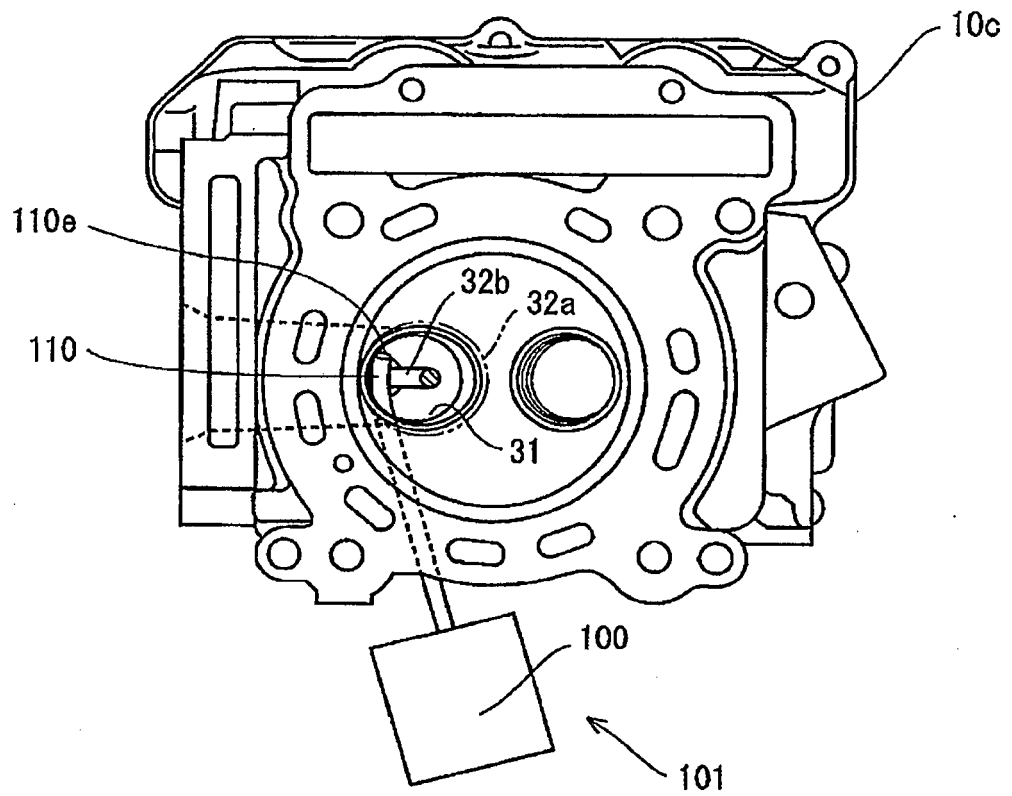
[Fig. 4]

FIG. 4



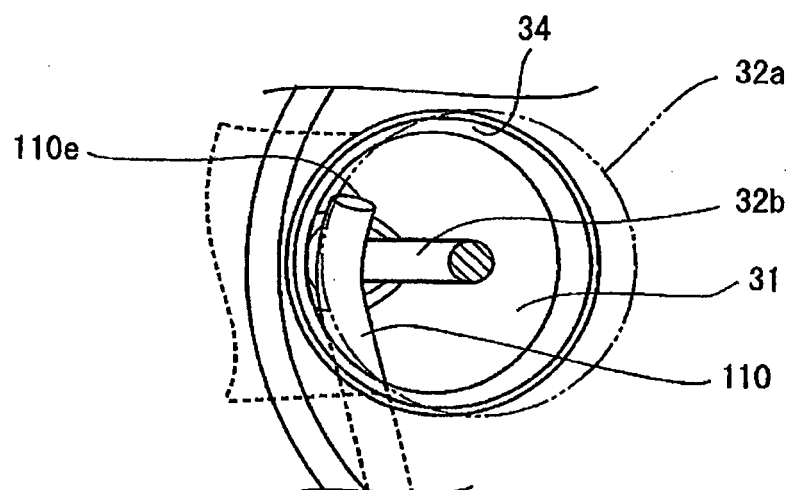
[Fig. 5]

FIG. 5



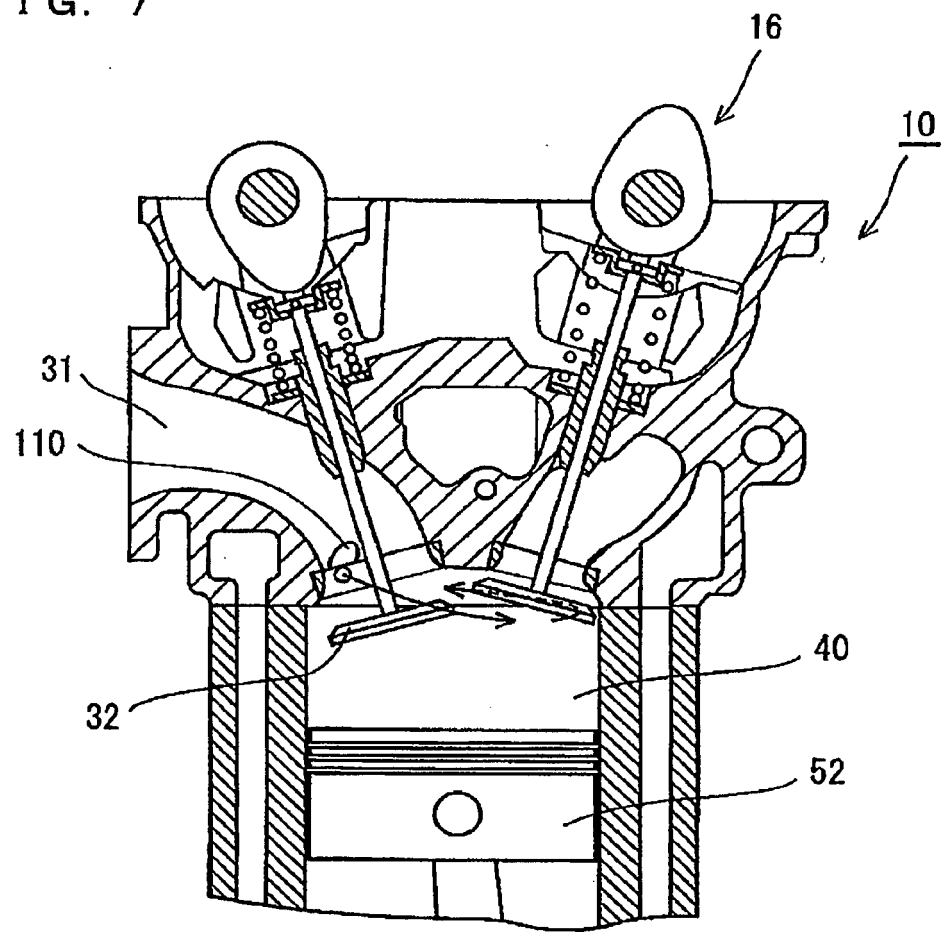
[Fig. 6]

FIG. 6



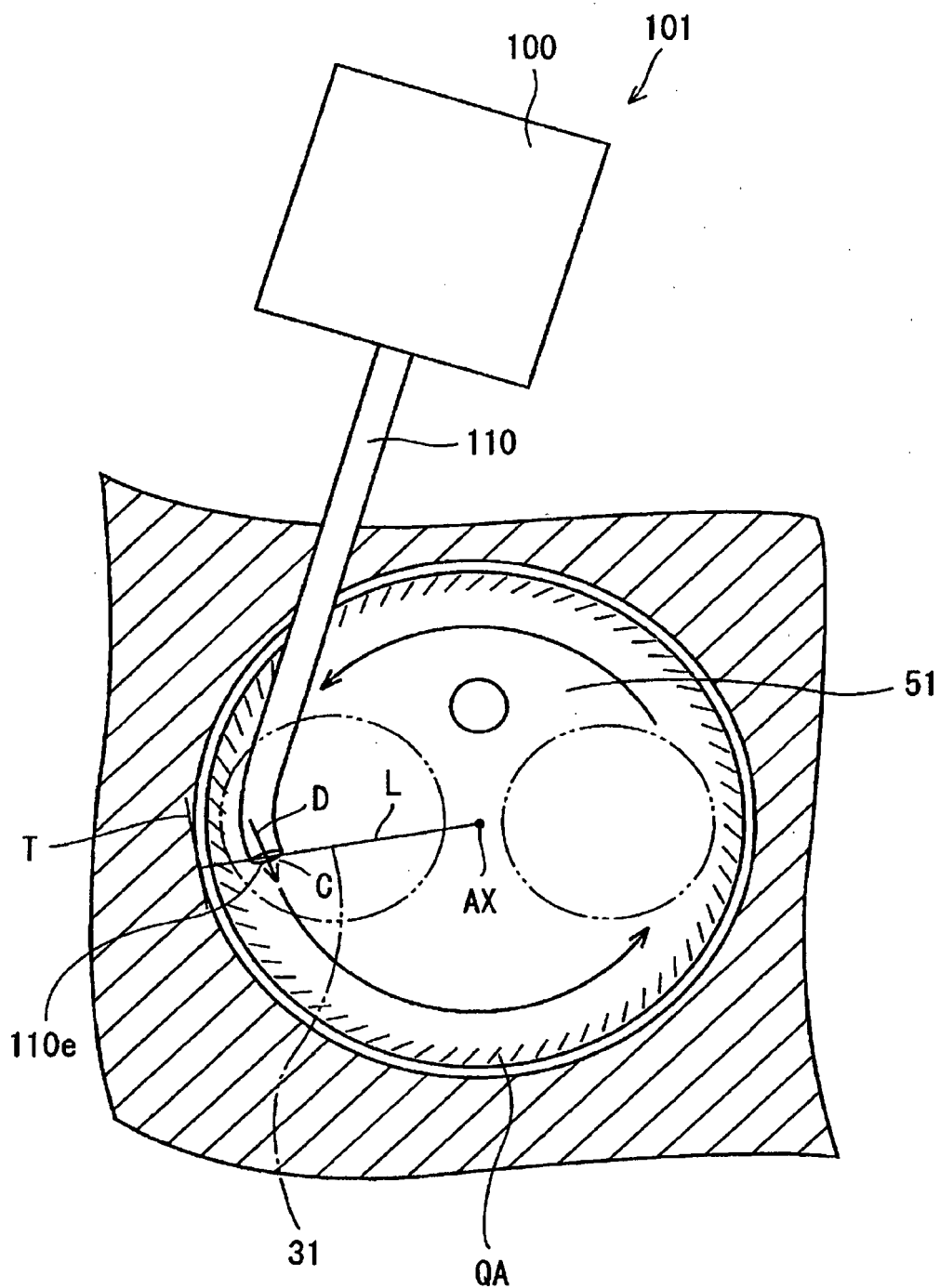
[Fig. 7]

FIG. 7



[Fig. 8]

FIG. 8



[Fig. 9]

FIG. 9A

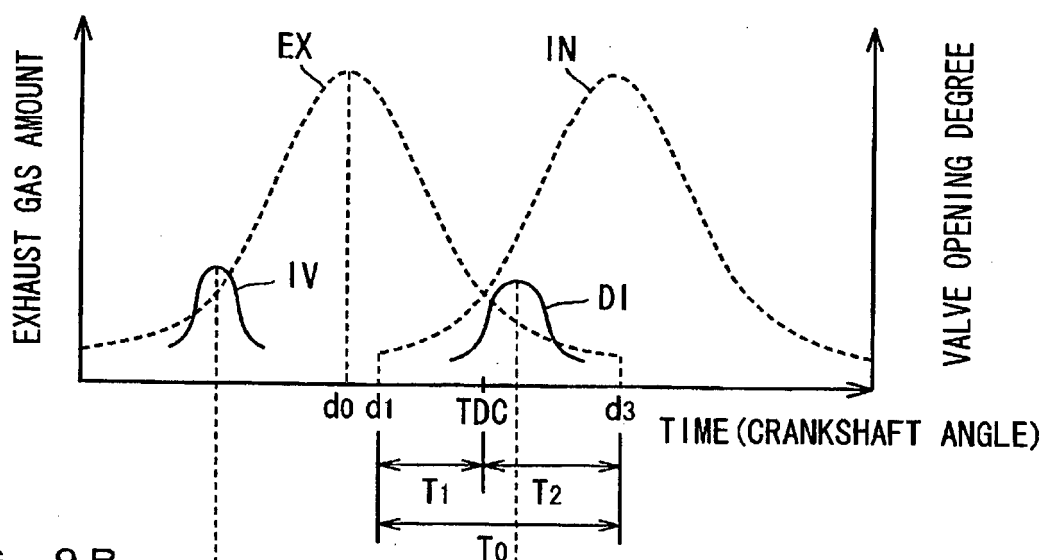
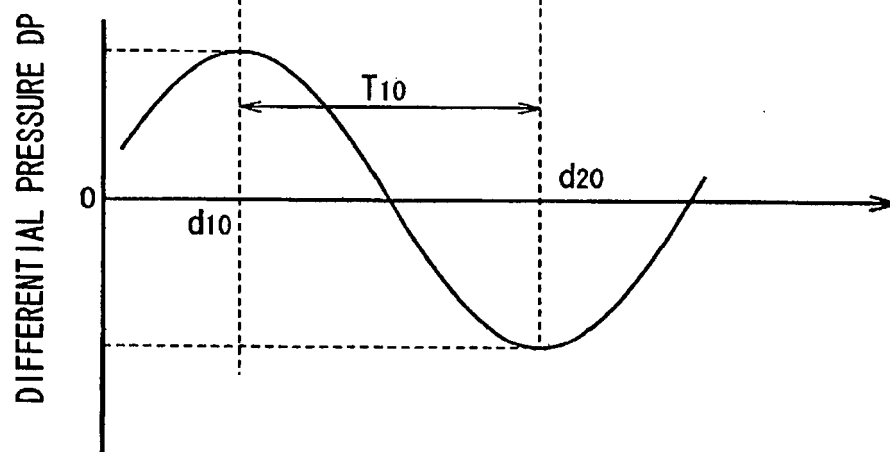
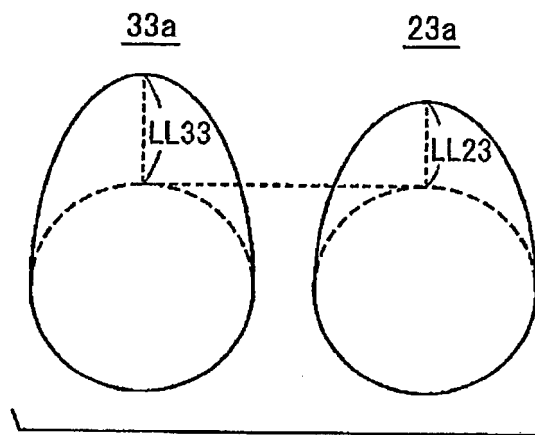


FIG. 9B



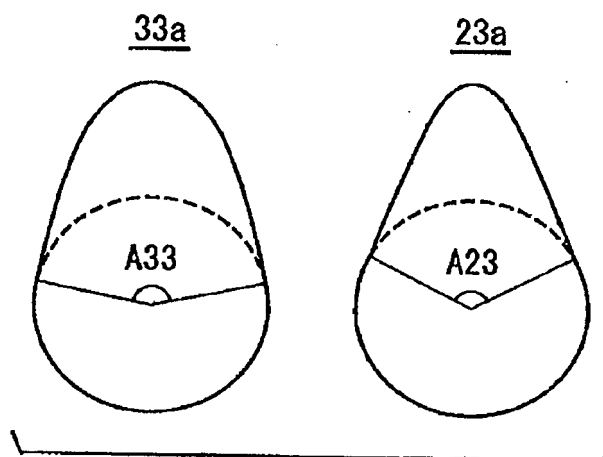
[Fig. 10]

F I G. 1 0



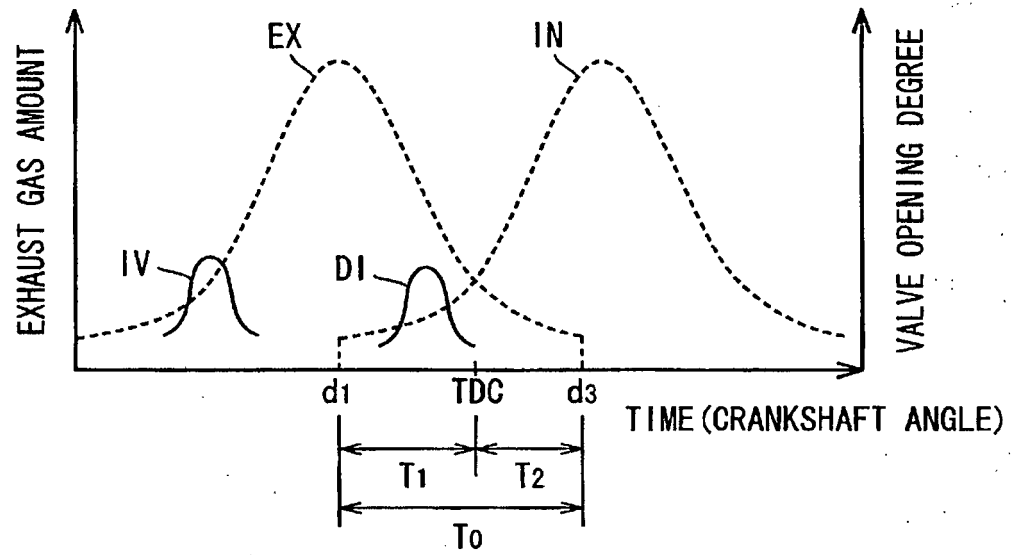
[Fig. 11]

F I G. 1 1



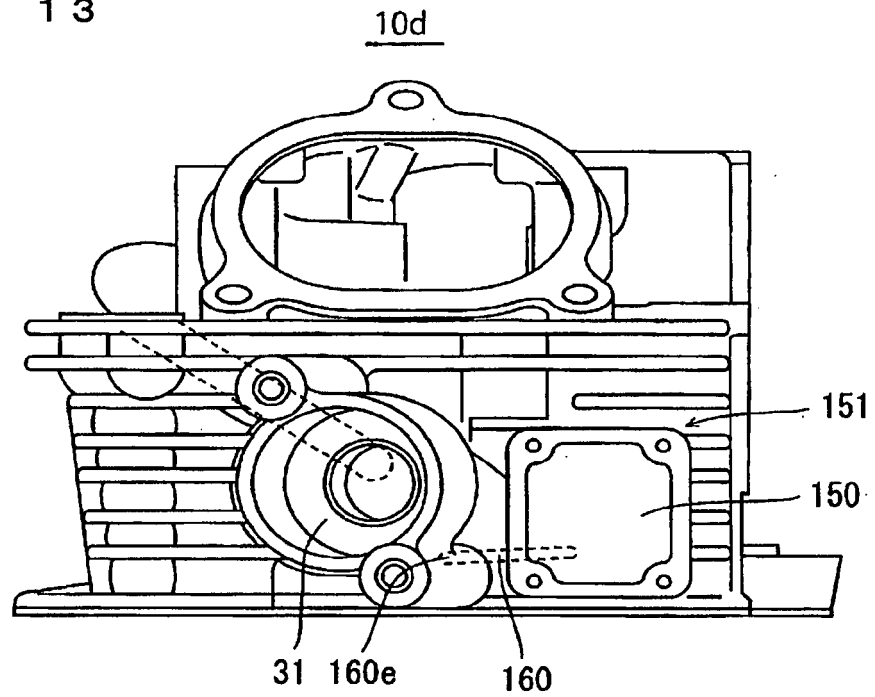
[Fig. 12]

FIG. 12



[Fig. 13]

FIG. 13



REFERENCES CITED IN THE DESCRIPTION

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