(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 3 309 376 A1**

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
18.04.2018 Bulletin 2018/16

(21) Application number: **16811168.0**

(22) Date of filing: **15.04.2016**

(51) Int Cl.:
F02D 29/02 (2006.01) ***F01L 1/04*** (2006.01)
F01L 13/00 (2006.01) ***F01L 13/02*** (2006.01)
F02D 13/02 (2006.01) ***F02D 27/00*** (2006.01)

(86) International application number:
PCT/JP2016/002057

(87) International publication number:
WO 2016/203687 (22.12.2016 Gazette 2016/51)

(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
Designated Validation States:
MA MD

(30) Priority: **15.06.2015 JP 2015120450**

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(54) ENGINE SYSTEM AND VEHICLE

(57) A camshaft rotates in forward and reverse directions in conjunction with a rotation of a crankshaft in the forward and reverse directions. An intake cam and a sub-intake cam are provided at the camshaft. The intake cam acts on an intake valve within a range of a crank angle corresponding to an intake process by integrally rotating with the camshaft. The sub-intake cam is rotatable within a constant angular range with respect to the camshaft, thereby being movable between a normal position and a start-up position in a circumferential direction of the camshaft. During the rotation of the crankshaft in the reverse direction, the sub-intake moves to the start-up position by rotating with a delay relative to the intake cam.

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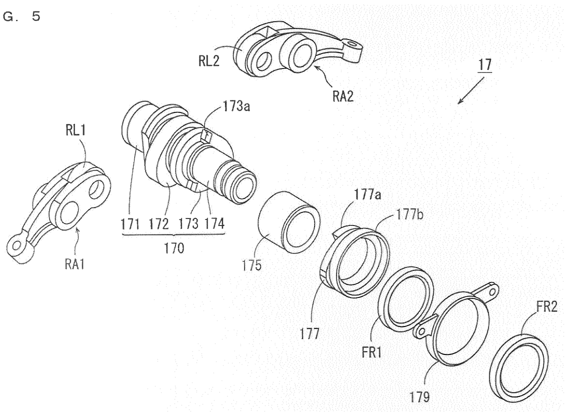

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Description

[Technical Field]

[0001] The present invention relates to an engine system and a vehicle including the engine system.

[Background Art]

[0002] During start-up of an engine, a large torque is required in order for a crank angle to exceed an angle corresponding to a first compression top dead center. In an engine system described in Patent Document 1, during start-up of an engine, a fuel-air mixture is introduced into a combustion chamber while a crankshaft rotates in reverse. With the fuel-air mixture in the combustion chamber compressed by the reverse rotation of the crankshaft, the fuel-air mixture in the combustion chamber is ignited. The rotation of the crankshaft is driven in a forward direction by energy of the combustion of the fuel-air mixture, so that a forward torque of the crankshaft is increased. Thus, the startability of the engine is enhanced.

[0003] A movement direction of a piston during the reverse rotation of the crankshaft is opposite to a movement direction of the piston during the forward rotation of the crankshaft. Therefore, in order to introduce a fuel-air mixture into the combustion chamber during the reverse rotation of the crankshaft, it is necessary that an intake valve is lifted in a range of a crank angle different from that of a normal intake stroke. In the above-mentioned engine system, a sub-intake cam for lifting the intake valve during the reverse rotation of the crankshaft is provided in addition to a main intake cam for lifting the intake valve during the forward rotation of the crankshaft.

[0004] A sub-intake cam is provided to be rotatable in a constant angular range with respect to a shaft portion of a camshaft. When the sub-intake cam is at a first position with respect to the shaft member, a cam nose of the sub-intake cam does not overlap with a cam nose of the main intake cam, so that the sub-intake cam lifts the intake valve separately from the main intake cam. When the sub-intake cam is at a second position with respect to the shaft portion, the cam nose of the sub-intake cam overlaps with the cam nose of the main intake cam, so that the sub-intake cam does not act on the intake valve. The sub-intake cam is biased by a torsion coil spring towards a first position.

[0005] During the reverse rotation of the crankshaft, the sub-intake cam pushes up a rocker arm at the first position, thereby lifting the intake valve. On the other hand, during the forward rotation of the crankshaft, the sub-intake cam is pushed back to the second position by a counterforce of the rocker arm. Therefore, the sub-intake cam does not lift the intake valve. When the rocker arm moves away from the sub-intake cam, the sub-intake cam moves to the first position by a biasing force of the torsion coil spring.

Patent Document 1: JP 2014-77405 A

[Summary of Invention]

[Technical Problem]

[0006] In a configuration described in the above-mentioned Patent Document 1, during the forward rotation of the crankshaft, the sub-intake cam moves between the first position and the second position by a counterforce of the rocker arm and a biasing force of the torsion coil spring each time the camshaft rotates once. Thus, various abnormal noises such as a contact noise of the sub-intake cam caused by the rocker arm is continuously generated during the normal operation.

[0007] An object of the present invention is to provide an engine system and a vehicle in which startability of an engine can be enhanced while the generation of an abnormal noise is prevented.

[Solution to Problem]

[0008]

(1) An engine system according to one aspect of the present invention includes an engine, a rotation driver that rotates a crankshaft of the engine in a forward direction and a reverse direction, and a controller, wherein the controller controls the engine and the rotation driver by rotating the crankshaft in the reverse direction and then combusting a fuel-air mixture in a combustion chamber of the engine such that the crankshaft is driven in the forward direction, the engine includes a valve driver that lifts an intake valve, the valve driver includes a shaft portion provided to rotate in the forward direction and the reverse direction in conjunction with a rotation of the crankshaft in the forward direction and the reverse direction, and first and second intake cams provided at the shaft portion, the first intake cam acts on the intake valve in a range of a crank angle corresponding to an intake process by integrally rotating with the shaft portion, the second intake cam is configured to be movable between a first position and a second position in a circumferential direction of the shaft portion by being rotatable within a constant angular range with respect to the shaft portion, the second intake cam overlaps with the first intake cam in an axis direction of the shaft portion when being at the first position, and acts on the intake valve within at least a part of a range of the crank angle corresponding to an exhaust stroke when being at the second position, and the second intake cam, during the rotation of the crankshaft in the forward direction, is at the first position and does not act on the intake valve, and the second intake cam, during the rotation of the crankshaft in the reverse direction, moves to the second position by rotating with a delay relative

to the first intake cam and acts on the intake valve.

In this engine system, the second intake cam is at the first position and does not act on the intake valve during the rotation of the crankshaft in the forward direction, and the second intake cam moves to the second position and acts on the intake valve during the rotation of the crankshaft in the reverse direction. The second intake cam acts on the intake valve in a range of the crank angle corresponding to the exhaust stroke at the second position, so that a fuel-air mixture is introduced into the combustion chamber of the engine while the crankshaft rotates in the reverse direction. The crankshaft is driven in the forward direction by the combustion of the fuel-air mixture. Thus, the startability of the engine can be enhanced.

During the rotation of the crankshaft in the reverse direction, the second intake cam moves to the second position by rotating with a delay relative to the first intake cam. Thus, it is possible to move the second intake cam to the second position during the rotation of the crankshaft in the reverse direction without complicating a configuration of the valve driver. Further, because the second intake cam is not biased by a biasing member at the second position, the second intake cam can be held at the first position during the rotation of the crankshaft in the forward direction. Thus, it is not necessary to move the second intake cam from the second position to the first position each time the shaft portion rotates once. Therefore, the generation of an abnormal noise such as a contact noise caused by the movement of the second intake cam is prevented.

(2) The valve driver may further include a stationary member, and a rotational resistance generation mechanism that generates a rotational resistance between the stationary member and the second intake cam, and during the rotation of the crankshaft in the reverse direction, the rotational resistance generated by the rotational resistance generation mechanism may be larger than the rotational resistance between the shaft portion and the second intake cam.

In this case, during the rotation of the crankshaft in the reverse direction, the second intake cam rotates with a delay relative to the first intake cam by the rotational resistance generated by the rotation resistance generation mechanism. Thus, the second intake can be stably moved to the second position using a simple configuration.

(3) The rotational resistance generation mechanism may include a friction member that generates a friction between the stationary member and the second intake cam. In this case, the rotational resistance can be generated between the stationary member and the second intake cam using a simple configuration and at low cost.

(4) The moment of inertia of the second intake cam and the rotational resistance between the shaft portion and the second intake cam may be set such that the second intake cam rotates with a delay relative to the first intake cam by inertia. In this case, it is possible to delay the rotation of the second intake cam while inhibiting an increase in number of components.

(5) The second intake cam may be held at the shaft portion via a rolling bearing. In this case, the rotational resistance between the shaft portion and the second intake cam can be reduced using a simple configuration, and the rotation of the second intake cam can be delayed.

(6) The valve driver may further include a one-way clutch that does not transmit the rotation of the second intake cam in the forward rotation with respect to the shaft portion from the second intake cam to the shaft portion, and transmits the rotation of the second intake cam in the reverse direction with respect to the shaft portion from the second intake cam to the shaft portion, and a resistance generation member that generates the rotational resistance between the one-way clutch and the shaft portion or between the one-way clutch and the second intake cam.

In this case, the rotation of the second intake cam in the forward direction with respect to the shaft portion is not transmitted from the second intake cam to the shaft portion by the one-way clutch. Therefore, during the rotation of the crankshaft in the reverse direction, a movement of the second intake cam to the second position is not prevented by the one-way clutch.

On the other hand, the rotation of the second intake cam in the reverse direction with respect to the shaft portion is transmitted from the second intake cam to the shaft portion by the one-way clutch. Therefore, during the rotation of the crankshaft in the reverse direction, even when a counterforce in the reverse direction is applied from the intake valve to the second intake cam, the second intake cam does not instantaneously move from the second position to the first position.

Because the rotational resistance is generated by the resistance generation member provided between the one-way clutch and the shaft portion or between the one-way clutch and the second intake cam, the second intake cam or the one-way clutch gently rotates in the forward direction with respect to the shaft portion while receiving the rotational resistance generated by the resistance generation member. Thus, the generation of an abnormal noise such as a contact noise caused by an instantaneous movement of the second intake cam is prevented.

(7) The valve driver may further include a centrifugal member, which is provided to rotate together with the shaft portion and is provided to be movable between a low speed position and a high speed position

with respect to the shaft portion depending on a magnitude of a centrifugal force generated by the rotation of the shaft portion, and the centrifugal member, before the combustion of the fuel-air mixture in the combustion chamber and during the rotation of the crankshaft in the reverse direction, may hold the second intake cam at the second position while being at the low speed position, and after the combustion of the fuel-air mixture in the combustion chamber and during the rotation of the crankshaft in the forward direction, may hold the second intake cam at the first position while being at the high speed position.

In this case, before the combustion of the fuel-air mixture and during the rotation of the crankshaft in the reverse direction, the rotation speed of the shaft portion of the valve driver is low, so that the centrifugal member is held at the low speed position. When the fuel-air mixture is combusted, the rotation speeds of the crankshaft and the shaft portion of the valve driver instantaneously increase. Therefore, the centrifugal member moves to the high speed position. The centrifugal member holds the second intake cam at the second position while being at the low speed position, and holds the second intake cam at the first position while being at the high speed position. Thus, any unnecessary movement of the second intake cam is prevented using a simple configuration utilizing a centrifugal force. Therefore, the generation of an abnormal noise caused by the movement of the second intake cam is prevented.

(8) The valve driver may further include a rocker arm abutting against the first and second intake cams, and the rocker arm, during the rotation of the crankshaft in the forward direction, may act on the second intake cam such that the second intake cam moves to the first position, and during the rotation of the crankshaft in the reverse direction, may act on the second intake cam such that the second intake cam moves to the second position.

In this case, during the rotation of the crankshaft in the forward direction, the second intake cam can be appropriately moved to the first position. Further, during the rotation of the crankshaft in the reverse direction, even in the case where the second intake cam rotates with only a small delay relative to the first intake cam, the second intake cam can be appropriately moved to the second position.

(9) A vehicle according to another aspect of the present invention includes a main body having a drive wheel, and the engine system, described above, that generates a motive power for rotating the drive wheel.

[0009] In this vehicle, the above-mentioned engine system is used, so that startability of the engine can be enhanced while the generation of an abnormal noise is prevented.

[Advantageous Effects of Invention]

[0010] The present invention enables startability of the engine to be enhanced while preventing the generation of an abnormal noise.

[Brief Description of Drawings]

[0011]

[FIG. 1] Fig. 1 is a schematic side view showing a schematic configuration of a motorcycle according to one embodiment of the present invention.

[FIG. 2] Fig. 2 is a schematic diagram for explaining a configuration of an engine system.

[FIG. 3] Fig. 3 is a diagram for explaining a normal operation of an engine unit.

[FIG. 4] Fig. 4 is a diagram for explaining a reverse rotation start-up operation of the engine unit.

[FIG. 5] Fig. 5 is an exploded perspective view of a valve driver.

[FIG. 6] Fig. 6 is a cross-sectional view of the valve driver and its peripheral portions.

[FIG. 7] Fig. 7 is a diagram for explaining a relationship among the valve driver, an intake valve and an exhaust valve.

[FIG. 8] Fig. 8 is a diagram for explaining a rotatable angular range of a sub-intake cam.

[FIG. 9] Fig. 9 is a diagram for explaining the operations of an intake cam and the sub-intake cam in a reverse rotation start-up operation.

[FIG. 10] Fig. 10 is a diagram for explaining the operations of the intake cam and the sub-intake cam in the reverse rotation start-up operation.

[FIG. 11] Fig. 11 is a diagram for explaining a first modified example of a valve driver.

[FIG. 12] Fig. 12 is a diagram for explaining a second modified example of a valve driver.

[FIG. 13] Fig. 13 is a diagram for explaining a third modified example of a valve driver.

[FIG. 14] Fig. 14 is a perspective view showing the appearance of a valve driver for explaining a fourth modified example.

[FIG. 15] Fig. 15 is a cutaway perspective view of the valve driver of Fig. 14 as viewed from a different position.

[FIG. 16] Fig. 16 is a diagram for explaining a rotation range of a sub-cam member.

[FIG. 17] Fig. 17 is a diagram for explaining the swinging of a centrifugal member.

[FIG. 18] Fig. 18 is a diagram for explaining the operations of an intake cam and a sub-intake cam in a reverse rotation start-up operation.

[FIG. 19] Fig. 19 is a diagram for explaining the operations of the intake cam and sub-intake cam in the reverse rotation start-up operation.

[FIG. 20] Fig. 20 is a diagram for explaining the operations of the intake cam and the sub-intake cam in the reverse rotation start-up operation.

[FIG. 21] Fig. 21 is a diagram for explaining the operations of the intake cam and the sub-intake cam in the reverse rotation start-up operation.

[FIG. 22] Fig. 22 is a diagram for explaining the operations of the intake cam and the sub-intake cam in the reverse rotation start-up operation.

[Description of Embodiments]

[0012] An engine system and a motorcycle according to embodiments of the present invention will be described below with reference to the drawings. The motorcycle is one example of a vehicle.

(1) Motorcycle

[0013] Fig. 1 is a schematic side view showing a 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 a front portion of a vehicle body 1 to be swingable to the right and the left. A handle 4 is attached to an upper end of the front fork 2, and a front wheel 3 is rotatably attached to a lower end of the front fork 2.

[0014] A seat 5 is provided at a substantially central upper portion of the vehicle body 1. An ECU (Engine Control Unit) 6, a battery BT and an engine unit EU are provided below the seat 5. The ECU 6, the battery BT and the engine unit EU constitute an engine system 200. A rear wheel 7 is rotatably attached to a lower portion of a rear end of the vehicle body 1. The rotation of the rear wheel 7 is driven by the motive power generated by the engine unit EU.

(2) Engine System

[0015] Fig. 2 is a schematic diagram for explaining a configuration of the engine system 200. As shown in Fig. 2, the engine unit EU includes an engine 10 and a rotary electrical machine 14. The engine 10 includes a cylinder CY, a piston 11, a connecting rod 12, a crankshaft 13, an intake valve 15, an exhaust valve 16, a valve driver 17, an injector 18 and an ignition device 19.

[0016] The piston 11 is provided to be reciprocatable in the cylinder CY and connected to the crankshaft 13 via the connecting rod 12. The crankshaft 13 is provided with the rotary electrical machine 14. The rotary electrical machine 14, which is connected to the battery BT, can drive the crankshaft 13 in a forward direction or a reverse direction by electrical power supplied from the battery BT, and can charge the battery BT by electrical power generated by the rotation of the crankshaft 13. The forward direction is a direction in which the crankshaft 13 rotates during a normal operation of the engine 10, whereas the reverse direction is a direction opposite to the forward direction. The rotary electrical machine 14 transmits a torque directly to the crankshaft 13 without a reduction gear. The rotation of the crankshaft 13 in the forward direction (forward rotation) is transmitted to the rear wheel 7, so that the rotation of the rear wheel 7 is driven. A starter motor and a generator may be provided separately instead of the rotary electrical machine 14.

[0017] A combustion chamber 31a is divided into sections by the cylinder CY and 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. Details of the valve driver 17 will be described below.

[0018] A throttle valve TV for adjusting a flow rate of air flowing in from the outside is provided in the intake passage 22. The injector 18 is configured to inject fuel into the intake passage 22. The ignition device 19 is configured to ignite a fuel-air mixture in the combustion chamber 31a.

[0019] The fuel injected by the injector 18 is mixed with air and then guided to the combustion chamber 31a, and the fuel-air mixture in the combustion chamber 31a is ignited by the ignition device 19. The reciprocating motion of the piston 11 due to the combustion of the fuel-air mixture is converted into the rotation motion of the crankshaft 13. The rotation force of the crankshaft 13 is transmitted to the rear wheel 7 of Fig. 1, so that the rear wheel 7 is driven.

[0020] The ECU 6 includes a CPU (Central Processing Unit) and a memory, for example. A microcomputer may be used instead of the CPU and the memory. The ECU 6 is electrically connected with a main switch 40, a starter switch 41, an intake pressure sensor 42, a crank angle sensor 43 and a current sensor 44. The main switch 40 is provided below the handle 4 of Fig. 1, for example, and the starter switch 41 is provided on the handle 4 of Fig. 1, for example. The main switch 40 and the starter switch 41 are operated by a rider. The intake pressure sensor 42 detects a pressure in the intake passage 22. The crank angle sensor 43 detects a crank angle indicating a rotation position of the crankshaft 13. The current sensor 44 detects a current flowing in the rotary electrical machine 14.

[0021] The operations or actuations of the main switch 40 and the starter switch 41 are supplied as operation signals to the ECU 6, and the results of detection by the intake pressure sensor 42, the crank angle sensor 43 and the current sensor 44 are supplied as detection signals to the ECU 6. The ECU 6 controls the rotary electrical machine 14, the injector 18 and the ignition device 19 based on the supplied operation signal and the supplied detection signal.

(3) Operation of Engine Unit

[0022] The engine 10 is started when the main switch

40 of Fig. 2 is turned on and the starter switch 41 is turned on, whereas the engine 10 is stopped when the main switch 40 of Fig. 2 is turned off. Start-up of the engine 10 refers to a combustion in the combustion chamber 31a being started by a start of fuel injection by the injector 18 and a start of ignition by the ignition device 19. Stopping of the engine 10 refers to the combustion in the combustion chamber 31a being stopped by the stoppage of at least one of the fuel injection by the injector 18 and the ignition by the ignition device 19.

[0023] Also, when a predetermined idle stop condition is satisfied, the engine 10 may be automatically stopped. After that, when a predetermined re-start condition is satisfied, the engine 10 may be automatically re-started. The idle stop condition may include a condition that relates to at least one of, for example, a throttle opening (a degree of opening of a throttle valve TV), a vehicle speed and a rotation speed of the engine 10 (a rotation speed of the crankshaft 13), and may further include another condition such as a condition that a brake lever is operated. The re-start condition refers to, for example, the throttle opening being larger than 0 when an accelerator grip is operated, and may include another condition such as a condition that an operation of the brake lever is released.

[0024] The engine unit EU performs a reverse rotation start-up operation during the start-up of the engine 10. Thereafter, the engine unit EU performs a normal operation that includes an intake stroke, a compression stroke, an expansion stroke and an exhaust stroke. Fig. 3 is a diagram for explaining the normal operation of the engine unit EU. Fig. 4 is a diagram for explaining the reverse rotation start-up operation of the engine unit EU.

[0025] In the following description, a top dead center through which the piston 11 passes at the time of shifting from the compression stroke to the expansion stroke is referred to as a compression top dead center, and a top dead center through which the piston 11 passes at the time of shifting from the exhaust stroke to the intake stroke is referred to as an exhaust top dead center. A bottom dead center through which the piston 11 passes at the time of shifting from the intake stroke to the compression stroke is referred to as an intake bottom dead center, and a bottom dead center through which the piston 11 passes at the time of shifting from the expansion stroke to the exhaust stroke is referred to as an expansion bottom dead center.

[0026] In Figs. 3 and 4, the range of the crank angle which is equivalent to two rotations (720 degrees) of the crankshaft 13 is represented by one circle. The two rotations of the crankshaft 13 are equivalent to one cycle of the engine 10. The crank angle sensor 43 of Fig. 2 detects a rotation position in a range in which the crankshaft 13 rotates once (360 degrees). Based on the pressure in the intake passage 22 detected by the intake pressure sensor 42, the ECU 6 determines to which one of the two rotations of the crankshaft 13 equivalent to one cycle of the engine 10 the angle detected by the crank angle sensor 43 corresponds. Thus, the ECU 6 can acquire the rotation position in the range of two rotations (720 degrees) of the crankshaft 13 as the crank angle.

[0027] In Figs. 3 and 4, an angle A0 is a crank angle when the piston 11 (Fig. 2) is positioned at the exhaust top dead center, an angle A2 is a crank angle when the piston 11 is positioned at the compression top dead center, an angle A1 is a crank angle when the piston 11 is positioned at the intake bottom dead center, and an angle A3 is a crank angle when the piston 11 is positioned at the expansion bottom dead center. An arrow R1 indicates a direction in which the crank angle changes during the forward rotation of the crankshaft 13, and an arrow R2 indicates a direction in which the crank angle changes during the reverse rotation of the crankshaft 13. Arrows P1 to P4 indicate directions in which the piston 11 moves during the forward rotation of the crankshaft 13. Arrows P5 to P8 indicate directions in which the piston 11 moves during the reverse rotation of the crankshaft 13.

(3-1) Normal Operation

[0028] The normal operation of the engine unit EU will be described with reference to Fig. 3. In the normal operation, the crankshaft 13 (Fig. 2) rotates forwardly, so that 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) is lowered in a range from the angle A0 to the angle A1, raised in a range from the angle A1 to the angle A2, lowered in a range from the angle A2 to the angle A3, and raised in a range from the angle A3 to the angle A0.

[0029] At an angle A11, the fuel is injected into the intake passage 22 (Fig. 2) by the injector 18 (Fig. 2). In the forward direction, the angle A11 is positioned at a further advanced angle than the angle A0. The intake port 21 (Fig. 2) is subsequently opened by the intake valve 15 (Fig. 2) in a range from an angle A12 to an angle A13. Thus, a fuel-air mixture including air and fuel is introduced into the combustion chamber 31a (Fig. 2) through the intake port 21. In the forward direction, the angle A12 is positioned at a further retarded angle than the angle A11 and at a further advanced angle than the angle A0, and the angle A13 is positioned at a further retarded angle than the angle A1.

[0030] Then, at an angle A14, the fuel-air mixture in the combustion chamber 31a (Fig. 2) is ignited by the ignition device 19 (Fig. 2). In the forward direction, the angle A14 is positioned at a further retarded angle than the angle A13 and at a further advanced angle than the angle A2. The fuel-air mixture is ignited, so that the fuel-air mixture is combusted in the combustion chamber 31a. Thereafter, the exhaust port 23 (Fig. 2) is opened by the exhaust valve 16 (Fig. 2) in a range from an angle A15 to an angle A16. Thus, the combusted gas is discharged from the combustion chamber 31a through the exhaust port 23. In the forward direction, the angle A15 is positioned at a further advanced angle than the angle A3, and the angle A16 is positioned at a further retarded angle than the angle A0.

(3-2) Reverse Rotation Start-up Operation

[0031] The reverse rotation start-up operation of the engine unit EU will be described with reference to Fig. 4. In the present embodiment, the crank angle is adjusted to an angle A20 by the forward rotation of the crankshaft 13 before the reverse rotation start-up operation. In the forward direction, the angle A20 is positioned at a further retarded angle than the angle A1 and at a further advanced angle than the angle A2.

[0032] In the reverse rotation start-up operation, the crank angle changes in a direction of the arrow R2 by the reverse rotation of the crankshaft 13 by the rotary electrical machine 14 (Fig. 2). In this case, as denoted by the arrows P5 to P8, the piston 11 is lowered in a range from the angle A2 to the angle A1, raised in a range from the angle A1 to the angle A0, lowered in the range from the angle A0 to the angle A3, and raised in a range from the angle A3 to the angle A2. The direction in which the piston 11 moves during the reverse rotation of the crankshaft 13 is opposite to the direction in which the piston 11 moves during the forward rotation of the crankshaft 13.

[0033] In the present example, also during the reverse rotation of the crankshaft 13, the intake port 21 is opened in a range from the angle A13 to the angle A12, and the exhaust port 23 is opened in a range from the angle A16 to the A15 similarly to during the forward rotation.

[0034] At an angle A23, fuel is injected to the intake passage 22 (Fig. 2) by the injector 18 (Fig. 2). In the reverse direction, the angle A23 is positioned at a further retarded angle than the angle A1 and at a further advanced angle than the angle A0. The intake port 21 (Fig. 2) is opened by the intake valve 15 (Fig. 2) in a range from an angle A21 to an angle A22. In the reverse direction, the angles A21, A21 are positioned in the range, from the angle A0 to the angle A3, corresponding to the exhaust stroke during the normal operation. In the range from the angle A1 to the angle A0, the piston 11 is raised. Therefore, even when the intake port 21 is opened in the range from the angle A13 to the angle A12, fuel and air are hardly introduced into the combustion chamber 31a. On the other hand, in the range from the angle A0 to the angle A3, the piston 11 is lowered, so that the intake port 21 is opened in a range from the angle A21 to the angle A22. Thus, the fuel-air mixture including air and fuel is introduced into the combustion chamber 31a through the intake port 21 from the intake passage 22.

[0035] As the crank angle comes closer to the angle A2, the fuel-air mixture introduced into the combustion chamber 31a is compressed. At an angle A31, the fuel-air mixture in the combustion chamber 31a is ignited by the ignition device 19 (Fig. 2), and a direction in which the crankshaft 13 is driven by the rotary electrical machine 14 is switched from the reverse direction to the forward direction. In the reverse direction, the angle A31 is positioned at a further retarded angle than the angle A3 and at a further advanced angle than the angle A2. For example, when a current of the rotary electrical machine 14 detected by the current sensor 44 of Fig. 2 reaches a threshold value, the fuel-air mixture is ignited by the ignition device 19. In this case, the crankshaft 13 is driven in the forward direction by the combustion of the fuel-air mixture, so that a forward torque of the crankshaft 13 is increased. Thus, the crank angle can exceed the angle A2 corresponding to the first compression top dead center. In the case where the crank angle can exceed the angle A2 corresponding to the first compression top dead center only by energy of combustion, the crankshaft 13 does not have to be driven in the forward direction by the rotary electrical machine 14. Thereafter, the engine unit EU is shifted to the above-mentioned normal operation.

(4) Configuration of Valve Driver

(4-1) Overall Configuration

[0036] A specific example of the configuration of the valve driver 17 will be described. Fig. 5 is an exploded perspective view of the valve driver 17, and Fig. 6 is a cross-sectional view of the valve driver 17 and its peripheral portions.

[0037] As shown in Figs. 5 and 6, the valve driver 17 includes a camshaft 170, a one-way clutch 175, a sub-intake cam 177, a friction member FR1, a holder 179, a friction member FR2, an intake rocker arm RA1 and an exhaust rocker arm RA2.

[0038] As shown in Fig. 5, the camshaft 170 includes a shaft portion 171, an exhaust cam 172, an intake cam 173 and a shaft portion 174. The shaft portions 171, 174 are provided to extend in one direction with the exhaust cam 172 and the intake cam 173 sandwiched therebetween. An axial center of the shaft portion 171 and an axial center of the shaft portion 174 are positioned on a common straight line. In the following description, an axis direction refers to a direction in parallel with the axial centers of the shaft portions 171, 174, and a circumferential direction refers to a direction that extends along a circle formed about the axial centers of the shaft portions 171, 174. The exhaust cam 172 and the intake cam 173 respectively have predetermined cam profiles and are provided between the shaft portions 171, 174 to be arranged in the axis direction. A cutout 173a is formed in a peripheral edge of one surface of the intake cam 173.

[0039] The one-way clutch 175 is of cylindrical shape. The one-way clutch 175 is rotatable in one direction of the circumferential direction with respect to the shaft portion 174, and is non-rotatable in the opposite direction. A rotation direction of the one-way clutch 175 will be described below.

[0040] The sub-intake cam 177, the friction member FR1, the holder 179 and the friction member FR1 are respectively provided to be annular. The sub-intake cam

177 has a predetermined cam profile. A projection piece 177a is provided at one surface of the sub-intake cam 177. As described below, a rotatable angular range of the sub-intake cam 177 with respect to the shaft portion 174 is restricted by the projection piece 177a and the cutout 173a of the intake cam 173. The range of the rotation of the sub-intake cam 177 will be described below. A cylindrical storage 177b is provided on the other surface of the sub-intake cam 177. The friction member FR1 is stored in the storage 177b. The holder 179 holds the friction member FR2. The friction members FR1, FR2 are respectively elastic. For example, an oil seal made of synthetic rubber or the like is used as the friction member FR1, FR2.

[0041] The intake rocker arm RA1 is provided to extend in a direction substantially orthogonal to the axis direction and on one side of the camshaft 170. The exhaust rocker arm RA2 is provided to extend in a direction substantially orthogonal to the axis direction and on the other side of the camshaft 170. The intake rocker arm RA1 and the exhaust rocker arm RA2 are provided to be respectively swingable with arm shafts SH1, SH2 (see Fig. 7, described below) in parallel with the axis direction as centers. A roller RL1 is attached to one end of the intake rocker arm RA1, and a roller RL2 is attached to one end of the exhaust rocker arm RA2.

[0042] As shown in Fig. 6, the camshaft 170 is held by the bearings B1, B2 to be rotatable about an axial center AC of the shaft portions 171, 174 in the cylinder head CH of the engine 10. An inner peripheral surface of the bearing B1 abuts against an outer peripheral surface of the shaft portion 171, and an inner peripheral surface of the bearing B2 abuts against an outer peripheral surface of the shaft portion 174. The roller RL1 of the intake rocker arm RA1 abuts against the intake cam 173, and the roller RL2 of the exhaust rocker arm RA2 abuts against the exhaust cam 172. Further, a slipper surface SS is provided in a portion of the intake rocker arm RA1 adjacent to the roller RL1 in the axis direction. The slipper surface SS abuts against the sub-intake cam 177.

[0043] The one-way clutch 175 is attached onto the outer peripheral surface of the shaft portion 174. The sub-intake cam 177 is attached onto an outer peripheral surface of the one-way clutch 175 to be adjacent to the intake cam 173. The holder 179 is fixed to the cylinder head CH to be adjacent to the sub-intake cam 177 and partially surround the outer peripheral surface of the one-way clutch 175.

[0044] An outer periphery of the friction member FR1 is fixed to the storage 177b of the sub-intake cam 177, and an inner periphery of the friction member FR1 is pressed against the outer peripheral surface of the one-way clutch 175. Thus, a rotational resistance is generated between the sub-intake cam 177 and the one-way clutch 175 by the friction member FR1. The inner periphery of the friction member FR1 may be fixed to the outer peripheral surface of the one-way clutch 175, and the outer periphery of the friction member FR1 may be pressed against an inner peripheral surface of the storage 177b of the sub-intake cam 177. A similar rotational resistance can be generated also in this case.

[0045] The holder 179 is fixed to the cylinder head CH, thereby not moving in conjunction with the rotation of the camshaft 170. Hereinafter, a part of the engine unit EU that does not move in conjunction with the rotation of the camshaft 170 is referred to as a stationary system. An outer periphery of the friction member FR2 is fixed to the holder 179, and an inner periphery of the friction member FR2 is pressed against the outer periphery of the one-way clutch 175. Therefore, the rotational resistance is generated between the stationary system and the one-way clutch 175 by the friction member FR2. The inner periphery of the friction member FR2 may be fixed to the outer peripheral surface of the one-way clutch 175, and the outer periphery of the friction member FR2 may be pressed against the inner peripheral surface of the holder 179. A similar rotational resistance can be generated also in this case. The rotational resistance generated by the friction member FR2 is smaller than the rotational resistance generated by the friction member FR1.

[0046] Fig. 7 is a diagram for explaining a relationship among the valve driver 17, the intake valve 15 and the exhaust valve 16. As shown in Fig. 7, the intake rocker arm RA1 is provided to be swingable with the arm shaft SH1 as a center, and the exhaust rocker arm RA2 is provided to be swingable with the arm shaft SH2 as a center. An abutment member AD1 is attached to an end opposite to the roller RL1 of the intake rocker arm RA1. The abutment member AD1 abuts against an upper end of the intake valve 15. An abutment member AD2 is attached to an end opposite to the roller RL2 of the exhaust rocker arm RA2. The abutment member AD2 abuts against an upper end of the exhaust valve 16.

[0047] The intake valve 15 is biased in a direction of closing the intake port 21 (Fig. 2) by a valve spring 15a. By a biasing force of the valve spring 15a, the intake valve 15 is pressed against the abutment member AD1, and the roller RL1 of the intake rocker arm RA1 is pressed against the intake cam 173. Further, the slipper surface SS of the intake rocker arm RA1 is pressed against the sub-intake cam 177 (see Fig. 6). The exhaust valve 16 is biased in a direction of closing the exhaust port 23 (Fig. 2) by the valve spring 16a. By a biasing force of the valve spring 16a, the exhaust valve 16 is pressed against the abutment member AD2, and the roller RL2 of the exhaust rocker arm RA2 is pressed against the exhaust cam 172.

[0048] Hereinafter, a rotation direction of the camshaft 170 during the forward rotation of the crankshaft 13 (Fig. 2) is referred to as the forward direction (a direction Q1 of Fig. 7), and a rotation direction of the camshaft 170 during the reverse rotation of the crankshaft 13 (Fig. 2) is referred to as the reverse direction (a direction Q2 of Fig. 7). The camshaft 170 rotates forwardly or in reverse, whereby the intake cam 173 and the sub-intake cam 177 swing the intake rocker arm RA1, and the exhaust cam 172 swings the exhaust rocker arm RA2. Thus, the intake valve 15 opens and closes the intake port 21, and the exhaust valve 16 opens and closes the exhaust port 23.

[0049] The one-way clutch 175 of Figs. 5 and 6 is rotatable in the forward direction Q1 and non-rotatable in the reverse direction Q2 with respect to the shaft portion 174. Specifically, the rotational resistance exerted on the one-way clutch 175 from the shaft portion 174 in the reverse direction Q2 is significantly small, and the rotational resistance exerted on the one-way clutch 175 from the shaft portion 174 in the forward direction Q1 is significantly large. The rotational resistance exerted on the one-way clutch 175 from the shaft portion 174 in the reverse direction Q2 is reduced by a rolling bearing, for example.

(4-2) Range of Rotation of Sub-intake Cam

[0050] Fig. 8 is a diagram for explaining a rotatable angular range of the sub-intake cam 177. In Fig. 8, the one-way clutch 175 is not shown. As shown in Fig. 8(a) and 8(b), a cutout 173a of the intake cam 173 is provided to extend in a circumferential direction. Similarly, the projection piece 177a of the sub-intake cam 177 is provided to extend in the circumferential direction. A length of the cutout 173a in the circumferential direction is larger than a length of the projection piece 177a in the circumferential direction. The projection piece 177a is arranged in the cutout 173a.

[0051] As shown in Fig. 8(a), one end TA1 of the projection piece 177a abuts against one end TB1 of the cutout 173a, whereby the rotation of the sub-intake cam 177 in the reverse direction Q2 with respect to the shaft portion 174 is prevented. On the other hand, as shown in Fig. 8(b), the other end TA2 of the projection piece 177a abuts against the other end TB2 of the cutout 173a, whereby the rotation of the sub-intake cam 177 in the forward direction Q1 with respect to the shaft portion 174 is prevented. Thus, a rotatable angular range of the sub-intake cam 177 with respect to the shaft portion 174 is restricted. Specifically, a difference of an angle between the one end TB1 and the other end TB2 of the cutout 173a in the circumferential direction from an angle between the one end TA1 and the other end TA2 of the projection piece 177a in the circumferential direction is an angle by which the sub-intake cam 177 can rotate with respect to the shaft portion 174.

[0052] As shown in Fig. 8(a), with the one end TA1 of the projection piece 177a abutting against the one end TB1 of the cutout 173a, an entire cam nose 177T of the sub-intake cam 177 overlaps with a cam nose 173T of the intake cam 173 in the axis direction. Hereinafter, such a relative position of the sub-intake cam 177 with respect to the intake cam 173 is referred to as a normal position. On the other hand, as shown in Fig. 8(b), with the other end TA2 of the projection piece 177a abutting against the other end TB2 of the cutout 173a, the cam nose 177T of the sub-intake cam 177 deviates from the cam nose 173T of the intake cam 173 by a constant angle in the circumferential direction, and at least a part of the cam nose 177T of the sub-intake cam 177 does not overlap with the cam nose 173T of the intake cam 173. Hereinafter, such a relative position of the sub-intake cam 177 with respect to the intake cam 173 is referred to as a start-up position.

[0053] The sub-intake cam 177 does not act on the intake rocker arm RA1 (Fig. 7) at the normal position. On the other hand, the sub-intake cam 177 acts on the intake rocker arm RA1 at the start-up position. In this case, when the crank angle is in a range from the angle A21 to the angle A22 of Fig. 4, the intake rocker arm RA1 is driven and the intake valve 15 (Fig. 7) is lifted.

(5) Operations of Intake Cam and Sub-intake Cam

[0054] Figs. 9 and 10 are diagrams for explaining the operations of the intake cam 173 and the sub-intake cam 177 in the reverse rotation start-up operation. In the present example, with the crank angle at the angle A20 of Fig. 4, the sub-intake cam 177 is at the normal position as shown in Fig. 9(a). When the reverse rotation of the crankshaft 13 is started, the camshaft 170 rotates in the reverse direction Q2 as shown in Fig. 9(b). In this case, the rotational resistance (hereinafter referred to as the stationary system rotational resistance) generated by the friction member FR2 of Fig. 6 is exerted between the stationary system and the one-way clutch 175. As described above, the one-way clutch 175 is rotatable in the forward direction Q1 with respect to the shaft portion 174, so that the one-way clutch 175 rotates in the forward direction Q1 with respect to the shaft portion 174 by the stationary system rotational resistance. The rotational resistance (hereinafter referred to as the sub-cam rotational resistance) generated by the friction member FR1 of Fig. 6 is exerted between the sub-intake cam 177 and the one-way clutch 175. Therefore, the sub-intake cam 177 does not rotate with respect to the one-way clutch 175, and rotates in the forward direction Q1 together with the one-way clutch 175 with respect to the shaft portion 174.

[0055] In this manner, the reverse rotation of the camshaft 170 is started, and then the sub-intake cam 177 does not rotate with respect to the stationary system or rotates in reverse with respect to the stationary system at a speed lower than that of the camshaft 170. Thus, the sub-intake cam 177 rotates with a delay relative to the intake cam 173 and moves from the normal position to the start-up position.

[0056] During a period in which the crank angle is in a range from the angle A13 to the angle A12 of Fig. 4, the intake cam 173 pushes up the one end of the intake rocker arm RA1 as shown in Fig. 9(c). Thus, the intake valve 15 of Fig. 7 is lifted. Further, when the sub-intake cam 177 reaches the start-up position, the rotation of the sub-intake cam 177 with respect to the shaft portion 174 in the forward direction Q1 is prevented. Therefore, the sub-intake cam 177 rotates in the reverse direction Q2 together with the shaft portion 174. Further, the sub-cam rotational resistance is larger than the stationary system rotational resistance, so that the one-way clutch 175 rotates in the reverse direction Q2 together with the sub-intake cam 177 by the sub-cam rotational resistance.

[0057] During a period in which the crank angle is in a range from the angle A21 to the angle A22 of Fig. 4, the sub-intake cam 177 pushes up the one end of the intake rocker arm RA1 as shown in Fig. 9(d). Thus, the intake valve 15 of Fig. 7 is lifted.

[0058] While the cam nose 177T abuts against the intake rocker arm RA1 with the sub-intake cam 177 at the start-up position in the present example, the cam nose 177T (Fig. 8) may abut against the intake rocker arm RA1 with the sub-intake cam 177 not reaching the start-up position. In this case, the sub-intake cam 177 is rotated in the forward direction Q1 with respect to the shaft portion 174 by a counterforce of the intake rocker arm RA1. Thus, the sub-intake cam 177 reaches the start-up position. The sub-intake cam 177 does not push up the one end of the intake rocker arm RA1 until reaching the start-up position. When the sub-intake cam 177 reaches the start-up position, the sub-intake cam 177 pushes up the one end of the intake rocker arm RA1. Thus, similarly to the example of Fig. 9(d), when the crank angle is in a range from the angle A21 to the angle A22, the intake valve 15 is lifted.

[0059] As shown in Fig. 9(e), when an abutment position between the sub-intake cam 177 and the intake rocker arm RA1 goes beyond the tip end of the cam nose 177T, the force in the reverse direction Q2 is applied from the intake rocker arm RA1 to the sub-intake cam 177. The tip end of the cam nose 177T refers to a portion in an outer peripheral surface of the cam nose 177T at which a distance from the axial center of the shaft portion 174 is maximum. Because the one-way clutch 175 is non-rotatable in the reverse direction Q2 with respect to the shaft portion 174, the one-way clutch 175 is not rotating in reverse with respect to the shaft portion 174. On the other hand, the force applied from the intake rocker arm RA1 to the sub-intake cam 177 is larger than the sub-cam rotational resistance, so that the sub-intake cam 177 rotates in the reverse direction Q2 with respect to the one-way clutch 175 while receiving the sub-cam rotational resistance as shown in Fig. 9(f).

[0060] In this manner, a speed of the reverse rotation of the sub-intake cam 177 with respect to the shaft portion 174 decreases due to the sub-cam rotational resistance exerted between the sub-intake cam 177 and the one-way clutch 175. Therefore, the sub-intake cam 177 is prevented from instantaneously moving from the start-up position to the normal position. If the sub-intake cam 177 instantaneously moves from the start-up position to the normal position, the intake port 21 is instantaneously closed by the intake valve 15. Thus, the intake valve 15 collides with an edge of the intake port 21, and a contact noise is generated. Further, when the intake rocker arm RA1 also instantaneously moves, a contact noise caused by the movement of the intake rocker arm RA1 may be generated in the valve driver 17. In the present example, the sub-intake cam 177 gently moves from the start-up position to the normal position, so that the generation of such a contact noise is prevented.

[0061] Thereafter, when the crank angle reaches the angle A31 of Fig. 4, a fuel-air mixture is ignited in the combustion chamber 31a of Fig. 2, and the crankshaft 13 is driven in the forward direction. Thus, as shown in Fig. 10(a), the camshaft 170 rotates in the forward direction Q1. The one-way clutch 175 is non-rotatable in the reverse direction Q2 with respect to the shaft portion 174, thereby rotating together with the camshaft 170 in the forward direction Q1. Further, the sub-intake cam 177 rotates in the forward direction Q1 together with the one-way clutch 175 by the sub-cam rotational resistance.

[0062] As shown in Fig. 10(b), when the cam nose 177T of the sub-intake cam 177 abuts against the intake rocker arm RA1, the force in the reverse direction Q2 is applied from the intake rocker arm RA1 to the sub-intake cam 177. The one-way clutch 175 is non-rotatable in the reverse direction Q2 with respect to the shaft portion 174, thereby not rotating in reverse with respect to the shaft portion 174. On the other hand, because the force applied from the intake rocker arm RA1 to the sub-intake cam 177 is larger than the sub-cam rotational resistance, the sub-intake cam 177 does not push up the one end of the intake rocker arm RA1, and is rotated in the reverse direction Q2 with respect to the one-way clutch 175 by a counterforce of the intake rocker arm RA1.

[0063] Thus, as shown in Fig. 10(c), the sub-intake cam 177 moves to the normal position. Thereafter, during a period in which the crank angle is in a range from the angle A12 to the angle A13 of Fig. 3, the intake cam 173 pushes up the one end of the intake rocker arm RA1, so that the intake valve 15 of Fig. 7 is lifted. Thereafter, with the sub-intake cam 177 held at the normal position, the forward rotation of the camshaft 170 continues. Thus, during the normal operation, the sub-intake cam 177 does not drive the intake rocker arm RA1, and only the intake cam 173 drives the intake rocker arm RA1.

[0064] During the normal operation, when the rotation of the crankshaft 13 and the camshaft 170 is braked by a brake operation or the like, an inertial force in the forward direction Q1 is exerted on the sub-intake cam 177. Similarly to the example of Fig. 10(b), if the sub-intake cam 177 moves from the normal position towards the start-up position by the inertial force, the sub-intake cam 177 is pushed back to the normal position by the counterforce of the intake rocker arm RA1. During the normal operation, in the case where the sub-intake cam 177 frequently moves in this manner, a contact noise generated by the intake rocker arm RA1 and the sub-intake cam 177, a contact noise generated by the projection piece 177a and the cutout 173a of Fig. 8 and the like are frequently generated.

[0065] In the present example, the stationary system rotational resistance is exerted between the stationary system and the one-way clutch 175, and the sub-cam rotational resistance is exerted between the one-way clutch 175 and the sub-intake cam 177. Thus, during the forward rotation of the camshaft 170, the sub-intake cam 177 and the one-way clutch 175 are prevented from rotating in the forward direction Q1 with respect to the camshaft 170. Therefore, during the normal operation, the generation of an abnormal noise caused by the movement of the sub-intake cam 177 is prevented.

(6) Effects

[0066] In the engine system 200 according to the present embodiment, the crankshaft 13 rotates in reverse and then a fuel-air mixture is combusted, so that the crankshaft 13 is driven in the forward direction. Thus, the startability of the engine 10 is enhanced. Further, during the reverse rotation of the crankshaft 13, the sub-intake cam 177 rotates with a delay relative to the intake cam 173. Thus, it is possible to move the sub-intake cam 177 to the start-up position during the rotation of the crankshaft 13 in the reverse direction without complicating the configuration of the valve driver 17. Further, because the sub-intake cam 177 is not biased by a biasing member at the start-up position, the sub-intake cam 177 can be held at the normal position during the forward rotation of the crankshaft 13. Thus, it is not necessary to move the sub-intake cam 177 from the start-up position to the normal position for each rotation of the camshaft 170. Therefore, the generation of an abnormal noise such as a contact sound caused by the movement of the sub-intake cam 177 is prevented.

[0067] Further, in the present embodiment, the rotational resistance generated by the friction member FR2 is exerted between the stationary system and the one-way clutch 175, so that the sub-intake cam 177 rotates with a delay relative to the intake cam 173. Thus, the sub-intake cam 177 can be stably moved to the start-up position using a simple configuration.

(7) Modified Example of Valve Driver

(7-1) First Modified Example

[0068] Fig. 11 is a diagram for explaining the first modified example of the valve driver 17. As for the example of Fig. 11, differences from Figs. 5 and 6 will be described. The valve driver 17 of Fig. 11 includes a friction spring 180 instead of the holder 179 and the friction member FR2 of Figs. 5 and 6. The friction spring 180 is a torsion spring and includes a coil 181 and arm portions 182, 183. In the present example, the coil 181 of the friction spring 180 is fitted with the arm shaft SH2.

[0069] The arm portion 182 abuts against an outer peripheral surface of the storage 177b of the sub-intake cam 177. The arm portion 183 is fixed to the cylinder head CH (Fig. 6). In this case, the arm portion 183 is pressed against the sub-intake cam 177 with a constant force. Thus, the rotational resistance is generated between the stationary system and the sub-intake cam 177.

[0070] Therefore, similarly to the case where the friction member FR2 of Figs. 5 and 6 is used, the sub-intake cam 177 rotates with a delay relative to the intake cam 173 during the reverse rotation of the crankshaft 13. Thus, similarly to the example of Figs. 5 and 6, the sub-intake cam 177 can be stably moved to the start-up position using a simple configuration.

(7-2) Second Modified Example

[0071] Fig. 12 is a diagram for explaining the second modified example of a valve driver 17. As for the example of Fig. 12, differences from Figs. 5 and 6 will be described. The valve driver 17 of Fig. 12 includes a bar-shaped pressing member 185, a compression spring 186 and a support member 187 instead of the holder 179 and the friction member FR2 of Figs. 5 and 6. One end of the pressing member 85 is attached to a fixing portion HP via a shaft member 185a. The fixing portion HP is provided at the cylinder head CH (Fig. 6). The pressing member 185 is held to be swingable with the shaft member 185a as a center.

[0072] One end of the compression spring 186 is attached to the support member 187. The support member 187 is fixed to the fixing portion HP. The other end of the compression spring 186 abuts against the pressing member 85. The pressing member 85 is pressed against the sub-intake cam 177 by a biasing force of the compression spring 186. Thus, the rotational resistance is generated between the stationary system and the sub-intake cam 177.

[0073] Therefore, similarly to the case where the friction member FR2 of Figs. 5 and 6 is used, the sub-intake cam 177 rotates with a delay relative to the intake cam 173 during the reverse rotation of the crankshaft 13. Thus, similarly to the example of Figs. 5 and 6, the sub-intake cam 177 can be stably moved to the start-up position using a simple configuration.

(7-3) Third Modified Example

[0074] Fig. 13 is a diagram for explaining the third modified example of a valve driver 17. As for the example of Fig. 13, differences from the example of Figs. 5 and 6 will be described. The valve driver 17 of Fig. 13 includes an annular weight WT instead of the holder 179 and the friction member FR2 of Figs. 5 and 6. The weight WT is provided at the sub-intake cam 177. In the present example, the weight WT is attached onto the outer peripheral surface of the storage 177b.

[0075] The following formula (1) is satisfied, so that the sub-intake cam 177 rotates with a delay relative to the camshaft 170 by the inertial force during the reverse rotation of the camshaft 170.

$$I\omega > T_F \cdots (1)$$

[0076] In the formula (1), 'I' is the moment of inertia of the sub-intake cam 177, and 'ω' is the angular acceleration of the camshaft 170. Further, 'T_F' is a drag torque of the sub-intake cam 177 with respect to the shaft portion 174 of the camshaft 170.

[0077] The weight WT is provided, so that the moment of inertia of the sub-intake cam 177 increases. The drag torque T_F depends on the rotational resistance generated between the one-way clutch 175 and the shaft portion 174. As described above, the one-way clutch 175 is rotatable in the forward direction Q1 with respect to the shaft portion 174. Therefore, during the reverse rotation of the camshaft 170, the drag torque T_F is small. Thus, during the reverse rotation of the camshaft 170, the above formula (1) is satisfied, and the sub-intake cam 177 rotates with a delay relative to the camshaft 170.

[0078] In this manner, the moment of inertia of the sub-intake cam 177 and the rotational resistance between the shaft portion 174 and the one-way clutch 175 are set such that the sub-intake cam 177 rotates with a delay relative to the camshaft 170 by inertia. Thus, the sub-intake cam 177 can rotate with a delay while an increase in number of components is inhibited. A material (tungsten, for example) having a large specific gravity may be used as a material for the sub-intake cam 177, whereby the moment of inertia of the sub-intake cam 177 may be increased.

(7-4) Fourth Modified Example

[0079] In the example of Figs. 5 and 6, and the modified examples of Figs. 11 to 13, the one-way clutch 175 and the friction member FR1 are provided, so that the sub-intake cam 177 is prevented from instantaneously moving from the start-up position to the normal position by the reaction force from the intake rocker arm RA1. However, the present invention is not limited to this.

[0080] Fig. 14 is a perspective view showing the appearance of a valve driver 17 for explaining the fourth modified example. Fig. 15 is a cutaway perspective view of the valve driver 17 of Fig. 14 as viewed from a different position. As for the example of Figs. 14 and 15, differences from the example of Figs. 5 and 6 will be described.

[0081] The valve driver 17 of Figs. 14 and 15 includes a sub-cam member 210, a holding member 220 and a centrifugal member 230 instead of the one-way clutch 175, the sub-intake cam 177 and the friction member FR1 of Figs. 5 and 6.

[0082] The sub-cam member 210 includes a sub-intake cam 211, a rotation plate 212 and a projection piece 213. The sub-intake cam 211 has a cam profile similar to that of the sub-intake cam 177 of Figs. 5 and 6. A rotation plate 212 has a disc shape with the axial center of the shaft portion 174 of the camshaft 170 as a center. The projection piece 213 is provided to project from a predetermined position in a peripheral edge of the rotation plate 212 towards the side opposite to the sub-intake cam 211 in the axis direction. The sub-cam member 210 is provided to be rotatable in a circumferential direction with respect to the shaft portion 174 of the camshaft 170.

[0083] The sub-cam member 210 is configured such that the sub-intake cam 211 rotates with a delay relative to the intake cam 173. For example, as shown in the example of Figs. 5 and 6, the example of Fig. 11 or the example of Fig. 12, a member that generates the rotational resistance between the stationary system and the sub-cam member 210 is provided, so that the sub-intake cam 211 rotates with a delay relative to the intake cam 173. Alternatively, as described in the example of Fig. 13, the moment of inertia of the sub-cam member 210 is set to be large, whereby the sub-intake cam 211 rotates with a delay relative to the intake cam 173.

[0084] The holding member 220 includes disc-shaped holding plates 221, 222 and a cylindrical coupler 223 (Fig. 15). The holding member 200 is fixed to the shaft portion 174 of the camshaft 170. Each of the holding plates 221, 222 has substantially the same diameter as that of the rotation plate 212 of the sub-cam member 210. The holding plates 221, 222 are at a constant distance from each other in the axis direction, and are coupled to each other via the coupler 223 (Fig. 15). Cutouts 221a, 222a extending in a circular arc shape in the circumferential direction are respectively formed at outer peripheries of the holding plates 221, 222. In the axis direction, the cutouts 221a, 222a overlap with each other. The cutouts 221a, 222a constitute a positioner 220C. The projection piece 213 of the sub-cam member 210 is arranged in the positioner 220C. As described below, a range of the rotation of the sub-cam member 210 with respect to the camshaft 170 and the holding member 220 is restricted by the projection piece 213 and the positioner 220C.

[0085] In Fig. 15, the cutaway holding member 220 and the cutaway shaft portion 174 are shown. The hatching illustrates a cutaway sectional view. The holding plate 222 of the holding member 220 is not shown in Fig. 15. The shaft portion 174 is inserted into the coupler 223 of the holding member 220. The holding pins 224, 225 extending in the axis direction are respectively provided to sandwich the coupler 223 between the holding plates 221, 222.

[0086] The centrifugal member 230 is arranged between the holding plates 221, 222 and provided to extend in a substantially circumferential direction. A hole 230a is formed in the centrifugal member 230. The holding pin 224 of the holding member 220 is inserted into the hole 230a. Thus, the centrifugal member 230 is held to be swingable with respect to the holding member 220 with the holding pin 224 as a center. An abutment portion 231 is provided at the end of the centrifugal member 230 on one side of the holding pin 224. A cutout 230b is formed at an outer periphery of the centrifugal member 230 on the other side of the holding pin 224.

[0087] A projection 232 projecting in the axis direction is provided at an end of the centrifugal member 230 on the other side of the holding pin 224. One end and the other end of a tension spring 240 are respectively engaged with the holding pin 225 of the holding member 220 and the projection 232 of the centrifugal member 230. The tension spring 240 biases the centrifugal member 230 in a direction in which the projection 232 comes closer to the holding pin 225. As described below, a movement of a projection piece 213a of the sub-cam member 210 is restricted by the centrifugal member 230.

[0088] Fig. 16 is a diagram for explaining a range of the rotation of the sub-cam member 210. As shown in Fig. 16(a), the projection piece 213 of the sub-cam member 210 abuts against one end TC1 of the positioner 220C, so that the rotation of the sub-cam member 210 in the reverse direction Q2 with respect to the camshaft 170 and the holding member 220 is prevented. In this case, as shown in Fig. 16(b), the entire cam nose 211T of the sub-intake cam 211 overlaps with the cam nose 173T of the intake cam 173 in the axis direction. That is, the sub-intake cam 211 is at the normal position.

[0089] On the other hand, as shown in Fig. 16(c), the projection piece 213 of the sub-cam member 210 abuts against the other end TC2 of the positioner 220C, so that the rotation of the sub-cam member 210 in the forward direction Q1 with respect to the camshaft 170 and the holding member 220 is prevented. In this case, as shown in Fig. 16(d), the cam nose 211T of the sub-intake cam 211 and the cam nose 173T of the intake cam 173 deviate from each other by a constant angle in the circumferential direction. That is, the sub-intake cam 211 is at the start-up position.

[0090] Fig. 17 is a diagram for explaining the swinging of the centrifugal member 230. As shown in Fig. 17(a), in the case where a centrifugal force exerted on the centrifugal member 230 is small, an inner periphery of the centrifugal member 230 is maintained abutting against the outer peripheral surface of the coupler 223 by a biasing force of the tension spring 240 (Fig. 15). In this case, a portion of the centrifugal member 230 on the one side of the holding pin 224 projects into the positioner 220C, and a portion of the centrifugal member 230 on the other side of the holding pin 224 is stored between the holding plates 221, 222. Hereinafter, such a position of the centrifugal member 220 is referred to as a low rotation position. In the case where the rotation speed of the camshaft 170 is equal to or lower than a constant value, the centrifugal member 230 is held at the low rotation position.

[0091] In the case where the centrifugal member 230 is at the low rotation position, the abutment portion 231 is positioned in the vicinity of the other end TC2 in the positioner 230C. Therefore, when the projection piece 213 is at the other end TC2 of the positioner 220C, the movement of the projection piece 213 is prevented by an abutment of the abutment portion 231 against the projection piece 213. Thus, the projection piece 213 is held at the other end TC2 of the positioner 220C. Therefore, the sub-intake cam 211 is held at the start-up position of Fig. 16(d).

[0092] On the other hand, as shown in Fig. 17(b), when a centrifugal force exerted on the centrifugal member 230 is increased, the centrifugal member 230 moves such that the inner periphery of the centrifugal member 230 moves away from the outer peripheral surface of the coupler 233. In this case, a portion of the centrifugal member 230 on the one side of the holding pin 224 is stored between the holding plates 221, 222, and a portion of the centrifugal member 230 on the other side of the holding pin 224 projects into the positioner 220C. Hereinafter, such a position of the centrifugal member 230 is referred to as a high rotation position. In the case where the rotation speed of the camshaft 170 is higher than the above-mentioned constant value, the centrifugal member 230 is held at the high rotation position.

[0093] In the case where the centrifugal member 230 is positioned at the high rotation position, a cutout 230b is positioned in the vicinity of the one end TC1 of the positioner 230C. Therefore, in the case where being at the one end TC1 of the positioner 220C, the projection piece 213 is fitted with the cutout 230b. Thus, the projection piece 213 is held at the one end TC1 of the positioner 220C. Therefore, the sub-intake cam 211 is held at the normal position of Fig. 16(b).

[0094] Figs. 18 to 22 are diagrams for explaining the operations of the intake cam 173 and the sub-intake cam 211 in the reverse rotation start-up operation. In Figs. 18(a), 19(a), 20(a), 21(a) and 22(a), the states of the intake cam 173, the sub-intake cam 211, the intake rocker arm RA1 and the intake valve 15 are shown. In Figs. 18(b), 19(b), 20(b), 21(b) and 22(b), the states of the projection piece 213 and the centrifugal member 230 are shown.

[0095] At the start of the reverse rotation of the crankshaft 13, the sub-intake cam 211 is at the normal position as shown in Fig. 18(a). Further, as shown in Fig. 18(b), the centrifugal member 230 is at the low rotation position, and the projection piece 213 is at the one end TC1 of the positioner 220C. When the reverse rotation of the crankshaft 13 is started, the camshaft 170 rotates in the reverse direction Q2, and the intake cam 173 pushes up the one end of the intake rocker arm RA1 as shown in Fig. 19(a). Thus, the intake valve 15 is lifted. On the other hand, the sub-cam member 210 rotates with a delay relative to the intake cam 173. Thus, the sub-cam member 210 rotates in the forward direction Q1 with respect to the shaft portion 174, and the sub-intake cam 211 moves towards the start-up position. Further, as shown in Fig. 19(b), with the centrifugal member 230 held at the low rotation position, the projection piece 213 of the sub-cam member 210 moves from the one end TC1 towards the other end TC2 of the positioner 220C.

[0096] Substantially, as shown in Fig. 20(a), when the cam nose 211T of the sub-intake cam 221 abuts against the intake rocker arm RA1, the force in the forward direction Q1 is exerted on the sub-intake cam 211 from the intake rocker arm RA1. Thus, the sub-intake cam 211 reaches the start-up position. Further, as shown in Fig. 20(b), the projection piece 213 of the sub-cam member 210 reaches the other end TC2 of the positioner 220C. In this case, the projection piece 213 pushes down a portion of the centrifugal member 230 on the one side of the holding pin 224 and moves to the other end TC2 of the positioner 220C by the force applied from the intake rocker arm RA1 to the sub-intake cam 211.

[0097] Subsequently, as shown in Fig. 21(a), when the abutment position of the intake rocker arm RA1 goes beyond the tip end of the cam nose 211T, the force in the reverse direction Q2 is applied from the intake rocker arm RA1 to the sub-intake cam 211. In this case, as shown in Fig. 21(b), the abutment portion 231 of the centrifugal member 230 abuts against the projection piece 213, so that the projection piece 213 is prevented from moving towards the one end TC1 of the positioner 220C. Therefore, the sub-cam member 210 does not rotate in the reverse direction Q2 with respect to the camshaft 170, and the sub-intake cam 211 is held at the start-up position. Thus, the generation of a contact noise in the intake valve 15 and the valve driver 17 is prevented.

[0098] Thereafter, a fuel-air mixture is combusted in the combustion chamber 31a of Fig. 2, and the crankshaft 13 is driven in the forward direction. Thus, the camshaft 170 rotates in the forward direction Q1. In this case, the rotation speeds of the crankshaft 13 and the camshaft 170 instantaneously increase. Therefore, the centrifugal member 230 moves to the high rotation position, and the abutment portion 231 moves to a position inward of the holding plates 221, 222 of Fig. 14. Therefore, the projection 213 is movable towards the one end TC1 of the positioner 220C. In this state, the cam nose 211T of the sub-intake cam 211 abuts against the intake rocker arm RA1 while the camshaft 170 rotates in the forward direction Q1, and the force in the reverse direction Q2 is applied from the intake rocker arm RA1 to the sub-intake cam 211.

[0099] Thus, as shown in Fig. 22(a), the sub-cam member 210 rotates in the reverse direction Q2 with respect to the camshaft 170, and the sub-intake cam 211 moves to the start-up position. Further, as shown in Fig. 22(b), the projection piece 213 moves to the one end TC1 of the positioner 220C. In this case, the projection piece 213 pushes down a portion of the centrifugal member 230 on the other side of the holding pin 224 and moves to the one end TC1 of the positioner 220C by the force in the reverse direction Q2 applied from the intake rocker arm RA1 to the sub-intake cam 211. At the one end TC1 of the positioner 220C, the projection piece 213 is fitted with the cutout 230b of the centrifugal member 230. Thus, the projection piece 213 is prevented from moving from the one end TC1 of the positioner 220C. Therefore, the sub-cam member 210 is prevented from rotating in the forward direction Q1 with respect to the camshaft 170, and the sub-intake cam 211 is held at the normal position. Thus, during the normal operation, the generation of an abnormal noise caused by the movement of the sub-cam member 210 is prevented.

[0100] In this manner, before the combustion of the fuel-air mixture and during the reverse rotation of the crankshaft 13, the sub-intake cam 211 is held at the start-up position by the centrifugal member 230. After the combustion of the fuel-air mixture and during the forward rotation of the crankshaft 13, the sub-intake cam 211 is held at the normal position. Thus, any unnecessary movement of the sub-intake cam 211 is prevented using a simple configuration for utilizing a centrifugal force. Therefore, the generation of an abnormal noise caused by the movement of the sub-intake cam 211 is prevented.

(8) Other Embodiments

[0101] While the intake valve 15 and the exhaust valve 16 are driven by the intake cam 173, the sub-intake cams 177, 211 and the exhaust cam 172 via the intake rocker arm RA1 and the exhaust rocker arm RA2 in the above-mentioned embodiment, the present invention is not limited to this. The engine 10 may be configured such that the intake cam 173 and the sub-intake cams 177, 211 directly drive the intake valve 15, and may be configured such that the exhaust cam 172 directly drives the exhaust valve 16.

[0102] Further, in the above-mentioned embodiment, the exhaust cam 172, the intake cam 173 and the sub-intake cams 177, 211 are respectively provided at the common camshaft 170. However, the present invention is not limited to this. A camshaft for the intake cam 173 and the sub-intake cams 177, 211 and a camshaft for the exhaust cam 172 may be separately provided.

[0103] Further, the above-mentioned embodiment is an example in which the present invention is applied to the motorcycle. However, the present invention is not limited to this. The present invention may be applied to another straddled vehicle such as a motor tricycle or an ATV (All Terrain Vehicle) or any another vehicle such as a four-wheeled automobile.

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

[0104] 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.

[0105] In the above-mentioned embodiments, the engine system 200 is an example of an engine system, the engine 10 is an example of an engine, the rotary electrical machine 14 is an example of a rotation driver, the crankshaft 13 is an example of a crankshaft, the ECU 6 is an example of a controller and the valve driver 17 is an example of a valve driver. Further, the camshaft 170 is an example of a shaft portion, the intake cam 173 is an example of a first intake cam, the sub-intake cams 177, 211 are examples of a second intake cam, the normal position is an example of a first position, and the start-up position is an example of a second position. Further, the cylinder head CH or the arm shaft SH2 is an example of a stationary member, the friction member FR2, the friction spring 180 or the pressing member 185 is an example of a rotational resistance generation mechanism, the friction member FR2 is an example of a friction member, the one-way clutch 175 is an example of a one-way clutch, the friction member FR1 is an example of a resistance generation member, the centrifugal member 230 is an example of a centrifugal member and the intake rocker arm RA1 is an example of a rocker arm. Further, the motorcycle 100 is an example of a vehicle, the body 1 is an example of a main body, and the rear wheel 7 is an example of a drive wheel.

[0106] As each of constituent elements are recited in the claims, various other elements having configurations or functions described in the claims can also be used.

[Industrial Applicability]

[0107] The present invention can be effectively utilized for various types of engine systems.

Claims

1. An engine system comprising:

   an engine;
   a rotation driver that rotates a crankshaft of the engine in a forward direction and a reverse direction; and
   a controller, wherein
   the controller controls the engine and the rotation driver to rotate the crankshaft in the reverse direction and to cause a combustion of a fuel-air mixture in a combustion chamber of the engine such that the crankshaft is driven in the forward direction,
   the engine includes a valve driver that lifts an intake valve,
   the valve driver includes
   a shaft portion provided to rotate in the forward direction and the reverse direction in conjunction with a rotation of the crankshaft in the forward direction and the reverse direction, and
   first and second intake cams provided at the shaft portion,
   the first intake cam acts on the intake valve in a range of a crank angle corresponding to an intake process by integrally rotating with the shaft portion,
   the second intake cam is configured to be movable between a first position and a second position in a circumferential direction of the shaft portion by being rotatable within a constant angular range with respect to the shaft portion,
   the second intake cam overlaps with the first intake cam in an axis direction of the shaft portion when being at the first position, and acts on the intake valve within at least a part of a range of the crank angle corresponding to an exhaust stroke when being at the second position, and
   the second intake cam, during the rotation of the crankshaft in the forward direction, is at the first position and does not act on the intake valve, and the second intake cam, during the rotation of the crankshaft in the reverse direction, moves to the second position by rotating with a delay relative to the first intake cam and acts on the intake valve.

2. The engine system according to claim 1, wherein the valve driver further includes
   a stationary member, and
   a rotational resistance generation mechanism that generates a rotational resistance between the stationary member and the second intake cam, and
   during the rotation of the crankshaft in the reverse direction, the rotational resistance generated by the rotational resistance generation mechanism is larger than a rotational resistance between the shaft portion and the second intake cam.

3. The engine system according to claim 2, wherein the rotational resistance generation mechanism includes a friction member that generates a friction between the stationary member and the second intake cam.

4. The engine system according to any one of claims 1 to 3, wherein
   the moment of inertia of the second intake cam and the rotational resistance between the shaft portion and the second intake cam are set such that the second intake cam rotates with a delay relative to the first intake cam by inertia.

5. The engine system according to claim 4, wherein the second intake cam is held at the shaft portion via a rolling bearing.

6. The engine system according to any one of claims 1 to 5, wherein
   the valve driver further includes
   a one-way clutch that does not transmit the rotation of the second intake cam in the forward rotation with respect to the shaft portion from the second intake cam to the shaft portion, and transmits the rotation of the second intake cam in the reverse direction with respect to the shaft portion from the second intake cam to the shaft portion, and
   a resistance generation member that generates a

rotational resistance between the one-way clutch and the shaft portion or between the one-way clutch and the second intake cam.

7. The engine system according to any one of claims 1 to 6, wherein
the valve driver further includes a centrifugal member, which is provided to rotate together with the shaft portion and is provided to be movable between a low speed position and a high speed position with respect to the shaft portion depending on a magnitude of a centrifugal force generated by the rotation of the shaft portion, and
the centrifugal member, before the combustion of the fuel-air mixture in the combustion chamber and during the rotation of the crankshaft in the reverse direction, holds the second intake cam at the second position while being at the low speed position, and after the combustion of the fuel-air mixture in the combustion chamber and during the rotation of the crankshaft in the forward direction, holds the second intake cam at the first position while being at the high speed position.

8. The engine system according to any one of claims 1 to 7, wherein
the valve driver further includes a rocker arm abutting against the first and second intake cams, and
the rocker arm, during the rotation of the crankshaft in the forward direction, acts on the second intake cam such that the second intake cam moves to the first position, and during the rotation of the crankshaft in the reverse direction, acts on the second intake cam such that the second intake cam moves to the second position.

9. A vehicle comprising;
a main body having a drive wheel; and
the engine system according to any one of claims 1 to 8 that generates a motive power for rotating the drive wheel.

FIG. 1

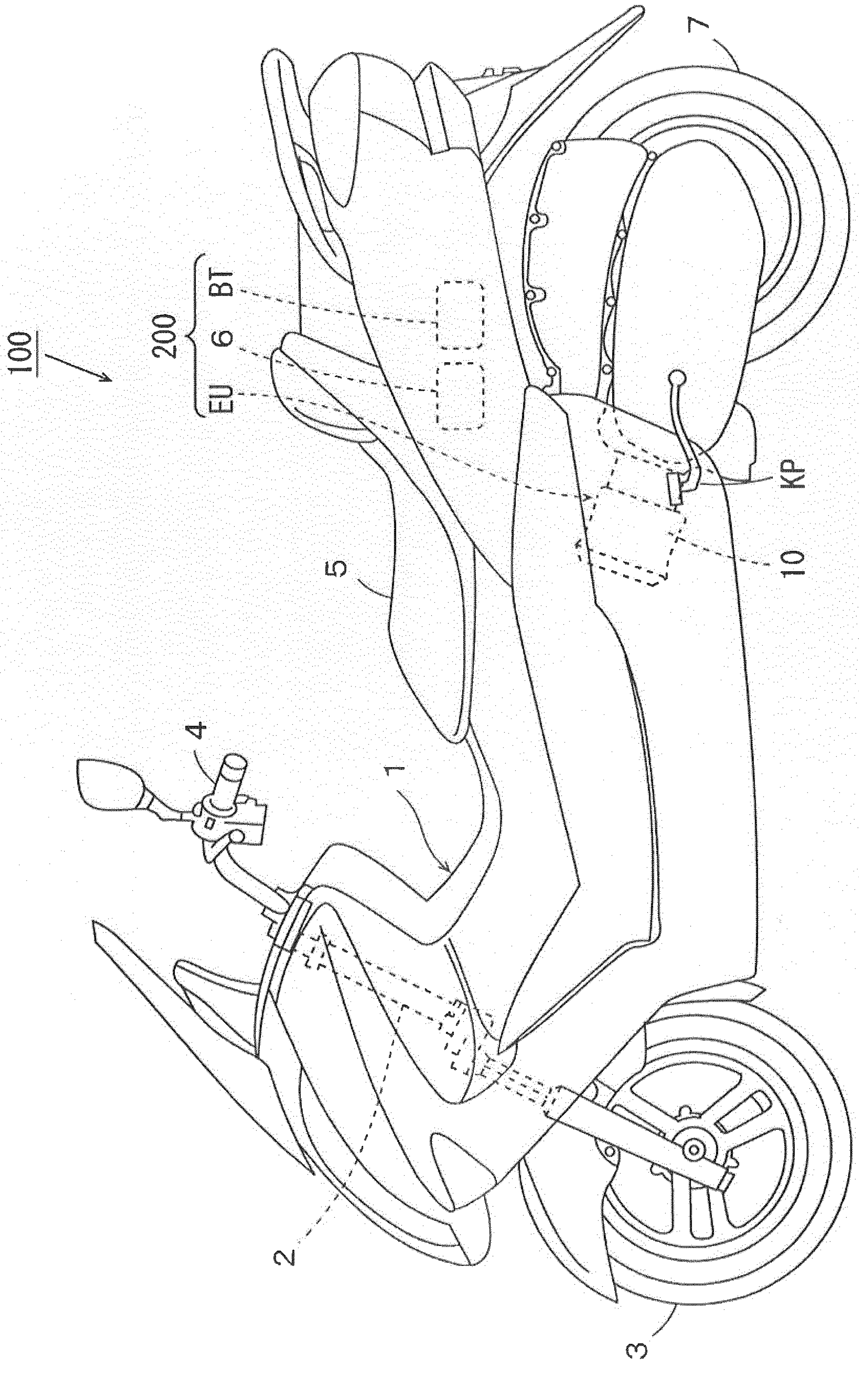
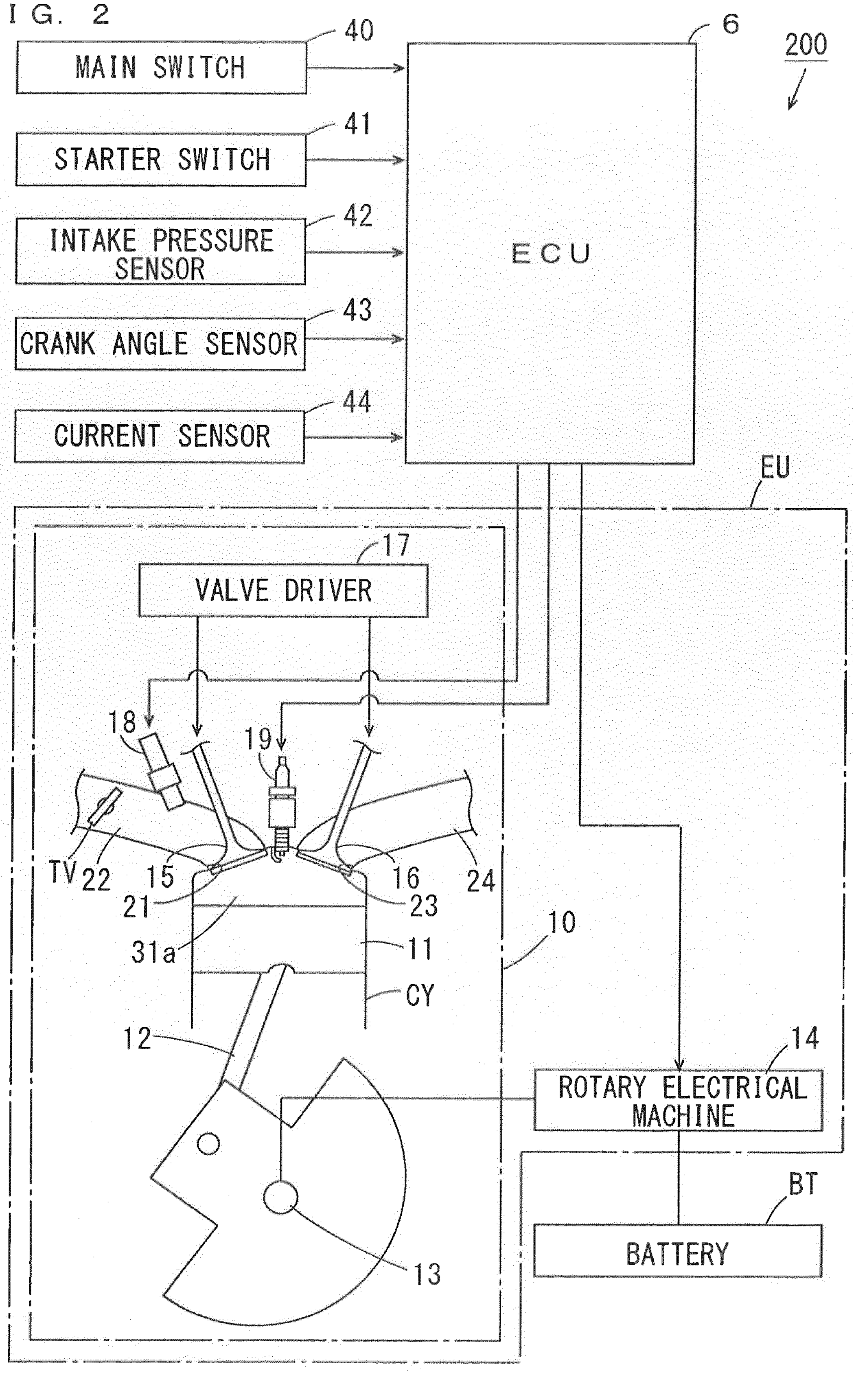
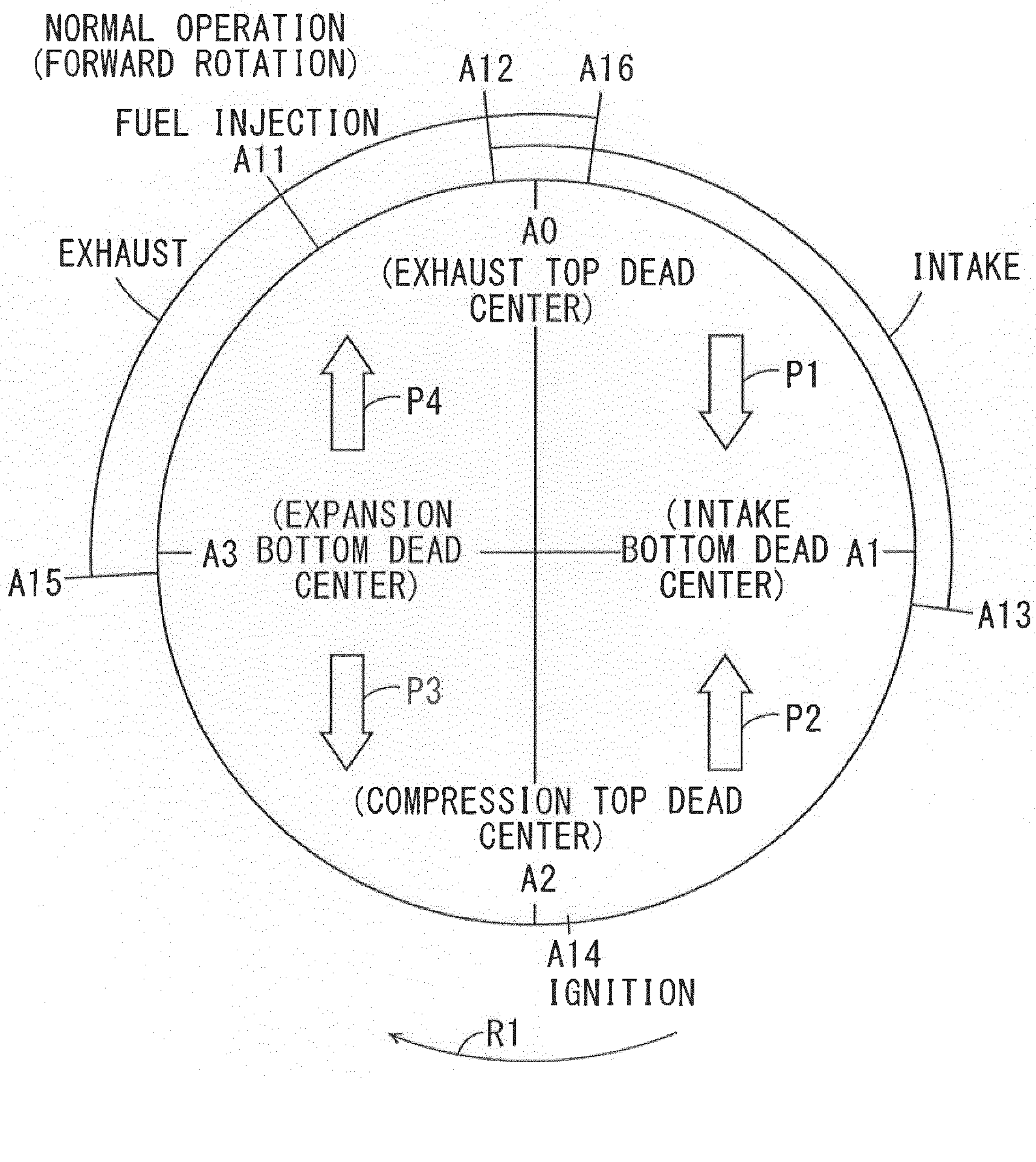


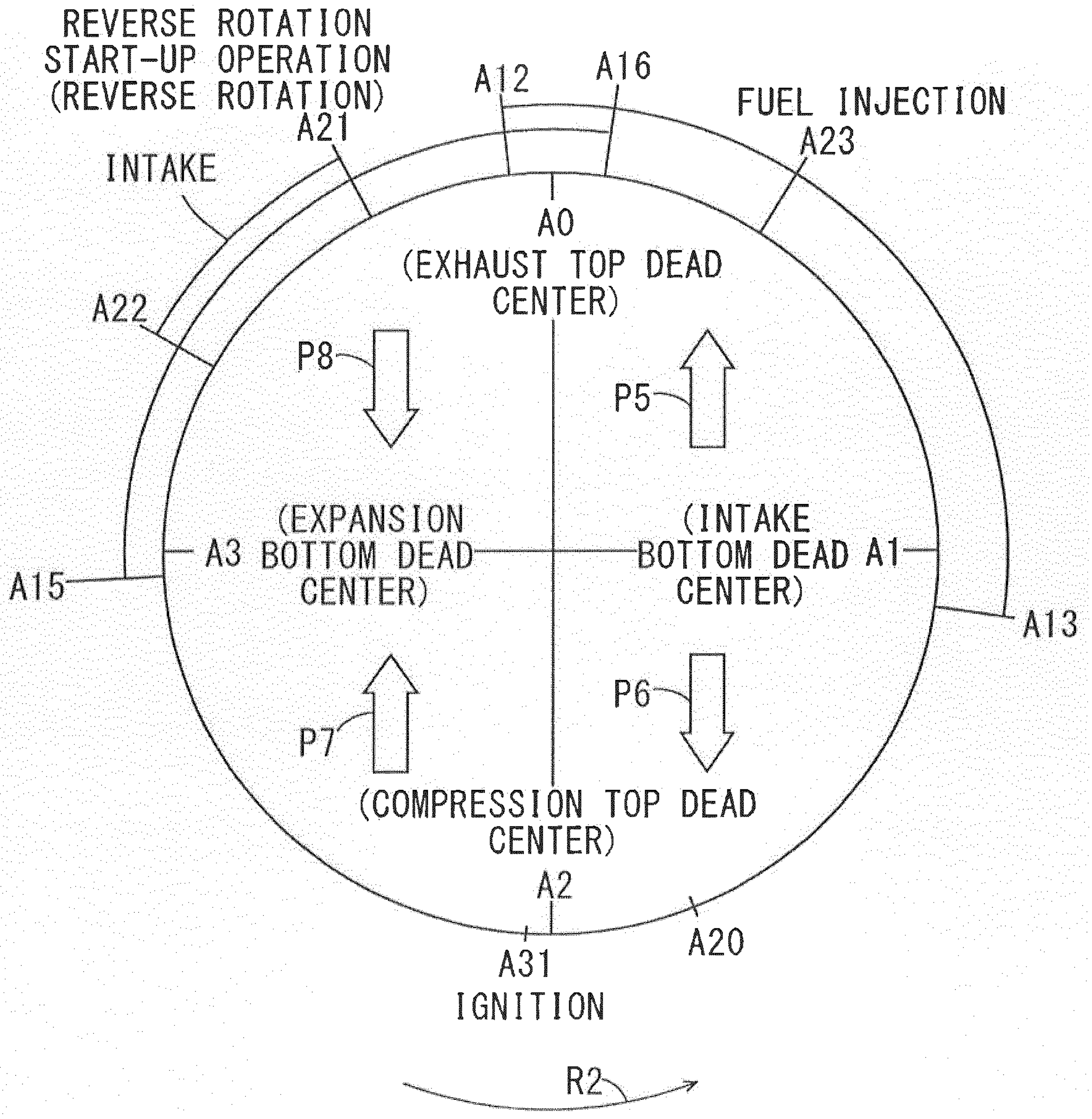
FIG. 2


40
MAIN SWITCH
41
STARTER SWITCH
42
INTAKE PRESSURE SENSOR
43
CRANK ANGLE SENSOR
44
CURRENT SENSOR
6
ECU
200
EU
17
VALVE DRIVER
18
19
TV
22
15
21
31a
16
24
23
11
10
CY
12
14
ROTARY ELECTRICAL MACHINE
BT
BATTERY
13

F I G. 3


NORMAL OPERATION
(FORWARD ROTATION)
A12
A16
FUEL INJECTION
A11
EXHAUST
INTAKE
A0
(EXHAUST TOP DEAD
CENTER)
P1
P4
(EXPANSION
A3 BOTTOM DEAD
CENTER)
(INTAKE
BOTTOM DEAD A1
CENTER)
A15
A13
P3
P2
(COMPRESSION TOP DEAD
CENTER)
A2
A14
IGNITION
R1

F I G. 4


REVERSE ROTATION
START-UP OPERATION
(REVERSE ROTATION)
A21
INTAKE
A22
A12
A16
FUEL INJECTION
A23
A0
(EXHAUST TOP DEAD
CENTER)
P8
P5
(EXPANSION
A3 BOTTOM DEAD
CENTER)
(INTAKE
BOTTOM DEAD A1
CENTER)
A15
A13
P6
P7
(COMPRESSION TOP DEAD
CENTER)
A2
A20
A31
IGNITION
R2

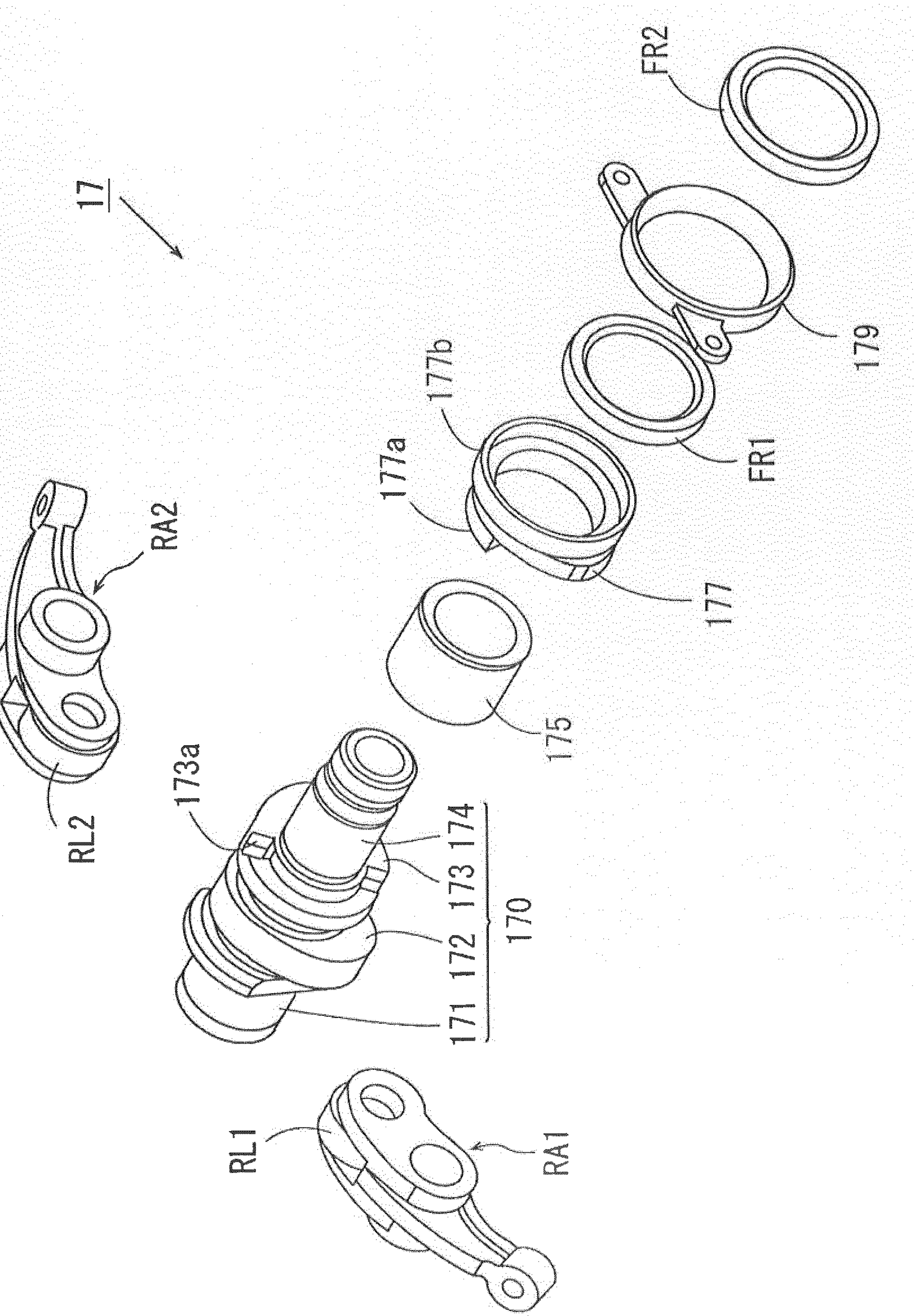
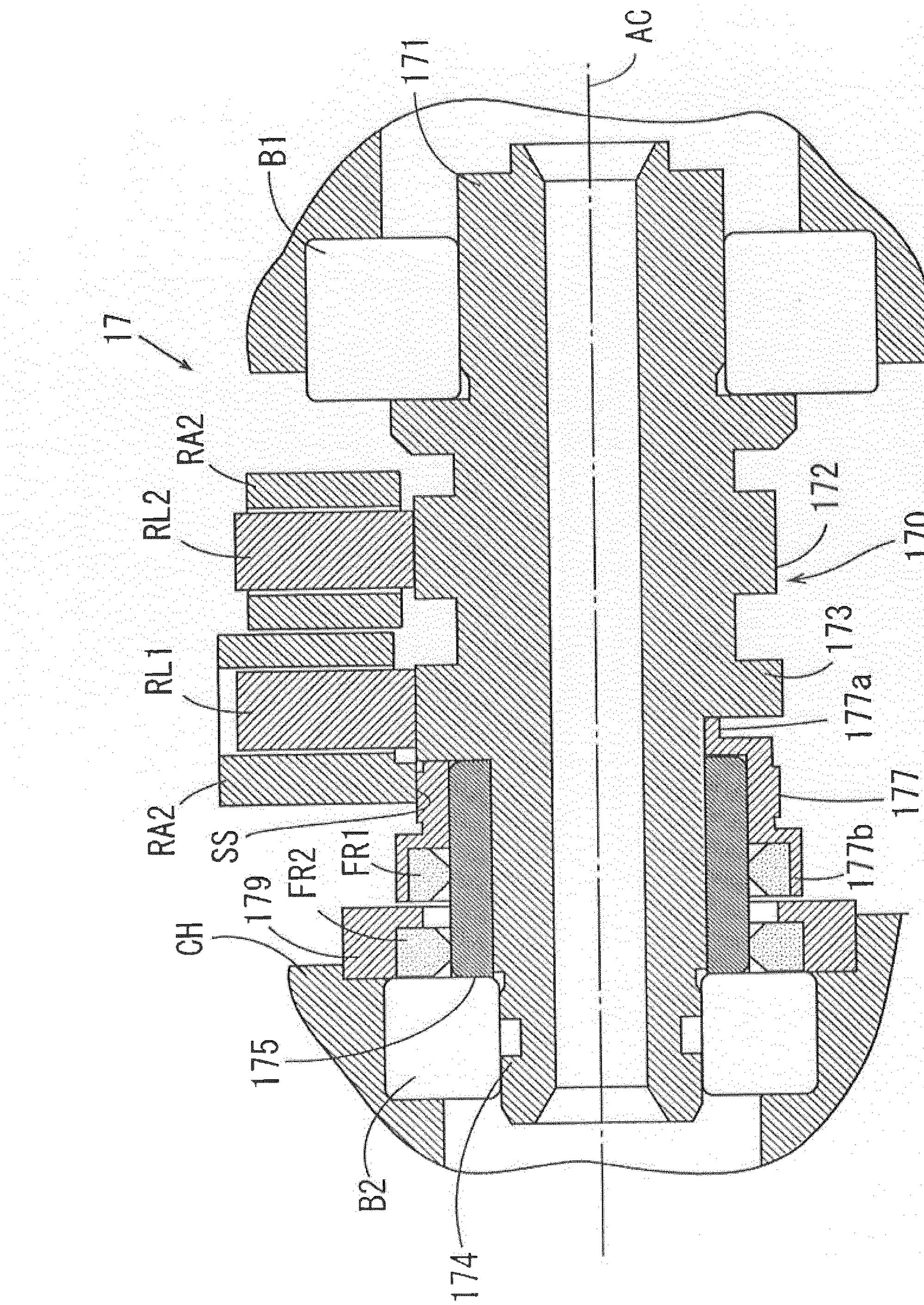

17
RA2
RL2
173a
171 172 173 174
170
175
177a
177b
177
FR1
179
FR2
RL1
RA1

FIG. 5


AC
171
B1
17
RA2
RL2
172
170
173
RL1
177a
177
RA2
SS
FR1
177b
FR2
179
CH
175
B2
174

F I G. 6

FIG. 7

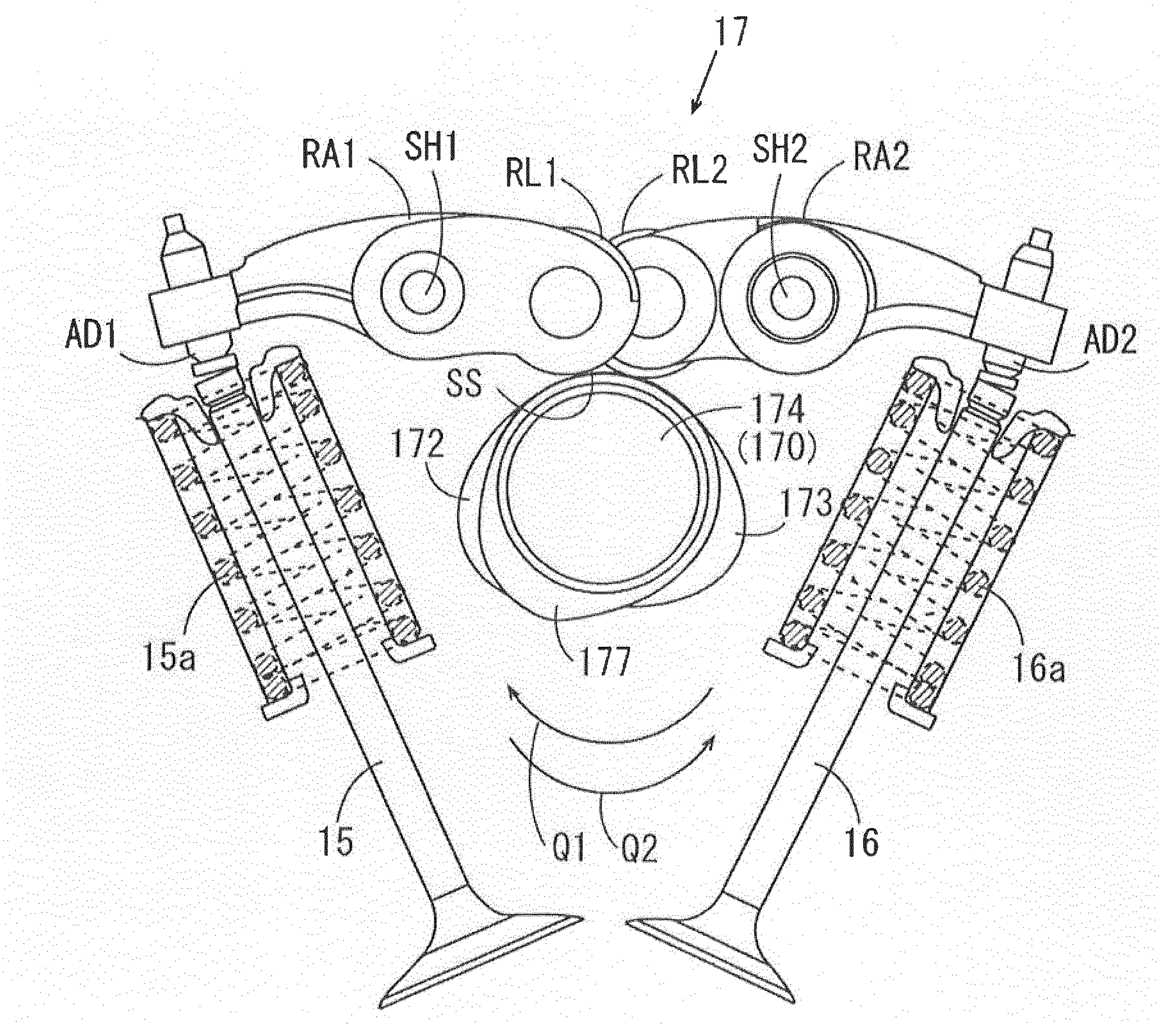

17
RA1
SH1
RL1
RL2
SH2
RA2
AD1
AD2
SS
174
(170)
172
173
15a
177
16a
15
Q1
Q2
16

FIG. 8

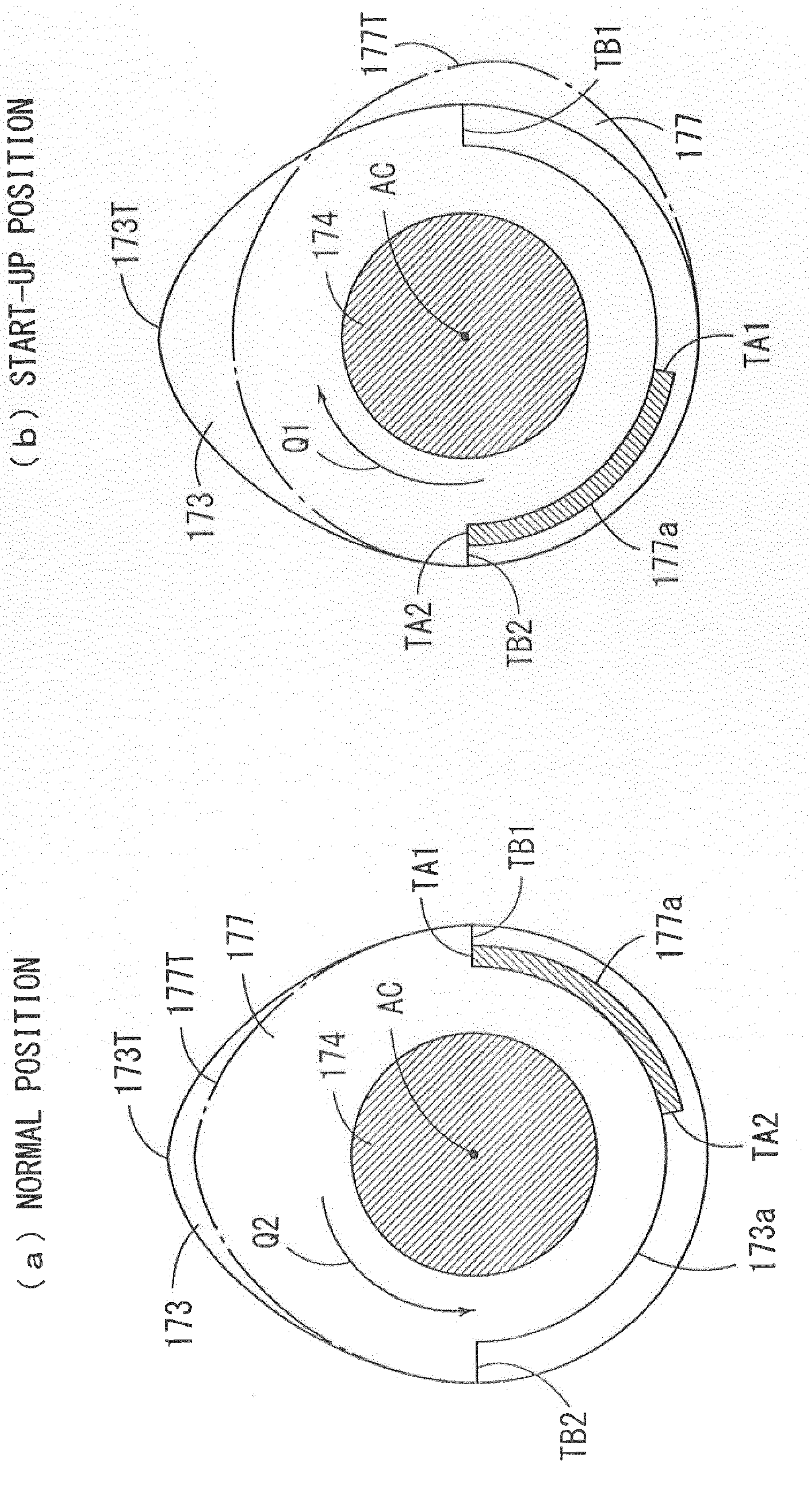

(a) NORMAL POSITION
173T
177T
177
174
AC
TA1
TB1
177a
TA2
173a
Q2
173
TB2
(b) START-UP POSITION
177T
TB1
177
AC
174
173T
TA1
Q1
173
177a
TA2
TB2

FIG. 9

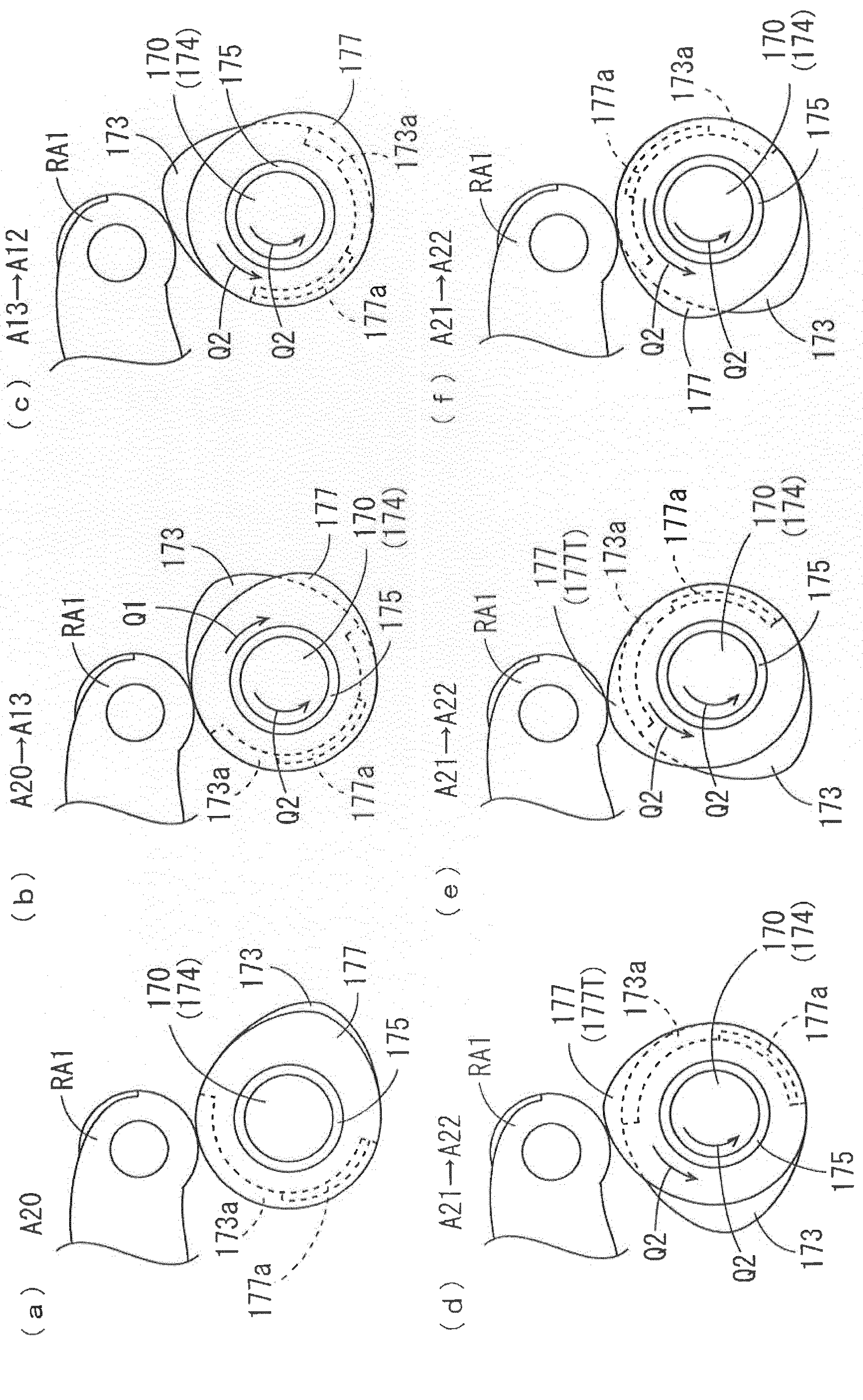
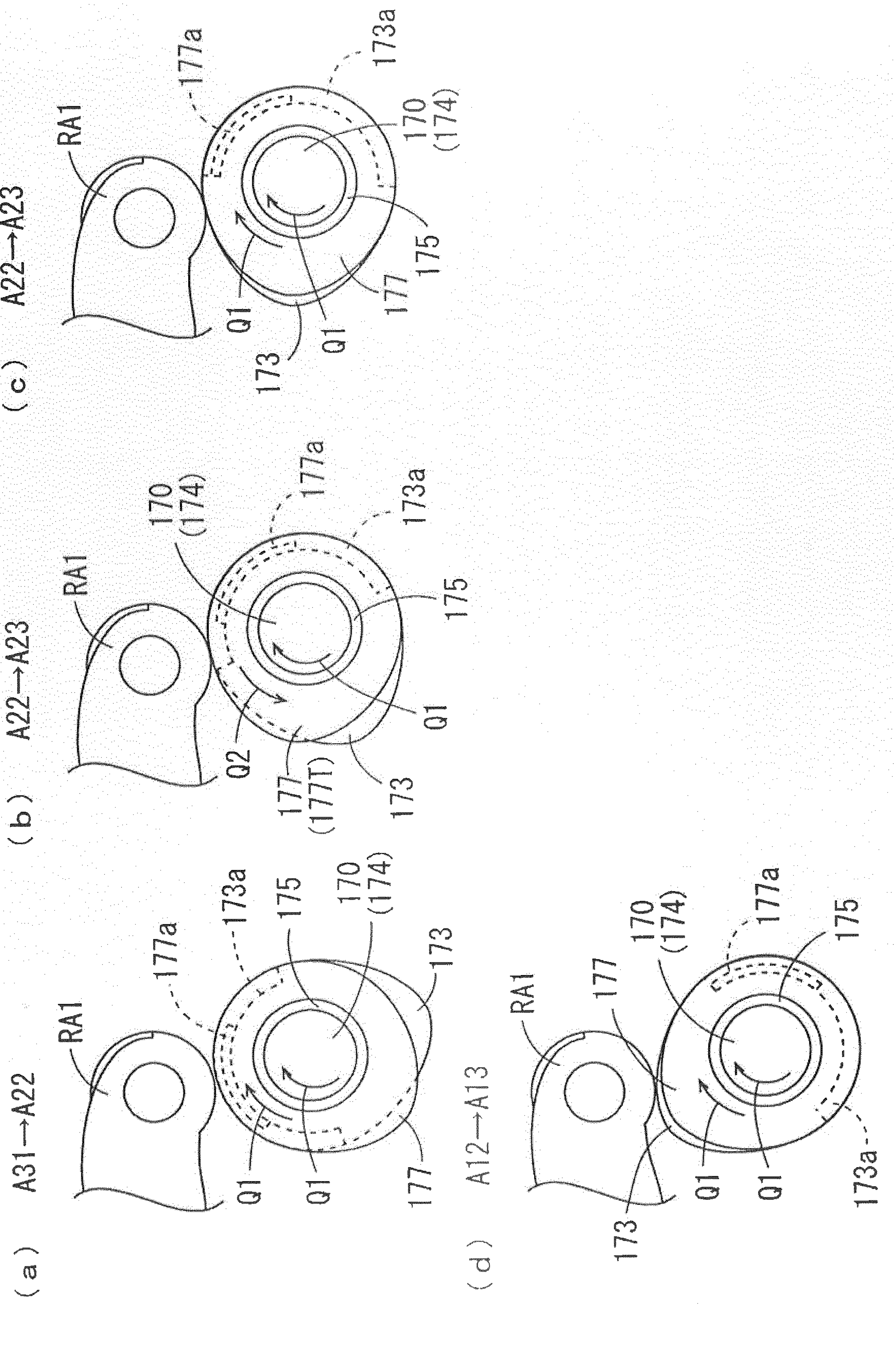
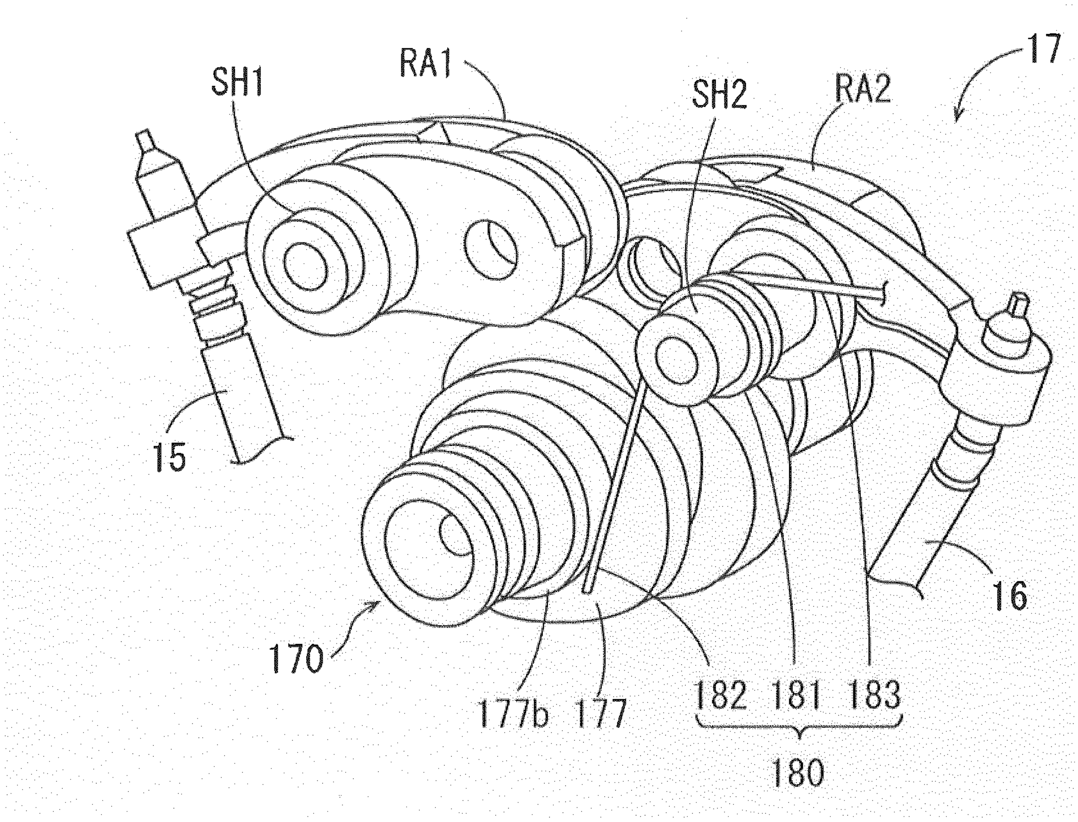

(a) A20
RA1
170 (174)
173
177
175
173a
177a
(b) A20→A13
RA1
Q1
173
177
170 (174)
175
173a
Q2
177a
(c) A13→A12
RA1
173
170 (174)
175
177
173a
Q2
Q2
177a
(d) A21→A22
RA1
177 (177T)
173a
170 (174)
177a
175
Q2
Q2
173
(e) A21→A22
RA1
177 (177T)
173a
177a
170 (174)
175
Q2
Q2
173
(f) A21→A22
RA1
177a
173a
170 (174)
175
Q2
177
Q2
173

FIG. 10


(a)
A31→A22
RA1
177a
173a
175
170
(174)
173
Q1
Q1
177
(b)
A22→A23
RA1
170
(174)
177a
173a
175
Q2
Q1
177
(177T)
173
(c)
A22→A23
RA1
177a
173a
170
(174)
175
177
Q1
Q1
173
(d)
A12→A13
RA1
177
170
(174)
177a
175
173
Q1
Q1
173a

F I G. 1 1



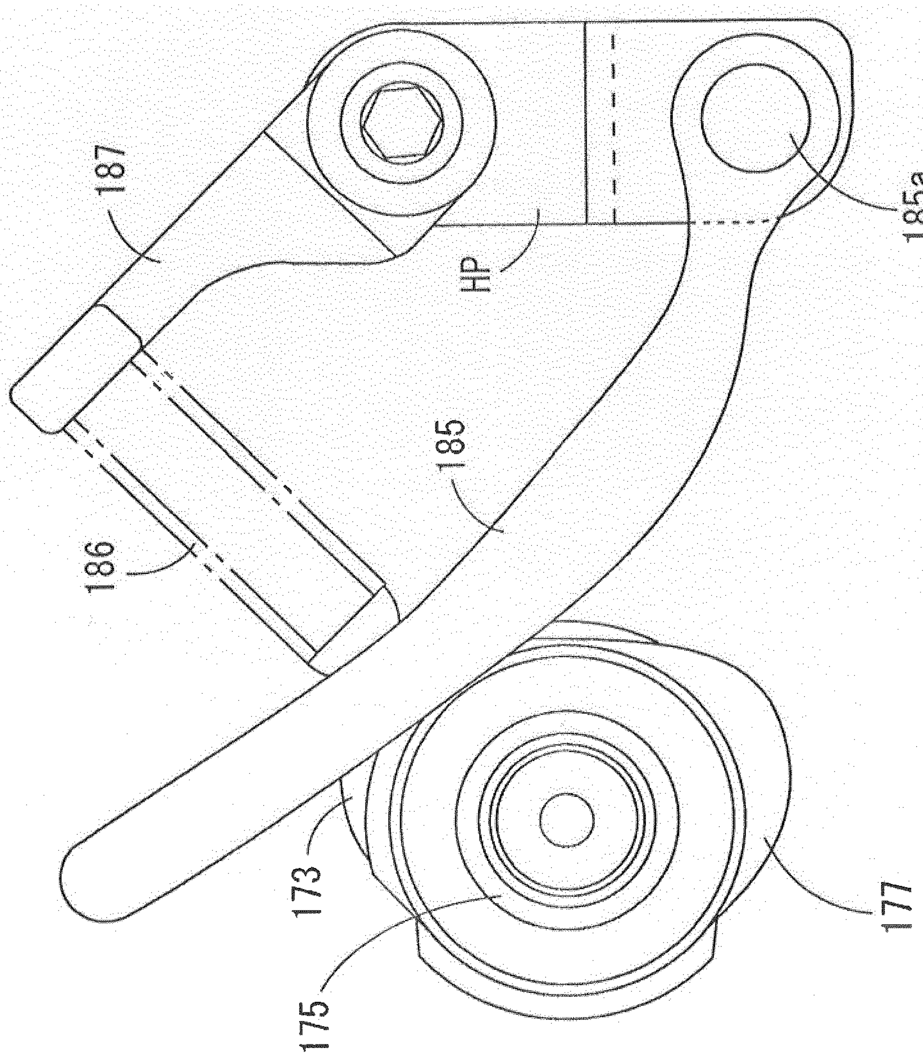


FIG. 12

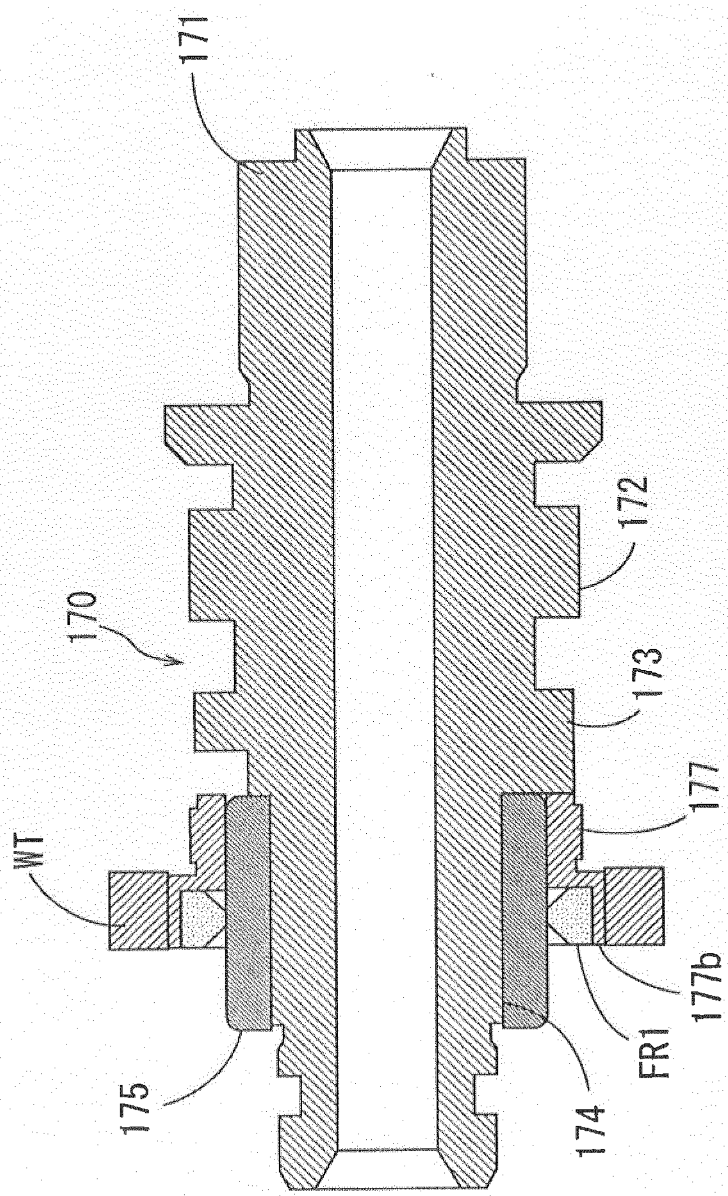


FIG. 13

F I G. 1 4

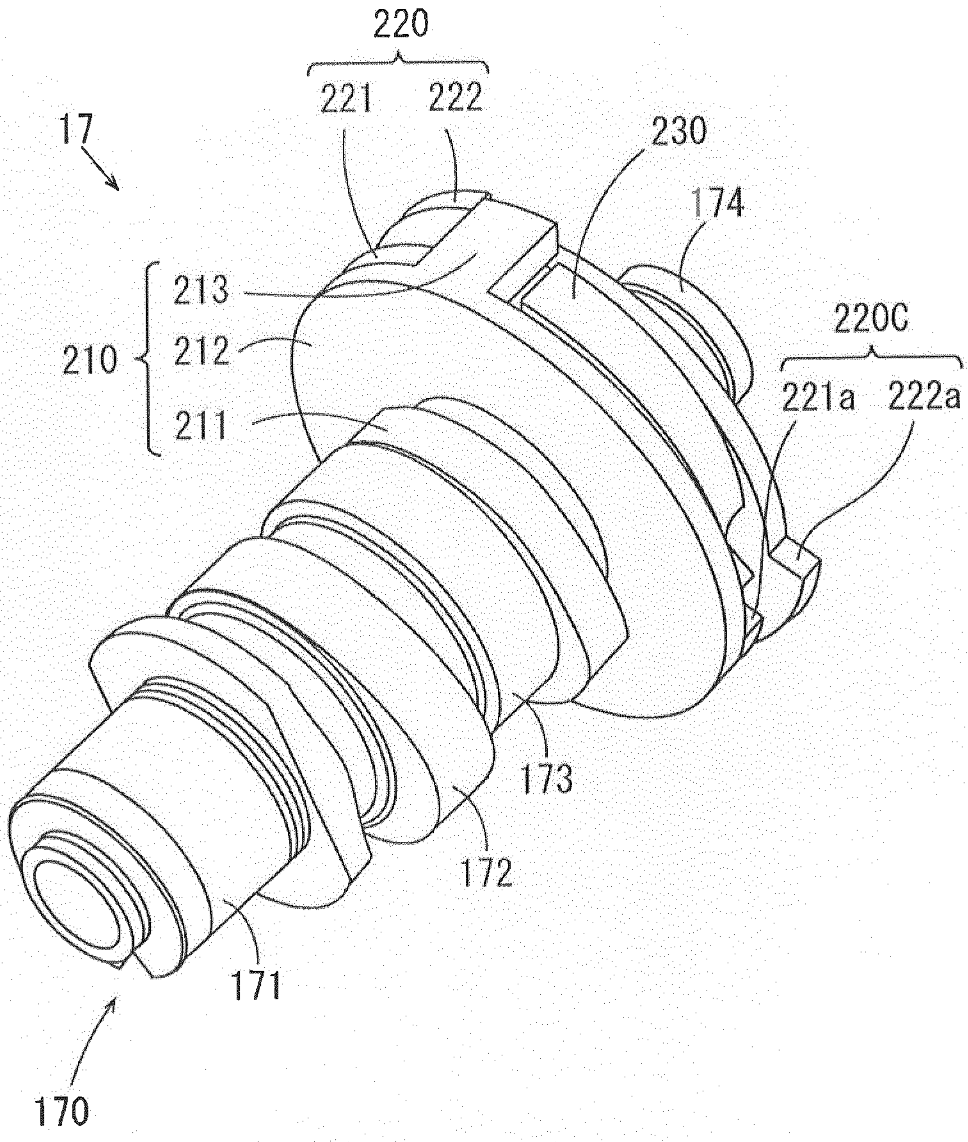

220
221
222
17
230
174
213
210
212
211
220C
221a
222a
173
172
171
170

FIG. 15

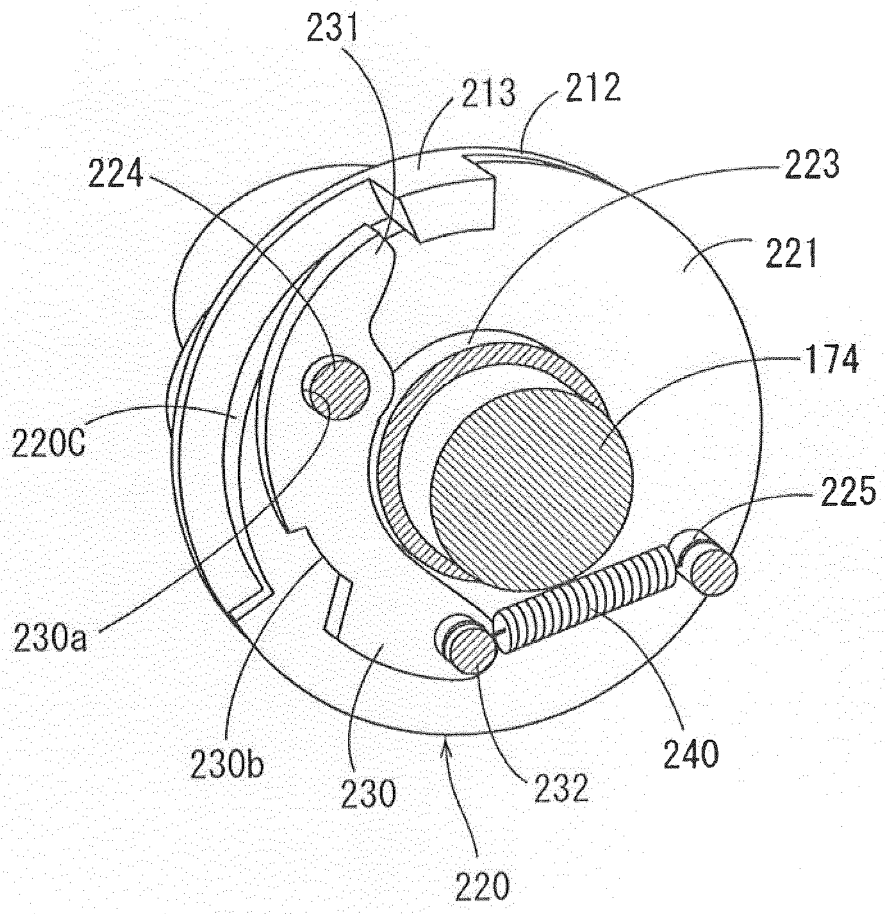
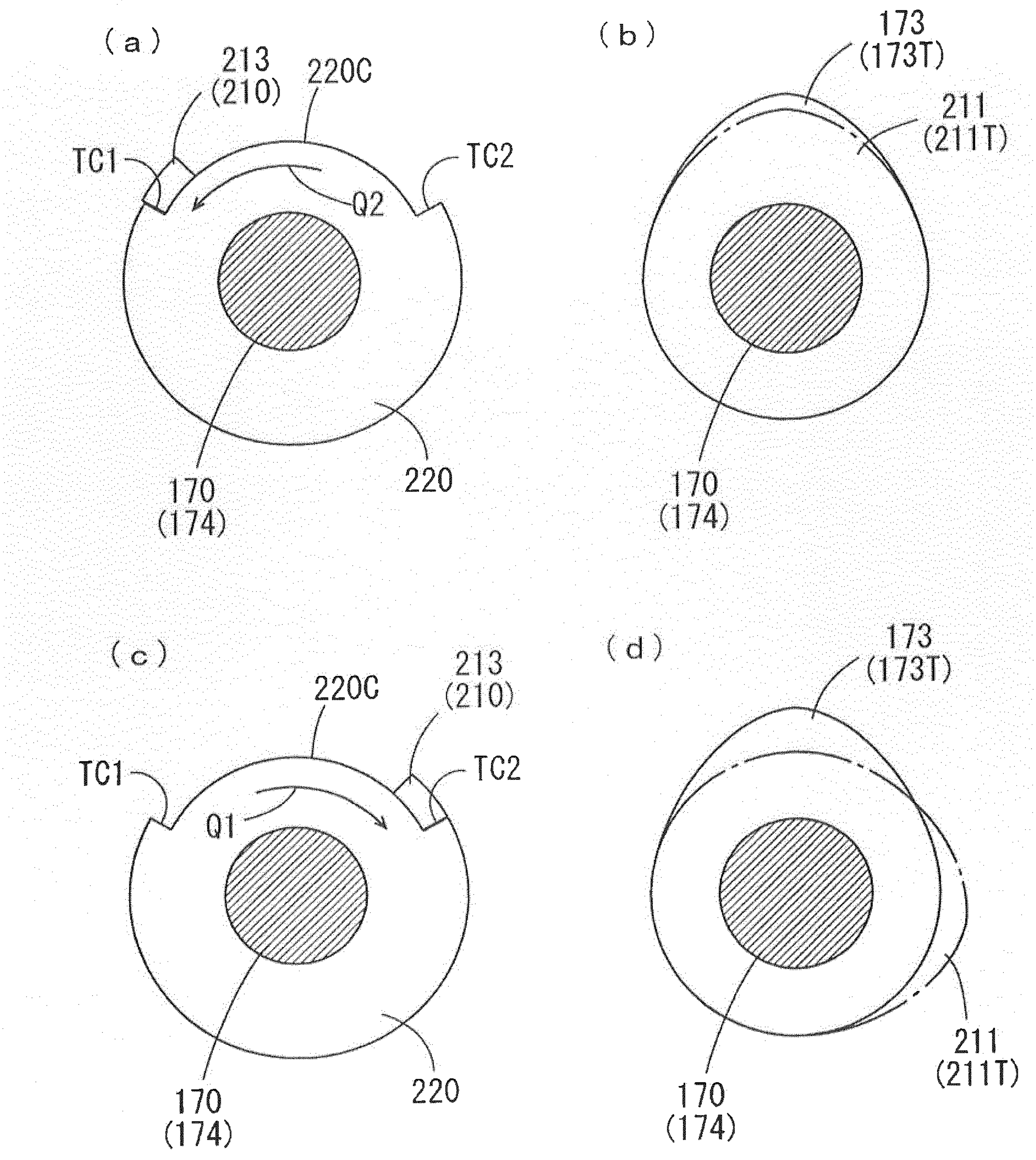


FIG. 16


(a)
213
(210)
220C
TC1
TC2
Q2
170
(174)
220
(b)
173
(173T)
211
(211T)
170
(174)
(c)
220C
213
(210)
TC1
TC2
Q1
170
(174)
220
(d)
173
(173T)
170
(174)
211
(211T)

ＦＩＧ．１７

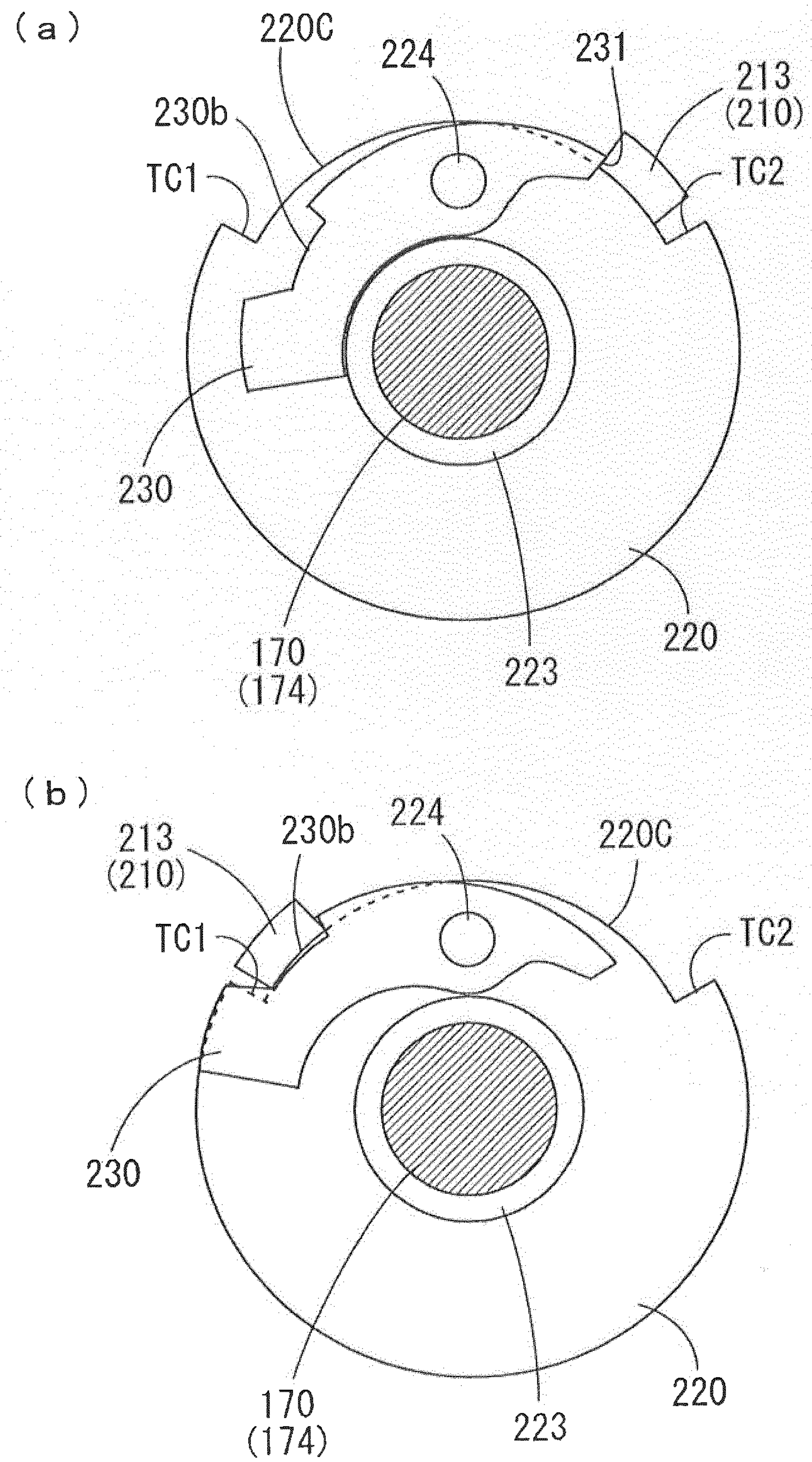
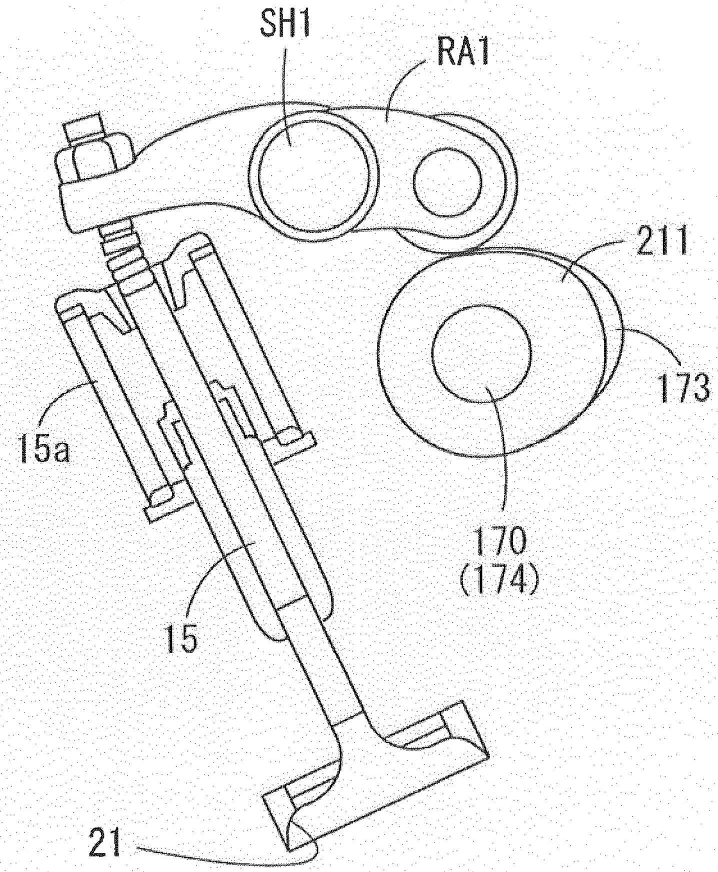
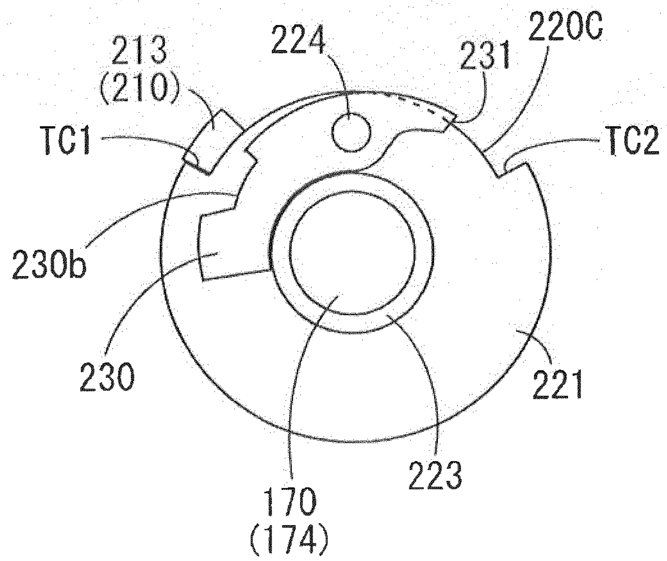

(a)
220C
224
231
213
(210)
230b
TC1
TC2
230
170
(174)
223
220
(b)
213
(210)
230b
224
220C
TC1
TC2
230
170
(174)
223
220

FIG. 18

(a)

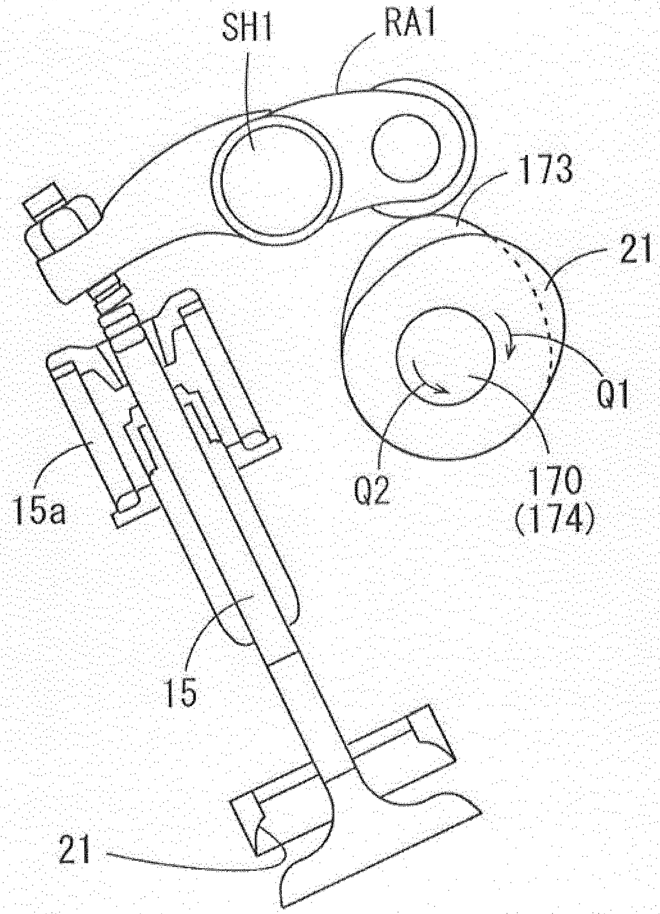

SH1
RA1
211
173
15a
170
(174)
15
21

(b)


213
(210)
224
231
220C
TC1
TC2
230b
230
221
223
170
(174)

F I G. 1 9

(a)


SH1
RA1
173
211
Q1
Q2
170
(174)
15a
15
21

(b)

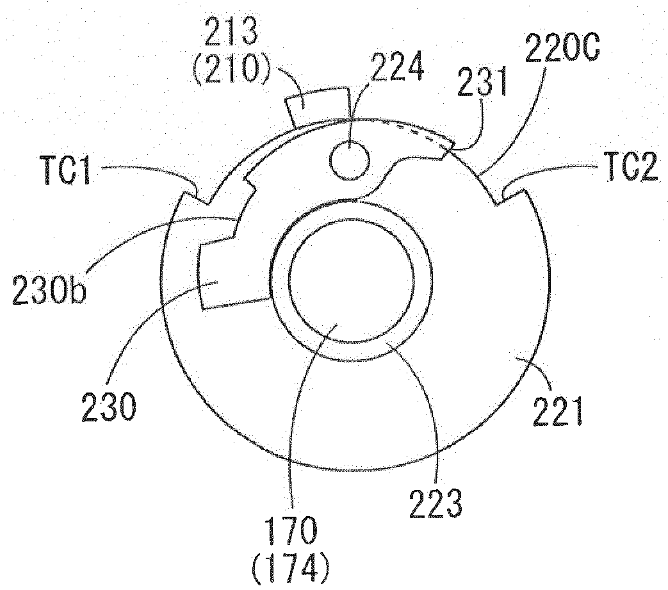
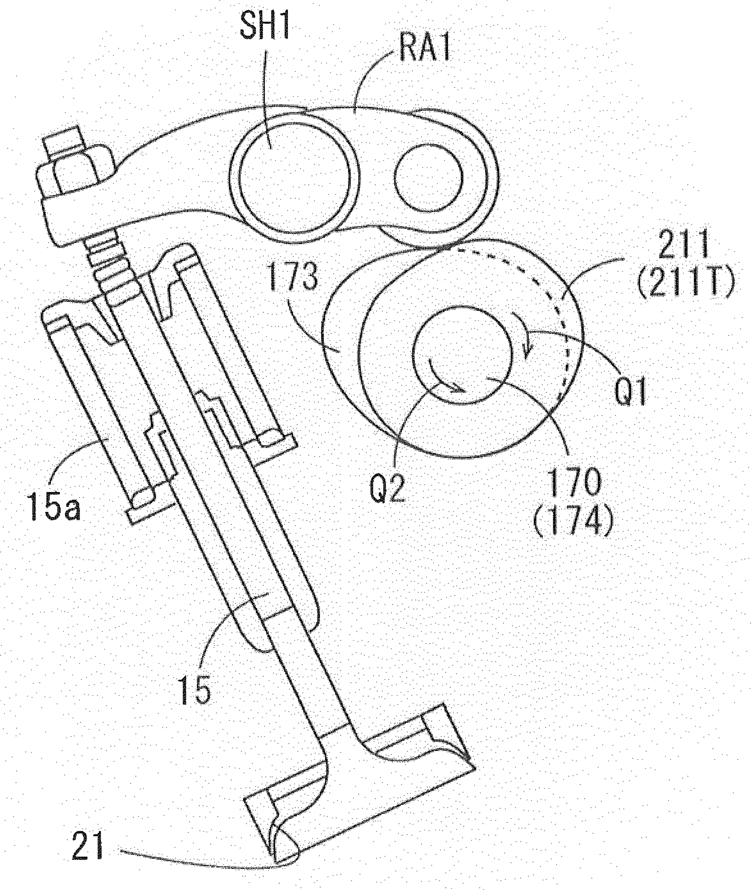

213
(210)
224
231
220C
TC1
TC2
230b
230
221
223
170
(174)

FIG. 20

(a)


SH1
RA1
211
(211T)
173
Q1
Q2
170
(174)
15a
15
21

(b)

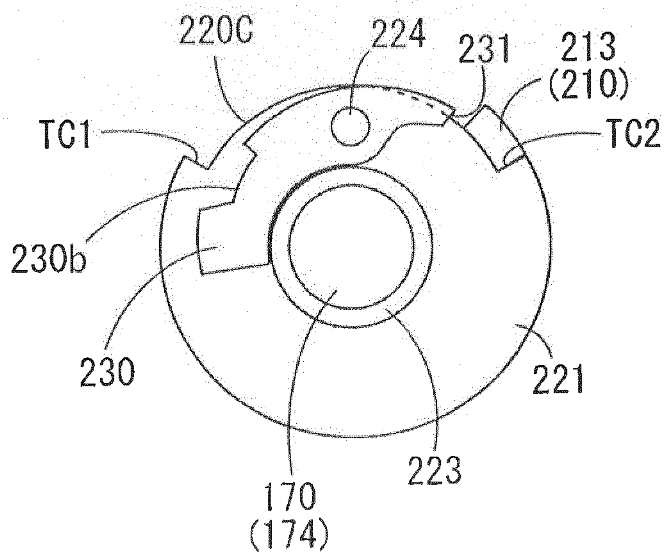
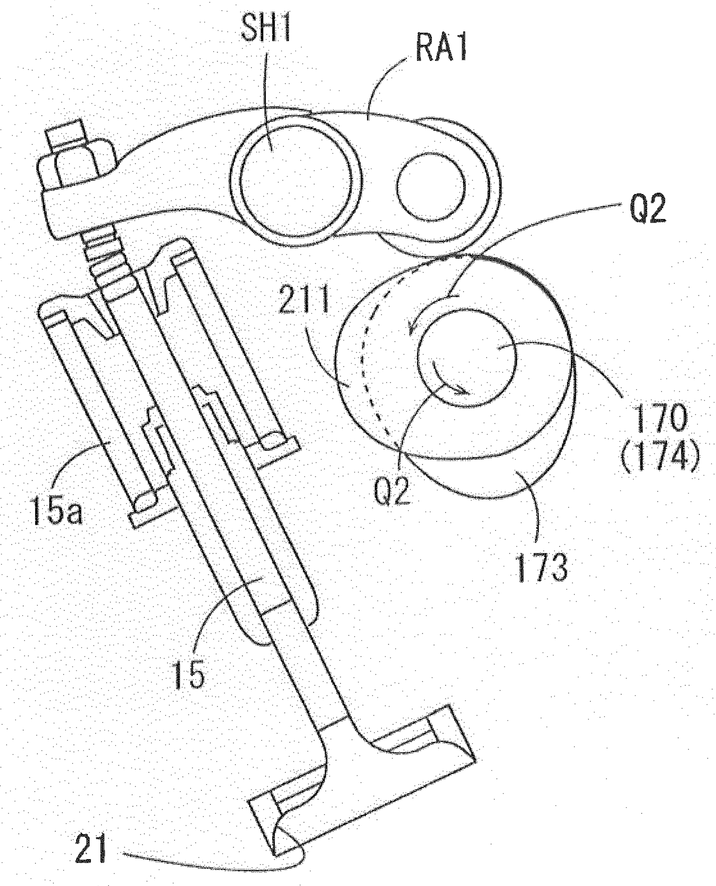

220C
224
231
213
(210)
TC1
TC2
230b
230
221
223
170
(174)

FIG. 21

(a)


SH1
RA1
Q2
211
170
(174)
Q2
15a
173
15
21

(b)

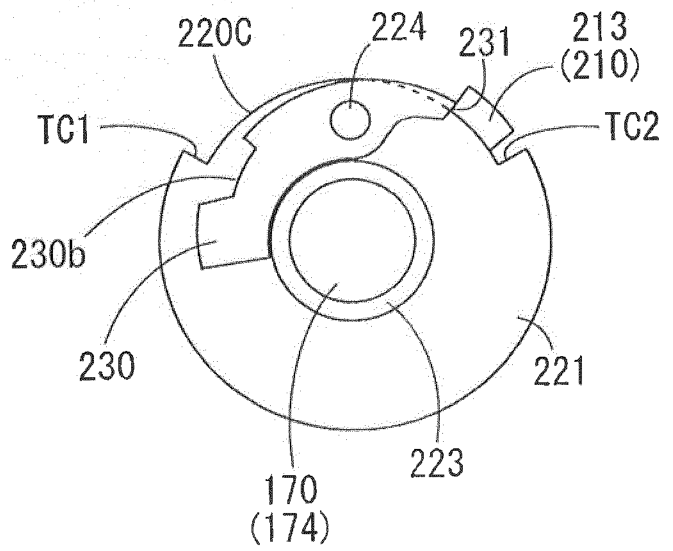
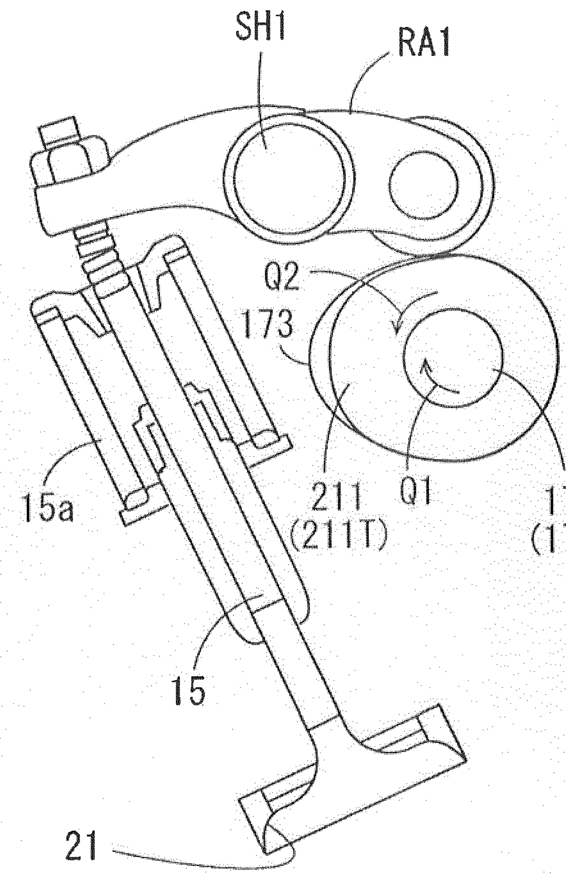
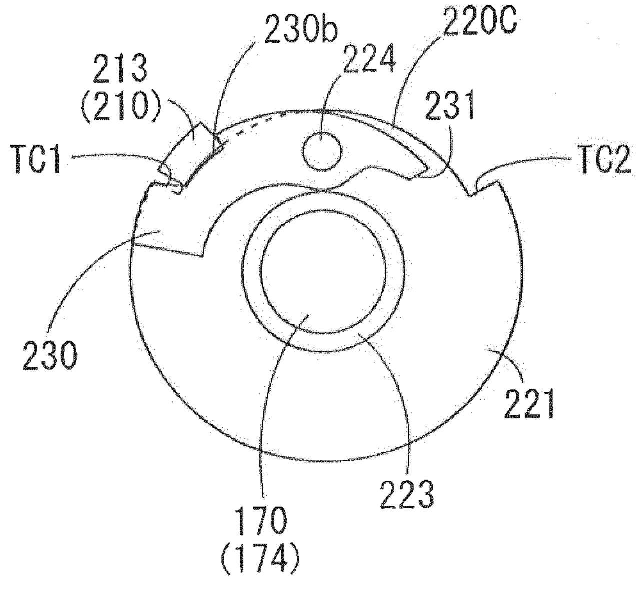

220C
224
231
213
(210)
TC1
TC2
230b
230
221
223
170
(174)

FIG. 22

(a)


SH1
RA1
Q2
173
15a
211
(211T)
Q1
170
(174)
15
21

(b)


230b
220C
213
(210)
224
231
TC1
TC2
230
221
223
170
(174)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2016/002057

A. CLASSIFICATION OF SUBJECT MATTER
F02D29/02(2006.01)i, *F01L1/04*(2006.01)i, *F01L13/00*(2006.01)i, *F01L13/02*(2006.01)i, *F02D13/02*(2006.01)i, *F02D27/00*(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F02D29/02, F01L1/04, F01L13/00, F01L13/02, F02D13/02, F02D27/00

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2016
Kokai Jitsuyo Shinan Koho	1971-2016	Toroku Jitsuyo Shinan Koho	1994-2016

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 2014-77405 A (Yamaha Motor Co., Ltd.), 01 May 2014 (01.05.2014), paragraphs [0040] to [0129]; fig. 1 to 21 & EP 2719883 A1 paragraphs [0025] to [0115]; fig. 1 to 21	1,9 2-8
Y A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 85058/1986(Laid-open No. 195608/1987) (Nissan Motor Co., Ltd.), 12 December 1987 (12.12.1987), page 5, line 1 to page 8, line 13; fig. 1 to 7 (Family: none)	1,9 2-8

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
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"E" earlier application or patent but published on or after the international filing date
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"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 June 2016 (16.06.16)	28 June 2016 (28.06.16)

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3,Kasumigaseki,Chiyoda-ku, Tokyo 100-8915,Japan	Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2016/002057

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 78429/1984(Laid-open No. 190911/1985) (Fuji Heavy Industries Ltd.), 18 December 1985 (18.12.1985), page 7, line 12 to page 9, line 1; fig. 1 to 4 (Family: none)	1-9
A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 186667/1987(Laid-open No. 91007/1989) (Fuji Heavy Industries Ltd.), 15 June 1989 (15.06.1989), page 7, lines 9 to 19; page 11, line 11 to page 12, line 11 (Family: none)	1-9

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REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 2014077405 A **[0005]**