



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
16.04.2014 Bulletin 2014/16

(21) Application number: **13188298.7**

(22) Date of filing: **11.10.2013**

(51) Int Cl.:
F02D 41/06 (2006.01) **F02N 11/04** (2006.01)
F02N 19/00 (2010.01) **F02N 99/00** (2010.01)
F01L 1/344 (2006.01) **F01L 1/047** (2006.01)

(84) Designated Contracting States:
AL 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 RS SE SI SK SM TR
Designated Extension States:
BA ME

(30) Priority: **11.10.2012 JP 2012226053**

(71) Applicant: **Yamaha Hatsudoki Kabushiki Kaisha Iwata-shi, Shizuoka-ken 438 (JP)**

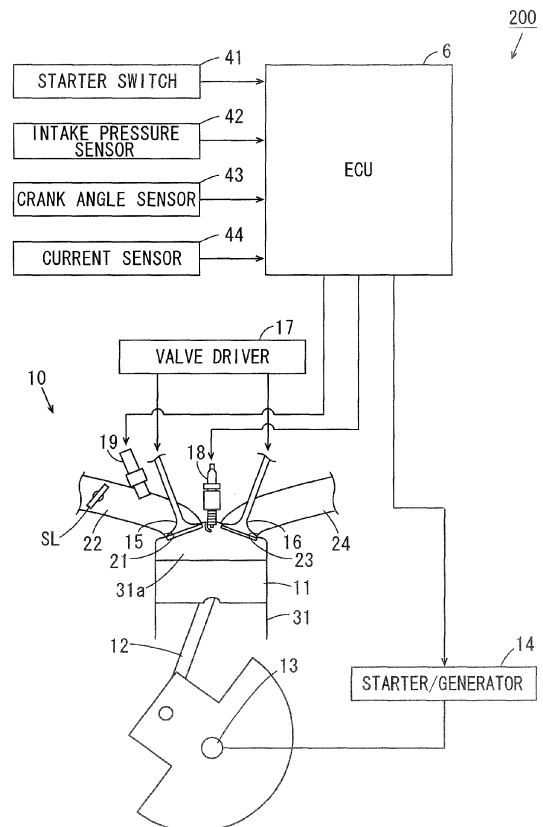
(72) Inventors:
• **Masuda, Takahiro**
Shizuoka-ken, 438-8501 (JP)
• **Sakai, Kouji**
Shizuoka-ken, 438-8501 (JP)

(74) Representative: **Zimmermann, Tankred Klaus et al**
Patentanwälte Schoppe, Zimmermann, Stöckeler, Zinkler & Partner
Postfach 246
82043 Pullach (DE)

(54) **Engine System**

(57) An engine system includes a single-cylinder engine (10) and an ECU. A crankshaft (13) is rotated in a reverse direction by a starter/generator (14) at the start-up of the engine. A valve driver (17) drives an intake valve (15) such that fuel injected by an injector is led to a combustion chamber (31a) from an intake passage (22) through an intake port at a first time point in a period during which the crankshaft (13) is rotated in the reverse direction. Thereafter, a fuel-air mixture is ignited by an ignition plug at a second time point at which the fuel-air mixture is compressed in the combustion chamber (31a) by the rotation of the crankshaft (13) in the reverse direction and a piston does not reach a compression top dead center.

FIG. 2



Description

BACKGROUND OF THE INVENTION

(1) Field of the Invention

[0001] The present invention relates to an engine system.

(2) Description of Related Art

[0002] There is a saddle-straddling type motor vehicle including a single-cylinder engine such as a motorcycle or the like in which a generator having the function of a starter motor (hereinafter referred to as a starter/generator) is provided at a crankshaft. In such a vehicle, a torque is directly transmitted from the starter/generator to the crankshaft without a reduction gear. In this case, the torque transmitted to the crankshaft is markedly smaller than a torque transmitted to the crankshaft from the starter motor separately provided from the generator via the reduction gear.

[0003] When the single-cylinder engine is stopped, a piston is normally moved by inertia to a position immediately before reaching a compression top dead center at which the pressure in a combustion chamber is at peak. Therefore, a larger torque is required in order for the piston to go over the first compression top dead center at the engine start-up. However, as described above, when the torque is directly transmitted from the starter/generator to the crankshaft, enough torque for starting the engine may not be obtained and the piston may not be able to go over the first compression top dead center. Therefore, there is a technique for rotating the crankshaft in a forward direction after rotating the crankshaft in a reverse direction in order to enhance startability of the engine.

[0004] In an engine start-up control device described in JP 2005-248921 A, the crankshaft is rotated in a reverse direction to a predetermined position by the starter/generator provided at the crankshaft after the engine is stopped, and the crankshaft is rotated in the forward direction from the position at the engine start-up. In this case, a rotor position of the starter/generator is detected by a rotor sensor, and a rotation direction of the engine is determined based on an output signal of the rotor sensor. A fuel injection and ignition are prohibited during the reverse rotation of the engine based on its determination result.

BRIEF SUMMARY OF THE INVENTION

[0005] It is an object of the present invention to provide an engine system in which an engine can be stably started and a size of the engine can be reduced.

[0006] This object is achieved by an engine system according to claim 1.

[0007] It has been found out by the inventors that in conventional approaches, even if the crankshaft is rotated

in the forward direction after being rotated in the reverse direction, enough torque may not be obtained and the piston may not be able to go over the first compression top dead center.

[0008] In order to stably start the engine using the starter/generator as described above, an equal amount of torque to a torque transmitted from the starter motor to the crankshaft via the reduction gear is required to be generated by the starter/generator. This requires a high-performance starter/generator. However, a size of such a starter/generator is larger than the generator separately provided from the starter motor. Therefore, a size of the engine is increased. Further, if the larger-size starter/generator operates as a generator, and particularly the rotation speed of the engine is high, excess electric power is likely to be generated and a loss of electric power is increased.

(1) According to an aspect of the present invention, an engine system includes a single-cylinder engine and a controller configured to control the single-cylinder engine, wherein the single-cylinder engine includes a fuel injection device arranged at an intake passage, a valve driver configured to respectively drive an intake valve configured to open and close an intake port and an exhaust valve configured to open and close an exhaust port, an ignition device configured to ignite a fuel-air mixture in a combustion chamber, and a starter/generator provided at a crankshaft and configured to rotate the crankshaft in forward or reverse directions and generate electric power by a rotation of the crankshaft, the controller is configured to control the starter/generator to rotate the crankshaft in the reverse direction during start-up, the valve driver is configured to drive the intake valve such that fuel injected by the fuel injection device is led to the combustion chamber from the intake passage through the intake port at a first time point in a time period during which the crankshaft is rotated in the reverse direction, and the controller is configured to control the ignition device such that the fuel-air mixture is ignited at a second time point at which the fuel-air mixture is compressed in the combustion chamber by the rotation of the crankshaft in the reverse direction and a piston does not reach a compression top dead center after the fuel is led to the combustion chamber at the first time point.

[0009] In this engine system, the crankshaft is rotated in the reverse direction by the starter/generator at the start-up of the single-cylinder engine. At the first time point in a period during which the crankshaft is rotated in the reverse direction, the intake valve is driven by the valve driver such that the fuel injected by the fuel injection device is led from the intake passage to the combustion chamber through the intake port. After the fuel is led to the combustion chamber at the first time point, the fuel-air mixture is ignited by the ignition device at the second

time point at which the fuel-air mixture is compressed in the combustion chamber by the rotation of the crankshaft in the reverse direction and the piston does not reach the compression top dead center.

[0010] In this case, the piston is driven by the energy of explosion carried out in the combustion chamber such that the crankshaft is rotated in the forward direction. Thus, the enough torque in the forward direction is obtained and the piston can easily go over the compression top dead center. Therefore, the engine can be stably started. Further, because the enough torque for starting the engine can be obtained by the ignition of the fuel-air mixture without using the large-size starter/generator, the size of the engine can be reduced. On the other hand, even if the engine displacement is large and it is more difficult for the piston to go over the first compression top dead center, not the starter motor that transmits a torque to the crankshaft via the reduction gear but the starter/generator that directly transmits a torque to the crankshaft can be used. Furthermore, because it is not necessary to use the large-size starter/generator, generation of the excess electric power can be suppressed.

(2) The first time point may be included in a period during which the piston falls from an exhaust top dead center during the rotation of the crankshaft in the reverse direction.

[0011] In this case, the fuel and air can be reliably led to the combustion chamber during the rotation of the crankshaft in the reverse direction.

(3) The valve driver may be configured to drive the exhaust valve such that the exhaust port is opened during a period in which a rotation angle of the crankshaft is in a first range, and drives the intake valve such that the intake port is opened during a period in which the rotation angle of the crankshaft is in a second range, during the rotation of the crankshaft in the forward direction and drive the intake valve such that the intake port is opened during a period in which the rotation angle of the crankshaft is in a third range within the first range during the rotation of the crankshaft in the reverse direction, and the third range may be larger than a range in which the first range and the second range overlap with each other.

[0012] The moving directions of the piston are opposite from each other between the cases in which the crankshaft is rotated in the forward and reverse directions. Therefore, the intake is performed during the rotation of the crankshaft in the reverse direction in an angular range at which the exhaust is to be performed during the rotation of the crankshaft in the forward direction. The third range is then set larger than the second range within the first range such that the enough intake is performed during the rotation of the crankshaft in the reverse direction. This

enables the enough fuel and air to be led to the combustion chamber. As a result, the explosion can be appropriately carried out in the combustion chamber.

(4) The second range and the third range may be separated from each other. In this case, the fuel and air can be led to the combustion chamber at an appropriate time.

(5) The valve driver may be configured to drive the exhaust valve such that the exhaust port is not opened during a period in which the rotation angle of the crankshaft is at least in the third range during the rotation of the crankshaft in the reverse direction.

[0013] In this case, during the rotation of the crankshaft in the reverse direction, because the intake port is opened and the exhaust port is closed in the third range, the fuel and air can be efficiently led to the combustion chamber.

(6) The controller may be configured to control the fuel injection device such that the fuel is injected when the rotation angle of the crankshaft is in a fourth range during the rotation of the crankshaft in the forward direction and the fuel is injected when the rotation angle of the crankshaft is in a fifth range different from the fourth range during the rotation of the crankshaft in the reverse direction.

[0014] In this case, the fuel can be injected at an appropriate time in the respective times of the rotations of the crankshaft in the forward and reverse directions. This enables the fuel to be appropriately led to the combustion chamber.

(7) The fifth range may be set to be positioned at a further advanced angle than the fourth range during the rotation of the crankshaft in the reverse direction.

[0015] In this case, the fuel can be injected at an appropriate time during the rotation of the crankshaft in the reverse direction. Thus, the fuel can be appropriately led to the combustion chamber.

(8) The fifth range may be within the second range. In this case, during the rotation of the crankshaft in the reverse direction, the fuel can be injected before the intake port is opened. This enables the fuel to be sufficiently led to the combustion chamber at the time of the intake.

(9) The valve driver may include a shaft provided to be rotated in conjunction with the rotation of the crankshaft, a first intake cam provided to be integrally rotated with the shaft and configured to operate the intake valve, a second intake cam provided to be rotatable with respect to the shaft and configured to operate the intake valve, a first restriction mechanism configured to restrict a movement of the second intake cam with respect to the shaft and a first ener-

gize member configured to energize the second intake cam, wherein the first restriction mechanism may be provided such that rotation of the second intake cam in a first direction is blocked at a first position of the shaft and rotation of the second intake cam in a second direction opposite to the first direction is blocked at a second position of the shaft, the second intake cam may be configured to operate the intake valve at the first position and not to operate the intake valve at the second position, the first energize member may be configured to energize the second intake cam in the first direction, a counterforce larger than an energizing force of the first energize member may be applied to the second intake cam from the intake valve such that the second intake cam is moved in the second direction during the rotation of the crankshaft in the forward direction, and the second intake cam may be configured to be moved to the first position by the energizing force of the first energize member such that the second intake cam operates the intake valve during the rotation of the crankshaft in the reverse direction.

[0016] In this case, during the rotation of the crankshaft in the forward direction, only the first intake cam operates the intake valve and the second intake cam does not operate the intake valve because of being moved in the second direction. On the other hand, during the rotation of the crankshaft in the reverse rotation, the first intake cam operates the intake valve and the second intake cam operates the intake valve because of being moved to the first position. Thus, the intake port can be opened during the rotation of the crankshaft in the reverse direction in an angular range at which the exhaust is to be performed during the rotation of the crankshaft in the forward direction. This enables the fuel to be sufficiently introduced into the combustion chamber.

(10) The first intake cam may have a first cam nose, the second intake cam may have a second cam nose, and the entire second cam nose may overlap with the first cam nose when the second intake cam is at the second position, and at least part of the second cam nose does not have to overlap with the first cam nose when the second intake cam is at the first position.

[0017] In this case, the second intake cam can be switched between the state of operating the intake valve and the state of not operating the intake valve with a simple configuration.

(11) The valve driver may further include an exhaust cam provided to be rotatable with respect to the shaft and configured to operate the exhaust valve, a blocker provided to be movable between a rotation blocked position at which rotation of the exhaust cam with respect to the shaft is blocked at a predeter-

mined position of the shaft and a rotatable position at which the exhaust cam is rotatable with respect to the shaft, and a mover configured to move the blocker to the rotation blocked position during the rotation of the crankshaft in the forward direction and to the rotatable position during the rotation of the crankshaft in the reverse direction.

[0018] In this case, during the rotation of the crankshaft in the forward direction, because the blocker is moved to the rotation blocked position by the mover, the exhaust cam is fixed at a predetermined position of the shaft. This causes the exhaust cam to operate the exhaust valve. On the other hand, during the rotation of the crankshaft in the reverse direction, because the blocker is moved to the rotatable position by the mover, the exhaust cam is rotatable with respect to the shaft. Thus, the exhaust cam does not operate the exhaust valve at least in a predetermined angular range. Therefore, the exhaust port can be appropriately opened during the rotation of the crankshaft in the forward direction, and the exhaust port can be kept closed during the rotation of the crankshaft in the reverse direction. As a result, the intake can be efficiently performed during the rotation of the crankshaft in the reverse direction.

(12) The valve driver may further include a second restriction mechanism configured to restrict a movement of the exhaust cam with respect to the shaft, the second restriction mechanism may be provided to block the rotation of the exhaust cam in the first direction at a third position of the shaft and the rotation of the exhaust cam in the second direction at a fourth position of the shaft, a counterforce may be applied from the exhaust valve to the exhaust cam such that the exhaust cam is moved in the first direction, during the rotation of the crankshaft in the reverse direction, and the blocker may be configured to block the exhaust cam at the fourth position in the rotation blocked position.

[0019] In this case, during the rotation of the crankshaft in the forward direction, the exhaust cam is blocked at the fourth position by the second restriction mechanism. In this state, the exhaust cam is fixed with respect to the shaft by the blocker. On the other hand, during the rotation of the crankshaft in the reverse direction, the exhaust cam is rotated in the first direction by the counterforce applied by the exhaust valve. Therefore, the exhaust cam can be switched between the state of operating the exhaust valve and the state of not operating the exhaust valve in a predetermined angular range with a simple configuration.

(13) The valve driver may further include a second energize member configured to energize the exhaust cam in the second direction, and an energizing force of the second energize member may be smaller

than the counterforce in the first direction applied from the exhaust valve to the exhaust cam during the rotation of the crankshaft in the reverse direction.

[0020] In this case, during the rotation of the crankshaft in the reverse direction, because the energizing force in the second direction by the second energize member is smaller than the counterforce in the first direction from the exhaust valve, the exhaust cam is prevented from operating the exhaust valve at the fourth position. On the other hand, during the rotation of the crankshaft in the forward direction, the exhaust cam is reliably moved to the fourth position by being energized in the second direction.

(14) The controller may be configured to control such that the fuel-air mixture is ignited by the ignition device while the crankshaft is rotated in the forward direction at the second time point. In this case, the crankshaft can be reliably rotated in the forward direction after the second time point.

(15) The controller may be configured to control such that the crankshaft is driven in the forward direction by the starter/generator after the second time point. In this case, an even larger torque in the forward direction can be obtained after the second time point. Thus, the piston can easily go over the compression top dead center.

(16) According to another aspect of the present invention, a saddle-straddling type motor vehicle includes a main body having a drive wheel and the engine system according to the one aspect of the present invention described above that generates power for rotating the drive wheel.

[0021] In this saddle-straddling type motor vehicle, the drive wheel is rotated by the power generated by the engine system. This causes the main body to move. In this case, because the engine system according to the one aspect of the present invention described above is used, the engine can be stably started and the size of the engine can be reduced.

[0022] The present invention enables the engine to be stably started and an increase in size of the engine to be suppressed.

[0023] Other features, elements, characteristics, and advantages of the present invention will become more apparent from the following description of preferred embodiments of the present invention with reference to the attached drawings.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

[0024]

Fig. 1 is a schematic side view showing the schematic configuration of a motorcycle according to an

embodiment of the present invention;

Fig. 2 is a schematic view for explaining the configuration of an engine system;

Fig. 3 is a diagram for explaining the operation of an engine;

Fig. 4 is a diagram for explaining the operation of the engine;

Fig. 5 is a flowchart of a first example for engine start-up processing;

Fig. 6 is a flowchart of the first example for the engine start-up processing;

Fig. 7 is a flowchart of the first example for the engine start-up processing;

Fig. 8 is a flowchart of a second example for the engine start-up processing;

Fig. 9 is a schematic side view for explaining a specific example of a valve driver;

Fig. 10 is a cross sectional view of the valve driver and its peripheral portions;

Fig. 11 is an external perspective view of the valve driver;

Fig. 12 is a cross sectional view of the valve driver; Fig. 13 is a partially exploded perspective view of the valve driver;

Fig. 14 is a partially exploded perspective view of the valve driver;

Fig. 15 is an external perspective view of a switching mechanism;

Fig. 16 is a cross sectional view of the switching mechanism;

Fig. 17 is an exploded perspective view of a pressure mechanism;

Figs. 18(a) and 18(b) are diagrams for explaining a main-intake cam and a sub-intake cam;

Figs. 19(a) to 19(d) are diagrams for explaining the function of the main-intake cam and the sub-intake cam during a forward rotation of a crankshaft;

Figs. 20(a) to 20(d) are diagrams for explaining the function of the main-intake cam and the sub-intake cam during a reverse rotation of the crankshaft;

Figs. 21 (a) and 21 (b) are diagrams for showing lift amounts of an intake valve;

Figs. 22(a) and 22(b) are cross sectional views for explaining an exhaust cam;

Figs. 23(a) to 23(d) are diagrams for explaining the function of the exhaust cam during the forward rotation of the crankshaft;

Figs. 24(a) to 24(d) are diagrams for explaining the function of the exhaust cam during the reverse rotation of the crankshaft;

Figs. 25(a) and 25(b) are diagrams for showing the operation of the exhaust cam immediately after a rotation direction of the crankshaft is switched from a reverse direction to a forward direction;

Figs. 26(a) and 26(b) are diagrams for explaining the operation of the switching mechanism; and

Figs. 27(a) and 27(b) are diagrams for explaining another example of the switching mechanism.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0025] In the following, a motorcycle will be described as one example of a saddle-straddling type motor vehicle according to embodiments of the present invention with reference to the drawings.

(1) Motorcycle

[0026] Fig. 1 is a schematic side view showing the schematic configuration of the motorcycle according to one embodiment of the present invention. In the motorcycle 100 of Fig. 1, a front fork 2 is provided at the front of a vehicle body 1 to be swingable from side to side. A handle 4 is attached to the upper end of the front fork 2, and a front wheel 3 is attached to the lower end of the front fork 2 to be rotatable.

[0027] A seat 5 is provided at the substantially center of the upper portion of the vehicle body 1. An ECU (Engine Control Unit) 6 is arranged at the lower portion behind the seat 5, and a single-cylinder engine 10 is provided below the seat 5. An engine system 200 is constituted by the ECU 6 and the engine 10. A rear wheel 7 is attached to the lower portion of the rear end of the vehicle body 1 to be rotatable. The rear wheel 7 is rotated by power generated by the engine 10.

(2) Engine System

[0028] Fig. 2 is a schematic diagram for explaining the configuration of the engine system 200. As shown in Fig. 2, the engine 10 includes a piston 11, a connecting rod 12, a crankshaft 13, a starter/generator 14, an intake valve 15, an exhaust valve 16, a valve driver 17, an ignition plug 18 and an injector 19.

[0029] The piston 11 is provided to be reciprocable in a cylinder 31 and connected to the crankshaft 13 via the connecting rod 12. The reciprocating motion of the piston 11 is transformed into the rotational motion of the crankshaft 13. The starter/generator 14 is provided at the crankshaft 13. The starter/generator 14 is a generator having the function of a starter motor, rotates the crankshaft 13 in forward and reverse directions and generates electric power by the rotation of the crankshaft 13. The starter/generator 14 directly transmits a torque to the crankshaft 13 without a reduction gear therebetween. A one-way clutch (not shown) is provided between the crankshaft 13 and the rear wheel 7. The rotation of the crankshaft 13 in the forward direction (hereinafter referred to as a forward rotation) is transmitted to the rear wheel 7 through the one-way clutch, and the rotation of the crankshaft 13 in the reverse direction (hereinafter referred to as a reverse rotation) is not transmitted to the rear wheel 7.

[0030] A combustion chamber 31a is formed on the piston 11. The combustion chamber 31a communicates with an intake passage 22 through an intake port 21 and communicates with an exhaust passage 24 through an

exhaust port 23. An intake valve 15 is provided to open and close the intake port 21, and an exhaust valve 16 is provided to open and close the exhaust port 23. The intake valve 15 and the exhaust valve 16 are driven by the valve driver 17. A throttle valve SL for adjusting an amount of air flowing in from the outside is provided at the intake passage 22. The ignition plug 18 is configured to ignite a fuel-air mixture in the combustion chamber 31a. The injector 19 is configured to inject fuel into the intake passage 22.

[0031] The ECU 6 includes a CPU (Central Processing Unit) and a memory, for example. A microcomputer may be used instead of the CPU or the memory. A starter switch 41, an intake pressure sensor 42, a crank angle sensor 43 and a current sensor 44 are electrically connected to the ECU 6. The starter switch 41 is provided at the handle 4 of Fig. 1, for example, and is operated by a driver. The intake pressure sensor 42 detects pressure in the intake passage 22. The crank angle sensor 43 detects a rotation angle of the crankshaft 13. The current sensor 44 detects a current that flows in the starter/generator 14 (hereinafter referred to as a motor current).

[0032] The operation of the starter switch 41 is supplied to the ECU 6 as an operation signal, and the detection results of the intake pressure sensor 42, the crank angle sensor 43 and the current sensor 44 are supplied to the ECU 6 as detection signals. The ECU 6 controls the starter/generator 14, the ignition plug 18 and the injector 19 based on the supplied operation signal and the detection signals.

(3) Operation of the Engine

[0033] Figs. 3 and 4 are diagrams for explaining the operation of the engine 10. Fig. 3 shows the operation of the engine 10 during normal running, and Fig. 4 shows the operation of the engine 10 during the start-up. Here, the normal running refers to the state in which the engine 10 stably operates after the start-up of the engine 10.

[0034] In Figs. 3 and 4, a rotation angle in a range of two rotations (720 degrees) of the crankshaft 13 is shown by one circle. The two rotations of the crankshaft 13 are equivalent to one cycle of the engine 10. The one cycle of the engine 10 includes an intake stroke, a compression stroke, a combustion stroke and an exhaust stroke. Hereinafter, the rotation angle of the crankshaft 13 is referred to as a crank angle.

[0035] The crank angle sensor 43 of Fig. 2 detects the rotation angle in a range of one rotation (360 degrees) of the crankshaft 13. The ECU 6 determines which one of the two rotations of the crankshaft 13 equivalent to the one cycle of the engine 10 the crank angle detected by the crank angle sensor 43 corresponds to, based on the pressure in the intake passage 22 detected by the intake pressure sensor 42. Thus, the ECU 6 can obtain the rotation angle in the range of the two rotations (720 degrees) of the crankshaft 13.

[0036] In Figs. 3 and 4, an angle A0 is the crank angle

when the piston 11 (Fig. 2) is positioned at an exhaust top dead center, an angle A2 is the crank angle when the piston 11 is positioned at a compression top dead center and angles A1, A3 are the crank angles when the piston 11 is positioned at a bottom dead center. An arrow R1 indicates the direction of the change of the crank angle during the forward rotation of the crankshaft 13, and an arrow R2 indicates the direction of the change of the crank angle during the reverse rotation of the crankshaft 13. Arrows P1 to P4 indicate the moving direction of the piston 11 during the forward rotation of the crankshaft 13, and arrows P5 to P8 indicate the moving direction of the piston 11 during the reverse rotation of the crankshaft 13.

(3-1) During the Normal Running

[0037] First, the operation of the engine 10 during the normal running will be described with reference to Fig. 3. During the normal running, the crankshaft 13 (Fig. 2) is rotated in the forward direction. Thus, the crank angle changes in the direction of the arrow R1. In this case, as indicated by the arrows P1 to P4, the piston 11 (Fig. 2) falls in a range from the angle A0 to the angle A1, the piston 11 rises in a range from the angle A1 to the angle A2, the piston 11 falls in a range from the angle A2 to the angle A3 and the piston 11 rises in a range from the angle A3 to the angle A0.

[0038] At an angle A11, the fuel is injected into the intake passage 22 (Fig. 2) by the injector 19 (Fig. 2). In the forward direction, the angle A11 is positioned at the further advanced angle than the angle A0. The angle A11 is an example of a fourth range. Then, in a range from an angle A12 to an angle A13, the intake port 21 (Fig. 2) is opened by the intake valve 15 (Fig. 2). In the forward direction, the angle A12 is positioned at the further retarded angle than the angle A11 and at the further advanced angle than the angle A0, and the angle A13 is positioned at the further retarded angle than the angle A1. The range from the angle A12 to the angle A13 is an example of a second range. Thus, the fuel-air mixture including air and the fuel is introduced into the combustion chamber 31a (Fig. 2) through the intake port 21.

[0039] Next, at an angle A14, the fuel-air mixture in the combustion chamber 31a (Fig. 2) is ignited by the ignition plug 18 (Fig. 2). The angle A14 substantially matches with the angle A2. This causes an explosion in the combustion chamber 31a. Energy generated by the explosion is turned into the driving force for the piston 11. Thereafter, in a range from an angle A15 to an angle A16, the exhaust port 23 (Fig. 2) is opened by the exhaust valve 16 (Fig. 2). In the forward direction, the angle A15 is positioned at the further advanced angle than the angle A3, and the angle A16 is positioned at the further retarded angle than the angle A0. The range from the angle A15 to the A16 is an example of a first range. This causes the combusted gas to be exhausted from the combustion chamber 31a through the exhaust port 23.

(3-2) At the Start-Up

[0040] Next, the operation of the engine 10 during the start-up will be described with reference to Fig. 4. In Fig. 4, the crankshaft 13 (Fig. 2) is first rotated in the forward or reverse direction such that the crank angle is adjusted to an angle A30. The angle A30 is positioned between the angle A1 and the angle A2. Then, the crankshaft 13 is rotated in the reverse direction from the angle A30.

[0041] During the reverse rotation of the crankshaft 13, the crank angle changes in the direction of the arrow R2. In this case, as shown by the arrows P5 to P8, the piston 11 falls in a range from the angle A2 to the angle A1, the piston 11 rises in a range from the angle A1 to the angle A0, the piston 11 falls in a range from the angle A0 to the angle A3 and the piston 11 rises in a range from the angle A3 to the angle A2. The moving direction of the piston 11 during the reverse rotation of the crankshaft 13 is opposite to the moving direction of the piston 11 during the forward rotation of the crankshaft 13.

[0042] At an angle A23, the fuel is injected into the intake passage 22 (Fig. 2) by the injector 19 (Fig. 2). In the reverse direction, the angle A23 is positioned at the further advanced angle than the angle A0. The angle A23 is an example of a fifth range. Further, in ranges from the angle A13 to the angle A12 and from an angle A21 to an angle A22, the intake port 21 (Fig. 2) is opened by the intake valve 15 (Fig. 2). In the reverse direction, the angles A21, A22 are positioned at the further retarded angle than the angle A0. In this case, because the piston 11 rises in the range from the angle A1 to the angle A0, air and the fuel are hardly introduced into the combustion chamber 31a in the range from the angle A13 to the angle A12. Thereafter, because the piston 11 falls in the range from the angle A0 to the angle A3, the fuel-air mixture including air and the fuel is introduced into the combustion chamber 31a through the intake port 21 in the range from the angle A21 to the angle A22. A time point at which the crank angle is in the range from the angle A21 to the angle A22 is an example of a first time point. Further, the ranges from the angle A16 to the angle A12 and from the angle A21 to the angle A22 are examples of a third range.

[0043] Then, at an angle A31, the rotation direction of the crankshaft 13 is switched from the reverse direction to the forward direction. In the reverse direction, the angle A31 is positioned at a slightly further advanced angle than the angle A2. Thus, the crank angle changes in the direction of the arrow R1. Further, at the angle A31, the fuel-air mixture in the combustion chamber 31a is ignited by the ignition plug 18 (Fig. 2). This causes the explosion in the combustion chamber 31a to be carried out and the crankshaft 13 to be driven. A time point at which the crank angle is the angle A31 is an example of a second time point.

[0044] In the present embodiment, the fuel-air mixture in the combustion chamber 31a is ignited by the ignition plug 18 after the reverse rotation of the crankshaft 13 is stopped. Thus, the crankshaft 13 can be reliably driven

in the forward direction. If the crankshaft 13 can be driven in the forward direction by adjusting the timing of the ignition or the like, the fuel-air mixture in the combustion chamber 31a may be ignited by the ignition plug 18 before the reverse rotation of the crankshaft 13 is stopped.

[0045] Thereafter, the similar operation to Fig. 3 is performed. Specifically, the fuel is injected into the intake passage 22 (Fig. 2) at the angle A11 of Fig. 3, and the fuel-air mixture is introduced into the combustion chamber 31a in the range from the angle A12 to the angle A13. Next, the fuel-air mixture in the combustion chamber 31a is ignited by the ignition plug 18 (Fig. 2) at the angle A14, and the combusted gas is exhausted from combustion chamber 31a through the exhaust port 23 in a range of the angle A15 to the angle A16. Thereafter, the engine 10 is changed to the normal running.

[0046] In such a way, in the present embodiment, at the start-up of the engine 10, the fuel-air mixture is led to the combustion chamber 31a while the crankshaft 13 is rotated in reverse by the starter/generator 14, and thereafter, the fuel-air mixture in the combustion chamber 31a is ignited while the piston 11 is close to the compression top dead center. Thus, the piston 11 is driven such that the crankshaft 13 is rotated in the forward direction, whereby an enough torque in the forward direction can be obtained. As a result, the piston 11 can easily go over the first compression top dead center.

[0047] Note that, the exhaust port 23 may be opened by the exhaust valve 16 in the range from the angle A15 to the angle A16, after the rotation direction of the crankshaft 13 is switched from the reverse direction to the forward direction at the angle A31 and before the intake port 21 is opened by the intake valve 15 in the range from the angle A12 to the angle A13 of Fig. 3. In this case, the combusted gas due to the ignition at the angle A31 is exhausted from the combustion chamber 31a before the intake is performed in the range from the angle A12 to the angle A13.

(4) Engine Start-Up Processing

(4-1) First Example

[0048] At the start-up of the engine 10, the ECU 6 performs the engine start-up processing based on the control program stored in advance in the memory. Figs. 5 to 7 are flowcharts of the first example of the engine start-up processing. The engine start-up processing is started by turning a main switch (not shown) on, for example.

[0049] As shown in Fig. 5, the ECU 6 first determines whether or not the current crank angle is stored in the memory (step S1). The current crank angle is previously stored in the memory when the engine 10 is stopped last time, for example. If the current crank angle is stored, the ECU 6 controls the starter/generator 14 such that the current crank angle matches with the angle A30 of Fig. 4 (step S2).

[0050] If the current crank angle is not stored, the ECU

6 controls the starter/generator 14 such that the crankshaft 13 is rotated in the forward direction (step S3). In this case, a torque of the starter/generator 14 is adjusted based on the detection signal from the current sensor 44 (Fig. 2) such that the piston 11 does not go over the compression top dead center (the angle A2 of Figs. 3 and 4).

[0051] Next, the ECU 6 determines whether or not a specified time period has elapsed since the rotation of the crankshaft 13 was started in the step S3 (step S4). If the specified time period has not elapsed, the ECU 6 controls the starter/generator 14 such that the rotation of the crankshaft 13 in the forward direction continues. When the specified time period has elapsed, the ECU 6 controls the starter/generator 14 such that the rotation of the crankshaft 13 is stopped (step S5). Thus, the crank angle is adjusted to be close to the angle A30 of Fig. 4.

[0052] Note that, in the step S3, the crank angle may be detected when the crankshaft 13 is rotated in the forward direction, and the crank angle may be adjusted to the angle A30 of Fig. 4 based on its detected value.

[0053] Then, as shown in Fig. 6, the ECU 6 determines whether or not predetermined start-up condition of the engine 10 is satisfied (step S6). The start-up condition of the engine 10 is that the starter switch 41 (Fig. 2) is turned on, for example. Another condition, for example when a brake switch (not shown) is turned off, an accelerator grip (not shown) is operated, or voltage of a battery (not shown) is reduced, may be set as the start-up condition of the engine 10.

[0054] When the start-up condition of the engine 10 is satisfied, the ECU 6 performs a timeout setting for the engine start-up processing (step S7). Specifically, an elapsed time period is measured from that time point. When the elapsed time period reaches a predetermined end time period, the engine start-up processing is forcibly terminated (step S17 described below).

[0055] Next, the ECU 6 controls the starter/generator 14 such that the crankshaft 13 is rotated in the reverse direction (step S8). Then, the ECU 6 determines whether or not the current crank angle has reached the angle A23 of Fig. 4 based on the detection signals from the intake pressure sensor 42 (Fig. 2) and the crank angle sensor 43 (Fig. 2) (step S9). The ECU 6 repeats the processing of the step S9 until the current crank angle reaches the angle A23. When the current crank angle reaches the angle A23, the ECU 6 controls the injector 19 such that the injection of the fuel into the intake passage 22 (Fig. 2) is started (step S10).

[0056] Next, the ECU 6 determines whether or not a predetermined injection time period has elapsed since the injection of the fuel was started in the step S10 (step S11). The ECU 6 controls the injector 19 such that the injection of the fuel continues until the predetermined injection time period elapses. When the predetermined injection time period has elapsed, the ECU 6 controls the injector 19 such that the injection of the fuel is stopped (step S12).

[0057] Next, as shown in Fig. 7, the ECU 6 determines

whether or not the motor current has reached a predetermined threshold value based on the detection signal from the current sensor 44 (step S13). In this case, the closer the crank angle comes to the angle A2 of Fig. 4, the larger the motor current becomes. In this example, when the crank angle reaches the angle A31 of Fig. 4, the motor current reaches the threshold value.

[0058] When the electric current flowing in the starter/generator 14 reaches the predetermined threshold value, the ECU 6 controls the starter/generator 14 such that the rotation of the crankshaft 13 in the reverse direction is stopped (step S14) and starts to energize the ignition plug 18 (step S15). Next, the ECU 6 determines whether or not a predetermined energization time period has elapsed since the energization was started in the step S15 (step S16). The ECU 6 continues to energize the ignition plug 18 until the predetermined energization time period elapses. When the predetermined energization time period has elapsed, the ECU 6 stops the energization of the ignition plug 18 (step S17). Thus, the fuel-air mixture in the combustion chamber 31a is ignited. Further, the ECU 6 controls the starter/generator 14 such that the crankshaft 13 is rotated in the forward direction (step S18). Thus, the ECU 6 terminates the engine start-up processing. Thereafter, the ECU 6 performs the control operation corresponding to the operation during the normal running of Fig. 3. The driving of the crankshaft 13 by the starter/generator 14 is stopped after a predetermined time period has elapsed since the processing of the step S18, for example.

[0059] In the step S13, if the motor current has not reached the threshold value, the ECU 6 determines whether or not the predetermined end time period has elapsed since the timeout setting in the step S7 of Fig. 6 (step S19). The predetermined end time period may elapse since the timeout setting when the electric current flowing in the starter/generator 14 does not reach the threshold value due to trouble with the engine 10. The trouble with the engine 10 includes an operational problem with the starter/generator 14, an operational problem of the valve driver 17 or the like. If the end time period has not elapsed, the ECU 6 returns to the processing of the step S13. When the end time period has elapsed, the ECU 6 controls the starter/generator 14 such that the rotation of the crankshaft 13 in the reverse direction is stopped (step S20), and warns the driver that the trouble with the engine 10 has occurred (step S21). Specifically, a warning lamp (not shown), for example, is lit. Thus, the ECU 6 terminates the engine start-up processing.

(4-2) Second Example

[0060] Fig. 8 is a flowchart of the second example of the engine start-up processing. The ECU 6 may perform the processing of the steps S31 to S41 of Fig. 8 instead of the steps S13 to S21 of Fig. 7.

[0061] In the example of Fig. 8, the ECU 6 determines whether or not the crankshaft 13 has been rotated a pre-

determined angle of reverse rotation after the reverse rotation of the crankshaft 13 was started in the step S8 of Fig. 6 based on the detection signal from the crank angle sensor 43 (Fig. 2) (step S31). The angle of reverse rotation is equivalent to the angle from the angle A30 to the angle A31 of Fig. 4. If a prescribed number of pulses that corresponds to the angle of reverse rotation is supplied from the crank angle sensor 43 as the detection signal after the reverse rotation of the crankshaft 13 is started, for example, the ECU 6 determines that the crankshaft 13 has been rotated the angle of reverse rotation.

[0062] If the crankshaft 13 has been rotated the angle of reverse rotation, the ECU 6 controls the starter/generator 14 such that the rotation of the crankshaft 13 in the reverse direction is stopped (step S32) and starts to energize the ignition plug 18 (step S33).

[0063] Next, the ECU 6 determines whether or not the crankshaft 13 has been rotated a predetermined energization angle after the energization was started in the step S33 (step S34). The energization angle is equivalent to the angle by which the crankshaft 13 is rotated in the energization time period in the step S16 of Fig. 7. The ECU 6 determines that the crankshaft 13 has been rotated the energization angle if a prescribed number of pulses that corresponds to the energization angle is supplied from the crank angle sensor 43 as the detection signal after the energization is started, for example.

[0064] If the crankshaft 13 has been rotated the energization angle, the ECU 6 stops the energization to the ignition plug 18 (step S35), controls the starter/generator 14 such that the crankshaft 13 is rotated in the forward direction (step S36) and terminates the engine start-up processing.

[0065] On the other hand, in the step S31, if the crankshaft 13 has not been rotated the angle of reverse rotation, the ECU 6 determines whether or not a predetermined first end time period since the timeout setting in the step S7 has elapsed (step S37). If the first end time period has not elapsed, the ECU 6 returns to the processing in the step S31. When the first end time period has elapsed, the ECU 6 controls the starter/generator 14 such that the rotation of the crankshaft 13 in the reverse direction is stopped (step S38), warns the driver that the trouble with the engine 10 has occurred (step S41) and terminates the engine start-up processing.

[0066] Further, in the step S34, if the crankshaft 13 has not been rotated the energization angle, the ECU 6 determines whether or not a predetermined second end time period has elapsed since the timeout setting in the step S7 (step S39). The second end time period is set longer than the first end time period described above. If the second end time period has not elapsed, the ECU 6 returns to the processing in the step S34. When the second end time period has elapsed, the ECU 6 stops the energization to the ignition plug 18 (step S40), warns the driver that the trouble with the engine 10 has occurred (step S41) and terminates the engine start-up processing.

ing.

[0067] Thus, in the second example, the reverse rotation of the crankshaft 13 is stopped based on the detection signal from the crank angle sensor 43 (steps S31, S32). Further, the energization to the ignition plug 18 is stopped based on the detection signal from the crank angle sensor 43 (steps S34, S35). Thus, the reverse rotation of the crankshaft 13 and the energization to the ignition plug 18 can be stopped at an appropriate time.

[0068] Further, if the second end time period has elapsed in the step S39 after the energization to the ignition plug 18 was started in the step S33, the energization to the ignition plug 18 is stopped in the step S40. Thus, the energization to the ignition plug 18 is prevented from continuing for a long period of time.

(5) Valve Driver

(5-1) Configuration

[0069] Description will be made of a specific example of the valve driver 17. Fig. 9 is a schematic side view for explaining the specific example of the valve driver 17. The valve driver 17 of Fig. 9 is a camshaft that drives the intake valve 15 and the exhaust valve 16 of Fig. 2 via an intake rocker arm 510 (Fig. 10) and an exhaust rocker arm 520 (Fig. 10) described below. The valve driver 17 is provided in a cylinder head 32 to be rotatable. The valve driver 17 has a sprocket 17a, and the crankshaft 13 has a sprocket 13a. A chain 25 with no ends is attached to the sprocket 13a and the sprocket 17a. Thus, the rotation of the crankshaft 13 is transmitted to the valve driver 17 through the chain 25. The rotation speed of the valve driver 17 is half of the rotation speed of the crankshaft 13.

(5-2) Driving of the Valve

[0070] Fig. 10 is a cross sectional view of the valve driver 17 and its peripheral portions. In Fig. 10, the valve driver 17 as viewed from the direction of the arrow G of Fig. 9 is shown. As shown in Fig. 10, the intake rocker arm 510 and the exhaust rocker arm 520 are provided in the cylinder head 32. The intake rocker arm 510 is provided to be swingable with a shaft 511 as a center. A roller 512 is provided at one end of the intake rocker arm 510 and an adjuster 513 is provided at the other end. The roller 512 abuts against a main-intake cam 240 or a sub-intake cam 245 of the valve driver 17. Details of the main-intake cam 240 or the sub-intake cam 245 will be described below. The adjuster 513 abuts against the upper end of the intake valve 15. The intake valve 15 is energized in a direction of closing the intake port 21 by a valve spring 15a. In this case, force is applied from the intake valve 15 to the intake rocker arm 510 in a direction of pushing up the adjuster 513. This causes the roller 512 of the intake rocker arm 510 to be pressed against the main-intake cam 240 or the sub-intake cam 245.

[0071] The exhaust rocker arm 520 is provided to be swingable with a shaft 521 as a center. A roller 522 is provided at one end of the exhaust rocker arm 520, and an adjuster 523 is provided at the other end. The roller 522 abuts against an exhaust cam 230 of the valve driver 17. Details of the exhaust cam 230 will be described below. An adjuster 523 abuts against the upper end of the exhaust valve 16. The exhaust valve 16 is energized in a direction of closing the exhaust port 23 by a valve spring 16a. Thus, force is applied from the exhaust valve 16 to the exhaust rocker arm 520 in a direction of pushing up the adjuster 523, and the roller 522 of the exhaust rocker arm 520 is pressed against the exhaust cam 230.

[0072] The valve driver 17 is rotated in a first direction Q1 during the forward rotation of the crankshaft 13 (Fig. 9), and the valve driver 17 is rotated in a second direction Q2 during the reverse rotation of the crankshaft 13. The valve driver 17 is rotated such that the main-intake cam 240 and the sub-intake cam 245 swing the intake rocker arm 510 and the exhaust cam 230 swings the exhaust rocker arm 520. Thus, the intake valve 15 opens and closes the intake port 21, and the exhaust valve 16 opens and closes the exhaust port 23.

[0073] Fig. 11 is an external perspective view of the valve driver 17, and Fig. 12 is a cross sectional view of the valve driver 17. Figs. 13 and 14 are partially exploded perspective views of the valve driver 17 as viewed from the directions different from each other. As shown in Figs. 11 and 12, the valve driver 17 includes the sprocket 17a, a shaft member 210, a spring fixing member 220, the exhaust cam 230, the sub-intake cam 245, a spring fixing member 250 and a switching mechanism 300.

[0074] As shown in Figs. 13 and 14, the shaft member 210 is substantially cylindrical and has a through hole 210a along an axis. In the following description, an axial direction means a direction parallel to the axis of the shaft member 210, and a circumferential direction means a circumferential direction with the axis of the shaft member 210 as a center. The main-intake cam 240 is integrally provided at the shaft member 210. The exhaust cam 230 and the spring fixing member 220 are attached to a portion of the shaft member 210 on one side of the main-intake cam 240. Further, the sub-intake cam 245 and the spring fixing member 250 are attached to a portion of the shaft member 210 on the other side of the main-intake cam 240.

[0075] As shown in Fig. 13, a flange portion 211, a cam attachment portion 212 and a bearing portion 213 are provided at a portion of the shaft member 210 on the one side of the main-intake cam 240. An outer diameter of the cam attachment portion 212 is smaller than an outer diameter of the flange portion 211, and an outer diameter of the bearing portion 213 is smaller than the outer diameter of the cam attachment portion 212. A through hole 210b is formed at the cam attachment portion 212. The through hole 210a and the through hole 210b communicate with each other as described below.

[0076] The exhaust cam 230 is substantially annular.

An inner diameter of the exhaust cam 230 is substantially equal to the outer diameter of the cam attachment portion 212 of the shaft member 210. The exhaust cam 230 is positioned on the cam attachment portion 212 of the shaft member 210 to abut against the flange portion 211. As described below, the exhaust cam 230 is provided to be rotatable in the circumferential direction in a predetermined angular range with respect to the shaft member 210.

[0077] The spring fixing member 220 is substantially cylindrical. An inner diameter of the spring fixing member 220 is substantially equal to an outer diameter of the bearing portion 213 of the shaft member 210. The spring fixing member 220 is positioned on the bearing portion 213 of the shaft member 210 to abut against the side surface of the cam attachment portion 212. The spring fixing member 220 is provided not to be rotated in the circumferential direction with respect to the shaft member 210.

[0078] A flange portion 221 is provided at the end of the spring fixing member 220. A twisted coil spring 225 is arranged on the outer peripheral surface of the spring fixing member 220 except for the flange portion 221. As shown in Fig. 12, one end of the twisted coil spring 225 is fixed to the flange portion 221 of the spring fixing member 220, and the other end is fixed to the side surface of the exhaust cam 230. The exhaust cam 230 is energized in the second direction Q2 (Fig. 10) with respect to the shaft member 210 by the twisted coil spring 225.

[0079] As shown in Fig. 14, a cam attachment portion 214, a spring attachment portion 215 and a bearing portion 216 are provided at a portion of the shaft member 210 on the other side of the main-intake cam 240. An outer diameter of the spring attachment portion 215 is smaller than an outer diameter of the cam attachment portion 214, and an outer diameter of the bearing portion 216 is smaller than an outer diameter of the spring attachment portion 215.

[0080] A sub-intake cam 245 is substantially annular. An inner diameter of the sub-intake cam 245 is substantially equal to the outer diameter of the cam attachment portion 214 of the shaft member 210. The sub-intake cam 245 is positioned on the cam attachment portion 214 of the shaft member 210 to abut against the main-intake cam 240. A long-sized opening 246 in the circumferential direction is formed at the sub-intake cam 245. Further, a fitting pin 241 (Fig. 12) is fixed to the main-intake cam 240 to project from the other side. A tip end of the fitting pin 241 is fitted into the opening 246 of the sub-intake cam 245. Details of the sub-intake cam 245 will be described below.

[0081] The spring fixing member 250 is substantially annular. An inner diameter of the spring fixing member 250 is substantially equal to an outer diameter of the spring attachment portion 215 of the shaft member 210. The spring fixing member 250 is positioned on the spring attachment portion 215 to abut against the side surface of the cam attachment portion 214. The spring fixing member 250 is provided not to be rotated in the circum-

ferential direction with respect to the shaft member 210.

[0082] A projection 251 is provided at the end of the spring fixing member 250. A twisted coil spring 255 is arranged on the outer peripheral surface of the spring fixing member 250. As shown in Fig. 12, one end of the twisted coil spring 255 is fixed to the projection 251 of the spring fixing member 250, and the other end is fixed to the side surface of the sub-intake cam 245. The sub-intake cam 245 is energized by the twisted coil spring 255 in the first direction Q1 (Fig. 10) with respect to the shaft member 210.

[0083] As shown in Fig. 12, the sprocket 17a is arranged at one end of the bearing portion 213 of the shaft member 210 to be vertical to the axial direction. An opening 17b is formed at the center of the sprocket 17a. Further, a screw thread is formed at the inner peripheral surface of one end of the through hole 210a. A bolt 260 is screwed into the through hole 210a through the opening 17b of the sprocket 17a. Thus, the sprocket 17a is fixed to the shaft member 210.

[0084] In the cylinder head 32 of Fig. 10, a bearing B1 is provided to abut against the outer peripheral surface of the bearing portion 213 of the shaft member 210, and a bearing B2 is provided to abut against the outer peripheral surface of the bearing portion 216. The shaft member 210 is held by the bearings B1, B2 to be rotatable in the circumferential direction.

[0085] Fig. 15 is an external perspective view of the switching mechanism 300, and Fig. 16 is a cross sectional view of the switching mechanism 300. As shown in Figs. 15 and 16, the switching mechanism 300 includes a spring engaging member 310, a spring 315, a moving member 320, a fitting member 330, a spring 335, a pressure mechanism 340 and a sliding mechanism 350.

[0086] As shown in Fig. 16, the spring engaging member 310 is arranged to be opposite to a tip end of the bolt 260 of Fig. 12 in the through hole 210a of the shaft member 210. One end of the spring 315 is engaged with the spring engaging member 310.

[0087] The moving member 320 is arranged to be adjacent to the spring engaging member 310 and movable in the axial direction in the through hole 210a of the shaft member 210. The moving member 320 has a movement blocking portion 321, a spring engaging portion 322, a first abutment portion 323, a tapered portion 324, a second abutment portion 325 and a pressure receiving portion 326. The movement blocking portion 321 is provided to project from the spring engaging portion 322 in the axial direction. An outer diameter of the spring engaging portion 322 is larger than an outer diameter of the movement blocking portion 321 and substantially equal to an inner diameter of the through hole 210a. The spring 315 is arranged to surround the outer peripheral surface of the movement blocking portion 321, and the other end of the spring 315 is engaged with the spring engaging portion 322.

[0088] The tapered portion 324 is provided between the first and second abutment portions 323, 325. An outer

diameter of the second abutment portion 325 is larger than an outer diameter of the first abutment portion 323. The tapered portion 324 is formed such that its outer diameter gradually becomes larger from the first abutment portion 323 towards the second abutment portion 325. Thus, the outer peripheral surface of the first abutment portion 323 and the outer peripheral surface of the second abutment portion 325 are connected with each other through the outer peripheral surface of the tapered portion 324. The pressure receiving portion 326 is provided at the other end of the moving member 320.

[0089] The through hole 210b is formed at the shaft member 210 to vertically intersect with the through hole 210a. The through hole 210b is opened on the outer peripheral surface of the cam attachment portion 212. The fitting member 330 is arranged in the through hole 210b. The fitting member 330 is constituted by an abutment portion 331 and a fitting portion 332. An outer diameter of the abutment portion 331 is larger than an outer diameter of the fitting portion 332. The abutment portion 331 has an abutment surface convexly curving. The abutment surface of the abutment portion 331 abuts against the first abutment portion 323, the tapered portion 324 or the second abutment portion 325 of the moving member 320 depending on the position of the moving member 320 in the axial direction. The spring 335 is arranged to surround the outer peripheral surface of the fitting member 332. One end of the spring 335 is engaged with the abutment portion 331, and the other end is engaged with a step formed at the end of the through hole 210b. When the abutment portion 331 abuts against the first abutment portion 323, the fitting portion 332 of the fitting member 330 is stored in the through hole 210b of the shaft member 210. On the other hand, when the abutment portion 331 abuts against the second abutment portion 325, the fitting portion 332 of the fitting member 330 projects from the outer peripheral surface of the cam attachment portion 212 of the shaft member 210.

[0090] Fig. 17 is an explosive perspective view of the pressure mechanism 340. As shown in Fig. 17, the pressure mechanism 340 includes a cover member 410, a rotation member 420, an annular member 430, ball members 431a, 431b, a holding member 440 and a bar-shaped member 450. The cover member 410 is substantially cylindrical. As shown in Fig. 16, an inner diameter of the cover member 410 is set to become smaller in steps from one end to the other end. Thus, steps 411, 412 are formed inside of the cover member 410.

[0091] As shown in Fig. 17, the rotation member 420 is substantially columnar and has a ball receiving portion 421, a flange portion 422 and a sliding portion 423. A pair of grooves 424a, 424b spirally extending is provided at the outer peripheral surface of the ball receiving portion 421 to be symmetrical with respect to an axis of the rotation member 420. The holding member 440 is substantially cylindrical and has a ball holding portion 441 and a bar holding portion 442. Outer and inner diameters of the ball holding portion 441 are larger than outer and inner

diameters of the bar holding portion 442, respectively.

[0092] As shown in Fig. 16, the bar-shaped member 450 is inserted into the bar holding portion 442 of the holding member 440. The bar holding portion 442 is inserted into the through hole 210a of the shaft member 210. The bar-shaped member 450 is held by the bar holding portion 442 to extend in the axial direction of the shaft member 210. One end of the bar-shaped member 450 abuts against the pressure receiving portion 326 of the moving member 320 in the through hole 210a. A pair of recesses 441a, 441b is formed at the inner peripheral surface of the ball holding portion 441 of the holding member 440. The ball members 431a, 431b are fitted into the recesses 441a, 441b, respectively. Further, the annular member 430 is arranged to abut against one end of the ball holding portion 441. Movement in the axial and circumferential directions of the ball members 431a, 431b with respect to the ball holding portion 441 is blocked by the recesses 441a, 441b of the ball holding portion 441 and the annular member 430. One end of the ball receiving portion 421 of the rotation member 420 is inserted into the ball holding portion 441 of the holding member 440 and the ball members 431a, 431b are fitted into the grooves 424a, 424b, respectively. The other end of the bar-shaped member 450 abuts against the end surface of the ball receiving member 421 of the rotation member 420.

[0093] The cover member 410 is attached to the holding member 440 and the rotation member 420 to cover the outer peripheral surface of the ball holding portion 441 of the holding member 440 and the outer peripheral surface of the ball receiving portion 421 of the rotation member 420. An inner diameter of one end of the cover member 410 is substantially equal to outer diameters of the ball holding portion 441 of the holding member 440 and the annular member 430, and an inner diameter of the other end of the cover member 410 is substantially equal to an outer diameter of the sliding portion 423 of the rotation member 420. An inner diameter of an intermediate portion of the cover member 410 is substantially equal to an outer diameter of the flange portion 422 of the rotation member 420.

[0094] The annular member 430 abuts against the step 411 of the cover member 410 in the cover member 410. Further, in the state of Fig. 16, the flange portion 422 of the rotation member 420 abuts against the step 412. The sliding portion 423 of the rotation member 420 projects from the other end of the cover member 410 in the axial direction.

[0095] The pressure mechanism 340 is integrally rotated with the shaft member 210 except for the rotation member 420. The rotation member 420 is provided to be able to rotate a predetermined angle with respect to the shaft member 210 in the circumferential direction.

[0096] The sliding mechanism 350 includes a fixing member 351 and a sliding member 352. The fixing member 351 is substantially cylindrical and fixed to the cylinder head 32 of Fig. 10 to surround the outer peripheral sur-

face of the sliding portion 423 of the rotation member 420. The sliding member 352 is annular and attached to the inner peripheral surface of the fixing member 351. The sliding member 352 is elastic and abuts against the outer peripheral surface of the sliding portion 423 of the rotation member 420.

[0097] As described above, the ball members 431a, 431b are fitted into the spiral grooves 424a, 424b formed at the outer peripheral surface of the rotation member 420. Therefore, the rotation member 420 is rotated with respect to the shaft member 210, whereby the rotation member 420 is moved in the axial direction with respect to the shaft member 210. In the present embodiment, the rotation member 420 is rotated in the first direction Q1 with respect to the shaft member 210 such that the rotation member 420 is moved in a direction away from the shaft member 210. On the other hand, the rotation member 420 is rotated in the second direction Q2 with respect to the shaft member 210 such that the rotation member 420 is moved in a direction closer to the shaft member 210.

[0098] During the forward rotation of the crankshaft 13, the fitting portion 332 of the fitting member 330 is kept in a state of projecting from the outer peripheral surface of the cam attachment portion 212 of the shaft member 210 (hereinafter referred to as a rotation blocked state). On the other hand, during the reverse rotation of the crankshaft 13, the fitting portion 332 of the fitting member 330 is kept in a state of being stored in the through hole 210b of the shaft member 210 (hereinafter referred to as a rotatable state). Description will be made below of switching between the rotation blocked state and the rotatable state.

(5-3) Main-Intake Cam and Sub-Intake Cam

[0099] Figs. 18(a) and 18(b) are diagrams for explaining the main-intake cam 240 and the sub-intake cam 245. As shown in Figs. 18(a) and 18(b), the fitting pin 241 attached to the main-intake cam 240 is fitted into the opening 246 of the sub-intake cam 245. The main-intake cam 240 is integrally provided with the shaft member 210, and the sub-intake cam 245 is rotatable in the circumferential direction with respect to the shaft member 210. The sub-intake cam 245 is rotated with respect to the shaft member 210 such that the fitting pin 241 is moved in the circumferential direction in the opening 246. A rotatable angular range of the sub-intake cam 245 with respect to the shaft member 210 depends on a length of the opening 246.

[0100] As shown in Fig. 18(a), the fitting pin 241 abuts against one end CA of the opening 246 of the sub-intake cam 245 such that the rotation of the intake-cam 245 in the first direction Q1 is blocked. In this state, a cam nose 245T of the sub-intake cam 245 does not overlap with a cam nose 240T of the main-intake cam 240. The position of the sub-intake cam 245 of Fig. 18(a) is an example of a first position.

[0101] On the other hand, as shown in Fig. 18(b), the fitting pin 241 abuts against the other end CB of the opening 246 of the sub-intake cam 245 such that the rotation of the intake-cam 245 in the second direction Q2 is blocked. In this state, the entire cam nose 245T of the sub-intake cam 245 overlaps with the cam nose 240T of the main-intake cam 240. The position of the sub-intake cam 245 of Fig. 18(b) is an example of a second position.

[0102] A length from the axis of the shaft member 210 to the tip end of the cam nose 240T is larger than a length from the axis of the shaft member 210 to the tip end of the cam nose 245T. Here, the tip end of the cam nose refers to a portion of the outer peripheral surface of the cam nose which a length from the axis of the shaft member 210 is the largest. Further, in the following description, a rise portion of the cam nose refers to a boundary portion between the cam nose and another portion and a portion of the outer peripheral surface of the cam nose which a length from the axis of the shaft member 210 is the smallest.

[0103] As described above, the sub-intake cam 245 is energized in the first direction Q1 (Fig. 16) by the twisted coil spring 255 of Fig. 12. Energizing force in the first direction Q1 applied from the twisted coil spring 255 to the sub-intake cam 245 is smaller than force in the second direction Q2 applied from the intake rocker arm 510 of Fig. 10 to the sub-intake cam 245 as counterforce during the rotation of the valve driver 17. Therefore, if the force in the second direction Q2 is applied from the intake rocker arm 510 to the sub-intake cam 245 during the rotation of the valve driver 17, the sub-intake cam 245 is rotated in the second direction Q2 in a rotatable range with respect to the shaft member 210.

[0104] The function of the main-intake cam 240 and the sub-intake cam 245 with respect to the roller 512 of the intake rocker arm 510 of Fig. 10 will be described. Figs. 19(a) to 19(d) are diagrams for explaining the function of the main-intake cam 240 and the sub-intake cam 245 during the forward rotation of the crankshaft 13, and Figs. 20(a) to 20(d) are diagrams for explaining the function of the main-intake cam 240 and the sub-intake cam 245 during the reverse rotation of the crankshaft 13. Figs. 21 (a) and 21 (b) are diagrams showing lift amounts of the intake-valve 15.

[0105] The shaft member 210 is rotated in the first direction Q1 during the forward rotation of the crankshaft 13. As shown in Fig. 19(a), if neither the cam nose 245T of the sub-intake cam 245 nor the cam nose 240T of the main-intake cam 240 abuts against the roller 512, the force in the second direction Q2 is not applied from the roller 512 to the sub-intake cam 245. In this case, the fitting pin 241 is kept in a state of abutting against the one end CA of the opening 246 of the sub-intake cam 245 by the energizing force of the twisted coil spring 255 (Fig. 12). Further, the intake valve 15 of Fig. 10 is not lifted and the intake port 21 is closed. Hereinafter, the position of the roller 512 while the valve 15 is not lifted is referred to as an initial position.

[0106] As shown in Fig. 19(b), when the rise portion of the cam nose 245T of the sub-intake cam 245 abuts against the roller 512, the force in the second direction Q2 is applied from the roller 512 to the sub-intake cam 245. In this case, the sub-intake cam 245 is rotated in the second direction Q2 with respect to the shaft member 210 such that the rise portion of the cam nose 245T is kept in a state of abutting against the roller 512. Therefore, the roller 512 is not driven by the sub-intake cam 245 and kept at the initial position.

[0107] Next, as shown in Fig. 19(c), when the cam nose 240T of the main-intake cam 240 reaches the roller 512, the cam nose 240T pushes up the roller 512. Thus, as shown in Fig. 21(a), the intake valve 15 is lifted in the range from the angle A12 to the angle A13 and the intake port 21 is opened.

[0108] Then, as shown in Fig. 19(d), when the tip end of the cam nose 240T of the main-intake cam 240 comes closer to the roller 512, the cam nose 245T of the sub-intake cam 245 is moved away from the roller 512. In this case, the force in the second direction Q2 is not applied from the roller 512 to the sub-intake cam 245. Therefore, the sub-intake cam 245 is rotated in the first direction Q1 with respect to the shaft member 210 by the energizing force of the twisted coil spring 255 (Fig. 12). Thus, the fitting pin 241 returns to be in the state of abutting against the one end CA of the opening 246 of the sub-intake cam 245. Thereafter, the operation of Figs. 19(a) to 19(d) is repeated.

[0109] Thus, during the forward rotation of the crankshaft 13, only the main-intake cam 240 drives the intake rocker arm 510 without having the sub-intake cam 245 drive the intake rocker arm 510. Therefore, the intake valve 15 of Fig. 10 is lifted and the intake port 21 is opened only in the range from the angle A12 to the angle A13 of Fig. 21(a).

[0110] During the reverse rotation of the crankshaft 13, the shaft member 210 is rotated in the second direction Q2. As shown in Fig. 20(a), while the roller 512 does not abut against the cam nose 245T of the sub-intake cam 245, similarly to the state of Fig. 19(a), the force in the second direction Q2 is not applied from the roller 512 to the sub-intake cam 245. In this case, the fitting pin 241 is kept in the state of abutting against the one end CA of the opening 246 of the sub-intake cam 245 by the energizing force of the twisted coil spring 255 (Fig. 12).

[0111] As shown in Fig. 20(b), when the cam nose 240T of the main-intake cam 240 reaches the roller 512, the cam nose 240T pushes up the roller 512. Thus, as shown in Fig. 21(b), the intake valve 15 is lifted and the intake port 21 is opened in the range from the angle A13 to the angle A12.

[0112] Then, as shown in Fig. 20(c), when the cam nose 245T of the sub-intake cam 245 reaches the roller 512, force in the first direction Q1 is applied from the roller 512 to the sub-intake cam 245. In this case, the fitting pin 241 is kept in the state of abutting against the one end CA of the opening 246 of the sub-intake cam 245,

and the cam nose 245T pushes up the roller 512. Thus, as shown in Fig. 21 (b), the intake valve 15 is lifted and the intake port 21 is opened in the range from the angle A21 to the angle A22.

[0113] Next, as shown in Fig. 20(d), when the abutment position of the roller 512 goes beyond the tip end of the cam nose 245T, the force in the second direction Q2 is applied from the roller 512 to the sub-intake cam 245. This causes the sub-intake cam 245 to be rotated in the second direction Q2 with respect to the shaft member 210 and the roller 512 to return to the initial position. In this case, as shown in Fig. 21 (b), the lift amount of the intake valve 15 is sharply reduced at the angle A22.

[0114] Thus, during the reverse rotation of the crankshaft 13, both the main intake-cam 240 and the sub-intake cam 245 drive the intake rocker arm 510. Therefore, the intake valve 15 of Fig. 10 is lifted and the intake port 21 is opened in the ranges from the angle A13 to the angle A12 and from the angle A21 to the angle A22 of Fig. 21 (b).

[0115] The results described above cause the opening and closing operation of the intake port 21 during the normal running shown in Fig. 3 and the opening and closing operation of the intake port 21 during the start-up shown in Fig. 4 to be realized.

(5-4) Exhaust Cam

[0116] Figs. 22(a) to 22(d) are diagrams for explaining the exhaust cam 230. As shown in Fig. 22(a), the fitting pin 217 is fixed to the cam attachment portion 212 of the shaft member 210 to project from the outer peripheral surface in a direction vertical to the axis direction. A groove 231 is formed at the inner peripheral surface of the exhaust cam 230 to extend in the circumferential direction. The tip end of the fitting pin 217 is arranged in the groove 231 of the exhaust cam 230.

[0117] The exhaust cam 230 is rotated with respect to the shaft member 210 such that the fitting pin 217 is moved in the groove 231. A rotatable angular range of the exhaust cam 230 with respect to the shaft member 210 depends on a length of the groove 231.

[0118] As shown in Fig. 22(a), the fitting pin 217 abuts against one end DA of the groove 231 of the exhaust cam 230 such that the rotation of the exhaust cam 230 in the second direction Q2 with respect to the shaft member 210 is blocked. Further, as shown in Fig. 22(b), the fitting pin 217 abuts against the other end DB of the groove 231 of the exhaust cam 230 such that the rotation of the exhaust cam 230 in the first direction Q1 with respect to the shaft member 210 is blocked. The position of the exhaust cam 230 of Fig. 22(a) is an example of a fourth position, and the position of the exhaust cam 230 of Fig. 22(b) is an example of a third position.

[0119] A recess 232 is formed at the inner peripheral surface of the exhaust cam 230. While the fitting pin 217 abuts against the one end DA of the groove 231 of the exhaust cam 230 (the state of Fig. 22(a)), the recess 232

is positioned on an extending line of the through hole 210b. In this state, when the fitting portion 332 of the fitting member 330 is fitted into the recess 232, the rotation of the exhaust cam 230 with respect to the shaft member 210 is blocked.

[0120] As described below, the switching mechanism 300 (Fig. 16) is kept in the rotation blocked state during the forward rotation of the crankshaft 13. In this case, the fitting portion 332 of the fitting member 330 is fitted into the recess 232 while the fitting pin 217 abuts against the one end DA of the groove 231 of the exhaust cam 230, and the rotation of the exhaust cam 230 with respect to the shaft member 210 is blocked. On the other hand, during the reverse rotation of the crankshaft 13, the switching mechanism 300 (Fig. 12) is kept in the rotatable state. Thus, the exhaust cam 230 is rotatable with respect to the shaft member 210 in a predetermined range.

[0121] As described above, the exhaust cam 230 is energized in the second direction Q2 by the twisted coil spring 225 of Fig. 12. The energizing force in the second direction Q2 applied from the twisted coil spring 225 to the exhaust cam 230 is smaller than the force in the first direction Q1 applied from the exhaust rocker arm 520 of Fig. 10 to the exhaust cam 230 as the counterforce during the rotation of the valve driver 17. Therefore, when the force in the first direction Q1 is applied from the exhaust rocker arm 520 to the exhaust cam 230 during the rotation of the valve driver 17, the exhaust cam 230 is rotated in the first direction Q1 with respect to the shaft member 210 in a rotatable range.

[0122] Function of the exhaust cam 230 with respect to the roller 522 of the exhaust rocker arm 520 of Fig. 10 will be described. Figs. 23(a) to 23(d) are diagrams for explaining the function of the exhaust cam 230 during the forward rotation of the crankshaft 13, and Figs. 24(a) to 24(d) are diagrams for explaining the function of the exhaust cam 230 during the reverse rotation of the crankshaft 13.

[0123] During the forward rotation of the crankshaft 13, as shown in Figs. 23(a) to 23(d), the exhaust cam 230 is integrally rotated with the shaft member 210 in the first direction Q1 while the fitting pin 217 abuts against the one end DA of the groove 231 of the exhaust cam 230. In this case, the cam nose 230T of the exhaust cam 230 pushes up the roller 522. Thus, the exhaust valve 16 of Fig. 10 is lifted and the exhaust port 23 is opened in the range from the angle A15 to the angle A16 of Fig. 3.

[0124] Fig. 24(a) shows the state of the exhaust cam 230 when the crank angle is the angle A30 of Fig. 4, and Fig. 24(d) shows the state of the exhaust cam 230 when the crank angle is the angle A31 of Fig. 4. Figs. 24(b) and 24(c) show the states of the exhaust cam 230 between the states of Fig. 24(a) and Fig. 24(d). As described above, the reverse rotation of the crankshaft 13 is performed in the range from the angle A30 to the angle A31 of Fig. 4.

[0125] During the reverse rotation of the crankshaft 13, the exhaust cam 230 can be rotated with respect to the

shaft member 210. Further, the exhaust cam 230 is energized in the second direction Q2 by the twisted coil spring 225 of Fig. 12. When the crank angle is at the angle A30 of Fig. 4, the cam nose 230T of the exhaust cam 230 does not abut against the roller 522 as shown in Fig. 24(a). Therefore, the force in the first direction Q1 is not applied from the roller 522 to the exhaust cam 230, and the fitting pin 217 is kept in a state of abutting against the one end DA of the groove 231 by the energizing force of the twisted coil spring 225.

[0126] Then, as shown in Fig. 24(b), when the rise portion of the cam nose 230T of the exhaust cam 230 abuts against the roller 522, the force in the first direction Q1 is applied from the roller 522 to the exhaust cam 230. The force in the first direction Q1 applied from the roller 522 to the cam nose 230T is larger than the force in the second direction Q2 applied from the twisted coil spring 225 to the exhaust cam 230. Therefore, as shown in Fig. 24(c), only the shaft member 210 is rotated in the second direction Q2 while the rise portion of the cam nose 230T is kept in a state of abutting against the roller 522 without having the cam nose 230T push up the roller 522.

[0127] Thereafter, if the rotation of the shaft member 210 in the second direction Q2 continues, the fitting pin 217 abuts against the other end DB of the groove 231 and the exhaust cam 230 is integrally rotated with the shaft member 210. In this case, the roller 522 is pushed up by the cam nose 230T. However, in the present embodiment, even if the crank angle reaches the angle A31 of Fig. 4, the fitting pin 217 does not abut against the other end DB of the groove 231 as shown in Fig. 24(d). Therefore, during the reverse rotation of the crankshaft 13, the exhaust rocker arm 520 is not driven and the exhaust port 23 is not opened.

[0128] Figs. 25(a) and 25(b) are diagrams showing the operation of the exhaust cam 230 immediately after the rotation direction of the crankshaft 13 is switched from the reverse direction to the forward direction. As shown in Fig. 25(a), the rise portion of the cam nose 230T abuts against the roller 522 and the fitting pin 217 is between the one end DA and the other end DB of the groove 231 immediately after the rotation direction of the crankshaft 13 is switched from the reverse direction to the forward direction. In this case, only the shaft member 210 is rotated in the first direction Q1 while the rise portion of the cam nose 230T is kept in the state of abutting against the roller 522 by the energizing force of the twisted coil spring 225 of Fig. 12.

[0129] Thereafter, as shown in Fig. 25(b), when the fitting pin 217 abuts against the one end DA of the groove 231, the switching mechanism 300 switches to the rotation blocked state and the rotation of the exhaust cam 231 with respect to the shaft member 210 is blocked. Thereafter, as shown in Figs. 23(a) to 23(d), the exhaust cam 230 is integrally rotated with the shaft member 210 and drives the exhaust rocker arm 520.

[0130] The results described above cause the opening and closing operation of the exhaust port 23 during the

normal running shown in Fig. 3 and the opening and closing operation of the exhaust port 23 at the start-up shown in Fig. 4 to be realized.

(5-5) Switching Mechanism

[0131] Figs. 26(a) and 26(b) are diagrams for explaining the operation of the switching mechanism 300. Fig. 26(a) shows the switching mechanism 300 in the rotatable state, and Fig. 26(b) shows the switching mechanism 300 in the rotation blocked state. In Figs. 26(a) and 26(b), one direction in the axial direction is a third direction Q3, and the other direction is a fourth direction Q4. The third direction Q3 is a direction in which the moving member 320 comes closer to the spring engaging member 310, and the fourth direction Q4 is a direction in which the moving member 320 moves away from the spring engaging member 310.

[0132] As shown in Fig. 26(a), in the rotatable state, the flange portion 422 of the rotation member 420 abuts against the step 412 of the cover member 410, and the bar-shaped member 450 is stored in the holding member 440. In this case, the pressure receiving portion 326 of the moving member 320 abuts against one end of the holding member 440, and the first abutment portion 323 of the moving member 320 is positioned on the extending line of the through hole 210b of the shaft member 210. Thus, the abutment portion 331 of the fitting member 330 abuts against the first abutment portion 323 of the moving member 320, and the fitting portion 332 is stored in the through hole 210b. The position of the fitting member 330 of Fig. 26(a) is an example of a rotatable position.

[0133] As shown in Fig. 26(b), in the rotation blocked state, the flange portion 422 of the rotation member 420 abuts against the annular member 30, and the bar-shaped member 450 projects from the one end of the holding member 440 in the third direction Q3. In this case, the second abutment portion 325 of the moving member 320 is positioned on the extending line of the through hole 210b of the shaft member 210. Thus, the fitting portion 331 of the fitting member 330 abuts against the second abutment portion 325 of the moving member 320, and the fitting portion 332 of the fitting member 330 objects from the outer peripheral surface of the cam attachment portion 212 of the shaft member 210. Therefore, the fitting portion 332 of the fitting member 330 is fitted into the recess 232 of the exhaust cam 230 (Figs. 22(a) and 22(b)). The position of the fitting member 330 of Fig. 26(b) is an example of the rotation blocked position.

[0134] The switching mechanism 300 is in the rotation blocked state of Fig. 26(b) before the start-up of the engine 10. At the start-up of the engine 10, the crankshaft 13 is rotated in the reverse direction, and the shaft member 210 is rotated in the second direction Q2. Each portion of the switching mechanism 300 except for the sliding mechanism 350 is rotated in the second direction Q2 together with the shaft member 210. In this case, the friction force in the first direction Q1 is exerted from the

sliding member 352 of the sliding mechanism 350 onto the sliding portion 423 of the rotation member 420. Therefore, the rotation member 420 is rotated in the first direction Q1 with respect to the shaft member 210 and is moved in the fourth direction Q4 in the axial direction. The flange portion 422 of the rotation member 420 abuts against the step 412 of the cover member 410 such that the rotation in the first direction Q1 and the movement in the fourth direction Q4 of the rotation member 420 are blocked.

[0135] When the rotation member 420 is moved in the fourth direction Q4, the moving member 320 and the bar-shaped member 450 are moved in the fourth direction Q4 by the energizing force of the spring 315. Thus, the bar-shaped member 450 is stored in the holding member 440, and the pressure receiving portion 326 of the moving member 320 abuts against the one end of the holding member 440. Further, the abutment portion 331 of the fitting member 330 abuts against the first abutment portion 323 of the moving member 320 by the energizing force of the spring 335. Thus, the fitting portion 332 of the fitting member 330 is stored in the through hole 210b of the shaft member 210. In such a way, the switching mechanism 300 switches from the rotation blocked state of Fig. 26(b) to the rotatable state of Fig. 26(a).

[0136] Thereafter, the rotation direction of the crankshaft 13 switches from the reverse direction to the forward direction, and the shaft member 210 is rotated in the first direction Q1. However, as shown in Fig. 25(a), the fitting pin 217 does not abut against the one end DA of the groove 231 of the exhaust cam 230 and the recess 232 of the exhaust cam 230 is not positioned on the extending line of the through hole 210b of the shaft member 210 immediately after the rotation direction of the crankshaft 13 switches from the reverse direction to the forward direction. Therefore, the fitting portion 332 of the fitting member 330 is kept in the state of being stored in the through hole 210b of the shaft member 210.

[0137] As shown in Fig. 25(b), when the fitting pin 217 abuts against the one end DA of the groove 231 of the exhaust cam 230, the switching mechanism 300 switches from the rotatable state of Fig. 26(a) to the rotation blocked state of Fig. 26(b). Specifically, the shaft member 210 is rotated in the first direction Q1 such that friction force in the second direction Q2 is exerted from the sliding member 352 of the sliding mechanism 350 onto the sliding portion 423 of the rotation member 420. Therefore, the rotation member 420 is rotated in the second direction Q2 with respect to the shaft member 210 and is moved in the third direction Q3 of the axial direction. The flange portion 422 of the rotation member 420 abuts against the annular member 430 such that the rotation in the second direction Q2 and the movement in the third direction Q3 of the rotation member 420 are blocked.

[0138] The rotation member 420 is moved in the third direction Q3 such that the one end of the bar-shaped member 450 projects from the holding member 440 in the third direction Q3. This causes the moving member

320 to be moved in the third direction Q3 and the movement blocking portion 321 of the moving member 320 to abut against the spring engaging member 310. Further, the abutment portion 331 of the fitting member 330 is pressed in the direction away from the axis of the shaft member 210 by the tapered portion 324 of the moving member 320. Thus, the fitting member 330 is moved against the energizing force of the spring 335 in the direction away from the axis of the shaft member 210, and the fitting portion 332 of the fitting member 330 projects outside of the through hole 210b. This causes the fitting portion 332 of the fitting member 330 to fit into the recess 232 of the exhaust cam 230 (Figs. 22(a) and 22(b)). In such a way, the switching mechanism 300 switches from the rotatable state of Fig. 26(a) to the rotation blocked state of Fig. 26(b).

(5-6) Another Example of the Switching Mechanism

[0139] Figs. 27(a) and 27(b) are diagrams for explaining another example of the switching mechanism 300. As for the switching mechanism 300 of Figs. 27(a) and 27(b), difference from the examples of Figs. 26(a) and 26(b) will be described. In the switching mechanism 300 of Figs. 27(a) and 27(b), an outer diameter of the first abutment portion 323 of the moving member 320 is larger than an outer diameter of the second abutment portion 325. The tapered portion 324 is formed such that an outer diameter gradually becomes smaller from the first abutment portion 323 towards the second abutment portion 325. Thus, the outer peripheral surface of the first abutment portion 323 and the outer peripheral surface of the second abutment portion 325 are connected via the outer peripheral surface of the tapered portion 324.

[0140] As shown in Fig. 27(a), while the abutment portion 331 of the fitting member 330 abuts against the first abutment portion 323 of the moving member 320, the fitting portion 332 of the fitting member 330 projects from the outer peripheral surface of the cam attachment portion 212 of the shaft member 210. Thus, the switching mechanism 300 enters the rotation blocked state. On the other hand, as shown in Fig. 27(b), while the fitting portion 331 of the fitting member 330 abuts against the second abutment portion 325 of the moving member 320, the fitting portion 332 of the fitting member 330 is stored in the through hole 210b of the shaft member 210. Thus, the switching mechanism 300 enters the rotatable state.

[0141] Spiral grooves 424c, 424d are formed at the outer peripheral surface of the ball receiving portion 421 of the rotation member 420 instead of the grooves 424a, 424b of Figs. 26(a) and 26(b). With respect to the axis of the rotation member 420, a direction of the spiral of the groove 424c is opposite to a direction of the spiral of the groove 424a, and a direction of the spiral of the groove 424d is opposite to a direction of the spiral of the groove 424b. The ball member 431a is fitted into the groove 424c, and the ball member 431b is fitted into the groove 424d.

[0142] In this case, the rotation member 420 is rotated in the first direction Q1 with respect to the shaft member 210 such that the rotation member 420 is moved in the third direction Q3. On the other hand, the rotation member 420 is rotated in the second direction Q2 with respect to the shaft member 210 such that the rotation member 420 is moved in the fourth direction Q4.

[0143] The switching mechanism 300 is in the rotation blocked state of Fig. 27(a) before the start-up of the engine 10. At the start-up of the engine 10, the crankshaft 13 is rotated in the reverse direction, and the shaft member 210 is rotated in the second direction Q2. This causes the friction force in the first direction Q1 to be exerted from the sliding member 352 of the sliding mechanism 350 onto the sliding portion 423 of the rotation member 420. Therefore, the rotation member 420 is rotated in the first direction Q1 with respect to the shaft member 210 and is moved in the third direction Q3 of the axial direction.

[0144] The rotation member 420 is moved in the third direction Q3 such that the one end of the bar-shaped member 450 projects from the holding member 440 in the third direction Q3. This causes the moving member 320 to be moved in the third direction Q3 and the movement blocking portion 321 of the moving member 320 to abut against the spring engaging member 310. Further, the abutment portion 331 of the fitting member 330 abuts against the second abutment portion 325 of the moving member 320 by the energizing force of the spring 335. This causes the fitting member 330 to be stored in the through hole 210b of the shaft member 210. In such a way, the switching mechanism 300 switches from the rotation blocked state of Fig. 27(a) to the rotatable state of Fig. 27(b).

[0145] Thereafter, when the rotation direction of the crankshaft 13 is switched from the reverse direction to the forward direction, the shaft member 210 is rotated in the first direction Q1. This causes the friction force in the second direction Q2 to be exerted from the sliding member 352 of the sliding mechanism 350 onto the sliding portion 423 of the rotation member 420. As shown in Fig. 25(b), when the fitting pin 217 abuts against the one end of the groove 231, the rotation member 420 is rotated in the second direction Q2 with respect to the shaft member 210 and is moved in the fourth direction Q4 of the axial direction.

[0146] When the rotation member 420 is moved in the fourth direction Q4, the moving member 320 and the bar-shaped member 450 are moved in the fourth direction Q4 by the energizing force of the spring 315. This causes the bar-shaped member 450 to be stored in the holding member 440 and the pressure receiving portion 326 of the moving member 320 to abut against the one end of the holding member 440. Further, the abutment portion 331 of the fitting member 330 is pressed by the tapered portion 324 of the moving member 320 in a direction away from the axis of the shaft member 210. Thus, the fitting member 330 is moved against the energizing force of the

spring 335 in the direction away from the axis of the shaft member 210 and the fitting portion 332 of the fitting member 330 projects outside of the through hole 210b. As a result, the fitting portion 332 of the fitting member 330 is fitted into the recess 232 of the exhaust cam 230 (Figs. 22(a) and 22(b)). In such a way, the switching mechanism 300 switches from the rotatable state of Fig. 27(b) to the rotation blocked state Fig. 27(a).

(6) Effects

[0147] In the engine system 200 according to the present embodiment, the crankshaft 13 is rotated in reverse by the starter/generator 14 at the start-up of the engine 10. During the reverse rotation of the crankshaft 13, the intake valve 15 is driven by the valve driver 17 such that the fuel injected by the injector 19 is led to the combustion chamber 31a. Thereafter, the fuel-air mixture in the combustion chamber 31a is ignited by the ignition plug 18 while the piston 11 is close to the compression top dead center.

[0148] Thus, the piston 11 is driven such that the crankshaft 13 is rotated in the forward direction. Therefore, an enough torque in the forward direction can be obtained, and the piston 11 can easily go over the compression top dead center. Therefore, the engine 10 can be stably started. Further, because an enough torque for the start-up of the engine 10 can be obtained by the ignition of the fuel-air mixture without using the large-size starter/generator 14, a size of the engine 10 can be reduced. Further, because it is not necessary to use the large-size starter/generator 14, generation of the excess power can be suppressed.

[0149] Further, in this embodiment, the intake valve 15 is driven by the valve driver 17 such that the intake port 21 is opened in the range from the angle A21 to the angle A22 only during the reverse rotation of the crankshaft 13. Thus, the fuel-air mixture can be reliably led to the combustion chamber 31a during the reverse rotation of the crankshaft 13 while a backflow of the combusted gas to the intake passage 22 is prevented during the forward rotation of the crankshaft 13.

[0150] Further, in the present embodiment, the exhaust valve 16 is driven by the valve driver 17 such that the exhaust port 23 is not opened during the reverse rotation of the crankshaft 13. Thus, during the reverse rotation of the crankshaft 13, the fuel-air mixture can be efficiently led to the combustion chamber 31a in the range from the angle A21 to the angle A22.

[0151] Further, in the present embodiment, the fuel is injected by the injector 19 at the angle A11 positioned between the angle A0 and the angle A3 during the forward rotation of the crankshaft 13, and the fuel is injected by the injector 19 at the angle A23 positioned between the angle A0 and the angle A1 during the reverse rotation of the crankshaft 13. Thus, in the respective times of the forward rotation and the reverse rotation of the crankshaft 13, the fuel is injected into the intake passage 22 before

the intake port 21 is opened. As a result, the fuel can be appropriately led to the combustion chamber 31a.

[0152] Further, in the present embodiment, the fuel-air mixture in the combustion chamber 31a is ignited by the ignition plug 18 after the rotation of the crankshaft 13 in the reverse direction is stopped at the angle A31. Thus, the crankshaft 13 can be reliably rotated in the forward direction after the ignition of the fuel-air mixture.

[0153] Further, in the present embodiment, the crankshaft 13 is driven in the forward direction by the starter/generator 14 after the ignition of the fuel-air mixture at the angle A31. This enables an even larger torque in the forward direction to be obtained. Therefore, the piston 11 can reliably go over the compression top dead center.

(7) Other Embodiments

(7-1)

[0154] While the fuel is injected into the intake passage 22 by the injector 19 with the intake port 21 closed, and thereafter, the intake port 21 is opened such that the fuel is led to the combustion chamber 31a from the intake passage 22 through the intake port 21 in the embodiment described above, the invention is not limited to this. The fuel may be directly injected into the combustion chamber 31a by the injector 19 through the intake port 21 with the intake port 21 opened.

(7-2)

[0155] While the intake port 21 is opened in the range from the angle A12 to the angle A13 in the both times of the forward and reverse rotations of the crankshaft 13 in the embodiment described above, the invention is not limited to this. During the reverse rotation of the crankshaft 13, the intake port 21 does not have to be opened in the range from the angle A12 to the angle A13.

(7-3)

[0156] While the reverse rotation of the crankshaft 13 is started after the crank angle is adjusted to the angle A30 in the embodiment described above, the invention is not limited to this. If the fuel-air mixture can be introduced into the combustion chamber 31a during the reverse rotation of the crankshaft 13, the reverse rotation of the crankshaft 13 may be started at any position.

(7-4)

[0157] While the camshaft is used as the valve driver 17 in the embodiment described above, the invention is not limited to this. A hydraulic valve driving mechanism, an electromagnetic valve driving mechanism or the like may be used as the valve driver 17.

(7-5)

[0158] While the rotation angle in the range of two rotations of the crankshaft 13 (720 degrees) is obtained based on the crank angle detected by the crank angle sensor 43 and the pressure in the intake passage 22 detected by the intake pressure sensor 42 in the embodiment described above, the invention is not limited to this. For example, the cam angle sensor that detects the rotation angle of the valve driver 17 (hereinafter referred to as a cam angle) may be provided, and the rotation angle in the range of the two rotations of the crankshaft 13 may be obtained based on the detection result of the cam angle sensor. Alternatively, the rotation angle in the range of two rotations of the crankshaft 13 may be obtained based on the crank angle detected by the crank angle sensor 43 and the cam angle detected by the cam angle sensor. In this case, more accurate rotation angle in the range of two rotations of the crankshaft 13 can be obtained.

(7-6)

[0159] While an electric current that flows through the starter/generator 14 is detected by the current sensor 44 in the embodiment described above, the invention is not limited to this. If the starter/generator 14 can be appropriately controlled, the current sensor 44 does not have to be provided.

(7-7)

[0160] While the embodiment described above is an example in which the present invention is applied to the motorcycle, the invention is not limited to this. This invention may be applied to another saddle-straddling type motor vehicle such as a motor tricycle, an ATV (All Terrain Vehicle) or the like.

(8) Correspondences between Constituent Elements in Claims and Parts in Preferred Embodiments

[0161] In the following paragraphs, non-limiting examples of correspondences between various elements recited in the claims below and those described above with respect to various preferred embodiments of the present invention are explained.

[0162] In the embodiment described above, the engine system 200 is an example of an engine system, the engine 10 is an example of a single-cylinder engine, the ECU 6 is an example of a controller, the intake passage 22 is an example of an intake passage, the injector 19 is an example of a fuel injection device, the intake port 21 is an example of an intake port, the exhaust port 23 is an example of an exhaust port, the intake valve 15 is an example of an intake valve, the exhaust valve 16 is an example of an exhaust valve and the valve driver 17 is an example of a valve driver. Further, the combustion

chamber 31a is an example of a combustion chamber, the ignition plug 18 is an example of an ignition device, the crankshaft 13 is an example of a crankshaft, the starter/generator 14 is an example of a starter/generator and the piston 11 is an example of a piston.

[0163] Further, the shaft member 210 is an example of a shaft, the main-intake cam 240 is an example of a first intake cam, the sub-intake cam 245 is an example of a second intake cam, the opening 246 and the fitting pin 241 are examples of a first restriction mechanism, the twisted coil spring 255 is an example of a first energize member, the first direction Q1 is an example of a first direction and the second direction Q2 is an example of a second direction.

[0164] Further, the cam nose 240T is an example of a first cam nose, the cam nose 245T is an example of a second cam nose, the exhaust cam 230 is an example of an exhaust cam, the fitting member 330 is an example of a blocker, the moving member 320 is an example of a mover, the groove 231 and the fitting pin 217 are examples of a second restriction mechanism and the twisted coil spring 225 is an example of a second energize member. Further, the motorcycle 100 is an example of a saddle-straddling type motor vehicle, the rear wheel 7 is an example of a drive wheel and the vehicle body 1 is an example of a main body.

[0165] As each of various elements recited in the claims, various other elements having configurations or functions described in the claims can be also used.

[0166] 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. An engine system comprising:

a single-cylinder engine (10); and
a controller (6) configured to control the single-cylinder engine (10), wherein
the single-cylinder engine (10) includes
a fuel injection device (19) arranged at an intake passage (22),
a valve driver (17) configured to respectively drive an intake valve (15) configured to open and close an intake port and an exhaust valve (16) configured to open and close an exhaust port,
an ignition device (18) configured to ignite a fuel-air mixture in a combustion chamber (31a), and
a starter/generator (14) provided at a crankshaft (13) and configured to rotate the crankshaft (13) in forward and reverse directions and generate

- electric power by a rotation of the crankshaft (13),
the controller (6) is configured to control the starter/generator (14) to rotate the crankshaft (13) in the reverse direction during start-up,
the valve driver (17) is configured to drive the intake valve (15) such that fuel injected by the fuel injection device (19) is led to the combustion chamber (31a) from the intake passage (22) through the intake port at a first time point in a time period during which the crankshaft (13) is rotated in the reverse direction, and
the controller (6) is configured to control the ignition device (18) such that the fuel-air mixture is ignited at a second time point at which the fuel-air mixture is compressed in the combustion chamber (31a) by the rotation of the crankshaft (13) in the reverse direction and a piston does not reach a compression top dead center after the fuel is led to the combustion chamber (31a) at the first time point.
2. The engine system according to claim 1, wherein the first time point is included in a period during which the piston falls from an exhaust top dead center during the rotation of the crankshaft (13) in the reverse direction.
 3. The engine system according to claim 1 or 2, wherein the valve driver (17) is configured to drive the exhaust valve (16) such that the exhaust port is opened during a period in which a rotation angle of the crankshaft (13) is in a first range, and drive the intake valve (15) such that the intake port is opened during a period in which the rotation angle of the crankshaft (13) is in a second range, during the rotation of the crankshaft (13) in the forward direction and drive the intake valve (15) such that the intake port is opened during a period in which the rotation angle of the crankshaft (13) is in a third range within the first range during the rotation of the crankshaft (13) in the reverse direction, and the third range is larger than a range in which the first range and the second range overlap with each other.
 4. The engine system according to claim 3, wherein the second range and the third range are separated from each other.
 5. The engine system according to claim 3 or 4, wherein the valve driver (17) is configured to drive the exhaust valve (16) such that the exhaust port is not opened during a period in which the rotation angle of the crankshaft (13) is at least in the third range during the rotation of the crankshaft (13) in the reverse direction.
 6. The engine system according to any one of claims 3 to 5, wherein the controller (6) is configured to control the fuel injection device (19) such that the fuel is injected when the rotation angle of the crankshaft (13) is in a fourth range during the rotation of the crankshaft (13) in the forward direction and the fuel is injected when the rotation angle of the crankshaft (13) is in a fifth range different from the fourth range during the rotation of the crankshaft (13) in the reverse direction.
 7. The engine system according to claim 6, wherein the fifth range is set to be positioned at a further advanced angle than the fourth range during the rotation of the crankshaft (13) in the reverse direction.
 8. The engine system according to claim 6 or 7, wherein the fifth range is within the second range.
 9. The engine system according to any one of claims 3 to 8, wherein the valve driver (17) includes a shaft (210) provided to be rotated in conjunction with the rotation of the crankshaft (13), a first intake cam (240) provided to be integrally rotated with the shaft (210) and configured to operate the intake valve (15), a second intake cam (245) provided to be rotatable with respect to the shaft (210) and configured to operate the intake valve (15), a first restriction mechanism (241, 246) configured to restrict a movement of the second intake cam (245) with respect to the shaft (210) and a first energize member (255) configured to energize the second intake cam (245), wherein the first restriction mechanism (241, 246) is provided such that rotation of the second intake cam (245) in a first direction is blocked at a first position of the shaft (210) and rotation of the second intake cam (245) in a second direction opposite to the first direction is blocked at a second position of the shaft (210), the second intake cam (245) is configured to operate the intake valve (15) at the first position and not to operate the intake valve (15) at the second position, the first energize member (255) is configured to energize the second intake cam (245) in the first direction, a counterforce larger than an energizing force of the first energize member (255) is applied to the second intake cam (245) from the intake valve (15) such that the second intake cam (245) is moved in the second direction during the rotation of the crankshaft (13) in the forward direction, and the second intake cam (245) is configured to be moved to the first position by the energizing force of the first energize member (255) such that the second

intake cam (245) operates the intake valve (15) during the rotation of the crankshaft (13) in the reverse direction.

10. The engine system according to claim 9, wherein the first intake cam (240) has a first cam nose (240T), the second intake cam (245) has a second cam nose (245T), and the entire second cam nose (245T) overlaps with the first cam nose (240T) when the second intake cam (245) is at the second position, and at least part of the second cam nose (245T) does not overlap with the first cam nose (240T) when the second intake cam (245) is at the first position.
11. The engine system according to claim 9 or 10, wherein the valve driver (17) further includes an exhaust cam (230) provided to be rotatable with respect to the shaft (210) and configured to operate the exhaust valve, a blocker (330) provided to be movable between a rotation blocked position at which rotation of the exhaust cam (230) with respect to the shaft (210) is blocked at a predetermined position of the shaft (210) and a rotatable position at which the exhaust cam (230) is rotatable with respect to the shaft (210), and a mover (320) configured to move the blocker (330) to the rotation blocked position during the rotation of the crankshaft (13) in the forward direction and to the rotatable position during the rotation of the crankshaft (13) in the reverse direction.
12. The engine system according to claim 11, wherein the valve driver (17) further includes a second restriction mechanism (217, 231) configured to restrict a movement of the exhaust cam (230) with respect to the shaft (210), the second restriction mechanism (217, 231) is provided to block the rotation of the exhaust cam (230) in the first direction at a third position of the shaft (210) and the rotation of the exhaust cam (230) in the second direction at a fourth position of the shaft (210), a counterforce is applied from the exhaust valve (16) to the exhaust cam (230) such that the exhaust cam (230) is moved in the first direction, during the rotation of the crankshaft (13) in the reverse direction, and the blocker (330) is configured to block the exhaust cam (230) at the fourth position in the rotation blocked position.
13. The engine system according to claim 12, wherein the valve driver (17) further includes a second energize member (225) configured to energize the exhaust cam (230) in the second direction, and

an energizing force of the second energize member (225) is smaller than the counterforce in the first direction applied from the exhaust valve (16) to the exhaust cam (230) during the rotation of the crankshaft (13) in the reverse direction.

14. The engine system according to any one of claims 1 to 13, wherein the controller (6) is configured to control such that the fuel-air mixture is ignited by the ignition device (18) while the crankshaft (13) is rotated in the forward direction at the second time point.
15. The engine system according to claim 14, wherein the controller (6) is configured to control such that the crankshaft (13) is driven in the forward direction by the starter/generator (14) after the second time point.

FIG. 1

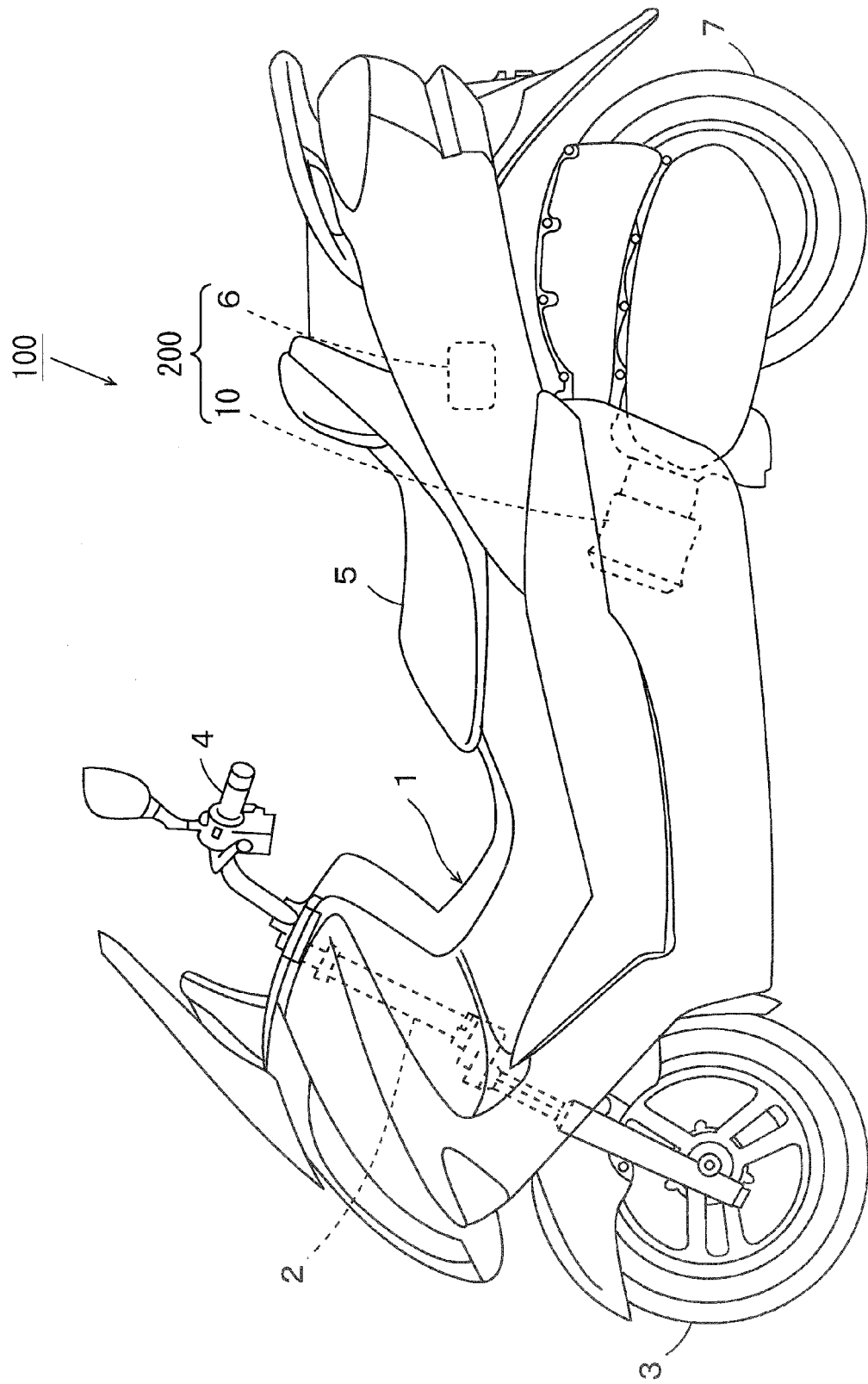


FIG. 2

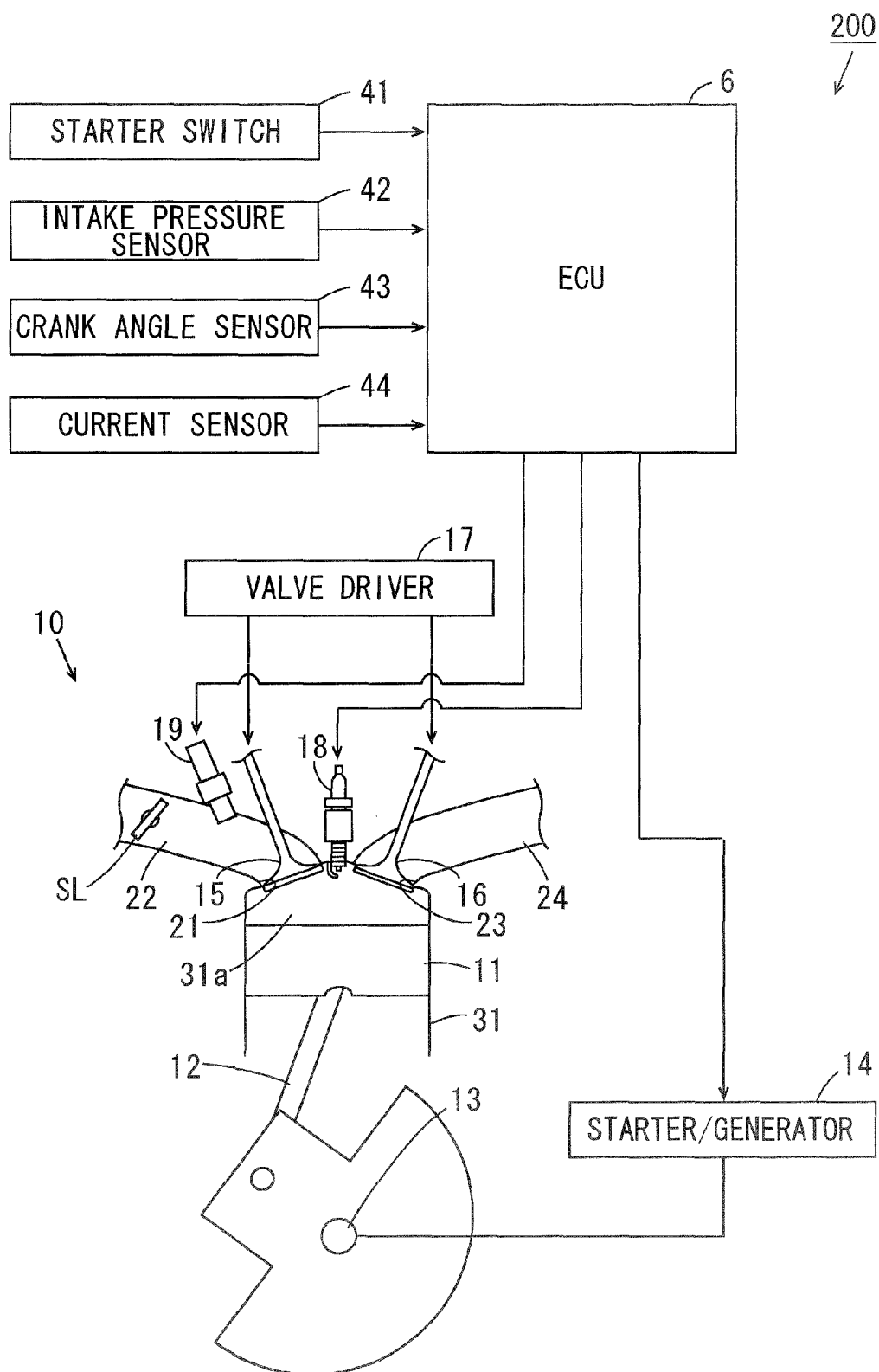


FIG. 3

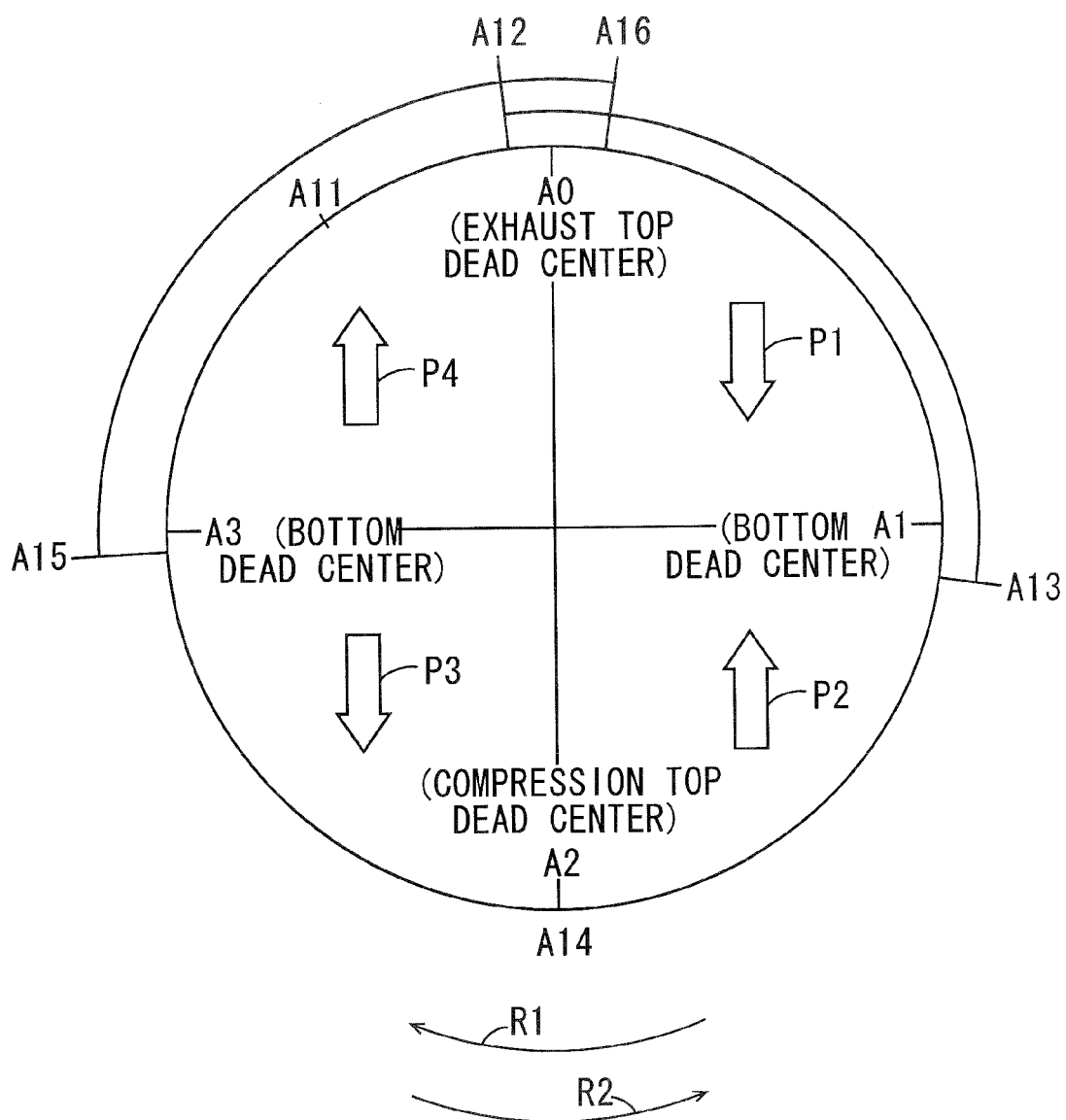


FIG. 4

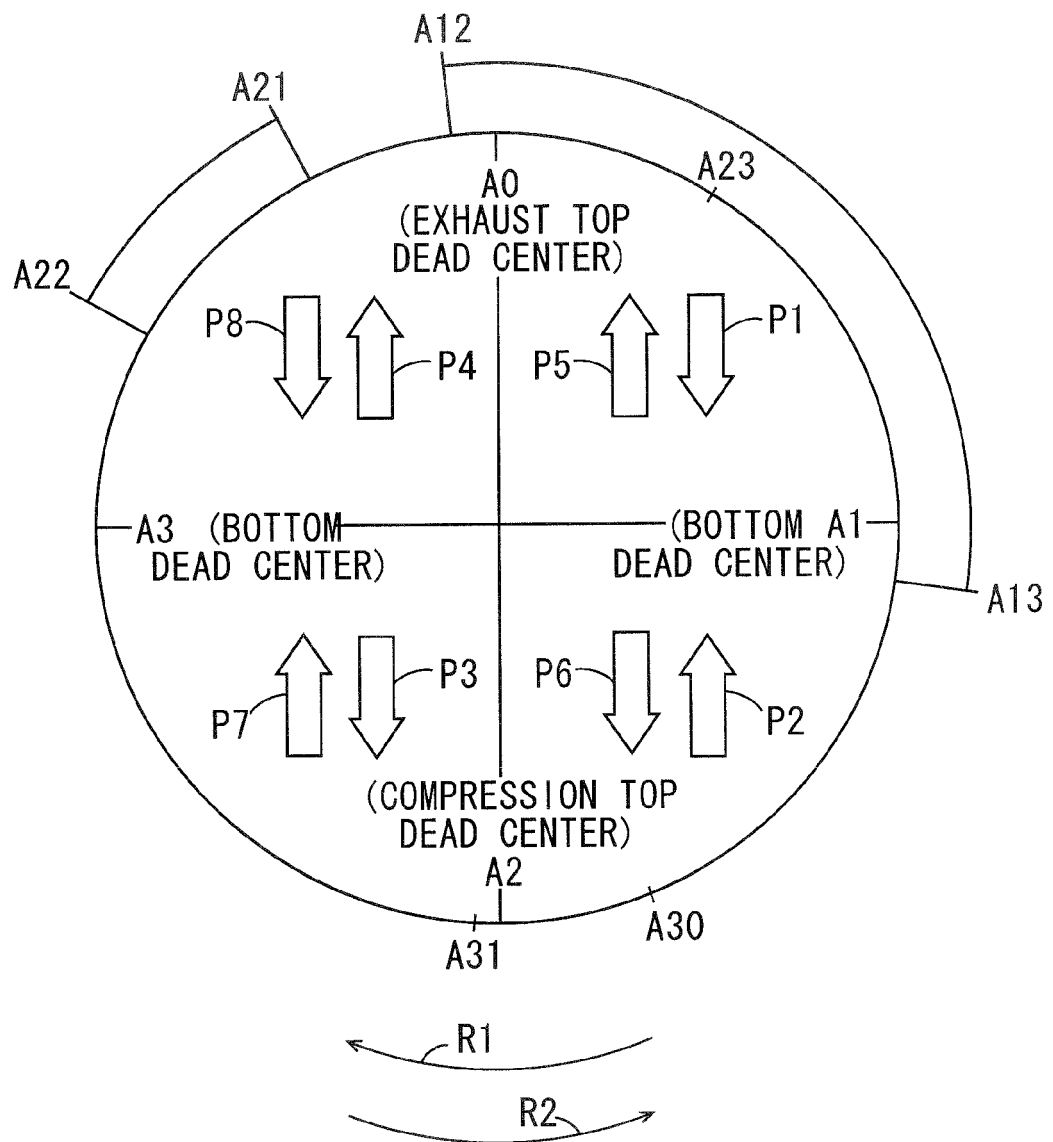


FIG. 5

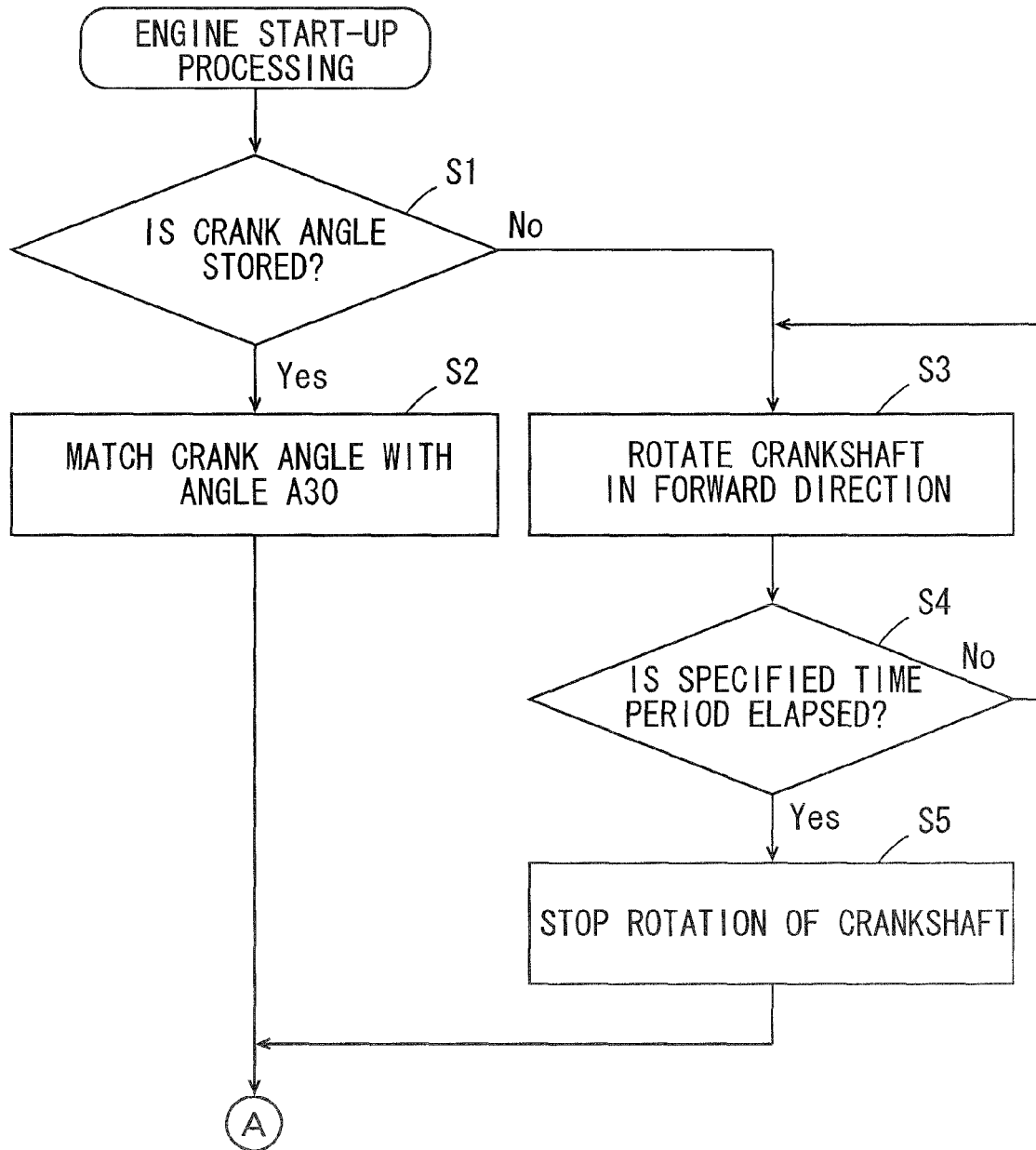


FIG. 6

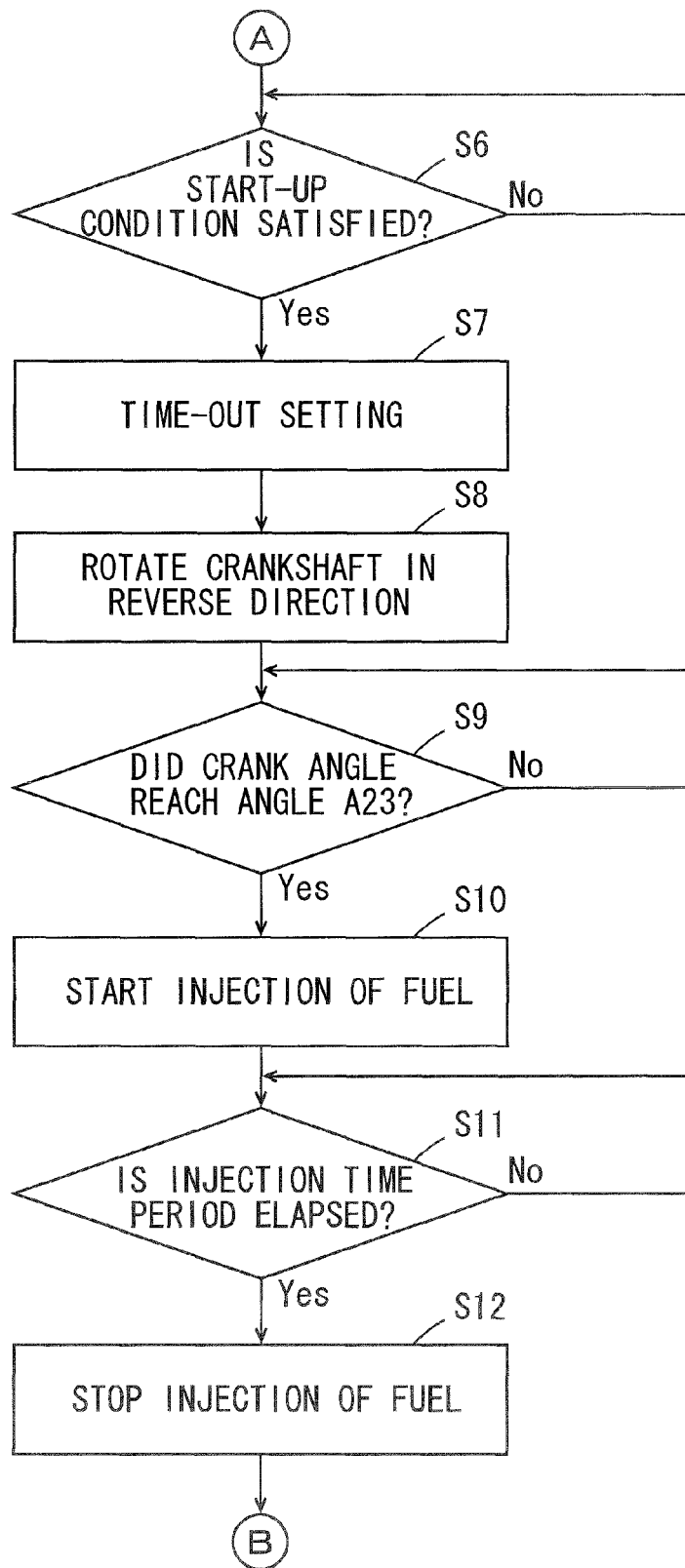


FIG. 7

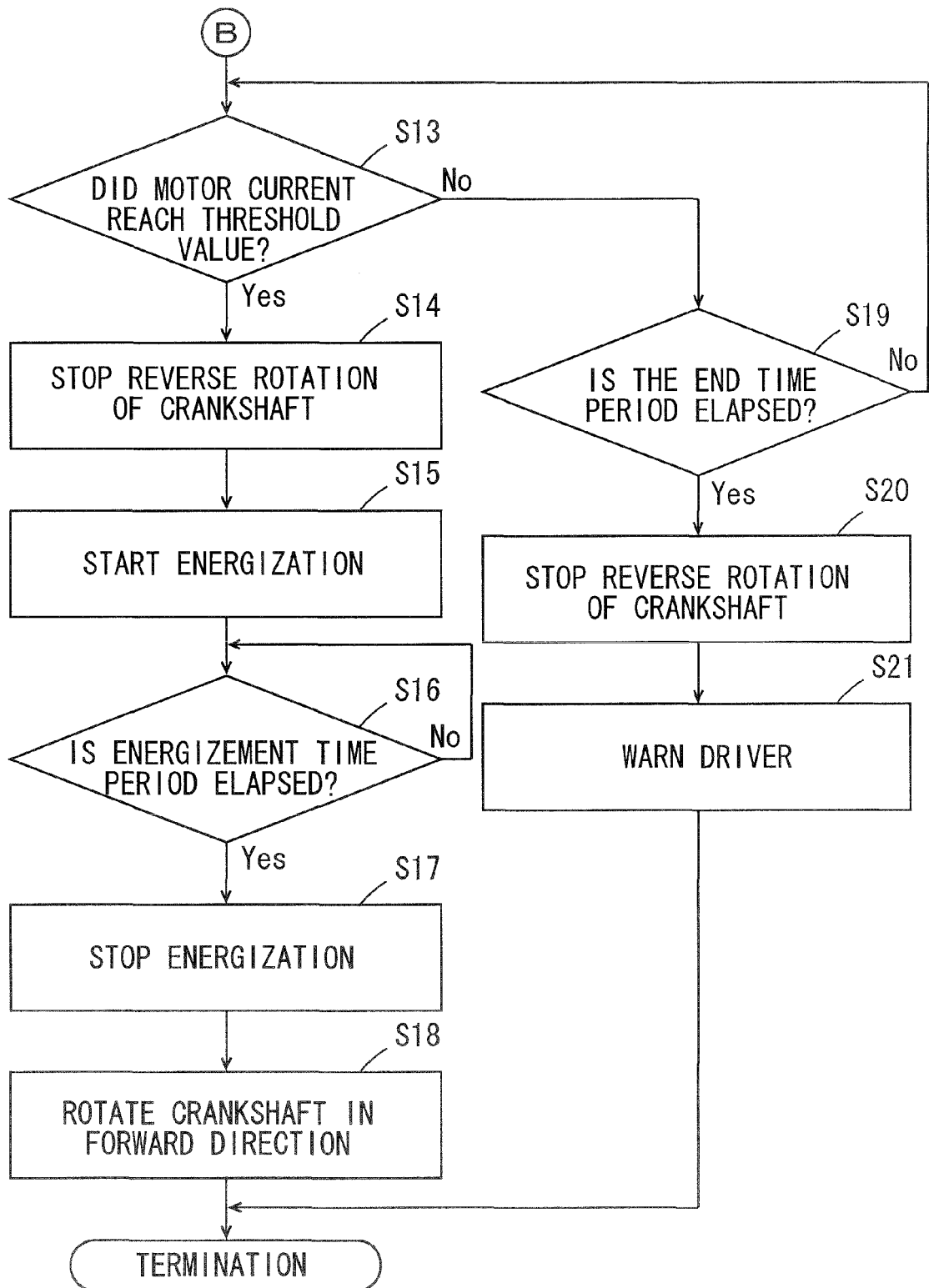


FIG. 8

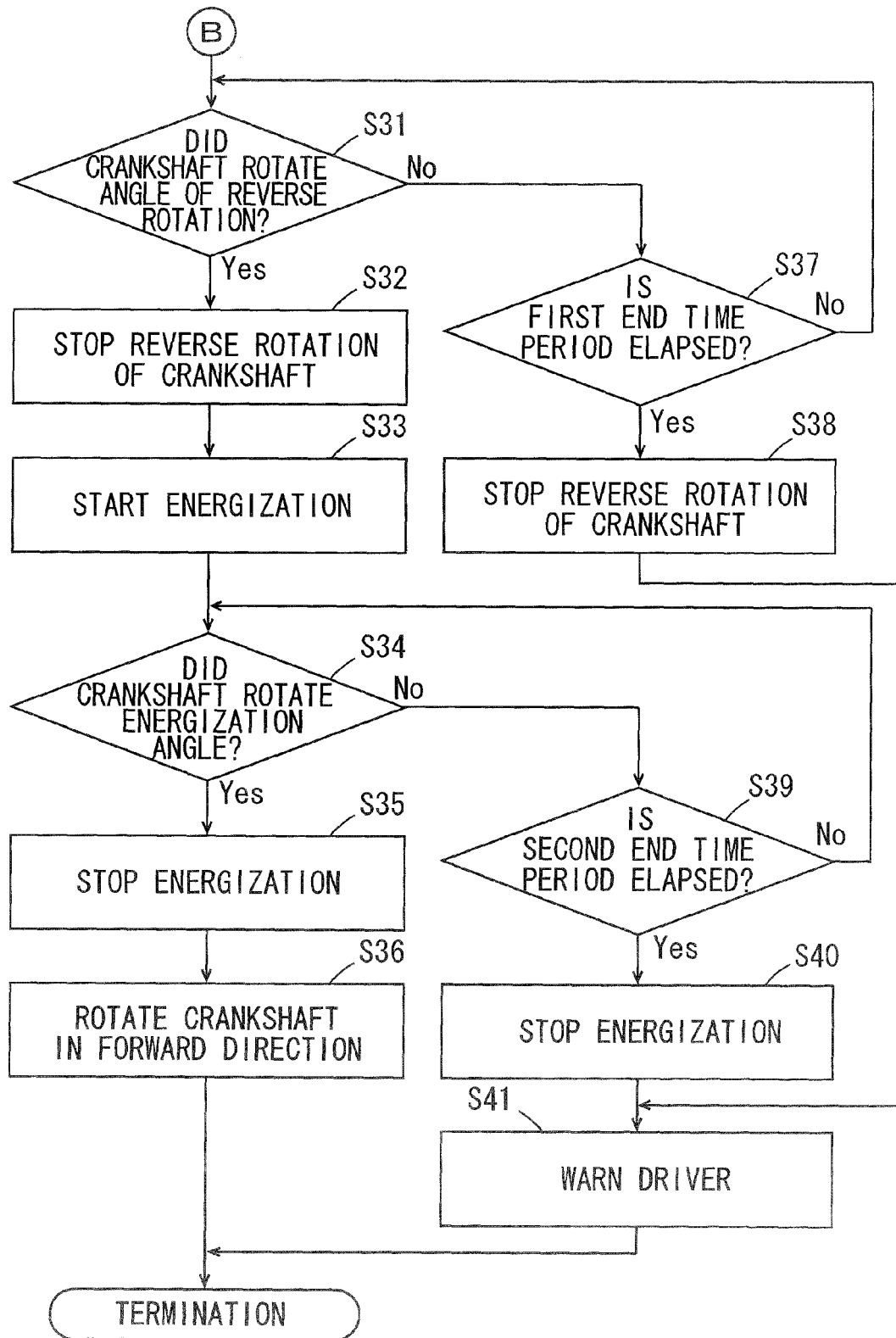


FIG. 9

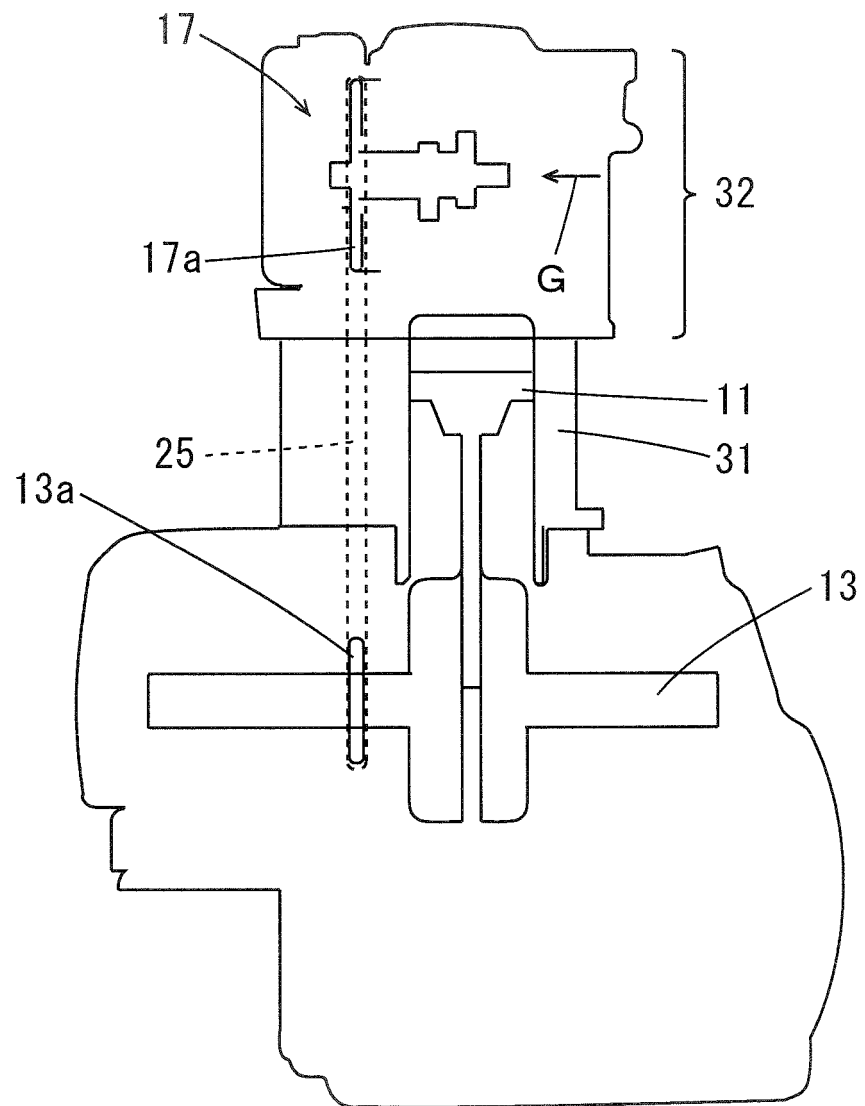


FIG. 10

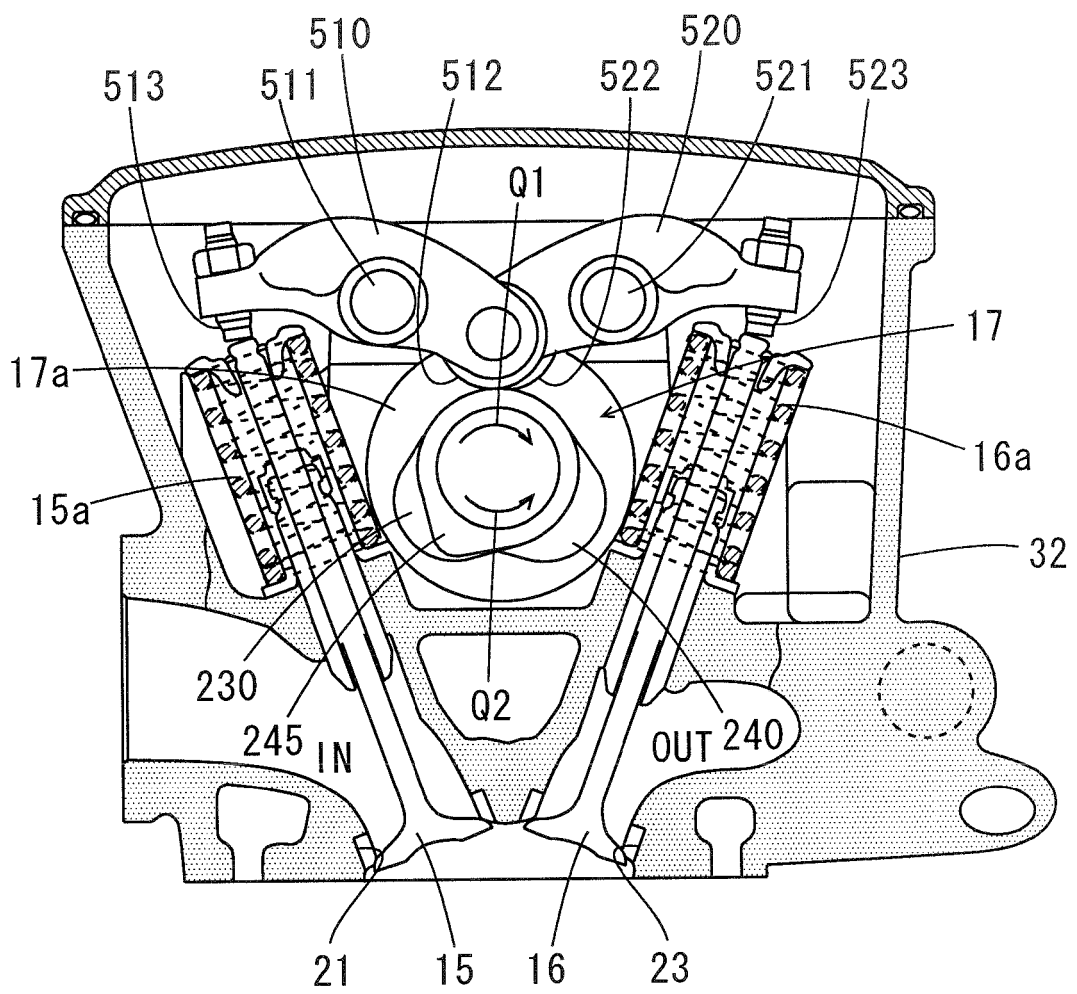


FIG. 11

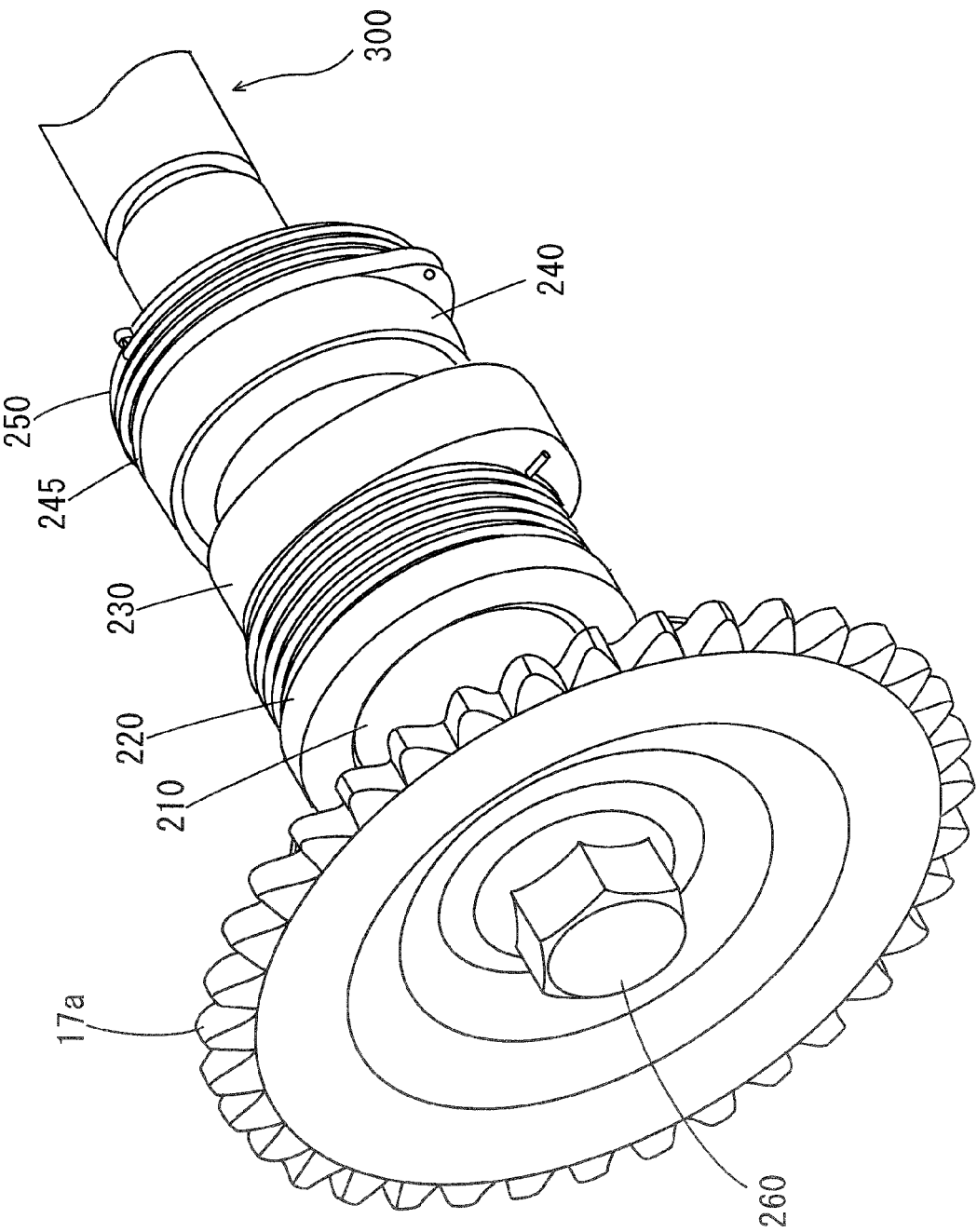


FIG. 12

17

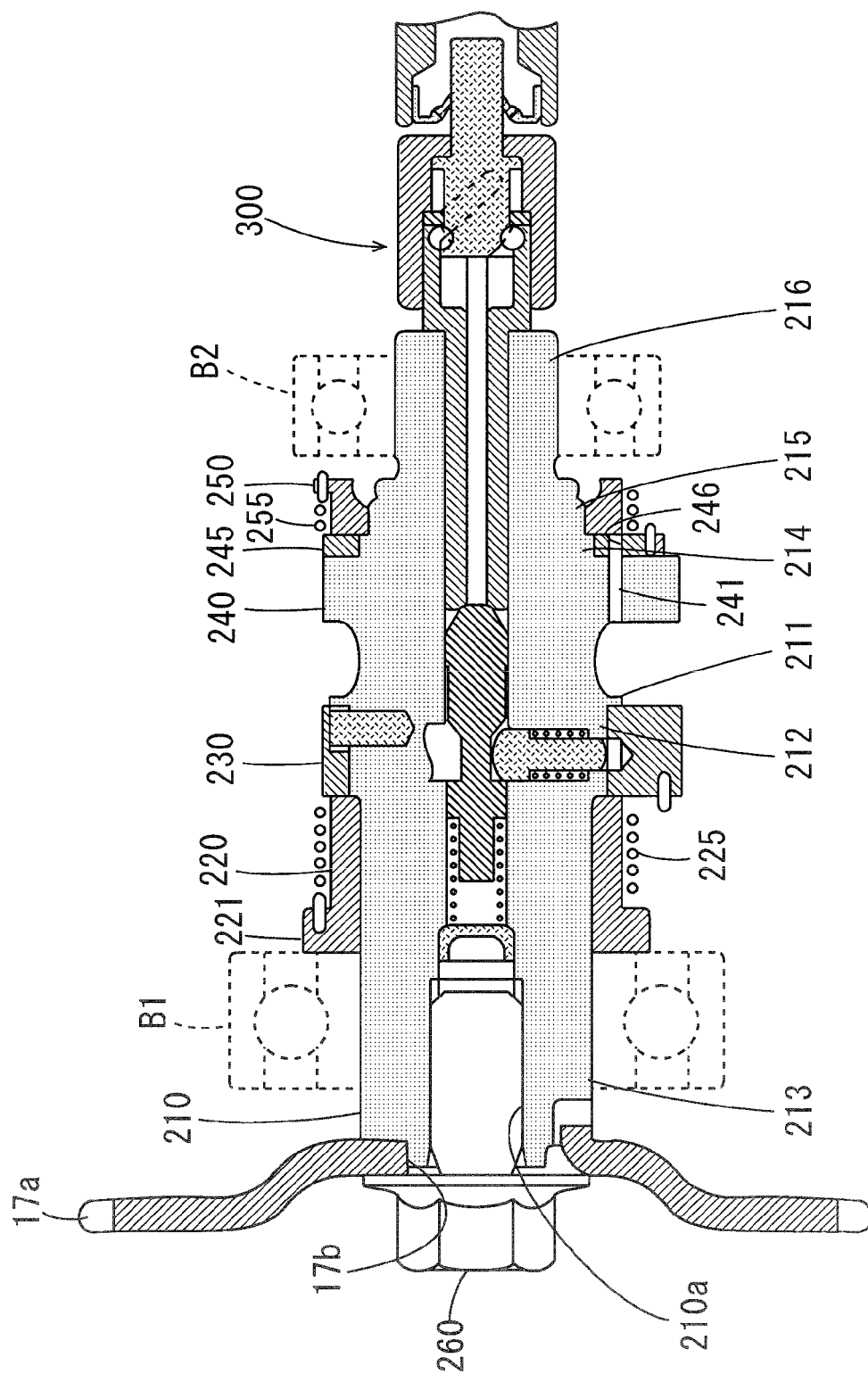


FIG. 13

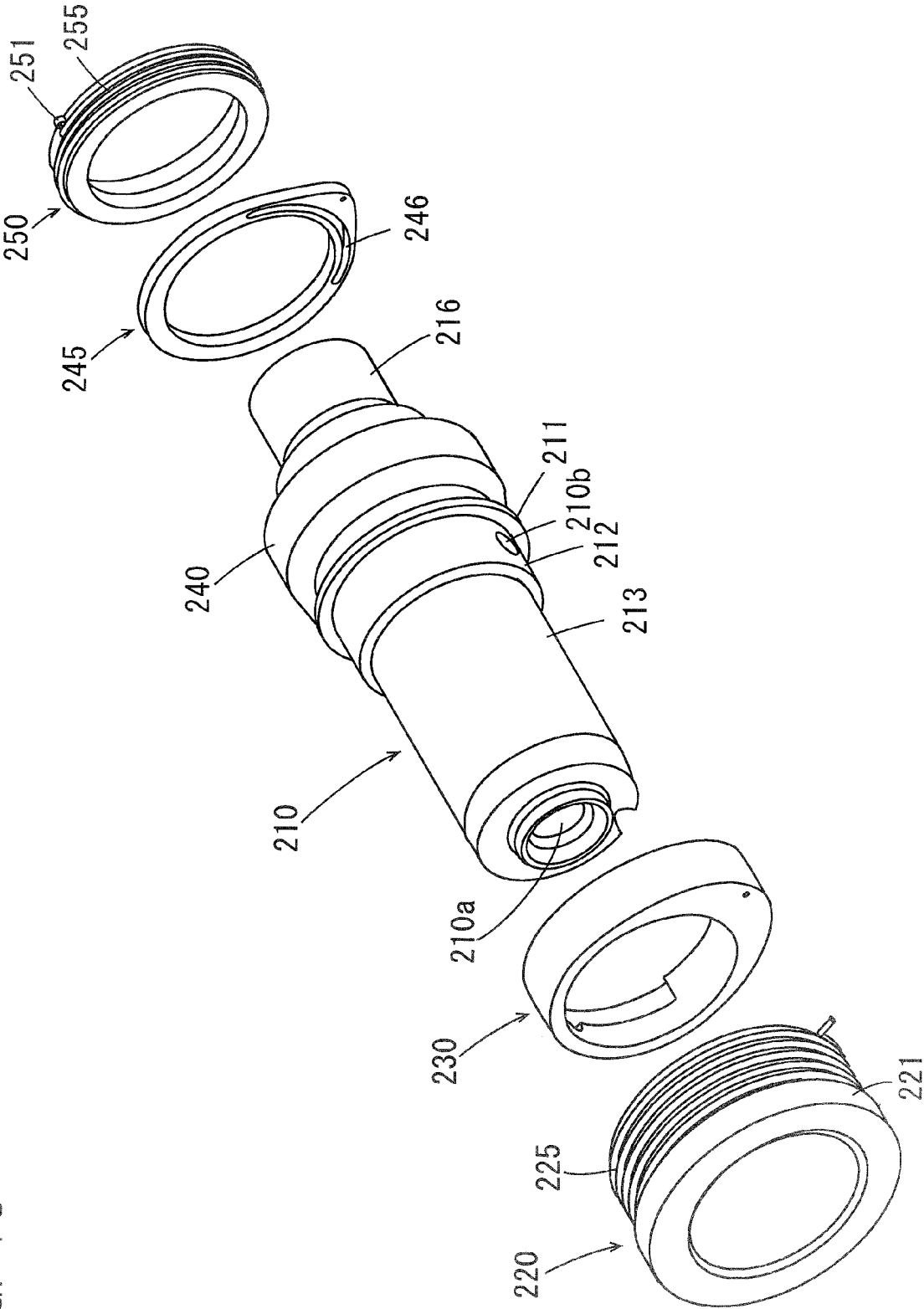


FIG. 14

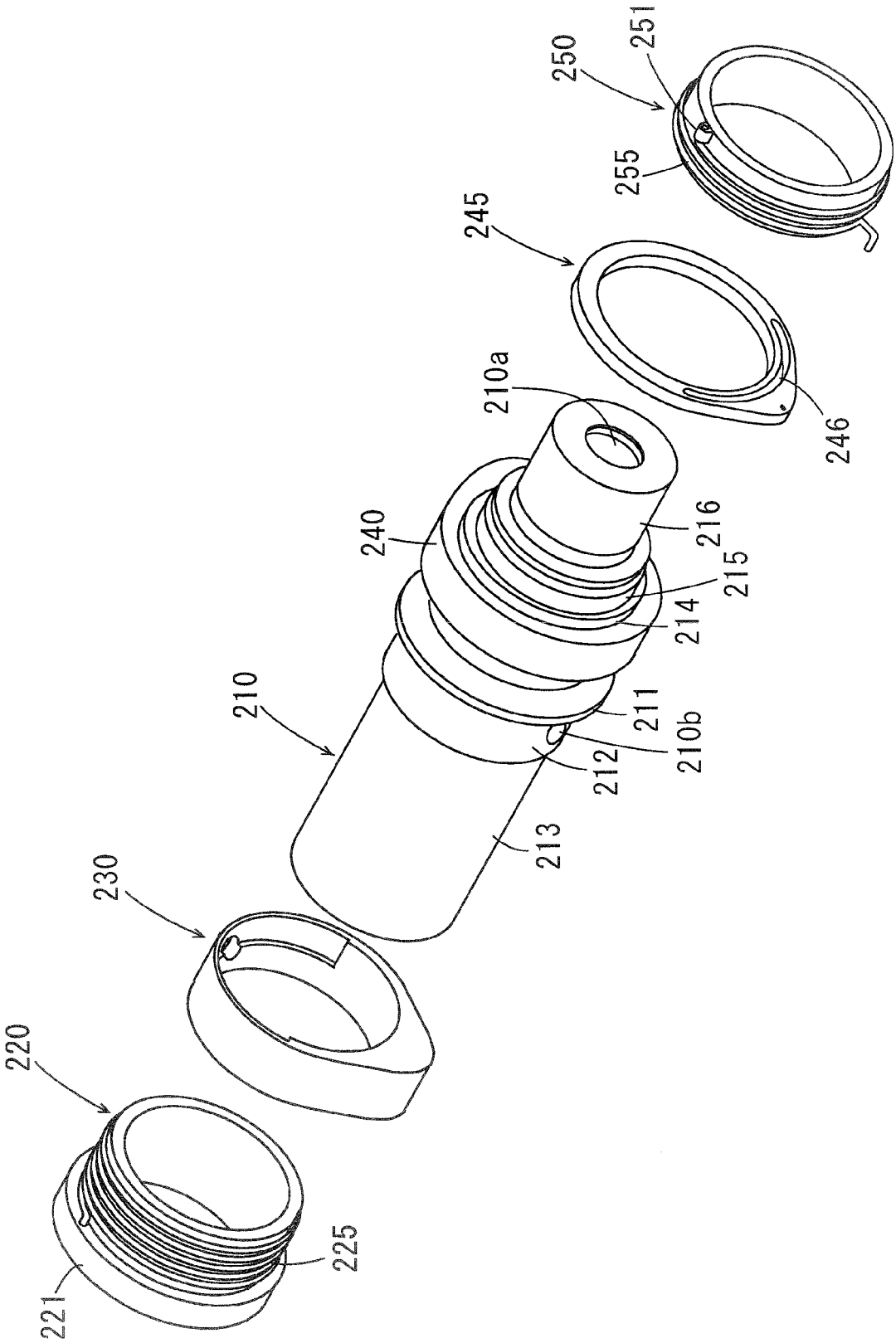


FIG. 15

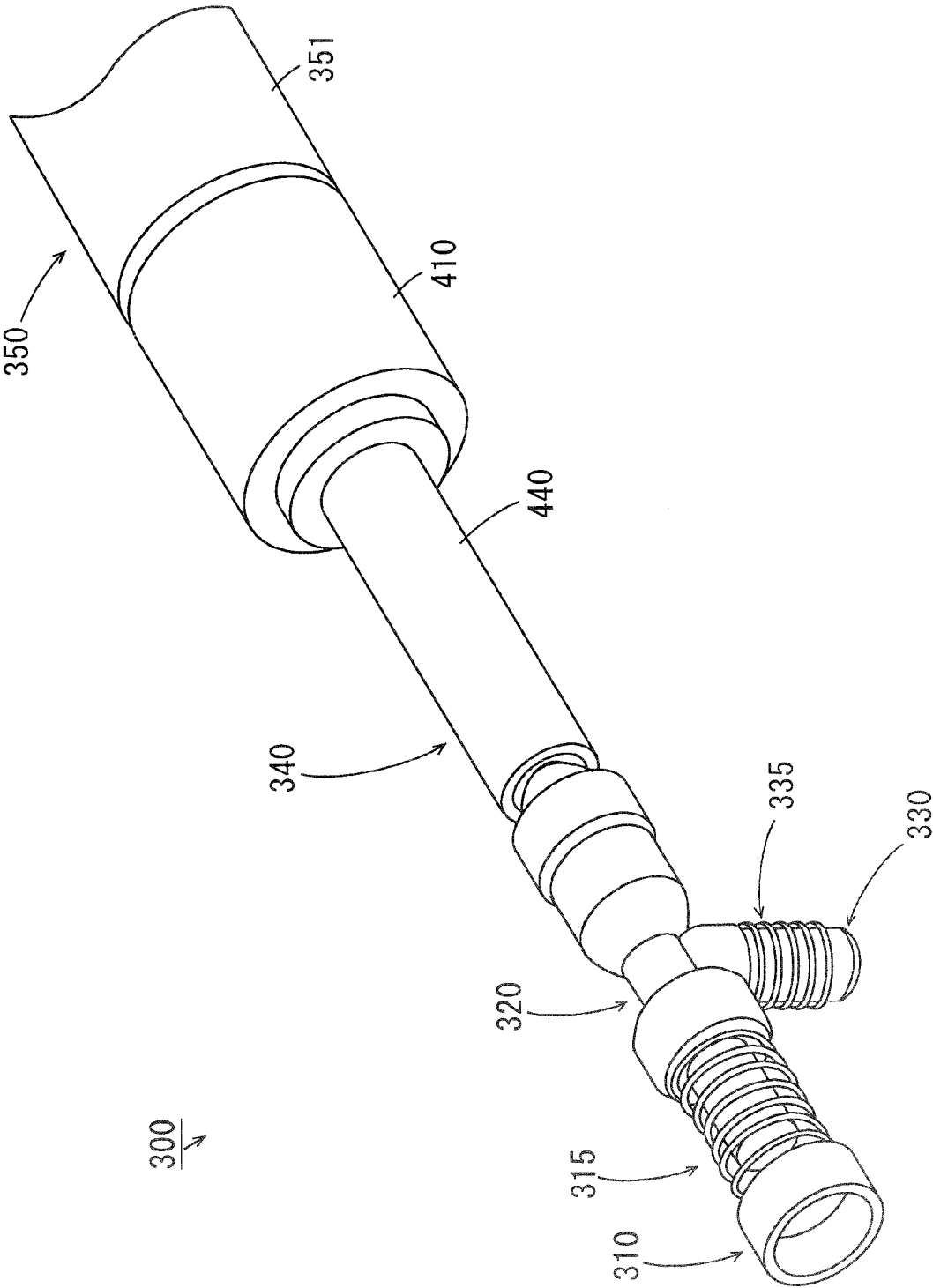


FIG. 16

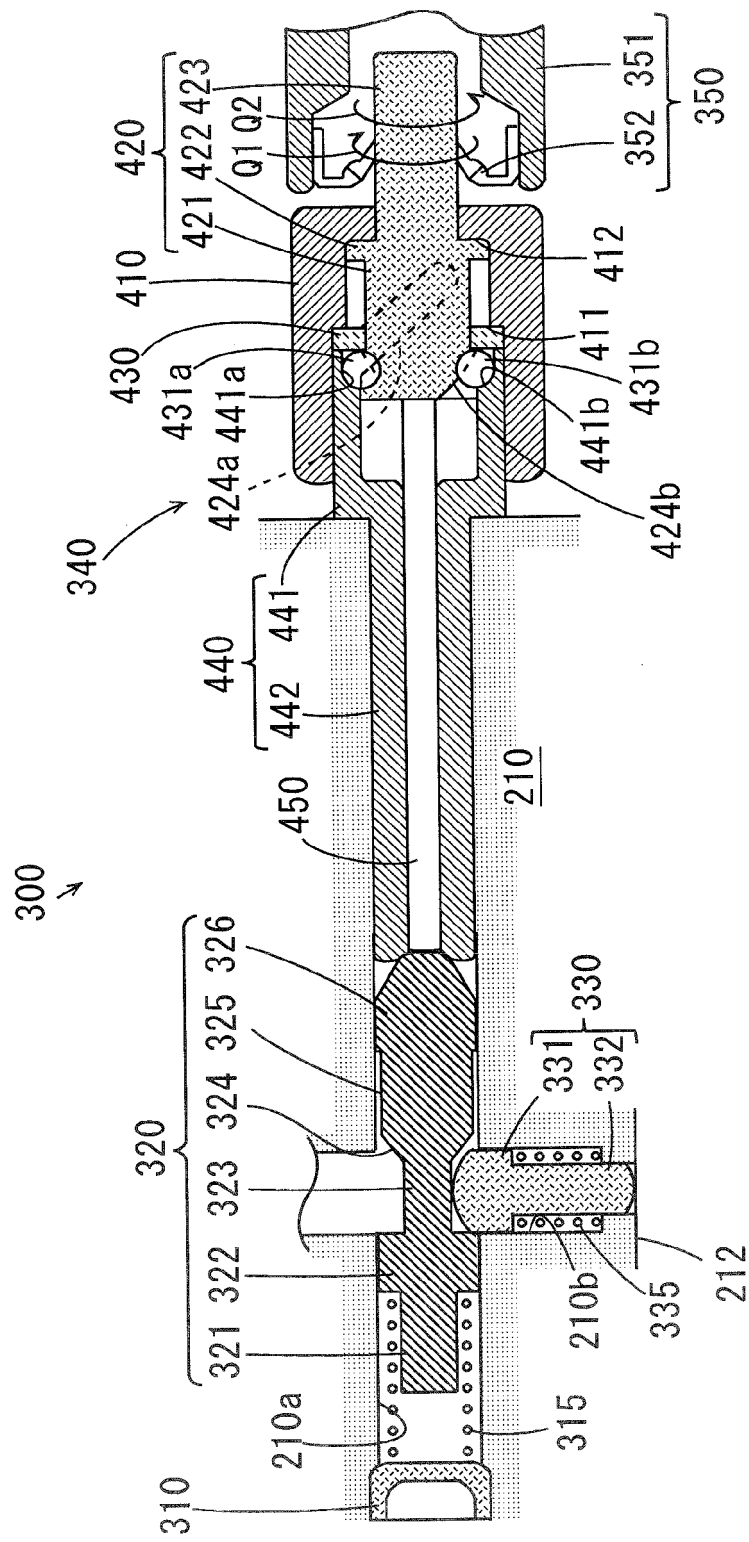


FIG. 17

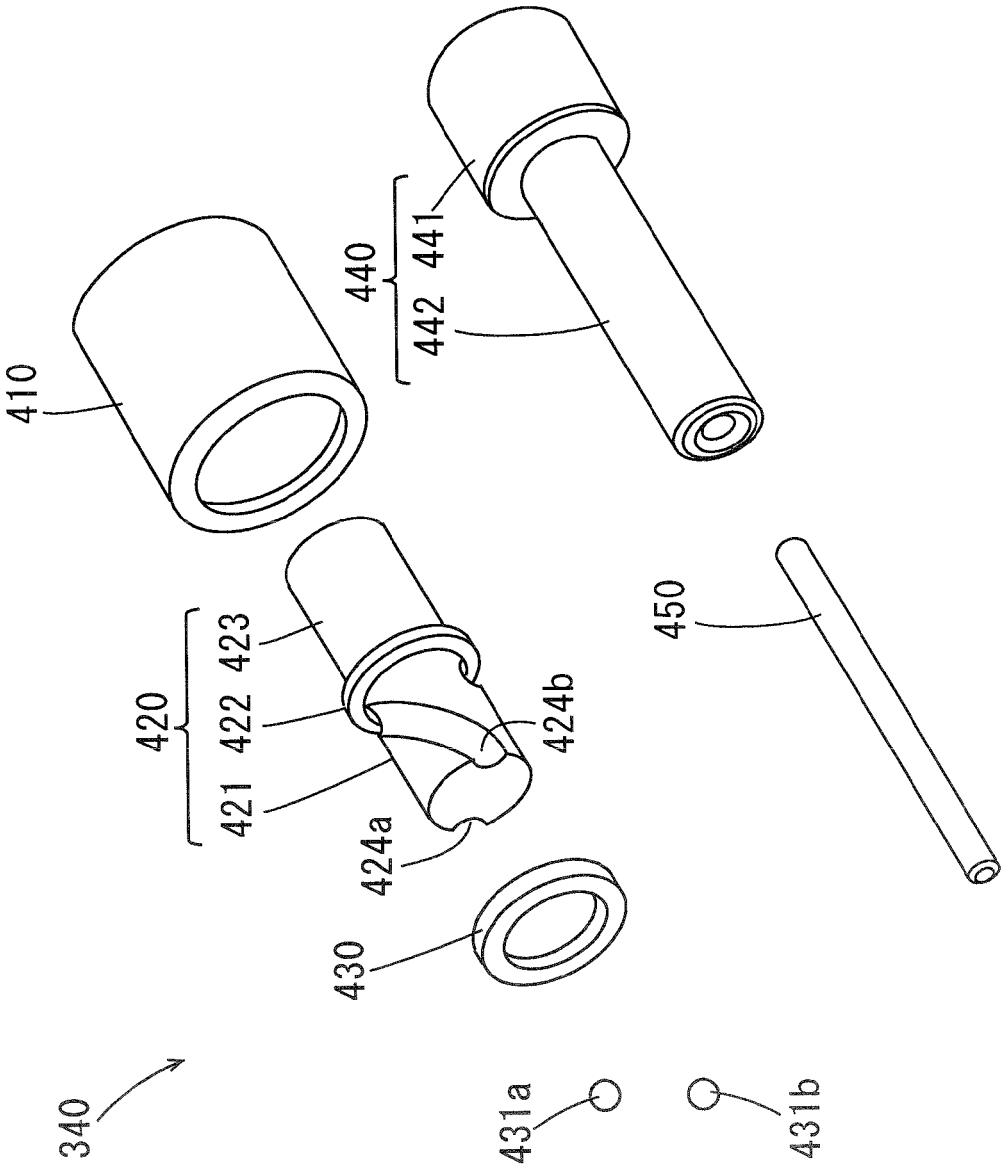


FIG. 18 (a)

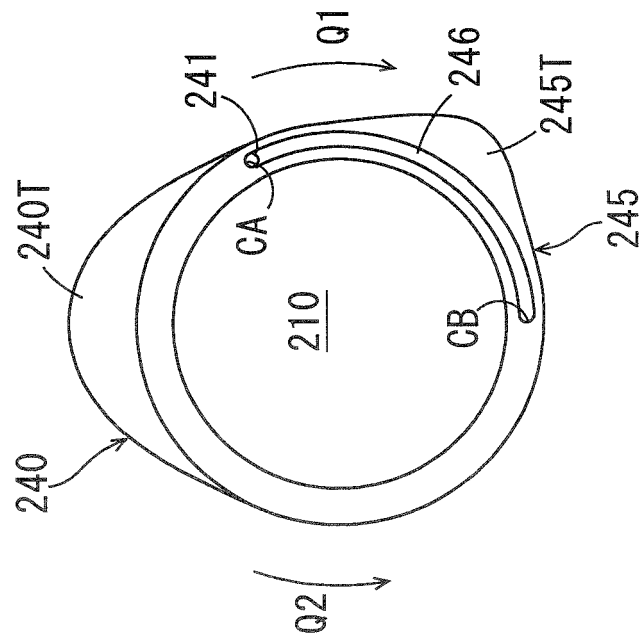


FIG. 18 (b)

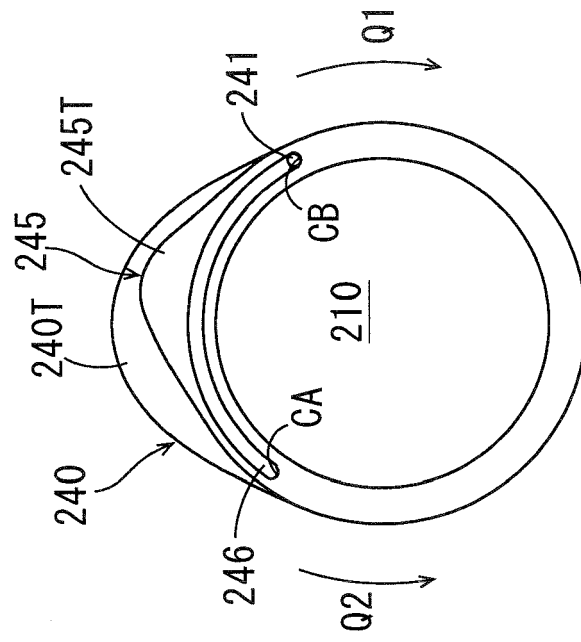


FIG. 19 (a) FIG. 19 (b) FIG. 19 (c) FIG. 19 (d)

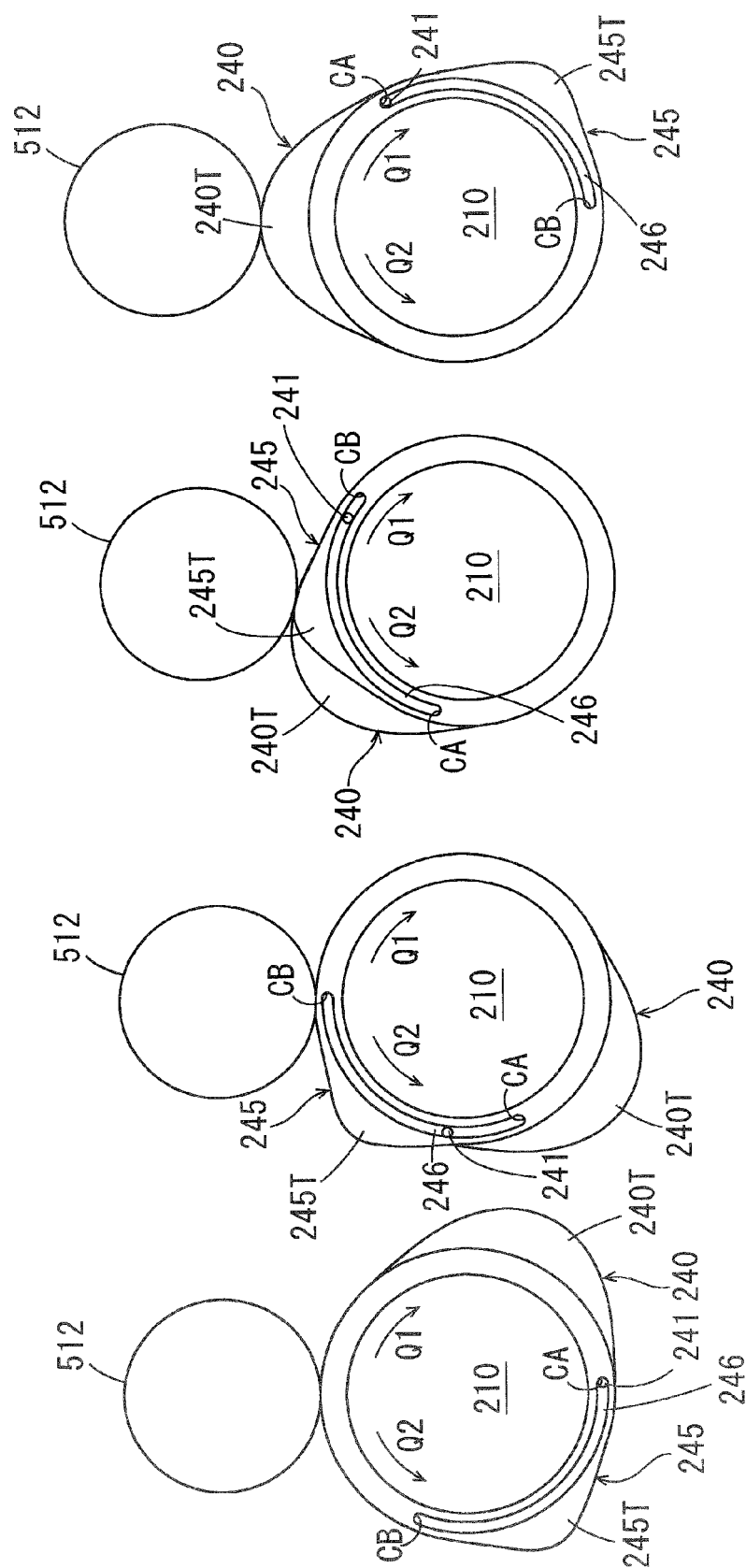


FIG. 20 (a) FIG. 20 (b) FIG. 20 (c) FIG. 20 (d)

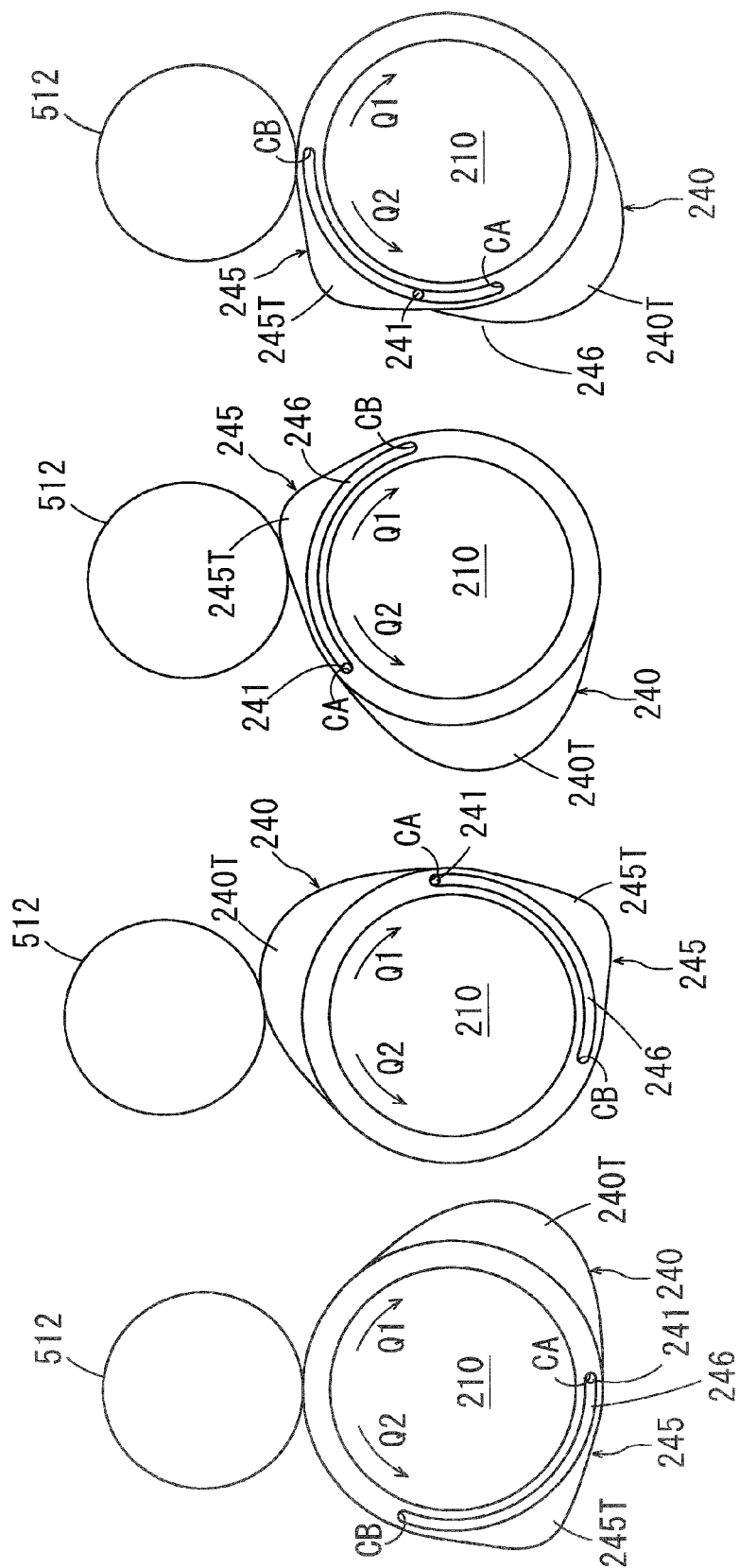


FIG. 21 (a)

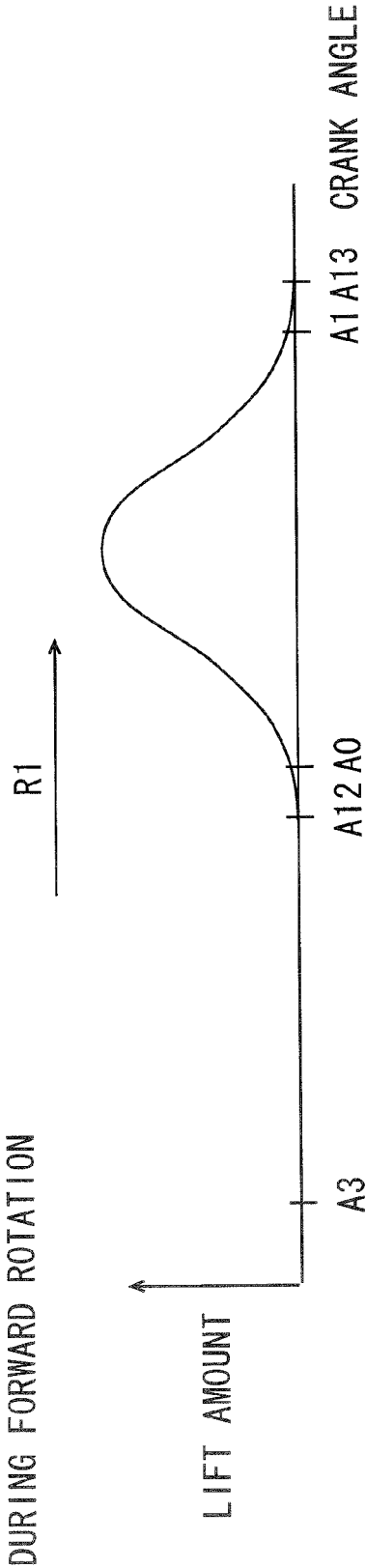


FIG. 21 (b)

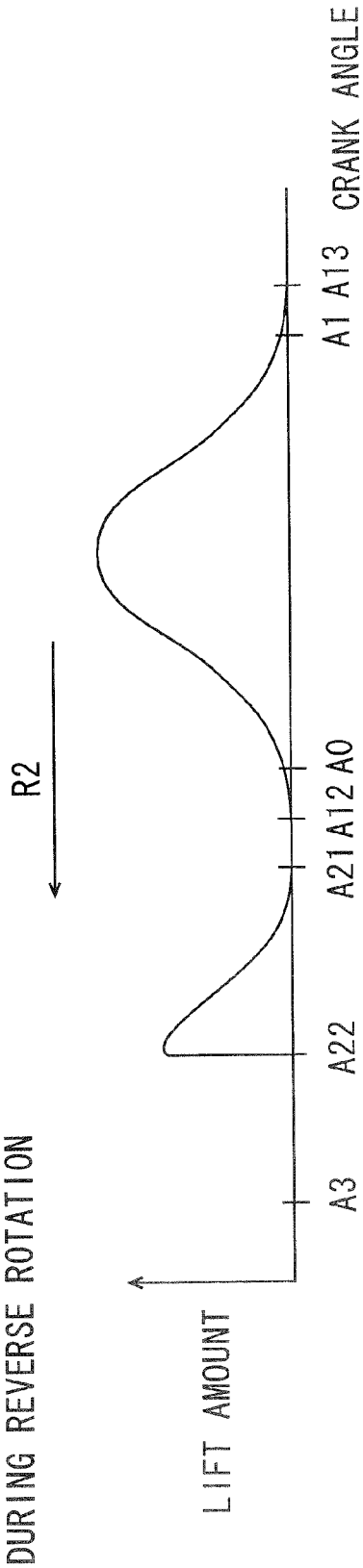


FIG. 22 (a)

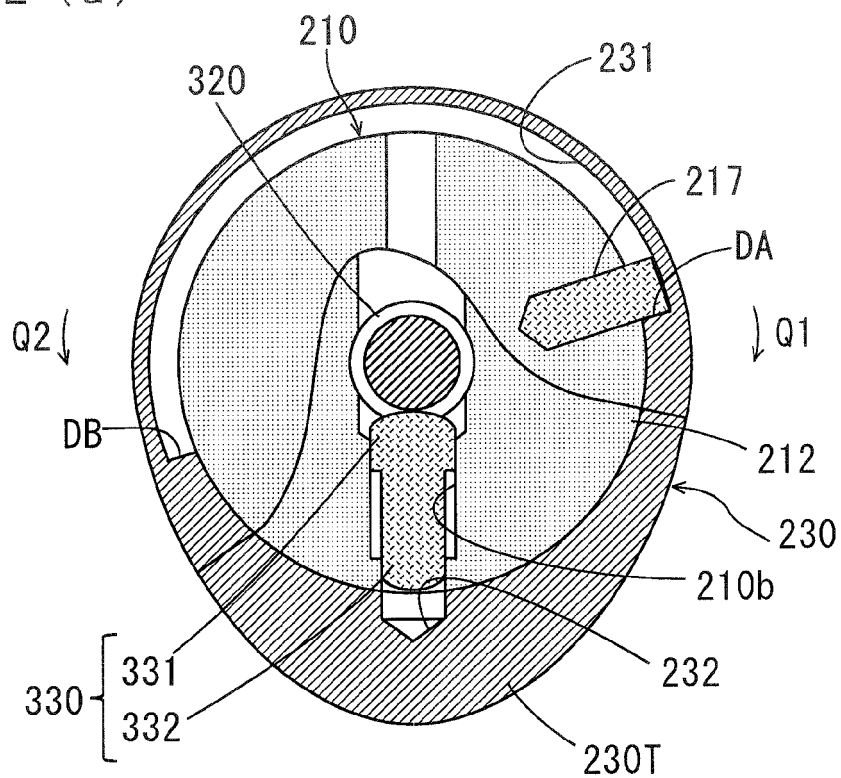
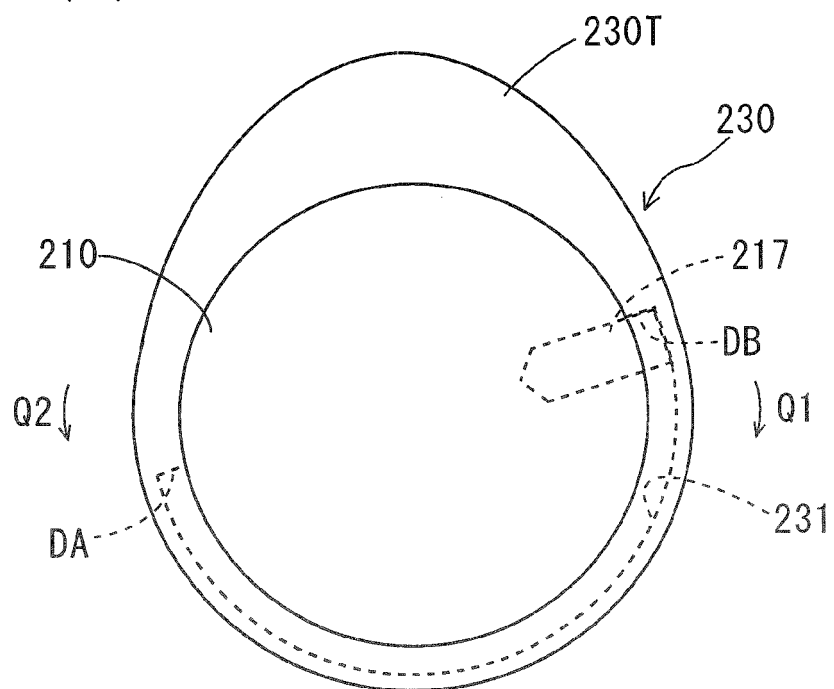


FIG. 22 (b)



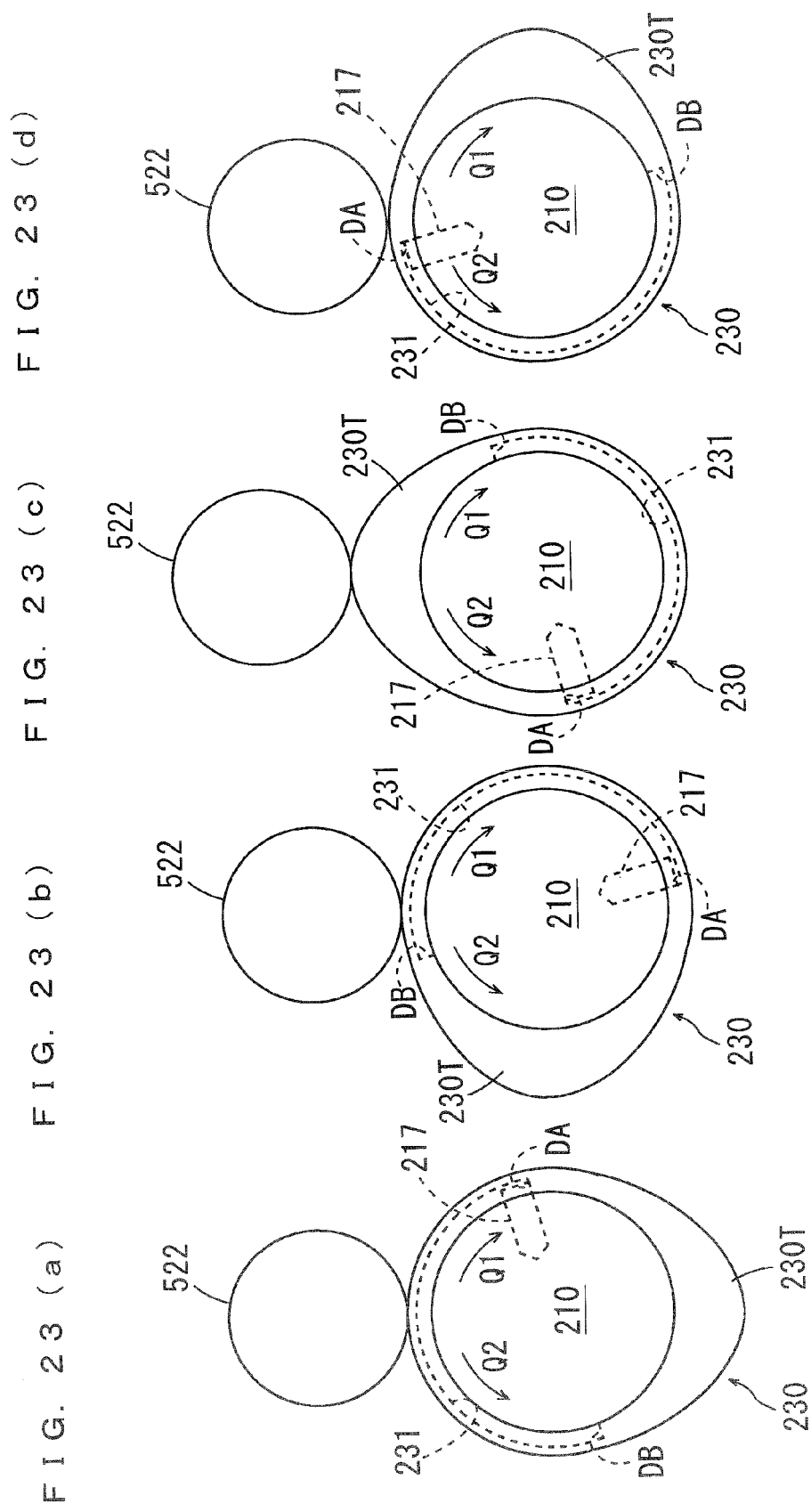
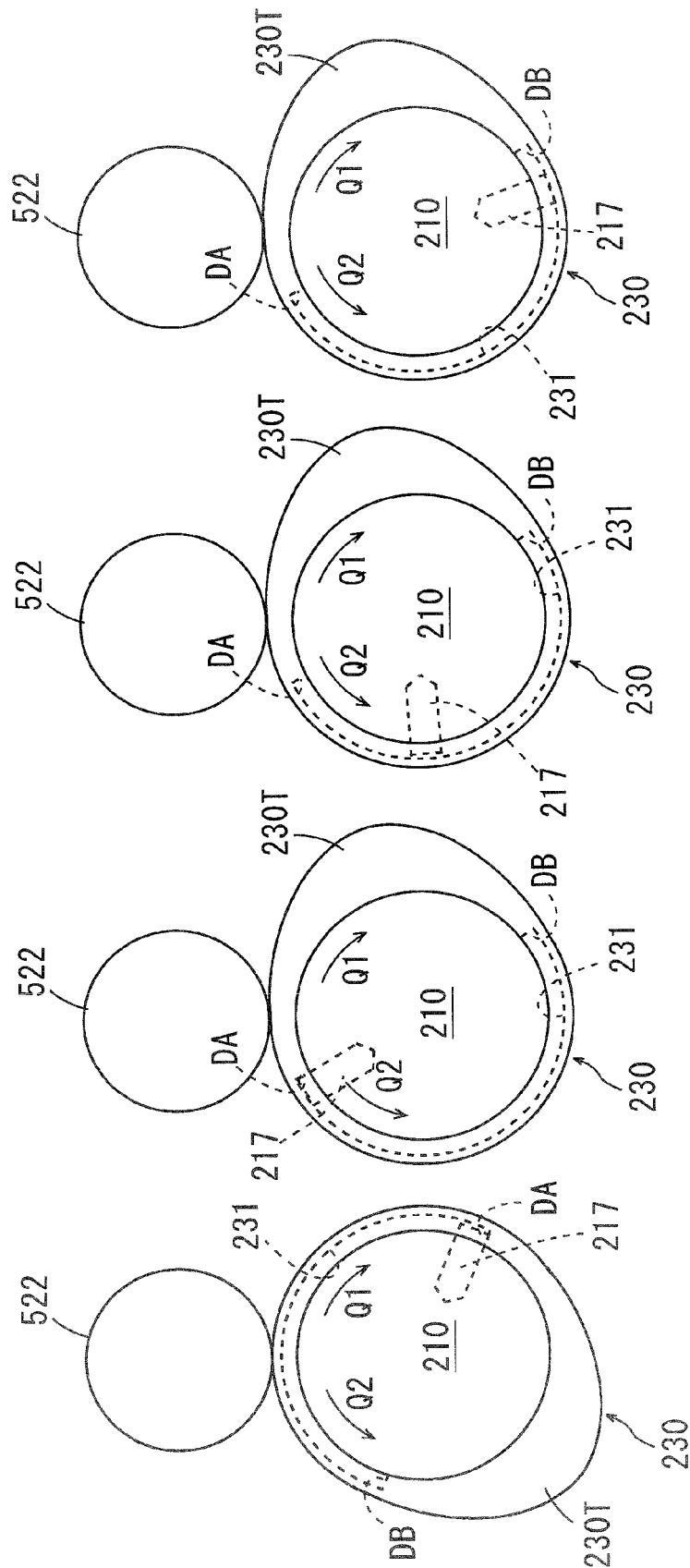


FIG. 24 (a) FIG. 24 (b) FIG. 24 (c) FIG. 24 (d)



(ANGLE A31)

(ANGLE A30)

FIG. 25 (b)

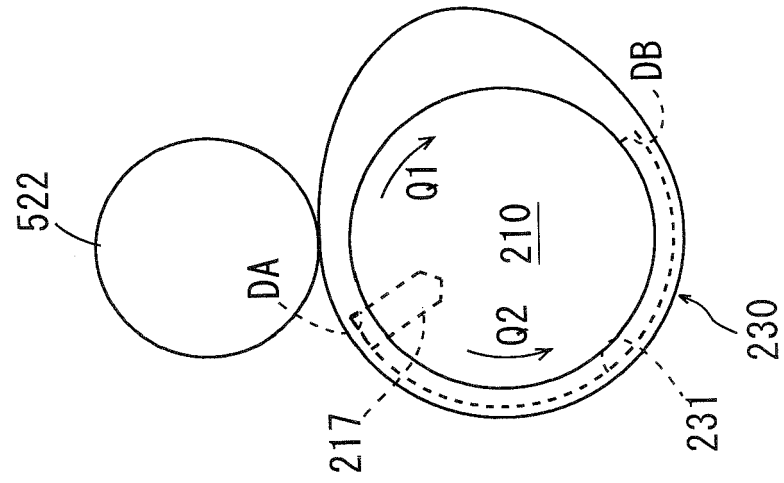


FIG. 25 (a)

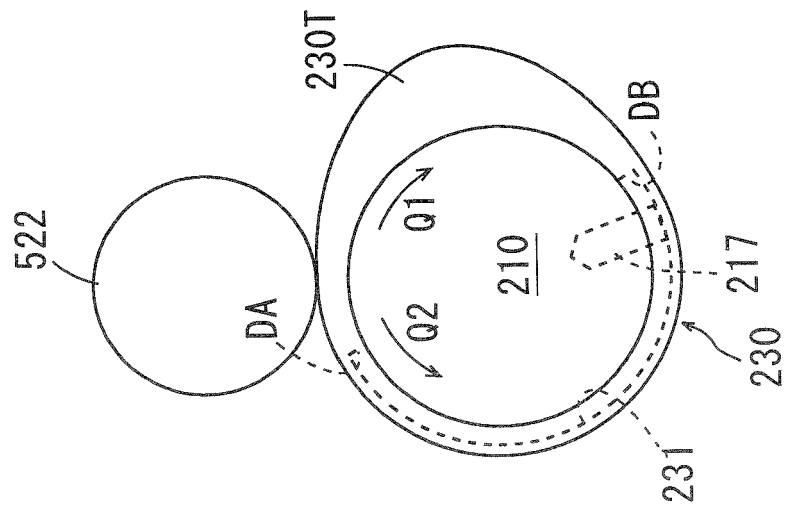


FIG. 26 (a)

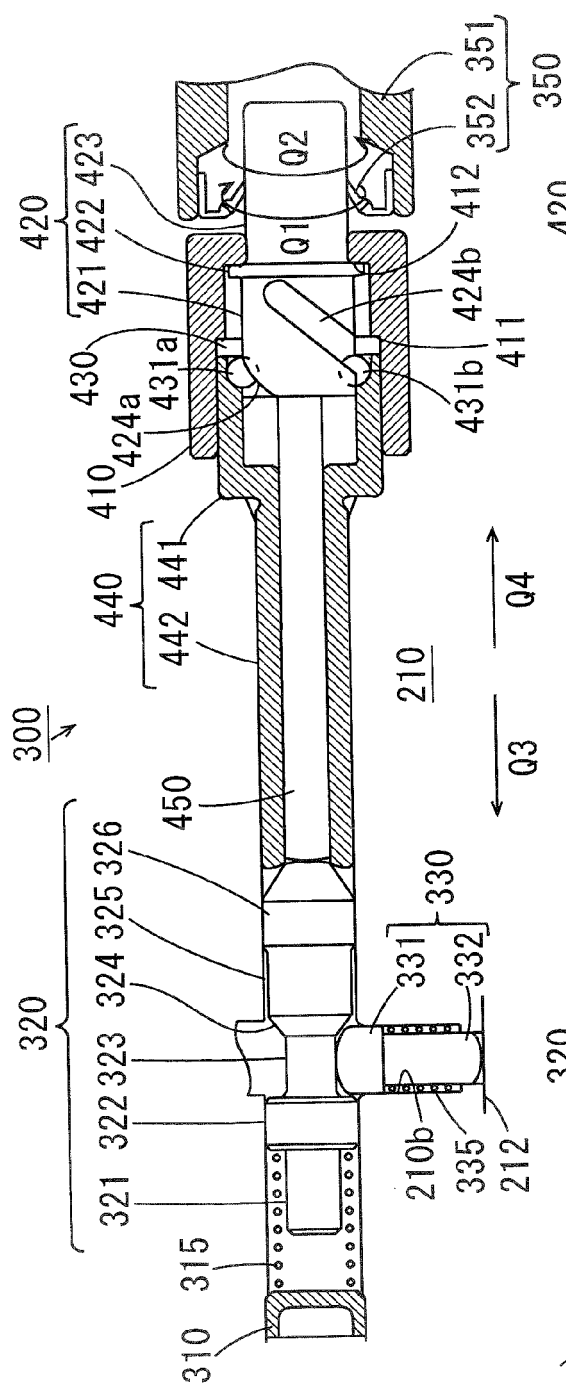


FIG. 26 (b)

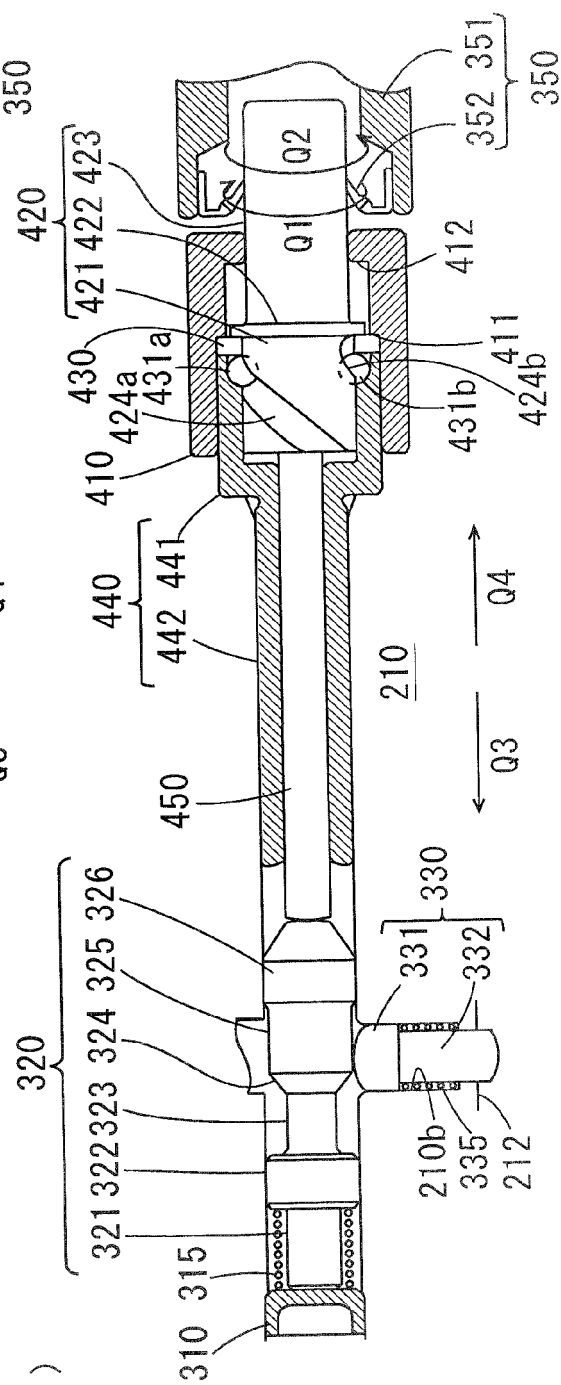


FIG. 27 (a)

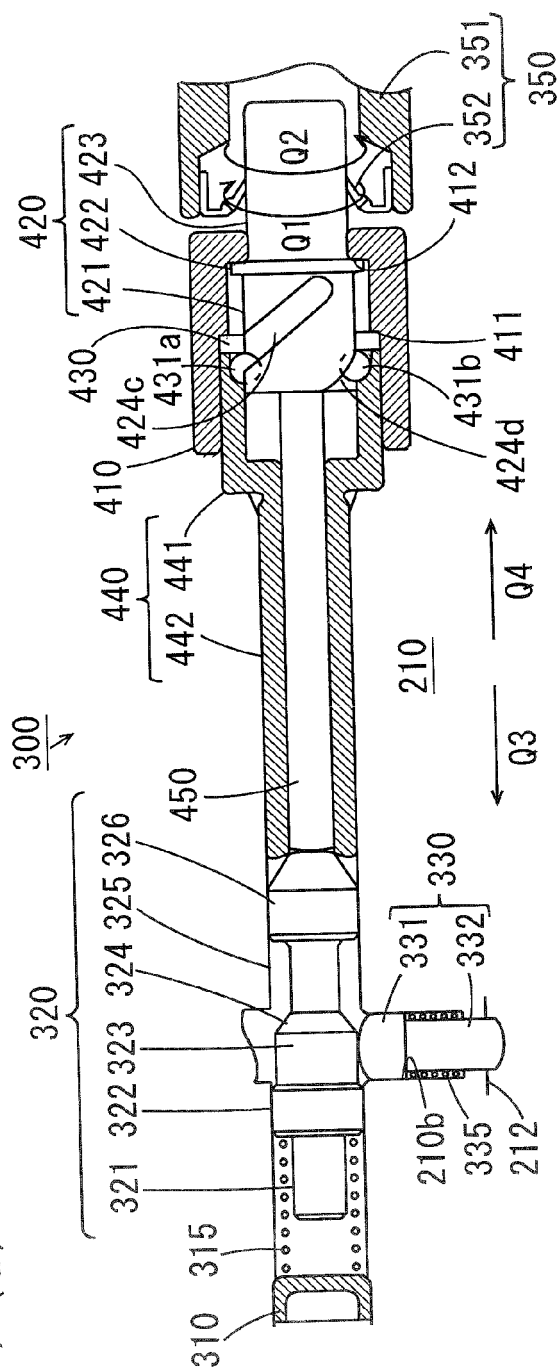
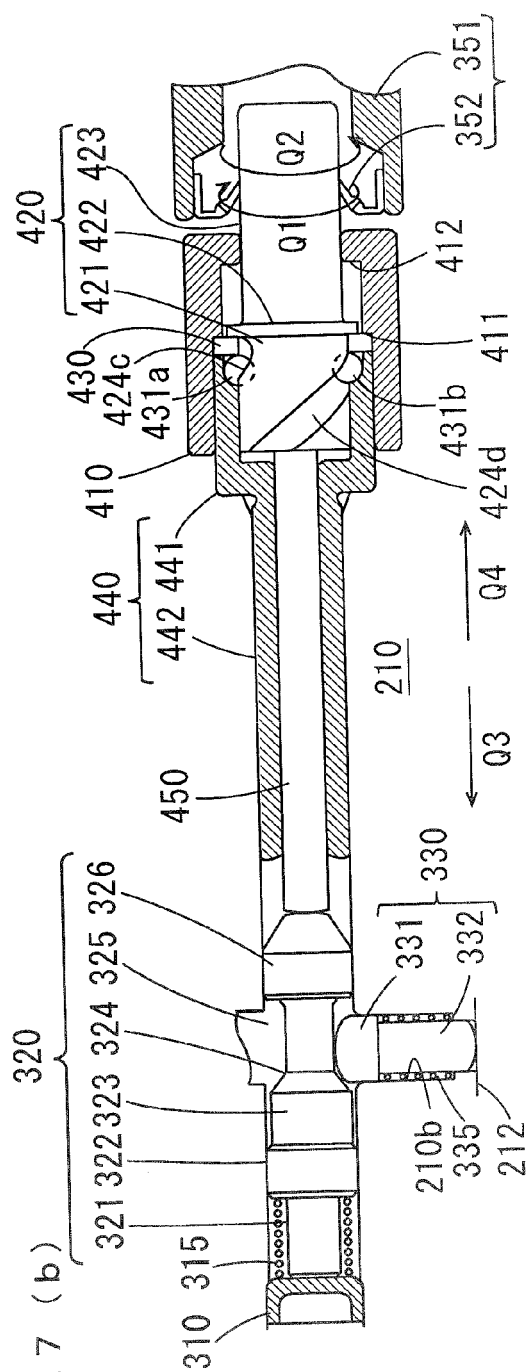


FIG. 27 (b)





EUROPEAN SEARCH REPORT

Application Number
EP 13 18 8298

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	US 2007/204827 A1 (KISHIBATA KAZUYOSHI [JP] ET AL) 6 September 2007 (2007-09-06) * paragraphs [0011], [0012], [0019], [0021] - [0024] - paragraphs [0029], [0030], [0034]; figures 1-3 * * paragraphs [0073], [0074], [0078], [0092], [0093] - paragraphs [0011] - [0113], [0122], [0124], [0128]; figures 6a-6c, 11, 12 * * paragraphs [0141], [0145], [0148], [0150] - paragraphs [0154], [0155] * -----	1-15	INV. F02D41/06 F02N11/04 F02N19/00 F02N99/00 ADD. F01L1/344 F01L1/047
A	US 2010/275872 A1 (BELAU HORST [DE] ET AL) 4 November 2010 (2010-11-04) * paragraphs [0008], [0027] - [0033]; figures 1-4 * -----	1-15	
A	EP 1 840 369 A1 (MAZDA MOTOR [JP]) 3 October 2007 (2007-10-03) * paragraphs [0013] - [0017], [0020], [0031] - [0034], [0041] - [0044], [0075]; figures 1,2,4,5,6 * -----	1-15	TECHNICAL FIELDS SEARCHED (IPC)
A	JP 2007 092720 A (MAZDA MOTOR) 12 April 2007 (2007-04-12) * abstract; figures 1,2 * -----	1-15	F02D F02N F01L
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 17 January 2014	Examiner Ossanna, Luca
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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EP 13 18 8298

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The members are as contained in the European Patent Office EDP file on
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17-01-2014

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