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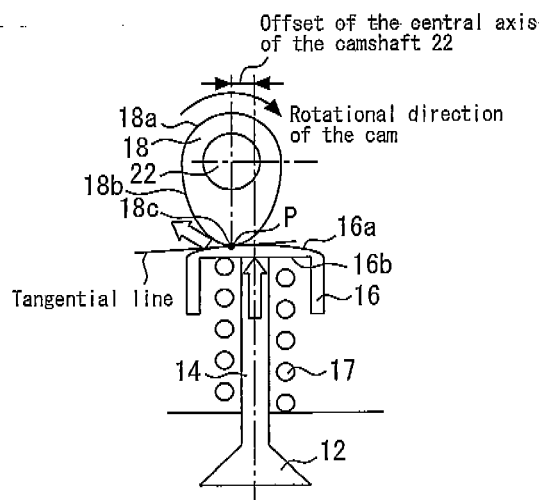
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(54) **VARIABLE VALVE GEAR**

(57) A motor 30 or the like is used to drive a camshaft 22 or the like having a cam 18 or the like to push a valve 12 biased in the closing direction of the valve by a valve spring 17. Between the cam 18 or the like and the valve 12 is present a valve lifter 16 that abuts the cam 18 or

the like. The valve lifter 16 includes a top face 16a formed so that when viewed from the axial direction of the camshaft 22 or the like, a tangential direction to the nose tip 18c of the cam 18 or the like inclines with respect to the direction perpendicular to the axial line of a valve stem 14.

Fig. 5



Description

Technical Field

[0001] The present invention relates to a variable valve apparatus that drives a valve of an internal combustion engine.

Background Art

[0002] Referring to conventional techniques, Patent Document 1, for example, discloses an internal combustion engine that includes a valve-driving system using a motor to drive the opening and closing of a valve. If an error in the synchronous control of camshaft and crankshaft speeds occurs in this conventional valve-driving system, evacuation driving becomes possible by stopping the opening/closing of the valve by use of a lost-motion mechanism or by switching to a low-lift cam for driving the valve at a smaller amount of lift.

Including the above-mentioned document, the applicant is aware of the following documents as a related art of the present invention.

[0003]

[Patent Document 1] Japanese Laid-open Patent Application Publication No. 2005-54732

[Patent Document 2] Japanese Laid-open Utility Model Application Publication No. Hei 6-87605

[Patent Document 3] Japanese Laid-open Patent Application Publication No. 2004-225562

[Patent Document 4] Japanese Laid-open Patent Application Publication No. 2004-225610

[Patent Document 5] Japanese Patent No. 3359524

Disclosure of Invention

Problem to be Solved by the Invention

[0004] The type of variable valve apparatus that uses a cam to drive a valve via a valve lifter is known as one form of apparatus that conducts motor driving of a camshaft, as with the conventional valve-driving system discussed above. In such a type of variable valve apparatus, if the variable valve apparatus becomes abnormal and motor driving is stopped with the cam having its nose tip abutted upon the valve lifter, this stoppage could leave the valve open with the amount of valve lift maximized. If this situation happens, interference is likely to occur between the valve remaining stopped in the maximum lift state, and the piston continuing a reciprocating motion.

[0005] In the type of variable valve apparatus that uses a motor to rotationally drive a camshaft, if the evacuation control mechanism as used in the above conventional valve-driving system, that is, the mechanism for stopping the opening/closing of the valve or for switching to the low-lift cam, is equipped only to avoid the above interference, this will complicate the system configuration use-

lessly. In addition, In the type that employs the above evacuation control mechanism, after the error in the synchronous control of the camshaft and crankshaft speeds, the valve-piston interference could occur during the period of switching to the evacuation control.

[0006] The present invention was made for solving the foregoing problems, and an object of the invention is to provide a variable valve apparatus that uses a motor to rotationally drive a camshaft including a cam to push a valve biased to close by a valve spring, the apparatus being adapted for valve-piston interference in case of an abnormality to be reliably resolved using a simple configuration.

Means for solving the problem

[0007] A first aspect of the present invention for achieving the above first object is a variable valve apparatus that uses a motor to drive a camshaft including a cam for pushing a valve biased in the closing direction thereof by a valve spring, the variable valve apparatus, further comprising:

a valve lifter which abuts the cam between the cam and the valve;

wherein the valve lifter includes a top face formed such that when viewed from an axial direction of the camshaft, the direction of a tangential line to a nose tip of the cam inclines with respect to the direction perpendicular to the axial line of a valve stem.

[0008] A second aspect of the present invention is the variable valve apparatus according to the first aspect of the present invention,

wherein the inclining direction of the tangential line is a direction in which the distance between the tangential line and a bottom face of the valve lifter decreases as the inclination goes in the traveling direction of a contact point between the cam during forward rotation thereof and the valve lifter.

[0009] A third aspect of the present invention is the variable valve apparatus according to the first or second aspect of the present invention, wherein the top face, when viewed from the axial direction of the camshaft, is formed into a convexly curved shape to be convex toward the cam.

[0010] A fourth aspect of the present invention is the variable valve apparatus according to the third aspect of the present invention,

wherein on the top face formed into the convexly curved shape to be convex toward the cam, an apical point whose height above the bottom face of the valve lifter is maximized, and the contact point between the nose tip and the valve lifter are spaced from each other when viewed from the axial direction of the camshaft.

[0011] A fifth aspect of the present invention is the variable valve apparatus according to the third or fourth aspect of the present invention,

wherein the top face having the convexly curved shape to be convex toward the cam is formed to have a maximum achievable height above the bottom face of the valve lifter, on a central axis of the valve lifter; and the camshaft is disposed such that a central axis thereof and the central axis of the valve lifter do not intersect with each other when viewed from the axial direction of the camshaft.

[0012] A sixth aspect of the present invention is the variable valve apparatus according to the third or fourth aspect of the present invention, wherein the camshaft is disposed such that a central axis thereof intersects with the central axis of the valve lifter when viewed from the axial direction of the camshaft; and the top face having the convexly curved shape to be convex toward the cam is formed such that when viewed from the axial direction of the camshaft, an apical point whose height above the bottom face of the valve lifter is maximized takes up an offset position relative to the axial line of the valve stem.

[0013] A seventh aspect of the present invention is the variable valve apparatus according to the first or second aspect of the present invention, wherein the top face, when viewed from the axial direction of the camshaft, is an inclined surface having a constant gradient.

[0014] An eighth aspect of the present invention is the variable valve apparatus according to any one of the first to seventh aspect of the present invention, further comprising:

electric power supply control means for stopping supply of electric power to the motor when a command value assigned to the motor to drive the camshaft reaches a predetermined value.

[0015] A ninth aspect of the present invention is the variable valve apparatus according to any one of the first to eighth aspect of the present invention, further comprising:

a torque reduction mechanism that generates a reduced torque for reduction in a driving torque of the camshaft;

wherein the torque reduction mechanism is constructed such that the reduced torque is small in comparison with a camshaft torque based upon a biasing force of the valve spring.

Advantages of the Invention

[0016] According to the first aspect of the present invention, even if the driving of the camshaft by the motor is stopped with the cam nose tip abutting upon the top face of the valve lifter, the biasing force of the valve spring acts to rotate the cam as well as to push the cam upward. The invention, therefore, allows the valve to be properly

prevented from remaining open in case of the abnormality, thus valve-piston interference to be avoided reliably.

[0017] According to the second aspect of the present invention, even if the driving of the camshaft by the motor is stopped with the cam nose tip abutting upon the top face of the valve lifter, the cam is returned in its forward rotational direction. After the occurrence of the abnormality, therefore, the invention allows easy cam-piston synchronization during a restart, and hence, reduction of likelihood of valve-piston interference. A reduction in the amount of electric power required immediately after the restart is additionally anticipated.

[0018] According to the third to seventh aspects of the present invention, even if the driving of the camshaft by the motor is stopped with the cam nose tip abutting upon the top face of the valve lifter, the biasing force of the valve spring acts to rotate the cam as well as to push the cam upward. The invention, therefore, allows the valve to be properly prevented from remaining open in case of the abnormality, thus valve-piston interference to be avoided reliably.

[0019] According to the eighth aspect of the present invention, even if an abnormality that leaves a driving force of the camshaft with respect to the motor occurs in the variable valve apparatus, the biasing force of the valve spring is permitted to be converted into a torque that rotates the cam. Accordingly, valve-piston interference can be avoided reliably.

[0020] According to the ninth aspect of the present invention, a sufficient biasing force of the valve spring in the variable valve apparatus with the torque reduction mechanism for reducing the driving torque of the camshaft can be obtained as a torque that rotates the cam, and thus, valve-piston interference can be avoided reliably.

Brief Description of Drawings

[0021]

Fig. 1 is a perspective view showing the configuration of the variable valve apparatus according to the first embodiment of the present invention.

Fig. 2 is an axial view of the camshaft for a further detailed description of its configuration shown in Fig. 1.

Figs. 3(A) and 3(B) are schematic diagrams showing the way the valve lifter is driven by the cam.

Fig. 4 is a reference diagram for structural comparison of a variable valve apparatus A having a valve lifter of a general shape, with respect to the variable valve apparatus according to the first embodiment of the present invention.

Fig. 5 is an explanatory diagram of the characteristic configuration according to the first embodiment of the present invention.

Fig. 6 is a diagram showing a first variant relating to a top-face shape of a valve lifter and an arrangement

relationship between the valve lifter and the camshaft.

Fig. 7 is a diagram showing a second variant relating to the top-face shape of a valve lifter.

Fig. 8 is a flowchart illustrating a routine that is executed in the second embodiment of the present invention.

Figs. 9(A) and 9(B) are diagrams illustrating a configuration of a torque reduction mechanism in a variable valve apparatus according to the third embodiment of the present invention.

Fig. 10 is a diagram that illustrates general settings of the reduced torque in a torque reduction mechanism having substantially the same configuration as that of the torque reduction mechanism shown in Fig. 9.

Fig. 11 is a diagram illustrating the settings of the reduced torque stemming from the torque reduction mechanism in the third embodiment of the present invention.

Best Mode for Carrying Out the Invention

First Embodiment

[Variable Valve Apparatus Configuration]

[0022] Hereinafter, a basic configuration of a variable valve system 10 according to a first embodiment of the present invention will be described referring to Figs. 1 to 3.

[0023] Fig. 1 is a perspective view showing the configuration of the variable valve apparatus 10 according to the first embodiment of the present invention. The variable valve apparatus 10 shown in Fig. 1 is an apparatus for driving a valve of an internal combustion engine. The system configuration here assumes that the internal combustion engine is constructed as a straight four-cylinder engine. Reference numbers #1 to #4 in Fig. 1 denote first to fourth cylinders, respectively, of the internal combustion engine. The system also assumes that as in a general internal combustion engine, the explosion stroke of the internal combustion engine is sequentially performed in cylinders #1, #3, #4, and #2 in the order named. In addition, the present embodiment assumes that the variable valve apparatus 10 functions as an apparatus to drive air intake valves of each cylinder, and the configuration of the variable valve apparatus 10 on the exhaust valve side is omitted in Fig. 1. The variable valve apparatus 10, however, may be constructed as an apparatus for driving the exhaust valves of each cylinder, in place of or in addition to the intake valves.

[0024] The configuration shown in Fig. 1 includes two valves 12 for each cylinder, the valves each functioning as an intake valve. Each valve 12 has a valve stem 14 fixed thereto. The valve stem 14 has a valve lifter 16 at its upper end. A biasing force of a valve spring 17 (see Fig. 5) is acting upon the valve stem 14, which is biased

to close by the biasing force. The variable valve apparatus 10 of the present embodiment is characterized by the shape of a top face 16a of the valve lifter 16 and by the arrangement relationship between the valve lifter 16 and cams 18 and 20 described later herein. These sections characterizing the apparatus will be described later with reference to Fig. 5.

[0025] Each valve lifter 16 has a corresponding cam 18 or 20 at its upper section. As shown in Fig. 1, the cams corresponding to the valve lifters 16 disposed above the #1 and #4 cylinders, and the cams corresponding to the valve lifters 16 disposed above the #2 and #3 cylinders are termed the cams 18 and 20, respectively, for distinction in the present embodiment. The cams 18 corresponding to the #1 and #4 cylinders are each fixed to a camshaft 22. The cams 20 corresponding to the #2 and #3 cylinders are each fixed to a camshaft 24 rotatable with respect to the camshaft 22 and disposed coaxially therewith. That is to say, the configuration shown in Fig. 1 shares the camshafts for each cylinder that is 360° CA different in explosion timing. The two camshafts, namely, the camshaft 22 corresponding to the #1 and #4 cylinders, and the camshaft 24 corresponding to the #2 and #3 cylinders are both constructed to be able to rotate or swing in a circumferential direction independently of each other. The camshafts 22 and 24 are rotatably supported by a support member such as a cylinder head not shown.

[0026] A first driven gear 26 is coaxially fixed to the camshaft 22. The first driven gear 26 has a first output gear 28 meshed therewith. The first output gear 28 is fixed to an output shaft of a first motor 30. The first motor 30 is a servomotor controllable in rotational speed and in the amount of rotation. For example, a brushless motor or the like is preferably used as the first motor 30. The first motor 30 contains a rotational angle detection sensor such as a resolver or rotary encoder to detect the rotational position (rotational angle) of the motor. This configuration allows a torque of the first motor 30 to be transmitted to the camshaft 22 via the gears 26 and 28.

[0027] A second driven gear 32 is coaxially fixed to the camshaft 24. The second driven gear 32 has a second output gear 36 meshed therewith via an intermediate gear 34. The second output gear 36 is fixed to an output shaft of a second motor 38. A detailed configuration of the second motor 38 is substantially the same as that of the first motor 30. This configuration allows a torque of the second motor 38 to be transmitted to the camshaft 24 via the gears 32, 34, and 36.

[0028] The system shown in Fig. 1 includes an electronic control unit (ECU) 40. Sensors not shown, such as a crank angle sensor and a cam angle sensor, and actuators such as the first motor 30 and the second motor 38 are connected to the ECU 40. The ECU 40 can use outputs of these sensors to control the rotational speeds of the first motor 30 and the second motor 38, and the respective amounts of rotation. More specifically, the ECU 40 can rotate the camshaft 22 or the like by assigning a driving command to the motor 30 or the like for

continuous unidirectional driving of the camshaft 22. The ECU 40 can also swing the camshaft 22 or the like by assigning another driving command to the motor 30 or the like for reversal of the rotational direction thereof during an opening period of the valve 12.

[0029] Fig. 2 is an axial view of the camshaft 22 for a further detailed description of its configuration shown in Fig. 1. As described above, the cams 18 (#1) and the cams 18 (#4) are fixed to the camshaft 22. As shown in Fig. 2, each cam 18 (#1) for the #1 cylinder has two cam faces, 18a and 18b, that differ in profile. The circular base 18a, one of the two cam faces, is formed to be constantly distanced from a center of the camshaft 22. The nose 18b, the other cam face, is formed so that the distance from the center of the camshaft 22 increases progressively and so that once a top portion 18c (nose tip 18c) has been overstepped, the distance diminishes progressively. Each cam 18 (#4) for the #4 cylinder also has substantially the same circular base 18a and nose 18b as those of the cam 18 (#1). The top portion 18c of the cam 18 (#1) and the top portion 18c of the cam 18 (#4) are arranged to have an offset of 180° from each other in the circumferential direction of the camshaft 22. Although detailed description is omitted herein, the present embodiment assumes that the cams 20 (#2) and cams 20 (#3) on the camshaft 24 corresponding to the #2 and #3 cylinders are each constructed similarly to those of the camshaft 22.

[0030] Figs. 3(A) and 3(B) are schematic diagrams showing the way the valve lifter 16 is driven by the cam 18. The description given below will use a configuration of the cam 18. The same also applies to a configuration of the cam 20. In addition, in this description, if there is no essential difference between the configuration of the cam 18 and that of the cam 20, only either one of the configurations will be described per Fig. 3 and subsequent drawings, and the other configuration may be omitted.

[0031] As shown in Fig. 3, the valve lifter 16 that abuts the cam 18 is disposed between the cam 18 and the valve 12 (see Fig. 1). The valve lifter 16 has a top face 16a that abuts the cam 18. When the circular base 18a of the cam 18 and the valve lifter 16 abut each other, the biasing force of the valve spring 17 brings the valve into firm contact with a valve seat (not shown), thus closing the valve.

[0032] When a rotary motion of the first motor 30 is transmitted to the camshaft 22 via the gears 26, 28, the cam 18 rotates integrally with the camshaft 22 and while the nose 18b gets over the valve lifter 16, the valve lifter 16 is pushed downward to lift (open) the valve 12 in defiance of the biasing force of the valve spring 17.

[0033] Figs. 3 (A) and 3 (B) show two driving modes of the cam 18. A forward driving mode that is one of the driving modes rotates the first motor 30 continuously in one direction so that as shown in Fig. 3(A), the cam 18 continuously rotates forward in excess of a maximum lifting position, that is, the position at which the nose tip

18c of the cam 18, the top 18c, abuts the valve lifter 16. A swinging mode that is the other driving mode reciprocates the cam 18 as shown in Fig. 3(B), by changing the rotational direction of the first motor 30 before the maximum lifting position in the forward driving mode is reached.

[0034] In the forward driving mode, the rotational speed of the cam 18 is controlled, whereby the operating angle of the valve is controlled. In the swinging mode, the operating angle and maximum lift amount of the valve 12 can be controlled by controlling the rotational speed of the cam 18 and the swinging angle range thereof.

[Feature sections of the present embodiment]

[0035] Next, feature sections of the present embodiment are described below referring to Figs. 4 and 5.

Fig. 4 is a reference diagram for structural comparison of a variable valve apparatus A having a valve lifter of a general shape, with respect to the variable valve apparatus 10 of the present embodiment, and shows the apparatus A existing when viewed from an axial direction of a camshaft. The variable valve apparatus A compared with the variable valve apparatus 10 of the present embodiment includes the valve lifter having a general top face formed to be planar for perpendicularity to an axial line of a valve stem as shown in Fig. 4.

[0036] Some abnormality associated with the variable valve apparatus A, such as a loss of rotational synchronization between its camshaft and crankshaft, may result in a stoppage of a motor. Under the stopped motor state, despite such factors resisting the rotation of the camshaft as friction between the cam and the valve lifter, friction between the motor and the camshaft, and inertia of the motor, the camshaft itself is basically in a rotatable state. If the variable valve apparatus A becomes abnormal, therefore, when a nose portion other than a tip of the nose is in contact with the valve lifter (e.g., when the state shown in Fig. 3(B) occurs), the cam is rotated by valve spring repulsion force and the valve is returned to its closed state.

[0037] However, in the case that the top face of the valve lifter is of such a planar shape as described above, the valve is likely to remain open with the maximum amount of lift if, as shown in Fig. 4, the driving of the camshaft by the motor is stopped with the cam nose tip abutting the top face of the valve lifter.

[0038] The above situation occurs because, in the configuration shown in Fig. 4, when the nose tip of the cam abuts the top face of the valve lifter, a tangential direction that connects the nose tip and the top face becomes perpendicular to the axial line of the valve stem, with the result that the valve spring repulsion force marked with an arrow in Fig. 4 acts only in the upward pushing direction of the camshaft and does not act in the rotational direction of the cam. In addition, the above situation structurally occurs not only in the case that top face of the valve lifter is planar. The same will also occur in the case

of the top face not being planar, provided that the tangential direction with the nose tip of the cam and the top face of the valve lifter abutting each other becomes perpendicular to the axial line of the valve stem.

[0039] The occurrence of the above situation could cause interference between the valve that will remain open and a piston that will continue reciprocating. In the present embodiment, therefore, the configuration shown in Fig. 5 is used to prevent the valve from stopping in its maximum lifting state.

[0040] Fig. 5 is an explanatory diagram of the characteristic configuration of the present embodiment and shows the apparatus existing when viewed from an axial direction of the camshaft 22. As shown in Fig. 5, in order that when viewed from the axial direction of the camshaft 22 in the present embodiment, a tangential direction connecting the nose tip 18c of the cam 18 and the top face 16a of the valve lifter 16 inclines with respect to the direction perpendicular to the axial line of the valve stem 14, the shape of the top face 16a of the valve lifter 16 is determined and the arrangement relationship between the valve lifter 16 and the camshaft 22 is adjusted.

[0041] Additionally, in order that the inclining direction of the tangent line matches a direction in which the distance between the tangent line and a bottom face 16b of the valve lifter 16 decreases as the tangent line extends in the traveling direction of the contact point between the forward rotating cam 18 and the valve lifter 16 (i.e., a leftward direction in Fig. 5), the shape of the top face 16a of the valve lifter 16 is determined and the arrangement relationship between the valve lifter 16 and the camshaft 22 is adjusted.

[0042] In the present embodiment, the top face 16a of the valve lifter 16, when viewed from the axial direction of the camshaft 22 as shown in Fig. 5, is formed into a convexedly curved shape to be convex with respect to the cam 18, and more specifically, into a cylindrical shape, as a more specific example showing the above-described shape of the top face 16a and the above arrangement relationship. In addition, the camshaft 22 is disposed with its central axis offset with respect to that of the valve lifter 16 so that an apical point on the top face 16a, that is, the highest point above the bottom 16b, and the contact point P between the nose tip 18c and the top face 16a become spaced from each other when viewed from the axial direction of the camshaft 22. Furthermore, in the present embodiment, the top face 16a that has been formed into the convexedly curved shape is formed for the valve lifter 16 to have a maximum achievable height on its central axis, and the camshaft 22 is disposed for the central axis thereof to be distant from that of the valve lifter 16 when viewed from the axial direction of the camshaft 22.

[0043] Furthermore, in the configuration of Fig. 5, the disposition of the camshaft 22 with respect to the valve lifter 16 is adjusted so that the offset direction of the central axis of the camshaft 22 with respect to that of the valve lifter 16 matches the traveling direction of the con-

tact point P between the forward rotating cam 18 and the valve lifter 16.

[0044] Furthermore, the present embodiment has a swirl-stopping mechanism to prevent the valve lifter 16 from rotating with respect to the cam 18 so that during actual operation of the variable valve apparatus, the above tangential direction is always maintained in the foregoing direction. Such a swirl-stopping mechanism, although details are omitted in Fig. 5, can be realized in, for example, the configuration described below. That is to say, a pin that faces perpendicularly to an axial line of the valve stem is made to penetrate the valve lifter. In addition, a guide groove for the pin to extend in the axial-line direction of the valve stem is formed in a cylinder head that is a peripheral member of the valve lifter, and the pin is engaged with the guide groove.

[0045] As described above, in the configuration of Fig. 5, in order that when viewed from the axial direction of the camshaft 22, the tangential direction connecting the nose tip 18c of the cam 18 and the top face 16a of the valve lifter 16 inclines with respect to the direction perpendicular to the axial line of the valve stem 14, the shape of the top face 16a of the valve lifter 16 is determined and the arrangement relationship between the valve lifter 16 and the camshaft 22 is adjusted. According to this configuration, even if the nose tip 18c of the cam 18 abuts the top face 16a of the valve lifter 16 during the stopped state of the motor, the repulsion force of the valve spring acts to rotate the cam 18 as well as to push the cam 18 upward.

[0046] This means that according to the above configuration, not only a component of the axial-line direction of the valve stem 14 but also a decomposition component (marked with an arrow in Fig. 5) that is inclined to the axial-line direction of the valve stem 14 exists in the valve spring repulsion force acting upon the cam 18. As a result, the cam 18 rotates to actuate the valve in the closing direction thereof.

[0047] By virtue of this, according to the configuration of the present embodiment, interference between the valve 12 and the piston during the occurrence of an abnormality can be avoided reliably in a mechanical manner using a simple configuration, without relying upon such evacuation control mechanism as provided in the conventional technology. If an error in the synchronous control of the camshaft and crankshaft speeds is detected, interference between the valve and the piston can also be avoided during the period of switching to such evacuation control.

[0048] Furthermore, in the foregoing configuration that Fig. 5 shows, in order that the inclining direction of the tangent line matches the direction in which the distance between the tangent line and the bottom face 16b of the valve lifter 16 decreases as the tangent line extends in the traveling direction of the contact point between the forward rotating cam 18 and the valve lifter 16 (i.e., the leftward direction in Fig. 5), the shape of the top face 16a of the valve lifter 16 is determined and the arrangement

relationship between the valve lifter 16 and the camshaft 22 is adjusted. More specifically, such a configuration is realized by adjusting the disposition of the camshaft 22 with respect to the valve lifter 16 so that the offset direction of the central axis of the camshaft 22 with respect to that of the valve lifter 16 matches the traveling direction of the contact point P between the forward rotating cam 18 and the valve lifter 16.

[0049] According to such a configuration, if the motor is stopped with the nose tip 18c of the cam 18 abutting upon the top face 16a of the valve lifter 16, the cam 18 is made to escape in the forward rotational direction. As a result, the final stopping position of the cam 18 after the escape operation thereof has been conducted becomes the position that the normal valve 12 occupies immediately after the lifting operation thereof has ended. If this consideration is given to the escape direction of the cam 18, the excellent effects described below can be yielded.

[0050] That is to say, in the configuration with the two motors, 30 and 38, that share the driving of all cylinders' air intake valves, as in the present embodiment, when the cam 18 is rotated during the restart following the occurrence of an abnormality, a cam angle margin of about 60° will be created until the lifting of the valve is started next time. If a phase of the cam angle is discriminated in the section of about 60°, synchronization with a piston phase can be implemented and the likelihood of valve-piston interference can be reduced. In addition, since kinetic energy can be given to the cam 18 by raising the rotational speed thereof to a sufficiently high level in the section of about 60°, a reduction in the amount of electric power required immediately after the restart is anticipated.

[0051] Meanwhile, in the above-described first embodiment, the top face 16a of the valve lifter 16, when viewed from the axial direction of the camshaft 22, is formed into a convexedly curved shape to be convex with respect to the cam 18, and more specifically, into a cylindrical shape. Additionally, the top face 16a formed into the convexedly curved shape is formed for the valve lifter 16 to have the maximum achievable height on its central axis, and the camshaft 22 is disposed for the central axis thereof to be distant from that of the valve lifter 16 when viewed from the axial direction of the camshaft 22. However, if the top-face shape of the valve lifter in the present invention and the arrangement relationship between the valve lifter and the camshaft incorporate the consideration needed to ensure that when viewed from the axial direction of the camshaft, the tangential direction connecting the nose tip of the cam and the top face of the valve lifter inclines with respect to the direction perpendicular to the axial line of the valve stem, application of the invention is not limited to the above configuration shown in Fig. 5, and the invention can be applied to, for example, such configurations as shown in Fig. 6 or 7.

[0052] Fig. 6 is a diagram showing a first variant relating to a top-face shape of a valve lifter and an arrange-

ment relationship between the valve lifter and the camshaft. In the configuration that Fig. 6 shows, the camshaft 22 is disposed so that when an axial line of the valve stem 14 (i.e., a central axis of the valve lifter 42) is viewed from the axial direction of the camshaft 22, the central axis thereof is positioned on an extension line of the axial line of the valve stem 14. In addition, the top face 42a of the valve lifter 42, when viewed from the axial direction of the camshaft 22, is formed into a convexedly curved shape to be convex with respect to the cam 18, and more specifically, into a cylindrical shape.

[0053] However, unlike the above-described configuration shown in Fig. 5, the top face 42a formed into the convexedly curved shape is formed so that when viewed from the axial direction of the camshaft 22, an apical point on the top face 42a, that is, the highest point from a bottom face 42b, takes up an offset position with respect to the axial line of the valve stem 14 (i.e., the central axis of the valve lifter 42).

[0054] Furthermore, in the configuration of Fig. 6, the shape of the top face 42a is determined so that the offset direction of the apex of the top face 42a with respect to the central axis of the valve lifter 42 becomes the opposite of the traveling direction of a contact point Q between the forward rotating cam 18 and the valve lifter 16, that is, becomes a rightward direction in Fig. 6. In such an offset direction, the cam 18 is made to escape in its forward rotational direction, if the motor is stopped with the nose tip 18c of the cam 18 abutting upon the top face 42a of the valve lifter 42.

The valve lifter 42 can have substantially the same swirl-stopping mechanism as used in the configuration of the first embodiment.

[0055] Fig. 7 is a diagram showing a second variant relating to the top-face shape of a valve lifter. In the configuration that Fig. 7 shows, the top face 44a of the valve lifter 44, when viewed from the axial direction of the camshaft 22, is formed to be an inclined surface having a constant gradient. In addition, the top face 44a is inclined to a direction in which the distance to a bottom face 44b of the valve lifter 44 diminishes as the inclination of the top face 44a goes in the traveling direction of a contact point R between the forward rotating cam 18 and the valve lifter 44. In such an inclined direction, the cam 18 is made to escape in its forward rotational direction, if the motor is stopped with the nose tip 18c of the cam 18 abutting upon the top face 44a of the valve lifter 44.

The valve lifter 44 can have substantially the same stopping-stopping mechanism as used in the configuration of the first embodiment.

Second Embodiment

[0056] Next, a second embodiment of the present invention is described below referring to Fig. 8.

An apparatus according to the present embodiment can be implemented by using the hardware configurations shown in Figs. 1 to 3 and 5, and making the ECU 40

execute the routine shown in Fig. 8 described later herein.

[Feature sections of the second embodiment]

[0057] If an abnormality that has been caused to the variable valve apparatus 10 is of a mode that completely powers off the motor, adoption of the above-described configuration shown in Fig. 5 allows interference between the valve 12 and the piston to be avoided reliably, since the cam 18 or the like is rotated by valve spring repulsion. The mode of the abnormality, however, could be such that instead of the motor being completely powered off, the force for driving the cam 18 remains in the motor. If this state actually happens, the valve 12 will stop in a lifted condition since the driving torque of the camshaft 22 by the motor and the torque upon the camshaft 22, based upon the biasing force of the valve spring 17, will be balanced while the cam 18 is holding down the valve 12 from above.

[0058] Consequently, interference between the valve 12 and the piston is likely. In the present embodiment, therefore, in order to ensure reliable avoidance of valve-piston interference even in the event of the abnormality of the above mode, supply of electric power to the motor is stopped when the driving repulsion force for motor driving of the cam 18 reaches or exceeds a predetermined level, and more specifically, when a current command value (torque command value) assigned from the ECU 40 to the motor reaches a predetermined value.

[0059] Fig. 8 is a flowchart of the routine which the ECU 40 executes to implement the above function. In the routine of Fig. 8, whether the camshaft 22 is in a stopped state is first discriminated in accordance with an output of the cam angle sensor (step 100). As a result, if the camshaft 22 is judged to be in a stopped state, then the current command value that the ECU 40 assigns to the motor is acquired (step 102).

[0060] Next, whether the current command value that was acquired in above step 102 is in excess of the predetermined value is discriminated (step 104). If the camshaft 22 is in a stopped state and the electric power is supplied to the motor, the position of the cam 18 is maintained with the valve 12 remaining lifted by the cam 18. If the amount of lift at this time increases above a certain level, interference is likely to occur between the valve 12 and the piston that is continuing the reciprocating motion. The driving repulsion force due to the valve-spring repulsion force existing when the cam 18 presses the valve 12 increases with increases in the amount of lift of the valve 12, since the valve spring repulsion force increases. The current command value that has been assigned to the cam 18, therefore, increases with the increases in the amount of lift of the valve 12. The predetermined value in step 104 is set to be a value allows discrimination of whether the amount of lift of the valve 12 has increased to such a level that causes valve-piston interference.

[0061] If, in step 104, the current command value is judged to be in excess of the predetermined value, supply

of the electric power to the motor is stopped (step 106).

[0062] According to the above-described routine shown in Fig. 8, if, under the stopped state of the camshaft 22, the current command value assigned thereto is in excess of the predetermined value and the valve 12 is judged to be liable to interfere with the piston, supply of the electric power to the motor is stopped. In other words, the biasing force of the valve spring 17 is permitted to be converted into a torque that rotates the cam 18. The variable valve apparatus is also constructed so that the shape of the valve lifter 16 in the present embodiment and the arrangement relationship between the valve lifter 16 and the camshaft 22 are substantially the same as in Fig. 5. Provided that supply of the electric power to the motor is stopped, therefore, the valve 12 can be prevented from being maintained in a lifted state, irrespective of the position of the contact point existing between the nose 18b of the cam 18 and the top face 16a when the motor is stopped. In this way, the control function of the present embodiment allows interference between the valve 12 and the piston to be avoided reliably, regardless of the mode of the abnormality of the variable valve apparatus 10.

[0063] In the second embodiment, which has been described above, the "electric power supply control means" in the earlier description of the eighth aspect of the present invention herein will be realized when the routine process shown in Fig. 8 is executed by the ECU 40.

30 Third Embodiment

[0064] Next, a third embodiment of the present embodiment is described below with reference to Figs. 9 to 11.

Figs. 9(A) and 9(B) are diagrams illustrating a configuration of a torque reduction mechanism 52 in a variable valve apparatus 50 according to the third embodiment of the present invention. More specifically, Fig. 9(A) shows the variable valve apparatus 50 existing when viewed from the axial direction of the camshaft 22, and Fig. 9(B) shows the variable valve apparatus 50 existing when viewed from the direction of arrow A in Fig. 9(A). In Fig. 9, the same constituent elements as those shown in Fig. 1, are each assigned the same reference number, with their description omitted or simplified.

[0065] The variable valve apparatus 50 of the present embodiment is constructed similarly to the variable valve apparatus 10 of the first embodiment, except that the apparatus 50 includes the torque reduction mechanism 52 shown in Fig. 9. The torque reduction mechanism 52 is a reduced-torque generator for reducing the torque generated when the motor 30 or the like drives the camshaft 22 or the like. The torque reduction mechanism 52 includes an antiphase cam 54 and a biasing mechanism 58 that imparts a biasing force of a spring 56 to the antiphase cam 54. The torque reduction mechanism 52 is provided at ends of two camshafts 22 and 24 each in the variable valve apparatus 50. Since such configuration of

the torque reduction mechanism 52 is known, detailed description of the configuration is omitted herein.

[0066] Fig. 10 is a diagram that illustrates general settings of the reduced torque in a torque reduction mechanism having substantially the same configuration as that of the torque reduction mechanism 52 shown in Fig. 9. The waveform denoted by a solid line in Fig. 10 indicates how the driving torque of the camshaft changes while the camshaft rotates through one full turn in a configuration not using such a torque reduction mechanism. Except for factors such as cam - valve lifter friction, the torque upon the camshaft, based upon the biasing force of the valve spring, constitutes a principal part of the driving torque of the camshaft. For this reason, the driving torque of the camshaft increases gradually as the cam rotates and pushes the valve downward in defiance of the valve spring force, and exhibits a maximum value in immediate front of a maximum lifting position. The driving torque of the camshaft subsequently decreases and instantaneously becomes zero at the maximum lifting position. After the maximum lifting position has been overstepped, the valve spring repulsion force assists the cam rotation. This changes the camshaft torque into a minus value, and after a minus peak has been reached, the camshaft torque approaches zero with the valve being closed.

[0067] As represented using a waveform denoted by a broken line in Fig. 10, in order to reduce such driving torque of the camshaft as discussed above, the reduced torque stemming from the torque reduction mechanism is generally given as a torque oriented in a direction reverse to that of the camshaft torque based upon the biasing force of the valve spring. That is to say, these torques counteract each other as shown in Fig. 10. The profile of the antiphase cam 54 and the biasing force of the spring 56 are adjusted appropriately to achieve those settings of the reduced torque. When the reduced torque is applied, a final driving torque of the camshaft is, theoretically, cleared to zero (except for friction) with the cam present at any rotary position.

[0068] As a result, when the torque reduction mechanism is used at such general settings as described above, even if contact with the valve lifter is occurring at whatever position of the cam nose, that is, even except when the nose tip of the cam comes into contact with the valve lifter, the torque that rotates the cam in the closing direction of the valve is not exerted upon the camshaft. Therefore, the cam is likely to stop with the valve in a lifted state. This is liable to cause valve-piston interference.

[0069] Fig. 11 is a diagram illustrating the settings of the reduced torque stemming from the torque reduction mechanism 52 in the present embodiment. In the present embodiment, in order to solve the above problem, the reduced torque stemming from the torque reduction mechanism 52 is set to be as shown in Fig. 11. More specifically, as shown in Fig. 11, the reduced torque stemming from the torque reduction mechanism 52 is set to be smaller than the torque exerted upon the camshaft 22 on the basis of the biasing force of the valve spring

17. If the reduced torque is set to have such a value, the torque that is a resultant value of the camshaft torque and the reduced torque (i.e., the waveform denoted by a thick broken line in Fig. 11) acts in a counter direction with respect to the rotation of the cam 18. This means that sufficient biasing force of the valve spring 17 can be obtained as the torque that rotates the cam 18.

[0070] Additionally, the reduced torque that the torque reduction mechanism 52 assigns is determined so that the resulting differential torque is slightly greater than a sum of cam - valve lifter friction, meshing friction of gears arranged between the motor and the camshaft, motor inertia, and other factors resisting the rotation of the camshaft.

[0071] Even when the settings shown in Fig. 11 are adopted, sections with the above differential torque becoming zero near the maximum lifting position will exist. Accordingly, in the present embodiment, the variable valve apparatus is constructed so that as in the first embodiment, the shape of the top face 16a of the valve lifter 16 and the arrangement relationship between the valve lifter 16 and the camshaft 22 are as shown in Fig. 5. Even at the sections where the differential torque becomes zero, the valve spring repulsion force can be distributed into the torque that rotates the cam 18.

[0072] According to the above-described configuration of the present embodiment, even in the variable valve apparatus 50 having the torque reduction mechanism 52 intended to reduce the driving torque of the camshaft 22 or the like, interference between the valve 12 and the piston can be reliably avoided using a simple configuration, irrespective of the stopping position of the cam 18 or the like in case of an abnormality.

Claims

1. A variable valve apparatus that uses a motor to drive a camshaft including a cam for pushing a valve biased in the closing direction thereof by a valve spring, the variable valve apparatus, further comprising:

a valve lifter which abuts the cam between the cam and the valve;

wherein the valve lifter includes a top face formed such that when viewed from an axial direction of the camshaft, the direction of a tangential line to a nose tip of the cam inclines with respect to the direction perpendicular to the axial line of a valve stem.

2. The variable valve apparatus of an internal combustion engine according to claim 1, wherein the inclining direction of the tangential line is a direction in which the distance between the tangential line and a bottom face of the valve lifter decreases as the inclination goes in the traveling direction of a contact point between the cam during for-

ward rotation thereof and the valve lifter.

3. The variable valve apparatus according to claim 1 or 2,
wherein the top face, when viewed from the axial direction of the camshaft, is formed into a convexedly curved shape to be convex toward the cam. 5
4. The variable valve apparatus according to claim 3, wherein on the top face formed into the convexedly curved shape to be convex toward the cam, an apical point whose height above the bottom face of the valve lifter is maximized, and the contact point between the nose tip and the valve lifter are spaced from each other when viewed from the axial direction of the camshaft. 10 15
5. The variable valve apparatus according to claim 3 or 4,
wherein the top face having the convexedly curved shape to be convex toward the cam is formed to have a maximum achievable height above the bottom face of the valve lifter, on a central axis of the valve lifter; and
the camshaft is disposed such that a central axis thereof and the central axis of the valve lifter do not intersect with each other when viewed from the axial direction of the camshaft. 20 25
6. The variable valve apparatus according to claim 3 or 4, wherein the camshaft is disposed such that a central axis thereof intersects with the central axis of the valve lifter when viewed from the axial direction of the camshaft; and 30 35
the top face having the convexedly curved shape to be convex toward the cam is formed such that when viewed from the axial direction of the camshaft, an apical point whose height above the bottom face of the valve lifter is maximized takes up an offset position relative to the axial line of the valve stem. 40
7. The variable valve apparatus according to claim 1 or 2, wherein the top face, when viewed from the axial direction of the camshaft, is an inclined surface having a constant gradient. 45
8. The variable valve apparatus according to any one of claims 1 to 7, further comprising: 50

electric power supply control means for stopping supply of electric power to the motor when a command value assigned to the motor to drive the camshaft reaches a predetermined value. 55
9. The variable valve apparatus according to any one of claims 1 to 8, further comprising:

a torque reduction mechanism that generates a reduced torque for reduction in a driving torque of the camshaft;

wherein the torque reduction mechanism is constructed such that the reduced torque is small in comparison with a camshaft torque based upon a biasing force of the valve spring.

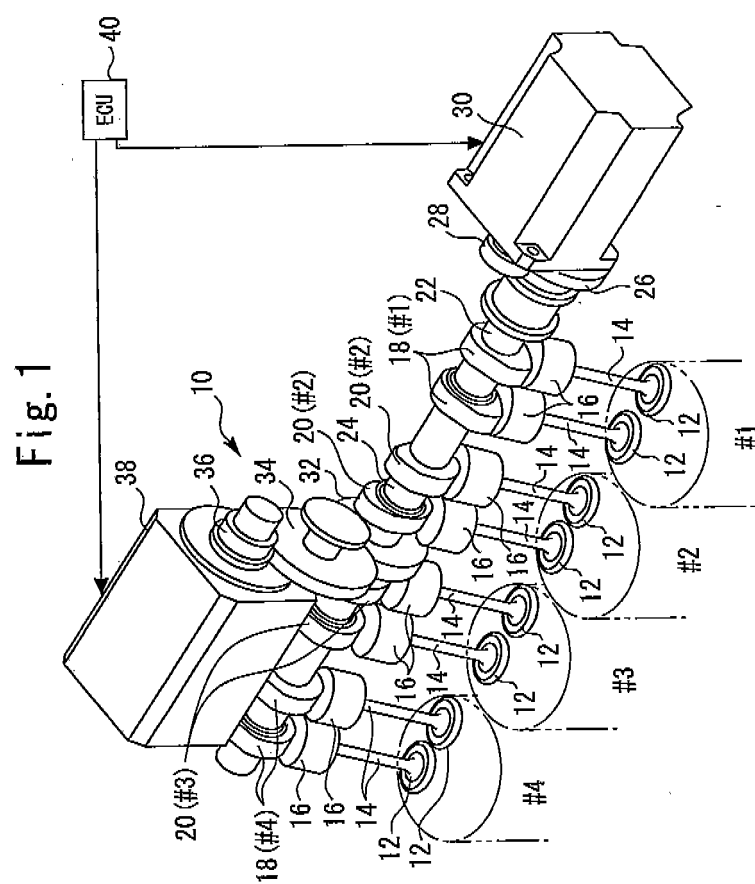


Fig. 2

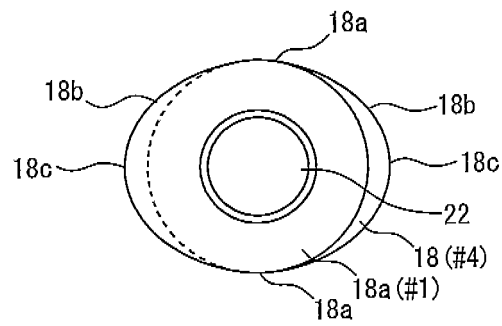


Fig. 3

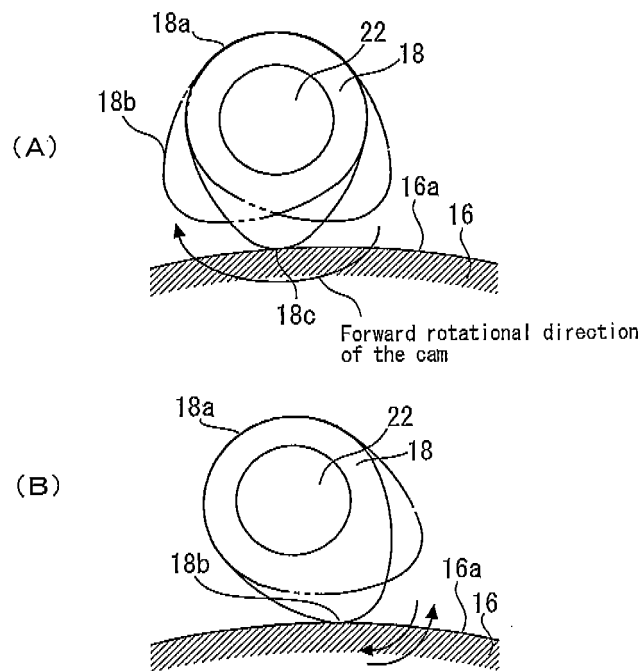


Fig. 4

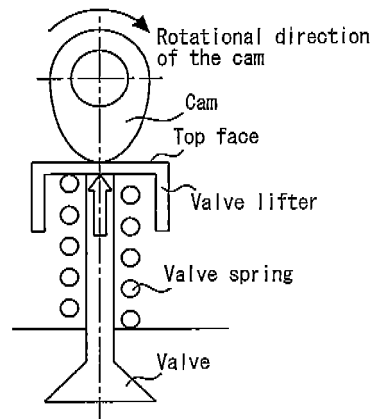


Fig. 5

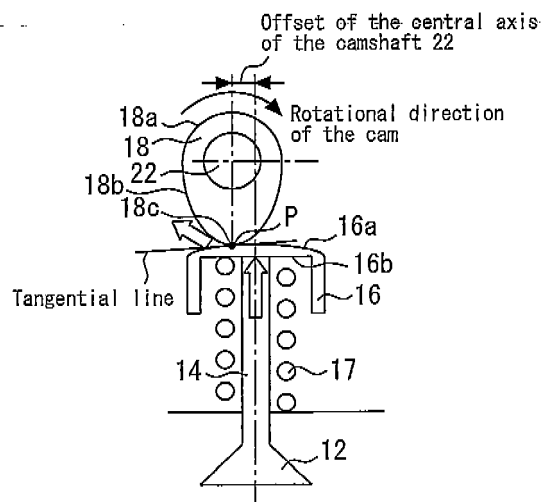


Fig. 6

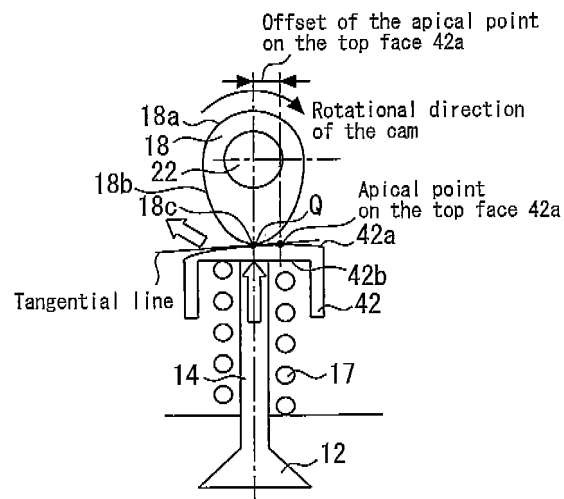


Fig. 7

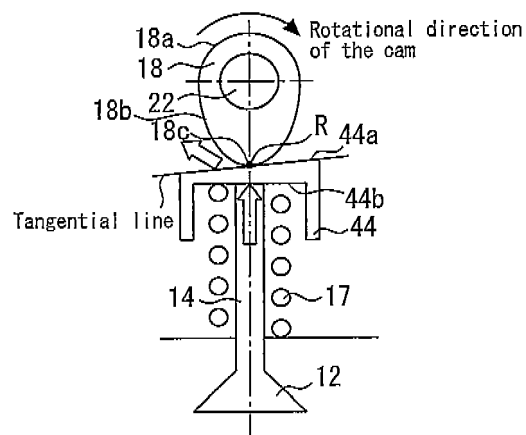


Fig. 8

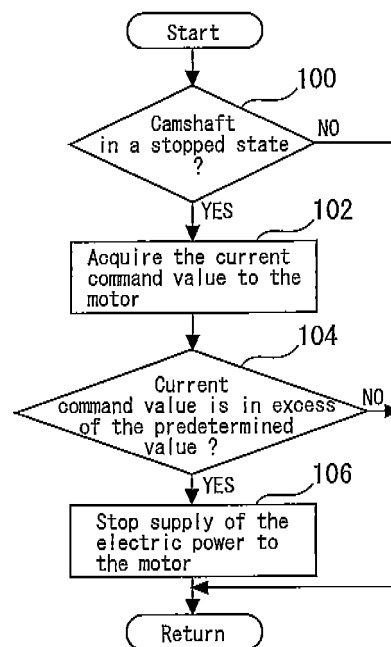


Fig. 9

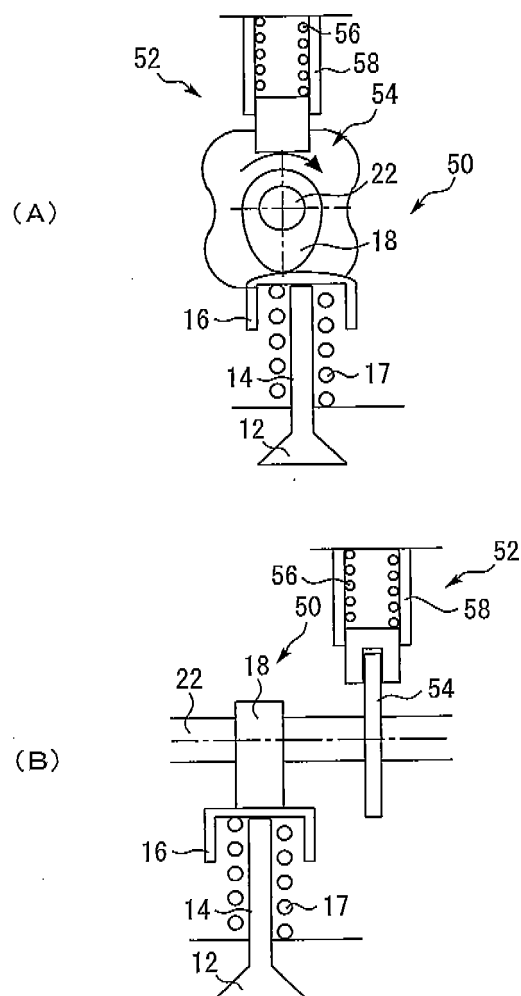


Fig. 10

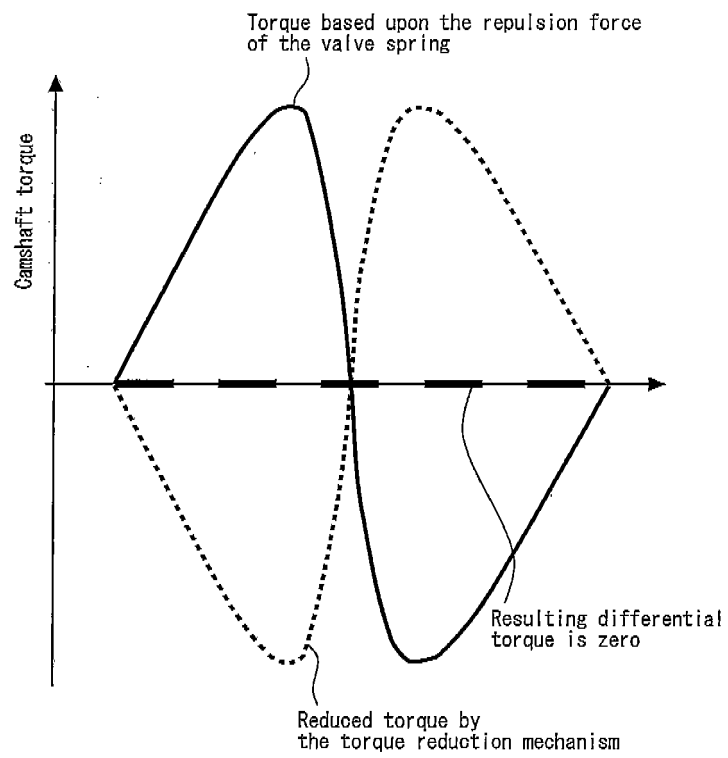
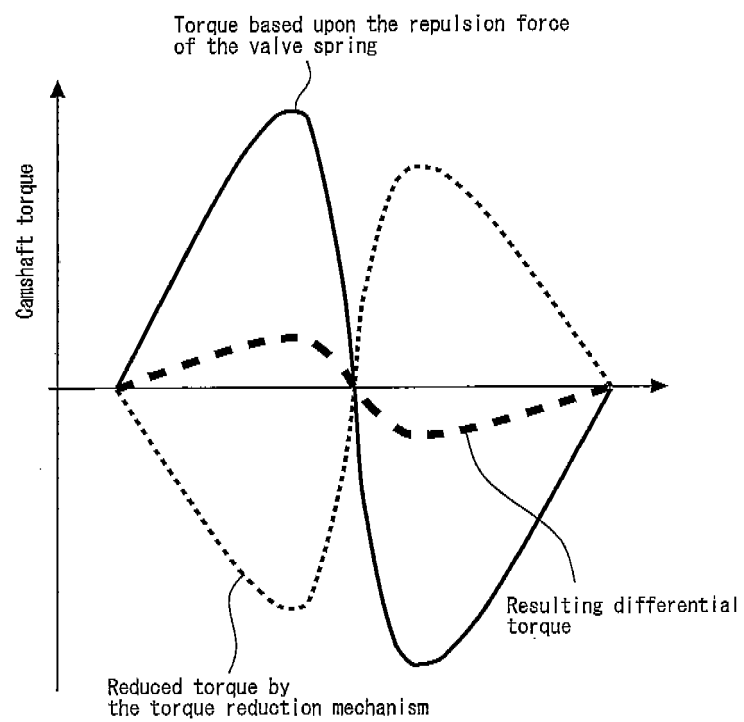


Fig. 11



ENCLOSURE C

ENGLISH TRANSLATION OF THE AMENDMENTS MADE
UNDER ARTICLE 34 AS ANNEXED TO THE
INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2007/071997

A. CLASSIFICATION OF SUBJECT MATTER

F01L13/00(2006.01)i, F01L1/14(2006.01)i, F01L1/16(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F01L13/00, F01L1/14, F01L1/16

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

Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2008

Kokai Jitsuyo Shinan Koho 1971-2008 Toroku Jitsuyo Shinan Koho 1994-2008

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 2005-54732 A (Toyota Motor Corp.), 03 March, 2005 (03.03.05), Par. Nos. [0012], [0043], [0044]; Figs. 1 to 2 & US 2005/0028768 A1 & DE 102004038130 A & FR 002858831 A	1, 7-9 2-6
Y A	JP 48-5325 B1 (Nissan Motor Co., Ltd.), 16 February, 1973 (16.02.73), Column 1, lines 19 to 23; Figs. 2 to 4 (Family: none)	1, 7-9 2-6
Y A	JP 6-17610 A (Toyota Motor Corp.), 25 January, 1994 (25.01.94), Par. Nos. [0006], [0011]; Fig. 2 (Family: none)	1, 7-9 2-6

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

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Date of the actual completion of the international search

14 February, 2008 (14.02.08)

Date of mailing of the international search report

26 February, 2008 (26.02.08)

Name and mailing address of the ISA/

Japanese Patent Office

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2007/071997

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	JP 2005-315185 A (Toyota Motor Corp.), 10 November, 2005 (10.11.05), Claim 1; Fig. 1 (Family: none)	9
Y	JP 2005-171937 A (Toyota Motor Corp.), 30 June, 2005 (30.06.05), Par. No. [0022] & US 2007/0068473 A1 & EP 001692373 A & WO 2005/057060 A2	9
A	JP 2004-225562 A (Nissan Motor Co., Ltd.), 12 August, 2004 (12.08.04), Par. No. [0007]; Fig. 1 (Family: none)	2-6
A	JP 2004-225610 A (Riken Corp.), 12 August, 2004 (12.08.04), Par. No. [0010]; Fig. 1 (Family: none)	2-6

Form PCT/ISA/210 (continuation of second sheet) (April 2007)

REFERENCES CITED IN THE DESCRIPTION

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- JP 2004225562 A [0003]
- JP 2004225610 A [0003]
- JP 3359524 B [0003]