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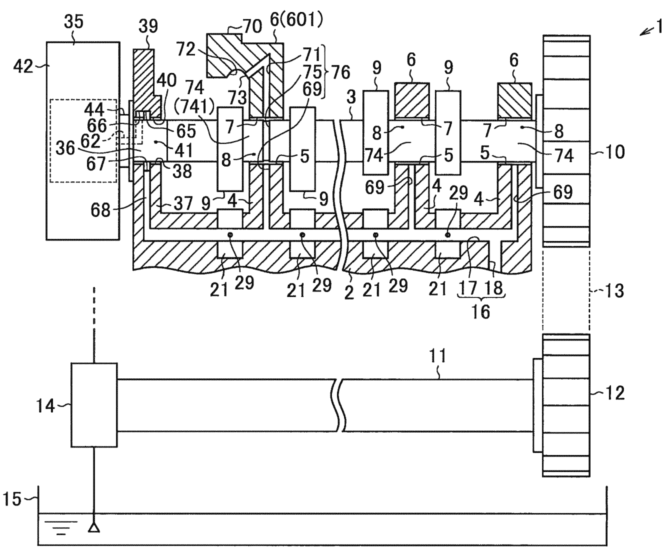
(54) INTERNAL COMBUSTION ENGINE

(57) An internal combustion engine (1) includes: a cylinder head (2); an oil feed passage (16); a camshaft (3); a vacuum pump (35) that has a rotor (36) and a housing (42), with a negative-pressure chamber defined by the rotor (36) and the housing (42) being connected to the oil feed passage (16), and is configured to generate negative pressure inside the negative-pressure chamber as the rotor (36) rotates; a hydraulic lash adjuster (21) connected to the oil feed passage (16); and a branch passage (76) branched from the oil feed passage (16). An open hole (73) open to the atmosphere is provided at a leading end of the branch passage (76), and oil is fed through the open hole (73) to the camshaft (3) while the internal combustion engine (1) is in operation, and air is introduced through the open hole (73) into the vacuum pump (35) while the internal combustion engine (1) is stopped.

FIG. 1



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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to an internal combustion engine.

2. Description of Related Art

[0002] The cylinder head of an internal combustion engine has an oil feed passage formed therein, and oil pumped up from an oil pump is fed through the oil feed passage to parts of the internal combustion engine. In the internal combustion engine described in Japanese Patent Application Publication No. 2009-121258, the cylinder head is provided with hydraulic lash adjusters. With oil fed through the oil feed passage to the lash adjusters, the clearance between the cams, provided on the camshaft, and the rocker arms is adjusted.

[0003] The internal combustion engine described in Japanese Patent Application Publication No. 2007-278205 is provided with a vacuum pump that generates negative pressure. The vacuum pump includes a rotor that rotates integrally with the camshaft. Therefore, oil that allows smooth rotation of such a rotating body is fed to the vacuum pump through an oil feed passage formed in the cylinder head.

[0004] In an internal combustion engine equipped with a vacuum pump, when driving of the vacuum pump stops as the engine stops, negative pressure remaining inside the vacuum pump may cause oil to be suctioned from the oil feed passage of the cylinder head into the vacuum pump. As a result, when the internal combustion engine is restarted after having been stopped, the amount of oil remaining in the oil feed passage may have become smaller.

[0005] Therefore, in the case where the internal combustion engine is provided with both a vacuum pump and a hydraulic lash adjuster and configured to feed oil from the oil feed passage of the cylinder head to both the vacuum pump and the hydraulic lash adjuster, when restarted after having been stopped, the internal combustion engine may fail to quickly feed oil from the oil feed passage to the lash adjuster, causing malfunction of the lash adjuster.

SUMMARY OF THE INVENTION

[0006] Having been contrived in view of the above problem, the present invention provides an internal combustion engine that is provided with both a vacuum pump and a lash adjuster and yet hardly causes malfunction of the lash adjuster.

[0007] According to one aspect of the present invention, there is provided an internal combustion engine that has: a cylinder head; an oil pump; an oil feed passage that is provided inside the cylinder head and fed with oil pumped up from the oil pump; and a camshaft attached to the cylinder head. The internal combustion engine further includes a vacuum pump, a hydraulic lash adjuster, and a branch passage. Here, the vacuum pump has a rotor that is coupled to the camshaft and rotates integrally with the camshaft, a housing that houses the rotor, and a negative-pressure chamber that is defined by the rotor and the housing and connected to the oil feed passage. The vacuum pump is configured to generate negative pressure inside the negative-pressure chamber as the rotor rotates. The lash adjuster is connected to the oil feed passage, and is configured to adjust a clearance between a cam, provided on the camshaft, and a rocker arm by means of oil fed from the oil feed passage. The branch passage is branched from the oil feed passage and provided with an open hole open to the atmosphere at a leading end of the branch passage, and the branch passage is configured to feed oil through the open hole to the camshaft while the internal combustion engine is in operation, and to introduce air through the open hole into the vacuum pump while the internal combustion engine is stopped.

[0008] According to the configuration of the internal combustion engine as described above, when the internal combustion engine stops and oil inside the oil feed passage is suctioned into the vacuum pump, air is introduced into the oil feed passage through the open hole of the branch passage. Then, when the air introduced through the open hole is drawn into the vacuum pump and the vacuum pump and the atmosphere communicate with each other, air is subsequently suctioned into the vacuum pump, which prevents oil from being further drawn into the vacuum pump. Thus, the amount of oil suctioned into the vacuum pump while the internal combustion engine is stopped is reduced.

[0009] On the other hand, while the internal combustion engine is in operation, the oil fed to the oil feed passage passes through the branch passage and is fed through the open hole to the camshaft. Therefore, according to the above configuration, it is possible to prevent a decrease in the amount of oil remaining in the oil feed passage by reducing the amount of oil suctioned from the oil feed passage into the vacuum pump. Accordingly, oil can be quickly fed to the lash adjuster at restart of the internal combustion engine. Thus, even when both the vacuum pump and the lash adjuster are provided, malfunction of the lash adjuster hardly occurs.

[0010] In this internal combustion engine, the cylinder head may be provided with a bearing that supports the camshaft, and a cam cap may be attached to the bearing. A bearing hole configured to support the camshaft may be provided by the bearing and the cam cap. The open hole may be provided in the cam cap to be open toward the camshaft, and the branch passage may extend from the oil feed passage to the open hole through the inside of the bearing and the cam cap.

[0011] In the above internal combustion engine, a plurality of cam caps may be attached to the cylinder head to be arrayed in an extension direction of a center axis of the camshaft, and of the plurality of cam caps, a cam cap located on the nearest side of the vacuum pump in the extension direction may be provided with the open hole. Alternatively, a plurality of cam caps may be attached to the cylinder head to be arrayed in an extension direction of a center axis of the camshaft, and of the plurality of cam caps, a cam cap located on the nearest side of the vacuum pump in the extension direction and a plurality of cam caps close to that cam cap may be each provided with the open hole.

[0012] Accordingly, the cam cap located closest to the vacuum pump when the plurality of cam caps are arrayed in the extension direction of the center axis of the camshaft is provided with the open hole, or not only the cam cap located closest to the vacuum pump but also other cam caps close to that cam cap are each provided with the open hole. Therefore, the distance between the vacuum pump and the open hole is reduced, and the amount of oil suctioned from the oil feed passage into the vacuum pump before the vacuum pump communicates with the atmosphere can be reduced. Thus, it is possible to further prevent a decrease in the amount of oil remaining inside the oil feed passage while the internal combustion engine is stopped.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] Features, advantages, and technical and industrial significance of exemplary embodiments of the invention will be described below with reference to the accompanying drawings, in which like numerals denote like elements, and wherein:

FIG. 1 is a sectional view schematically showing the configuration of an internal combustion engine of an embodiment as one example of the present invention;
FIG. 2 is a sectional view showing the configuration of a valve mechanism of the internal combustion engine;
FIG. 3 is a sectional view showing the configuration of a lash adjuster of the valve mechanism;
FIG. 4 is a sectional view showing the configuration of a vacuum pump provided in the internal combustion engine;
FIG. 5 is an exploded perspective view of the vacuum pump;
FIG. 6 is a side view showing the vacuum pump with a cover removed;
FIG. 7 is a sectional view showing the flow of oil fed into an oil feed passage while the internal combustion engine is in operation;
FIG. 8 is a sectional view schematically showing the flow of oil inside the oil feed passage and the flow of air inside a branch passage while the internal combustion engine is stopped;
FIG. 9 is a sectional view showing the flow of oil and the flow of air inside the oil feed passage when air is introduced from the branch passage into the oil feed passage while the internal combustion engine is stopped; and
FIG. 10 is a sectional view schematically showing a state in which air is introduced through the branch passage into the vacuum pump while the internal combustion engine is stopped.

DETAILED DESCRIPTION OF EMBODIMENTS

[0014] In the following, one embodiment of an internal combustion engine will be described with reference to FIG. 1 to FIG. 10. As shown in FIG. 1, a cylinder head 2 of an internal combustion engine 1 is provided with a plurality of bearings 4 that support a camshaft 3. The bearing 4 has a semicircular recess 5 formed therein. A cam cap 6 is attached to each bearing 4. Each cam cap 6 has a semicircular recess 7 formed therein that is symmetrical to the recess 5 of the bearing 4. Thus, when the cam cap 6 is attached to the bearing 4, a bearing hole 8 that receives the camshaft 3 is formed by the bearing 4 and the cam cap 6.

[0015] The camshaft 3 is inserted through each bearing hole 8, and the camshaft 3 is rotatably supported by the bearings 4 and the cam caps 6. Thus, the plurality of cam caps 6 are attached to the cylinder head 2 to be arrayed in the extension direction of the center axis of the camshaft 3.

[0016] The camshaft 3 has a plurality of cams 9 that rotate integrally with the camshaft 3, and a timing pulley 10 is connected to one end (right end in FIG. 1) of the camshaft 3. A crank pulley 12 is connected to one end (right end in FIG. 1) of a crankshaft 11. A timing belt 13 is wound around each of the pulleys 10, 12. Thus, as the crankshaft 11 rotates, the camshaft 3 rotates in conjunction with the crankshaft 11.

[0017] An engine-driven oil pump 14 is connected to the other end (left end in FIG. 1) of the crankshaft 11. The oil pump 14 is driven as the crankshaft 11 rotates, and thereby pumps up oil stored in an oil pan 15 and feeds the oil to parts of the internal combustion engine 1.

[0018] The cylinder head 2 has an oil feed passage 16 formed therein that is fed with the oil pumped up from the oil pump 14. The oil feed passage 16 has a first oil feed passage 17 that extends inside the cylinder head 2 in the axial direction of the camshaft 3 (left-right direction in FIG. 1), and a second oil feed passage 18 that connects the first oil feed passage 17 and an oil passage formed inside the cylinder block to each other. The oil feed passage 16 is connected to the oil pump 14 through the oil passage formed inside the cylinder block.

[0019] Next, a valve mechanism of the internal combustion engine 1 will be described with reference to FIG. 2 and FIG. 3. As shown in FIG. 2, the plurality of cams 9 fixed to the camshaft 3 are each in contact with a rocker arm 19. The rocker arm 19 has one end portion (left end portion in FIG. 2) supported on an engine valve 20, and the other end portion (right end portion in FIG. 2) supported on a lash adjuster 21. Thus, when the cam 9 rotates as the camshaft 3 rotates, the rocker arm 19 swings with the other end portion supported on the lash adjuster 21 serving as the supporting point. While a force pushing the rocker arm 19 downward is being applied by a nose part 22 of the cam 9, the engine valve 20 is pushed downward against the urging force of a valve spring 23. As a result, a head 24 of the engine valve 20 separates from the cylinder head 2, leaving the engine valve 20 open. After the nose part 22 of the cam 9 has pushed the rocker arm 19 downward, the engine valve 20 is pushed upward by the urging force of the valve spring 23 until the head 24 comes into contact with the cylinder head 2, leaving the engine valve 20 closed. As the engine valve 20 is thus pushed upward, the rocker arm 19 is also pushed upward.

[0020] As shown in FIG. 3, the lash adjuster 21 has a one-end-closed cylindrical body 25 mounted on the cylinder head 2, and a one-end-closed cylindrical plunger 26 that is inserted into the body 25 and reciprocates in the axial direction of the body 25 (upper-lower direction in FIG. 3). A low-pressure chamber 27 is formed inside the plunger 26. The low-pressure chamber 27 communicates with a feed hole 29 of the body 25 through a communication hole 28 provided in the plunger 26. As shown in FIG. 1, each lash adjuster 21 is connected to the oil feed passage 16 provided in the cylinder head 2. As shown in FIG. 3, the feed hole 29 of the body 25 is connected to the oil feed passage 16. Thus, the oil feed passage 16 communicates with the low-pressure chamber 27 through the feed hole 29 and the communication hole 28, so that the oil is fed from inside the oil feed passage 16 into the low-pressure chamber 27.

[0021] An outflow port 30 is provided at a top part of the plunger 26. The rocker arm 19 is connected to the top part of the plunger 26. Thus, the outflow port 30 is covered by the rocker arm 19. Excess oil of the oil fed into the low-pressure chamber 27 leaks through the outflow port 30, and is discharged to the outside through the gap between the plunger 26 and the rocker arm 19.

[0022] The lash adjuster 21 is further provided with a high-pressure chamber 31 defined by a bottom part of the plunger 26 and an inner wall of the body 25. A valve hole 33 that is opened and closed by a check valve 32 is formed in the bottom part of the plunger 26. When opened, the check valve 32 provides communication between the low-pressure chamber 27 and the high-pressure chamber 31, allowing the oil to flow from the low-pressure chamber 27 into the high-pressure chamber 31.

[0023] The high-pressure chamber 31 is provided with a spring 34 that urges in a direction in which the plunger 26 is protruded from the body 25 (upward in FIG. 3). Thus, the other end portion of the rocker arm 19 is always urged upward by the top part of the plunger 26. The one end portion of the rocker arm 19 is always urged upward by the action of the valve spring 23 of the engine valve 20. Thus, even when the cam 9 and the rocker arm 19 wear as the rocker arm 19 is pressed against the cam 9, the clearance therebetween is adjusted to zero.

[0024] When the plunger 26 is further protruded from the body 25 by the urging force of the spring 34 to adjust the clearance to zero, the volume of the high-pressure chamber 31 increases and the internal pressure thereof decreases. As a result, the check valve 32 is opened and the oil flows from the low-pressure chamber 27 into the high-pressure chamber 31. Then, the check valve 32 is closed when an amount of oil equivalent to the increase in volume of the high-pressure chamber 31 has flowed from the low-pressure chamber 27 into the high-pressure chamber 31. In this state, if a load in a direction in which the plunger 26 is pushed downward by the rotation of the cam 9 (downward in FIG. 3) acts on the plunger 26 through the rocker arm 19, the depression of the plunger 26 is restricted by the oil inside the high-pressure chamber 31. Then, the plunger 26 is retained at that position. As a result, the engine valve 20 is opened and closed according to a predetermined lift profile that corresponds to the shape of the nose part 22 of the cam 9. Thus, the lash adjuster 21 is a hydraulic lash adjuster that adjusts the clearance between the cam 9 and the rocker arm 19 by means of the oil fed from the oil feed passage 16.

[0025] As shown in FIG. 1, a vacuum pump 35 is connected to the other end of the camshaft 3. The vacuum pump 35 is provided with a rotor 36 that is coupled to the camshaft 3 and rotates integrally with the camshaft 3. The cylinder head 2 is provided with a rotor bearing 37 that supports the rotor 36. The rotor bearing 37 has a semicircular recess 38 formed therein. A rotor cap 39 is attached to the rotor bearing 37. The rotor cap 39 has a semicircular recess 40 formed therein that is symmetrical to the recess 38 of the rotor bearing 37. Thus, a rotor bearing hole 41 that rotatably supports the rotor 36 is formed by the rotor bearing 37 and the rotor cap 39.

[0026] Next, the configuration of the vacuum pump 35 will be described with reference to FIG. 4 to FIG. 6. As shown in FIG. 4 and FIG. 5, a housing 42 of the vacuum pump 35 has a tubular shape, and has a housing part 43 and a supporting part 44 smaller in diameter than the housing part 43. As shown in FIG. 5, the housing part 43 has a substantially elliptical sectional shape, while the supporting part 44 has a circular sectional shape. The supporting part 44 is provided at a position eccentric relative to the housing part 43. A flange 45 with an increased diameter is provided at an end portion of the supporting part 44. As shown in FIG. 4, the flange 45 of the supporting part 44 is fixed to the rotor bearing 37 and the rotor cap 39 of the cylinder head 2. The inside diameter of the supporting part 44 is substantially equal to the diameter of the rotor bearing hole 41, and when the housing 42 is attached, the supporting part 44 and the rotor bearing hole 41 communicate with each other.

[0027] As shown in FIG. 5, the rotor 36 housed in the housing 42 has a columnar shape. The rotor 36 has a shaft part 46 inserted into the supporting part 44 of the housing 42, and a sliding part 47 larger in diameter than the shaft part 46. The length of the shaft part 46 in the axial direction is larger than the length of the supporting part 44 in the axial direction. Therefore, when the shaft part 46 is inserted into the supporting part 44, one end portion of the shaft part 46 sticks out from the supporting part 44. Thus, as shown in FIG. 4, when the vacuum pump 35 is attached, the rotor 36 is inserted into the supporting part 44 and the rotor bearing hole 41 and rotatably supported by the supporting part 44 and the rotor bearing hole 41.

[0028] Returning to FIG. 5, the sliding part 47 has a slide groove 48 extending in the radial direction. A vane 49 is attached to the slide groove 48 to be slidable along the slide groove 48 in the radial direction of the rotor 36.

[0029] The vacuum pump 35 has a cover 50. The cover 50 has substantially the same shape as the sectional shape of the housing part 43 of the housing 42, and is mounted on the housing 42 with the vane 49 and the rotor 36 housed inside the housing 42.

[0030] As shown in FIG. 6, when the rotor 36 and the vane 49 are attached to the housing 42, spaces R1, R2, R3 partitioned by the rotor 36 and the vane 49 are formed inside the housing part 43 of the housing 42. The center axis of the rotor 36 and the center axis of the supporting part 44 almost overlap each other, and the rotor 36 is eccentric relative to the housing part 43. As described above, the housing part 43 has a substantially elliptical sectional shape, so that, when the rotor 36 and the vane 49 rotate inside the housing 42, the vane 49 slides inside the slide groove 48 while maintaining both ends thereof in contact with the housing part 43, and thereby varies the volumes of the spaces R1, R2, R3.

[0031] In the state shown in FIG. 6, a suction port 51 that provides communication between the space inside the housing 42 and the space inside a brake vacuum servo device is provided at a border portion between the space R1 and the space R2 in the housing 42. Thus, when the rotor 36 rotates in the counterclockwise direction from the state shown in FIG. 6, the space R1 and the space inside the brake vacuum servo device communicate with each other. As the volume of the space R1 increases with the rotation of the rotor 36, negative pressure is generated inside the space R1. Due to the negative pressure generated inside the space R1, air inside the vacuum servo device is suctioned into the space R1 through the suction port 51, and negative pressure is generated inside the vacuum servo device.

[0032] When the rotor 36 rotates in the counterclockwise direction from the state shown in FIG. 6, communication between the space R2 and the suction port 51 is interrupted. Then, the volume of the space R2 decreases as the rotor 36 rotates. Thus, air is compressed in the space R2 as the rotor 36 rotates.

[0033] As shown in FIG. 4, the housing 42 is further provided with an air discharge port 52. The discharge port 52 is connected to the space R3 in the state shown in FIG. 6. Thus, in the process in which the volume of the space R3 decreases as the rotor 36 rotates in the counterclockwise direction in FIG. 6, the compressed air inside the space R3 is discharged through the discharge port 52.

[0034] Thus, the vacuum pump 35 generates negative pressure by repeatedly performing the suction stroke of suctioning air (space R1 in FIG. 6), the compression stroke of compressing the suctioned air (space R2 in FIG. 6), and the exhaust stroke of discharging the compressed air (space R3 in FIG. 6) by rotating the rotor 36. That is, when the vacuum pump 35 is driven, the spaces R1, R2, R3 defined by the housing part 43 of the housing 42 and the rotor 36 repeat the suction stroke, the compression stroke, and the exhaust stroke, respectively, and each become a negative-pressure chamber in which negative pressure is generated.

[0035] As shown in FIG. 4, the discharge port 52 is provided with a reed valve 53. The reed valve 53 is a plate-like member made of metal, for example, and closes the discharge port 52. The reed valve 53 is fixed to the housing 42 through a bolt 55, with a stopper member 54 laid on the reed valve 53. A part of the stopper member 54 located on the upper side in FIG. 4 extends while bending to separate from the reed valve 53. Thus, with a part of the reed valve 53 held between the housing 42 and the stopper member 54 serving as the supporting point, the opposite part of the reed valve 53 can elastically deform toward the stopper member 54.

[0036] Therefore, when air inside one of the spaces R1, R2, R3 that communicates with the discharge port 52 is compressed and the pressure inside the space becomes high, the one end of the reed valve 53 elastically deforms until coming into contact with the stopper member 54, so that the discharge port 52 is opened. On the other hand, when air is discharged and the pressure inside the space decreases, the reed valve 53 elastically returns and closes the discharge port 52. Thus, it is possible to discharge air from the housing 42 through the discharge port 52, as well as to prevent the inflow of air through the discharge port 52 into the housing 42.

[0037] As shown in FIG. 4, a columnar coupling 56 is coupled to the shaft part 46 of the rotor 36. As shown in FIG. 5, a rectangular protrusion 57 is formed on the shaft part 46 of the rotor 36, and a groove 58 of substantially the same shape as the protrusion 57 is formed in the coupling 56. Thus, the rotor 36 and the coupling 56 are coupled to each other with the protrusion 57 formed on the shaft part 46 of the rotor 36 inserted and engaged in the groove 58 of the coupling 56.

[0038] The camshaft 3 is coupled to the coupling 56. A rectangular projection 59 is formed on one end portion of the coupling 56. A groove 60 of substantially the same shape as the projection 59 is formed on the end portion of the camshaft 3, and the coupling 56 and the camshaft 3 are coupled to each other with the projection 59 of the coupling 56 inserted and engaged in the groove 60. Thus, the rotor 36 is coupled to the camshaft 3 through the coupling 56.

[0039] As shown in FIG. 4, a pump oil passage 62 communicating with a negative-pressure chamber 61 is formed in the vacuum pump 35 in order to feed oil to parts on which rotating bodies, such as the vane 49 and the rotor 36, slide. The negative-pressure chamber 61 refers to the spaces R1, R2, R3. The pump oil passage 62 is composed of a first oil passage 63 that extends in the axial direction of the rotor 36 (left-right direction in FIG. 4) and is open to the slide groove 48, and a second oil passage 64 that extends from the first oil passage 63 in the radial direction of the rotor 36 (upper-lower direction in FIG. 4) and is open in an outer peripheral surface of the rotor 36.

[0040] An oil feed groove 65 extending in the axial direction of the rotor 36 is formed in the recess 40 of the rotor cap 39. In the state shown in FIG. 4, one end portion of the oil feed groove 65 faces the opening of the second oil passage 64 of the rotor 36, and the other end portion of the oil feed groove 65 extends further toward the camshaft 3 than the second oil passage 64. An upper groove 66 that extends along the entire periphery, i.e., along the upper-half periphery of the rotor bearing hole 41, is formed in the recess 40 of the rotor cap 39. The upper groove 66 is connected to the other end portion of the oil feed groove 65.

[0041] A lower groove 67 that extends along the entire periphery, i.e., along the lower-half periphery of the rotor bearing hole 41, is formed in the recess 38 of the rotor bearing 37. The lower groove 67 is connected to the upper groove 66. Thus, the lower groove 67 is connected to the pump oil passage 62 through the upper groove 66 and the oil feed groove 65.

[0042] As shown in FIG. 1, an introduction passage 68 that connects the oil feed passage 16 and the lower groove 67 to each other is provided inside the rotor bearing 37. Thus, the oil inside the oil feed passage 16 is fed to the oil feed groove 65 through the introduction passage 68, the lower groove 67, and the upper groove 66. While the internal combustion engine 1 is in operation, the rotor 36 rotates and the second oil passage 64 and the oil feed groove 65 intermittently communicate with each other. As shown in FIG. 4, when the second oil passage 64 and the oil feed groove 65 communicate with each other, the oil inside the oil feed groove 65 is fed to the pump oil passage 62. The oil fed to the pump oil passage 62 flows out from the opening of the first oil passage 63 through the slide groove 48 into the negative-pressure chamber 61. As a result, the gap between the vane 49 and the housing 42 and the gap between the rotor 36 and the housing 42 are lubricated. Thus, the negative-pressure chamber 61 and the oil feed passage 16 are connected to each other through the pump oil passage 62, the oil feed groove 65, the upper groove 66, the lower groove 67, and the introduction passage 68. The oil fed to the negative-pressure chamber 61 is discharged through the discharge port 52 along with the air inside the housing 42.

[0043] As shown in FIG. 1, journal oil passages 69 that are open to the bearing holes 8 through the inside of the bearings 4 are each connected to the oil feed passage 16. Of the plurality of cam caps 6, a cam cap 601 located furthest on the side of the vacuum pump 35 (left side in FIG. 1) in the extension direction of the camshaft 3 is provided, at an upper end portion thereof, with a bent part 70 that extends while bending to cover the upper side of the cam 9. A cam cap oil passage 71 extending upward from the bearing hole 8 is formed inside the cam cap 6. The cam cap oil passage 71 is bent at an upper end portion thereof and passes through the inside of the bent part 70, and has, at the leading end, an open hole 73 that is open in a lower surface 72 of the bent part 70 facing the camshaft 3. Thus, the open hole 73 is provided to be open to the atmosphere and open toward the camshaft 3.

[0044] Of journal parts 74 of the camshaft 3 supported by the bearing holes 8, a journal part 741 supported by the cam cap 601 and the bearing 4 has a ring groove 75 formed to extend along the entire periphery. Thus, the oil fed from the oil feed passage 16 to the bearing hole 8 through the journal oil passage 69 is fed to the cam cap oil passage 71 through the ring groove 75 of the journal part 741. The oil inside the cam cap oil passage 71 is discharged through the open hole 73 and fed to the camshaft 3. In this embodiment, therefore, a branch passage 76 that is branched from the oil feed passage 16 and has the open hole 73 open to the atmosphere at the leading end is composed of the journal oil passage 69, the ring groove 75, and the cam cap oil passage 71. The branch passage 76 extends from the oil feed passage 16 to the open hole 73 through the inside of the bearing 4 and the cam cap 601.

[0045] The ring groove 75 is not formed in the other journal parts 74 of the camshaft 3. While the camshaft 3 is rotating, a small amount of oil is drawn by the rotation from the journal oil passages 69 into the bearing holes 8 supporting the journal parts 74. On the other hand, while the rotation of the camshaft 3 is stopped, the openings of the journal oil passages 69 are closed by the camshaft 3.

[0046] Next, the workings of the internal combustion engine 1 of this embodiment will be described with reference to FIG. 7 to FIG. 10. As shown in FIG. 7, while the internal combustion engine 1 is in operation, the oil pump 14 is driven, so that oil is fed into the oil feed passage 16. As indicated by the solid arrows in FIG. 7, the oil inside the oil feed passage 16 is fed to parts through the passages connected to the oil feed passage 16. Specifically, the oil having flowed into the introduction passage 68 connected to the oil feed passage 16 flows into the pump oil passage 62 through the lower groove 67, the upper groove 66, and the oil feed groove 65, and is fed into the vacuum pump 35. Meanwhile, the oil having flowed into the journal oil passages 69 connected to the oil feed passage 16 is fed into the bearing holes 8. In the bearing 4 located furthest on the side of the vacuum pump 35, the oil having flowed into the journal oil passage 69 is fed to the cam cap oil passage 71 through the ring groove 75 of the camshaft 3. Then, the oil is fed through the open hole 73 of the cam cap oil passage 71 to the camshaft 3. Thus, while the internal combustion engine 1 is in operation, the oil fed to the oil feed passage 16 passes through the branch passage 76 and is fed through the open hole 73 to the camshaft 3. Since the lash adjusters 21 are also connected to the oil feed passage 16, the oil is fed into the lash adjusters 21 through the oil feed passage 16. As a result, the oil feed passage 16 and the other passages are filled with oil while the internal combustion engine 1 is in operation.

[0047] On the other hand, when the internal combustion engine 1 stops, negative pressure remains in the negative-pressure chamber 61 of the vacuum pump 35. Accordingly, as indicated by the solid arrows in FIG. 8, the oil inside the oil feed passage 16 communicating with the negative-pressure chamber 61 is suctioned into the vacuum pump 35.

[0048] In this embodiment, the branch passage 76 that is branched from the oil feed passage 16 and provided with the open hole 73 open to the atmosphere at the leading end is provided. Therefore, when oil is suctioned from the oil feed passage 16 into the vacuum pump 35, air is introduced through the open hole 73 of the branch passage 76 into the oil feed passage 16 as indicated by the dashed arrows in FIG. 8.

[0049] Then, as shown in FIG. 9, when air is introduced through the branch passage 76 into the oil feed passage 16, the oil inside the oil feed passage 16 is divided by the air. When flowing through the same passage under the same conditions, oil undergoes a larger pressure loss than air. That is, air flows more easily than oil through the oil feed passage 16. For this reason, after the oil inside the oil feed passage 16 is divided by the air, the air preferentially flows from the branch passage 76 into the oil feed passage 16 as indicated by the dashed arrows in FIG. 9, so that the suction of oil inside the oil feed passage 16, which is divided by the air and disconnected from the negative-pressure chamber 61, is stopped.

[0050] Then, as shown in FIG. 10, when the oil is further suctioned and the air introduced through the open hole 73 reaches the vacuum pump 35, the vacuum pump 35 and the atmosphere communicate with each other. In this state, the air is subsequently suctioned into the vacuum pump 35 as indicated by the dashed arrows in FIG. 10, which prevents further drawing of the oil. Then, when the air is suctioned and negative pressure inside the vacuum pump 35 is consumed, drawing of air is stopped.

[0051] In the conventional configuration in which the oil feed passage 16 is not provided with the branch passage 76, while the internal combustion engine 1 is stopped, only oil is suctioned from the oil feed passage 16 and negative pressure inside the vacuum pump 35 is consumed, so that a large amount of oil is suctioned into the vacuum pump 35.

[0052] In this embodiment, as described above, air is introduced into the vacuum pump 35 through the branch passage 76 having the open hole 73. Thus, compared with the conventional configuration, the amount of oil suctioned from the oil feed passage 16 into the vacuum pump 35 is reduced.

[0053] If a large amount of oil is suctioned from the oil feed passage 16 into the vacuum pump 35 as in the conventional configuration, the amount of oil remaining inside the oil feed passage 16 decreases. If started in such a state, the internal combustion engine 1 may fail to promptly feed oil to the lash adjusters 21 due to the time taken to fill the inside of the oil feed passage 16 with oil. In that case, the high-pressure chamber 31 cannot be replenished with oil even when the plunger 26 protrudes to adjust the clearance between the cam 9 and the rocker arm 19, so that, when a load acts on the plunger 26 from the rocker arm 19, the plunger 26 is not retained at its position but depressed into the body 25. This results in malfunction of the lash adjusters 21, which may make it no longer possible to open and close the engine valve 20 according to a predetermined lift profile that corresponds to the shape of the nose part 22 of the cam 9.

[0054] In this embodiment, the amount of oil suctioned into the vacuum pump 35 is reduced, and a decrease in the amount of oil remaining inside the oil feed passage 16 is prevented. Thus, when the internal combustion engine 1 is restarted, the inside of the oil feed passage 16 is promptly filled with oil as the oil pump 14 is driven, and the oil is quickly fed to the lash adjusters 21. As a result, the lash adjusters 21 become promptly operable after start of the internal combustion engine 1.

[0055] When the branch passage 76 having the open hole 73 open to the atmosphere is connected to the oil feed passage 16, oil leaks through the open hole 73 while the internal combustion engine 1 is in operation. In this embodiment, the open hole 73 is provided in the cam cap 6 and the oil is fed through the open hole 73 to the camshaft 3. Thus, the oil leaking through the open hole 73 during operation of the internal combustion engine 1 can be effectively utilized.

[0056] Of the plurality of cam caps 6, the cam cap 6 (601) located furthest on the side of the vacuum pump 35 in the extension direction of the camshaft 3 is provided with the open hole 73, so that the distance between the vacuum pump 35 and the open hole 73 is reduced, and the amount of oil suctioned from the oil feed passage 16 into the vacuum pump 35 before the vacuum pump 35 communicates with the atmosphere is reduced.

[0057] The embodiment having been described above can offer the following advantages.

(1) The branch passage 76 that is branched from the oil feed passage 16 and has the open hole 73 at the leading end is provided, and oil is fed through the open hole 73 to the camshaft 3 while the internal combustion engine 1 is in operation, and air is introduced through the open hole 73 into the vacuum pump 35 while the internal combustion engine 1 is stopped. Accordingly, the amount of oil suctioned from the oil feed passage 16 into the vacuum pump

35 while the internal combustion engine 1 is stopped is reduced, and a decrease in the amount of oil remaining inside the oil feed passage 16 can be prevented. Thus, oil can be quickly fed to the lash adjusters 21 at restart of the internal combustion engine 1. Therefore, even when both the vacuum pump 35 and the lash adjusters 21 are provided, malfunction of the lash adjusters 21 hardly occurs.

(2) Of the plurality of cam caps 6, the cam cap 601 located furthest on the side of the vacuum pump 35 in the extension direction of the camshaft 3 is provided with the open hole 73, so that the distance between the vacuum pump 35 and the open hole 73 is reduced, and the amount of oil suctioned from the oil feed passage 16 into the vacuum pump 35 before the vacuum pump 35 communicates with the atmosphere is reduced. Thus, it is possible to further prevent a decrease in the amount of oil remaining inside the oil feed passage 16 while the internal combustion engine 1 is stopped.

[0058] The above embodiment can also be implemented with the following modifications made thereto.

- The cam cap 6 in which the open hole 73 is formed is not limited to the one located furthest on the side of the vacuum pump 35 in the extension direction of the camshaft 3. For example, the open hole 73 may be formed in the cam cap 6 located second closest to the vacuum pump 35 in the extension direction, or in the cam cap 6 located further away from the vacuum pump 35. In this case, the cam cap oil passage 71 that provides communication between the open hole 73 and the bearing hole 8 should be formed inside the cam cap 6 having the open hole 73, and the ring groove 75 should be formed in the journal part 74 of the camshaft 3 supported by the cam cap 6 in which the cam cap oil passage 71 is formed. In this configuration, too, the branch passage 76 is formed by the journal oil passage 69, the ring groove 75, and the cam cap oil passage 71, so that air can be introduced through the branch passage 76 into the vacuum pump 35 while the internal combustion engine 1 is stopped. Alternatively, a plurality of cam caps 6 each having the open hole 73 may be provided; for example, the open hole 73 may be formed in both the cam cap 6 (601) located furthest on the side of the vacuum pump 35 and the cam cap 6 located second closest to the vacuum pump 35. In other words, a plurality of branch passages 76 may be provided.
- While the branch passage 76 is composed of the journal oil passage 69, the ring groove 75, and the cam cap oil passage 71 in the above embodiment, the ring groove 75 can be omitted. For example, it is not absolutely necessary to provide the ring groove 75, if a connection groove that extends in the circumferential direction and connects the journal oil passage 69 and the cam cap oil passage 71 to each other is formed in the bearing hole 8.
- The position of the open hole 73 in the cam cap 6 may be arbitrarily changed as long as oil can be fed to the camshaft 3. - The configurations of the branch passage 76 and the open hole 73 are not limited to those described above. For example, a tubular cam shower pipe that extends in the extension direction of the camshaft 3 may be connected to a portion of the oil feed passage 16 located close to the vacuum pump 35. Drip holes which are open to the atmosphere and through which oil is dripped and fed to the camshaft 3 are formed in the cam shower pipe. While the internal combustion engine 1 is in operation, oil fed from the oil feed passage 16 is fed through the cam shower pipe from the drip holes to the camshaft 3, and while the internal combustion engine 1 is stopped, air suctioned through the drip holes is introduced through the cam shower pipe into the oil feed passage 16 and fed into the vacuum pump 35. In this configuration, too, the same advantage as (1) can be obtained. In this configuration, the cam shower pipe functions as the branch passage and the drip holes function as the open hole.
- The lower groove 67 of the rotor bearing 37 does not have to be provided along the entire periphery as long as the lower groove 67 can provide communication between the introduction passage 68 and the upper groove 66. - The upper groove 66 of the rotor cap 39 does not have to be provided along the entire periphery as long as the upper groove 66 can provide communication between the oil feed groove 65 and the lower groove 67.
- The driving method of the camshaft 3 is not limited to that of the above embodiment. For example, a crank sprocket, instead of the crank pulley 12, may be provided at the one end of the crankshaft 11, and a timing sprocket, instead of the timing pulley 10, may be provided at the one end of the camshaft 3. Then, a timing chain may be wound around each of the sprockets. In this configuration, too, the camshaft 3 can be driven in conjunction with the crankshaft 11. Alternatively, a crank gear may be provided at the one end of the crankshaft 11, and a timing gear meshing with the crank gear may be provided at the one end of the camshaft 3. In this configuration, the timing gear rotates through the crank gear as the crankshaft 11 rotates. Thus, in this configuration, too, the camshaft 3 can be driven in conjunction with the crankshaft 11.

Claims

1. An internal combustion engine comprising: a cylinder head (2); an oil pump (14); an oil feed passage (16) that is provided inside the cylinder head (2) and adapted to be fed with oil pumped up from the oil

pump (14); and a camshaft (3) attached to the cylinder head (2), the internal combustion engine being **characterized in that**
the internal combustion engine (1) further comprises a vacuum pump (35), a hydraulic lash adjuster (21), and a branch passage (76),
the vacuum pump (35) has a rotor (36) that is coupled to the camshaft (3) and is configured to rotate integrally with the camshaft (3), a housing (42) that houses the rotor (36), and a negative-pressure chamber (61) that is defined by the rotor (36) and the housing (42) and connected to the oil feed passage (16), and the vacuum pump (35) is configured to generate negative pressure inside the negative-pressure chamber (61) as the rotor (36) rotates,
the lash adjuster (21) is connected to the oil feed passage (16), and is configured to adjust a clearance between a cam (9), provided on the camshaft (3), and a rocker arm (19) by means of oil fed from the oil feed passage (16), and
the branch passage (76) is branched from the oil feed passage (16) and provided with an open hole (73) open to the atmosphere at a leading end of the branch passage (76), and the branch passage (76) is configured to feed oil through the open hole (73) to the camshaft (3) while the internal combustion engine (1) is in operation, and to introduce air through the open hole (73) into the vacuum pump (35) while the internal combustion engine (1) is stopped.

2. The internal combustion engine according to claim 1, **characterized in that**
the cylinder head (2) is provided with a bearing (4) that supports the camshaft (3), and a cam cap (6) is attached to the bearing (4),
a bearing hole (8) configured to support the camshaft (3) is provided by the bearing (4) and the cam cap (6),
the open hole (73) is provided in the cam cap (6) to be open toward the camshaft (3), and
the branch passage (76) extends from the oil feed passage (16) to the open hole (73) through the inside of the bearing (4) and the cam cap (6).

3. The internal combustion engine according to claim 2, **characterized in that**
a plurality of cam caps (6) are attached to the cylinder head (2) to be arrayed in an extension direction of a center axis of the camshaft (3), and
of the plurality of cam caps (6), a cam cap (601) located on the nearest side of the vacuum pump (35) in the extension direction is provided with the open hole (73).

4. The internal combustion engine according to claim 2, **characterized in that**
a plurality of cam caps (6) are attached to the cylinder head (2) to be arrayed in an extension direction of a center axis of the camshaft (3), and
of the plurality of cam caps (6), a cam cap (601) located on the nearest side of the vacuum pump (35) in the extension direction and a cam cap (6) close to the cam cap (601) are each provided with the open hole (73).

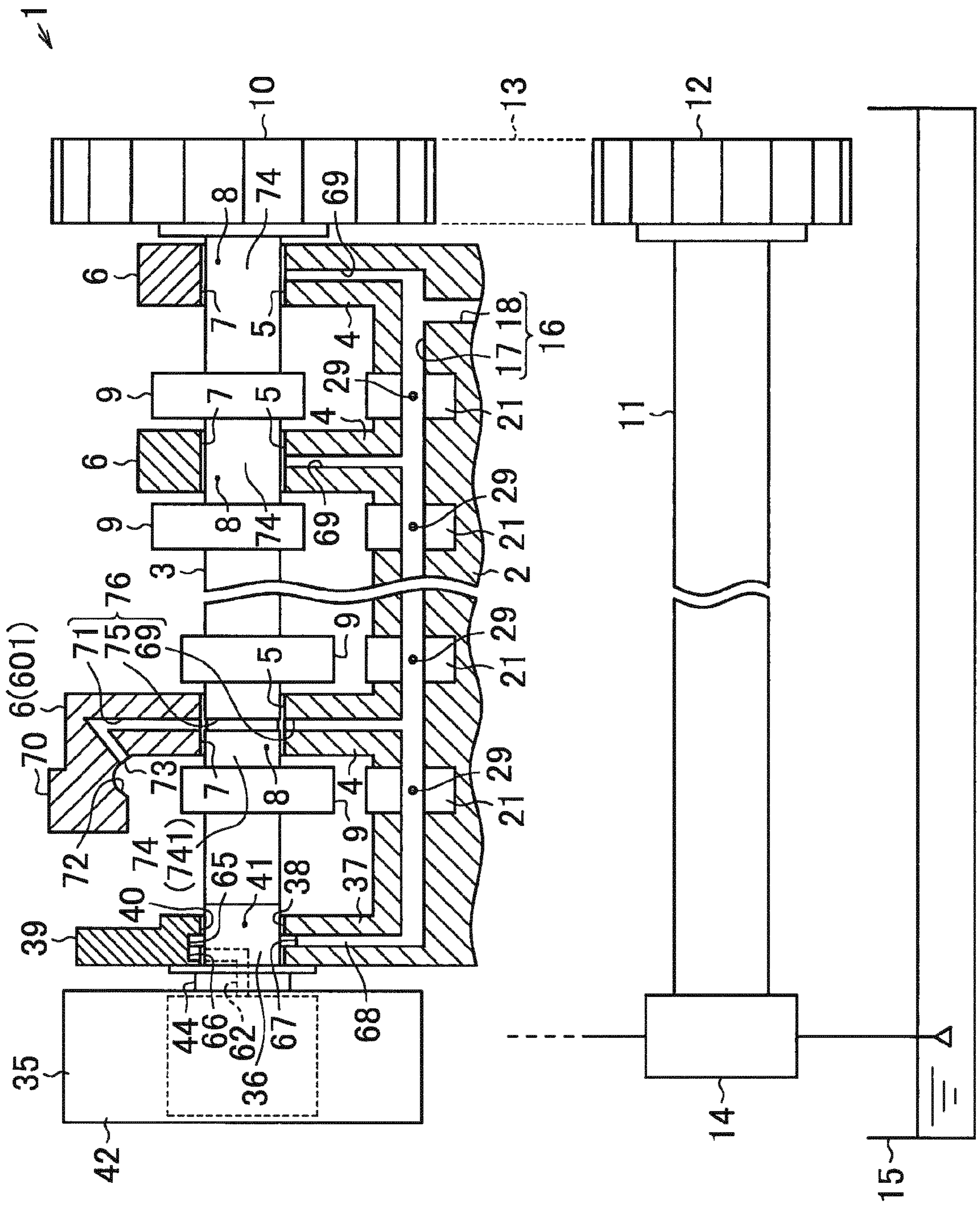

FIG. 1

FIG. 2

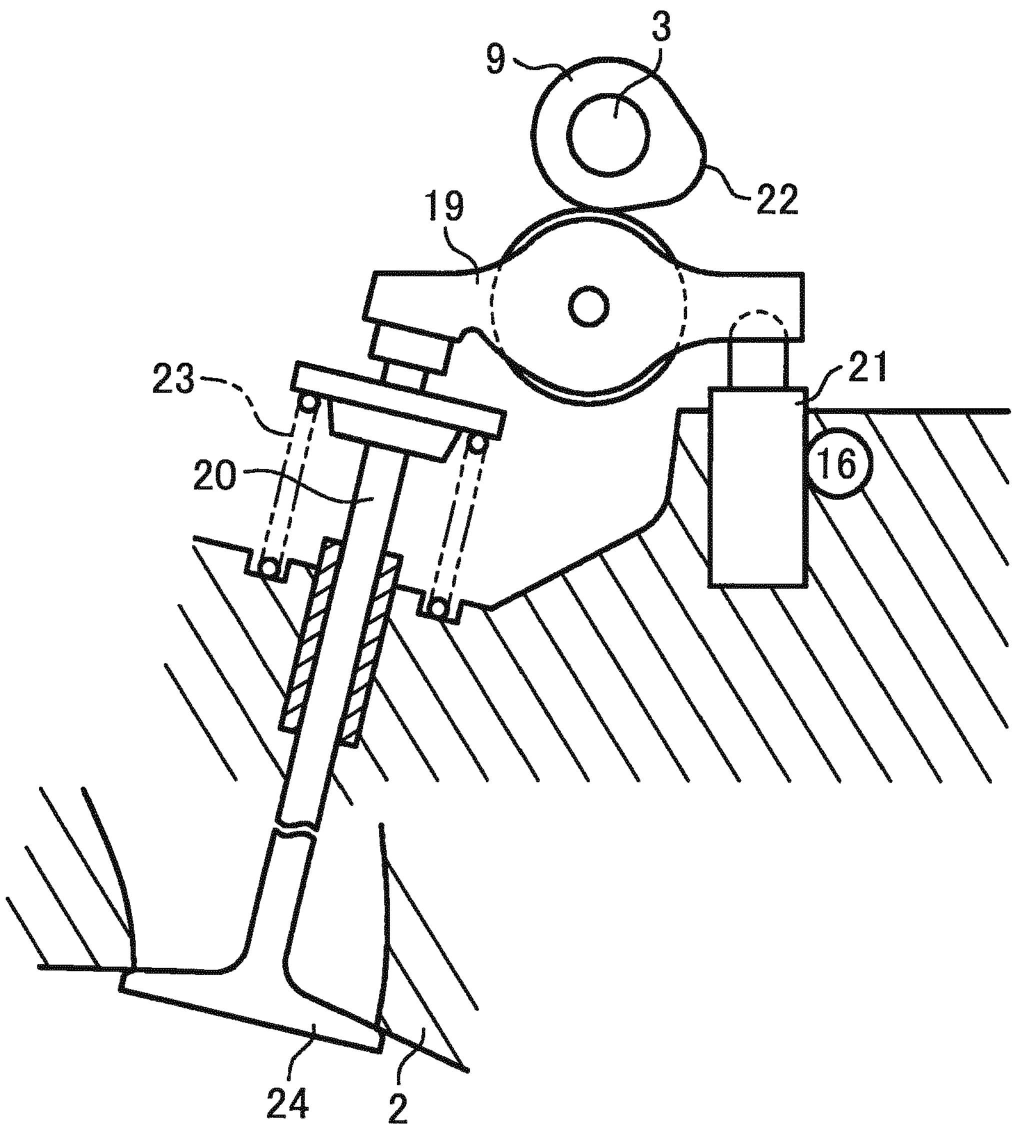

FIG. 3

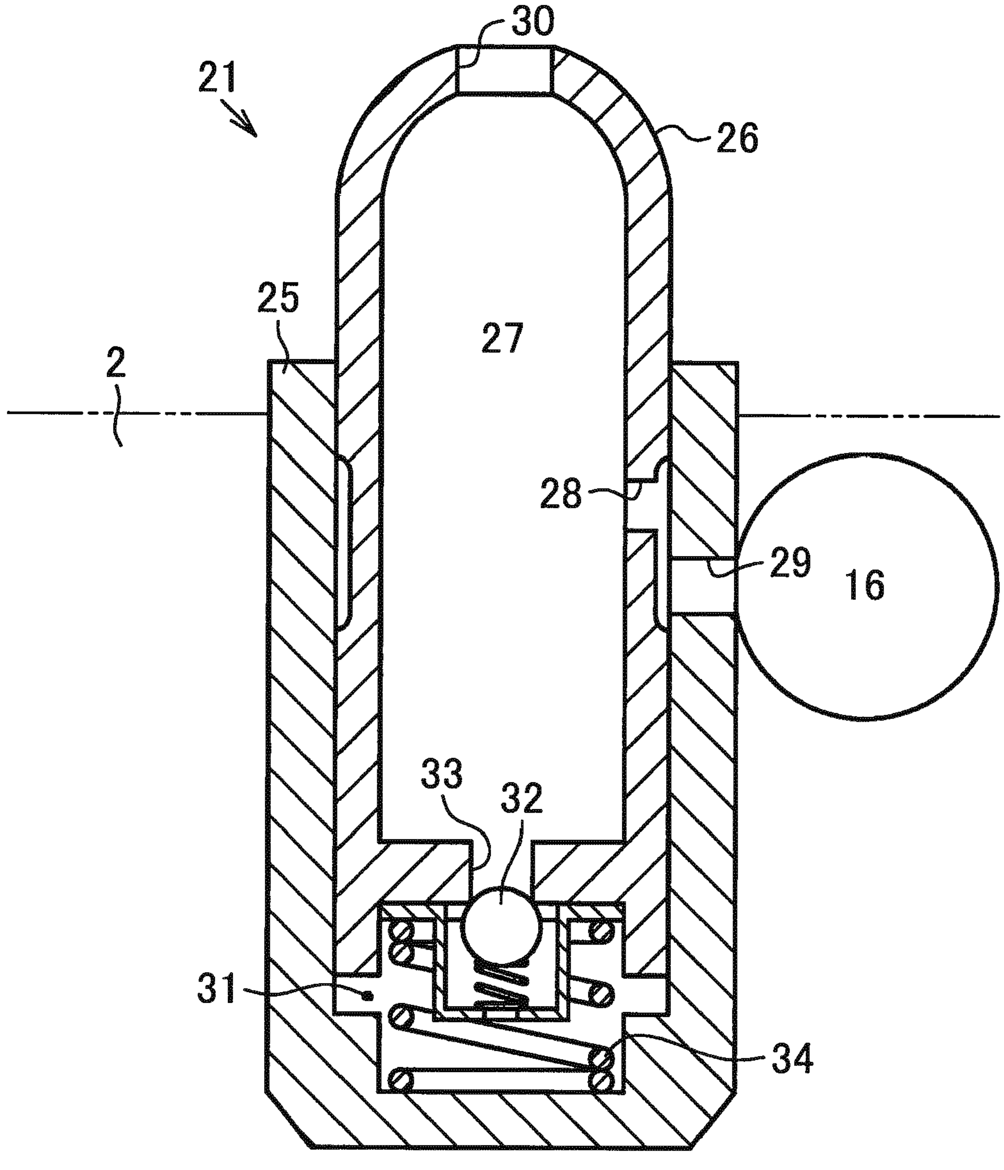

FIG. 4

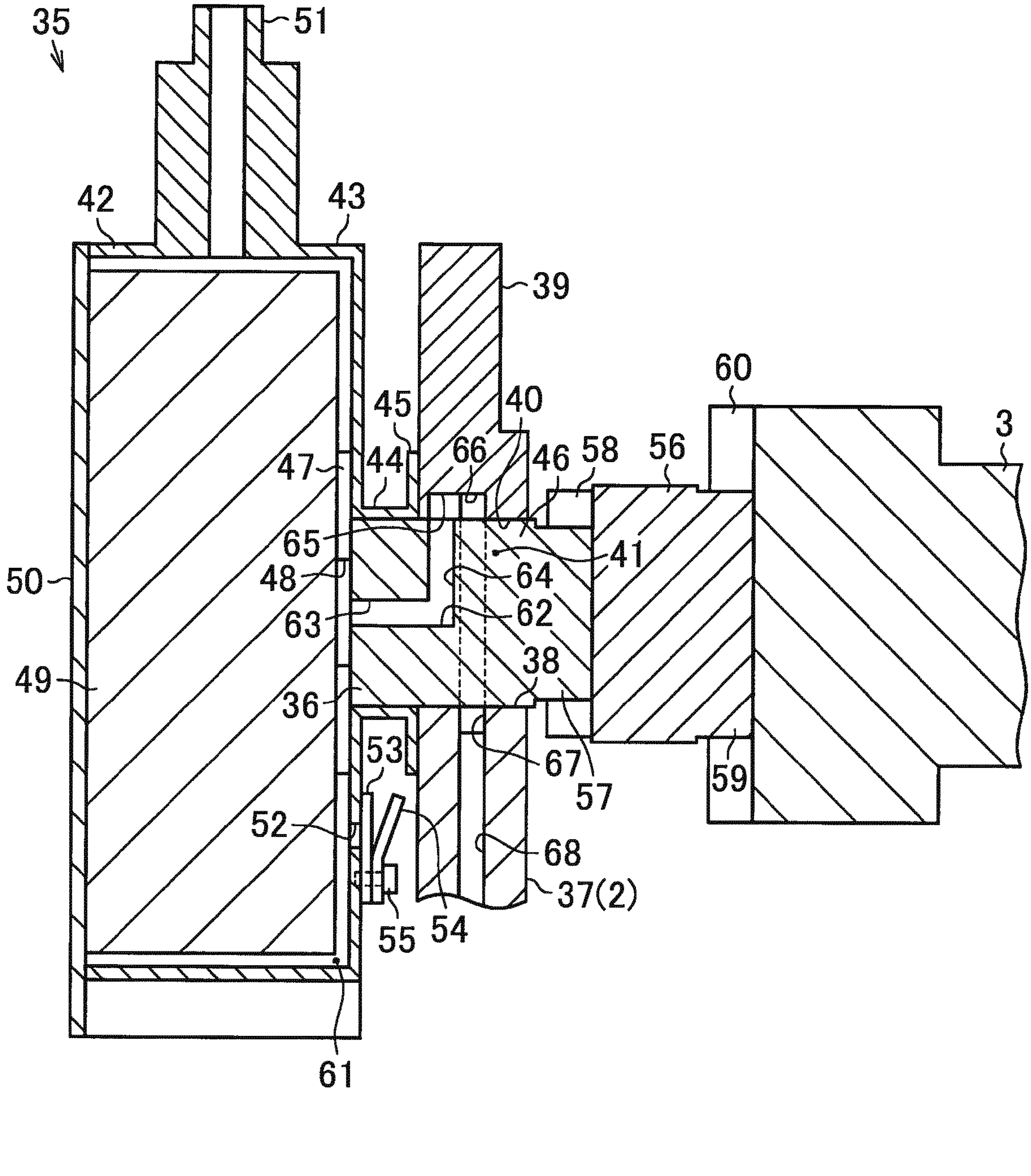
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FIG. 5

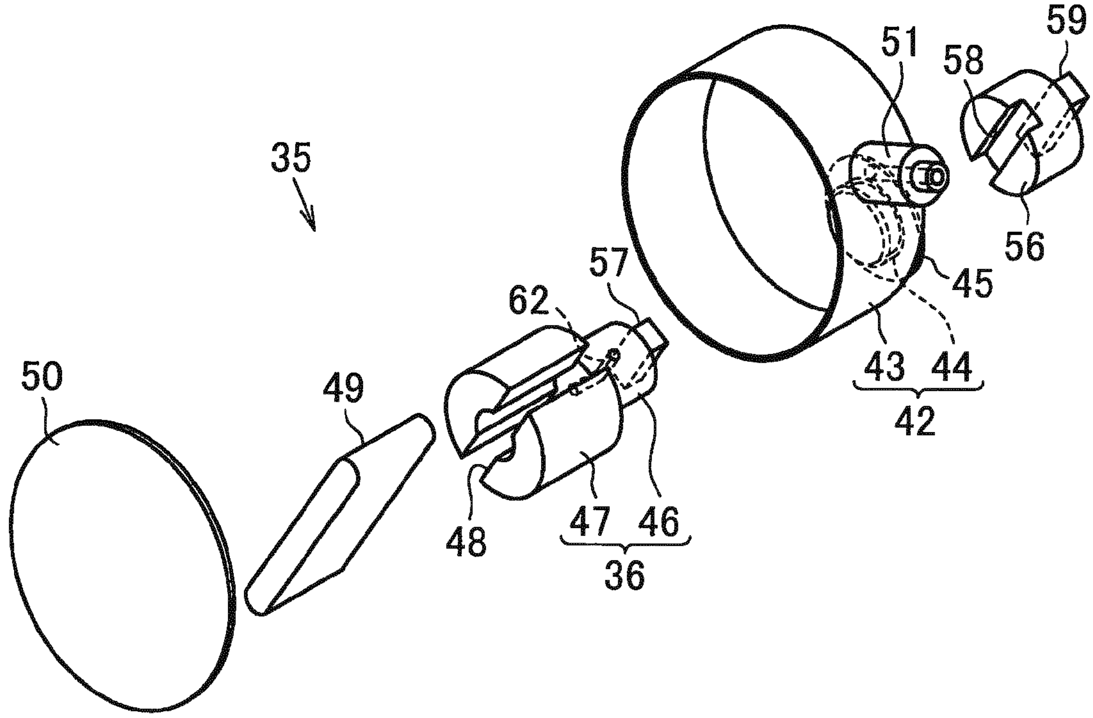
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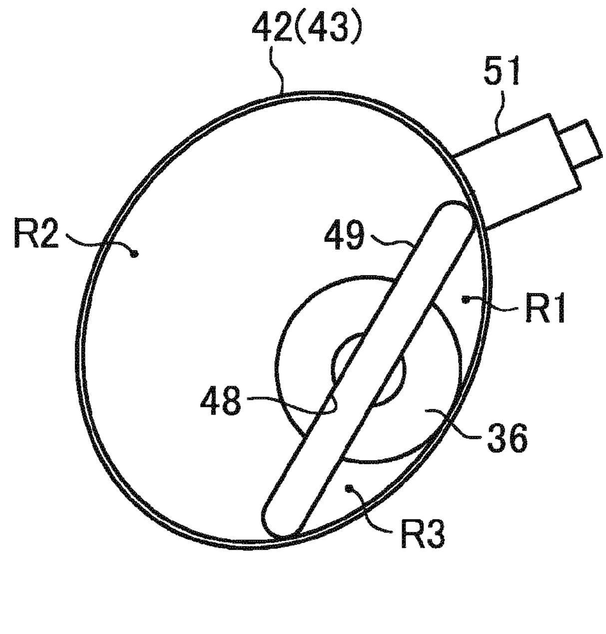
FIG. 6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R2
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R1
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R3

FIG. 7

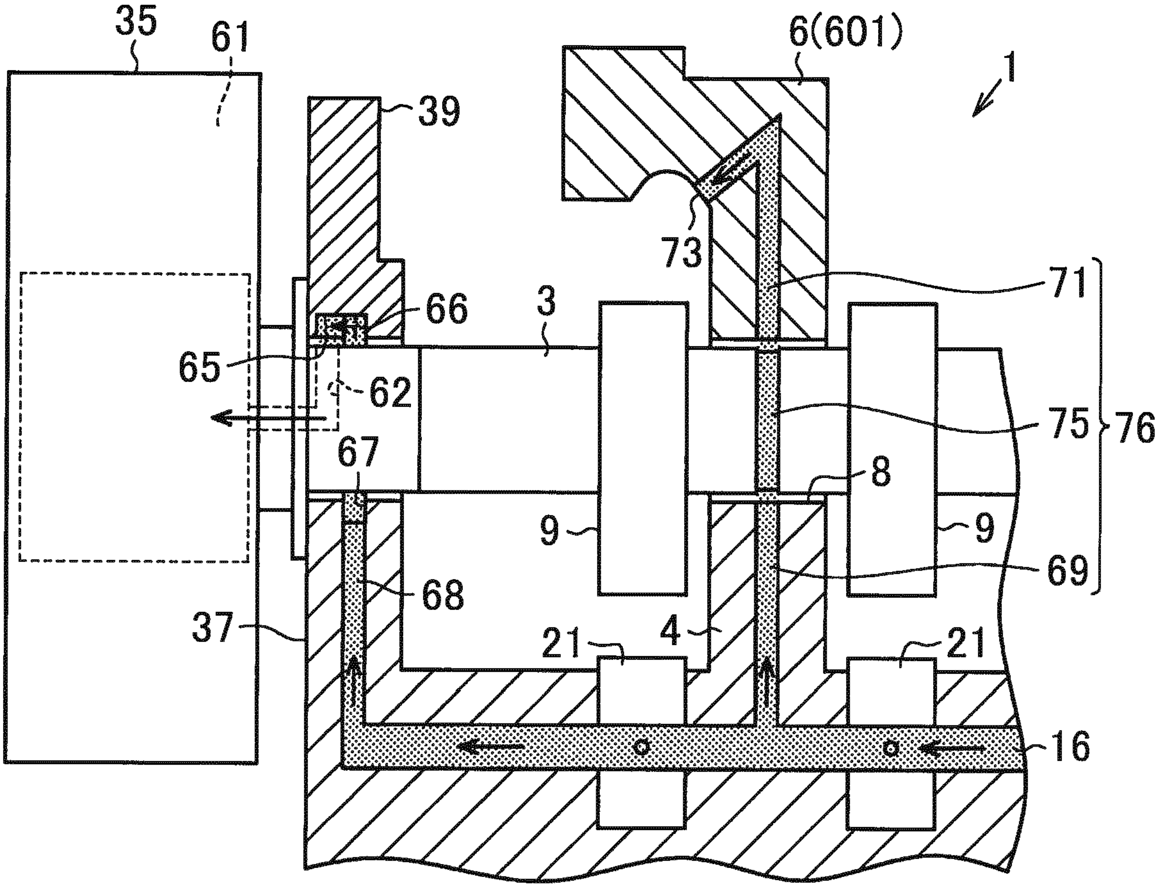


FIG. 8

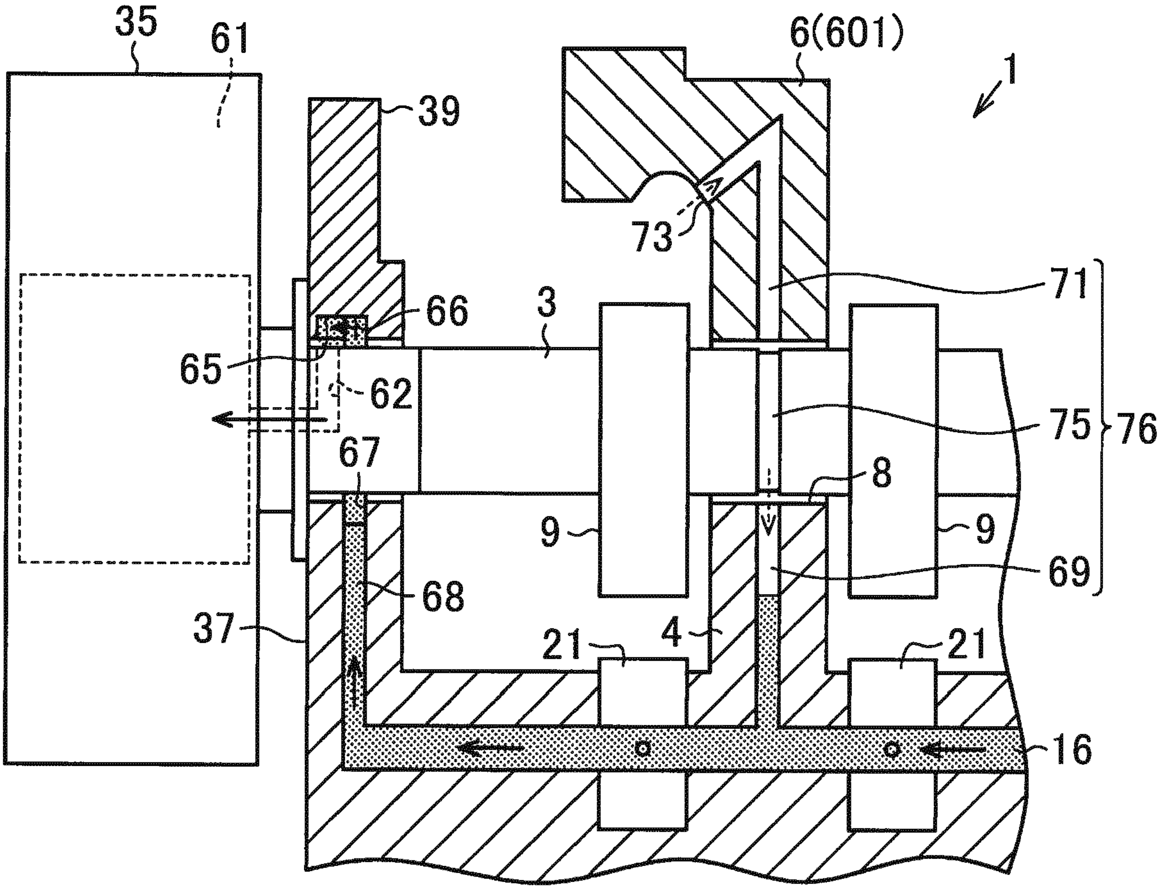


FIG.9

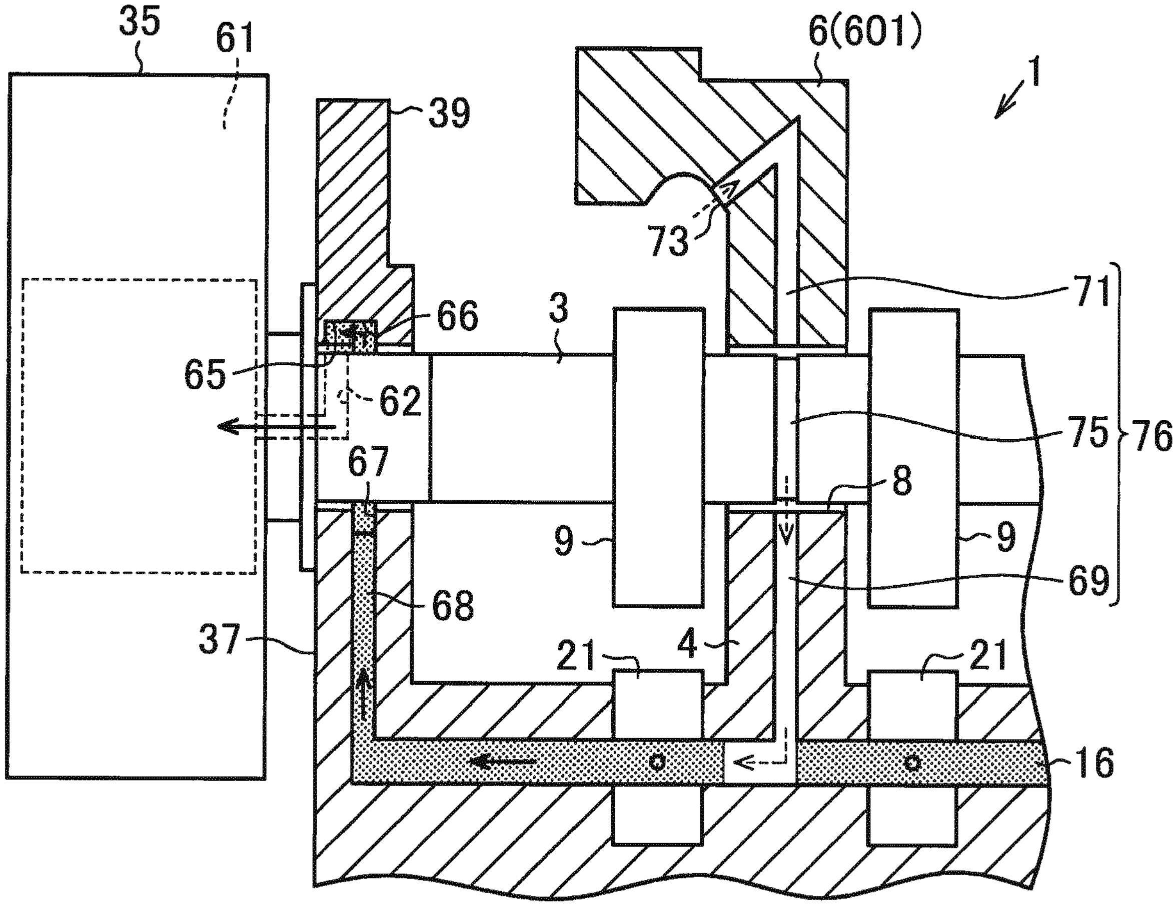
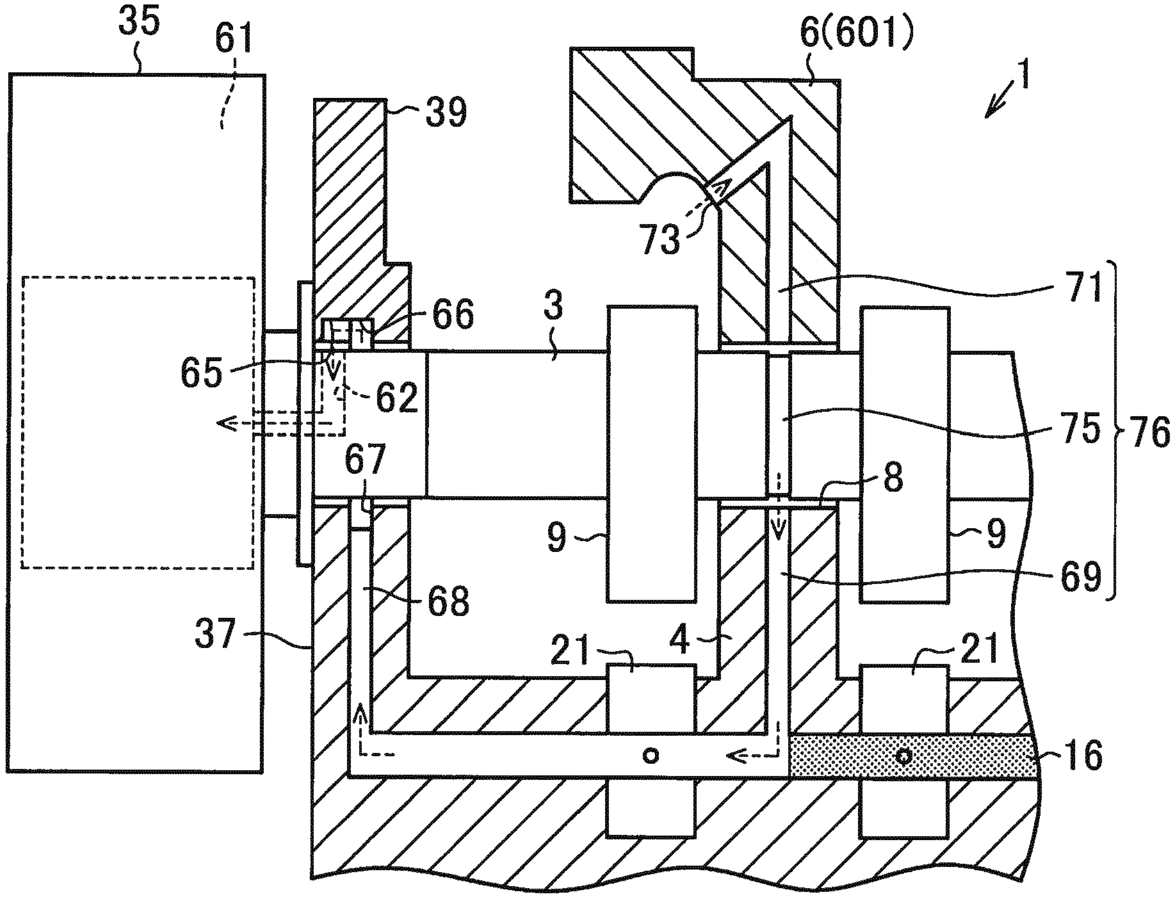


FIG. 10



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EUROPEAN SEARCH REPORT

Application Number
EP 16 18 0061

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F01M
F01L

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	22 November 2016	Klinger, Thierry

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