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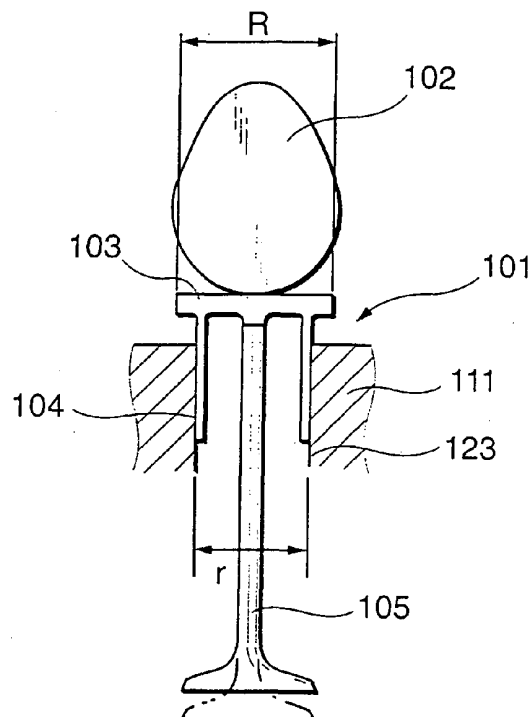
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(54) **Internal combustion engine**

(57) A valve driving apparatus using a direct driving type valve lifter is disposed between a cam (803) and a valve (105,117,118,217,317,417,517,617,717,807), said apparatus comprising: a guide hole (123,213,313,413,513,613,713,806) and a direct driving type valve lifter (101,214,314,414,514,614,714,811) including a tappet portion (103,216,316,416,516,616,716,813), and a guide portion (104,215,315,415,515,615,715,812) having one end portion coupled to said tappet portion and housed within said guide hole so as to slide freely therein to the axial direction of said poppet valve in an interlocked manner; wherein a diameter (r) of said guide portion is formed to be smaller than a diameter (R) of said tappet portion; characterized in that said valve lifter (101,214,314,414,514,614,714,811) is inclined in a direction perpendicular to a rotational axis of the cam relative to the head bolt (109) for securing the cylinder head; and said valve lifter is arranged so as to be adjacent to the head bolt in a planar view.

FIG.1



Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to an internal combustion engine comprising a valve driving apparatus for driving a valve which opens and closes a suction port or an exhaust port in an internal combustion engine. In particular, the invention relates to a valve driving apparatus using a direct driving type valve lifter which can be miniaturized and light-weighted while maintaining a sufficient lift amount of the valve to improve the operation efficiency thereof.

2. Description of the Related Art

[0002] The valve driving apparatus using the direct driving type valve lifter is disclosed, for example, in Japanese Patent Unexamined Publication No. Hei 10-331709. The direct driving type valve lifter includes a tappet portion which comes in contact with a cam disposed at an upper side of a cylinder head of an internal combustion engine and a guide portion slidably housed within the cylinder head. The valve lifter is disposed between the cam and a valve in such a manner that the tappet portion is pushed by a projected portion of the cam while the cam rotates to slide the guide portion along the cylinder head. Thus, the valve is moved integrally with the valve lifter toward its axial direction thereby to open and close a suction port or an exhaust port at which the valve is provided.

[0003] The tappet portion with which the projected portion of the cam comes in contact is configured in a substantially flat plate of circular shape so as to perform the linear contact with the projected portion of the cam. The cam profile is designed such that the tappet portion is brought in contact with the projected portion of the cam without deviating from the range of a diameter of the tappet portion and an allowable contact load is obtained at the tappet portion.

[0004] For example, in order to improve the output of the internal combustion engine with an increase in an air suction amount, it is necessary to increase a valve opening area. Since a lift amount of the valve is required to be increased in order to increase the valve opening area, the tappet portion is so designed as to have such a diameter that a sufficient lift amount of the valve can be secured.

[0005] To ensure the lift amount required for the valve, the diameter of the tappet portion must be set according to the lift amount. However, as the diameter of the tappet portion is set to be larger, the diameter of the guide portion becomes larger with the result that the size of the valve lifter becomes larger. On the other hand, since various mechanisms and structures exist in the vicinity of the cylinder head of the internal combustion engine, the

valve lifter is restricted in its position to be disposed. Thus, the maximum size of the valve lifter is limited and hence it is a problem to ensure the required lift amount of the valve while disposing the valve lifter in a limited space. Such a problem is more critical for a small-sized internal combustion engine.

[0006] When the size of the valve lifter is simply made larger, the inertia weight of the valve driving system becomes larger, and hence there is a fear that it becomes difficult to secure the required performance of the engine. Further, when the inertia weight of the valve driving system increases, it is required to increase the spring force of the spring system necessary for urging against the valve so as to close it. As a result, since a contact pressure between the tappet portion and the cam becomes high, there arises such a problem that the tappet portion and the cam are worn away.

[0007] The conventional valve driving apparatus also suffers from a problem on the lubrication performance. Such a problem will be described with reference to Figs. 25 and 26. Figs. 25 and 26 show the schematic configuration of a conventional valve driving apparatus using a direct driving type valve lifter. Fig. 25 shows a state where the valve lifter is not pushed down whereas Fig. 26 shows a state where the valve lifter is pushed down.

[0008] As shown in these figures, a cam 902 is disposed at the upper side of a cylinder head 901 of an internal combustion engine, and a guide hole 903 is defined in the interior of the cylinder head 901. The cylindrical portion (guide portion) of a cylindrical valve lifter 904 is slidably housed within the guide hole 903. The cam 902 abuts against the upper surface (tappet portion) of the valve lifter 904. A valve 905 (a suction valve or an exhaust valve) is disposed opposite to the cam 902 with respect to the valve lifter 904.

[0009] The valve lifter 904 is pushed down with rotation of the cam 902 and reciprocally moves within the guide hole 903 to thereby repeatedly open and close the valve 905. An oil reservoir 906 in which lubricant oil 907 is reserved is formed around the upper portion of the guide hole 903 so that both the tappet portion and the projected portion of the cam 902 are dipped into the lubricant oil 907 within the oil reservoir 906 when the valve lifter 904 is pushed down by the cam 902.

[0010] In most of the internal combustion engines, a predetermined clearance is defined between the guide hole 903 and the valve lifter 904 so that the valve lifter 904 is operable even at an extremely low temperature. Thus, the lubricant oil 907 within the oil reservoir 906 enters the clearance due to the rotation of the cam 902, the vertical reciprocation of the valve lifter 904, its own weight of the lubricant oil 907, etc., thereby lubricating the respective portions.

[0011] As described above, the projected portion of the cam 902 comes in linear contact with the tappet portion of the valve lifter 904. Since the contact portion between the projected portion of the cam 902 and the tappet portion moves within the range of the diameter of

the tappet portion, a position of the tappet portion at which a load is applied from the cam 902 changes with the result that the valve lifter 904 is applied with the opposite moment during the reciprocation.

[0012] Thus, when the lubricant oil 907 is at a high temperature, the clearance between the valve lifter 904 and the guide hole 903 becomes large and the viscosity of the lubricant oil becomes low so that noises are generated due to the discontinuous oil film at the clearance and a friction at the clearance becomes large. On the other hand, when the lubricant oil 907 is at a low temperature, the clearance between the valve lifter 904 and the guide hole 903 becomes smaller. Thus, the lubricant oil 907 hardly flows along the side portion of the guide hole 903 and the friction becomes larger. As a result, the output efficiency and the fuel costs of the internal combustion engine may be degraded and the abrasion of the valve lifter 904 etc. may be caused.

[0013] Further, in most of the internal combustion engines, the cylinder head is made of aluminum whereas the valve lifter is made of iron. As described above, a predetermined clearance is defined between the guide hole 903 and the valve lifter 904 so that the valve lifter 904 is operable even at an extremely low temperature. At a high temperature, the clearance between the valve lifter 904 and the guide hole 903 becomes larger so that the valve lifter 904 is inclined at a larger angle with respect to the guide hole 903 upon application of the above-mentioned moment to the valve lifter 904. On the contrary, since the tappet portion of the valve lifter 904 is configured in a plate shape, the rigidity of the outer peripheral portion thereof is high so that the tappet portion is hardly deformed.

[0014] As a result, when the lift amount is maximum, the posture of the valve lifter 904 changes to a large extent, and the oil film at the clearance is then pushed aside when the valve lifter 904 hits the inner surface of the guide hole 903, to thereby generate large metallic sound. Further, since the friction and the degree of the abrasion become larger, the output efficiency and the fuel costs of the internal combustion engine may be degraded.

[0015] EP 0 454 518 A1 discloses an internal combustion engine according to the preamble of claim 1.

SUMMARY OF THE INVENTION

[0016] The invention has been made to solve the above-mentioned various problems with the conventional valve driving apparatus for an internal combustion engine using the direct driving type valve lifter.

[0017] An object of the invention is to provide an internal combustion engine having a valve driving apparatus using a direct driving type valve lifter which can be miniaturized and light-weighted while maintaining a sufficient lift amount of a valve in a restricted space to improve the operation efficiency.

[0018] The internal combustion engine according to

the invention comprises the features set forth in claim 1.

[0019] Since the tappet portion can secure such a diameter capable of realizing a required lift amount and the diameter of the guide portion can be made small, the valve lifter can be miniaturized and light-weighted. As a result, it becomes possible to secure a high output efficiency of the engine while reducing the occupied area of components related to the valve in the vicinity of the cylinder head. Further, since the components related to the valve can be housed in a small space, the degree of the freedom for the arrangement of other components can be improved. Furthermore, since the valve lifter is miniaturized and light-weighted, the valve driving apparatus can cope with the high speed of the engine.

[0020] Preferred embodiments are described in the dependent claims. When the poppet valve driven by the valve driving apparatus according to the invention is provided at the suction path of the engine, it is possible to increase the amount of the suction air by using the valve lifter thus miniaturized and light-weighted, so that the operation efficiency of the engine can be improved.

[0021] In the case where the engine is arranged in a manner that the cam shaft is disposed on the upper side of the cylinder head, and the suction path is opened at its one end to the combustion chamber of the internal combustion engine and opened at its the other end to the upper surface of the cylinder head, the valve lifter is restricted in its position when the valve lifter is used in the cylinder head having such a suction path. However, the valve driving apparatus according to the invention can secure a sufficient lift amount despite of such a restriction.

[0022] In the case where the two or more poppet valves disposed in each of the cylinders of the engine are driven so as to be opened and closed by the valve lifters, since the number of the valve lifters is large, the valve lifter is also restricted in its position. However, the valve driving apparatus according to the invention can secure a sufficient lift amount despite of such a restriction.

[0023] Cylinder head bolts can be disposed in a sufficient space when the valve driving apparatus according to the invention is employed. More preferably, even in a case where the cylinder head bolts are required to be provided close to the valve lifter, when the valve lifter is disposed so as to be inclined with respect to the axis line of the cylinder of the engine, the cylinder head bolts can be fastened without interfering the valve lifter.

[0024] When the diameter of the tappet portion is smaller than the diameter of the base circular portion of the cam, the lubricant oil splashed can be directly introduced to the cam.

[0025] In the direct driving type valve lifter used in the valve driving apparatus according to the invention, preferably there is provided an elastic deformation promotion portion for promoting elastic deformation of the guide portion when the guide portion is housed within the guide hole. In this arrangement, when the valve lifter

changes its posture during its lifting operation, the elastic deformation of the guide portion can be promoted. Thus, the noise caused by the striking operation when the valve lifter changes its posture can be suppressed and the friction can be prevented from increasing, so that the durability of the valve lifter can be improved, and further the output efficiency and the fuel cost of the engine can be improved.

[0026] Preferably, the elastic deformation promotion portion is provided at the guide portion in vicinity of the boundary between the tappet portion and the guide portion, whereby the guide portion can be elastically deformed easily along the guide hole when the valve lifter changes its posture.

[0027] Further, preferably, the elastic deformation promotion portion provided in the vicinity of the boundary between the tappet portion and the guide portion is a groove provided at the peripheral portion of the guide portion. In this case, since the groove can be used as a recess portion required at the time of performing the grinding process of the rear surface of the tappet portion and the outer peripheral surface of the guide hole, the valve lifter can be processed easier.

BRIEF DESCRIPTION OF THE DRAWINGS

[0028]

Fig. 1 is a front view showing the configuration of a valve driving apparatus used in an internal combustion engine according to a first embodiment of the invention;

Fig. 2 is a front view showing the main portion of an internal combustion engine to which the valve driving apparatus shown in Fig. 1 is applied;

Fig. 3 is a plan view showing the main portion of Fig. 2 seen from the axial direction of a cylinder of the internal combustion engine;

Fig. 4 is a front view schematically showing the configuration of a valve driving apparatus according to a second embodiment of the invention;

Fig. 5 is a front view schematically showing the configuration of the valve driving apparatus according to the second embodiment of the invention;

Fig. 6 is a front view schematically showing the configuration of a valve driving apparatus according to a third embodiment of the invention;

Fig. 7 is a front view showing the configuration of a valve driving apparatus according to a fourth embodiment of the invention;

Fig. 8 is a side view showing the configuration of the valve driving apparatus according to the fourth embodiment of the invention;

Fig. 9 is a front view showing the configuration of the valve driving apparatus according to the fourth embodiment of the invention;

Fig. 10 is a side view showing the configuration of the valve driving apparatus according to the fourth

embodiment of the invention;

Fig. 11 is a view showing the valve driving apparatus taken along a line VIII - VIII in Figs. 7 and 9;

Fig. 12 is a front view showing the configuration of a valve driving apparatus according to a fifth embodiment of the invention;

Fig. 13 is a front view showing the configuration of the valve driving apparatus according to the fifth embodiment of the invention;

Fig. 14 is a view showing the valve driving apparatus taken along a line XI - XI in Fig. 12;

Fig. 15 is a front view showing the configuration of a valve driving apparatus according to a sixth embodiment of the invention;

Fig. 16 is a front view showing the configuration of the valve driving apparatus according to the sixth embodiment of the invention;

Fig. 17 is a view showing the valve driving apparatus taken along a line XIV - XIV in Fig. 15;

Fig. 18 is a front view showing the configuration of a valve driving apparatus according to a seventh embodiment of the invention;

Fig. 19 is a view showing the valve driving apparatus taken along a line XVI - XVI in Fig. 18;

Fig. 20 is a front view showing the configuration of a valve driving apparatus according to an eighth embodiment of the invention;

Fig. 21 is a front view showing the configuration of the valve driving apparatus according to the eighth embodiment of the invention;

Fig. 22 is a view showing the valve driving apparatus taken along a line III - III in Fig. 21;

Fig. 23 is a front view showing the configuration of the valve driving apparatus according to the eighth embodiment of the invention;

Fig. 24 is a view showing the valve driving apparatus taken along a line V - V in Fig. 23;

Fig. 25 is a front view showing the configuration of a conventional valve driving apparatus; and

Fig. 26 is a front view showing the configuration of a conventional valve driving apparatus.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0029] Now, a description will be given in more detail of preferred embodiments of the invention with reference to the accompanying drawings.

[0030] A valve driving apparatus according to a first embodiment of the invention will be described with reference to Figs. 1 to 3.

[0031] Referring to Fig. 1, a valve lifter 101 includes a tappet portion 103 which is in contact with a cam 102 disposed at the upper side of a cylinder head 111 of an internal combustion engine. A portion of the tappet portion 103 which is in contact with the projected portion of the cam 102 is configured in a substantially-flat circular plate. The projected portion of the cam 102 comes in

linear contact with the tappet portion 103. The valve lifter 101 includes a guide portion 104 of a hollow cylindrical shape continuous to the lower portion of the tappet portion 103. The guide portion 104 is slidably housed within a guide hole 123 of the cylinder head 111. A diameter r of the guide portion 104 is set to be smaller than a diameter R of the tappet portion 103.

[0032] With the above configuration, the diameter R of the tappet portion 103 is so set as to secure the required lift amount of the valve lifter 101, that is, such a lift amount of the valve lifter 101 as to ensure a tumble ratio of a predetermined value or more and a desired flow rate. In addition, since the diameter of the guide portion 104 is made smaller, the valve lifter 101 is intended so as to be miniaturized and light-weighted. In other words, it becomes possible to provide the tappet portion 103 having such the diameter R as to obtain the lift amount capable of securing the high engine performance while reducing the occupied area of components related to a valve in the vicinity of the cylinder head 111. Further, since the components related to the valve can be housed in a small space, the degree of the freedom for arrangement of other components can be improved with the advantage in space. Furthermore, since the valve lifter 101 is miniaturized and light-weighted, the valve driving apparatus is adaptive to the high speed of the internal combustion engine.

[0033] The tip portion of the shaft portion of a poppet valve (hereinafter merely referred to as "valve") 105 is disposed within the guide portion 104 of the valve lifter 101 so as to abut against the lower surface of the tappet portion 103 and the valve 105 is urged upward by a not-shown spring. That is, the valve lifter 101 is disposed between the cam 102 and the valve 105. The projected portion of the cam 102 is brought into contact with the tappet portion 103 by the rotation of the cam 102 to push the valve lifter 101 downward so that the valve 105 is pushed down together with the valve lifter 101 against the urging force of the spring, thereby opening the valve 105. Since the inertia load of the valve driving system is made small due to the miniaturization and the light-weighting of the valve lifter 101, it is not necessary to make the spring force of the spring larger, thereby making it hard to wear away the cam 102 and the tappet portion 103.

[0034] The internal combustion engine with the valve driving apparatus according to the first embodiment will be described with reference to Figs. 2 and 3. As shown in Fig. 2, a cylinder block 112 of the internal combustion engine is equipped with a cylinder 113. A piston 114 is disposed within the cylinder 113 so as to be reciprocated therein. A concave-shaped cavity 114a is defined in the top surface of the piston 114 so that the cavity 114a produces such a reverse tumble flow that a suction air within the cylinder 113 flows almost just above. A suction valve seat 115 and an exhaust valve seat 116 are disposed within a combustion chamber 110 of the cylinder 113. The suction valve seat 115 is openable and clos-

able by a suction valve 117 (valve 105) and the exhaust valve seat 116 is openable and closable by an exhaust valve 118 (valve 105).

[0035] The cylinder block 112 is coupled to the cylinder head 111 by means of head bolts 109. The valve lifter 101 is disposed to be slanted along the axis of the suction valve 117 (or the exhaust valve 118) within the cylinder head 111. The guide portion 104 is slidably supported by the cylinder head 111. The suction valve 117 (or the exhaust valve 118) is disposed within the valve lifter 101 in a state where it is urged in a direction of closing the valve 117 (or 118) through a retainer 119 and a spring 120. Each of the suction valve 117 and the exhaust valve 118 is provided at the cylinder head 111 with a predetermined angle θ relative to the axial line of the cylinder 113. The angle θ of the suction valve 117 may be identical with or different from the angle θ of the exhaust valve 118.

[0036] The valve lifter 101 is arranged in a manner that a diameter r of the guide portion 104 (see Fig. 1) is smaller than a diameter R of the tappet portion 103 (see Fig. 1) and the valve lifter 101 is disposed in an inclined manner. Thus, the space in a plan view can be secured arbitrarily and the degree of the freedom for the angles θ of the suction valve 117 and the exhaust valve 118 is increased. As exemplarily shown as for the exhaust valve 118 in Fig. 2, a shim 131 may be disposed between the valve lifter 101 and the exhaust valve 118 (or the suction valve 117).

[0037] The cylinder head 111 is equipped with a suction port 121 communicating with the suction valve seat 115 along the axial direction of the cylinder 113 or vertically and also with an exhaust port 122 communicating with the exhaust valve seat 116. Since the suction port 121 is disposed 17 along the axial line of the cylinder or vertically and the suction valve 117 is disposed with the given angle θ relative to the axial line of the cylinder, a suction air from the suction port 121 can flow just downwardly into the cylinder 113. As a result, the cavity 114a of the piston 114 can generate such a reverse tumble flow that the suction air within the cylinder 113 flows almost just upward. Fuel is directly injected into the combustion chamber 110, and the stratified combustion can be performed due to the reverse tumble flow of the suction air.

[0038] As shown in Fig. 3, the tappet portions 103 of the valve lifter 101 and the head bolts 109 are disposed in such a state that the diameter d of the bolt bearing surface of the head bolt 109 and a virtual columnar shape obtained by extending the tappet portion 103 with the diameter R axially of the suction valve 117 (or the exhaust valve 118), are overlapped when seen from the plane of the bolt bearing surface. The head bolt 109 is not overlapped with the tappet portion 103 in a state where the valve lift amount is 0 when seen along the axial line of the head bolt 109. That is, the following relation is satisfied:

$$P + R > p - d$$

where p is a pitch of the head bolts 109 and P is a pitch of the tappet portions 103.

[0039] Since the valve lifter 101 is disposed in a slanted state with respect to the axial line of the cylinder 113, even if the diameter d of the bolt bearing surface of the head bolt 109 and the virtual columnar shape are overlapped when seen from the plane of the bolt bearing surface, the head bolts 109 can be fastened without interfering with the valve lifters 101. Further, since the diameter d of the bolt bearing surface of the head bolt 109 and the virtual columnar shape are overlapped when seen from the plane of the bolt bearing surface, the pitch p of the head bolts 109 can be made smaller so as to realize a sufficient amount of the valve lift (large lift amount) capable of securing the high engine performance even if a displacement amount of the internal combustion engine is small.

In the above-described first embodiment, the description has been given of the case where the invention is applied to the internal combustion engine of the type that the valve lifters 101 are inclined with respect to the axial line of the cylinder 113 (that is, toward the direction perpendicular to the axis line of the rotation center of the cam with respect to the vertical direction) and fuel is directly injected into the combustion chamber 110. However, the invention is not limited to the structure of the first embodiment but may be applied to other types of the internal combustion engine. More specifically, the invention may be applied to the internal combustion engine of the type that air-fuel mixture is introduced into the combustion chamber 110 so long as the tappet portion of the valve lifter 101 is pushed down by the cam 102. Also, the relation between the pitch P of the valve lifters 101 and the pitch p of the head bolts 109 is not limited to the above-described example, but other relation may be employed so that the diameter d of the bolt bearing surface of the head bolt 109 and the virtual columnar shape are not overlapped when seen from the plane of the bolt bearing surface.

[0040] The valve lifter 101 is disposed between the cam 102 formed at the cam shaft and the suction valve 117 (or the exhaust valve 118) which is provided at the suction port 121 (or the exhaust port 122) formed in the cylinder head 111 of the internal combustion engine and moved along the shaft of the valve 117 (or 118) to open and close the suction port 121 (or the exhaust port 122). The valve driving apparatus using the valve lifter 101 is equipped with the guide hole 123 defined in the cylinder head 111, and the direct driving type valve lifter which includes the tappet portion 103 which is in contact with the cam 102 and pushed down by the cam 102, and the guide portion 104 which is coupled at its end to the tappet portion 103 and housed within the guide hole 123 so as to be slid therein along the axial line of the suction valve 117 (or the exhaust valve 118) in an interlocked

manner as the pushed-down operation of the tappet portion 103 by the cam 102. Further, the diameter r of the guide portion 104 is made smaller than the diameter R of the tappet portion 103. With the above configuration, the diameter of the tappet portion 103 is set to such a value as to secure a lift amount of the valve lifter 101 necessary for obtaining a tumble ratio of the predetermined value or more and a desired flow rate. Further, since the diameter of the guide portion 104 is made small, the valve lifter 101 can be miniaturized and light-weighted.

[0041] Accordingly, it is possible to secure the high performance of the engine while reducing the occupied area of components related to the valve in the vicinity of the cylinder head 111. Also, since the components related to the valve can be housed in a small space, the degree of the freedom for the arrangement of other components can be improved. Furthermore, since the valve lifter 101 is miniaturized and light-weighted, the valve driving apparatus can be adapted to the high speed of the internal combustion engine.

[0042] Since the valve lifter 101 is inclined with respect to the axial line of the cylinder 113, even if the pitch p between the bearing surfaces of the head bolts 109 is made shorter than the width ($P + D$) of the tappet portions 103, the head bolts 109 can be fastened without interfering with the tappet portions 103. Further, since the suction valve 117 is disposed with the angle θ relative to the axial line of the cylinder 113, the invention is applicable to an internal combustion engine that has a suction port of the vertical type which generates the reverse tumble flow at the almost just above portion within the combustion chamber 110 and directly injects fuel within the combustion chamber 110. It is needless to say that in the internal combustion engine not requiring a large lift amount of the valve lifter, the lifter can be further miniaturized and light-weighted without changing the lift amount.

[0043] A valve driving apparatus according to a second embodiment of the invention will be described with reference to Figs. 4 and 5.

[0044] Fig. 4 shows a state where a valve lifter is not pushed down, and Fig. 5 shows a state where the valve lifter is pushed down.

[0045] Referring to these figures, a cam 212 is disposed at the upper side of a cylinder head 211 of an internal combustion engine and the cylinder head 211 is defined with a guide hole 213. A cylindrical guide portion 215 of a valve lifter 214 is slidably housed along and within the guide hole 213. A tappet portion 216 is provided at the upper portion of the guide portion 215. The tappet portion 216 is protruded toward the outer diameter direction of the guide portion 215 from the circumferential portion thereof to form a projected portion 230. The tappet portion 216 is continuous to the upper portion of the guide portion 215 to form an umbrella shape. The tappet portion 216 is configured in a substantially flat circular shape at a portion which is in contact with the

projected portion of the cam 212. The cam 212 comes in linear contact with the tappet portion 216. The entirety of the outer peripheral portion of the tappet portion 216 may not be protruded from the guide portion 215, but only a part of the outer peripheral portion of the tappet portion 216 may be protruded from the guide portion 215 by changing the diameter thereof.

[0046] The shaft portion of a valve 217 (a suction valve or an exhaust valve) is disposed within the guide portion 215 of the valve lifter 214 in such a manner that the tip portion of the shaft portion abuts against the lower surface of the tappet portion 216. The valve 217 is urged upward by a not-shown spring. That is, the valve lifter 214 is disposed between the cam 212 and the valve 217. The projected portion of the cam 212 is brought into contact with the tappet portion 216 by the rotation of the cam 212 to push the valve lifter 214 downward, so that the valve 217 is pushed down together with the valve lifter 214 against the urging force of the spring, thus opening the valve 217.

[0047] An oil reservoir 218 serving as an oil reservoir portion in which lubricant oil 219 is reserved is formed at the periphery of the upper portion (the tappet portion 216 side) of the guide hole 213. The tappet portion 216 is disposed within the oil reservoir 218 so as to form a slight clearance between the outer periphery, of the tappet portion 216 and the inner wall of the oil reservoir 218. That is, it is arranged that the tappet portion 216 moves within the oil reservoir 218 when the valve lifter 214 is lifted. As shown in Fig. 4, the depth d of the oil reservoir 218 is set so as to satisfy the following expression: $d \geq D - S$, where D is a length from the upper surface of the tappet portion 216 and the bottom surface of the oil reservoir 218 when the liter 214 is not pushed down.

[0048] Like the valve driving apparatus of the third embodiment shown in Fig. 6, the valve driving apparatus is arranged in a manner that, when a valve 317 is inclined with respect to the axial line of the cylinder (that is, toward the direction perpendicular to the axis line of the rotation center of the cam with respect to the vertical direction), at least a portion of the rear surface of a tappet portion 316 is positioned below the oil surface when a valve lifter 314 is lifted.

[0049] According to the valve driving apparatus arranged in the aforesaid manner, the load is applied from the cam on the right side surface of the tappet portion 216 (316) in Fig. 5 (Fig. 6) until the lift amount of the valve lifter reaches the maximum value after the start of the lifting operation of the valve lifter 214 (314). Thus, the moment acting on the valve lifter 214 (314) is generated to the same direction as the rotation direction of the cam 212 (312). As a result, the valve lifter 214 (314) inclines toward the right side in Fig. 5 (Fig. 6) and hence the clearance between the guide portion 215 (315) and the guide hole 213 (313) on the left side becomes larger at the upper portion thereof. When the clearance at the upper portion becomes larger in this manner, the lubri-

cant oil 219 (319) within the oil reservoir 218 (318) is pushed down (to the direction shown by an arrow A in Fig. 5 (Fig. 6)) by the rear surface of the tappet portion 216 (316) just above the clearance, whereby the lubricant oil 219 (319) is filled within the clearance.

[0050] Simultaneously, the lubricant oil 219 (319) is pushed out of the clearance between the outer peripheral portion of the tappet portion 216 (316) and the oil reservoir 218 (318) (to the direction shown by an arrow B in Fig. 5 (Fig. 6)), and the lubricant oil 219 (319) is introduced to the cam 212 (312) side. The lubricant oil 219 (319) within the oil reservoir 218 (318) is stirred by the tappet portion 216 (316) of an umbrella shape and the sludge etc. is ejected by the lifting operation of the valve lifter 214 (314).

[0051] After the valve lifter reaches the uppermost position to attain the maximum lift amount of the valve lifter, moment acts on the valve lifter 214 (314) to the direction opposite to that having been acted thereon, so that the valve lifter 214 (314) inclines toward the left side in Fig. 5 (Fig. 6). In this case, although the clearance between the guide portion 215 (315) and the guide hole 213 (313) on the left side becomes smaller at the upper portion thereof, since the lubricant oil 219 (319) filled in the clearance performs the squeeze effect, the valve lifter 214 (314) does not change its posture rapidly.

[0052] In the aforesaid valve driving apparatus, at the time of lifting the valve lifter 214 (314), the lubricant oil 219 (319) within the oil reservoir 218 (318) is pushed by the rear surface of the tappet portion 216 (316) into the clearance between the guide portion 215 (315) and the guide hole 213 (313). In this manner, the lubricant oil 219 (319) is supplied to the clearance between the guide portion 215 (315) and the guide hole 213 (313) irrespective of the viscosity of the lubricant oil 219 (319). Further, since the lubricant oil 219 (319) is pushed out of the clearance between the outer peripheral portion of the tappet portion 216 (316) and the oil reservoir 218 (318) and the lubricant oil 219 (319) is introduced to the cam 212 (312) side, the lubricant oil 219 (319) is supplied to the contact surface between the cam 212 (312) and the tappet portion 216 (316).

[0053] As a result, since the friction at the clearance and the contact surface becomes smaller, the noise caused by the striking operation when the valve lifter 214 (314) changes its posture can be reduced and also the degree of the abrasion caused by the striking operation can be reduced. Thus, the output efficiency and the fuel cost of the engine are improved, and further the durability and the reliability of the engine are also improved.

[0054] A valve driving apparatus according to a fourth embodiment of the invention will be explained with reference to Figs. 7 to 11.

[0055] Figs. 7 and 8 show a state where a valve lifter is not pushed down and Figs. 9 and 10 show a state where the valve lifter is pushed down. Fig. 11 is a diagram showing a part of the valve driving apparatus cut

away along a line VIII - VIII in Figs. 7 and 9.

[0056] As shown in these figures, a tappet portion 416 is protruded toward the outer diameter direction of a guide portion 415 from the circumferential portion thereof to form a projected portion (430). An oil reservoir 421 serving as an oil reservoir portion in which lubricant oil 419 is reserved is formed at the periphery of the upper portion of a guide hole 413. As shown in Figs. 7, 9 and 11, the oil reservoir 421 is provided with notched portions 422 which are formed by partially removing the opposite portions of the inner peripheral wall of the oil reservoir in a convex shape to the direction (left and right direction in the figure) perpendicular to the axis line of the rotation center of the cam 412. As shown in Figs. 8 and 10, the portions of the oil reservoir 421 (that is, the portions mainly along the axis line of the rotation center of the cam 412) except for the notched portions 422 are opposed to the tappet portion 416 through a small clearance therebetween.

[0057] According to the valve driving apparatus arranged in this manner, when the valve lifter 414 is lifted, the lubricant oil 419 within the oil reservoir 421 is pushed into the clearance between the guide portion 415 and the guide hole 413 by the rear surface of the tappet portion 416, so that the lubricant oil 419 is supplied to the clearance between the guide portion 415 and the guide hole 413. Further, the lubricant oil 419 is pushed out from the clearance between the outer peripheral portion of the tappet portion 416 and the oil reservoir 421 mainly along the axis line of the rotation center of the cam 412 and introduced on the cam 412 side. The lubricant oil 419 within the oil reservoir 421 is stirred by the tappet portion 416 of an umbrella shape and the sludge etc. is ejected by the lifting operation of the valve lifter 214. When the valve lifter 414 is lifted, the lubricant oil 419 is pushed out on the upper surface of the tappet portion 416 from the notched portions 422, and so much lubricant oil 419 is introduced on the contact surface between the cam 412 and the tappet portion 416, whereby the contact portion between the cam 412 and the tappet portion 416 is sufficiently lubricated.

[0058] As a result, since the friction at the clearance and the contact surface becomes smaller, the noise caused by the striking operation when the valve lifter 414 changes its posture can be reduced and also the degree of the abrasion caused by the striking operation can be reduced. Thus, the output efficiency and the fuel cost of the engine are improved, and further the durability and the reliability of the engine are also improved.

[0059] A valve driving apparatus according to a fifth embodiment of the invention will be described with reference to Figs. 12 to 14.

[0060] Fig. 12 shows a state where a valve lifter is not pushed down and Fig. 13 shows a state where the valve lifter is pushed down. Fig. 14 is a diagram showing a part of the valve driving apparatus cut away along a line XI - XI in Fig. 12.

[0061] As shown in these figures, a valve 517 is dis-

posed so as to be inclined with respect to the axial line of the cylinder (that is, toward the direction perpendicular to the axis line of the rotation center of the cam with respect to the vertical direction). A tappet portion 516 is protruded toward the outer diameter direction of a guide portion 515 from the circumferential portion thereof to form a projected portion (530). An oil reservoir 526 serving as an oil reservoir portion in which lubricant oil 519 is reserved is formed at the periphery of the upper portion of a guide hole 513. The oil reservoir 526 is provided with a notched portion 527 which is formed by partially removing a portion of the inner peripheral wall of the oil reservoir in a convex shape on the slanted inner side (left side in the figure) to the direction perpendicular to the axis line of the rotation center of a cam 512. The portion of the oil reservoir 526 except for the notched portion 527 is opposed to the tappet portion 516 through a small clearance therebetween.

[0062] According to the valve driving apparatus arranged in this manner, when a valve lifter 514 is lifted, the lubricant oil 519 is pushed out on the upper surface of the tappet portion 516 from the notched portion 527, and the lubricant oil 519 is introduced on the contact surface between the cam 512 and the tappet portion 516. Further, particularly, when the engine rotates in a high speed range, the lubricant oil 519 within the notched portion 527 is pressed at a high pressure by the tappet portion 516, so that the lubricant oil 519 is splashed toward the wall surface etc. of a cylinder head 511. Then, the lubricant oil 519 thus splashed is bounced off the wall surface etc. and introduced to the projected portion of the cam 512 whose diameter of the base circular portion is smaller than the diameter of the tappet portion 516. Thus, the contact portion between the cam 512 and the tappet portion 516 is sufficiently lubricated.

[0063] As a result, since the high friction and the high degree of the abrasion can be prevented at the contact surface, the output efficiency and the fuel cost of the engine are improved and further the durability and the reliability of the engine are also improved.

[0064] The sixth embodiment of the invention will be explained with reference to Figs. 15 to 17. Figs. 15 and 16 are front views showing the schematic arrangement of the valve driving apparatus according to the sixth embodiment, wherein Fig. 15 shows a state where a valve lifter is not pushed down and Fig. 16 shows a state where the valve lifter is pushed down. Fig. 17 is a diagram showing a part of the valve driving apparatus cut away along a line XIV - XIV in Fig. 15.

[0065] As shown in Figs. 15 and 16, a cam 631 is disposed at the upper side of the cylinder head 611 of the engine. The diameter r of a tappet portion 616 is made smaller than a diameter R of the base circular portion of the cam 631. The tappet portion 616 is protruded toward the outer diameter direction of a guide portion 615 from the circumferential portion thereof to form a projected portion (630). An oil reservoir 632 serving as an oil res-

ervoir portion in which lubricant oil 619 is reserved is formed at the periphery of the upper portion of a guide hole 613. As shown in Fig. 17, the oil reservoir 632 is provided with diameter enlarged portions 633 which are formed by partially removing the opposite portions of the inner peripheral wall of the oil reservoir in an elliptical shape in a manner that the major axis portion thereof is directed to the direction perpendicular to the axis line of the rotation center of a cam 631 (left and right direction in the figure). Each of the portions of the oil reservoir 632 except for the diameter enlarged portions 633 is opposed to the tappet portion 616 through a small clearance therebetween.

[0066] According to the valve driving apparatus arranged in this manner, when a valve lifter 614 is lifted, the lubricant oil 619 is pushed out on the upper surface of the tappet portion 616 from the diameter enlarged portions 633, and the lubricant oil 619 is introduced on the contact surface between the cam 631 and the tappet portion 616. Further, particularly, when the engine rotates in a high speed range, the lubricant oil 619 within the diameter enlarged portions 633 is pressed by the tappet portion 616 and so splashed. In this case, since the diameter r of the tappet portion 616 is made smaller than the diameter R of the base circular portion of the cam 631, the lubricant oil 619 thus splashed is directly introduced to the projected portion of the cam 631. Thus, the contact portion between the cam 631 and the tappet portion 616 is sufficiently lubricated.

[0067] As a result, since the high friction and the high degree of the abrasion can be prevented at the contact surface, the output efficiency and the fuel cost of the engine are improved and further the durability and the reliability of the engine are also improved.

[0068] A valve driving apparatus according to a seventh embodiment of the invention will be described with reference to Figs. 18 and 19.

[0069] As shown in these figures, a valve 717 is disposed so as to be inclined with respect to the axial line of the cylinder (that is, toward the direction perpendicular to the axis line of the rotation center of the cam with respect to the vertical direction). A tappet portion 716 is protruded toward the outer diameter direction of a guide portion 715 from the circumferential portion thereof to form a projected portion (730). An oil reservoir 736 serving as an oil reservoir portion in which lubricant oil 719 is reserved is formed at the periphery of the upper portion of a guide hole 713. The oil reservoir 736 is provided with a diameter enlarged portion 737 which is formed by partially removing a portion of the inner peripheral wall of the oil reservoir in a semi-elliptical shape in a manner that the major axis portion thereof is positioned on the slanted inner side (left side in the figure) to the direction perpendicular to the axis line of the rotation center of a cam 731. The portion of the oil reservoir 736 except for the diameter enlarged portion 737 is opposed to the tappet portion 716 through a small clearance therebetween.

[0070] According to the valve driving apparatus arranged in this manner, when a valve lifter 714 is lifted, the lubricant oil 719 is pushed out on the upper surface of the tappet portion 716 from the diameter enlarged portion 737, and the lubricant oil 719 is introduced on the contact surface between the cam 731 and the tappet portion 716. Further, particularly, when the engine rotates in a high speed range, the lubricant oil 719 within the diameter enlarged portion 737 is pressed by the tappet portion 716 and so splashed. In this case, since the diameter r of the tappet portion 716 is made smaller than the diameter R of the base circular portion of the cam 731, the lubricant oil 719 thus splashed is directly introduced to the projected portion of the cam 731. Thus, the contact portion between the cam 731 and the tappet portion 716 is sufficiently lubricated.

[0071] As a result, since the high friction and the high degree of the abrasion can be prevented at the contact surface, the output efficiency and the fuel cost of the engine are improved and further the durability and the reliability of the engine are also improved.

[0072] A valve driving apparatus according to an eighth embodiment of the invention will be described with reference to Figs. 20 to 24.

[0073] As shown in these figures, a cylindrical guide portion 812 of a valve lifter 811 is housed within a guide hole 806 of a cylinder head 802 so as to slide freely therealong. A disc-shaped tappet portion 813 is integrally provided at the upper portion of the guide portion 812. The diameter R of the tappet portion 813 is larger than the diameter r of the guide portion 812. The tappet portion 813 is configured so as to continue to the upper portion of the guide portion 812 to form an umbrella shape.

[0074] The tappet portion 813 is configured in a substantially flat circular shape at a portion which contacts with the projected portion of a cam 803. The projected portion of the cam 803 is made line contact with the tappet portion 813. The valve driving apparatus is set in a manner that when the valve 807 is pushed down at the maximum, that is, when the lift amount of the valve lifter 811 reaches the maximum value, only the guide portion 812 is housed within the guide hole 806 (the tappet portion 816 is not housed within the guide hole 806).

[0075] A peripheral groove 814 serving as an elastic deformation promotion portion r is formed at the outer periphery of the guide portion 812 at the root portion of the tappet portion 813 so that the elastic deformation of the guide portion 812 is promoted by the peripheral groove 814 when the guide portion 812 is housed within the guide hole 806.

[0076] According to the valve lifter 811 thus configured, as shown in Figs. 21 and 22, the load is applied from the cam on the right side surface of the tappet portion 813 in Fig. 21 until the lift amount of the valve lifter 811 reaches the maximum value after the start of the lifting operation of the valve lifter 811. Thus, the moment acting on the valve lifter 811 is generated to the same direction as the rotation direction of the cam 803. As a

result, the valve lifter 811 inclines toward the right side in the figure (that is, toward the direction perpendicular to the axis line of the rotation center of the cam with respect to the vertical direction) and hence the clearance between the guide portion 812 and the guide hole 806 on the right side becomes smaller at the upper portion thereof.

[0077] When the valve lifter 811 changes its posture by the moment acting thereon to the same direction as the rotation direction of the cam 803, the guide portion 812 is elastically deformed due to the peripheral groove 814 provided at the outer periphery of the guide portion 812 so that the outer periphery of the guide portion 812 is fitted to the inner periphery the guide hole 806. Thus, since the lubricant oil between the guide portion 812 and the guide hole 806 is prevented from being pushed aside and the oil film is maintained therebetween, the noise caused by the striking operation when the valve lifter changes its posture can be suppressed and also the abrasion caused by the striking operation can be suppressed, whereby the friction can be reduced.

[0078] As shown in Figs. 23 and 24, since the load is applied from the cam on the left side surface of the tappet portion 813 in Fig. 23 after the lift amount of the valve lifter reaches the maximum value, the moment acting on the valve lifter 811 is generated to the direction opposite to the rotation direction of the cam 803. As a result, the valve lifter 811 inclines to the left side in the figure and so the clearance between the guide portion 812 and the guide hole 806 on the left side becomes smaller at the upper portion thereof.

[0079] When the valve lifter 811 changes its posture by the moment acting thereon to the direction opposite to the rotation direction of the cam 803, the guide portion 812 is elastically deformed to the direction opposite to that of the case of Fig. 21 due to the peripheral groove 814 provided at the outer periphery of the guide portion 812 so that the outer periphery of the guide portion 812 is fitted to the inner periphery the guide hole 806. Thus, since the lubricant oil between the guide portion 812 and the guide hole 806 is prevented from being pushed aside and the oil film is maintained therebetween, the noise caused by the striking operation when the valve lifter changes its posture can be suppressed and also the abrasion caused by the striking operation can be suppressed, whereby the friction can be reduced.

[0080] Further, since the peripheral groove 814 provides a recess portion required at the time of performing the grinding process of the rear surface of the tappet portion 813 and the outer peripheral surface of the guide hole 812, the valve lifter 811 can be processed easier.

Claims

1. Internal combustion engine comprising a valve driving apparatus using a direct driving type valve lifter is disposed between a cam (102, 212, 312, 412,

512, 631, 731, 803) formed at a cam shaft and a poppet valve (105, 117, 118, 217, 317, 417, 517, 617, 717, 807) which is provided in a path (121, 122) formed at a cylinder head (111, 211, 311, 411, 511, 611, 711, 802) of an internal combustion engine and moves in an axial direction of said valve to open and close said path, said apparatus comprising:

a guide hole (123, 213, 313, 413, 513, 613, 713, 806) formed at said cylinder head; and
a direct driving type valve lifter (101, 214, 314, 414, 514, 614, 714, 811) including a tappet portion (103, 216, 316, 416, 516, 616, 716, 813) which is brought in contact with said cam and pressed by said cam, and a guide portion (104, 215, 315, 415, 515, 615, 715, 812) having one end portion coupled to said tappet portion and housed within said guide hole so as to slide freely therein to the axial direction of said poppet valve in an interlocked manner as a pushing operation of said tappet portion by said cam;

wherein a diameter (r) of said guide portion is formed to be smaller than a diameter (R) of said tappet portion;

characterized in that:

said valve lifter (101, 214, 314, 414, 514, 614, 714, 811) is inclined in a direction perpendicular to a rotational axis of the cam relative to the head bolt (109) for securing the cylinder head; and
said valve lifter is arranged so as to be adjacent to the head bolt in a planar view.

2. Internal combustion engine according to claim 1, wherein
the valve lifter and the head bolt (109) are disposed so that a diameter of a bolt bearing surface of the head bolt and a virtual columnar shape obtained by extending the diameter (R) of the tappet portion (103, 216, 316, 416, 516, 616, 716, 813) along an axis of the suction valve are overlapped in a plan view.
3. Internal combustion engine according to claim 2, wherein said path at least includes a suction path (121) of said internal combustion engine.
4. Internal combustion engine according to claim 3, wherein said cam shaft is disposed on an upper side of said cylinder head, and said suction path is opened at its one end to a combustion chamber of said internal combustion engine and opened at its other end to an upper surface of said cylinder head.
5. Internal combustion engine according to claim 3, wherein at least two of said suction paths (121) are

provided in each of the cylinders of said internal combustion engine; and each said suction path (121) extends in a direction perpendicular to the rotational axis of the cam and is provided with said poppet valve.

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6. Internal combustion engine according to claim 1, wherein the diameter of said tappet portion is smaller than a diameter of a base circular portion of said cam.

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7. Internal combustion engine according to claim 1, wherein the valve driving apparatus further comprises an elastic deformation promotion portion (814) for promoting elastic deformation of said guide portion when said guide portion is housed within said guide hole,

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wherein said elastic deformation promotion portion is a groove provided at a peripheral portion of said guide portion.

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8. Internal combustion engine according to claim 7, wherein said elastic deformation promotion portion is provided at said guide portion in vicinity of a boundary between said tappet portion and said guide portion.

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FIG.1

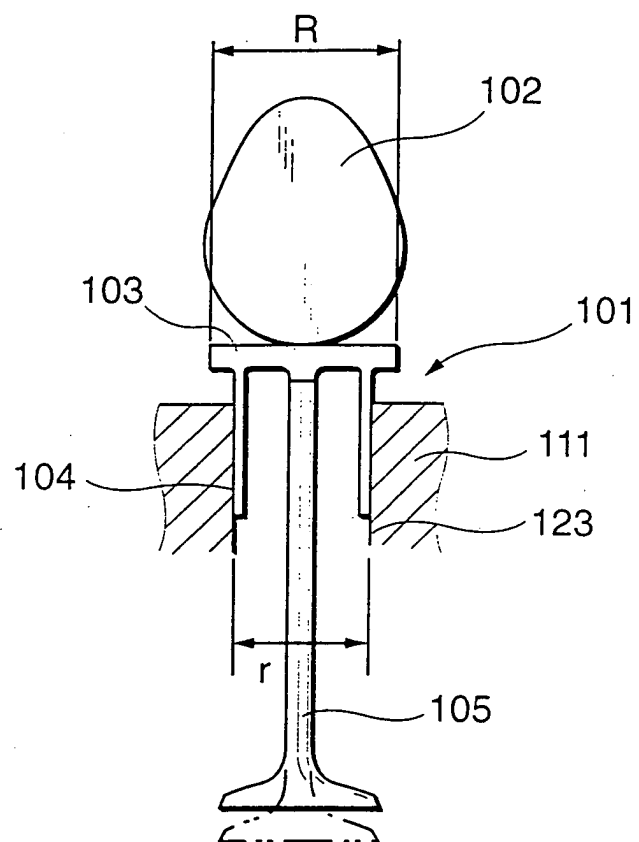


FIG.2

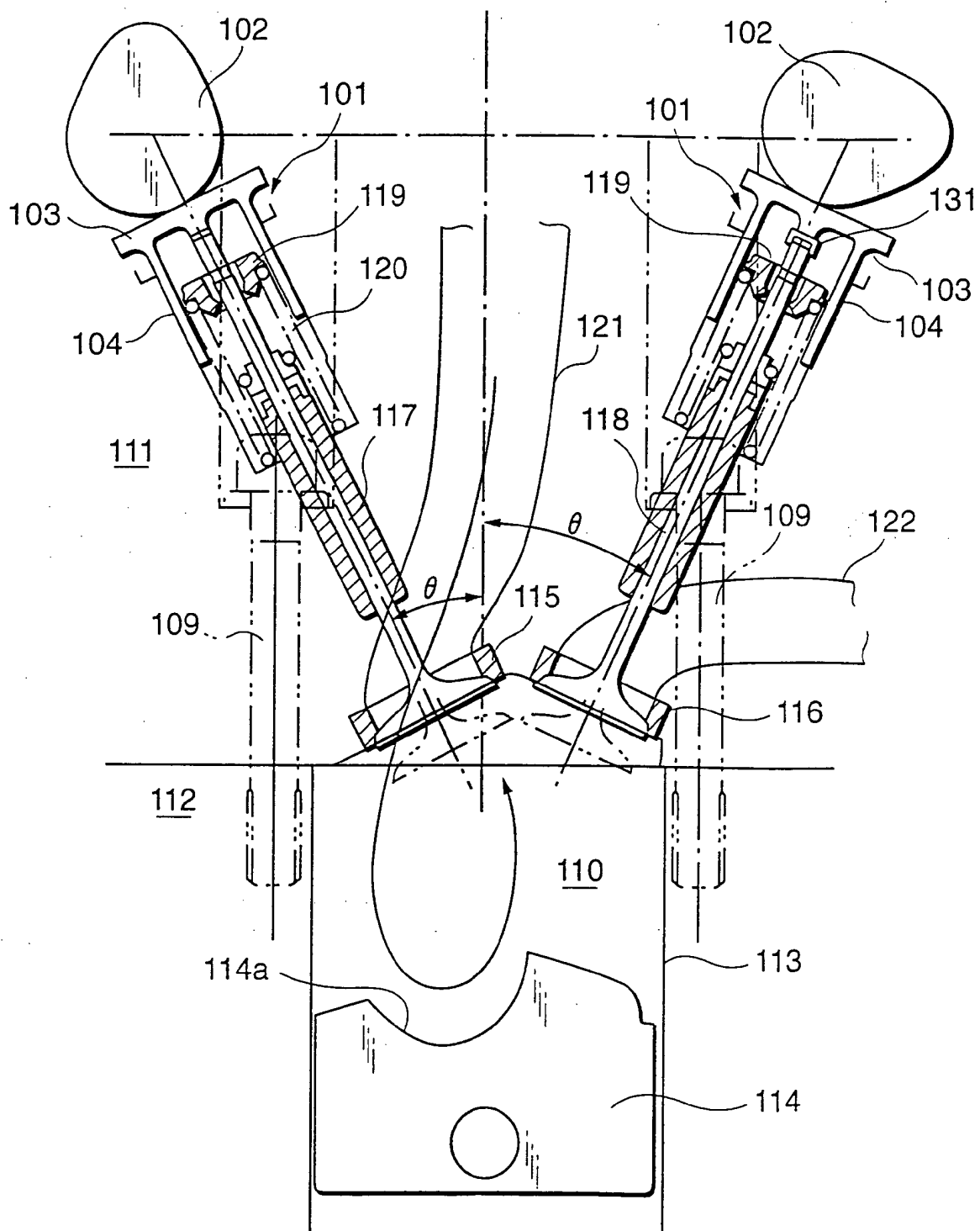


FIG.3

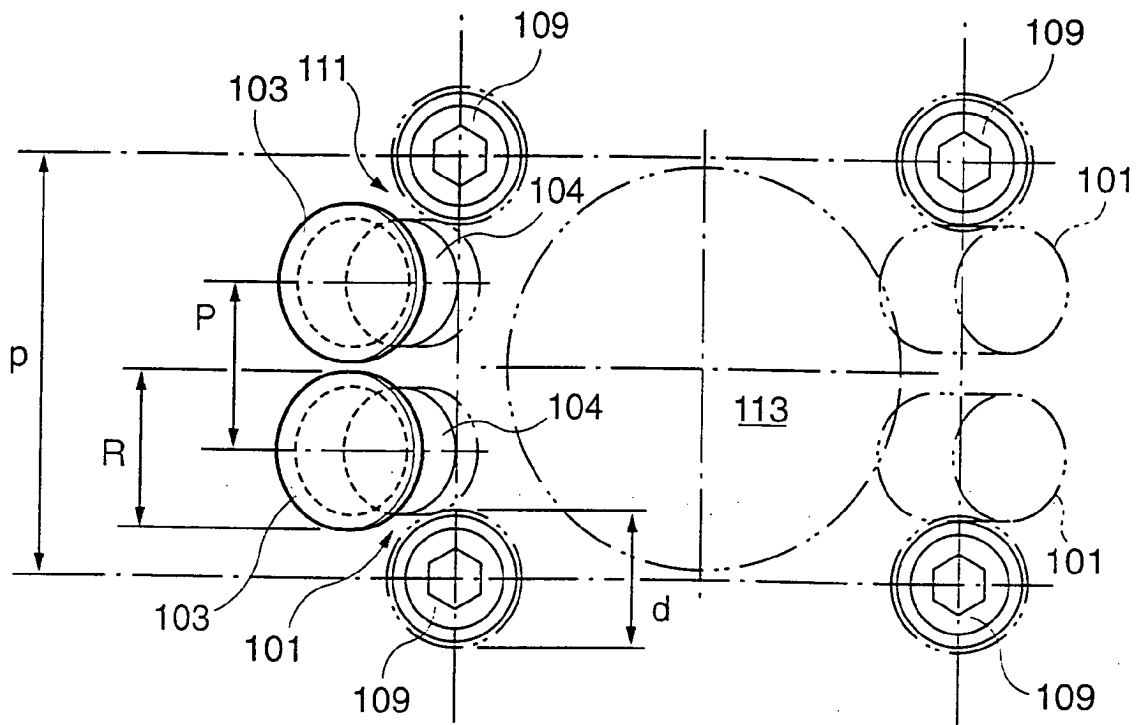


FIG.4

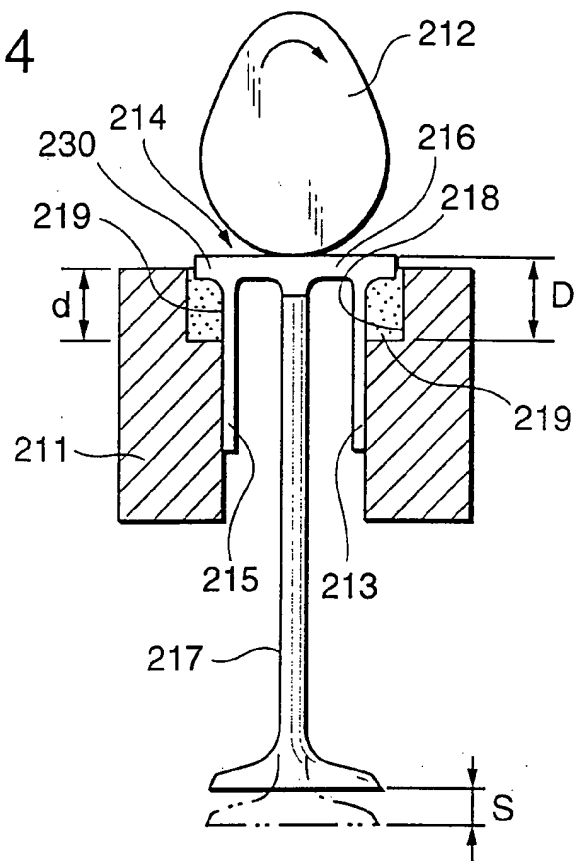


FIG.5

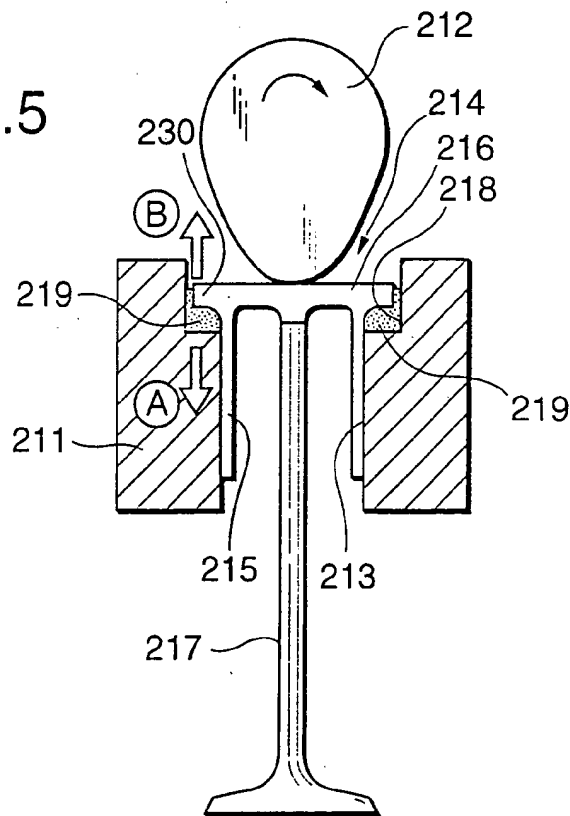


FIG.6

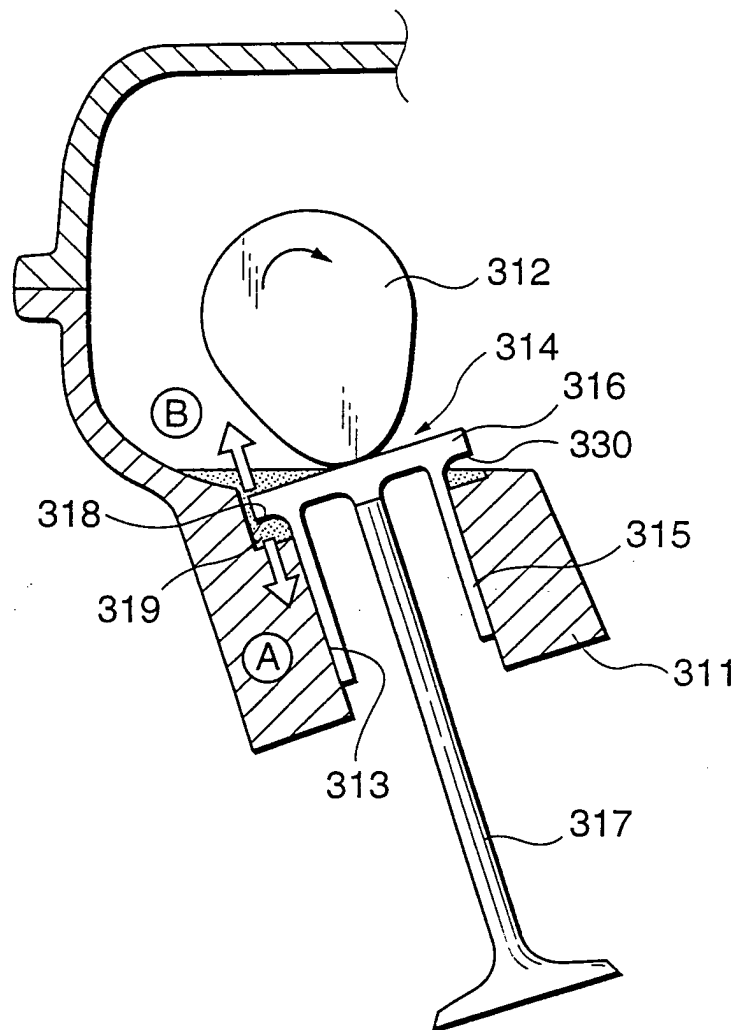


FIG.7

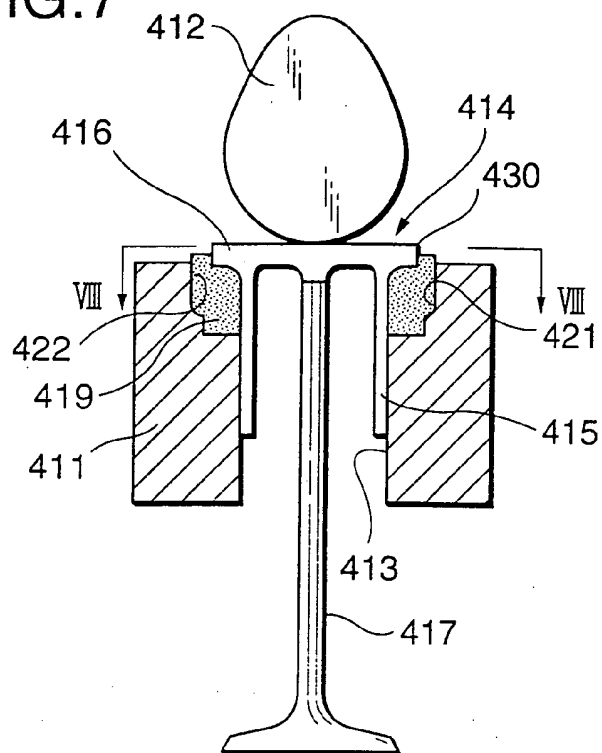


FIG.8

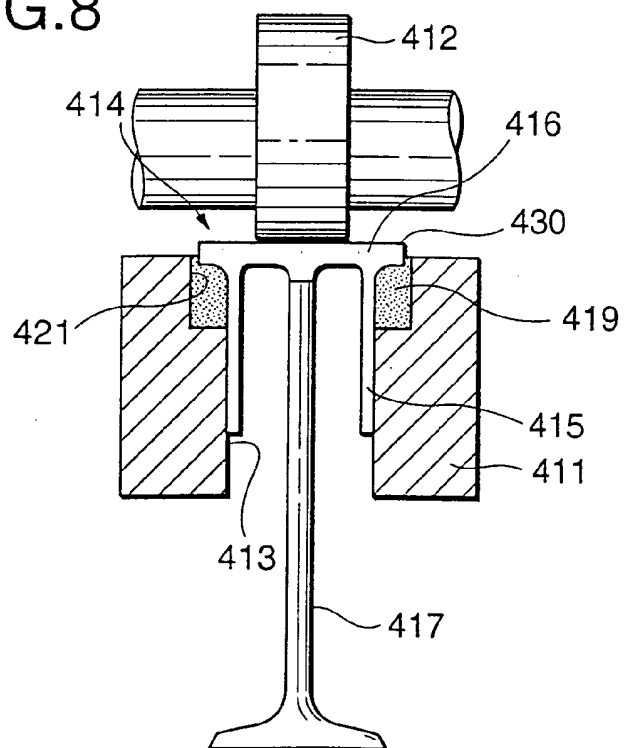


FIG.9

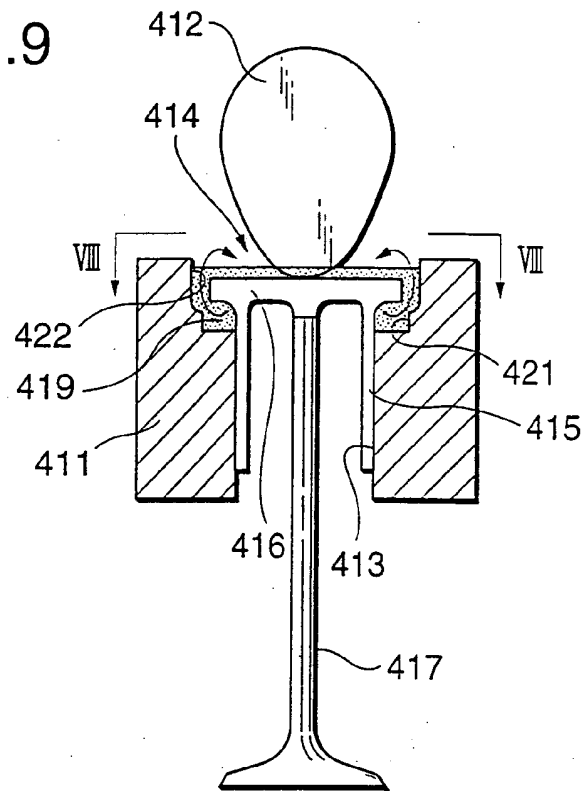


FIG.10

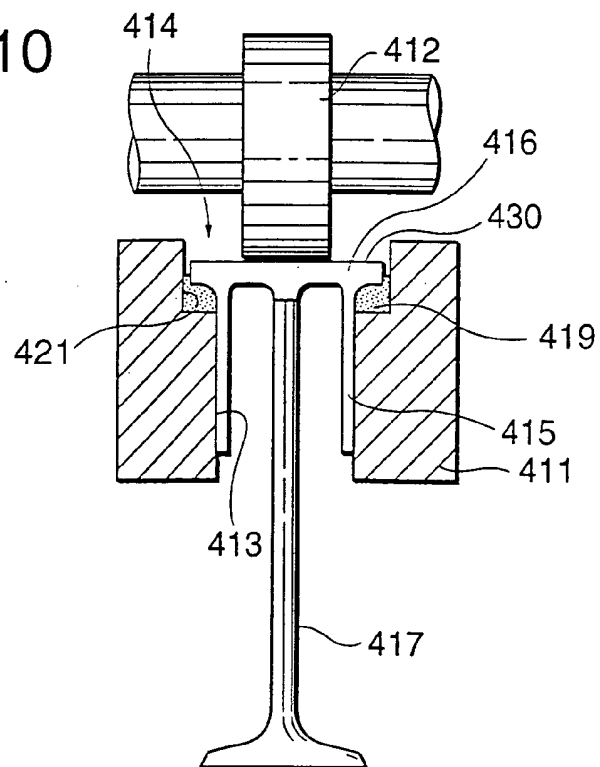


FIG.11

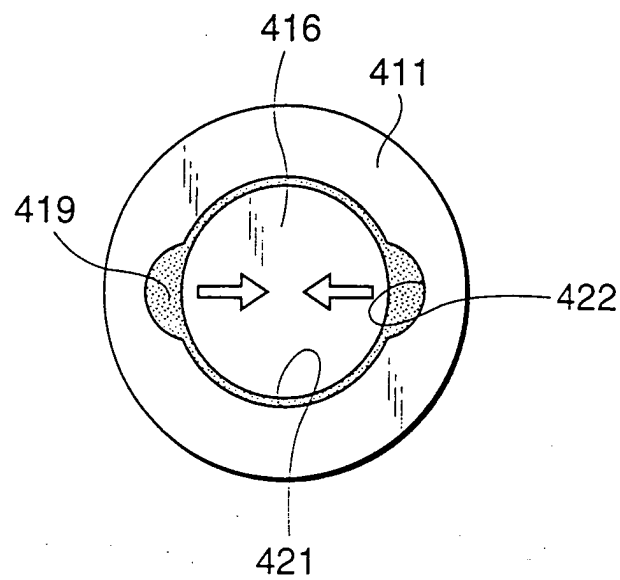


FIG.12

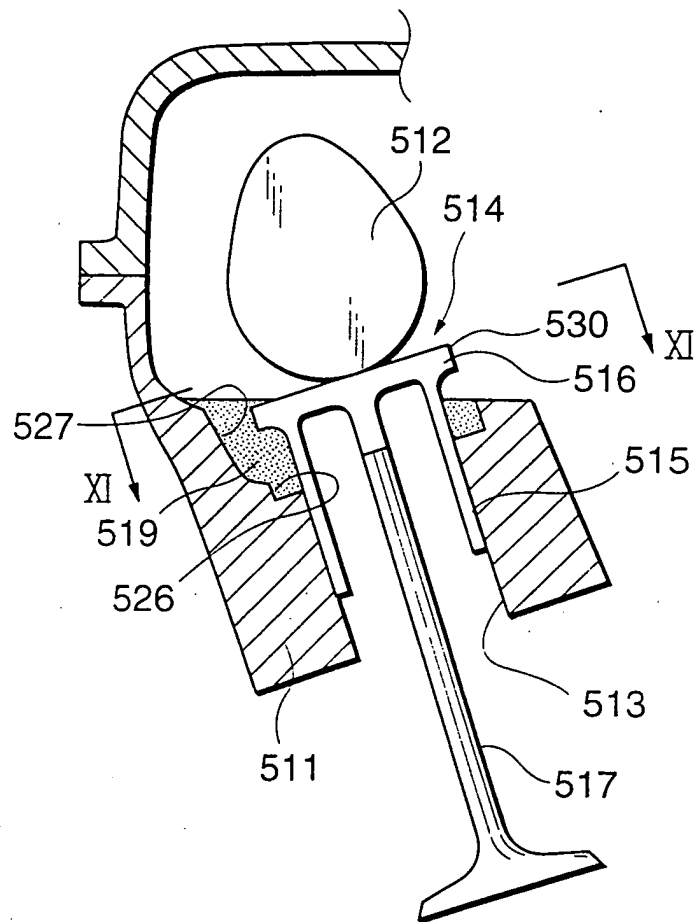


FIG.13

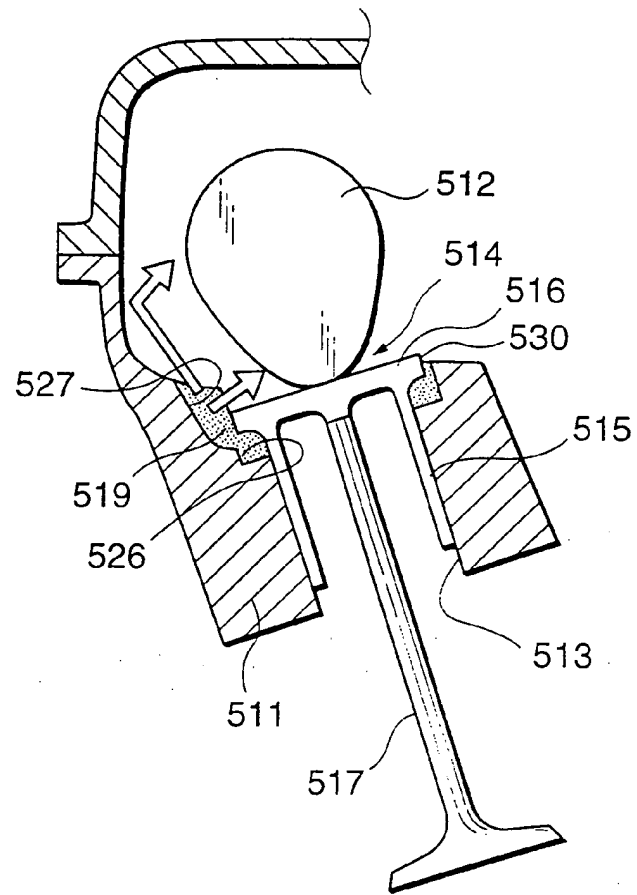


FIG.14

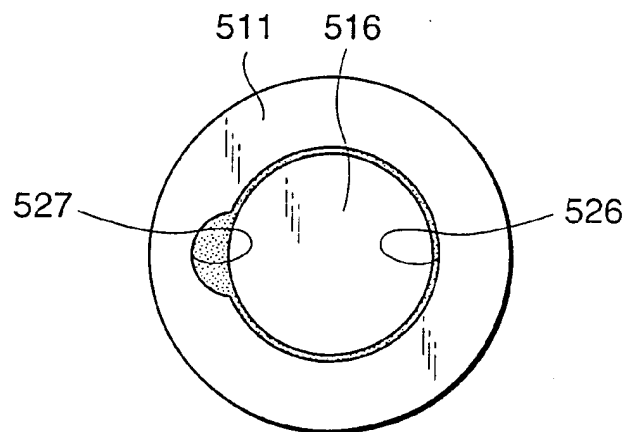


FIG.15

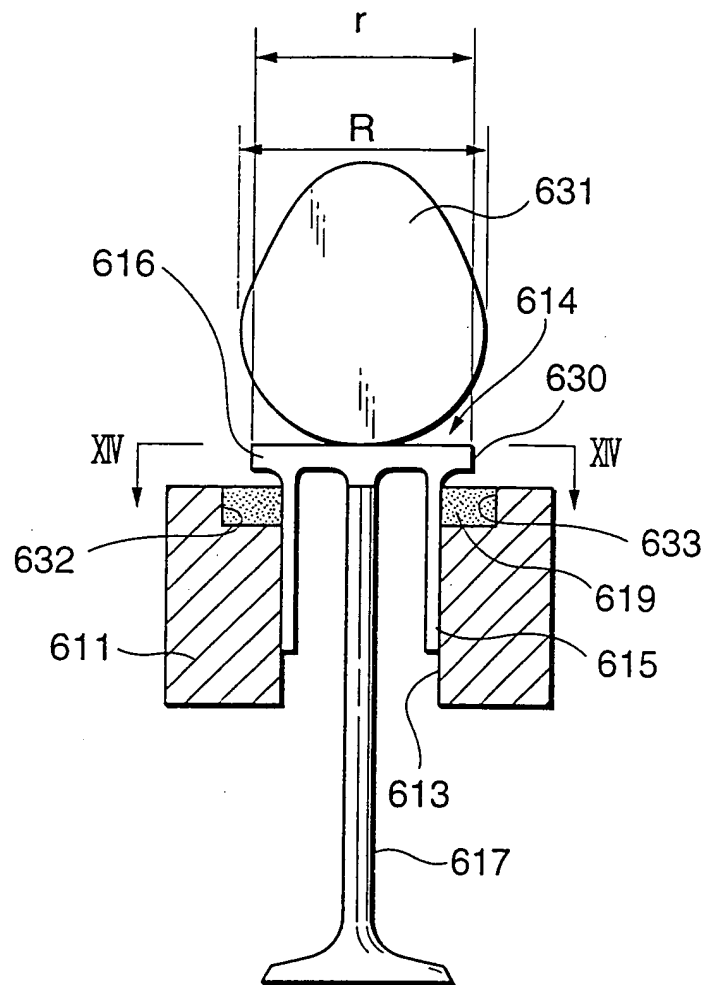


FIG.16

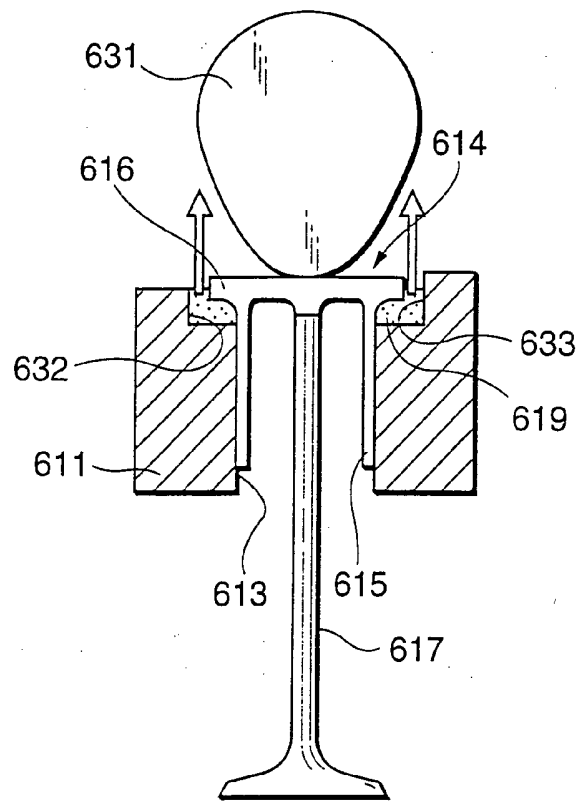


FIG.17

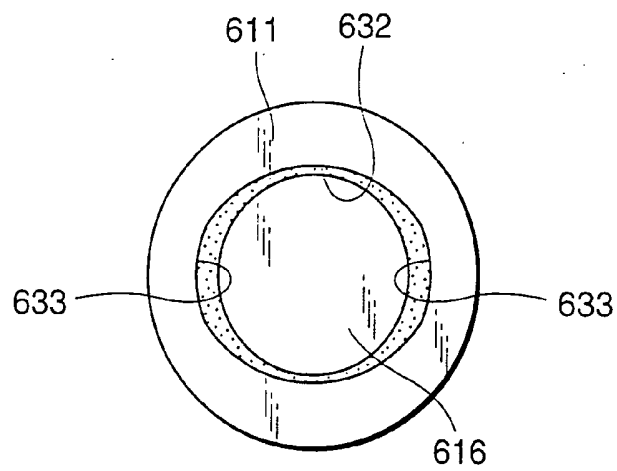


FIG.18

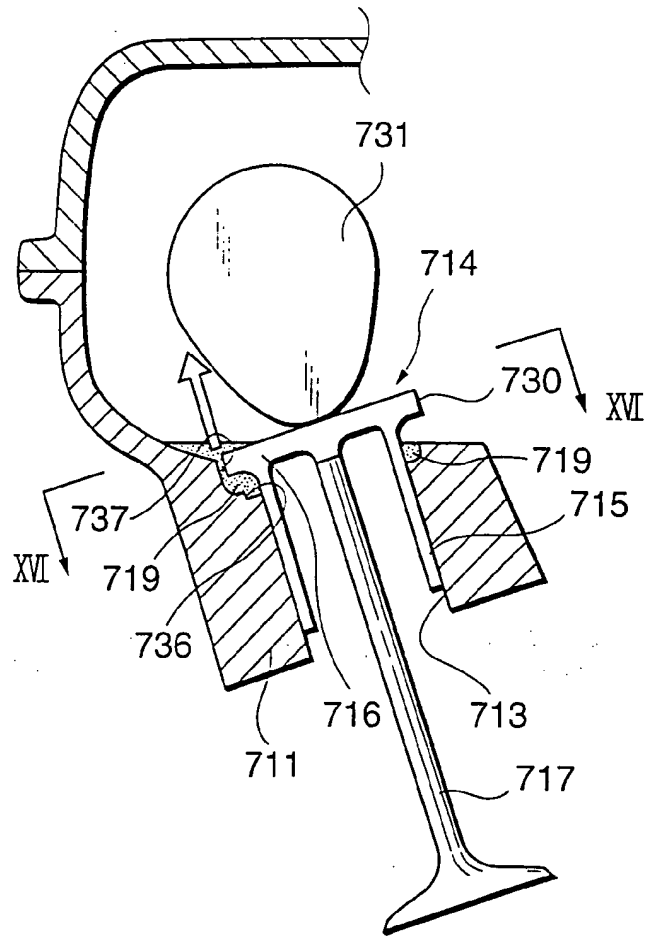


FIG.19

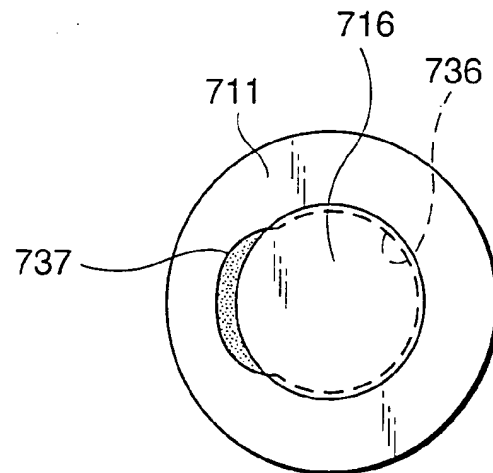


FIG.20

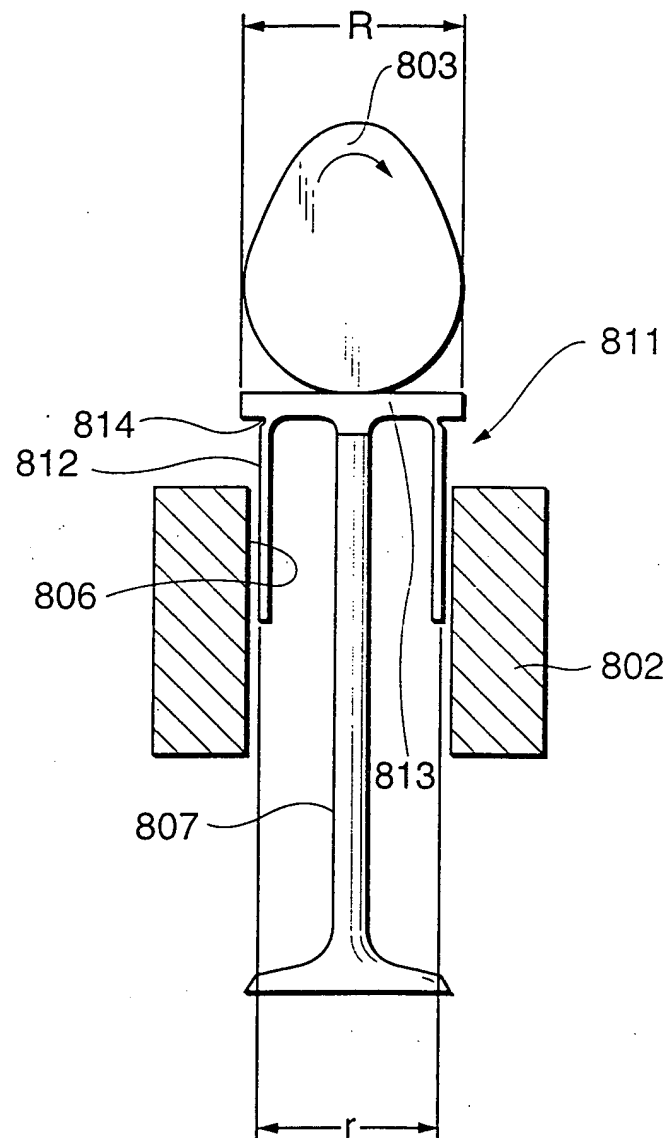


FIG.21

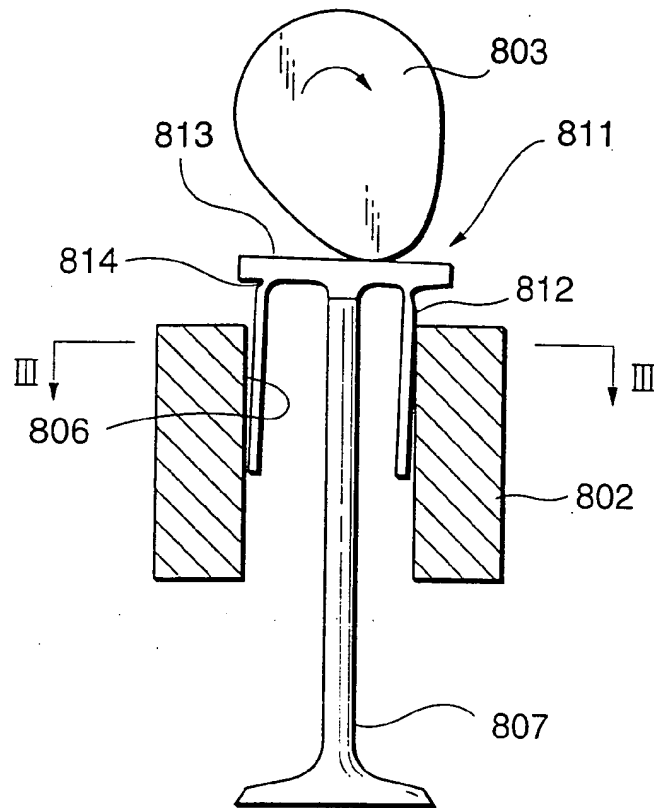


FIG.22

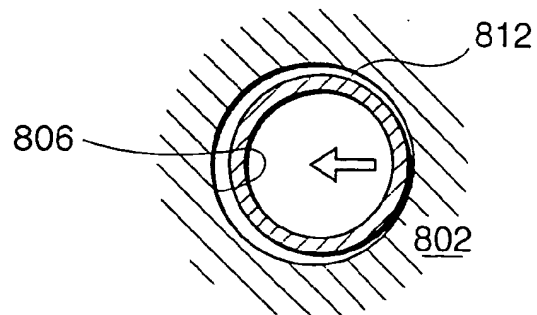


FIG.23

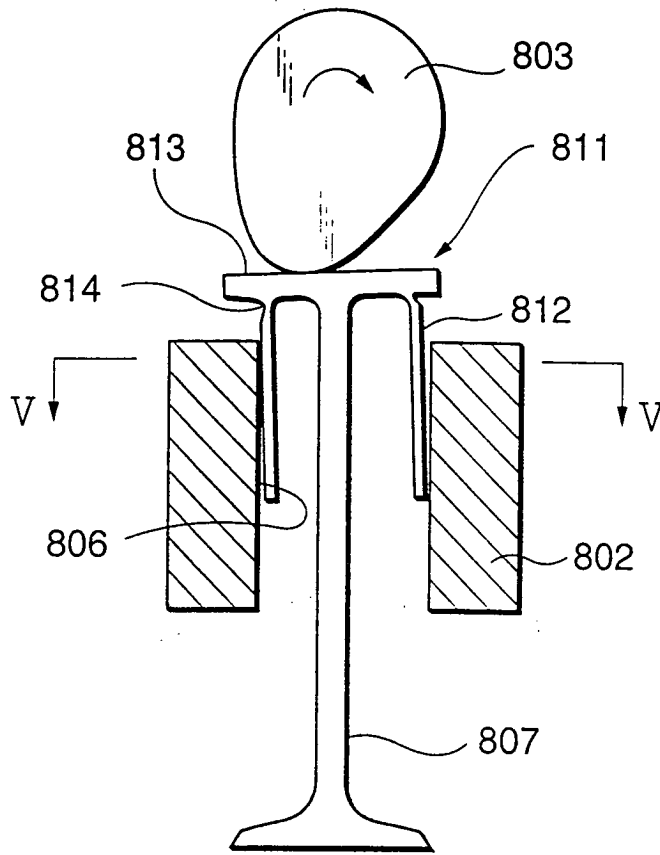


FIG.24

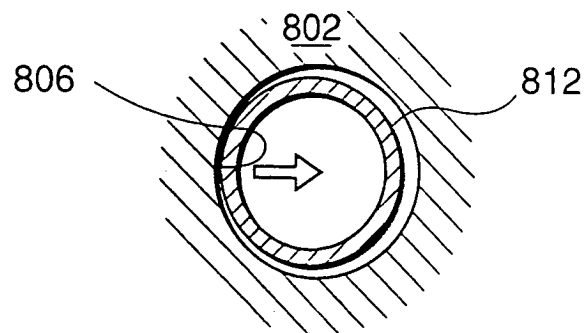


FIG.25

Prior art

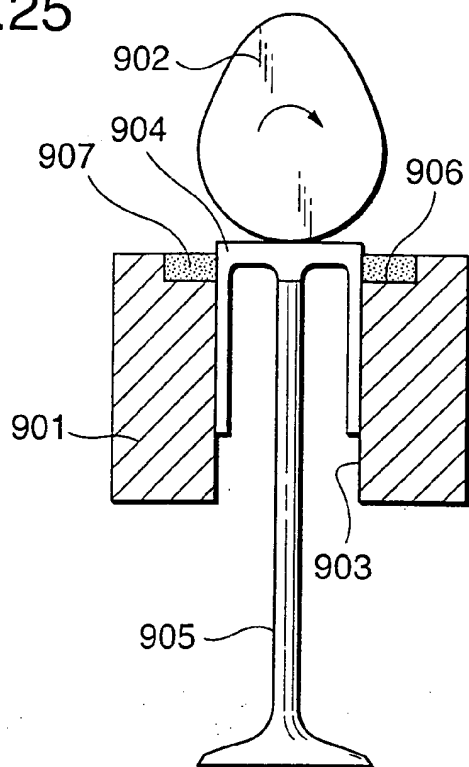


FIG.26

Prior art

