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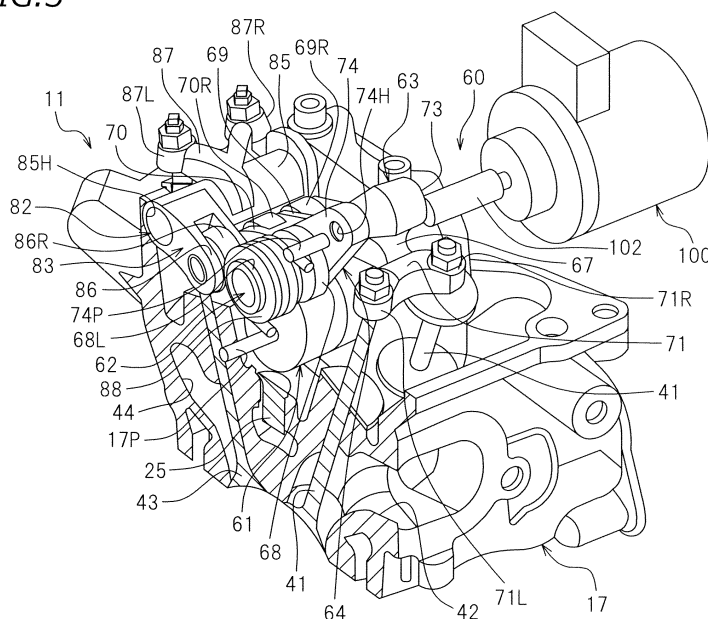
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(54) **INTERNAL COMBUSTION ENGINE AND STRADDLE-TYPE VEHICLE**

(57) An internal combustion engine (11) includes a first rocker arm (63), a second rocker arm (64) including a side face (74S) facing the first rocker arm (63), an intake valve (41), a solenoid (100) for moving a connecting pin (90) between a non-connecting position and a complete connecting position, and a drive signal supplying unit (120) for supplying a drive signal to the solenoid (100). The drive signal supplying unit (125) starts supplying the drive signal so as to cause a tip end (90T) of the con-

necting pin (90) to reach the position flush with a side face (74S) of the second rocker arm (64) after relative positions of the first rocker arm (63) and the second rocker arm (64) start to change, and to also cause the connecting pin (90) to reach the complete connecting position between the time when the second rocker arm (64) completes pivoting and the next time when the second rocker arm (64) starts to pivot.

FIG.3



Description

[0001] The present invention relates to a single-cylinder internal combustion engine, a straddle-type vehicle and a method for controlling a single-cylinder internal combustion engine.

[0002] Conventionally, internal combustion engines provided with a variable valve train mechanism, which can change the timing for opening and closing valves, are known. The internal combustion engine provided with the variable valve train mechanism can improve fuel consumption because it can open and close the valves at appropriate timing according to the operating condition.

[0003] A known example of the variable valve train mechanism has two rocker arms for driving a valve in association with rotation of a camshaft, a connecting pin that is insertable into holes formed in the two rocker arms, and an actuator for moving the connecting pin. (See, for example, JP 2012-077741 A.) In this variable valve train mechanism, the two rocker arms are connected to each other when the connecting pin is inserted into the holes of the two rocker arms, so that the two rocker arms drive the valve unitarily. When the connecting pin comes out of the hole of either of the rocker arms, the connection of the two rocker arms is released. In this case, the valve is driven by one of the rocker arms.

[0004] In the variable valve train mechanism disclosed in JP 2012-077741 A, the two rocker arms are connected and disconnected by moving a connecting pin linearly from a side of the two rocker arms. This makes it possible to connect and disconnect the two rocker arms with a simple structure. In addition, it is possible to reduce the size of the actuator.

[0005] The rocker arms pivot when driving the valve. When the two rocker arms are not pivoting, the positions of the holes of the two rocker arms are in agreement with each other. However, when at least one of the rocker arms is pivoting while the two rocker arms are not being connected to each other, the timings at which the two rocker arms pivot are different, so the holes of the two rocker arms are at different positions. Consequently, there is a risk that the connecting pin may not smoothly enter the hole in the rocker arm.

[0006] The present invention has been accomplished in view of the foregoing and other problems, and it is an object of the invention to provide a single-cylinder internal combustion engine, a straddle-type vehicle and a method for controlling a single-cylinder internal combustion engine that can smoothly change the timing of opening and closing of a valve and that can reduce the size of the actuator.

[0007] According to the present invention said object is solved by a single-cylinder internal combustion engine having the features of independent claim 1, a straddle-type vehicle according to claim 10 and a method for controlling a single-cylinder internal combustion engine having the features of independent claim 11. Preferred embodiments are laid down in the dependent claims.

[0008] An internal combustion engine according to the present teaching is a single-cylinder internal combustion engine comprising: a crankcase supporting a crankshaft; a rotational speed sensing unit configured to sense the rotational speed of the crankshaft; a rotational position sensing unit configured to sense the rotational position of the crankshaft; a cylinder unit connected to the crankcase and including a combustion chamber and a cam chain chamber positioned adjacent to the combustion chamber; a camshaft supported by the cylinder unit, and connected to the crankshaft by a cam chain disposed in the cam chain chamber; a first cam including a first lift portion and a first base portion and being configured to rotate integrally with the camshaft; a second cam, including a second base portion and a second lift portion having a different shape from that of the first lift portion, and being configured to rotate integrally with the camshaft; a rocker shaft supported by the cylinder unit and disposed parallel to the camshaft; a first rocker arm pivotably supported by the rocker shaft and configured to be pivoted by receiving a force from the first lift portion of the first cam; a second rocker arm, pivotably supported by the rocker shaft, configured to be pivoted by receiving a force from the second lift portion of the second cam, disposed to a side of the first rocker arm, and having a side face facing the first rocker arm; a valve disposed in the cylinder unit and configured to be driven by the first rocker arm or the second rocker arm to open and close the combustion chamber; a connecting pin being freely movable in a direction parallel to the rocker shaft; a solenoid configured to move the connecting pin between a non-connecting position, at which a tip end of the connecting pin is positioned in or adjacent to the first rocker arm relative to the side face of the second rocker arm with respect to a direction of an axial line of the rocker shaft so that the connecting pin does not connect the first rocker arm and the second rocker arm to each other, and a complete connecting position, at which the tip end of the connecting pin is positioned in or adjacent to the second rocker arm relative to the side face of the second rocker arm with respect to the direction of the axial line of the rocker shaft so that the connecting pin connects the first rocker arm and the second rocker arm to each other; and a controller configured to control the solenoid. The controller comprises: an instruction unit configured to issue an instruction for driving the solenoid based on the rotational speed of the crankshaft sensed by the rotational speed sensing unit; and a drive signal supplying unit configured to supply a drive signal to the solenoid when the instruction unit issues the instruction for driving the solenoid, based on the rotational position of the crankshaft sensed by the rotational position sensing unit. The drive signal supplying unit is configured to start supplying the drive signal so as to cause the tip end of the connecting pin to reach a position flush with the side face of the second rocker arm with respect to the direction of the axial line of the rocker shaft after one of the first rocker arm and the second rocker arm that should start to pivot earlier than the

other starts to pivot so that relative positions of the first rocker arm and the second rocker arm start to change, and to also cause the connecting pin to reach the complete connecting position between the time when the first rocker arm and the second rocker arm complete pivoting and the next time when the one of the first rocker arm and the second rocker arm that should start to pivot earlier than the other starts to pivot.

[0009] The internal combustion engine according to the present teaching includes the drive signal supplying unit configured to supply a drive signal to the solenoid. The drive signal supplying unit is configured to start supplying the drive signal to the solenoid. The supplying of the drive signal is started so as to cause the tip end of the connecting pin to reach the position flush with the side face of the second rocker arm with respect to the direction of the axial line of the rocker shaft after one of the first rocker arm and the second rocker arm that should start to pivot earlier than the other starts to pivot so that the relative positions of the first rocker arm and the second rocker arm start to change. When a small-sized solenoid, for example, is used as the actuator, the moving speed of the first rocker arm and the second rocker arm tend to be faster than the moving speed of the connecting pin. The term "small-sized solenoid" here means a solenoid having a small power and a small outer shape. Therefore, depending on the solenoid used, one of the first rocker arm and the second rocker arm may start to pivot before the connecting pin reaches the complete connecting position. When the tip end of the connecting pin is positioned in or adjacent to the second rocker arm relative to the side face of second rocker arm with respect to the direction of the axial line of the rocker shaft and has not yet reached the complete connecting position, the contact area between the connecting pin and the second rocker arm is small. This means that an excessive load resulting from the pivoting of one of the first rocker arm and the second rocker arm is applied to the tip end of the connecting pin. Consequently, the connecting pin cannot be moved to the complete connecting position smoothly when the first rocker arm and the second rocker arm are pivoting. In addition, when the connecting pin is slightly shifted toward the second rocker arm beyond the side face of the second rocker arm with respect to the direction of the axial line of the rocker shaft, the first rocker arm and the second rocker arm are not connected sufficiently. Therefore, the pivoting of one of the first rocker arm and the second rocker arm may cause the connecting pin to be repelled toward the first rocker arm with respect to the direction of the axial line of the rocker shaft. As the connecting pin is repelled, the first rocker arm and the second rocker arm are disconnected. Consequently, when at least one of the first rocker arm and the second rocker arm is pivoting, the connecting pin can be moved only to the side face of the second rocker arm with respect to the direction of the axial line of the rocker shaft, so the connecting pin cannot be moved to the complete connecting position smoothly. According to the present pre-

ferred embodiment, however, the tip end of the connecting pin has reached the complete connecting position when the tip end of the connecting pin is positioned in or adjacent to the second rocker arm relative to the side face of the second rocker arm with respect to the direction of the axial line of the rocker shaft before one of the first rocker arm and the second rocker arm that should start to pivot earlier than the other starts to pivot so that the relative positions of the first rocker arm and the second rocker arm start to change. Thus, the excessive load on the tip end of the connecting pin and the repelling of the connecting pin such as described above can be prevented. Moreover, the drive signal is supplied so as to cause the connecting pin to reach the complete connecting position between the time when the first rocker arm and the second rocker arm complete pivoting and the next time when the one of the first rocker arm and the second rocker arm that should start to pivot earlier than the other starts to pivot. Therefore, when the connecting pin moves from the non-connecting position to the complete connecting position, the first rocker arm and the second rocker arm have completed pivoting. In other words, the first rocker arm and the second rocker arm are no longer pivoting. Thereby, the connecting pin can move to the complete connecting position smoothly. As a result, the first rocker arm and the second rocker arm can be connected smoothly even when the actuator is a small-sized one. In other words, it is possible to achieve a smooth change from the valve opening and closing timing caused by the first rocker arm to the valve opening and closing timing caused by the second rocker arm. Thus, it becomes possible to provide an internal combustion engine equipped with a variable valve train mechanism that can smoothly change the timing of opening and closing of a valve and that can reduce the size of the actuator. It should be noted that the phrase "the tip end of the connecting pin is positioned in or adjacent to the first rocker arm relative to the side face of the second rocker arm with respect to the direction of the axial line of the rocker shaft" in the present description means that the connecting pin is positioned such that it overlaps the first rocker arm but does not overlap the second rocker arm with respect to the moving direction of the connecting pin. The phrase "the tip end of the connecting pin is positioned in or adjacent to the second rocker arm relative to the side face of the second rocker arm with respect to the direction of the axial line of the rocker shaft" means that the connecting pin is positioned such that a portion of the connecting pin overlaps the second rocker arm with respect to the moving direction of the connecting pin.

[0010] In another preferred embodiment, the drive signal supplying unit is configured to start supplying the drive signal so as to cause the tip end of the connecting pin to reach the position flush with the side face of the second rocker arm with respect to the direction of the axial line of the rocker shaft between the time when one of the first rocker arm and the second rocker arm that should start to pivot earlier than the other starts to pivot so that relative

positions of the first rocker arm and the second rocker arm start to change and the time when the first rocker arm and the second rocker arm complete pivoting, and to also cause the connecting pin to reach the complete connecting position between the time when the first rocker arm and the second rocker arm complete pivoting and the next time when the one of the first rocker arm and the second rocker arm that should start to pivot earlier than the other starts to pivot.

[0011] In the above-described preferred embodiment, the drive signal is supplied so as to cause the tip end of the connecting pin to reach the position flush with the side face of the second rocker arm with respect to the direction of the axial line of the rocker shaft between the time when one of the first rocker arm and the second rocker arm that should start to pivot earlier than the other starts to pivot so that the relative positions of the first rocker arm and the second rocker arm start to change and the time when the first rocker arm and the second rocker arm complete pivoting. This prevents the connecting pin from being repelled, and also allows more freedom in setting the time until the tip end of the connecting pin reaches the position flush with the side face. That is, the time until the tip end of the connecting pin reaches the position flush with the side face can be set relatively longer, so the size of the actuator can be prevented from increasing.

[0012] In another preferred embodiment, the drive signal supplying unit is configured to start supplying the drive signal so as to cause the tip end of the connecting pin to reach the position flush with the side face of the second rocker arm with respect to the direction of the axial line of the rocker shaft, and to also cause the connecting pin to reach the complete connecting position between the time when the first rocker arm and the second rocker arm complete pivoting and the next time when the one of the first rocker arm and the second rocker arm that should start to pivot earlier than the other starts to pivot.

[0013] As the connecting pin starts to move and is kept in contact with the side face of the second rocker arm, the force of the solenoid that pushes the connecting pin gradually increases. This can cause the force of the solenoid to become excessively large before the connecting pin becomes movable toward the second rocker arm beyond the side face of the second rocker arm with respect to the direction of the axial line of the rocker shaft, so the operating noise of the solenoid and/or the noise produced from the connecting pin may become louder. However, the just-described preferred embodiment can prevent the tip end of the connecting pin from making contact with the side face of the second rocker arm. Thus, it becomes possible to smoothly change the timing of opening and closing of the valve and also prevent the operating noise of the solenoid and/or the noise produced from the connecting pin from becoming louder.

[0014] In another preferred embodiment, the internal combustion engine may further comprise an elastic body configured to urge the connecting pin from the complete

connecting position toward the non-connecting position with respect to the direction of the axial line of the rocker shaft, and the drive signal supplying unit is configured to stop supplying the drive signal so as to cause the tip end of the connecting pin to return to the position flush with the side face of the second rocker arm with respect to the direction of the axial line of the rocker shaft, and to also cause the connecting pin to return to the non-connecting position between the time when the first rocker arm and the second rocker arm complete pivoting and the next time when the one of the first rocker arm and the second rocker arm that should start to pivot earlier than the other starts to pivot.

[0015] When the supplying of the drive signal is stopped, the connecting pin is moved by the elastic body from the complete connecting position toward the non-connecting position with respect to the direction of the axial line of the rocker shaft. When the connecting pin is positioned at an intermediate connecting position, which is between the complete connecting position and the non-connecting position, the contact area between the connecting pin and the second rocker arm is small. This means that an excessive load resulting from the pivoting of one of the first rocker arm and the second rocker arm is applied to the tip end of the connecting pin if one of the first rocker arm and the second rocker arm pivots with the connecting pin being at the intermediate connecting position. Consequently, the connecting pin cannot be moved to the non-connecting position smoothly when the first rocker arm and the second rocker arm are pivoting. In the just-described preferred embodiment, however, the first rocker arm and the second rocker arm do not pivot when the connecting pin is in the intermediate connecting position. This makes it possible to prevent the above-described problem and also to achieve a smooth change from the valve opening and closing timing caused by the second rocker arm to the valve opening and closing timing caused by the first rocker arm.

[0016] In another preferred embodiment, the first rocker arm and the second rocker arm are provided with respective holes to which the connecting pin is to be inserted; the connecting pin is retained in the hole of the first rocker arm when the connecting pin is at the non-connecting position, and the connecting pin is retained in the hole of the first rocker arm and the hole of the second rocker arm when the connecting pin is at the complete connecting position; the solenoid is disposed opposite to the second rocker arm relative to the first rocker arm with respect to a direction of an axial line of the connecting pin; and the solenoid includes a push rod configured to make contact with the connecting pin.

[0017] Thus, because the push rod of the solenoid moves the connecting pin, the connecting pin is inserted in the hole of the second rocker arm so that it can move to the complete connecting position. Thereby, the connecting pin connects the first rocker arm and the second rocker arm to each other.

[0018] In another preferred embodiment, the controller

further includes a monitoring unit configured to monitor a voltage of a battery, and a current controlling unit configured to control a current to be supplied to the solenoid based on the voltage monitored by the monitoring unit.

[0019] The force that is applied to the connecting pin by the solenoid varies depending on the value of the current supplied to the solenoid. In the just-described preferred embodiment, the current to be supplied to the solenoid is controlled based on the voltage of the battery. Thus, with a simple configuration, the solenoid can be controlled in such a manner that the valve opening and closing timing can be changed smoothly.

[0020] In another preferred embodiment, the controller may further include a current supply circuit for supplying a current to the solenoid by applying a voltage thereto as the drive signal, a freewheeling diode disposed in the current supply circuit so as to form a freewheeling circuit with the solenoid, and a switching element, disposed in the current supply circuit, for performing duty control of the voltage.

[0021] When the solenoid is continuously supplied with electric current, the temperature of the solenoid rises. As a consequence, the force of the solenoid reduces. However, the current to be supplied to the solenoid can be reduced by performing the duty control, and the temperature rise of the solenoid can be prevented. Moreover, since the freewheeling circuit is provided, the force of the solenoid can be kept applied to the solenoid while performing the duty control. This achieves a size reduction of the actuator while preventing the connecting pin from being moved at unexpected timing.

[0022] In another preferred embodiment, the controller may further include another switching element provided upstream of the solenoid in the freewheeling circuit.

[0023] Even when the current to the solenoid is cut off, current remains in the freewheeling diode, so the connecting pin does not move immediately. In the just-described preferred embodiment, another switching element is provided upstream of the solenoid. This makes it possible to cut off the current to the solenoid immediately by turning off the other switching element. As a result, the connecting pin can be allowed to move immediately. Therefore, the timing for opening and closing valves can be changed smoothly.

[0024] In another preferred embodiment, the controller is configured to shut off the current to be supplied to the solenoid by turning off the other switching element after reducing the value of the current to be supplied to the solenoid by the duty control.

[0025] If the other switching element is turned off while the value of the current to be supplied to the solenoid is relatively high, a relatively large counter-electromotive force is applied to the other switching element. With the above-described preferred embodiment, the other switching element is turned off after reducing the value of the current to be supplied to the solenoid by the duty control. As a result, the counter-electromotive force applied to the other switching element can be reduced.

[0026] A straddle-type vehicle according to the present teaching may comprise one of the foregoing internal combustion engine.

[0027] The present invention makes it possible to obtain a straddle-type vehicle that exhibits the above-described advantageous effects.

ADVANTAGEOUS EFFECTS OF INVENTION

[0028] As described above, the present invention makes it possible to provide an internal combustion engine equipped with a variable valve train mechanism that can smoothly change the timing of opening and closing of a valve and that can reduce the size of the actuator.

BRIEF DESCRIPTION OF DRAWINGS

[0029]

[Fig. 1] Fig. 1 is a right side view illustrating a motor-cycle according to one preferred embodiment.

[Fig. 2] Fig. 2 is a cross-sectional view taken along line II-II of Fig. 1, illustrating a power unit.

[Fig. 3] Fig. 3 is a cross-sectional perspective view illustrating a portion of an engine according to one preferred embodiment.

[Fig. 4A] Fig. 4A is a cross-sectional view illustrating a portion of the engine according to one preferred embodiment.

[Fig. 4B] Fig. 4B is a cross-sectional view illustrating a portion of the engine according to one preferred embodiment.

[Fig. 5] Fig. 5 is a graph illustrating intake valve lift amount by a first intake cam and intake valve lift amount by a second intake cam, according to one preferred embodiment.

[Fig. 6] Fig. 6 is a perspective view illustrating the structure of a portion around a first rocker arm and a second rocker arm, according to one preferred embodiment.

[Fig. 7] Fig. 7 is a side view illustrating the structure of the portion around the first rocker arm and the second rocker arm, according to one preferred embodiment.

[Fig. 8] Fig. 8 is a cross-sectional perspective view illustrating a state in which a connecting pin is not connecting a first intake rocker arm and a second intake rocker arm, according to one preferred embodiment.

[Fig. 9] Fig. 9 is a cross-sectional perspective view illustrating a state in which the connecting pin is connecting the first intake rocker arm and the second intake rocker arm, according to one preferred embodiment.

[Fig. 10A] Fig. 10A is a schematic view illustrating a state in which the connecting pin is positioned at a first non-connecting position.

[Fig. 10B] Fig. 10B is a schematic view illustrating a

state in which the connecting pin is positioned at a second non-connecting position.

[Fig. 10C] Fig. 10C is a schematic view illustrating a state in which the connecting pin is positioned at an intermediate connecting position.

[Fig. 10D] Fig. 10D is a schematic view illustrating a state in which the connecting pin is positioned at a complete connecting position.

[Fig. 11] Fig. 11 is a block diagram illustrating main elements of the engine according to one preferred embodiment.

[Fig. 12] Fig. 12 is a timing chart illustrating when the connecting pin moves from the non-connecting position to the complete connecting position, according to one preferred embodiment.

[Fig. 13] Fig. 13 is a timing chart illustrating when the connecting pin moves from the complete connecting position to the non-connecting position, according to one preferred embodiment.

[Fig. 14] Fig. 14 is a circuit diagram illustrating the current flow in a current supply circuit in a normal condition, according to one preferred embodiment.

[Fig. 15] Fig. 15 is a circuit diagram illustrating the current flow in the current supply circuit when the current is reverted, according to one preferred embodiment.

[Fig. 16] Fig. 16 is a timing chart illustrating when the connecting pin moves from the non-connecting position to the complete connecting position and further returns to the non-connecting position, according to one preferred embodiment.

[Fig. 17] Fig. 17 is a timing chart illustrating when the connecting pin moves from the disconnecting position to the complete connecting position, according to another preferred embodiment.

DESCRIPTION OF EMBODIMENTS

[0030] Hereinbelow, preferred embodiments will be described. As illustrated in Fig. 1, the straddle-type vehicle according to the present embodiment is a motorcycle 1. The type of the motorcycle 1 is not limited in any way, and the motorcycle 1 may be any type of motorcycle, such as a moped type motorcycle, an off-road type motorcycle, or an on-road type motorcycle. The straddle-type vehicle according to the present teaching is not limited to a motorcycle but may be any other straddle-type vehicle, such as ATV (all terrain vehicle), three-wheeled vehicle, and four-wheeled dune buggy. Note that the straddle-type vehicle means a vehicle such that the rider straddles the vehicle when riding.

[0031] In the following description, the terms "above/up," "below/down," "front," "rear," "left," and "right" refer respectively to above/up, below/down, front, rear, left, and right, as defined based on the perspective of the rider seated on a later-described seat 6 of the motorcycle 1, unless specifically indicated otherwise. The motorcycle 1 can be in a leaning position while traveling.

The terms "above/up" and "below/down" respectively mean the relative vertical positions above/up and below/down as used when the motorcycle 1 is stationary on a horizontal plane. Reference characters U, D, F, Re, L, and R in the drawings indicate up, down, front, rear, left, and right, respectively. The just-mentioned terms of positional relationship are also used for describing various parts of later-described engine 11. That is, the terms "front," "rear," "left," "right," "above/up," and "below/down" of the engine 11 respectively refer to front, rear, left, right, above/up, and below/down of the engine 11 as defined based on the perspective of the rider of the motorcycle 1 on which the engine 11 is mounted.

[0032] As illustrated in Fig. 1, the motorcycle 1 has a body frame 2, a power unit 10 swingably supported by the body frame 2, a seat 6 for a rider to sit on, and a low-floor foot board 7 positioned frontward relative to the seat 6. A head pipe 3 is provided at a front end of the body frame 2. A front fork 4 is pivotably supported by the head pipe 3. A front wheel 5 is supported at a lower end portion of the front fork 4.

[0033] The power unit 10 is what is called a unit swing type power unit. The power unit 10 is swingably supported by the body frame 2 via a pivot shaft, which is not shown in the drawings. A rear end portion of the power unit 10 is fitted to a drive shaft 8a of the rear wheel 8 on the left side of the motorcycle 1. A rear end portion of the rear arm 9 is supported on the drive shaft 8a of the rear wheel 8 on the right side of the motorcycle 1. A front end portion of the rear arm 9 is fitted to the power unit 10. As illustrated in Fig. 2, the power unit 10 includes an internal combustion engine 11 (hereinafter referred to as "engine") and a V-belt type continuously variable transmission 12 (hereinafter referred to as "CVT"). The drive force of the engine 11 is transmitted to the rear wheel 8 via the CVT 12.

[0034] The engine 11 has a crankcase 14 and a cylinder unit 19. The engine 11 has a cylinder body 16 connected to a front portion of the crankcase 14, a cylinder head 17 connected to the cylinder body 16, and a cylinder head cover 18 connected to the cylinder head 17. The cylinder body 16, the cylinder head 17, and the cylinder head cover 18 together constitute the cylinder unit 19. As viewed in plan, the cylinder unit 19 extends frontward from the crankcase 14. As illustrated in Fig. 1, the cylinder unit 19 is inclined frontward and obliquely upward as viewed in side view. The cylinder unit 19, however, may extend horizontally frontward from the crankcase 14 as viewed in side view. In the present preferred embodiment, the cylinder body 16 and the crankcase 14 are formed of separate parts. The cylinder body 16 and the crankcase 14 may be integrally formed with each other.

[0035] As illustrated in Fig. 2, the engine 11 has a crankshaft 15 extending in a lateral direction (i.e., in a vehicle width direction, or in a left-to-right/right-to-left direction). The crankshaft 15 is disposed in the crankcase 14. The crankshaft 15 is supported by the crankcase 14. The crankshaft 15 is provided with a sprocket 15S.

[0036] The CVT 12 is disposed to the left of the engine 11. The CVT 12 has a drive pulley 28 fitted to a left end portion of the crankshaft 15, a driven pulley 29 disposed to the rear of the drive pulley 28, and a V-belt 30 wrapped around the drive pulley 28 and the driven pulley 29. The driven pulley 29 is supported by a shaft 31. A starting clutch 32A, which is for interlocking the driven pulley 29 and the shaft 31 with each other when the rotation speed of the driven pulley 29 becomes higher than a predetermined speed, is fitted to the shaft 31. The shaft 31 is connected to a drive shaft 8a via a gear 32 and gears that are not shown in the drawings. A transmission case 33 is disposed to the left of the crankcase 14. The CVT 12 is disposed in the transmission case 33. A cover 34 is disposed to the left of the transmission case 33.

[0037] The cylinder unit 19 includes a cylinder 20. The cylinder 20 is formed inside the cylinder body 16. The cylinder 20 extends frontward from a front portion of the crankcase 14. The engine 11 is a single-cylinder engine. In the motorcycle 1 equipped with the single-cylinder engine 11, the maximum value of the rotation speed of the crankshaft 15 per unit time (i.e., the maximum rotation speed of the engine) tends to be higher than that in automobiles, and the opening and closing speed of a later-described intake valve 41 (see Fig. 3) also tends to be higher than that of automobiles. A piston 21 that reciprocates in the cylinder 20 is accommodated the cylinder 20. The piston 21 is connected to the crankshaft 15 via a connecting rod 22. A combustion chamber 24 is provided inside the cylinder unit 19. The combustion chamber 24 is defined by a recessed portion 23 of the cylinder head 17, an inner circumferential surface of the cylinder 20, and a top face of the piston 21. The combustion chamber 24 is provided with an ignition device 25 (see Fig. 3) for igniting the fuel in the combustion chambers 24.

[0038] The cylinder unit 19 has a cam chain chamber 35 positioned adjacent to the combustion chamber 24. The cam chain chamber 35 is positioned to the left of the combustion chamber 24. The cam chain chamber 35, however, may be disposed to the right of the combustion chamber 24. The cam chain chamber 35 is formed over the entirety of the cylinder head cover 18, the cylinder head 17, the cylinder body 16, and the crankcase 14. A cam chain 36 is disposed in the cam chain chamber 35. The cam chain 36 is wrapped around the sprocket 15S of the crankshaft 15 and a later-described cam chain sprocket 61 S. The cam chain 36 interlocks with the crankshaft 15.

[0039] As illustrated in Fig. 3, the engine 11 includes an intake valve 41 and an exhaust valve 43. As illustrated in Fig. 4A, the intake valve 41 and the exhaust valve 43 are disposed in the cylinder head 17 and in the cylinder head cover 18. The intake valve 41 opens and closes between an intake passage 42 and the combustion chamber 24. When the intake valve 41 opens, the intake passage 42 and the combustion chamber 24 are allowed to communicate with each other. When the intake valve 41 closes, the intake passage 42 and the combustion

chamber 24 are not allowed to communicate with each other. The exhaust valve 43 opens and closes the combustion chamber 24 and the an exhaust passage 44. Note that Fig. 4A does not show a later-described second intake rocker arm 64 (see Fig. 4B).

[0040] A valve train chamber 37 is formed inside the cylinder unit 19. The valve train chamber 37 is formed in the cylinder head 17 and the cylinder head cover 18. A variable valve train mechanism 60 is disposed in the valve train chamber 37. The variable valve train mechanism 60 drives the intake valve 41 and the exhaust valve 43.

[0041] The variable valve train mechanism 60 has a camshaft 61 extending in a lateral direction, an intake rocker shaft 62 parallel to the camshaft 61, an exhaust rocker shaft 82 parallel to the camshaft 61, a first intake rocker arm 63 for driving the intake valve 41, a second intake rocker arm 64 (see Fig. 3), and an exhaust rocker arm 83 for driving the exhaust valve 43. The camshaft 61, the intake rocker shaft 62, and the exhaust rocker shaft 82 are supported by the cylinder head 17.

[0042] As illustrated in Fig. 2, a cam chain sprocket 61 S is fitted to a left end portion of the camshaft 61. The camshaft 61 is connected to the crankshaft 15 via the cam chain 36. The rotation of the crankshaft 15 is transmitted through the cam chain 36 to the camshaft 61, whereby the camshaft 61 is rotated. The camshaft 61 is provided with a first intake cam 65 for driving the first intake rocker arm 63, a second intake cam 66 for driving the second intake rocker arm 64, and an exhaust cam 84 for driving the exhaust rocker arm 83. The first intake cam 65, the second intake cam 66, and the exhaust cam 84 are disposed side by side along the axial direction of the camshaft 61. The first intake cam 65, the second intake cam 66, and the exhaust cam 84 are disposed in that order from right to left along the axial direction of the camshaft 61. The order of arrangement of the first intake cam 65, the second intake cam 66, and the exhaust cam 84, however, is not limited thereto.

[0043] The first intake cam 65 rotates integrally with the camshaft 61. As illustrated in Fig. 4A, the first intake cam 65 comprises a base portion 65A having a certain outer diameter, and a lift portion 65B having a predetermined cam profile. The distance from the axial center O1 of the camshaft 61 to the outer periphery of the lift portion 65B is not constant. The longer the distance H2 from the axial center O1 of the camshaft 61 to a tip end 65BT of the lift portion 65B is, the greater the maximum lift amount of the intake valve 41 becomes. The greater the proportion of the lift portion 65B relative to the base portion 65A is, the longer the time during which the intake valve 41 remains open becomes. The greater the angle α formed by the axial center O1 of the camshaft 61 and two boundary portions 65X and 65Y between the base portion 65A and the lift portion 65B is, the longer the time during which the intake valve 41 remains open becomes. The distance H1 between the axial center O1 of the camshaft 61 and base portion 65A is shorter than the distance H2 between

the axial center O1 of the camshaft 61 and the tip end 65BT of the lift portion 65B. The second intake cam 66 rotates integrally with the camshaft 61. As illustrated in Fig. 4B, the second intake cam 66 comprises a base portion 66A having a certain outer diameter, and a lift portion 66B having a predetermined cam profile. The lift portion 66B has a different shape from that of the lift portion 65B. The distance from the axial center O1 of the camshaft 61 to the outer periphery of the lift portion 66B. The longer the distance I2 from the axial center O1 of the camshaft 61 to a tip end 66BT of the lift portion 66B is, the greater the maximum lift amount of the intake valve 41 becomes. The greater the proportion of the lift portion 66B relative to the base portion 66A is, the longer the time during which the intake valve 41 remains open becomes. The greater the angle β formed by the axial center O1 of the camshaft 61 and two boundary portions 66X and 66Y between the base portion 66A and the lift portion 66B is, the longer the time during which the intake valve 41 remains open becomes. The distance I1 between the axial center O1 of the camshaft 61 and base portion 66A is shorter than the distance I2 between the axial center O1 of the camshaft 61 and the tip end 66BT of the lift portion 66B. The distance H2 between the axial center O1 of the camshaft 61 and the tip end 65BT of the lift portion 65B of the first intake cam 65 is shorter than the distance I2 between the axial center O1 of the camshaft 61 and the tip end 66BT of the lift portion 66B of the second intake cam 66. As illustrated in Fig. 2, the exhaust cam 84 rotates integrally with the camshaft 61. The exhaust cam 84 has the same shape as that of the first intake cam 65. It is possible that the exhaust cam 84 may have a different shape from that of the first intake cam 65.

[0044] Fig. 5 is a graph illustrating the lift amount of the intake valve 41 caused by the first intake cam 65 and the lift amount of the intake valve 41 caused by the second intake cam 66. In Fig. 5, reference character Lq represents the lift amount of the intake valve 41. Reference character Ca represents the angle at which the crankshaft 15 rotates two times. Reference character Ic1 represents the lift amount of the intake valve 41 caused by the first intake cam 65. Reference character Ic2 represents the lift amount of the intake valve 41 caused by the second intake cam 66. When the crankshaft 15 rotates two times, the camshaft 61 rotates one time. As illustrated in Fig. 5, the lift amount of the intake valve 41 caused when the first intake cam 65 rotates one time is smaller than the lift amount of the intake valve 41 caused when the second intake cam 66 rotates one time. The greater the lift amount of the intake valve 41 is, the greater the air amount that flows into the combustion chamber 24 from the intake passage 42 will be. Note that the lift amount of the intake valve 41 caused by the first intake cam 65 means the amount of travel of a roller support portion 69 with reference to the position at which a roller 69R is in contact with the base portion 65A of the first intake cam 65. The lift amount of the intake valve 41 caused by the second intake cam 66 means the amount

of travel of a roller support portion 70 with reference to the position at which a roller 70R is in contact with the base portion 66A of the second intake cam 66.

[0045] As illustrated in Fig. 5, in the case where the second intake cam 66 opens and closes the intake valve 41, the intake valve 41 starts to open when the angle of the crankshaft 15 is at Ca1 in an exhaust stroke P1. The intake valve 41 reaches the maximum lift amount Lq2 when the angle of the crankshaft 15 is at Ca3 in an intake stroke P2. The intake valve 41 is closed when the angle of the crankshaft 15 is at Ca5 in a compression stroke P3. On the other hand, in the case where the first intake cam 65 opens and closes the intake valve 41, the intake valve 41 starts to open when the angle of the crankshaft 15 is at Ca2, which is greater than Ca1, in the exhaust stroke P1. The intake valve 41 reaches the maximum lift amount Lq1 when the angle of the crankshaft 15 is at Ca3 in the intake stroke P2. The maximum lift amount Lq1 is smaller than the maximum lift amount Lq2. The intake valve 41 is closed when the angle of the crankshaft 15 is at Ca4, which is an angle less than Ca5, in the compression stroke P3. Thus, the time during which the first intake cam 65 opens the intake valve 41 is shorter than the time during which the second intake cam 66 opens the intake valve 41. In the case where the first intake cam 65 opens and closes the intake valve 41, the intake valve 41 starts to open earlier and also closes earlier than in the case where the second intake cam 66 opens and closes the intake valve 41.

[0046] As illustrated in Fig. 6, the first intake rocker arm 63 is pivotably supported by the intake rocker shaft 62. The first intake rocker arm 63 has a body portion 67, a roller support portion 69, an arm portion 71, and a boss portion 73. As illustrated in Fig. 7, the body portion 67 has an insertion hole 67H in which the intake rocker shaft 62 is to be inserted. The roller support portion 69 is formed in a two-forked shape. The roller support portion 69 extends downward from the body portion 67. The roller 69R is rotatably supported on the roller support portion 69. As illustrated in Fig. 4A, the roller 69R is in contact with the first intake cam 65. The roller 69R is positioned in front of the first intake cam 65. The first intake rocker arm 63 is pivoted by receiving a force from the lift portion 65B of the first intake cam 65. By rotation of the first intake cam 65, the first intake rocker arm 63 is pivoted in the directions indicated by the arrows Z1 and Z2 in Fig. 4A. As illustrated in Fig. 3, the arm portion 71 has a pair of arms 71 R and 71 L. As illustrated in Fig. 4A, the arm portion 71 extends upward from the body portion 67. The arms 71 R and 71 L are disposed at the positions facing respective front ends 41 B of the intake valves 41. A pressing portion (not shown) is fitted to a position of the arm 71 R that faces the front end 41 B of one of the intake valves 41. A pressing portion 71 P is fitted to a position of the arm 71 L that faces the front end 41 B of the other one of the intake valves 41. The pressing portion 71 P protrudes toward the front end 41 B of the intake valve 41. The pressing portion 71 P is in contact with the front

end 41 B of the intake valve 41. It is possible that there may be a gap between the pressing portion 71 P and the front end 41 B of the intake valve 41. As illustrated in Fig. 3, the boss portion 73 extends frontward and obliquely upward from the body portion 67. As illustrated in Fig. 7, the boss portion 73 has a hole 73H in which a later-described connecting pin 90 is to be inserted. The boss portion 73 has a side face 73S that faces a side face 74S of a boss portion 74 of the second intake rocker arm 64.

[0047] The phrase "the first intake rocker arm 63 is pivoted" means that the first intake rocker arm 63 is pivoted about the intake rocker shaft 62 by the roller 69R making contact with the lift portion 65B of the first intake cam 65, with reference to the position of the first intake rocker arm 63 at which the roller 69R of the first intake rocker arm 63 is in contact with the base portion 65A of the first intake cam 65.

[0048] As illustrated in Fig. 6, the second intake rocker arm 64 is pivotably supported by the intake rocker shaft 62. As illustrated in Fig. 6, the second intake rocker arm 64 is disposed on a side of the first intake rocker arm 63. The second intake rocker arm 64 is disposed to the left of the first intake rocker arm 63. The second intake rocker arm 64 has a body portion 68, a roller support portion 70, and a boss portion 74. As illustrated in Fig. 7, the body portion 68 has an insertion hole 68H in which the intake rocker shaft 62 is to be inserted. The roller support portion 70 extends downward from the body portion 68. The roller support portion 70 is formed in a two-forked shape. The roller 70R is rotatably supported on the roller support portion 70. As illustrated in Fig. 4B, the roller 70R is in contact with the second intake cam 66. The roller 70R is positioned in front of the second intake cam 66. The second intake rocker arm 64 is pivoted by receiving a force from the lift portion 66B of the second intake cam 66. By rotation of the second intake cam 66, the second intake rocker arm 64 is pivoted in the directions indicated by the arrows Z1 and Z2 in Fig. 4B. As illustrated in Fig. 3, the boss portion 74 extends frontward and obliquely upward from the body portion 68. As illustrated in Fig. 7, the boss portion 74 has a hole 74H in which the connecting pin 90 is to be inserted. As illustrated in Fig. 4B, when the intake valve 41 is closed, the hole 73H of the boss portion 73 and the hole 74H of the boss portion 74 overlap with each other as viewed in side view. When the intake valve 41 is closed, the hole 73H of the boss portion 73 and the hole 74H of the boss portion 74 are in agreement with each other with respect to the direction of the axial line of the connecting pin 90. As illustrated in Fig. 3, a spring 88 is fitted to a left end portion 68L of the body portion 68. One end of the spring 88 is hooked on a pin 74P protruding leftward from the boss portion 74. As illustrated in Fig. 4B, the other end of the spring 88 is hooked on a pin 17P provided on the cylinder head 17. The spring 88 applies a force to the boss portion 74 in the direction indicated by the arrow Z2 of Fig. 4B. As illustrated in Fig. 7, the boss portion 74 has a side face 74S that faces the side face 73S of the boss portion 73 of the first intake

rocker arm 63.

[0049] The phrase "the second intake rocker arm 64 is pivoted" means that the second intake rocker arm 64 is pivoted about the intake rocker shaft 62 by the roller 70R making contact with the lift portion 66B of the second intake cam 66, with reference to the position of the second intake rocker arm 64 at which the roller 70R of the second intake rocker arm 64 is in contact with the base portion 66A of the second intake cam 66.

[0050] Referring to Fig. 5, the pivoting timing of the first intake rocker arm 63, which is pivoted by receiving a force from the lift portion 65B of the first intake cam 65, and the pivoting timing of the second intake rocker arm 64, which is pivoted by receiving a force from the lift portion 66B of the second intake cam 66, are compared. The second intake rocker arm 64 starts to pivot earlier than the first intake rocker arm 63, and completes the pivoting later than the first intake rocker arm 63.

[0051] As illustrated in Fig. 8, the variable valve train mechanism 60 has a connecting pin 90 that is movable in a direction parallel to the intake rocker shaft 62. The connecting pin 90 is inserted in the hole 73H formed in the boss portion 73 of the first intake rocker arm 63. The connecting pin 90 is insertable into the hole 74H formed in the boss portion 74 of the second intake rocker arm 64. The connecting pin 90 includes a body portion 90A in a columnar shape, and a protruding portion 90B protruding in a radial direction of the body portion 90A. The hole 73H, which is formed in the boss portion 73, includes a first hole 73HA having an inner diameter larger than the diameter of the body portion 90A but smaller than the diameter of the protruding portion 90B, and a second hole 73HB having an inner diameter larger than the diameter of the protruding portion 90B. As illustrated in Fig. 6, a tip end 90T of the connecting pin 90 is one of the end portions of the connecting pin 90 that is positioned opposite to a solenoid 100 relative to a push rod 102. In other words, the tip end 90T of the connecting pin 90 is the one end thereof that is initially inserted into the hole 73H of the second intake rocker arm 64 when the connecting pin 90 moves from a non-connecting position toward a complete connecting position. Also, the tip end 90T of the connecting pin 90 is the one end thereof that finally comes out of the hole 73H of the second intake rocker arm 64 when the connecting pin 90 moves from the complete connecting position toward the non-connecting position. At the non-connecting position, the tip end 90T of the connecting pin 90 is disposed at a position that overlaps the first intake rocker arm 63 in the moving direction of the connecting pin 90. At the complete connecting position, the tip end 90T of the connecting pin 90 is disposed at a position that overlaps the second intake rocker arm 64 in the moving direction of the connecting pin 90.

[0052] As illustrated in Fig. 8, the variable valve train mechanism 60 has a coil spring 91 for urging the connecting pin 90. The coil spring 91 is disposed around the body portion 90A. The coil spring 91 urges the connecting

pin 90 from the later-described complete connecting position toward the non-connecting position with respect to the direction of the axial line W (see Fig. 6) of the intake rocker shaft 62. In other words, the coil spring 91 urges the connecting pin 90 in a direction from the second intake rocker arm 64 toward the first intake rocker arm 63 with respect to the direction of the axial line W of the intake rocker shaft 62. The member for urging the connecting pin 90 toward the non-connecting position, however, is not limited to the coil spring 91, but may be an elastic body such as rubber. The hole 74H formed in the boss portion 74 of the second intake rocker arm 64 is larger than the diameter of the body portion 90A. When the connecting pin 90 does not connect the first intake rocker arm 63 and the second intake rocker arm 64 to each other, the first intake rocker arm 63 and the second intake rocker arm 64 pivot independently of each other. The phrase "when the first intake rocker arm 63 and the second intake rocker arm 64 are not connected" means a state in which the connecting pin 90 is inserted in the hole 73H of the first intake rocker arm 63 but the connecting pin 90 is not inserted in the hole 74H of the second intake rocker arm 64. On the other hand, when the connecting pin 90 connects the first intake rocker arm 63 and the second intake rocker arm 64 to each other, the first intake rocker arm 63 and the second intake rocker arm 64 pivot integrally with each other. The phrase "when the first intake rocker arm 63 and the second intake rocker arm 64 are connected" means a state in which the connecting pin 90 is inserted in both the hole 73H of the first intake rocker arm 63 and the hole 74H of the second intake rocker arm 64.

[0053] As illustrated in Fig. 3, the variable valve train mechanism 60 includes a solenoid 100 as an actuator. The solenoid 100 is disposed outside the valve train chamber 37 (see Fig. 4A). The solenoid 100 is disposed outside the cylinder unit 19 (see Fig. 2). The solenoid 100 may be accommodated in the valve train chamber 37. As illustrated in Fig. 7, the solenoid 100 is disposed opposite to the second intake rocker arm 64 relative to the first intake rocker arm 63 with respect to the direction of the axial line P of the connecting pin 90. The solenoid 100 is disposed to the right of the first intake rocker arm 63. The solenoid 100, the first intake arm 63, and the second intake arm 64 are disposed in that order from right to left along the direction of the axial line P of the connecting pin 90. The solenoid has a push rod 102. The push rod 102 is accommodated in the valve train chamber 37. The push rod 102 is in contact with an end portion 90S of the connecting pin 90. The push rod 102 moves in leftward and rightward directions depending on whether or not current is applied to the solenoid 100. When current is applied to the solenoid 100, the push rod 102 moves in the direction indicated by the arrow L1 in Fig. 7, causing the connecting pin 90 to move leftward. When the current supply to the solenoid 100 is cut off, the push rod 102 moves in the direction indicated by the arrow L2 in Fig. 7. At that time, no force is applied to the connecting

pin 90 from the solenoid 100. As a result, the connecting pin 90 moves rightward to the later-described non-connecting position because of the urging force of the coil spring 91.

[0054] As illustrated in Figs. 10A to 10D, the solenoid 100 moves the connecting pin 90 in a direction of the axial line W (see Fig. 6) of the intake rocker shaft 62 between a first non-connecting position Pn1 and the complete connecting position Pf. As illustrated in Fig. 10A, when no current is applied to the solenoid 100, the tip end 90T of the connecting pin 90 is positioned closer to the solenoid 100 relative to the side face 73S of the boss portion 73 of the first intake rocker arm 63 with respect to the direction of the axial line W of the intake rocker shaft 62. This position is defined as the "first non-connecting position Pn1". At that time, the connecting pin 90 is retained in the hole 73H of the boss portion 73 of the first intake rocker arm 63. The connecting pin 90 does not connect the first intake rocker arm 63 and the second intake rocker arm 64 to each other. When the connecting pin 90 is positioned at the first non-connecting position Pn1, no current is applied to the solenoid 100. When the connecting pin 90 is positioned at the first non-connecting position Pn1, the connecting pin 90 is urged by the coil spring 91 (see Fig. 8) in a direction from the second intake rocker arm 64 toward the first intake rocker arm 53 with respect to the direction of the axial line W of the intake rocker shaft 62. As illustrated in Fig. 10B, when current is applied to the solenoid 100, the connecting pin 90 moves in the direction indicated by the arrow L1 in Fig. 10B because of the pressing force of the push rod 102 (see Fig. 7). In other words, the connecting pin 90 moves toward the second intake rocker arm 64 with respect to the direction of the axial line W of the intake rocker shaft 62. As viewed in plan, the tip end 90T of the connecting pin 90 reaches the position flush with the side face 74S of the boss portion 74 of the second intake rocker arm 64 with respect to the direction of the axial line W of the intake rocker shaft 62. This position is defined as a "second non-connecting position Pn2". At that time, the connecting pin 90 is retained in the hole 73H of the boss portion 73 of the first intake rocker arm 63. The connecting pin 90 does not connect the first intake rocker arm 63 and the second intake rocker arm 64 to each other. A region that extends from the first non-connecting position Pn1 to the second non-connecting position Pn2 and that includes the first non-connecting position Pn1 and the second non-connecting position Pn2 is collectively referred to as a non-connecting position. At the non-connecting position, the first intake rocker arm 63 and the second intake rocker arm 64 pivot independently of each other. This means that the intake valve 41 is driven by the first intake rocker arm 63.

[0055] As illustrated in Fig. 10C, when the current application to the solenoid 100 is continued, the connecting pin 90 moves further in the direction indicated by the arrow L1 in Fig. 10C because of the pressing force of the push rod 102, and advances to the position at which it is

inserted into the hole 74H of the boss portion 74 of the second intake rocker arm 64. In other words, the tip end 90T of the connecting pin 90 is positioned toward the arrow L1 in Fig. 10C relative to the side face 74S of the boss portion 74 of the second intake rocker arm 64 with respect to the direction of the axial line W of the intake rocker shaft 62. This position is defined as an "intermediate connecting position Ph". The intermediate connecting position Ph represents a region that extends from the second non-connecting position Pn2 to the complete connecting position Pf and that does not include the second non-connecting position Pn2 or the complete connecting position Pf. Thereafter, as illustrated in Fig. 10D, when the current application to the solenoid 100 is further continued, the connecting pin 90 moves further in the direction indicated by the arrow L1 in Fig. 10D, and the connecting pin 90 reaches the complete connecting position Pf, at which the connecting pin 90 connects the first intake rocker arm 63 and the second intake rocker arm 64 to each other. At that time, the connecting pin 90 is retained in the hole 73H of the boss portion 73 of the first intake rocker arm 63 and in the hole 74H of the boss portion 74 of the second intake rocker arm 64. When the connecting pin 90 is positioned at the complete connecting position Pf, current is applied to the solenoid 100. At the intermediate connecting position Ph and the complete connecting position Pf, the first intake rocker arm 63 and the second intake rocker arm 64 pivot integrally with each other. As a result, the intake valve 41 is driven by the second intake rocker arm 64, which interlocks with the second intake cam 66 having the lift portion 65B with a greater lift amount. When the current application to the solenoid 100 is stopped, the connecting pin 90 moves in the direction indicated by the arrow L2 in Fig. 10D to the first non-connecting position Pn1 because of the coil spring 91 (see Fig. 8). By moving the connecting pin 90 between the first non-connecting position Pn1 and the complete connecting position Pf, the timing for opening and closing the intake valve 41 can be changed. In other words, the timing for opening and closing the intake valve 41 can be changed by changing the rocker arm that drives the intake valve 41.

[0056] As illustrated in Fig. 4A, the exhaust rocker arm 83 is pivotably supported by the exhaust rocker shaft 82. The exhaust rocker arm 83 has a body portion 85, a roller support portion 86, and an arm portion 87. The body portion 85 has an insertion hole 85H in which the exhaust rocker shaft 82 is to be inserted. The roller support portion 86 extends upward from the body portion 85. As illustrated in Fig. 3, the roller support portion 86 is formed in a two-forked shape. The roller 86R is rotatably supported on the roller support portion 86. The roller 86R is in contact with the exhaust cam 84 (see Fig. 2). The roller 86R is positioned in front of the exhaust cam 84. By rotation of the exhaust cam 84, the exhaust rocker arm 83 is pivoted in the directions indicated by the arrows S1 and S2 in Fig. 4A. The arm portion 87 has a pair of arms 87R and 87L. As illustrated in Fig. 4A, the arm portion 87

extends downward from the body portion 85. The arms 87R and 87L are disposed at the positions facing respective front ends 43B of the exhaust valves 43. A pressing portion (not shown) is fitted to a position of the arm 87R that faces the front end 43B of one of the exhaust valves 43. A pressing portion 87P is fitted to a position of the arm 87L that faces the front end 43B of the other one of the exhaust valves 43. The pressing portion protrudes toward the front end 43B of the exhaust valve 43. The pressing portion 87P is in contact with the front end 43B of the intake valve 43. It is possible that there may be a gap between the pressing portion 87P and the front end 43B of the exhaust valve 43.

[0057] As illustrated in Fig. 11, the engine 11 has a crankshaft sensor 50. The crankshaft sensor 50 includes a rotational speed sensing unit configured to sense the rotational speed of the crankshaft 15, and a rotational position sensing unit configured to sense the rotational position of the crankshaft 15. The phrase "sensing the rotational speed of the crankshaft 15 and the rotational position of the crankshaft 15" is meant to include the case in which the rotational speed of the crankshaft 15 and the rotational position of the crankshaft 15 are directly sensed and the case in which the rotational speed of the crankshaft 15 and the rotational position of the crankshaft 15 are indirectly sensed by estimating the rotational speed of the crankshaft 15 and the rotational position of the crankshaft 15. In the present preferred embodiment, the crankshaft sensor 50 senses that target portions, which are provided at regular intervals on a member that rotates integrally with the crankshaft 15, pass the crankshaft sensor 50 due to the rotation of the crankshaft 15. Based on the sensing of the target portions of the crankshaft sensor 50, the rotational speed of the crankshaft 15 and the rotational position of the crankshaft 15 are estimated, and the rotational speed of the crankshaft 15 and the rotational position of the crankshaft 15 are indirectly sensed. The term "rotation speed of the crankshaft 15" means the number of rotations of the crankshaft 15 per unit time. The term "rotation position of the crankshaft 15" means the rotation angle of the crankshaft 15. Note that the rotational speed sensing unit and the rotational position sensing unit may be provided in different sensors. In other words, it is possible to use two sensors, a first sensor having the rotational speed sensing unit and a second sensor having the rotational position sensing unit. The rotation condition of the camshaft 61 can be ascertained by sensing the rotational position of the crankshaft 15.

[0058] The engine 11 has an ECU 110 (Electronic Control Unit) as a controller for controlling various components including the solenoid 100. The ECU 110 includes an instruction unit 115, a drive signal supplying unit 125, a monitoring unit 130, and a current controlling unit 135.

[0059] The instruction unit 115 issues an instruction for driving the solenoid 100 based on the rotational speed of the crankshaft 15 sensed by the crankshaft sensor 50. For example, if the rotational speed of the crankshaft 15

becomes equal to or higher than a predetermined rotational speed, or if the rotational speed of the crankshaft 15 becomes lower than a predetermined rotational speed, the instruction unit 115 issues an instruction for driving the solenoid 100 based on the rotational speed of the crankshaft 15 sensed by the crankshaft sensor 50. The rotation speed of the crankshaft 15 at the time when the first intake rocker arm 63 and the second intake rocker arm 64 are connected to each other by driving the solenoid 100 and the rotation speed of the crankshaft 15 at the time when the first intake rocker arm 63 and the second intake rocker arm 64 are disconnected from each other by driving the solenoid 100 may be the same as or different from each other.

[0060] The drive signal supplying unit 125 supplies a drive signal to the solenoid 100 based on the rotational position of the crankshaft 15 sensed by the rotational position sensing unit 50 in a state in which driving of the solenoid 100 is instructed by the instruction unit 115. The degree of opening and closing of the intake valve 41 can be determined based on the rotational position of the crankshaft 15. The pivot positions of the first intake rocker arm 63 and the second intake rocker arm 64 can be determined based on the rotational position of the crankshaft 15. Based on the rotational position of the crankshaft 15, it is possible to determine whether the hole 73H of the first intake rocker arm 63 and the hole 74H of the second intake rocker arm 64 are in agreement with each other, or unaligned relative to each other, with respect to the direction of the axial line of the connecting pin 90. The drive signal supplying unit 125 is configured to start supplying the drive signal to the solenoid 100 so as to cause the tip end 90T of the connecting pin 90 to reach the position flush with the side face 74S (see Fig. 10B) of the boss portion 74 of the second intake rocker arm 64 with respect to the direction of the axial line W (see Fig. 6) of the intake rocker shaft 62 after one of the first intake rocker arm 63 and the second intake rocker arm 64 that should start to pivot earlier than the other starts to pivot so that relative positions of the first intake rocker arm 63 and the second intake rocker arm 64 start to change, and to also cause the connecting pin 90 to reach the complete connecting position (see Fig. 10D) between the time when the first intake rocker arm 63 and the second intake rocker arm 64 complete pivoting and the next time when the one of the first intake rocker arm 63 and the second intake rocker arm 64 that should start to pivot earlier than the other starts to pivot. In the present preferred embodiment, the second intake rocker arm 64 starts to pivot earlier than the first intake rocker arm 63 does. The second intake rocker arm 64 completes pivoting later than the first intake rocker arm 63 does.

[0061] The phrase "the first intake rocker arm 63 starts to pivot" means that the roller 69R of the first intake rocker arm 63 is removed from contact with the base portion 65A of the first intake cam 65 and is brought in contact with the lift portion 65B of the first intake cam 65. The phrase "the second intake rocker arm 64 starts to pivot"

means that the roller 70R of the second intake rocker arm 64 is removed from contact with the base portion 66A of the second intake cam 66 and is brought in contact with the lift portion 66B of the second intake cam 66.

[0062] The phrase "one of the first intake rocker arm 63 and the second intake rocker arm 64 that should start to pivot earlier than the other starts to pivot so that relative positions of the first intake rocker arm 63 and the second intake rocker arm 64 start to change" means that either the roller 69R of the first intake rocker arm 63 is removed from contact with the base portion 65A of the first intake cam 65 and is brought in contact with the lift portion 65B of the first intake cam 65, or the roller 70R of the second intake rocker arm 64 is removed from contact with the base portion 66A of the second intake cam 66 and is brought in contact with the lift portion 66B of the second intake cam 66, so that the relative positions of the hole 73H of the first intake rocker arm 63 and the hole 74H of the second intake rocker arm 64 start to change.

[0063] In the present preferred embodiment, the timing at which the roller 70R of the second intake rocker arm 64 is removed from contact with the base portion 66A of the second intake cam 66 and is brought in contact with the lift portion 66B of the second intake cam 66 is earlier than the timing at which the roller 69R of the first intake rocker arm 63 is removed from contact with the base portion 65A of the first intake cam 65 and is brought in contact with the lift portion 65B of the first intake cam 65. Accordingly, the timing at which "one of the first intake rocker arm 63 and the second intake rocker arm 64 that should start to pivot earlier than the other starts to pivot" means the timing at which the roller 70R of the second intake rocker arm 64 is removed from contact with the base portion 66A of the second intake cam 66 and is brought in contact with the lift portion 66B of the second intake rocker arm 66.

[0064] The phrase "the first intake rocker arm 63 completes pivoting" means that the roller 69R of the first intake rocker arm 63 is removed from contact with the lift portion 65B of the first intake cam 65 and is brought in contact with the base portion 65A of the first intake cam 65. The phrase "the second intake rocker arm 64 completes pivoting" means that the roller 70R of the second intake rocker arm 64 is removed from contact with the lift portion 66B of the second intake cam 66 and is brought in contact with the base portion 66A of the second intake cam 66.

[0065] The phrase "the first intake rocker arm 63 and the second intake rocker arm 64 complete pivoting" means a state in which neither the first intake rocker arm 63 nor the second intake rocker arm 64 is pivoting and the intake valve 41 is closed. That is, it means that the roller 69R of the first intake rocker arm 63 is removed from contact with the lift portion 65B of the first intake cam 65 and is brought in contact with the base portion 65A of the first intake cam 65 and also the roller 70R of the second intake rocker arm 64 is removed from contact with the lift portion 66B of the second intake cam 66 and

is brought in contact with the base portion 66A of the second intake cam 66.

[0066] In the present preferred embodiment, the timing at which the roller 70R of the second intake rocker arm 64 is removed from contact with the lift portion 66B of the second intake cam 66 and is brought in contact with the base portion 66A of the second intake cam 66 is later than the timing at which the roller 69R of the first intake rocker arm 63 is removed from contact with the lift portion 65B of the first intake cam 65 and is brought in contact with the base portion 65A of the first intake cam 65. Accordingly, the timing at which "the first intake rocker arm 63 and the second intake rocker arm 64 complete pivoting" means the timing at which the roller 70R of the second intake rocker arm 64 is removed from contact with the lift portion 66B of the second intake cam 66 and is brought in contact with the base portion 66A of the second intake cam 66.

[0067] The drive signal supplying unit 125 may be configured to start supplying the drive signal to the solenoid 100 when the first intake rocker arm 63 and the second intake rocker arm 64 complete pivoting. The drive signal supplying unit 125 may be configured to start supplying the drive signal to the solenoid 100 so as to cause the tip end 90T of the connecting pin 90 to reach the position flush with the side face 74S (see Fig. 10B) of the boss portion 74 of the second intake rocker arm 64 with respect to the direction of the axial line W (see Fig. 6) of the intake rocker shaft 62 after the intake valve 41 starts to open, and to also cause the connecting pin 90 to reach the complete connecting position (see Fig. 10D) between the time when the intake valve 41 finishes closing and the next time when the intake valve 41 starts to open. It should be noted that a time delay occurs between the time when the drive signal supplying unit 125 starts supplying the drive signal and the time when the solenoid 100 is driven and the push rod 102 is moved.

[0068] In addition, the drive signal supplying unit 125 is configured to stop supplying the drive signal to the solenoid 100 so as to cause the tip end 90T of the connecting pin 90 to return to the position flush with the side face 74S (see Fig. 10B) of the boss portion 74 of the second intake rocker arm 64 with respect to the direction of the axial line W (see Fig. 6) of the intake rocker shaft 62 and to also cause the connecting pin 90 to return to the first non-connecting position (see Fig. 10A) between the time when the first intake rocker arm 63 and the second intake rocker arm 64 complete pivoting and the next time when the one of the first intake rocker arm 63 and the second intake rocker arm 64 that should start to pivot earlier than the other starts to pivot.

[0069] The drive signal supplying unit 125 may be configured to stop supplying the drive signal to the solenoid 100 when the first intake rocker arm 63 and the second intake rocker arm 64 complete pivoting. The drive signal supplying unit 125 may be configured to stop supplying the drive signal to the solenoid 100 so as to cause the tip end 90T of the connecting pin 90 to return to the po-

sition flush with the side face 74S (see Fig. 10B) of the boss portion 74 of the second intake rocker arm 64, and to also cause the connecting pin 90 to return to the first non-connecting position (see Fig. 10A) between the time when the intake valve 41 finishes closing and the next time when the intake valve 41 starts to open.

[0070] The monitoring unit 130 monitors the voltage of a battery 105. The battery 105 is connected to the solenoid 100.

[0071] The current controlling unit 135 controls the current to be supplied to the solenoid 100. The just-mentioned controlling of the current is carried out based on the voltage of the battery 105 that is monitored by the monitoring unit 130. The current controlling unit 135 sets the current value to be supplied to the solenoid 100 according to the current voltage of the battery 105. The current controlling unit 135 can reduce fluctuations in the current to be supplied to the solenoid 100. Note that the current to be supplied to the solenoid 100 varies depending on the voltage of the battery 105 and temperature of the solenoid 100. The voltage of the battery 105 changes because the battery 105 is charged by the operation of the engine 11. The ECU 110 controls the solenoid 100 so that the temperature of the solenoid 100 does not increase easily. Therefore, variations in the current that result from variations in the temperature of the solenoid 100 are small. For this reason, the current can be controlled based on the voltage of the battery 105.

[0072] Next, the operations of the first intake rocker arm 63 and the second intake rocker arm 64 will be described. First, a description is given regarding the case in which the connecting pin 90 is positioned at the non-connecting position. The first intake rocker arm 63 is pivoted by receiving a force from the lift portion 65B of the first intake cam 65 to thereby drive the intake valve 41. More specifically, in association with rotation of the camshaft 61, the first intake cam 65, which is provided on the camshaft 61, rotates in the direction indicated by the arrow A in Fig. 4A. In association with rotation of the first intake cam 65, the lift portion 65B and the roller 69R come into contact with each other, and the roller support portion 69 moves in the direction indicated by the arrow X1 in Fig. 4A about the intake rocker shaft 62. The roller support portion 69 is connected to the arm portion 71 via the body portion 67. Therefore, the above-described movement of the roller support portion 69 causes the arm portion 71 to move in the direction indicated by the arrow Y1 in Fig. 4A about the intake rocker shaft 62. Thereby, the arm portion 71 pushes the intake valve 41 toward the inside of the combustion chamber 24. As a result, the intake valve 41 opens the passageway between the intake passage 42 and the combustion chamber 24.

[0073] As the camshaft 61 rotates further, the lift portion 65B no longer makes contact with the roller 69R, and the base portion 65A comes into contact with the roller 69R. At that time, the roller support portion 69 moves in the direction indicated by the arrow X2 in Fig. 4A. In association with the movement of the roller support portion

69, the arm portion 71 moves in the direction indicated by the arrow Y2 in Fig. 4A. Accordingly, the intake valve 41 also moves in the direction indicated by the arrow Y2 in Fig. 4A. As a result, the intake valve 41 closes the passageway between the intake passage 42 and the combustion chamber 24.

[0074] When the connecting pin 90 is positioned at the non-connecting position, the second intake rocker arm 64 does not drive the intake valve 41 even when it is pivoted by receiving a force from the lift portion 66B of the second intake cam 66. More specifically, in association with rotation of the camshaft 61, the second intake cam 66, which is provided on the camshaft 61, rotates in the direction indicated by the arrow A in Fig. 4B. In association with rotation of the second intake cam 66, the lift portion 66B and the roller 70R of the second intake cam 66 come into contact with each other, and the roller support portion 70 moves in the direction indicated by the arrow X3 in Fig. 4B about the intake rocker shaft 62. The roller support portion 70 is connected to the boss portion 74 via the body portion 68. Therefore, the above-described movement of the roller support portion 70 causes the boss portion 74 to move in the direction indicated by the arrow Z1 in Fig. 4B about the intake rocker shaft 62. However, the connecting pin 90 is positioned at the non-connecting position, so the connecting pin 90 does not connect the first intake rocker arm 63 and the second intake rocker arm 64 to each other. As a result, the above-described movement of the roller support portion 70 does not move the arm portion 71 of the first intake rocker arm 63.

[0075] Next, a description is given regarding the case in which the connecting pin 90 is positioned at the complete connecting position. As illustrated in Fig. 5, the lift amount of the intake valve 41 caused by the second intake cam 66 is larger than the lift amount of the intake valve 41 caused by the first intake cam 65. Therefore, as illustrated in Fig. 9, when the connecting pin 90 is positioned at the complete connecting position, the intake valve 41 is driven by the second intake rocker arm 64, which interlocks with the second intake cam 66. The connecting pin 90 connects the first intake rocker arm 63 and the second intake rocker arm 64 to each other. Thus, as described above, when the boss portion 74 moves in the direction indicated by the arrow Z1 in Fig. 4B about the intake rocker shaft 62, the boss portion 73 of the first intake rocker arm 63 also moves in the direction indicated by the arrow Z1 in Fig. 4B about the intake rocker shaft 62, and the arm portion 71 of the first intake rocker arm 63 moves in the direction indicated by the arrow Y1 in Fig. 4A about the intake rocker shaft 62. Thereby, the arm portion 71 pushes the intake valve 41 toward the inside of the combustion chamber 24. As a result, the intake valve 41 opens the passageway between the intake passage 42 and the combustion chamber 24. Because the lift amount of the intake valve 41 caused by the second intake cam 66 is larger than the lift amount of the intake valve 41 caused by the first intake cam 65,

the time in which the intake valve 41 is open becomes longer.

[0076] As the camshaft 61 rotates further, the lift portion 66B of the second intake cam 66 no longer makes contact with and the roller 70R, and the base portion 66A of the second intake cam 66 comes into contact with the roller 70R. At that time, the roller support portion 70 moves in the direction indicated by the arrow X4 in Fig. 4B. In association with the movement of the roller support portion 70, the boss portion 74 moves in the direction indicated by the arrow Z2 in Fig. 4B, and the boss portion 73 also moves in the direction indicated by the arrow Z2 in Fig. 4A. As a result, the arm portion 71 of the first intake rocker arm 63 moves in the direction indicated by the arrow Y2 in Fig. 4A. Accordingly, the intake valve 41 also moves in the direction indicated by the arrow Y2 in Fig. 4A. As a result, the intake valve 41 closes the passageway between the intake passage 42 and the combustion chamber 24.

[0077] Next, an example of the movement control process of the connecting pin 90 according to the present preferred embodiment will be described with reference to Fig. 12. Fig. 12 is a timing chart about the connecting of the first intake rocker arm 63 and the second intake rocker arm 64. In Fig. 12, the solid line represents the movement of the connecting pin 90 in the case that the drive signal supplying unit 125 is provided. The dash-dotted line represents the movement of the connecting pin 90 in the case that the drive signal supplying unit 125 is not provided. The dash-dot-dot line represents the actual movement of the intake valve 41. The dashed line represents the virtual movement of the intake valve 41.

[0078] In Fig. 12, reference character Pp indicates the position of the connecting pin 90. Reference character Pn1 represents the first non-connecting position. Reference character Pn2 represents the second non-connecting position. Reference character Pf represents the complete connecting position. The position Pp of the connecting pin 90 changes between the first non-connecting position Pn1, the second non-connecting position Pn2, and the complete connecting position Pf. Reference character Bp represents the lift amount of the intake valve 41. Reference character B0 indicates the position at which the first intake rocker arm 63 and the second intake rocker arm 64 complete pivoting and the intake valve 41 is closed, i.e., a lift amount of zero. Reference character B1 represents the lift amount at which the intake valve 41 is opened to the maximum by the first intake rocker arm 63. Reference character B2 represents the lift amount at which the intake valve 41 is opened to the maximum by the second intake rocker arm 64. Reference character T represents time. At times T1, T3x, and T5, the intake valve 41 starts to open, and at times T2, T4x, and T6, the intake valve 41 finishes closing.

[0079] First, the movements of the connecting pin 90 in the case that the drive signal supplying unit 125 is provided will be described. The instruction unit 115 issues an instruction for driving the solenoid 100 because

the rotation speed of the crankshaft 15 sensed by the crankshaft sensor 50 becomes equal to or higher than a predetermined rotation speed at time Tx while the motorcycle 1 is traveling. Based on the rotational position of the crankshaft 15 sensed by the crankshaft sensor 50, the drive signal supplying unit 125 starts supplying a drive signal to the solenoid 100 at time Tc1 so as to cause the tip end 90T of the connecting pin 90 to reach the second non-connecting position Pn2 after the second intake rocker arm 64 starts to pivot so that the relative positions of the first intake rocker arm 63 and the second intake rocker arm 64 start to change, and to also cause the connecting pin 90 to reach the complete connecting position Pf between the time when the first intake rocker arm 63 and the second intake rocker arm 64 complete pivoting and the next time when the second intake rocker arm 64 starts to pivot. At time Tc2, the connecting pin 90 starts to move. The position Pp of the connecting pin 90 starts to change from the first non-connecting position Pn1 to the second non-connecting position Pn2.

[0080] At time T3, the second intake rocker arm 64 starts to pivot, and the relative positions of the first intake rocker arm 63 and the second intake rocker arm 64 start to change. At time T3x, the first intake rocker arm 63 starts to pivot, and the intake valve 41 starts to open. At time Tc3, which is between the time when the second intake rocker arm 64 starts to pivot and the relative positions of the first intake rocker arm 63 and the second intake rocker arm 64 start to change and the time when the second intake rocker arm 64 completes pivoting, the tip end 90T of the connecting pin 90 reaches the second non-connecting position Pn2. At that time, the tip end 90T of the connecting pin 90 keeps pushing the side face 74S of the boss portion 74 of the second intake rocker arm 64.

[0081] At time T4x, the first intake rocker arm 63 completes pivoting, and the intake valve 41 finishes closing. At time T4, when the second intake rocker arm 64 completes pivoting, the hole 73H of the boss portion 73 of the first intake rocker arm 63 and the hole 74H of the boss portion 74 of the second intake rocker arm 64 overlap with each other as viewed in side view. As a result, the tip end 90T of the connecting pin 90 is allowed to be inserted into the hole 74H. At time Tc4, which is earlier than time T5 at which the second intake rocker arm 64 starts to pivot next, the connecting pin 90 reaches the complete connecting position Pf. This allows the first intake rocker arm 63 and the second intake rocker arm 64 to be connected to each other. Thereafter, at time T5, the second intake rocker arm 64 starts to pivot, and the intake valve 41 starts to open at the timing caused by the second intake rocker arm 64. At time T6, the second intake rocker arm 64 completes pivoting, and the intake valve 41 closes. From time T5 to time T6, the relative positions of the first intake rocker arm 63 and the second intake rocker arm 64 do not change because the first intake rocker arm 63 and the second intake rocker arm 64 are connected to each other.

[0082] Next, the movements of the connecting pin 90 in the case that the drive signal supplying unit 125 is not provided will be described. Supplying of a drive signal to the solenoid 100 is started at time Ta1, and then, the connecting pin 90 starts to move at time Ta2. At time Ta3, which is earlier than time T3, the tip end 90T of the connecting pin 90 reaches the second non-connecting position Pn2. At that time, the tip end 90T of the connecting pin 90 is allowed to be inserted into the hole 74H because neither the first intake rocker arm 63 nor the second intake rocker arm 64 is pivoting. When the second intake rocker arm 64 starts to pivot at time T3, the connecting pin 90 has not yet reached the complete connecting position Pf. Therefore, from time T3 to time T4, the connecting pin 90 does not connect the first intake rocker arm 63 and the second intake rocker arm 64 to each other completely. This means that the first intake rocker arm 63 and the second intake rocker arm 64 pivot with the connecting pin 90 not being positioned at the complete connecting position Pf, and the opening and closing of the intake valve 41 are performed at the timing caused by the second intake rocker arm 64. Because the connecting pin 90 has not been completely inserted in the hole 74H of the boss portion 74 of the second intake rocker arm 64, an excessive load is applied to the portion of the connecting pin 90 that has been inserted in the hole 74H. As a consequence, the connecting pin cannot be moved smoothly to the complete connecting position Pf. When the second intake rocker arm 64 completes pivoting at time T4, the tip end 90T of the connecting pin 90 starts to move again within the hole 74H toward the complete connecting position Pf. At time Ta4, the connecting pin 90 reaches the complete connecting position Pf.

[0083] Supplying of a drive signal to the solenoid 100 is started at time Tb1, and then, the connecting pin 90 starts to move at time Tb2. At time T3, the tip end 90T of the connecting pin 90 reaches the second non-connecting position Pn2. At that time, the tip end 90T of the connecting pin 90 is allowed to be inserted into the hole 74H because neither the first intake rocker arm 63 nor the second intake rocker arm 64 is pivoting. However, at time T3, the second intake rocker arm 64 starts to pivot simultaneously with the movement of the connecting pin 90. As a consequence, the connecting pin 90 is repelled toward the first intake rocker arm 63. In other words, the connecting pin 90 is repelled from the second non-connecting position Pn2 toward the first non-connecting position Pn1. Because the connecting pin 90 is repelled, the first intake rocker arm 63 and the second intake rocker arm 64 are disconnected. At time Tb3, the tip end 90T of the connecting pin 90 reaches the second non-connecting position Pn2 again, but the hole 73H of the boss portion 73 and the hole 74H of the boss portion 74 are not in agreement with each other with respect to the direction of the axial line of the connecting pin 90. For this reason, the tip end 90T of the connecting pin 90 cannot move beyond the second non-connecting position Pn2.

When the second intake rocker arm 64 completes pivoting at time T4, the tip end 90T of the connecting pin 90 starts to move within the hole 74H. At time Tb4, the connecting pin 90 reaches the complete connecting position Pf.

[0084] Next, an example of the movement control process of the connecting pin 90 according to the present preferred embodiment will be described with reference to Fig. 13. Fig. 13 is a timing chart about disconnecting the first intake rocker arm 63 and the second intake rocker arm 64 from each other. In Fig. 13, the solid line represents the movement of the connecting pin 90 in the case that the drive signal supplying unit 125 is provided. The dash-dotted line represents the movement of the connecting pin 90 in the case that the drive signal supplying unit 125 is not provided. The dash-dot-dot line represents the actual movement of the intake valve 41. The dashed line represents the virtual movement of the connecting pin 90. At times T1, T3, and T5x, the intake valve 41 starts to open, and at times T2, T4, and T6x, the intake valve 41 finishes closing.

[0085] First, the movements of the connecting pin 90 in the case that the drive signal supplying unit 125 is provided will be described. The instruction unit 115 issues an instruction for driving the solenoid 100 because the rotation speed of the crankshaft 15 sensed by the crankshaft sensor 50 becomes equal to or lower than a predetermined rotation speed at time Ty while the motorcycle 1 is traveling. The drive signal supplying unit 125 stops supplying the drive signal to the solenoid 100 at time Te1 so as to cause the tip end 90T of the connecting pin 90 to return to the second non-connecting position Pn2 and to also cause the connecting pin 90 to return to the first non-connecting position Pn1 between the time when the first intake rocker arm 63 and the second intake rocker arm 64 complete pivoting and the next time when the second intake rocker arm 64 starts to pivot. At time Te2, the connecting pin 90 starts to move because of the urging force of the coil spring 91. The position Pp of the connecting pin 90 starts to change from the complete connecting position Pf to the first non-connecting position Pn1.

[0086] The tip end 90T of the connecting pin 90 returns to the second non-connecting position Pn2 at time Te3, which is between time T4 at which the second intake rocker arm 64 completes pivoting to close the intake valve 41 and time T5 at which the second intake rocker arm 64 starts to pivot the next time, and the connecting pin 90 returns to the first non-connecting position Pn1 at time Te4, which is earlier than time T5. This allows the first intake rocker arm 63 and the second intake rocker arm 64 to be disconnected from each other. Thereafter, at time T5, the second intake rocker arm 64 starts to pivot, and the relative positions of the first intake rocker arm 63 and the second intake rocker arm 64 start to change. At time T5x, the first intake rocker arm 63 starts to pivot, and the intake valve 41 starts to open at the timing caused by the first intake rocker arm 63. At time T6x, the first

intake rocker arm 63 completes pivoting, and the intake valve 41 closes.

[0087] Next, the movements of the connecting pin 90 in the case that the drive signal supplying unit 125 is not provided will be described. At time Td1, supplying of a drive signal to the solenoid 100 is started, and then, at time Td2, the connecting pin 90 starts to move. At that time, the tip end 90T of the connecting pin 90 moves from the complete connecting position Pf toward the second non-connecting position Pn2 because neither the first intake rocker arm 63 nor the second intake rocker arm 64 is pivoting. When the second intake rocker arm 64 starts to pivot at time T3, the connecting pin 90 has not yet reached the second non-connecting position Pn2. Consequently, the first intake rocker arm 63 and the second intake rocker arm 64 pivot with the connecting pin 90 not being positioned at the complete connecting position Pf. That is, the opening and closing of the intake valve 41 are performed at the timing caused by the second intake rocker arm 64. Consequently, an excessive load is applied to the portion of the connecting pin 90 that has been inserted in the hole 74H. As a consequence, the connecting pin 90 cannot be moved smoothly to the second non-connecting position Pn2. When the second intake rocker arm 64 completes pivoting at time T4, the tip end 90T of the connecting pin 90 starts to move again within the hole 74H toward the second non-connecting position Pn2. The tip end 90T of the connecting pin 90 returns to the second non-connecting position Pn2 at time Td3, and the connecting pin 90 returns to the first non-connecting position Pn1 at time Td4, which is earlier than time T5.

[0088] As illustrated in Fig. 14, the ECU 110 has a current supply circuit 140. The current supply circuit 140 supplies current to the solenoid 100 by application of a voltage as the drive signal from the battery 105. The current supply circuit 140 has a freewheeling diode 145, a first switching element 150, and a second switching element 155 disposed therein. The freewheeling diode 145 forms a freewheeling circuit 160 together with the solenoid 100. The first switching element 150 performs duty control of the voltage of the battery 105. The second switching element 155 is provided upstream of the solenoid 100.

[0089] When current is supplied from the battery 105 with the first switching element 150 being turned on, the current flows through the solenoid 100 and thereafter flows to the first switching element 150, as indicated by the arrows M in Fig. 14. On the other hand, when current is supplied from the battery 105 with the first switching element 150 being turned off, the current flows in the freewheeling circuit 160, as indicated by the arrows N in Fig. 15. That is, the current keeps flowing through the solenoid 100, the freewheeling diode 145, the second switching element 155, and the solenoid 100, in that order.

[0090] Next, the flow of current at the time of the movement control process of the connecting pin 90 according to the present preferred embodiment will be described

with reference to Fig. 16. In Fig. 16, reference character DSS denotes the drive signal supplying unit 125. Reference character CUR denotes the value of the current flowing through the solenoid 100. Reference character SW1 denotes the first switching element 150. Reference character SW2 denotes the second switching element 155. Reference character Pp indicates the position of the connecting pin 90. Reference character Pn1 represents the first non-connecting position. Reference character Pf represents the complete connecting position. The position Pp of the connecting pin 90 changes between the first non-connecting position Pn1 and the complete connecting position Pf. Reference character T represents time.

[0091] Based on the rotational position of the crankshaft 15 sensed by the crankshaft sensor 50, the drive signal supplying unit 125 starts supplying a drive signal to the solenoid 100 at time T1 so as to cause the tip end 90T of the connecting pin 90 to reach the second non-connecting position Pn2 after the second intake rocker arm 64 starts to pivot and the relative positions of the first intake rocker arm 63 and the second intake rocker arm 64 start to change, and to also cause the connecting pin 90 to reach the complete connecting position Pf between the time when the first intake rocker arm 63 and the second intake rocker arm 64 complete pivoting and the next time when the second intake rocker arm 64 starts to pivot. When the drive signal supplying unit 125 starts supplying the drive signal to the solenoid 100, the ECU 110 turns on the first switching element 150 and the second switching element 155. At time T2, the connecting pin 90 reaches the complete connecting position Pf. Even after the connecting pin 90 has reached the complete connecting position Pf, current is kept passing through the solenoid 100. At time T3, the ECU 110 starts duty control. When time T3 is reached, the ECU 110 repeats turning the first switching element 150 on and off. Therefore, the value of the current supplied to the solenoid 100 gradually decreases. At time T4, the current value supplied to the solenoid 100 has reached X in the ECU 110, so the ECU 110 can turn off the first switching element 150 and the second switching element 155. The drive signal supplying unit 125 stops supplying the drive signal to the solenoid 100 at time T4 so as to cause the tip end 90T of the connecting pin 90 to return to the second non-connecting position Pn2 and to also cause the connecting pin 90 to return to the first non-connecting position Pn1 between the time when the first intake rocker arm 63 and the second intake rocker arm 64 complete pivoting and the next time when the second intake rocker arm 64 starts to pivot. It is desirable that the supplying of the drive signal to the solenoid 100 be stopped when the value of the current supplied to the solenoid 100 is equal to or less than X, and at a time later than time T4, at which the value of the current supplied to the solenoid 100 becomes equal to or less than X. At time T4, the value of the current supplied to the solenoid 100 has been reduced sufficiently. Therefore, even if a counter-electromotive force is produced

at the second switching element 155, the counter-electromotive force applied to the second switching element 155 can be made small. As a result, the second switching element 155 is prevented from breakage. The current supplied to the solenoid 100 can be immediately cut off by turning off the second switching element 155. As a result, the connecting pin 90 immediately starts to move toward the first non-connecting position Pn1 because of the coil spring 91. At time T5, the connecting pin 90 completes the movement to the first non-connecting position Pn1. Note that the supplying of the drive signal to the solenoid 100 may be stopped when the current value supplied to the solenoid 100 is not equal to or less than X. The supplying of the drive signal to the solenoid 100 may be stopped at any time.

[0092] There are constraints on component layout in the motorcycle 1, but it is possible to achieve a size reduction by using a small-sized solenoid 100. However, the small-sized solenoid 100 tends to produce a small force, so such a solenoid 100 requires a relatively long time for moving the connecting pin 90. As a consequence, it is possible that the connecting pin 90 may be repelled back toward the first intake rocker arm 63 in the case that the second intake rocker arm 64 has started to pivot when a portion of the connecting pin 90 is inserted in the hole 74H of the second intake rocker arm 64 but the connecting pin 90 has not yet reached the complete connecting position Pf, or in the case that one of the first intake rocker arm 63 and the second intake rocker arm 64 has started to pivot when the tip end 90T of the connecting pin 90 is inserted in the hole 74H of the second intake rocker arm 64. However, in the present preferred embodiment, the drive signal supplying unit 125 starts supplying the drive signal to the solenoid 100 so as to cause the tip end 90T of the connecting pin 90 to reach the second non-connecting position Pn2 after one of the first intake rocker arm 63 and the second intake rocker arm 64 that should start to pivot earlier than the other starts to pivot so that relative positions of the first intake rocker arm 63 and the second intake rocker arm 64 start to change, and to also cause the connecting pin 90 to reach the complete connecting position Pf between the time when the first intake rocker arm 63 and the second intake rocker arm 64 complete pivoting and the next time when the one of the first intake rocker arm 63 and the second intake rocker arm 64 that should start to pivot earlier than the other starts to pivot. This makes it possible to prevent the first intake rocker arm 63 and the second intake rocker arm 64 from integrally pivoting with each other when the connecting pin 90 has not yet reached the complete connecting position Pf and to prevent the connecting pin 90 from being repelled backward. Therefore, the timing for opening and closing valves can be changed smoothly. The rigidity of the connecting pin can be made relatively low because the tip end 90T of the connecting pin 90 is prevented from excessive load. Thus, the weight of the connecting pin 90 can be reduced. Moreover, it is also possible to reduce the size of the solenoid 100.

[0093] The drive signal supplying unit 125 also starts supplying the drive signal to the solenoid 100 so as to cause the tip end 90T of the connecting pin 90 to reach the second non-connecting position Pn2 between the time when one of the first intake rocker arm 63 and the second intake rocker arm 64 that should start to pivot earlier than the other starts to pivot and the time when the first intake rocker arm 63 and the second intake rocker arm 64 complete pivoting, and to also cause the connecting pin 90 to reach the complete connecting position Pf between the time when the first intake rocker arm 63 and the second intake rocker arm 64 complete pivoting and the next time when the one of the first intake rocker arm 63 and the second intake rocker arm 64 that should start to pivot earlier than the other starts to pivot. This prevents the connecting pin 90 from being repelled, and also allows more freedom in setting the time until the tip end 90T of the connecting pin 90 reaches the non-connecting position Pn2. That is, the time until the tip end 90T of the connecting pin 90 reaches the non-connecting position Pn2 can be set relatively longer, so the size of the solenoid 100 can be prevented from increasing.

[0094] On the other hand, when the supplying of the drive signal to the solenoid 100 is stopped, the connecting pin 90 is moved by the urging force of the coil spring 91 from the complete connecting position Pf toward the first non-connecting position Pn1 with respect to the direction of the axial line W of the intake rocker shaft 62. When the connecting pin 90 is positioned at the intermediate connecting position Ph, the second intake rocker arm 64 and the first intake rocker arm 63 pivot integrally with each other. This means that the load resulting from the pivoting of at least one of the first intake rocker arm 63 and the second intake rocker arm 64 is applied excessively to the tip end 90T of the connecting pin 90. In the present preferred embodiment, however, the first intake rocker arm 63 and the second intake rocker arm 64 do not pivot when the connecting pin 90 is in the intermediate connecting position Ph. As a result, the connecting pin 90 can be moved to the non-connecting position smoothly.

[0095] The force that is applied to the connecting pin 90 by the solenoid 100 varies depending on the value of the current supplied to the solenoid 100. The present preferred embodiment can reduce variations in the current to be supplied to the solenoid 100 based on the voltage of the battery 105. This eliminates the necessity of monitoring the current value, thus simplifying the configuration.

<SECOND PREFERRED EMBODIMENT>

[0096] In the first preferred embodiment, the tip end 90T of the connecting pin 90 reaches the position flush with the side face 74S (see Fig. 10B) of the boss portion 74 of the second intake rocker arm 64 after one of the first intake rocker arm 63 and the second intake rocker arm 64 that should start to pivot earlier than the other

starts to pivot so that the relative positions of the first intake rocker arm 63 and the second intake rocker arm 64 start to change. This means that the tip end 90T of the connecting pin 90 may keep pushing the side face 74S of the boss portion 74 from the time when one of the first intake rocker arm 63 and the second intake rocker arm 64 that should start to pivot earlier than the other starts to pivot until the time when the first intake rocker arm 63 and the second intake rocker arm 64 complete pivoting. As illustrated in Fig. 17, the second preferred embodiment prevents the tip end 90T of the connecting pin 90 from making contact with the side face 74S of the boss portion 74.

[0097] The drive signal supplying unit 125 supplies a drive signal to the solenoid 100 based on the rotational position of the crankshaft 15 sensed by the rotational position sensing unit 50 in a state in which driving of the solenoid 100 is instructed by the instruction unit 115. The drive signal supplying unit 125 is configured to start supplying the drive signal to the solenoid 100 so as to cause the tip end 90T of the connecting pin 90 to reach the position flush with the side face 74S (see Fig. 10B) of the boss portion 74 of the second intake rocker arm 64 and to also cause the connecting pin 90 to reach the complete connecting position (see Fig. 10D) between the time when the first intake rocker arm 63 and the second intake rocker arm 64 complete pivoting and the next time when one of the first intake rocker arm 63 and the second intake rocker arm 64 that should start to pivot earlier than the other starts to pivot. The drive signal supplying unit 125 may be configured to start supplying the drive signal to the solenoid 100 when the intake valve 41 is closed. The drive signal supplying unit 125 may be configured to start supplying the drive signal to the solenoid 100 so as to cause the tip end 90T of the connecting pin 90 to reach the position flush with the side face 74S (see Fig. 10B) of the boss portion 74 of the second intake rocker arm 64 and to also cause the connecting pin 90 to reach the complete connecting position (see Fig. 10D) between the time when the intake valve 41 finishes closing and the next time when the intake valve 41 starts to open.

[0098] Next, an example of the movement control process of the connecting pin 90 according to the present preferred embodiment will be described with reference to Fig. 17. Fig. 17 is a timing chart about the connecting of the first intake rocker arm 63 and the second intake rocker arm 64. In Fig. 17, the solid line represents the movement of the connecting pin 90 in the case that the drive signal supplying unit 125 is provided. The dash-dot-dot line represents the actual movement of the intake valve 41. The dashed line represents the virtual movement of the connecting pin 90.

[0099] The drive signal supplying unit 125 starts supplying the drive signal to the solenoid 100 at time Tf1 so as to cause the tip end 90T of the connecting pin 90 to reach the second non-connecting position Pn2 and to also cause the tip end 90T of the connecting pin 90 to reach the complete connecting position Pf between the

time when the first intake rocker arm 63 and the second intake rocker arm 64 complete pivoting and the next time when the second intake rocker arm 64 starts to pivot. At time Tf2, which is later than time T4 at which the second intake rocker arm 64 has completed pivoting, the connecting pin 90 starts to move. Note that if the tip end 90T of the connecting pin 90 has not yet reached the second non-connecting position Pn2 at time T4, the connecting pin 90 may start to move at a time earlier than time T4. At time Tf3, which is earlier than time T5 at which the second intake rocker arm 64 starts to pivot next, the tip end 90T of the connecting pin 90 reaches the second non-connecting position Pn2. At that time, the hole 73H of the boss portion 73 of the first intake rocker arm 63 and the hole 74H of the boss portion 74 of the second intake rocker arm 64 overlap each other with respect to the direction of the axial line of the connecting pin 90. As a result, the tip end 90T of the connecting pin 90 is allowed to be inserted into the hole 74H. At time Tf4, which is earlier than time T5 at which the second intake rocker arm 64 starts to pivot next, the connecting pin 90 reaches the complete connecting position Pf.

[0100] If the tip end 90T of the connecting pin 90 comes into contact with the side face 74S of the boss portion 74 of the second intake rocker arm 64 when the second intake rocker arm 64 starts to pivot and the relative positions of the first intake rocker arm 63 and the second intake rocker arm 64 start to change, the pressing force of the solenoid 100 that presses the connecting pin 90 gradually increases. This can cause the force of the solenoid 100 to become larger than is usual when the first intake rocker arm 63 and the second intake rocker arm 64 have completed pivoting and the connecting pin 90 is inserted into the hole 74H of the boss portion 74, which may increase the levels of the operating noise of the solenoid 100 and the noise produced from the connecting pin 90. Moreover, there is a risk that the solenoid 100 may be put under a load because the solenoid 100 is in a different operation from the normal operation. In order to withstand such a load, it is necessary to increase the rigidity of the solenoid 100. Increasing the rigidity of the solenoid 100 tends to result in an increase in cost and an increase in the size of the solenoid 100. In the present preferred embodiment, however, the tip end 90T of the connecting pin 90 does not make contact with the side face 74S of the boss portion 74 of the second intake rocker arm 64 when the connecting pin 90 moves from the first non-connecting position Pn1 toward the complete connecting position Pf. Therefore, it is possible to prevent potential problems that can arise in the solenoid 100 and also reduce the size of the solenoid 100.

[0101] In the foregoing preferred embodiments, the arms 71 R and 71 L of the first intake rocker arm 63 drive the intake valves 41, but it is also possible that the second intake rocker arm 64 may be provided with arms such as to drive the intake valves 41. When the connecting pin 90 does not connect the first intake rocker arm 63 and the second intake rocker arm 64 to each other, the intake

valves 41 are opened and closed by the pivoting of the second intake rocker arm 64. When the connecting pin 90 connects the first intake rocker arm 63 and the second intake rocker arm 64 to each other, the intake valves 41 are opened and closed by the pivoting of the first intake rocker arm 63.

[0102] In the foregoing preferred embodiments, the second intake rocker arm 64 starts to pivot earlier than the first intake rocker arm 63 so that the relative positions of the first intake rocker arm 63 and the second intake rocker arm 64 start to change, but this is merely illustrative. More specifically, the first intake rocker arm 63 may start to pivot earlier than the second intake rocker arm 64 so that the relative positions of the first intake rocker arm 63 and the second intake rocker arm 64 start to change.

[0103] In the foregoing preferred embodiments, the exhaust rocker arm 83 drives the exhaust valve 43. However, it is also possible to provide a first exhaust cam and a second exhaust cam that have different lift amounts, a first exhaust rocker arm and a second exhaust rocker arm that are driven by the respective exhaust cams, and a connecting pin capable of connecting and disconnecting the first exhaust rocker arm and the second exhaust rocker arm, as in the opening and closing of the intake valve 41. As a result, when the first exhaust rocker arm and the second exhaust rocker arm are not connected to each other, the exhaust valve can be opened and closed by the pivoting of the first exhaust rocker arm. On the other hand, when the first exhaust rocker arm and the second exhaust rocker arm are connected to each other, the exhaust valve can be opened and closed by the pivoting of the second exhaust rocker arm. Thus, the timing for opening and closing the exhaust valve can be changed by controlling the connecting and disconnecting of the first exhaust rocker arm and the second exhaust rocker arm.

[0104] In the foregoing preferred embodiments, the rotation condition of the camshaft 61 is ascertained by sensing the rotational speed and the rotational position of the crankshaft 15 with the crankshaft sensor 50, but this is merely illustrative. For example, it is possible to ascertain the rotation condition of the camshaft 61 by directly or indirectly sensing the rotational speed and the rotational position of another shaft or the like that is disposed downstream of the crankshaft 15, or by directly or indirectly sensing the rotational speed and the rotational position of the camshaft 61.

[0105] In the foregoing preferred embodiments, the ECU 110 starts the duty control at time T3, as illustrated in Fig. 16, but this is merely illustrative. For example, the ECU 110 may start the duty control at time T2. When this is the case, the duty ratio may be constant from time T2 to time T4. It is also possible that the duty ratio from time T3 onward may be smaller than the duty ratio until time T3, or that the duty ratio from time T3 onward may be larger than the duty ratio until time T3. Herein, the term "duty ratio" refers to the duty ratio of the pulse voltage

applied to the second switching element 155. Moreover, the duty ratio may be either constant or varied from time T2 to time T3. The duty ratio may also be either constant or varied from time T3 onward. In addition, the ECU 110 may not carry out the duty control at the time of the movement control process of the connecting pin 90.

[0106] The power unit 10 is not limited to a unit-swing-type power unit that is supported so as to be vertically swingable relative to the body frame 2, but may be a power unit that is non-swingably supported to the body frame 2. Such a power unit may be provided with, for example, an engine and a multi-gear type transmission mechanism positioned at the rear of the engine, and the engine and transmission mechanism may be disposed together in a crankcase.

Claims

1. A single-cylinder internal combustion engine (11) comprising:

a crankcase (14) supporting a crankshaft (15);
 a rotational speed sensing unit (50) configured to sense the rotational speed of the crankshaft (15);
 a rotational position sensing unit (50) configured to sense the rotational position of the crankshaft (15);
 a cylinder unit (19) connected to the crankcase (14) and including a combustion chamber (24) and a cam chain chamber (35) positioned adjacent to the combustion chamber (24);
 a camshaft (61) supported by the cylinder unit (19) and connected to the crankshaft (15) by a cam chain (36) disposed in the cam chain chamber (35);
 a first cam (65) including a first lift portion (65B) and a first base portion (65A) and being configured to rotate integrally with the camshaft (61);
 a second cam (66), including a second base portion (66A) and a second lift portion (66B) having a different shape from that of the first lift portion (65B), and being configured to rotate integrally with the camshaft (61);
 a rocker shaft (62) supported by the cylinder unit (19) and disposed parallel to the camshaft (61);
 a first rocker arm (63) pivotably supported by the rocker shaft (62) and configured to be pivoted by receiving a force from the first lift portion (65B) of the first cam (65);
 a second rocker arm (64), pivotably supported by the rocker shaft (62), configured to be pivoted by receiving a force from the second lift portion (66B) of the second cam (66), disposed to a side of the first rocker arm (63), and including a side face (74S) facing the first rocker arm (63);
 a valve (41) disposed in the cylinder unit (19)

and configured to be driven by the first rocker arm (63) or the second rocker arm (64) to open and close the combustion chamber (24);
 a connecting pin (90) being freely movable in a direction parallel to the rocker shaft (62);
 a solenoid (100) configured to move the connecting pin (90) between a non-connecting position (Pn1), at which a tip end (90T) of the connecting pin (90) is positioned in or adjacent to the first rocker arm (63) relative to the side face (74S) of the second rocker arm (64) with respect to a direction of an axial line (W) of the rocker shaft (62) so that the connecting pin (90) does not connect the first rocker arm (63) and the second rocker arm (64) to each other, and a complete connecting position (Pf), at which the tip end (90T) of the connecting pin (90) is positioned in or adjacent to the second rocker arm (64) relative to the side face (74S) of the second rocker arm (64) with respect to the direction of the axial line (W) of the rocker shaft (62) so that the connecting pin (90) connects the first rocker arm (63) and the second rocker arm (64) to each other; and
 a controller (110) configured to control the solenoid (100), wherein:

the controller (110) comprises:

an instruction unit (115) configured to issue an instruction for driving the solenoid (100) based on the rotational speed of the crankshaft (15) sensed by the rotational speed sensing unit (50);
 and
 a drive signal supplying unit (125) configured to supply a drive signal to the solenoid (100) when the instruction unit (115) issues the instruction for driving the solenoid (100), based on the rotational position of the crankshaft (15) sensed by the rotational position sensing unit (50), wherein
 the drive signal supplying unit (125) is configured to start supplying the drive signal so as to cause the tip end (90T) of the connecting pin (90) to reach a position flush with the side face (74S) of the second rocker arm (64) with respect to the direction of the axial line (W) of the rocker shaft (62) after one of the first rocker arm (63) and the second rocker arm (64) that should start to pivot earlier than the other starts to pivot so that relative positions of the first rocker arm (63) and the second rocker arm (64) start to change, and
 to also cause the connecting pin (90)

to reach the complete connecting position (Pf) between the time when the first rocker arm (63) and the second rocker arm (64) complete pivoting and the next time when the one of the first rocker arm (63) and the second rocker arm (64) that should start to pivot earlier than the other starts to pivot.

2. An internal combustion engine (11) according to claim 1, wherein the drive signal supplying unit (125) is configured to start supplying the drive signal so as to cause the tip end (90T) of the connecting pin (90) to reach the position flush with the side face (74S) of the second rocker arm (64) with respect to the direction of the axial line (W) of the rocker shaft (62) between the time when one of the first rocker arm (63) and the second rocker arm (64) that should start to pivot earlier than the other starts to pivot so that relative positions of the first rocker arm (63) and the second rocker arm (64) start to change and the time when the first rocker arm (63) and the second rocker arm (64) complete pivoting, and to also cause the connecting pin (90) to reach the complete connecting position (Pf) between the time when the first rocker arm (63) and the second rocker arm (64) complete pivoting and the next time when the one of the first rocker arm (63) and the second rocker arm (64) that should start to pivot earlier than the other starts to pivot.
3. An internal combustion engine (11) according to claim 1, wherein the drive signal supplying unit (125) is configured to start supplying the drive signal so as to cause the tip end (90T) of the connecting pin (90) to reach the position flush with the side face (74S) of the second rocker arm (64) with respect to the direction of the axial line (W) of the rocker shaft (62), and to also cause the connecting pin (90) to reach the complete connecting position (Pf) between the time when the first rocker arm (63) and the second rocker arm (64) complete pivoting and the next time when the one of the first rocker arm (63) and the second rocker arm (64) that should start to pivot earlier than the other starts to pivot.
4. An internal combustion engine (11) according to any one of claims 1 to 3, further comprising:

an elastic body (91) configured to urge the connecting pin (90) from the complete connecting position (Pf) toward the non-connecting position (Pn1) with respect to the direction of the axial line (W) of the rocker shaft (62), and wherein:

the drive signal supplying unit (125) is configured to stop supplying the drive signal so as to cause the tip end (90T) of the connect-

ing pin (90) to return to the position flush with the side face (74S) of the second rocker arm (64) with respect to the direction of the axial line (W) of the rocker shaft (62), and to also cause the tip end (90T) of the connecting pin (90) to return to the non-connecting position (Pn1) between the time when the first rocker arm (63) and the second rocker arm (64) complete pivoting and the next time when the one of the first rocker arm (63) and the second rocker arm (64) that should start to pivot earlier than the other starts to pivot.

5. An internal combustion engine (11) according to any one of claims 1 to 4, wherein:

the first rocker arm (63) and the second rocker arm (64) are provided with respective holes (73H, 74H) to which the connecting pin (90) is to be inserted;

the connecting pin (90) is retained in the hole (73H) of the first rocker arm (63) when the connecting pin (90) is at the non-connecting position (Pn1), and the connecting pin (90) is retained in the hole (73H) of the first rocker arm (63) and the hole (74H) of the second rocker arm (64) when the connecting pin (90) is at the complete connecting position (Pf);

the solenoid (100) is disposed opposite to the second rocker arm (64) relative to the first rocker arm (63) with respect to a direction of an axial line (P) of the connecting pin (90); and the solenoid (100) includes a push rod (102) configured to make contact with the connecting pin (90).

6. An internal combustion engine (11) according to any one of claims 1 to 5, wherein the controller (110) further comprises a monitoring unit (130) configured to monitor a voltage of a battery (105), and a current controlling unit (135) configured to control a current to be supplied to the solenoid (100) based on the voltage monitored by the monitoring unit (130).
7. An internal combustion engine (11) according to any one of claims 1 to 6, wherein the controller (110) further comprises a current supply circuit (140) configured to supply current to the solenoid (100) by applying a voltage thereto as the drive signal, a free-wheeling diode (145) disposed in the current supply circuit (140) so as to form a freewheeling circuit (160) with the solenoid (100), and a switching element (150) disposed in the current supply circuit (140) and configured to perform duty control of the voltage.
8. An internal combustion engine (11) according to claim 7, wherein the controller (110) further compris-

es another switching element (155) provided upstream of the solenoid (100) in the freewheeling circuit (160).

9. An internal combustion engine (11) according to any one of claims 1 to 8, wherein the controller (110) is configured to shut off the current to be supplied to the solenoid (100) by turning off the other switching element (155) after reducing the value of the current to be supplied to the solenoid (100) by the duty control. 5
10. A straddle-type vehicle (1) comprising an internal combustion engine (11) according to any one of claims 1 through 9. 10
11. A method for controlling a single-cylinder internal combustion engine (11) comprising a crankcase (14) supporting a crankshaft (15); 15
a cylinder unit (19) connected to the crankcase (14) and including a combustion chamber (24) and a cam chain chamber (35) positioned adjacent to the combustion chamber (24); a camshaft (61) supported by the cylinder unit (19) and connected to the crankshaft (15) by a cam chain (36) disposed in the cam chain chamber (35); 20
a first cam (65) including a first lift portion (65B) and a first base portion (65A) and being configured to rotate integrally with the camshaft (61); 25
a second cam (66), including a second base portion (66A) and a second lift portion (66B) having a different shape from that of the first lift portion (65B), and being configured to rotate integrally with the camshaft (61); 30
a rocker shaft (62) supported by the cylinder unit (19) and disposed parallel to the camshaft (61); 35
a first rocker arm (63) pivotably supported by the rocker shaft (62) and configured to be pivoted by receiving a force from the first lift portion (65B) of the first cam (65); 40
a second rocker arm (64), pivotably supported by the rocker shaft (62), configured to be pivoted by receiving a force from the second lift portion (66B) of the second cam (66), disposed to a side of the first rocker arm (63), and including a side face (74S) facing the first rocker arm (63); 45
a valve (41) disposed in the cylinder unit (19) and configured to be driven by the first rocker arm (63) or the second rocker arm (64) to open and close the combustion chamber (24); 50
a connecting pin (90) being freely movable in a direction parallel to the rocker shaft (62); a solenoid (100) configured to move the connecting pin (90) between a non-connecting position (Pn1), at which a tip end (90T) of the connecting pin (90) is positioned in or adjacent to the first rocker arm (63) relative to the side face (74S) of the second rocker arm (64) with respect to a direction of an axial line (W) of the 55

rocker shaft (62) so that the connecting pin (90) does not connect the first rocker arm (63) and the second rocker arm (64) to each other, and a complete connecting position (Pf), at which the tip end (90T) of the connecting pin (90) is positioned in or adjacent to the second rocker arm (64) relative to the side face (74S) of the second rocker arm (64) with respect to the direction of the axial line (W) of the rocker shaft (62) so that the connecting pin (90) connects the first rocker arm (63) and the second rocker arm (64) to each other;

the method comprises:

sensing the rotational speed of the crankshaft (15);
sensing the rotational position of the crankshaft (15);
issuing an instruction for driving the solenoid (100) based on the sensed rotational speed of the crankshaft (15); and
supplying a drive signal to the solenoid (100) when the instruction for driving the solenoid (100) is issued, based on the sensed rotational position of the crankshaft (15), and
start supplying the drive signal so as to cause the tip end (90T) of the connecting pin (90) to reach a position flush with the side face (74S) of the second rocker arm (64) with respect to the direction of the axial line (W) of the rocker shaft (62) after one of the first rocker arm (63) and the second rocker arm (64) that should start to pivot earlier than the other starts to pivot so that relative positions of the first rocker arm (63) and the second rocker arm (64) start to change, and to also cause the connecting pin (90) to reach the complete connecting position (Pf) between the time when the first rocker arm (63) and the second rocker arm (64) complete pivoting and the next time when the one of the first rocker arm (63) and the second rocker arm (64) that should start to pivot earlier than the other starts to pivot.

12. A method for controlling a single-cylinder internal combustion engine (11) according to claim 11, further comprising:

start supplying the drive signal so as to cause the tip end (90T) of the connecting pin (90) to reach the position flush with the side face (74S) of the second rocker arm (64) with respect to the direction of the axial line (W) of the rocker shaft (62) between the time when one of the first rocker arm (63) and the second rocker arm (64) that should start to pivot earlier than the other starts to pivot so that relative positions of the first rocker arm (63) and the second rocker arm (64) start to change and the time when the first

rocker arm (63) and the second rocker arm (64) complete pivoting, and to also cause the connecting pin (90) to reach the complete connecting position (Pf) between the time when the first rocker arm (63) and the second rocker arm (64) complete pivoting and the next time when the one of the first rocker arm (63) and the second rocker arm (64) that should start to pivot earlier than the other starts to pivot,
 or
 start supplying the drive signal so as to cause the tip end (90T) of the connecting pin (90) to reach the position flush with the side face (74S) of the second rocker arm (64) with respect to the direction of the axial line (W) of the rocker shaft (62), and to also cause the connecting pin (90) to reach the complete connecting position (Pf) between the time when the first rocker arm (63) and the second rocker arm (64) complete pivoting and the next time when the one of the first rocker arm (63) and the second rocker arm (64) that should start to pivot earlier than the other starts to pivot.

duty control.

13. A method for controlling a single-cylinder internal combustion engine (11) according to any one of claims 11 or 12, further comprising:

stop supplying the drive signal so as to cause the tip end (90T) of the connecting pin (90) to return to the position flush with the side face (74S) of the second rocker arm (64) with respect to the direction of the axial line (W) of the rocker shaft (62), and to also cause the tip end (90T) of the connecting pin (90) to return to the non-connecting position (Pn1) between the time when the first rocker arm (63) and the second rocker arm (64) complete pivoting and the next time when the one of the first rocker arm (63) and the second rocker arm (64) that should start to pivot earlier than the other starts to pivot.

14. A method for controlling a single-cylinder internal combustion engine (11) according to any one of claims 11 to 13, further comprising:

monitoring a voltage of a battery (105), and a current controlling unit (135) configured to control a current to be supplied to the solenoid (100) based on the monitored voltage.

15. A method for controlling a single-cylinder internal combustion engine (11) according to any one of claims 11 to 14, further comprising:

shutting off the current to be supplied to the solenoid (100) after reducing the value of the current to be supplied to the solenoid (100) by the

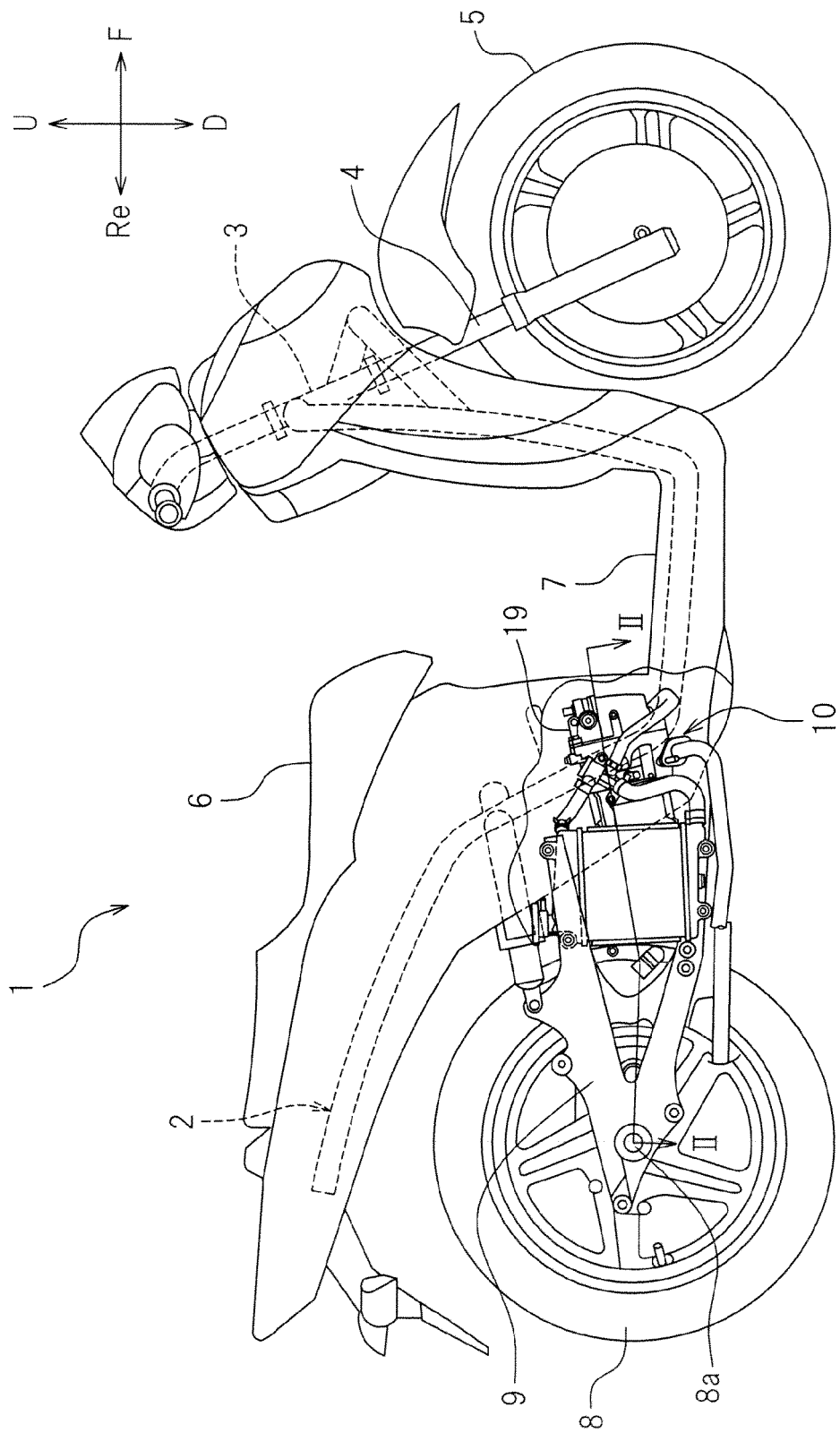


FIG. 1

FIG.2

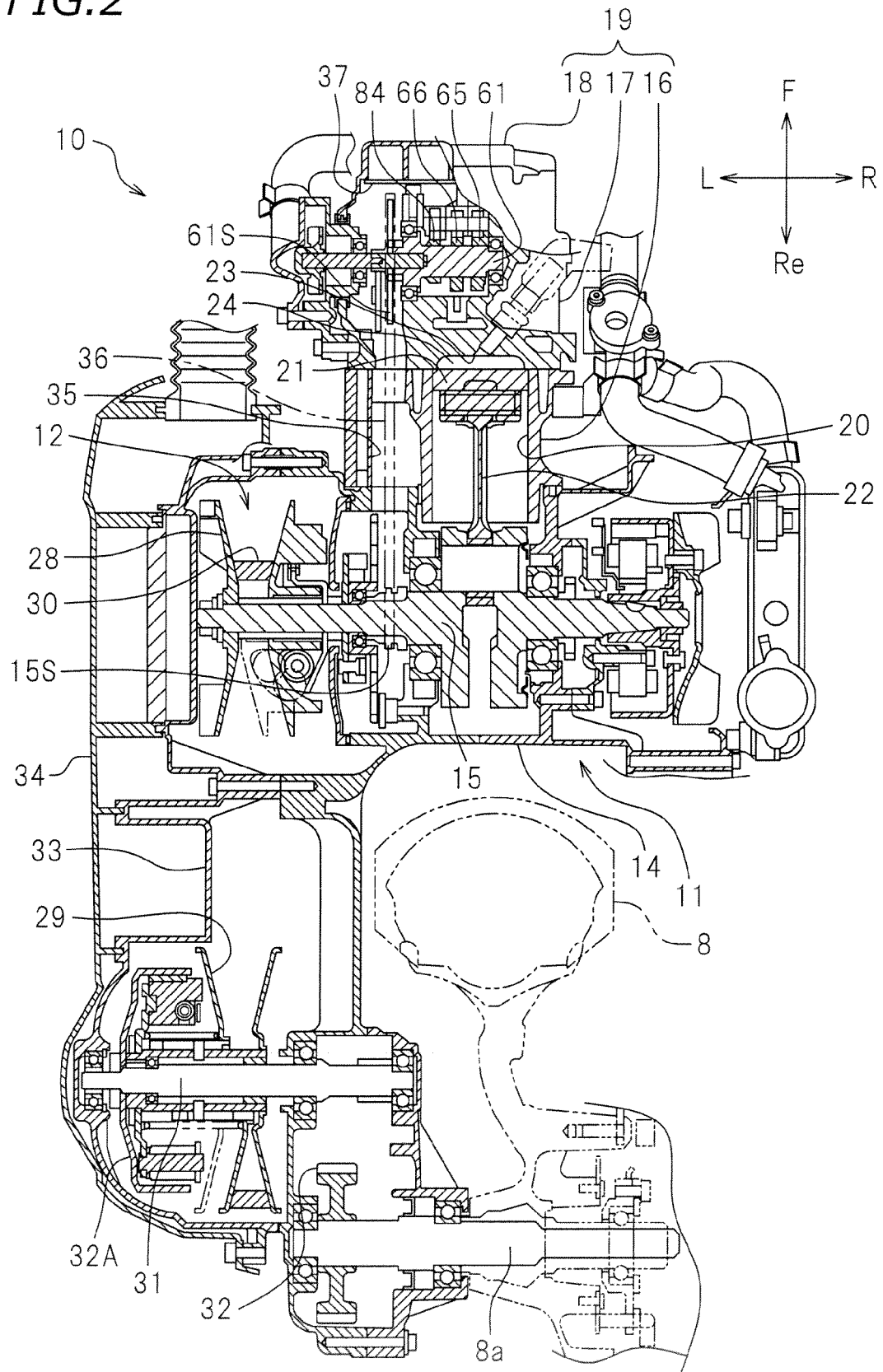


FIG.3

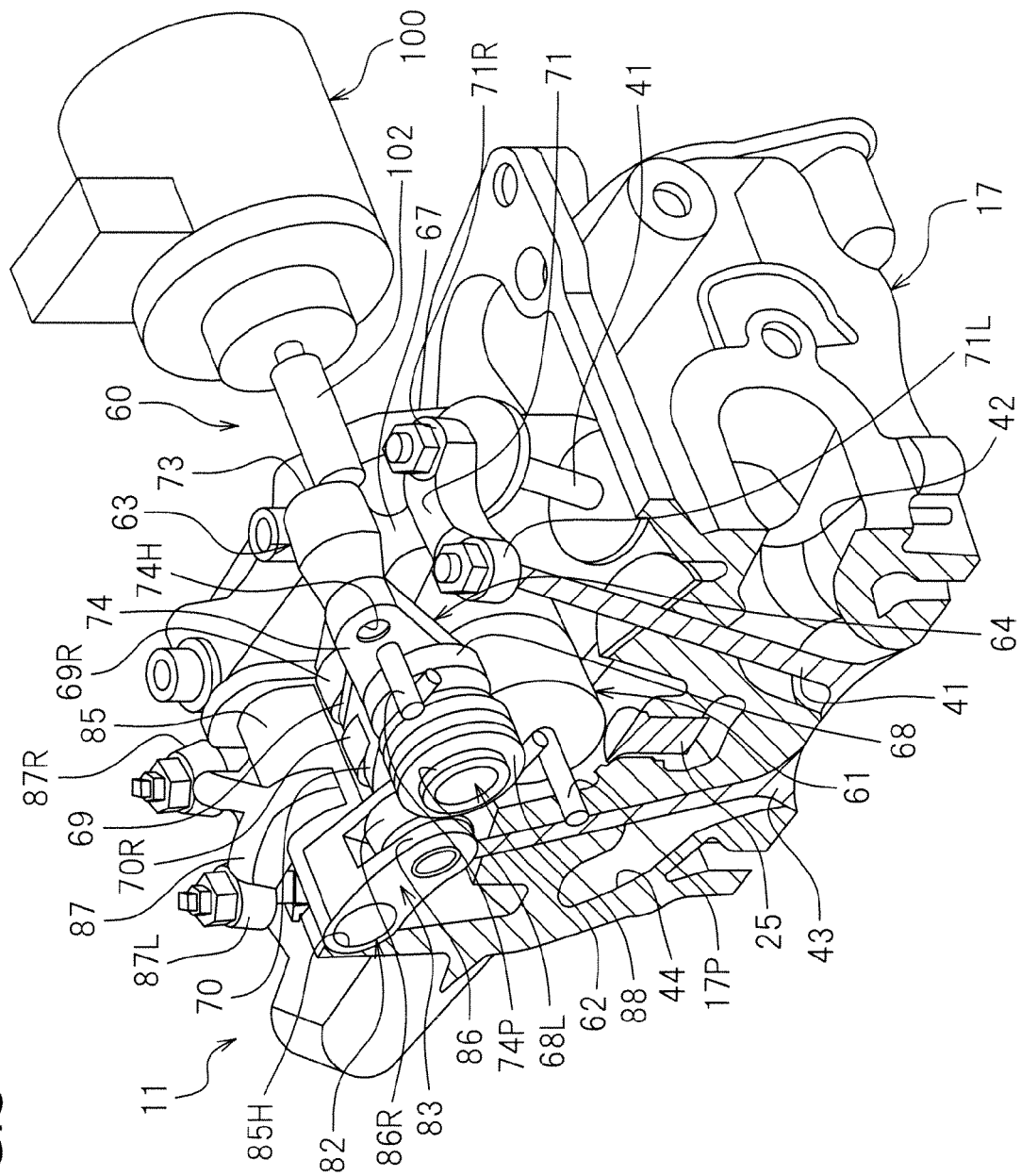


FIG. 4A

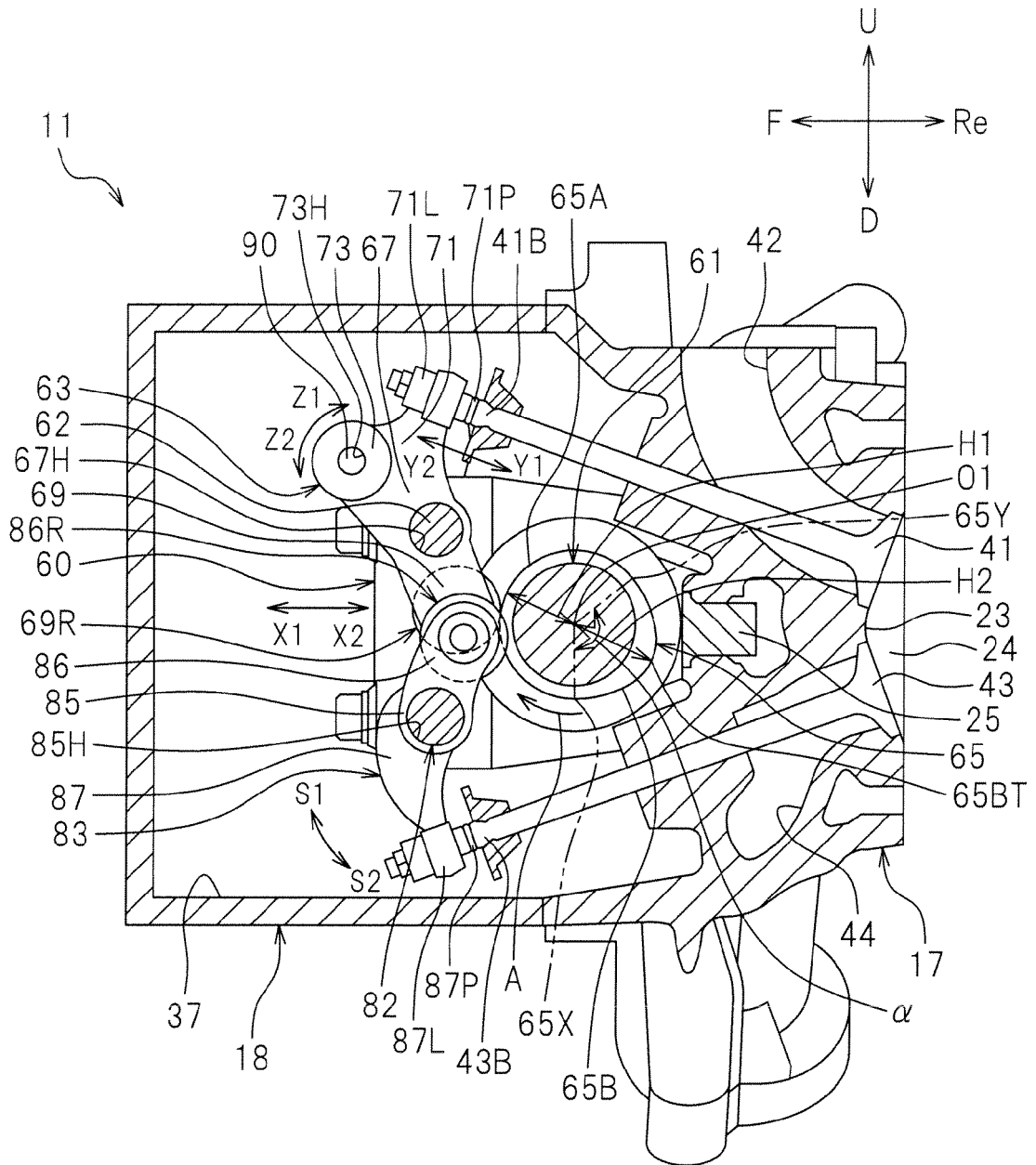


FIG. 4B

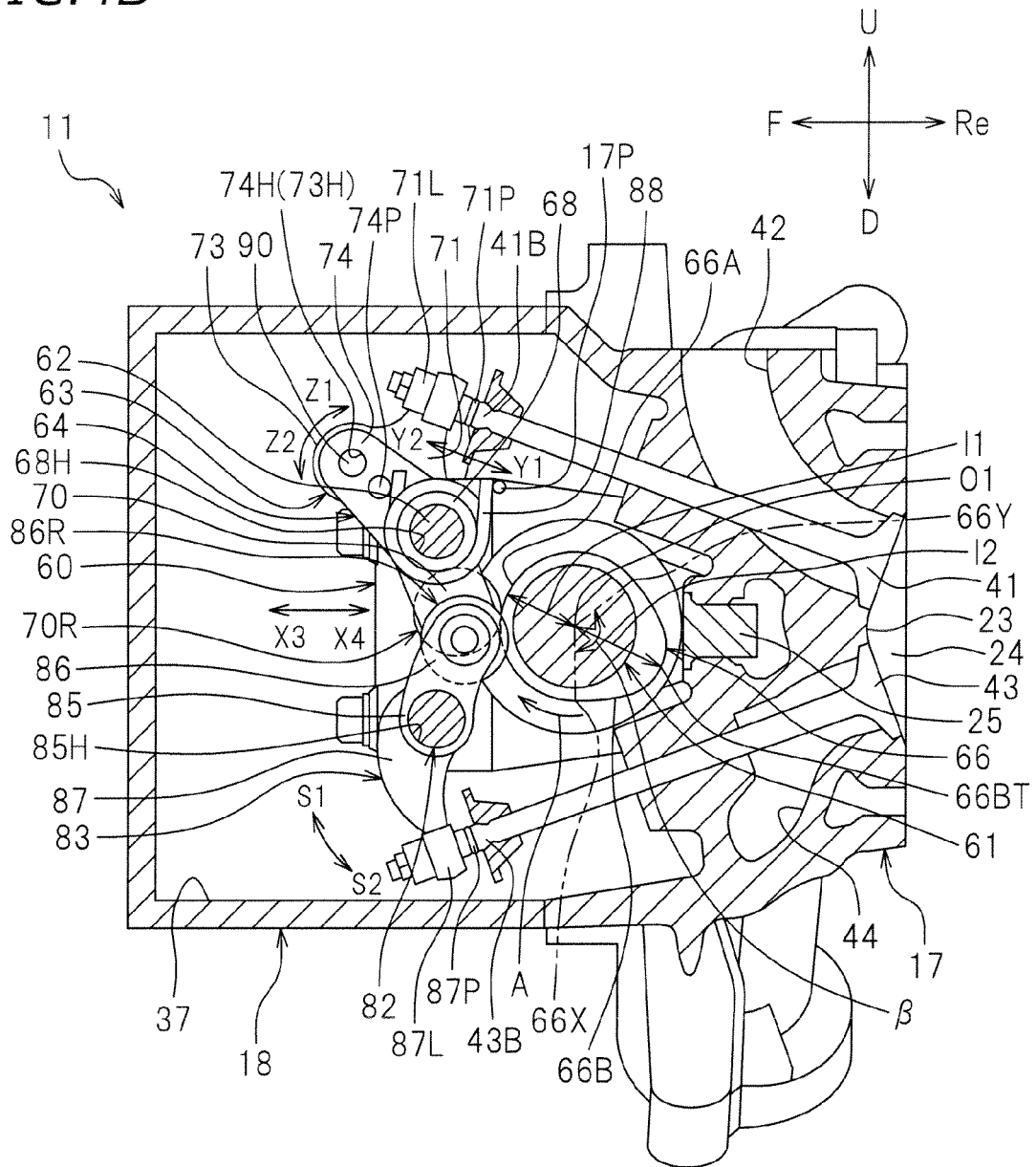


FIG.5

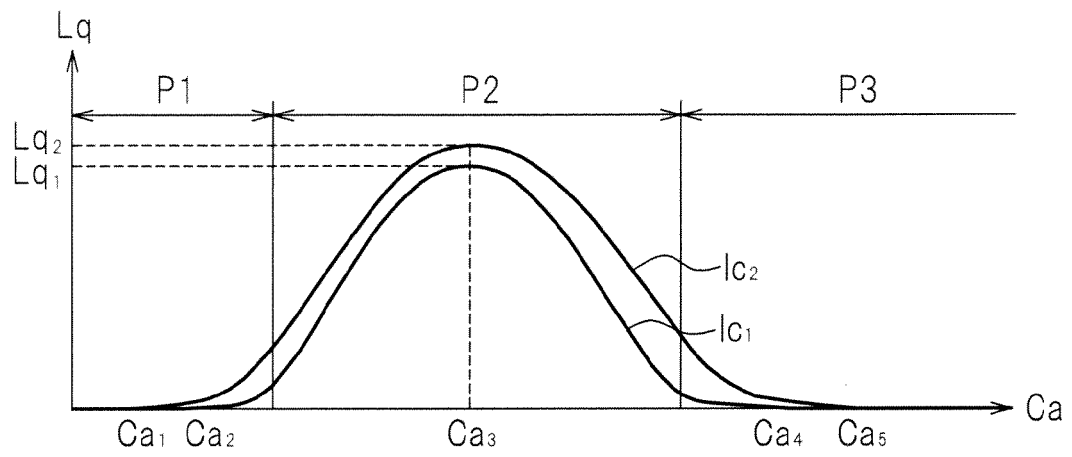


FIG.6

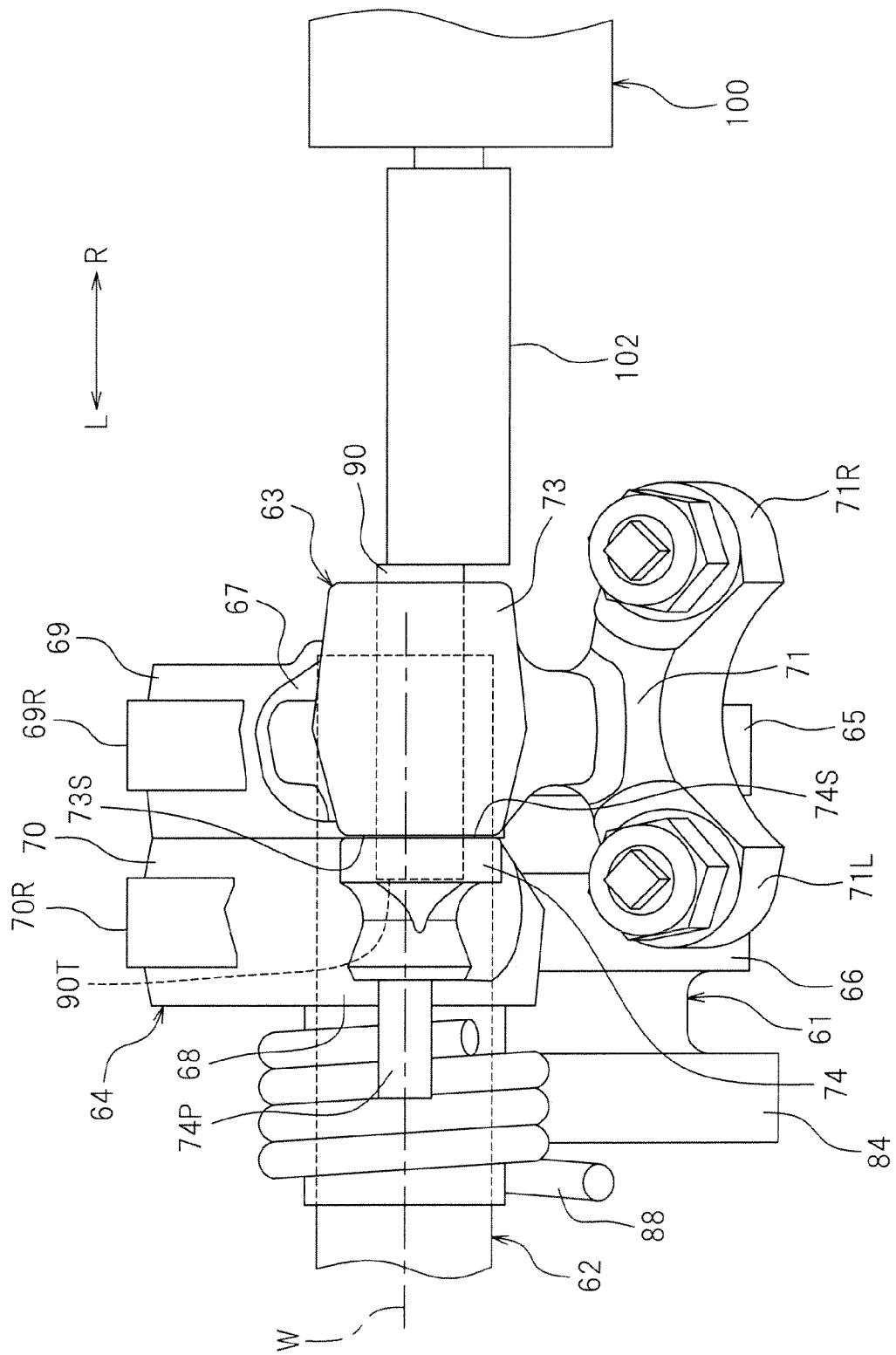


FIG. 7

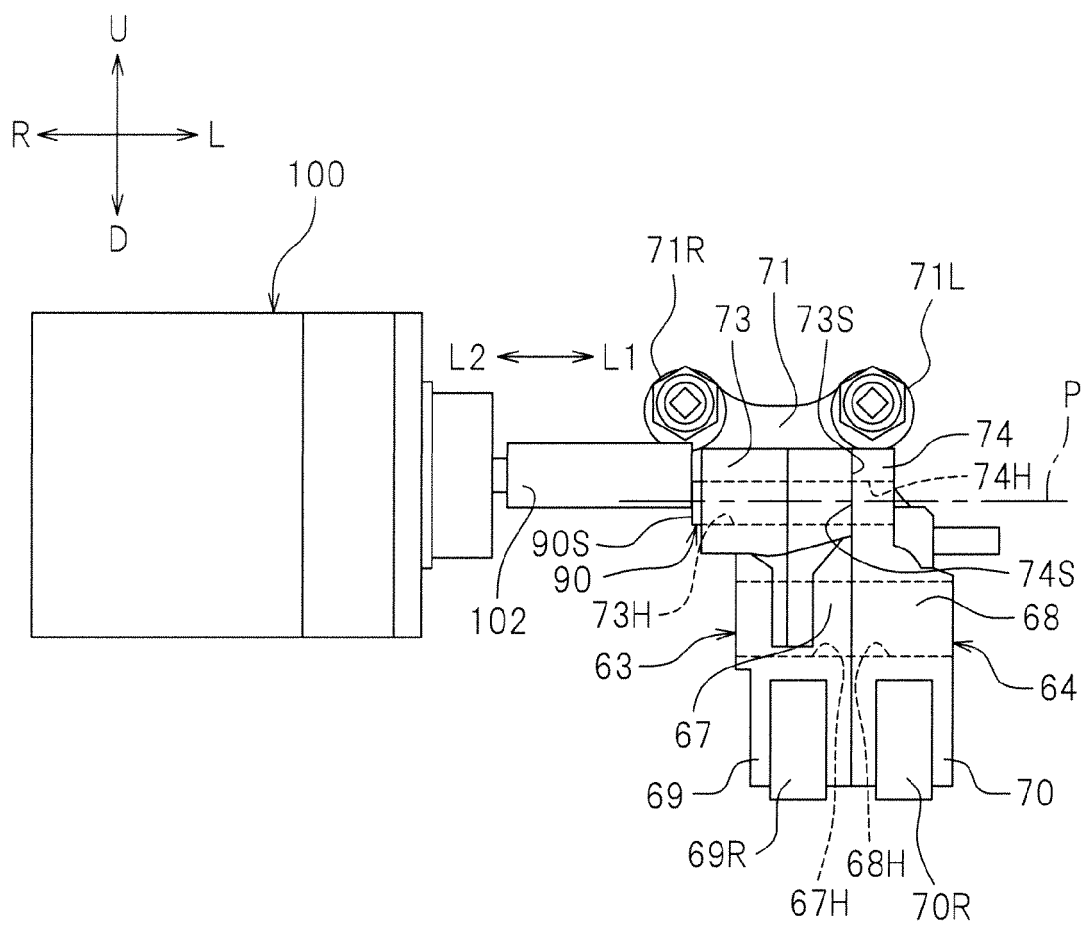
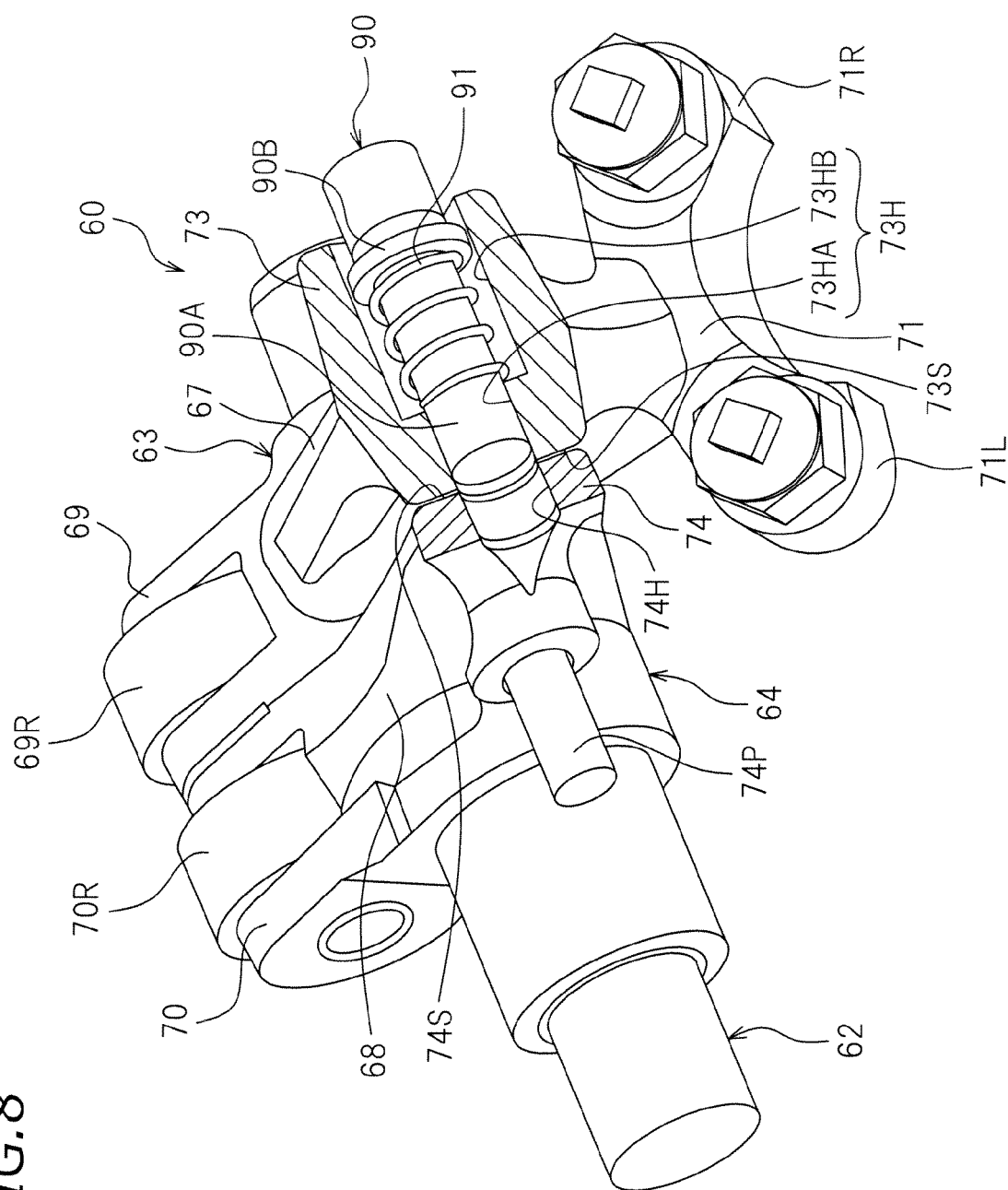


FIG. 8



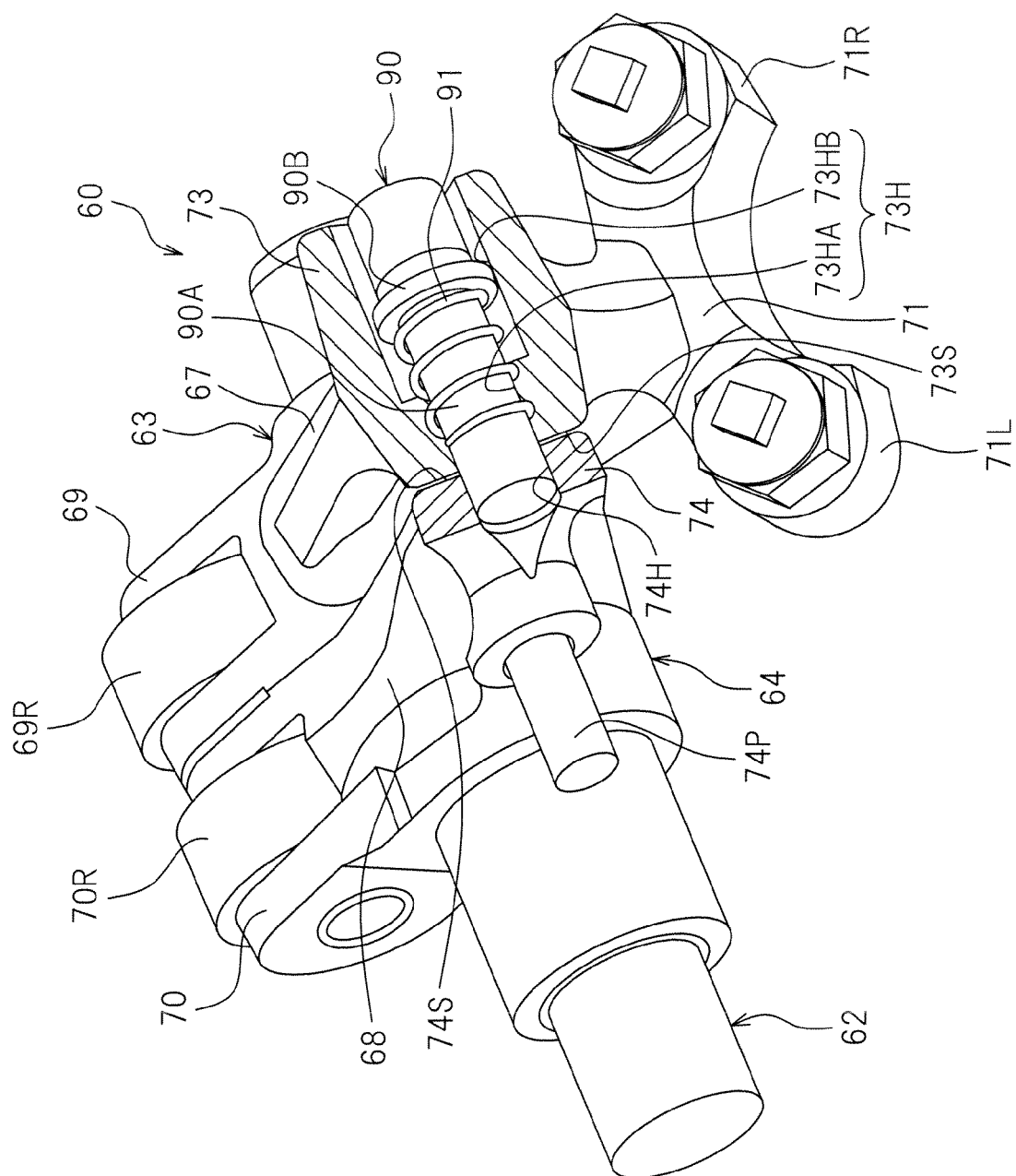


FIG. 9

FIG.10A

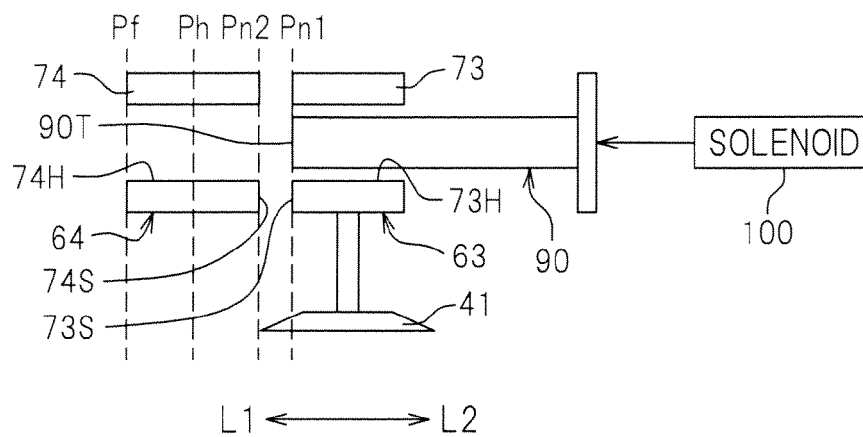


FIG.10B

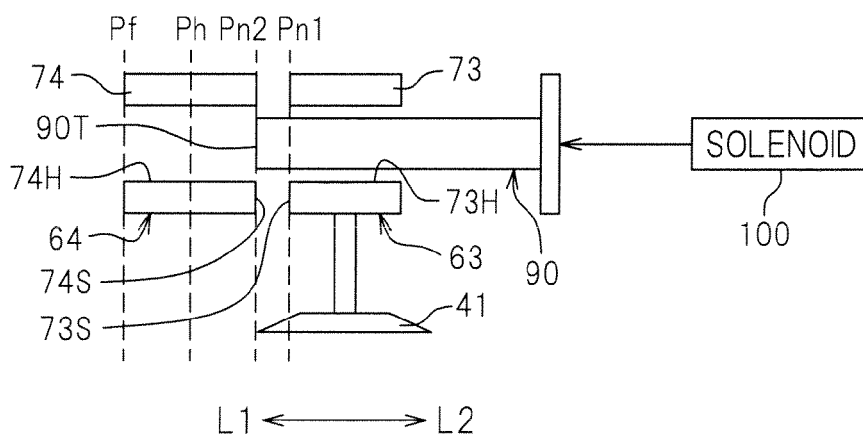


FIG. 10C

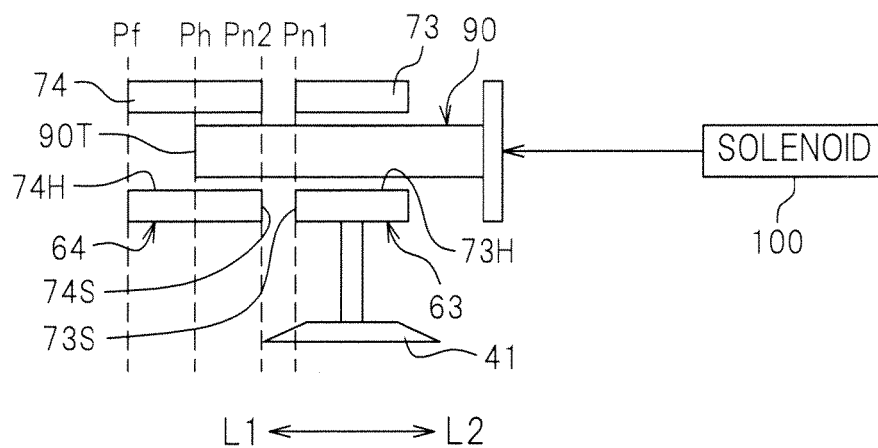


FIG. 10D

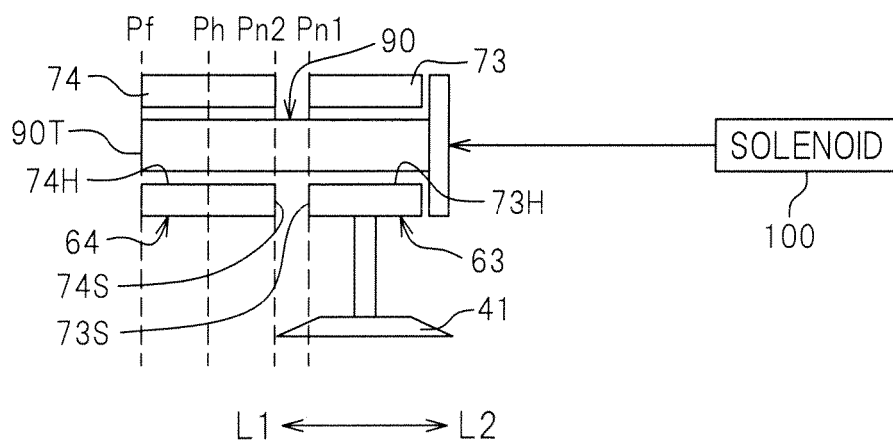


FIG. 11

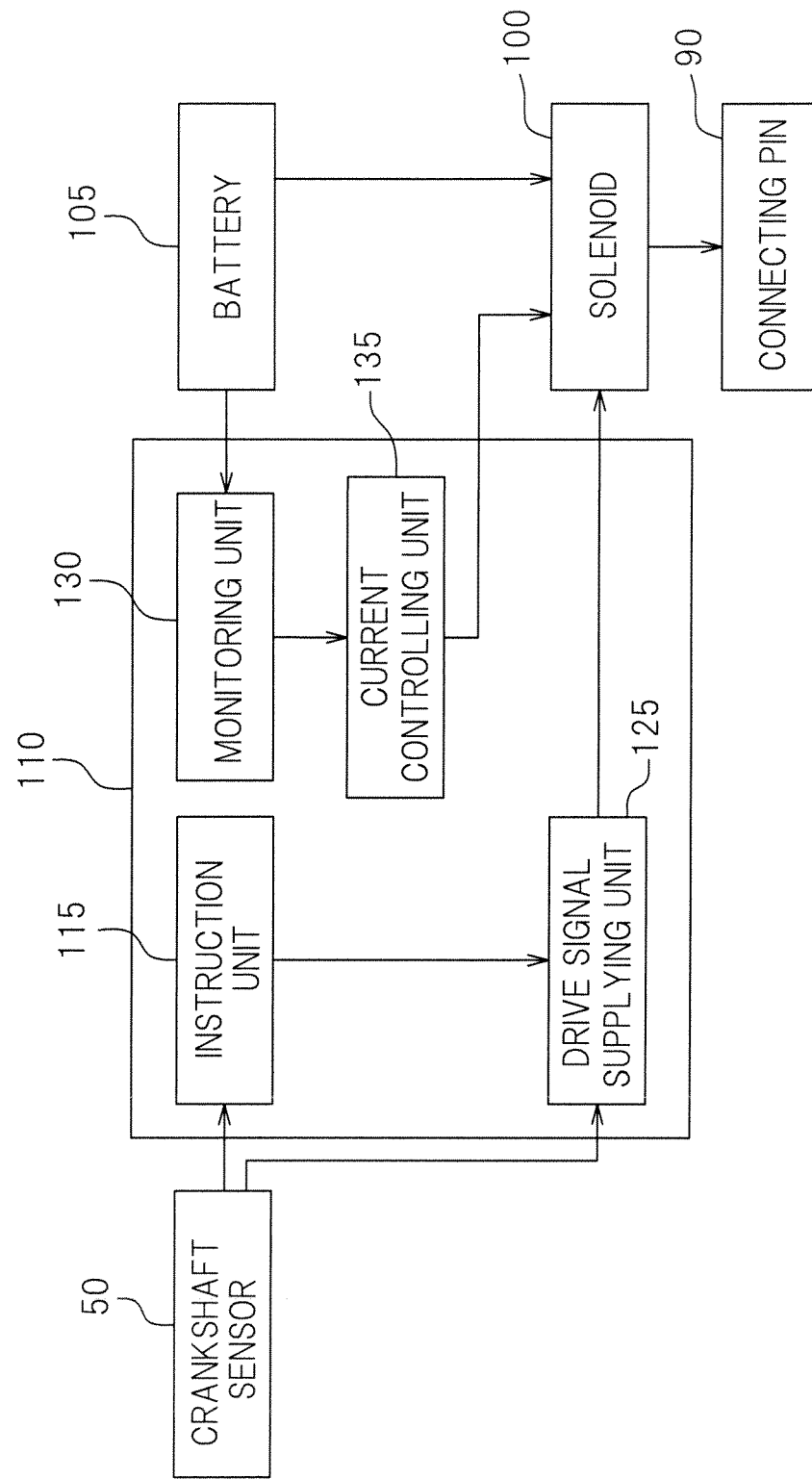


FIG. 12

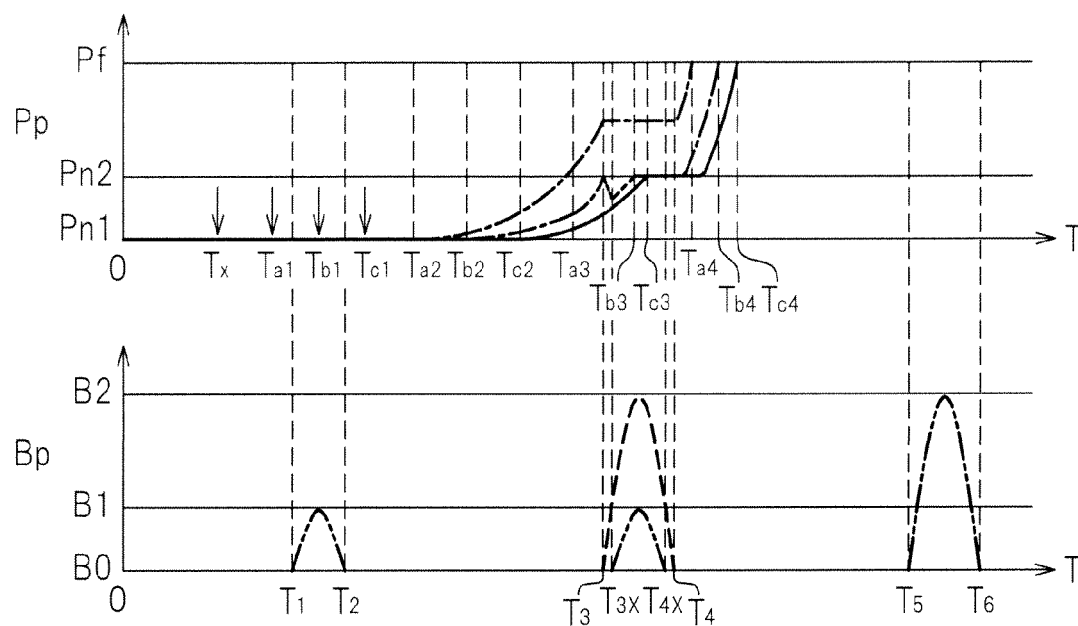


FIG. 13

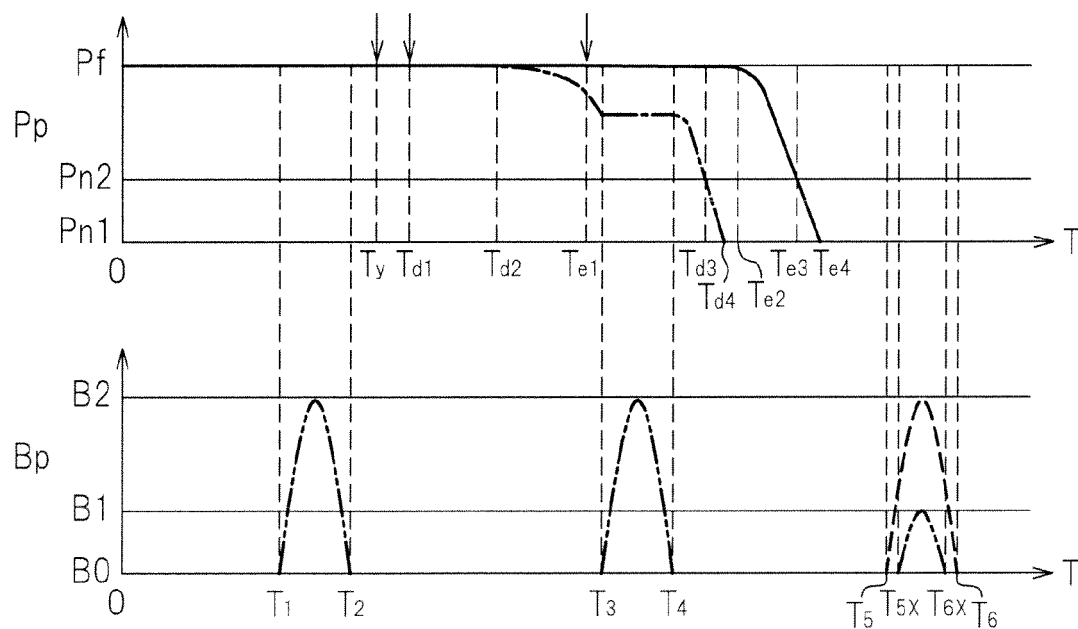


FIG. 14

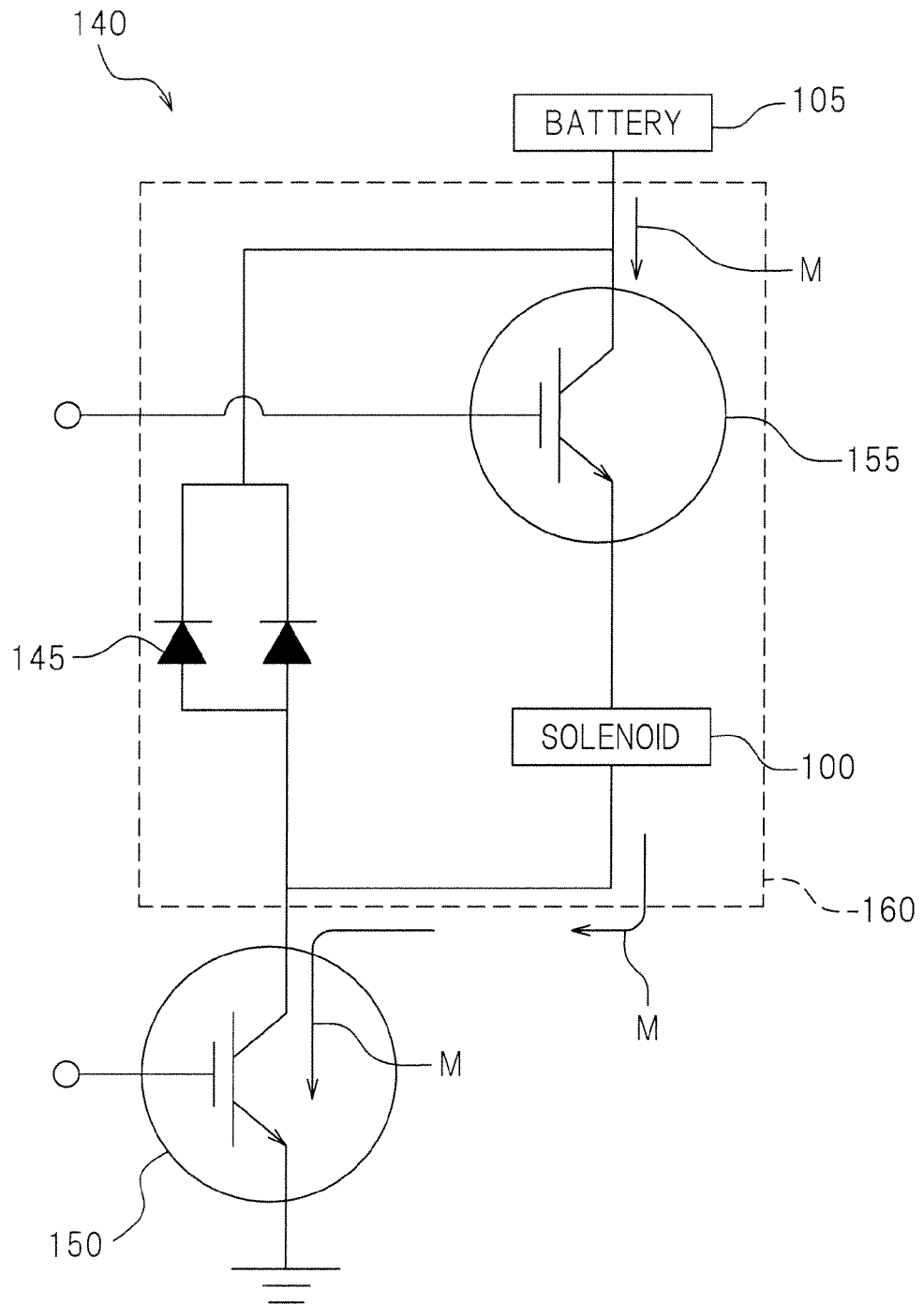


FIG. 15

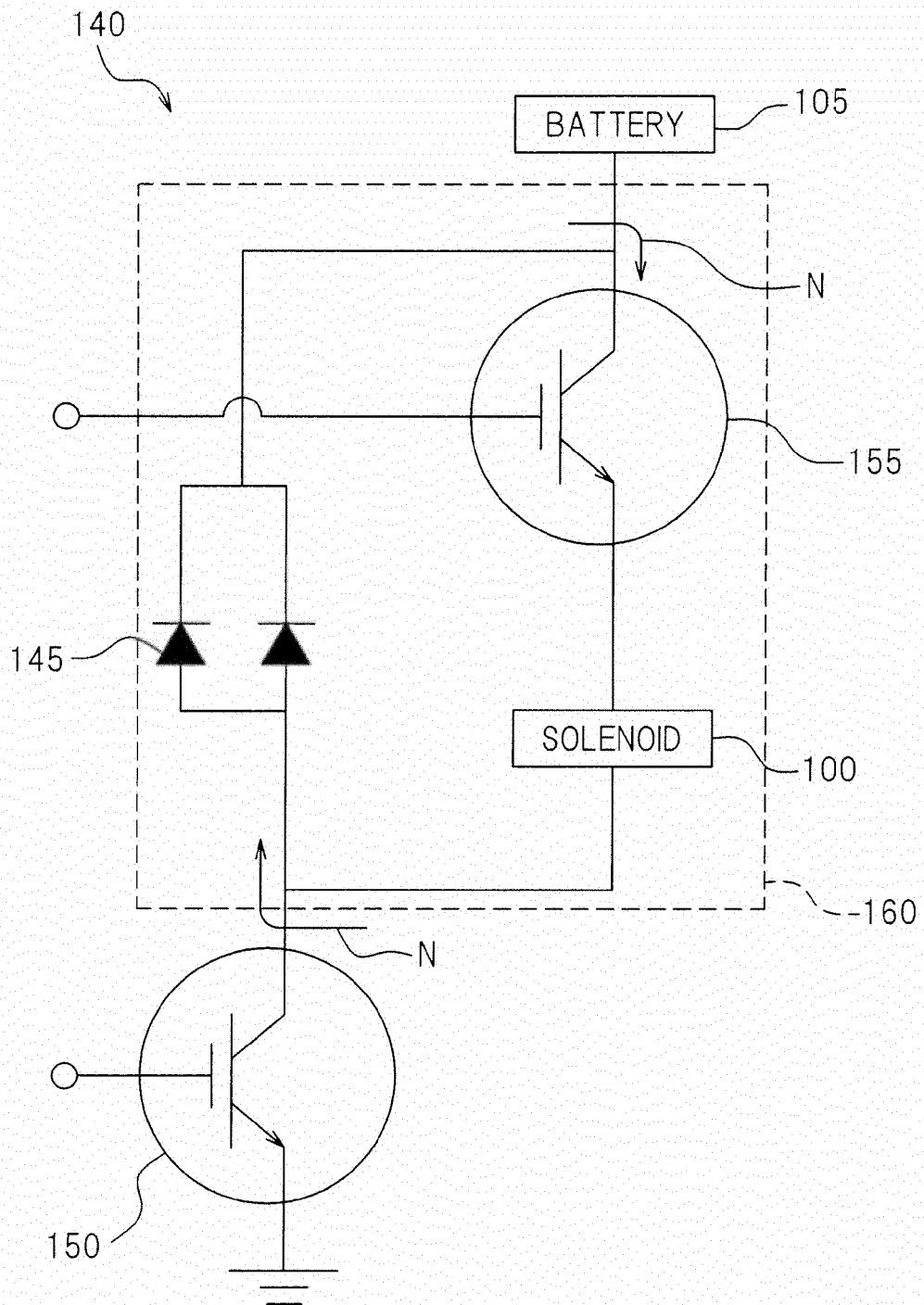


FIG. 16

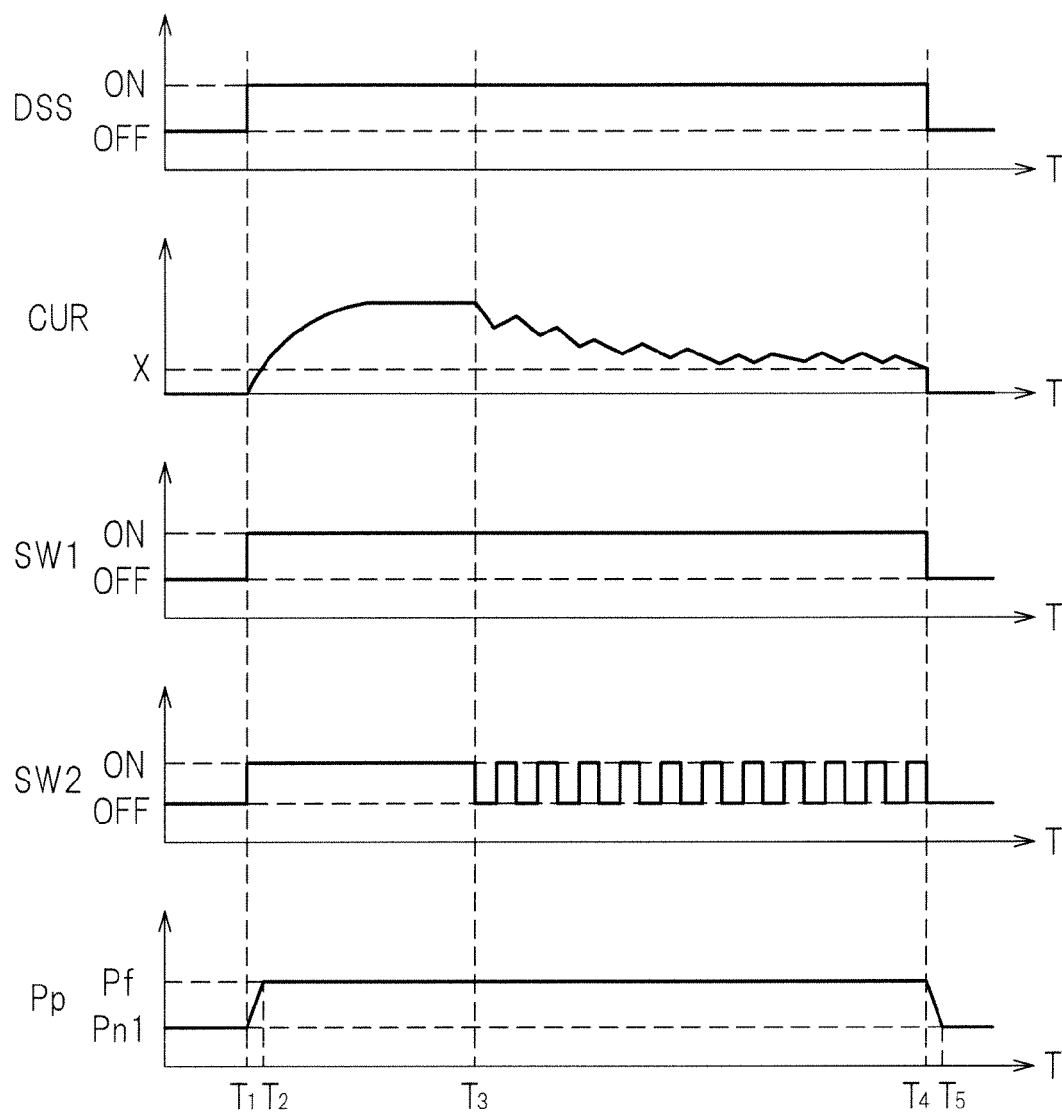
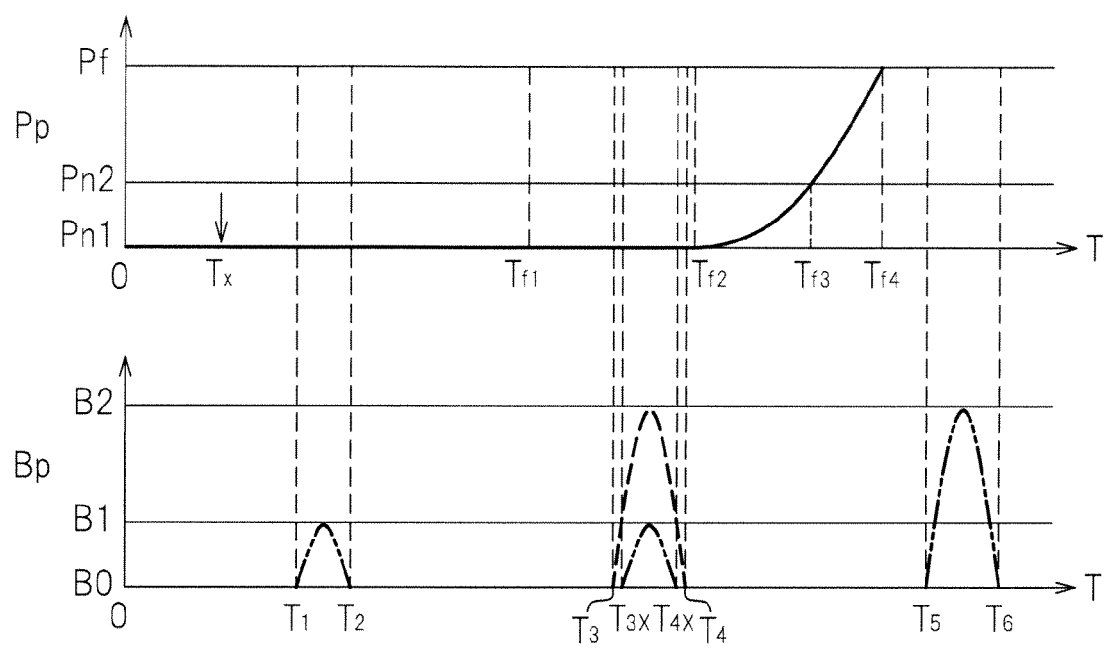


FIG. 17



REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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