US 20100242878A1

(19) United States
(12) Patent Application Publication
MAEKAWA
(10) Pub. No.: US 2010/0242878 A1
(43) Pub. Date: Sep. 30, 2010

(54) **VARIABLE VALVE APPARATUS FOR INTERNAL COMBUSTION ENGINE**

(75) Inventor: **Masahiro MAEKAWA**, Kawasaki-shi (JP)

Correspondence Address:
ROSSI, KIMMS & McDOWELL LLP.
20609 Gordon Park Square, Suite 150
Ashburn, VA 20147 (US)

(73) Assignee: **MITSUBISHI FUSO TRUCK AND BUS CORPORATION**, Kawasaki-shi (JP)

(21) Appl. No.: **12/814,139**

(22) Filed: **Jun. 11, 2010**

Related U.S. Application Data

(63) Continuation of application No. PCT/JP2008/073635, filed on Dec. 25, 2008.

(30) **Foreign Application Priority Data**

Dec. 27, 2007 (JP) 2007-338360
Jan. 11, 2008 (JP) 2008-004745

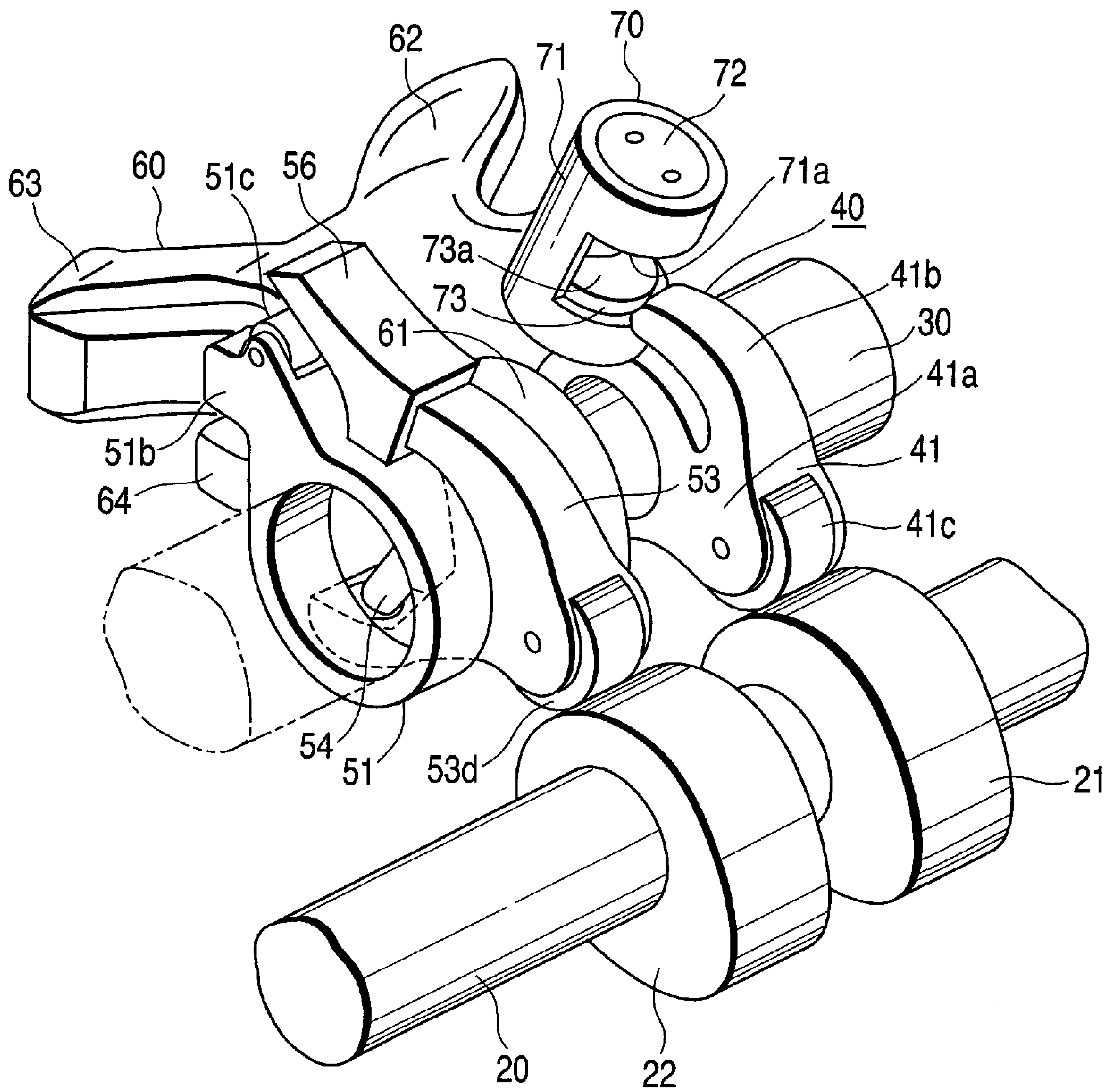
Publication Classification

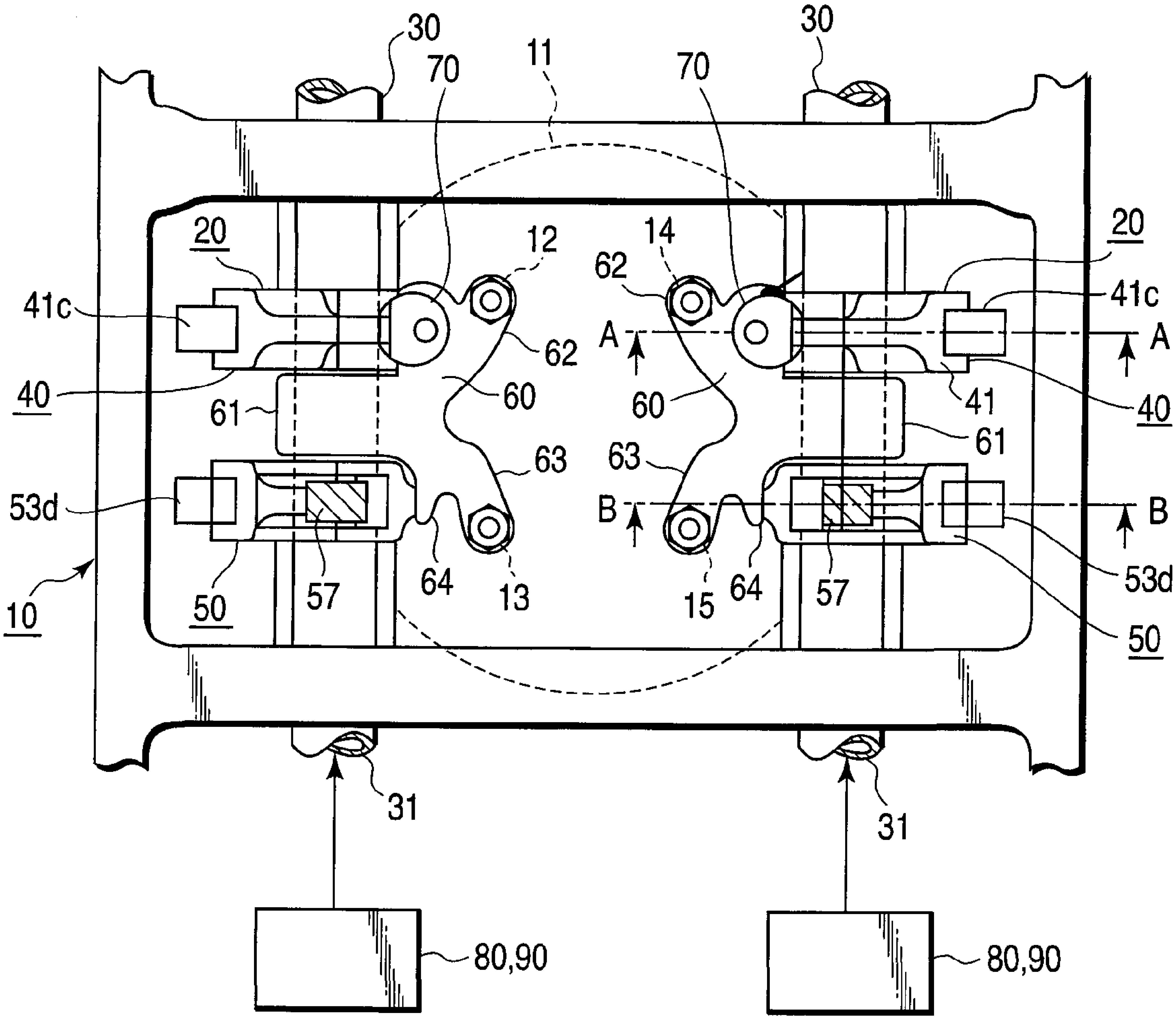
(51) **Int. Cl.**
F01L 1/34 (2006.01)

(52) **U.S. Cl.** **123/90.16**

(57) **ABSTRACT**

In order to simultaneously exert a plurality of functions such as execution of internal EGR, application of engine braking, improvement in fuel consumption and purification of exhaust gas, a variable valve apparatus for an internal combustion engine of the invention includes a cam shaft arranged to be rotatable on a cylinder head of the internal combustion engine, a rocker shaft arranged to be capable of oscillation in the internal combustion engine, a continuous variable rocker arm mechanism which is driven by a cam formed on the cam shaft, opens or closes air intake valves and exhaust valves, and continuously makes a lift of the valves variable, and a switching rocker arm mechanism which is driven by the cam formed on the cam shaft, opens or closes the air intake valves and the exhaust valves, and switches the lift of the valves in a stepwise manner.




30
30
70
11
70
20
12
14
62
20
41c
41c
62
A
A
40
61
60
60
41
40
61
63
63
53d
B
B
57
57
53d
10
50
64
13
15
64
50
31
31
80,90
80,90

F I G. 1

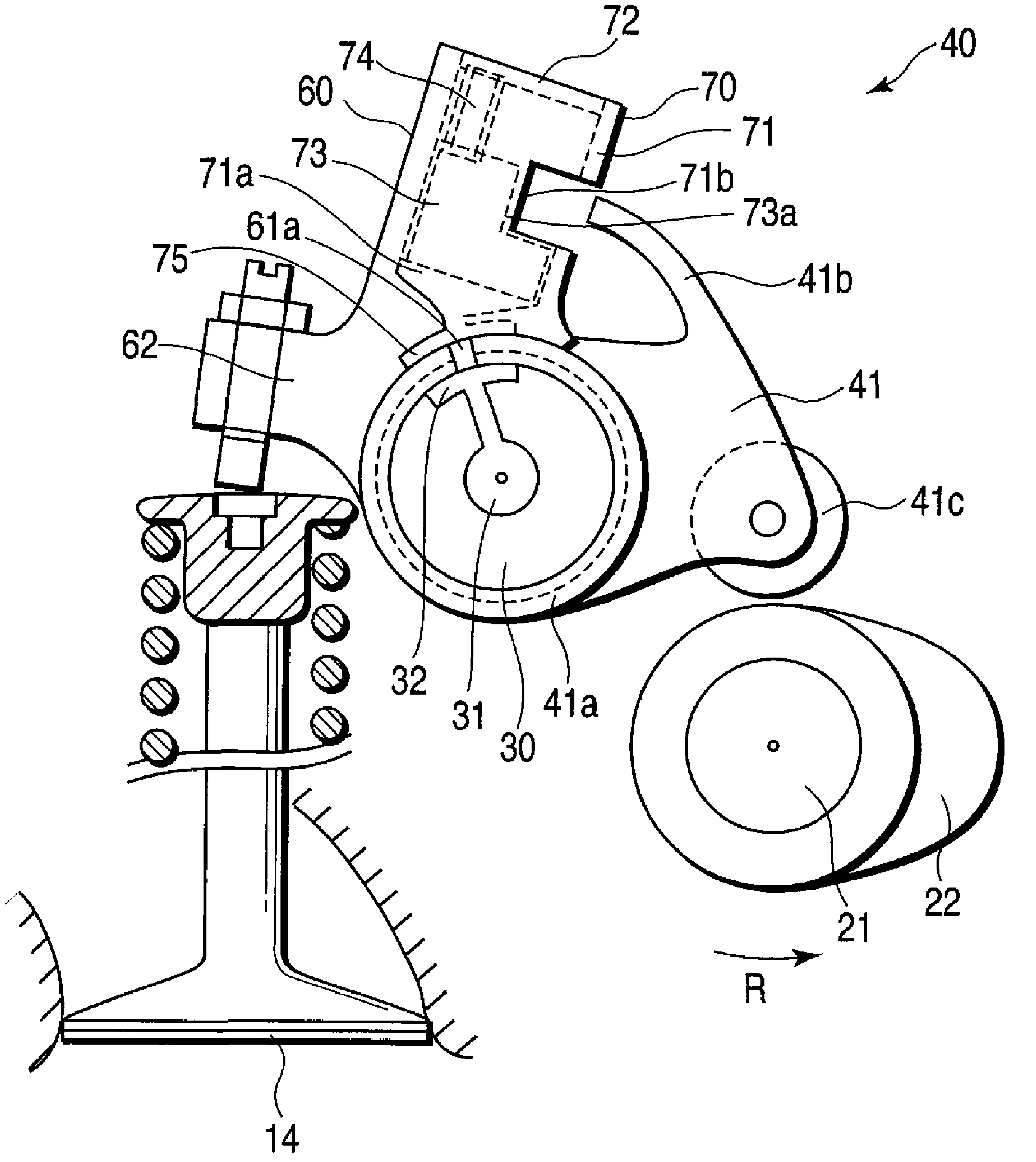
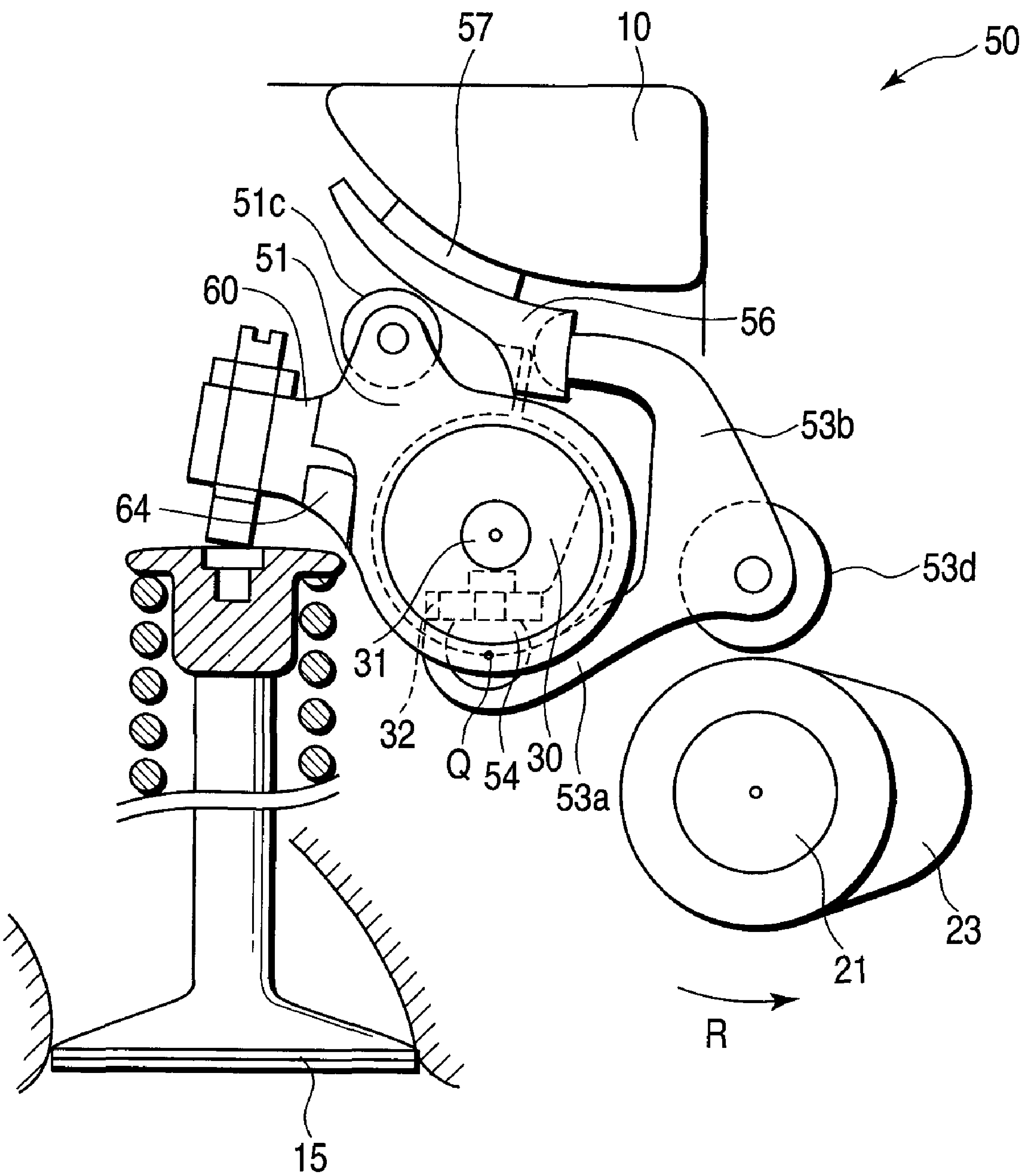
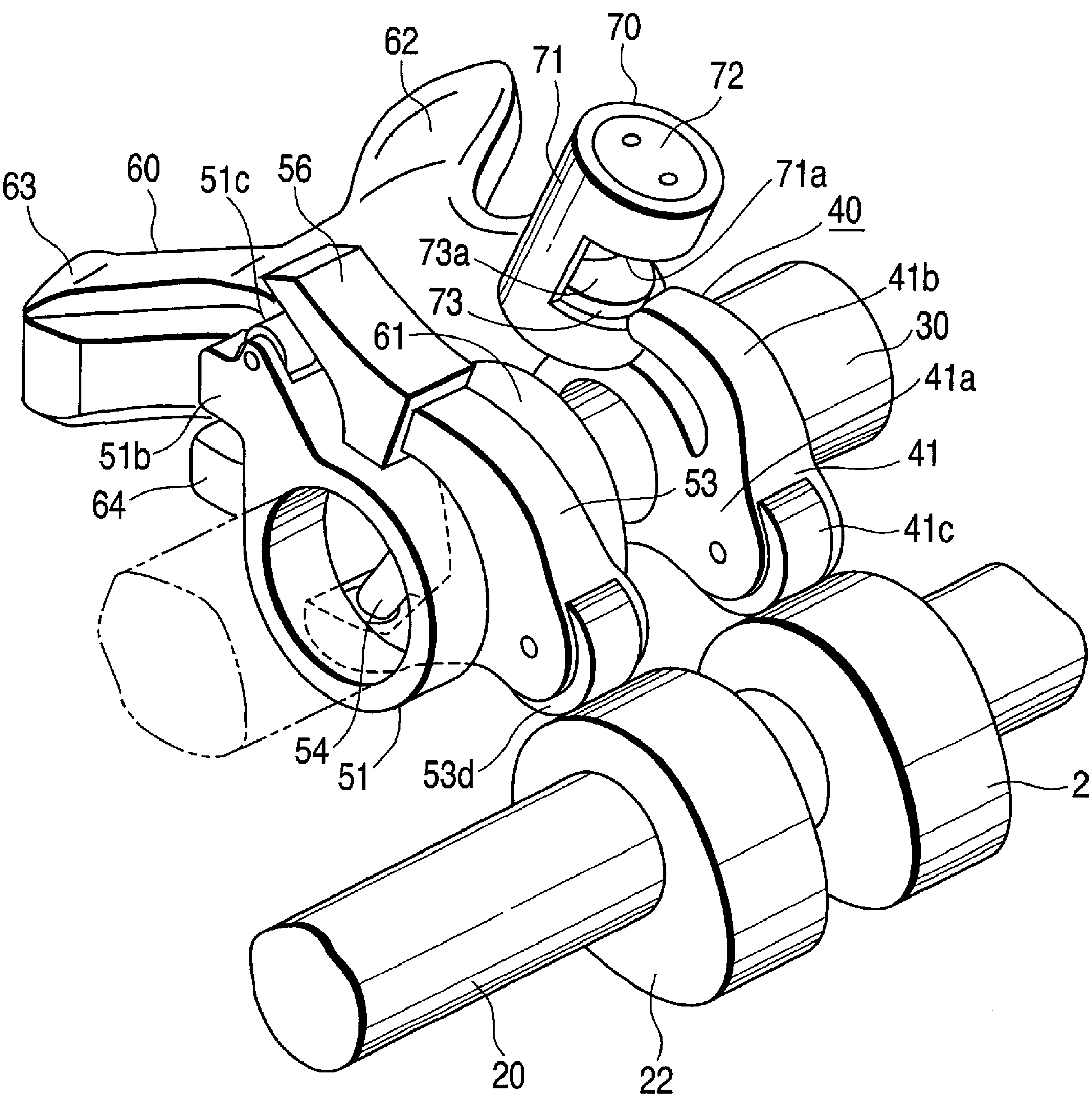

72
74
60
40
70
71
73
71a
71b
73a
61a
75
41b
62
41
41c
32
31
30
41a
21
22
R
14

FIG. 2

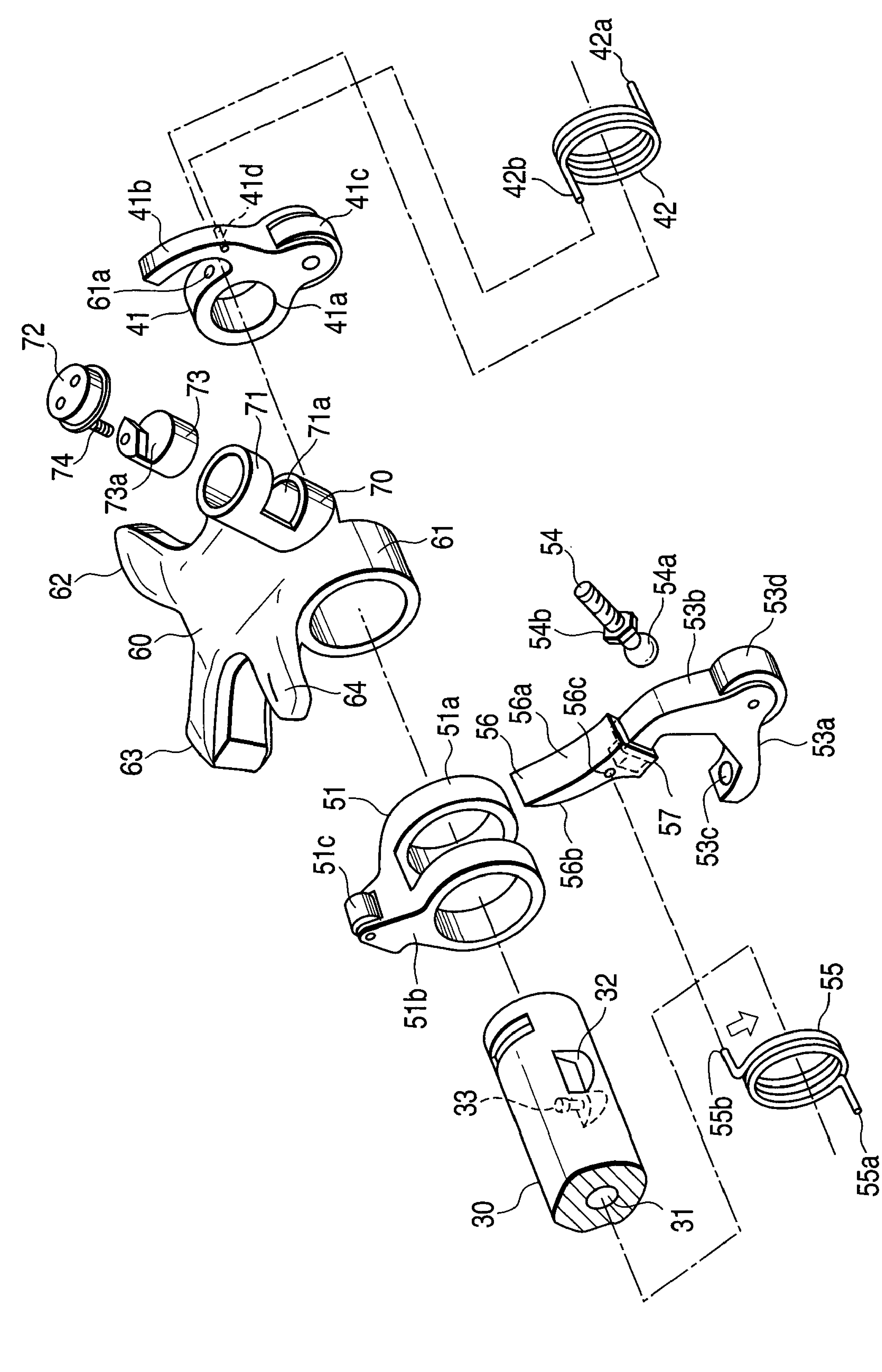


F I G. 3



62
70
71
72
63
60
51c
56
71a
40
73a
41b
73
30
61
41a
51b
53
41
64
41c
54
51
53d
21
20
22

F I G. 4



30
31
32
33
41
41a
41b
41c
41d
42
42a
42b
51
51a
51b
51c
53a
53b
53c
53d
54
54a
54b
55
55a
55b
56
56a
56b
56c
57
60
61
61a
62
63
64
70
71
71a
72
73
73a
74

FIG. 5

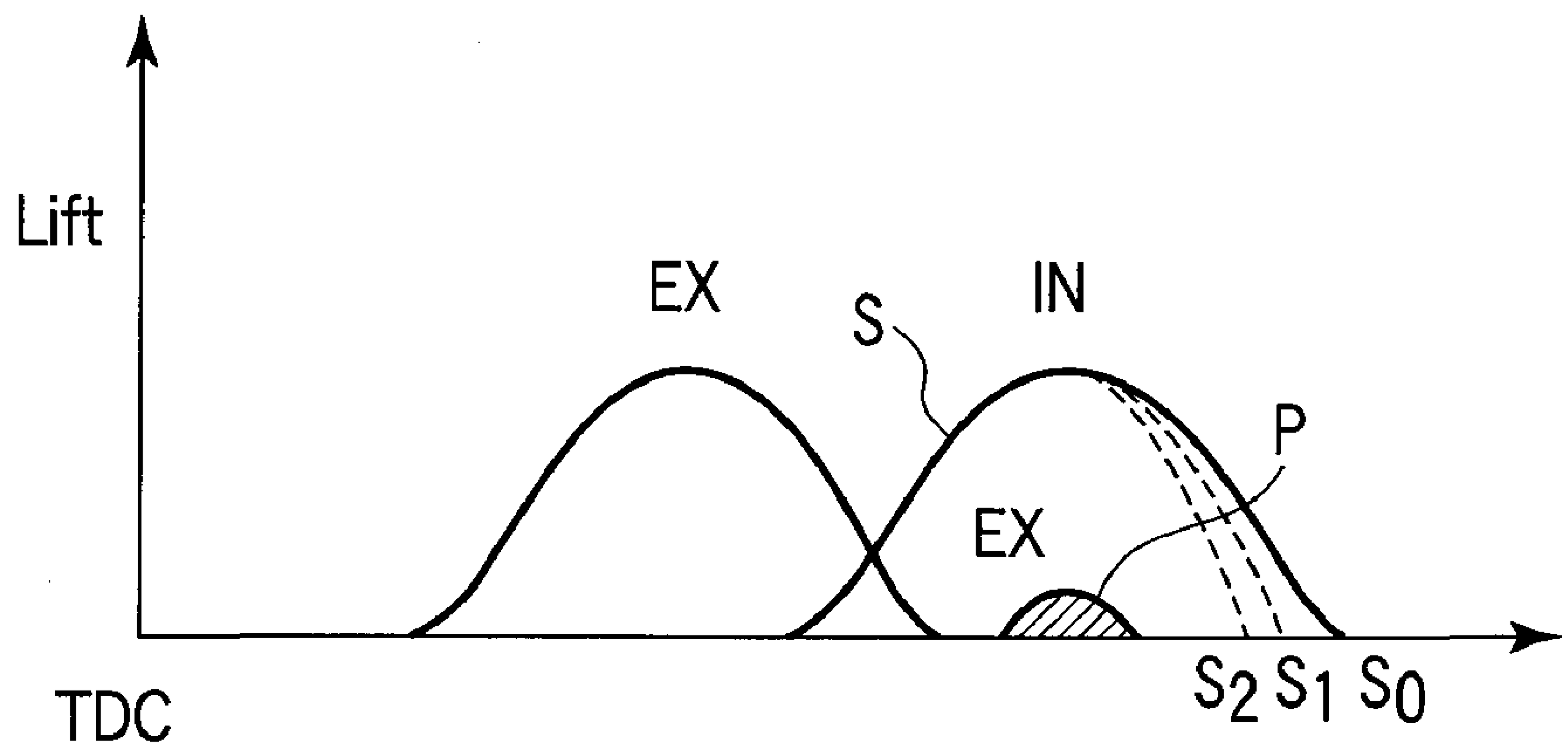

Lift
EX
S
IN
P
EX
TDC
S2 S1 S0

FIG. 6

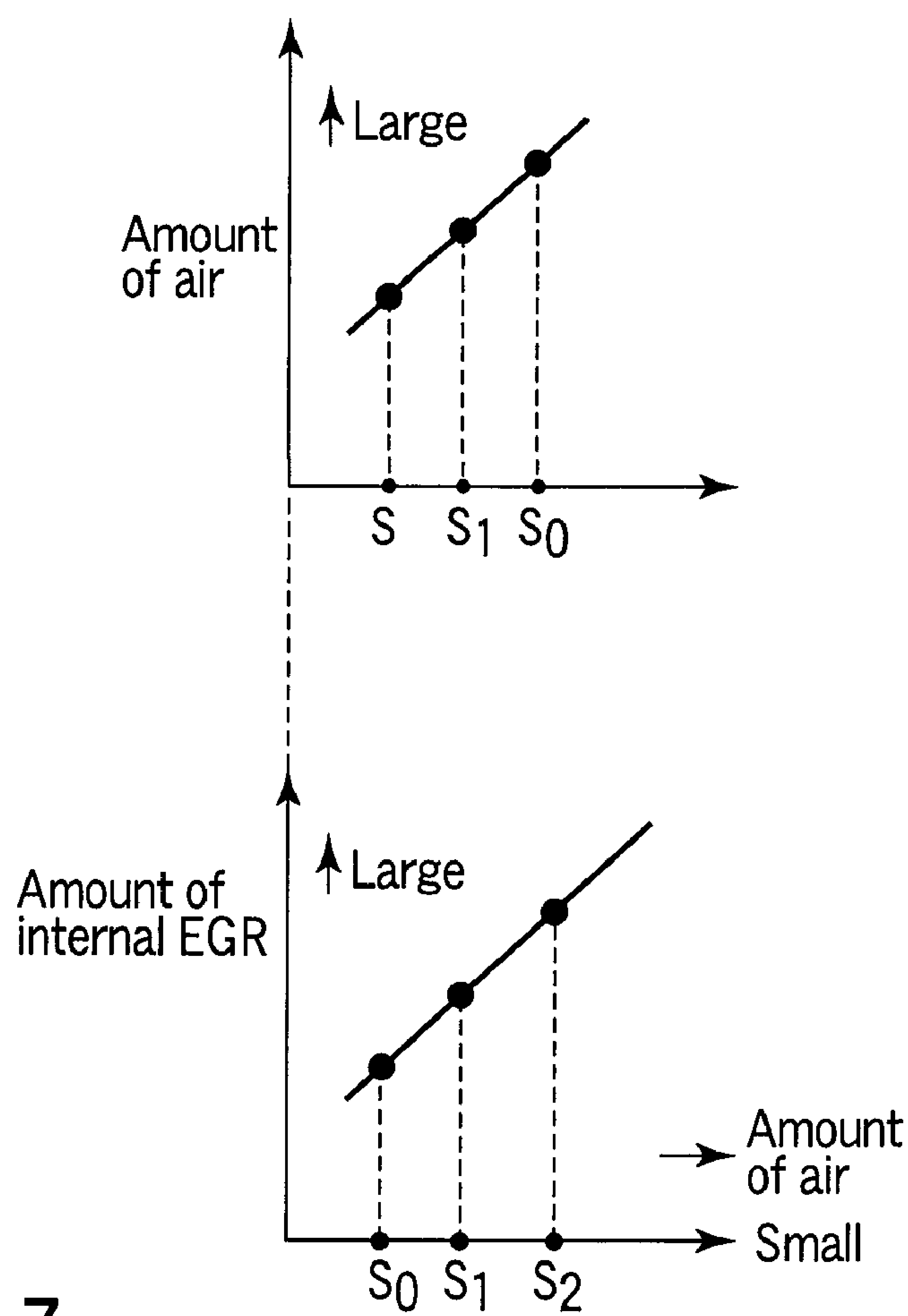

Large
Amount of air
S S1 S0
Large
Amount of internal EGR
Amount of air
Small
S0 S1 S2

FIG. 7

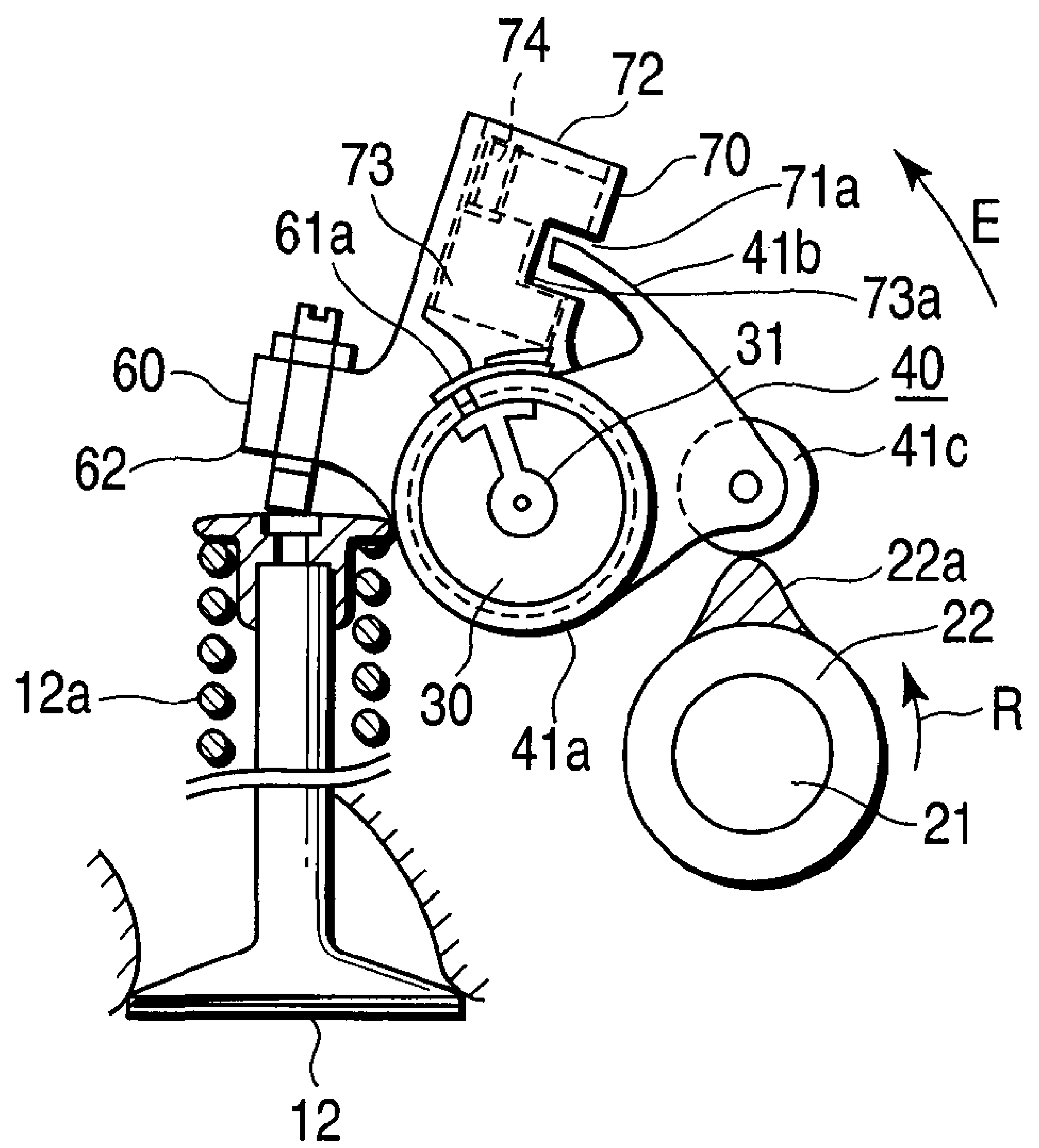

74
72
70
73
71a
61a
41b
73a
E
31
60
40
41c
62
22a
22
12a
30
41a
R
21
12

FIG. 8

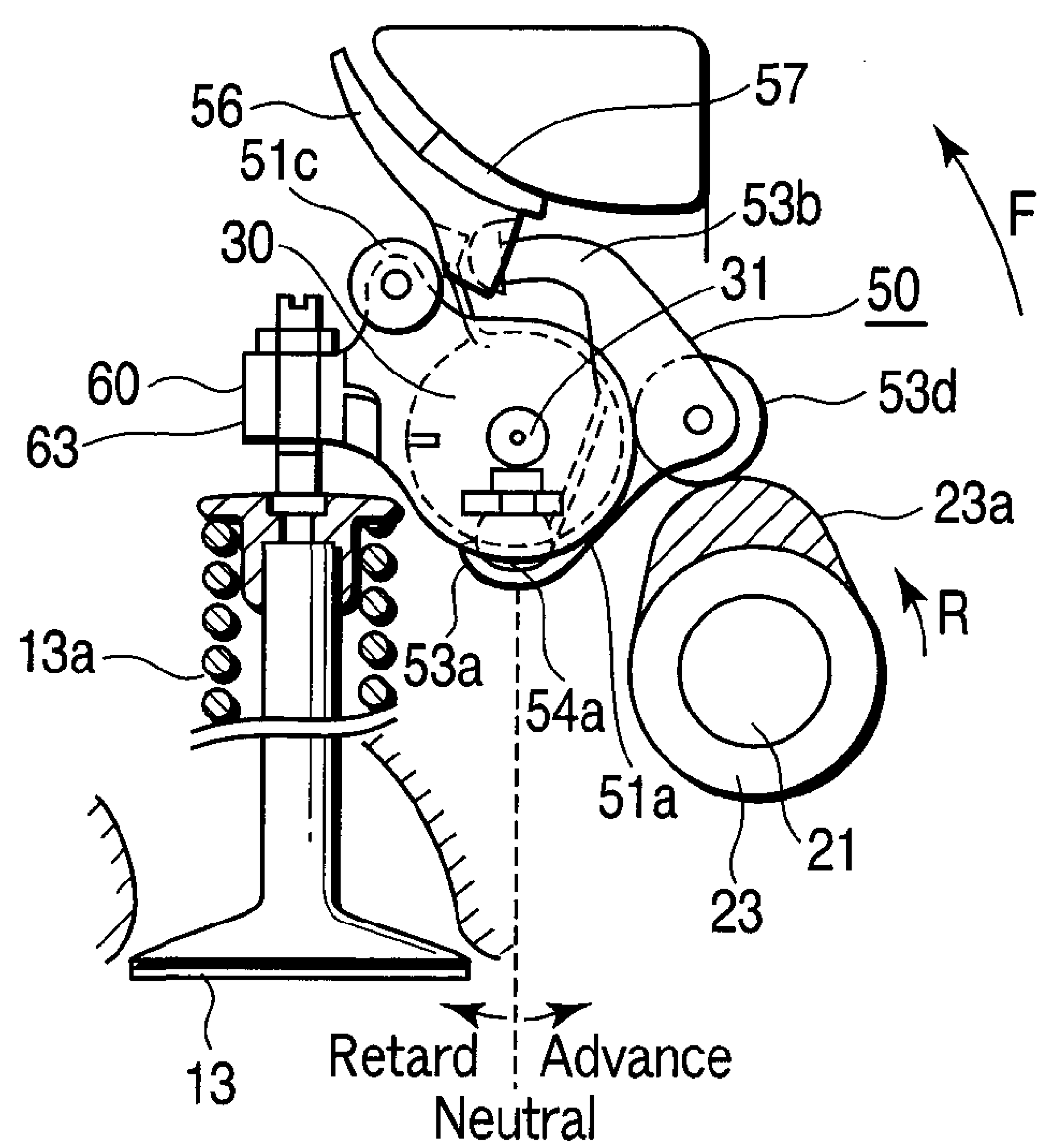
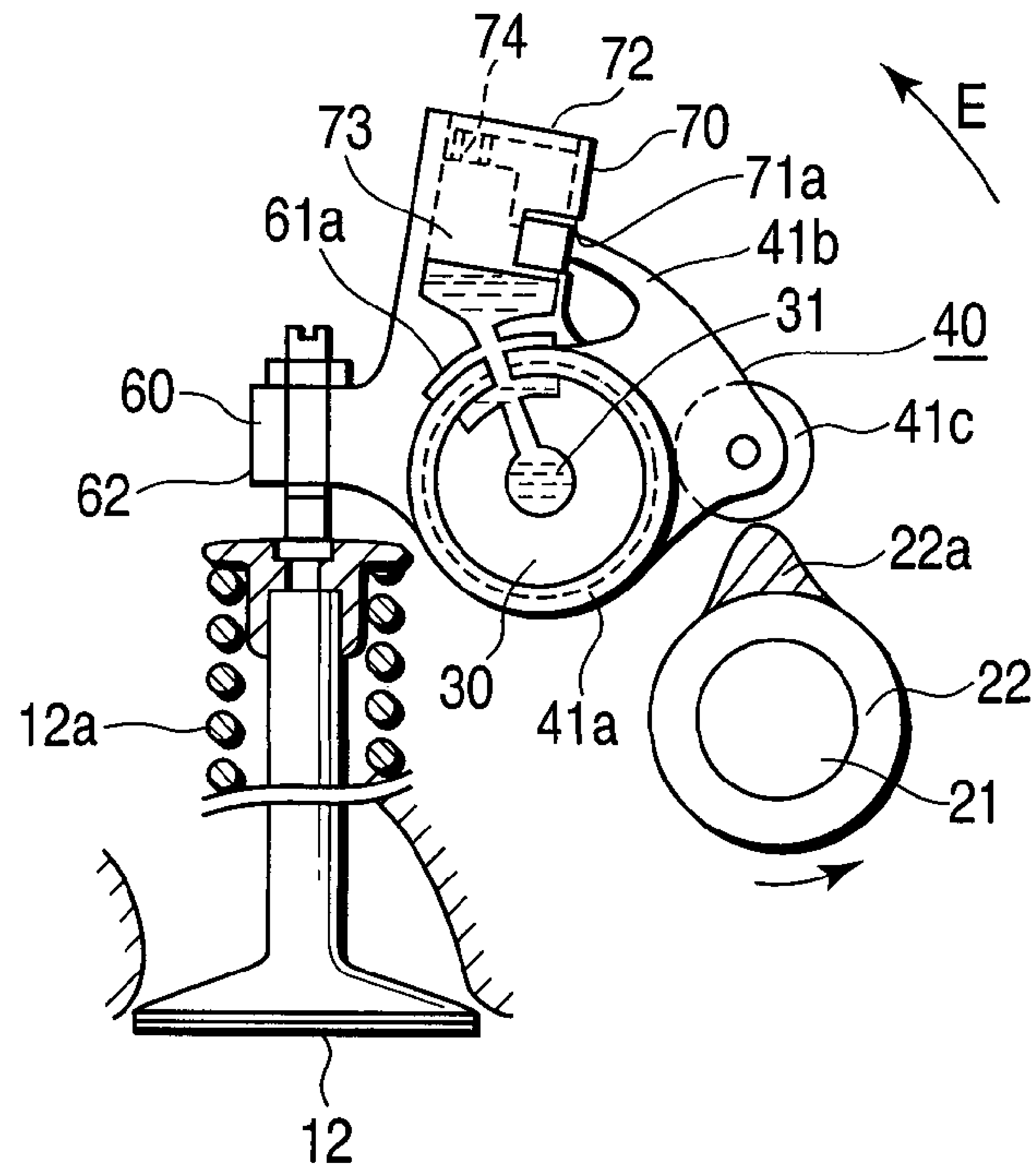
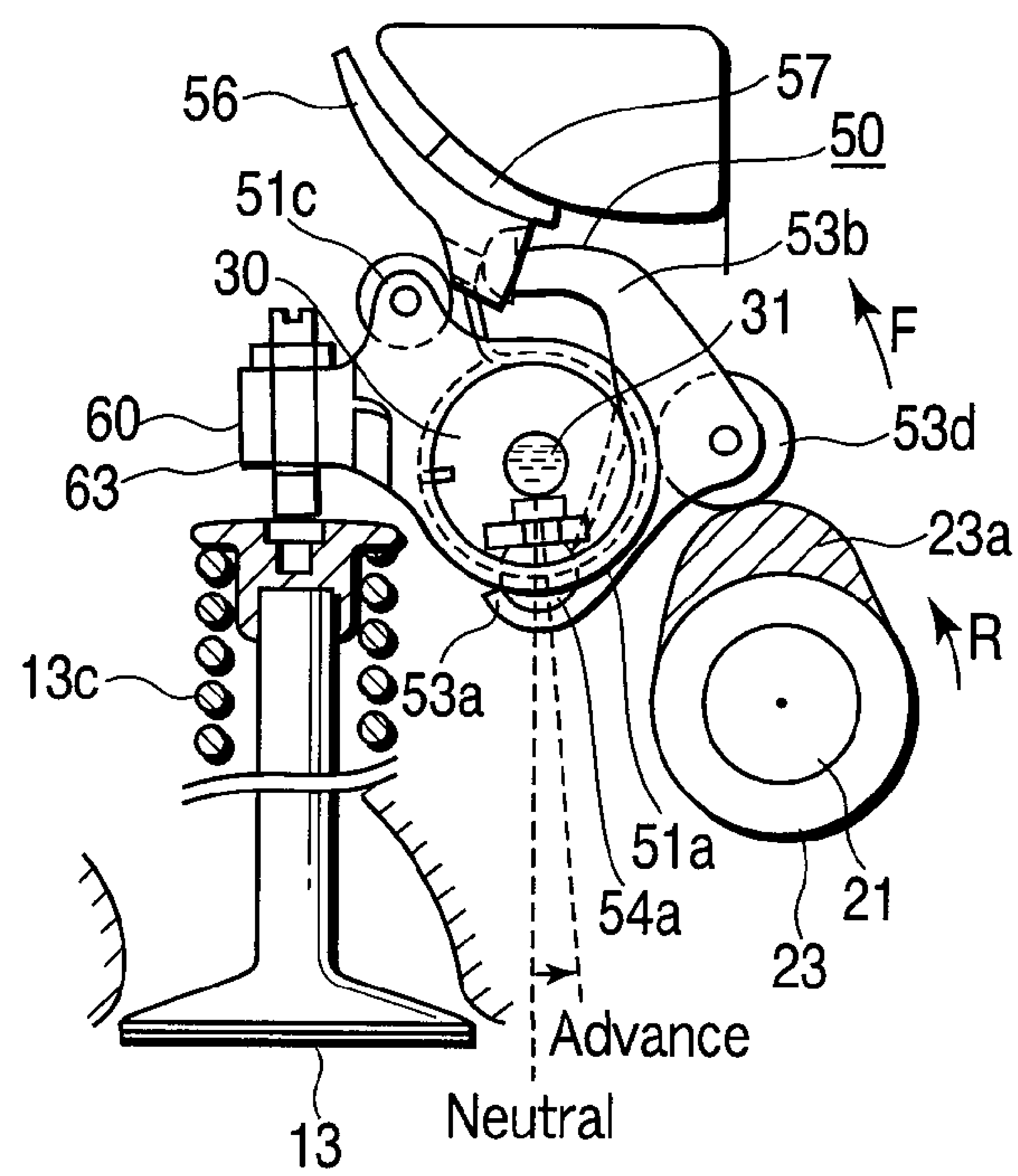

57
56
51c
53b
30
F
31
50
60
53d
63
23a
R
13a
53a
54a
51a
21
23
13
Retard
Advance
Neutral

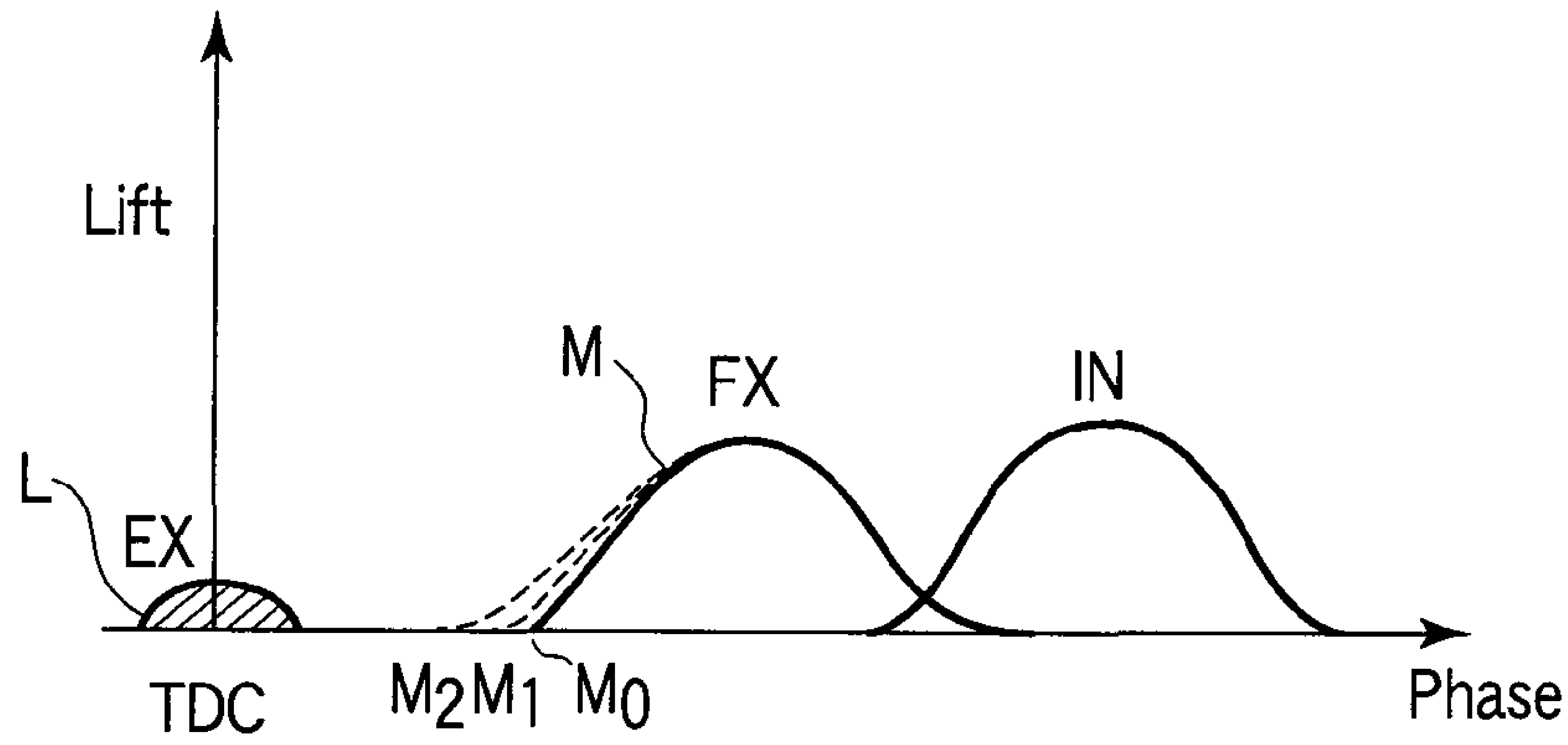
FIG. 9


74
72
E
73
70
71a
61a
41b
31
40
60
41c
62
22a
22
12a
30
41a
21
12

F I G. 10

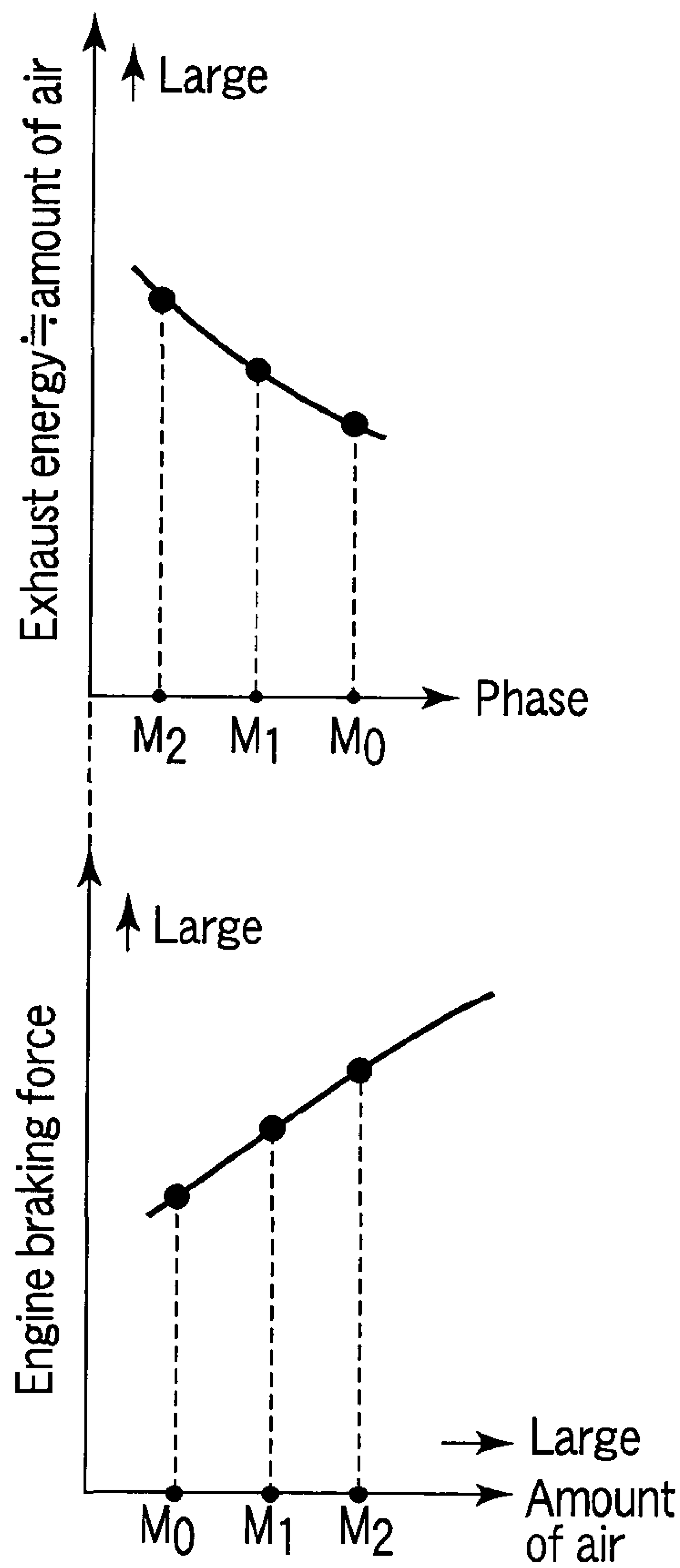

56
57
50
51c
53b
30
31
F
60
53d
63
23a
R
13c
53a
51a
21
54a
23
Advance
Neutral
13

F I G. 11



Lift
M
FX
IN
L
EX
TDC
M2M1 M0
Phase

F I G. 12



Large
Exhaust energy≑amount of air
Phase
M2
M1
M0
Large
Engine braking force
Large
Amount of air
M0
M1
M2

F I G. 13

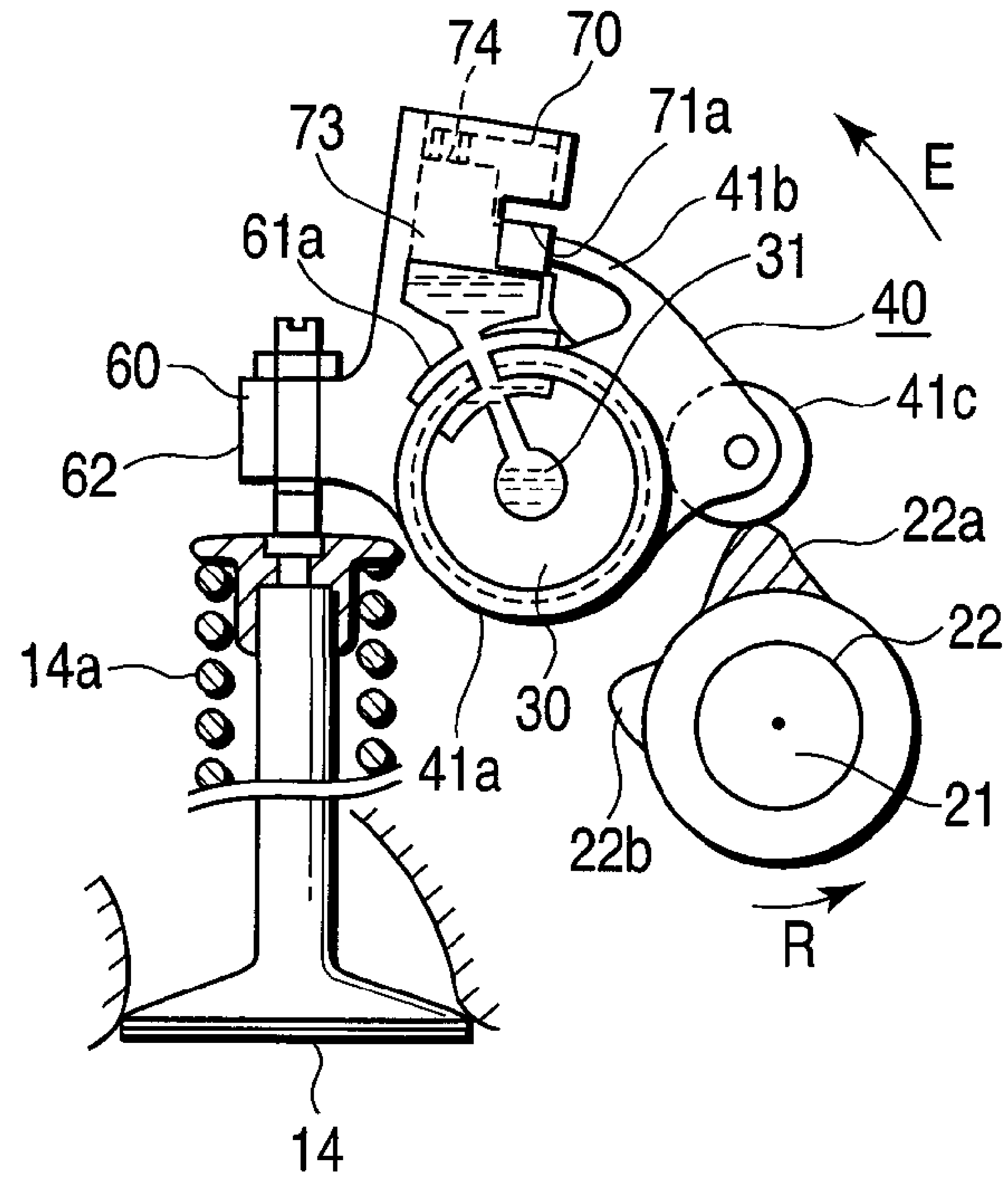

74
70
73
71a
E
41b
61a
31
40
60
41c
62
22a
22
14a
30
41a
21
22b
R
14

FIG. 14

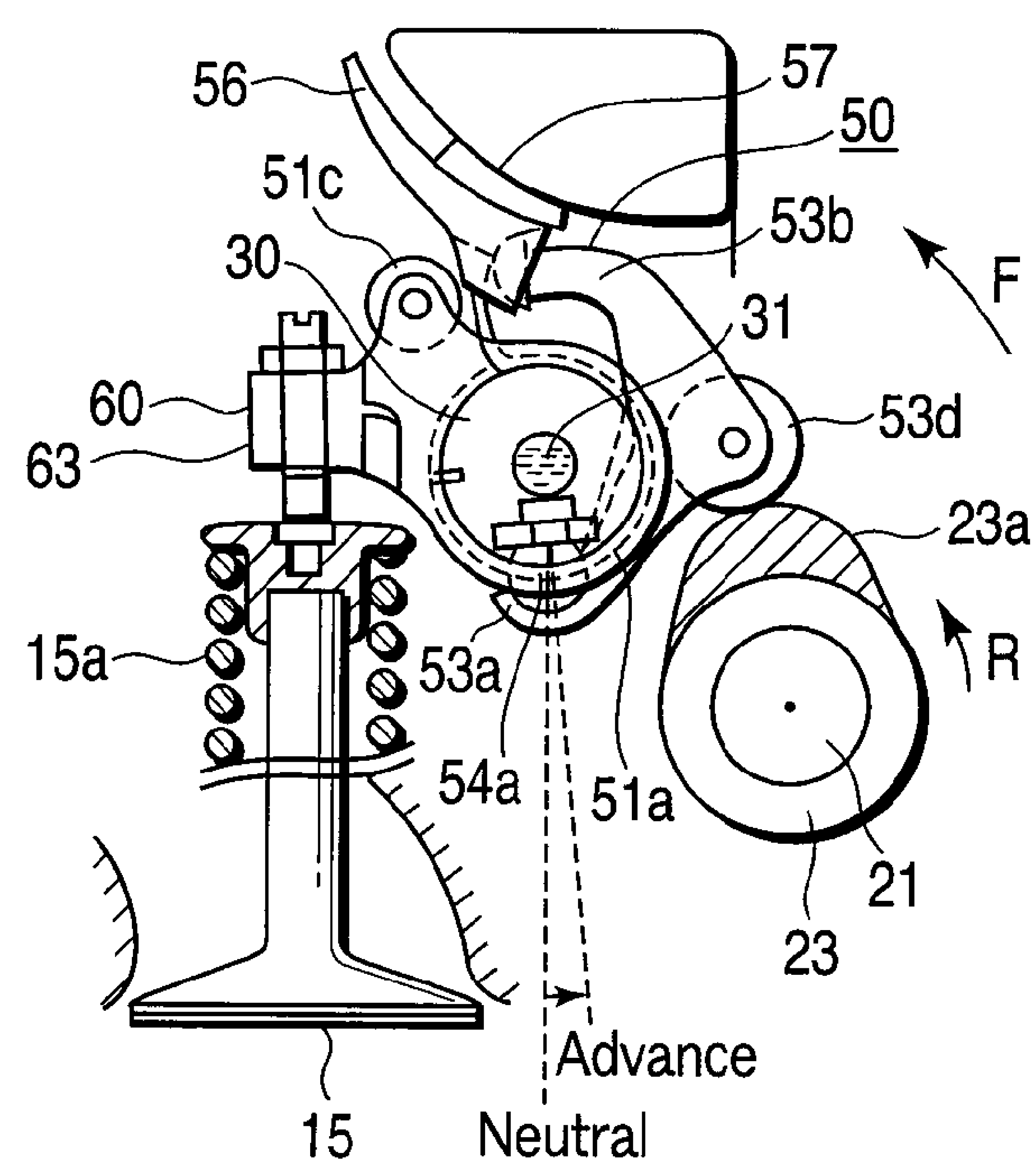

56
57
50
51c
53b
30
F
31
60
53d
63
23a
15a
53a
R
54a
51a
21
23
Advance
15
Neutral

FIG. 15

VARIABLE VALVE APPARATUS FOR INTERNAL COMBUSTION ENGINE

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This is a Continuation application of PCT Application No. PCT/JP2008/073635, filed Dec. 25, 2008, which was published under PCT Article 21(2) in Japanese.

[0002] This application is based upon and claims the benefit of priority from prior Japanese Patent Applications No. 2007-338360, filed Dec. 27, 2007; and No. 2008-004745, filed Jan. 11, 2008, the entire contents of both of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0003] 1. Field of the Invention

[0004] The present invention relates to a variable valve apparatus for an internal combustion engine which makes it possible to change drive phases and valve lifts of an air intake valve, an exhaust valve, and the like. 2. Description of the Related Art

[0005] In an internal combustion engine such as an automobile engine, a variable valve apparatus is known which changes drive phases and lifts of intake/exhaust valves depending on driving states of the internal combustion engine to purify an exhaust gas discharged from the engine or to reduce a fuel consumption of the automobile.

[0006] As the variable valve apparatus, a variable valve apparatus having a continuous variable rocker arm mechanism is known in which a third arm is arranged between a first arm which drives a valve and a second arm caused to oscillate by a cam, the valve is driven through the third arm, and a fulcrum of oscillation of the second arm is displaced to continuously change the phase and lift of the valve (for example, see Jpn. Pat. Appln. KOKAI Publication No. 2004-339079).

[0007] The variable valve apparatus having the continuous variable rocker arm mechanism adjusts the lift and phase of a valve to purify an exhaust gas and adjusts an opening valve angle to make it possible to improve a fuel consumption.

[0008] On the other hand, a variable valve apparatus having a switching rocker arm mechanism is known in which a mechanism which selectively transmits displacement is arranged between the first arm which drives the valve and the second arm caused to oscillate by the cam to operate or stop the first arm (for example, see Jpn. Pat. Appin. KOKAI Publication No. 2005-105953).

[0009] The variable valve apparatus having the switching rocker arm mechanism performs internal EGR by opening an exhaust valve in an intake stroke to make it possible to purify an exhaust gas and opens the exhaust valve at a compression top dead center to make it possible to apply the engine braking.

BRIEF SUMMARY OF THE INVENTION

[0010] However, the variable valve apparatus as described above must select any one of a switching rocker arm mechanism **40** and a continuous variable rocker arm mechanism **50**, and can exert only one of the functions of the mechanisms. Furthermore, although the switching rocker arm mechanism **40** can be instantaneously operated, the switching rocker arm mechanism **40** cannot be finely adjusted in lift and phase of the valve. On the other hand, although the continuous variable rocker arm mechanism **50** can be finely adjusted in lift and phase, the continuous variable rocker arm mechanism **50** requires about one second for an operation and has poor responsiveness.

[0011] Therefore, it is an object of the present invention to provide a variable valve apparatus for an internal combustion engine which can execute internal EGR and apply engine braking and can simultaneously exert a plurality of functions such as improvement in fuel consumption and purification of an exhaust gas.

[0012] In order to solve the problem and achieve the object, the variable valve apparatus for an internal combustion engine of the present invention has the following configuration.

[0013] A variable valve apparatus for an internal combustion engine, comprises a cam shaft arranged to be rotatable on a cylinder head of the internal combustion engine; a rocker shaft arranged to be capable of oscillation in the internal combustion engine; a continuous variable rocker arm mechanism which is driven by a cam formed on the cam shaft, opens or closes at least one of an air intake valve and an exhaust valve, and continuously makes a lift of the valve variable; and a switching rocker arm mechanism which is driven by the cam formed on the cam shaft, opens or closes at least one of the air intake valve and the exhaust valve, and switches the lift of the valve in a stepwise manner.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

[0014] FIG. **1** is a plan view showing a main part of a cylinder block in which a variable valve apparatus according to the present invention is incorporated.

[0015] FIG. **2** is a sectional view showing the cylinder head block cut along line A-A in FIG. **1** when viewed in a direction given by an arrow.

[0016] FIG. **3** is a sectional view showing the cylinder head block cut along line B-B in FIG. **1** when viewed in a direction given by an arrow.

[0017] FIG. **4** is a perspective view showing the variable valve apparatus.

[0018] FIG. **5** is an exploded perspective view showing the variable valve apparatus.

[0019] FIG. **6** is an explanatory diagram showing a control concept in execution of internal EGR.

[0020] FIG. **7** is an explanatory diagram showing a control concept in execution of internal EGR.

[0021] FIG. **8** is a sectional view showing an operation of a switching rocker arm mechanism in a normal operation.

[0022] FIG. **9** is a sectional view showing an operation of a continuous variable rocker arm mechanism in a normal operation.

[0023] FIG. **10** is a sectional view showing an operation of the switching rocker arm mechanism in execution of internal EGR.

[0024] FIG. **11** is a sectional view showing an operation of the continuous variable rocker arm mechanism in execution of internal EGR.

[0025] FIG. **12** is an explanatory diagram showing a control concept in application of engine braking.

[0026] FIG. **13** is an explanatory diagram showing a control concept in application of engine braking.

[0027] FIG. **14** is a sectional view showing an operation of the switching rocker arm mechanism in application of engine braking.

[0028] FIG. **15** is a sectional view showing an operation of the continuous variable rocker arm mechanism in application of engine braking.

DETAILED DESCRIPTION OF THE INVENTION

[0029] FIG. **1** is a plan view showing a main part of a cylinder head **10** in which a variable valve apparatus **20** for an internal combustion engine according to a first embodiment of the invention is incorporated, FIG. **2** is a sectional view showing the cylinder head **10** cut along line A-A in FIG. **1** when viewed in a direction given by an arrow, FIG. **3** is a sectional view showing the cylinder head **10** cut along line B-B in FIG. **1** when viewed in a direction given by an arrow, FIG. **4** is a perspective view showing the variable valve apparatus **20**, and FIG. **5** is an exploded perspective view showing the variable valve apparatus **20**.

[0030] As shown in FIGS. **1** to **3**, one pair of air intake valves **12** and **13** and one pair of exhaust valves **14** and **15** are arranged on the cylinder head **10**. The air intake valves **12** and **13** are arranged in an intake path **10***a* of the cylinder head **10** such that the air intake valves **12** and **13** can be reciprocated in an axial direction, and the air intake valves **12** and **13** are always biased in such a direction that the intake path **10***a* is closed by valve springs **12***a* and **13***a*. The exhaust valves **14** and **15** are arranged in an exhaust path **10***b* of the cylinder head **10** such that the exhaust valves **14** and **15** can be reciprocated in the axial direction, and the exhaust valves **14** and **15** are always biased in such a direction the intake path **10***a* is closed by valve springs **14***a* and **15***a*. The cylinder **11** is attached to a cylinder block (not shown) located below the cylinder head **10**.

[0031] The variable valve apparatus **20** is a valve operation apparatus which opens/closes valves of an internal combustion engine. One pair of variable valve apparatuses **20** is arranged to sandwich the cylinder **11**. Since the one pair of variable valve apparatuses **20** has a structure symmetrical with reference to the cylinder **11**, only the variable valve apparatus **20** on the exhaust valves **14** and **15** side will be explained, and an explanation of the variable valve apparatus **20** on the air intake valves **12** and **13** side is not explained.

[0032] The cylinder head **10** comprises one pair of cam shafts **21** arranged to be rotatable, one pair of rocker shafts **30** arranged to be capable of oscillation, one pair of switching rocker arm mechanisms **40** which are driven by a cam **22** formed on the cam shaft **21** and open and close the air intake valves **12** and **13** and the exhaust valves **14** and **15** and switch lifts of the air intake valves **12** and **13** and the exhaust valves **14** and **15** in a stepwise manner, and one pair of continuous variable rocker arm mechanisms **50** which are driven by a cam **23** formed on the cam shaft **21** and open and close the air intake valves **12** and **13** and the exhaust valves **14** and **15** and continuously make the lifts variable. The switching rocker arm mechanisms **40** and the continuous variable rocker arm mechanisms **50** share a rocker arm **60**.

[0033] The cam shafts **21** and the rocker shafts **30** are connected to a crank shaft (not shown) of an internal combustion engine through a cam chain, gears, and the like. When the crank shaft is rotated, the cams **22** and **23** having different cam profiles are rotationally driven in a direction indicated by an arrow R. The cams **22** and **23** drive the variable valve apparatus **20** at a predetermined timing described later.

[0034] An oil path **31** to which engine oil is supplied is arranged inside the rocker shaft **30**. An oil pressure supply mechanism **80** which supplies the engine oil to the oil path **31** is connected to the oil path **31**. The rocker shaft **30** comprises a drive mechanism **90** which controls a rotational angle position about a shaft center line of the rocker shaft **30**. Furthermore, a notch **32** is formed in the rocker shaft **30** at a position corresponding to the continuous variable rocker arm mechanism **50**.

[0035] With reference to FIGS. **2** and **5**, the switching rocker arm mechanism **40** will be explained. The switching rocker arm mechanism **40** comprises the shared rocker arm **60** supported by the rocker shafts **30** to be capable of oscillation and formed to make it possible to drive the exhaust valves **14** and **15**, and a switching rocker arm **41** driven by the cam **22** and arranged to be capable of oscillation on the rocker shaft **30**.

[0036] In the switching rocker arm **41**, a boss portion **41***a* supported by the rocker shaft **30** to be capable of oscillation is formed; a strike arm **41***b* which projects upwardly from the boss portion **41***a*, enters a window portion **71***b* of a vertical piston structure **70** serving as a transmission mechanism described later, and retreats from the window portion **71***b* is formed; and a roller **41***c* capable of oscillation is formed. When the roller **41***c* is brought into contact with the cam **22** to rotate the cam **22**, the switching rocker arm **41** is caused to oscillate by using a shaft center line of the rocker shaft **30** as a fulcrum. A trench **41***d* is formed in the switching rocker arm **41**.

[0037] Reference number **42** in FIG. **5** denotes a torsion coil spring. A bent portion **42***a* is formed on one end side of the spring, and a moving portion **42***b* extending in an axial direction of the rocker shafts **30** and bent to the outside in the radial direction is formed on the other end side of the spring. The bent portion **42***a* is inserted into the cylinder head **10**. When the moving portion **42***b* of the torsion coil spring **42** is engaged in the trench **41***d*, the torsion coil spring **42** biases the switching rocker arm **41** such that the roller **41***c* moves along the lines of the cam **22**.

[0038] The shared rocker arm **60** comprises a boss portion **61** fitted in the rocker shaft **30** portion to be capable of oscillation, arms **62** and **63** extending from the boss portion **61** to the exhaust valves **14** and **15**, and a pressed portion **64** pressed by a pressing portion **53***b* described later. In the boss portion **61**, a flow path **61***a* which guides the engine oil from the oil path **31** is formed.

[0039] In the boss portion **61**, as a transmission mechanism to selectively transmit displacement from the switching rocker arm **41** to the shared rocker arm **60**, the cylindrical vertical piston structure **70** is arranged. The vertical piston structure **70** comprises a storage tube **71** having a hollow portion **71***a* continuing to an internal surface of the boss portion **61** and the window portion **71***b* on the side surface, a lid member **72** which blocks an upper-end opening of the hollow portion **71***a* of the storage tube **71**, a piston **73** reciprocatingly stored in the hollow portion **71***a*, and a spring **74** arranged on the lid member **72** to bias the piston **73** on the boss portion **61** side. A notch **73***a* is formed in the piston **73**. The notch **73***a* is generally set such that the notch **73***a* is located at a position of the window portion **71***b* by the operation of the spring **74**. When oil pressure is applied by the oil pressure supply mechanism **80**, engine oil is supplied from the oil path **31** to the hollow portion **71***a* to compress the spring **74** and push up the piston **73**. In this manner, a circumference of the piston **73** is exposed to the window portion **71***b*. In contrast to this, when the oil pressure is released, the piston

73 is pushed down by the operation of the spring 74. An on/off operation of the oil pressure can be instantaneously performed.

[0040] The strike arm 41*b* is arranged to face the window portion 71*b*. The strike arm 41*b* is formed to have a shape such that the strike arm 41*b* idly moves in the notch 73*a* when the notch 73*a* is positioned at the window portion 71*b* and moves while being struck on the circumference portion of the piston 73 when the circumference portion is positioned at the window portion 71*b*.

[0041] In this manner, in the structure, when the strike arm 41*b* of the switching rocker arm 41 is not struck on the piston 73, cam displacement from the switching rocker arm 41 is not transmitted to the shared rocker arm 60. When the strike arm 41*b* is struck on the piston 73, the cam displacement from the switching rocker arm 41 opens the exhaust valves 14 and 15 through the shared rocker arm 60. An oil discharge chamber 32 having a width larger than that of the flow path 61*a* is formed in the rocker shaft 30 on the downstream side of the oil path 31, so that the engine oil can be supplied to the hollow portion 71*a* even when the position of the flow path 61*a* is changed by oscillation of the rocker shaft 30 itself or oscillation of the switching rocker arm 41 with rotation of the cam 22. The width of the oil discharge chamber 32 is preferably larger than a distance of oscillation of the switching rocker arm 41 and preferably set to a width at which the engine oil can be supplied to the flow path 61*a* even when the rocker shaft 30 reaches the position of maximum oscillation.

[0042] Furthermore, an oil supply chamber 75 having a width larger than that of the flow path 61*a* is formed in the vertical piston structure 70 on an upstream side of the hollow portion 71*a*. Even when the switching rocker arm 41 is caused to oscillate with rotation of the cam 22 to change the position of the flow path 61*a*, the engine oil can be supplied to the hollow portion 71*a*. The width of the oil supply chamber 75 is preferably larger than a distance of oscillation of the switching rocker arm 41.

[0043] The continuous variable rocker arm mechanism 50 will be explained with reference to FIGS. 3 and 5. The continuous variable rocker arm mechanism 50 comprises the shared rocker arm 60 supported by the rocker shaft 30 to be capable of oscillation and formed to make it possible to drive the exhaust valves 14 and 15, a continuous variable arm 53 driven by the cam 23 and arranged to be capable of oscillation about a fulcrum Q set on the rocker shaft 30 side, and an intermediate arm 51 which is arranged between the shared rocker arm 60 and the continuous variable arm 53 and transmits oscillation displacement of the continuous variable arm 53 to the shared rocker arm 60 to drive the shared rocker arm 60.

[0044] The intermediate arm 51 comprises an annular shaft fitting portion 51*a* and a pressing portion 51*b* projecting from the shaft fitting portion 51*a* in a radial direction. A roller 51*c* is arranged on the pressing portion 51*b*. When the intermediate arm 51 is caused to oscillate about the rocker shaft 30, the pressing portion 53*b* presses the pressed portion 64 of the shared rocker arm 60, and the shared rocker arm 60 opens the exhaust valves 14 and 15.

[0045] The continuous variable arm 53 comprises a connection member 54 which connects the continuous variable arm 53 and the rocker shaft 30. The connection member 54 is a stud bolt, has a spherical universal coupling 54*a* on one end side thereof, is screwed into a screw hole 33 formed in the notch 32 of the rocker shaft 30, and is fixed by a lock nut 54*b*. When the connection member 54 is fixed to the rocker shaft 30, the universal coupling 54*a* functions as the fulcrum Q.

[0046] Reference number 55 in FIG. 5 denotes a torsion coil spring. The torsion coil spring 55 has a bent portion 55*a* formed on one end side thereof, and a moving portion 55*b* formed on the other end side thereof, extending in an axial direction of the rocker shaft 30 and bent to the outside in the radial direction. The bent portion 55*a* is inserted into the cylinder head 10.

[0047] The continuous variable arm 53 is formed to have an almost laterally-facing U shape in a side view. A laterally-facing U-shaped base end 53*a* is formed on a lower side in FIG. 5, and a contact portion 53*b* is formed on an upper side in FIG. 5. The base end 53*a* has a recessed portion 53*c* formed on an upper surface thereof. The recessed portion 53*c* is formed to have an almost semi-spherical shape corresponding to the spherical shape of the universal coupling 54*a* and incorporated to be capable of oscillation by using the universal coupling 54*a* as a fulcrum.

[0048] On the continuous variable arm 53, a roller 53*d* is arranged to be capable of oscillation at an intermediate position between the base end 53*a* and the contact portion 53*b*. When the roller 53*d* is brought into contact with the cam 23 and the cam 23 is rotated, the continuous variable arm 53 is caused to oscillate by using the center of the universal coupling 54*a* as a fulcrum.

[0049] Reference number 56 in FIG. 5 denotes a transformation member. The transformation member 56 is formed to have a triangular tabular shape which is long on one end side, and a slide surface portion 56*a* is formed on an upper-side surface in FIG. 5, and a transmission surface portion 56*b* is arranged on a lower-side surface in FIG. 5. The slide surface portion 56*a* is formed to have a curvature equal to that of a pad 57 (see FIG. 9) fixed to the cylinder head 10 and slidably moves along an arc-like lower surface of the pad 57.

[0050] The transmission surface portion 56*b* is formed such that a distance between the transmission surface portion 56*b* and the slide surface portion 56*a* has a predetermined value along the slide surface portion 56*a* . More specifically, the transmission surface portion 56*b* is formed such that, when the transformation member 56 is slidably moved along an arc-like lower surface of the pad 57, a member being in contact with the transmission surface portion 56*b* at a predetermined position makes a predetermined motion in a direction perpendicular to the pad 57 with the movement of the transformation member 56.

[0051] A trench 56*c* is formed in the transmission surface portion 56*b*, and the moving portion 55*b* of the torsion coil spring 55 is engaged in the trench 56*c*. When the moving portion 55*b* is engaged in the trench 56*c*, the torsion coil spring 55 biases the transformation member 56 such that the transformation member 56 moves to the continuous variable arm 53 side.

[0052] Furthermore, a semi-cylindrical joint 57 is arranged between the transformation member 56 and the contact portion 53*b* of the continuous variable arm 53. The joint 57 is attached to the contact portion 53*b* of the continuous variable arm 53 and slidably fitted on the transformation member 56. The joint 57 is designed to absorb a change in a contact angle between the transformation member 56 and the contact portion 53*b* and to transmit a pressing operation of the continuous variable arm 53 to the transformation member 56.

[0053] An operation of the continuous variable rocker arm mechanism 50 will be explained with reference to FIG. 9.

When a valve opening timing or a valve closing timing of the exhaust valve is to be retarded, the rocker shaft **30** is caused to oscillate by the drive mechanism **90** in such a direction that the universal coupling **54***a* of the connection member **54** approaches the exhaust valves **14** and **15** with reference to a neutral position.

[0054] The base end **53***a* is pulled to the left by the universal coupling **54***a*, and the continuous variable arm **53** moves to the left as a whole. On the other hand, the transformation member **56** is biased by the torsion coil spring **55** on the continuous variable arm **53** side. For this reason, the transformation member **56** is brought into tight contact with the pad **57**, and the roller **53***d* is brought into contact with the cam **23**. At this time, since the cam shafts **21** rotate counterclockwise, an angle between a start point of a cam nose and a contact point between the roller **53***d* and the cam **23** is set to be widest, and the continuous variable arm **53** is driven by the cam **23** later than that in the neutral state. As a result, the valve opening timing or the valve closing timing are retarded.

[0055] On the other hand, when a valve opening or valve closing timing of an exhaust valve is to be advanced, the universal coupling **54***a* of the connection member **54** is caused to oscillate in such a direction that the universal coupling **54***a* goes away from the exhaust valves **14** and **15** side with reference to the neutral position.

[0056] The base end **53***a* is pulled to the right by the universal coupling **54***a*, and the continuous variable arm **53** moves to the right as a whole. On the other hand, the transformation member **56** is biased by the torsion coil spring **55** on the continuous variable arm **53** side. For this reason, the transformation member **56** is brought into tight contact with the pad **57**, and the roller **53***d* is brought into contact with the cam **23**.

[0057] At this time, since the cam shafts **21** rotate counterclockwise, an angle between a start point of a cam nose and a contact point between the roller **53***d* and the cam **23** is set to be narrowest, and the continuous variable arm **53** is driven by the cam **23** earlier than that in the neutral state. As a result, the valve opening timing or the valve closing timing are advanced.

[0058] The retarding and advancing adjustments are continuously performed by continuously adjusting an angle position of the rocker shaft **30**.

[0059] As described above, the variable valve apparatus **20** can change a valve opening timing and a valve closing timing by making the drive mechanism **90** cause the rocker shaft **30** to oscillate. For this reason, the valve opening timing and the valve closing timing are changed to make it possible to increase an intake air flow and to achieve a reduction in fuel consumption.

[0060] With this configuration, in the internal combustion engine comprising the variable valve apparatus **20** having the switching rocker arm mechanism **40** and the continuous variable rocker arm mechanism **50**, the following control can be performed.

[0061] First, the operations of the switching rocker arm mechanism **40** and the continuous variable rocker arm mechanism **50** performed when an amount of internal EGR is optimized will be explained while comparing a "normal operation" and an "internal EGR operation". FIG. **6** is a graph showing a relationship between the phase and lift of the cam shaft **21**. Reference symbol EX denotes opening valves (lifts) of the exhaust valves **14** and **15**, and reference symbol IH denotes opening valves (lifts) of the air intake valves **12** and **13**.

<Normal Operation>

[0062] The cam shaft **21** causes an exhaust stroke which opens the exhaust valves **14** and **15** to slightly overlap an intake stroke performed by opening the air intake valves **12** and **13**. An operation of the switching rocker arm mechanism **40** at this time is shown in FIG. **8**, and an operation of the continuous variable rocker arm mechanism **50** at this time is shown in FIG. **9**. In the normal operation, on both the air intake valves **12** and **13** side and the exhaust valves **14** and **15** side, an operation mode of the switching rocker arm mechanism **40** is set to be off, and an operation mode of the continuous variable rocker arm mechanism **50** is set to a normal (neutral) mode.

[0063] More specifically, when the operation mode of the switching rocker arm mechanism **40** is set to be off, oil pressure is not applied by the oil pressure supply mechanism **80**, and engine oil is not supplied into the hollow portion **71***a* in the switching rocker arm mechanism **40**. For this reason, the piston **73** is biased downward by an elastic force of the spring **74**, and the notch **73***a* is located at the window portion **71***b*. On the other hand, the roller **41***c* moves along the cam **22** by the rotation of the cam **22** rotated by the cam shaft **21**, and the switching rocker arm **41** oscillates about the rocker shaft **30** at predetermined intervals in a direction indicated by an arrow E in FIG. **8**. However, even when the strike arm **41***b* is inserted into the window portion **71***b*, the strike arm **41***b* is inserted into only the notch **73***a* but not brought into contact with the piston **73**. Therefore, motion of the switching rocker arm **41** is not transmitted to the shared rocker arm **60**. Consequently, the switching rocker arm mechanism **40** does not operate, and the air intake valves **12** and **13** and the exhaust valves **14** and **15** are not driven.

[0064] In the continuous variable rocker arm mechanism **50**, the rocker shaft **30** is set at a neutral position by means of the drive mechanism **90**. Therefore, the roller **53***d* moves along the cam **23** by rotation of the cam **23** rotated by the cam shaft **21**, and the continuous variable arm **53** oscillates about the rocker shaft **30** at predetermined intervals in a direction indicated by an arrow F in FIG. **9**. In this manner, motion of the continuous variable arm **53** is transmitted to the shared rocker arm **60** through the transformation member **56** and the intermediate arm **51**, and the air intake valves **12** and **13** and the exhaust valves **14** and **15** are driven along a profile of the cam **23**.

[0065] As described above, in the normal operation, by the continuous variable rocker arm mechanism **50**, the air intake valves **12** and **13** and the exhaust valves **14** and **15** are driven according to phases and lifts which change along a solid line S.

<Internal EGR Operation>

[0066] In an internal EGR operation, on the air intake valves **12** and **13** side, the operation mode of the switching rocker arm mechanism **40** is set to be off, and the operation mode of the continuous variable rocker arm mechanism **50** is set to an early closing (advance) mode. On the exhaust valves **14** and **15** side, the operation mode of the switching rocker arm mechanism **40** is set to be on, and the operation mode of the continuous variable rocker arm mechanism **50** is set to a normal (neutral) mode.

[0067] The operations of the switching rocker arm mechanism **40** and the continuous variable rocker arm mechanism **50** are summarized as follows.

TABLE 1

Optimization of amount of internal EGR		
	Switching rocker arm mechanism	Continuous variable rocker arm mechanism
Air intake valve	OFF	Early closing
Exhaust valve	ON	Normal

[0068] When the operation mode of the switching rocker arm mechanism **40** on the exhaust valves **14** and **15** side is set to be on, oil pressure is applied by the oil pressure supply mechanism **80**. As shown in FIG. **10**, in the switching rocker arm mechanism **40**, engine oil is supplied into the hollow portion **71***a*. For this reason, the piston **73** rises against the elastic force of the spring **74**, and the circumference of the piston **73** is positioned at the window portion **71***b*. On the other hand, the roller **41***c* moves along the cam **22** by rotation of the cam **22** rotated by the cam shaft **21**, and the switching rocker arm **41** oscillates about the rocker shaft **30** at predetermined intervals in a direction indicated by an arrow E in FIG. **8**. When the strike arm **41***b* is inserted into the window portion **71***b*, the strike arm **41***b* is brought into contact with the circumference of the piston **73**. Therefore, motion of the switching rocker arm **41** is transmitted to the shared rocker arm **60**, and the exhaust valves **14** and **15** are driven along a profile of the cam **22**. A nose **22***a* of the cam **22** corresponds to reference symbol P in FIG. **6**.

[0069] In the continuous variable rocker arm mechanism **50** on the air intake valves **12** and **13** side, the rocker shaft **30** is rotated counterclockwise by a predetermined angle by means of the drive mechanism **90** and set at an advance angle position. A fulcrum of oscillation of the continuous variable arm **53** is distanced from the air intake valves **12** and **13**. In this state, by rotation of the cam **23** rotated by the cam shaft **21**, the roller **53***d* moves along the cam **23**, and the continuous variable arm **53** oscillates about the rocker shaft **30** at predetermined intervals in a direction indicated by an arrow F in FIG. **11**. In this manner, motion of the continuous variable arm **53** is transmitted to the shared rocker arm **60** through the transformation member **56** and the intermediate arm **51**, and the air intake valves **12** and **13** are driven while being advanced with respect to the profile of the cam **23**.

[0070] As described above, in an intake stroke of the internal EGR operation, the air intake valves **12** and **13** are driven by the continuous variable rocker arm mechanism **50**, and the exhaust valves **14** and **15** are driven by the switching rocker arm mechanism **40**. Therefore, the air intake valves **12** and **13** open according to phases and lifts indicated by reference symbol S in FIG. **6**, and the exhaust valves **14** and **15** open according to phases and lifts indicated by reference symbol P in FIG. **6**. More specifically, the exhaust valves **14** and **15** open at timings indicated by reference symbol P in FIG. **6**. That is, since the exhaust valves **14** and **15** open in the intake stroke, an exhaust gas temporarily exhausted from the cylinder **11** is taken into the cylinder **11** to cause an internal EGR operation.

[0071] Since the lifts of the exhaust valves **14** and **15** at this time are constant, an amount of internal EGR is constant. On the other hand, since an operation state of the engine is not constant, a required amount of EGR changes. For this reason, this fine adjustment is performed by the operations of the air intake valves **12** and **13**. More specifically, in order to prevent a reduction in NO_x from being hindered due to an excessively small amount of internal EGR, the end of closing of the air intake valves **12** and **13** is made early to make it possible to reduce an amount of intake itself, and the amount of internal EGR consequently relatively increases. FIG. **7** shows a relationship between closing end phases and amounts of air of the air intake valves **12** and **13** and a relationship between the closing end phases and the amounts of internal EGR of the air intake valves **12** and **13**. When the air intake valves **12** and **13** are closed in a phase S**1** or S**2** slightly earlier than a standard closing end phase S**0**, an amount of air decreases, and the amount of internal EGR increases.

[0072] As described above, the switching rocker arm mechanism **40** and the continuous variable rocker arm mechanism **50** are operated in conjunction with each other to make it possible to obtain a more appropriate amount of EGR and to purify an exhaust gas.

[0073] Operations of the switching rocker arm mechanism **40** and the continuous variable rocker arm mechanism **50** in an engine braking operation will be explained while comparing a "normal operation" and an "engine braking operation". FIG. **12** is a graph showing a relationship between the phase and lift of the cam shaft **21**. Reference symbol EX denotes opening valves (lifts) of the exhaust valves **14** and **15**, and reference symbol IH denotes opening valves (lifts) of the air intake valves **12** and **13**.

<Normal Operation>

[0074] The cam shaft **21** causes an exhaust stroke which opens the exhaust valves **14** and **15** to slightly overlap an intake stroke performed by opening the air intake valves **12** and **13**. An operation of the switching rocker arm mechanism **40** at this time is shown in FIG. **8**, and an operation of the continuous variable rocker arm mechanism **50** at this time is shown in FIG. **9**. In the normal operation, on both the air intake valves **12** and **13** side and the exhaust valves **14** and **15** side, an operation mode of the switching rocker arm mechanism **40** is set to be off, and an operation mode of the continuous variable rocker arm mechanism **50** is set to a normal (neutral) mode.

[0075] The operation of the switching rocker arm mechanism **40** and the operation of the continuous variable rocker arm mechanism **50** in the normal state will not be explained because the operations are the same as those in FIGS. **8** and **9**.

<Engine Braking Operation>

[0076] In an engine braking operation, on the air intake valves **12** and **13** side, the operation mode of the switching rocker arm mechanism **40** is set to be off, and the operation mode of the continuous variable rocker arm mechanism **50** is set to a normal (neutral) mode. On the exhaust valves **14** and **15** side, the operation mode of the switching rocker arm mechanism **40** is set to be on, and the operation mode of the continuous variable rocker arm mechanism **50** is set to an early opening (advance) mode.

[0077] The operations of the switching rocker arm mechanism **40** and the continuous variable rocker arm mechanism **50** are summarized as follows.

TABLE 2

Engine braking operation		
	Switching rocker arm mechanism	Continuous variable rocker arm mechanism
Air intake valve	OFF	Normal
Exhaust valve	ON	Early opening

[0078] When the operation mode of the switching rocker arm mechanism **40** on the exhaust valves **14** and **15** side is set to be on, oil pressure is applied by the oil pressure supply mechanism **80**. As shown in FIG. **14**, in the switching rocker arm mechanism **40**, engine oil is supplied into the hollow portion **71***a*. For this reason, the piston **73** rises against the elastic force of the spring **74**, and the circumference of the piston **73** is positioned at the window portion **71***b*. On the other hand, the roller **41***c* moves along the cam **22** by rotation of the cam **22** rotated by the cam shaft **21**, and the switching rocker arm **41** oscillates about the rocker shaft **30** at predetermined intervals in a direction indicated by an arrow E in FIG. **14**. When the strike arm **41***b* is inserted into the window portion **71***b*, the strike arm **41***b* is brought into contact with the circumference of the piston **73**. Therefore, motion of the switching rocker arm **41** is transmitted to the shared rocker arm **60**, and the exhaust valves **14** and **15** are driven along a profile of the cam **22**. The nose **22***a* of the cam **22** corresponds to reference symbol L in FIG. **6**.

[0079] As shown in FIG. **15**, in the continuous variable rocker arm mechanism **50** on the exhaust valves **14** and **15** side, the rocker shaft **30** is rotated counterclockwise by a predetermined angle by means of the drive mechanism **90** and set at an advance angle position. A fulcrum of oscillation of the continuous variable arm **53** is distanced from the air intake valves **12** and **13**. In this state, by rotation of the cam **23** rotated by the cam shaft **21**, the roller **53***d* moves along the cam **23**, and the continuous variable arm **53** oscillates about the rocker shaft **30** at predetermined intervals in a direction indicated by an arrow F in FIG. **15**. In this manner, motion of the continuous variable arm **51** is transmitted to the shared rocker arm **60** through the transformation member **56** and the intermediate arm **51**, and the air intake valves **12** and **13** are driven while being advanced with respect to the profile of the cam **23**.

[0080] As described above, in the engine braking operation, the air intake valves **12** and **13** are driven by the continuous variable rocker arm mechanism **50**, and the exhaust valves **14** and **15** are driven by both the switching rocker arm mechanism **40** and the continuous variable rocker arm mechanism **50**. Therefore, the air intake valves **12** and **13** open according to phases and lifts indicated by reference symbol N in FIG. **12**, and the exhaust valves **14** and **15** open according to phases and lifts indicated by reference symbols M and L in FIG. **12**. More specifically, the switching rocker arm mechanism **40** opens the exhaust valves **14** and **15** at timings indicated by reference symbol L in FIG. **12**. That is, the exhaust valves **14** and **15** open at a compression top dead center (TDC) to operate a compression brake. Since the lifts of the exhaust valves **14** and **15** are constant, the braking effect is constant.

[0081] On the other hand, since the operation state of the engine is not constant, a necessary braking force changes. For this reason, this fine adjustment is performed by the operations of the exhaust valves **14** and **15** driven by the continuous variable rocker arm mechanism **50**. More specifically, when the exhaust valves **14** and **15** start to open in a phase M**1** or M**2** slightly earlier than a standard phase M**0** to make an opening timing early, an exhaust energy (amount of air) can be increased, and the braking force is consequently relatively increased. FIG. **13** shows a relationship between opening start phases of the exhaust valves **14** and **15** and the exhaust energy (amount of air) and a relationship between the opening start phases of the exhaust valves **14** and **15** and the engine braking force.

[0082] As described above, when the switching rocker arm mechanism **40** and the continuous variable rocker arm mechanism **50** are operated in conjunction with each other, a more appropriate engine braking force can be obtained, and preferable drive feeling can be obtained.

[0083] As described above, according to the variable valve apparatus **20** for an internal combustion engine according to the embodiment, a plurality of functions such as execution of internal EGR, application of engine braking, improvement in fuel consumption, and purification of an exhaust gas can be simultaneously exerted.

[0084] According to the present invention, valves are opened or closed by using both the switching rocker arm mechanism and the continuous variable rocker arm mechanism to make it possible to realize a plurality of functions such as instantaneous switching of opening/closing timings of the valves and fine control of lifts.

[0085] Furthermore, transmission of oscillation displacement is selectively performed as needed to make it possible to open or close a valve without delay. The transmission of oscillation displacement is continuously performed to make it possible to finely control the drive phase and lift of the valve. When fine adjustment of an amount of EGR is performed while performing the internal EGR, an exhaust gas can be purified. Engine braking can be applied, and the effect can be enhanced.

What is claimed is:

1. A variable valve apparatus for an internal combustion engine, comprising:

a cam shaft arranged to be rotatable on a cylinder head of the internal combustion engine;

a rocker shaft arranged to be capable of oscillation in the internal combustion engine;

a continuous variable rocker arm mechanism which is driven by a cam formed on the cam shaft, opens or closes at least one of an air intake valve and an exhaust valve, and continuously makes a lift of the valve variable; and

a switching rocker arm mechanism which is driven by the cam formed on the cam shaft, opens or closes at least one of the air intake valve and the exhaust valve, and switches the lift of the valve in a stepwise manner.

2. The variable valve apparatus for an internal combustion engine according to claim **1**, wherein

the switching rocker arm mechanism comprises:

a shared rocker arm which is supported on the rocker shaft to be capable of oscillation and configured to drive the valve;

a switching rocker arm which is driven by the cam and arranged to be capable of oscillation on the rocker shaft; and

a transmission mechanism which selectively transmits displacement from the switching rocker arm to the shared rocker arm.

3. The variable valve apparatus for an internal combustion engine according to claim **1**, wherein

the continuous variable rocker arm mechanism comprises:

a shared arm supported on the rocker shaft to be capable of oscillation and configured to drive the valve;

a continuous variable arm driven by the cam and arranged to be capable of oscillation about a fulcrum arranged on the rocker shaft side;

an intermediate arm supported by the rocker shaft to be capable of oscillation and arranged between the shared arm and the continuous variable arm;

a transformation member which is arranged between the intermediate arm and the continuous variable arm and transmits oscillation displacement of the continuous variable arm to the shared arm through the intermediate arm; and

a drive mechanism which causes the rocker shaft to oscillate to displace the fulcrum.

4. The variable valve apparatus for an internal combustion engine according to claim **1**, wherein

the internal combustion engine comprises the continuous variable rocker arm mechanism on an intake side and the switching rocker arm mechanism on an exhaust side, and

when the internal combustion engine is in an intake stroke, the exhaust valve is opened by the switching rocker arm mechanism, and the air intake valve is closed early by the continuous variable rocker arm mechanism.

5. The variable valve apparatus for an internal combustion engine according to claim **1**, wherein

the internal combustion engine comprises at least one of the exhaust valves driven by the switching rocker arm mechanism and at least one of the exhaust valves driven by the continuous variable rocker arm mechanism per cylinder, and

when the internal combustion engine is near a compression top dead center, the exhaust valve is opened by the switching rocker arm mechanism, and the exhaust valve is opened early by the continuous variable rocker arm mechanism.

* * * * *