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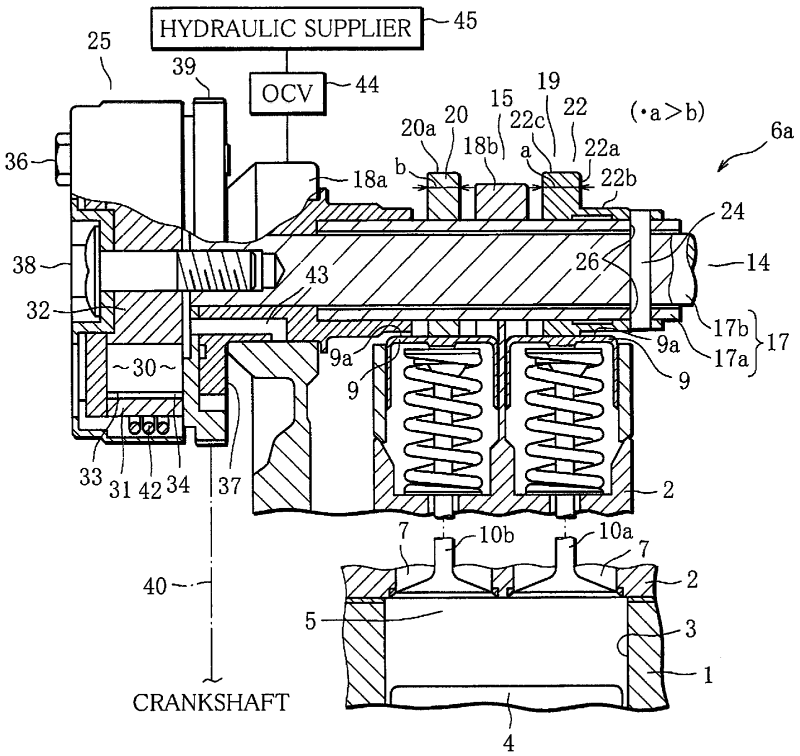
(54) **VARIABLE VALVE DEVICE OF AN INTERNAL COMBUSTION ENGINE**

(57) A variable valve device has a configuration in which a first cam (20) and a second cam (22a) that is a counterpart of the first cam are disposed in the outside of a shaft member (17) so that the second cam (22a) is displaceable in the circumferential direction, and is formed so that a cam face (22c) of the second cam has a cam width dimension a that is larger than a cam width b of a cam face of the first cam.

FIG. 2




EP 2 505 795 A1

# Description

## Technical Field

**[0001]** The invention relates to a variable valve device for an internal combustion engine, which changes the phase of either one of a pair of cams that activates a pair of intake or exhaust valves in relation to the other cam by means of a cam-phase changing mechanism.

## Background Art

**[0002]** In a reciprocal engine (internal combustion engine) installed in an automobile, a variable valve device is mounted on a cylinder head to take measure against engine exhaust emission and reduce pumping loss.

**[0003]** The variable valve device has a structure that varies valve phases in a multivalve (a pair of intake valves and a pair of exhaust valves) that is often employed in engines, to thereby change a period in which the multivalve is open. For example, a system has been proposed, which varies the phase of either one of a pair of cams that activates a pair of intake or exhaust valves in relation to the other cam.

**[0004]** The variable valve device mentioned above is difficult to be materialized with a common camshaft in which a cam forms an integral part of a shaft member. For that reason, the variable valve device utilizes a camshaft having an assembled cam structure, in which a separate cam member (part) is rotatably fastened to a shaft member, to vary valve phases. For example, as disclosed in Patent Documents 1 and 2, a first cam on a fixed side is fixed to the outside of the shaft member that is driven by crank output according to the layout of a pair of intake or exhaust valves, and a second cam that is a counterpart of the first, which has a cam width identical to the first cam and is located on a movable side, is fitted to be displaceable in a circumferential direction. This way, the phase of the second cam is changed on the basis of the phase of the first cam by using a cam-phase changing mechanism such as a movable vane mechanism.

**[0005]** Just like the other engines, the displacement of the first and second cams is transmitted to each valve via a driven member of a tappet member (or a rocker member or the like), changing to a great degree a period in which the pair of intake or exhaust valves is open.

## Prior Art Document

## Patent Document

**[0006]**

**Patent Document 1:** Unexamined Japanese Patent Document (Kokai) No. 2009-144521
**Patent Document 2:** Unexamined Japanese Patent Document (Kokai) No. 2009-144522

## Disclosure of the Invention

## Problem to be Solved by the Invention

**[0007]** In a common camshaft in which a cam forms an integral part of a shaft member, if there is a cam journal between a first cam and a second cam, and the first and second cams are almost the same in valve lift and timing, a valve lift load is applied uniformly over the width of the cam journal. This prevents an increase in misalignment. However, when the phases of the first and second cams are displaced in a variable valve device, misalignment takes place because the valve lift load is applied with time lags to the front and rear of the cam journal in the width direction of the cam journal. As a result, the cam faces of the first and second cams are reduced in contact area with respect to a cam-contact portion of a tappet and that of a rocker, and are applied with high load. The cam faces then become incapable of maintaining adequate lubrication, which triggers an increase in friction or local wear in contact portions.

**[0008]** Unlike the case in which the second cam forms an integral part of a common shaft member or unlike the first cam fixed to the shaft member, the second cam used in the variable valve device is pivotable in a circumferential direction of the shaft member. To this end, there is microscopic clearance between the second cam and the shaft member, which is necessary for the pivoting motion of the second cam. The clearance encourages the misalignment of the second cam and leads to an increase in further friction against the cam-contact portions of the tappet and the rocker, and local wear. The misalignment destabilizes the clearance and increases a bias load applied onto a sliding surface of the second cam and that of the shaft member. Due to the increase of friction, response is deteriorated, and wear appears in the site of friction.

**[0009]** The variable valve device has the problem that its variable performance is fluctuated when these events take place. A considerable way to solve this problem is to carry out the processing for correcting the misalignment, to improve assembly precision, to utilize materials with high abrasion resistance that can cope with misalignment or to apply surface treatment. However, they are all costly alternatives, and there has been a demand for some other technology.

**[0010]** It is an object of the invention to provide a variable valve device for an internal combustion engine, which is enhanced in resistance against misalignment of a movable cam to be varied in phase, with a simple structure.

## Means for Solving the Problem

**[0011]** In order to accomplish the above object, a variable valve device for an internal combustion engine claimed in claim 1, which varies valve phases of a pair of intake valves or valve phases of a pair of exhaust valves, which is provided to each cylinder, the device having a shaft member that is driven by crank output of an internal combustion engine; a first cam that is disposed in the outside of the shaft member and has a cam face that drives one of the pair of intake valves or one of the pair of exhaust valves; a second cam that is disposed in the outside of the shaft member to be displaceable in a circumferential direction and has a cam face that drives the other intake valve or the other exhaust valve; and a cam-phase changing mechanism that changes a phase of the second cam relative to the first cam, wherein the cam face of the second cam is formed to have a cam width dimension that is larger than a cam width of the cam face of the first cam.

**[0012]** The variable valve device for an internal combustion engine according to claim 1, as claimed in claim 2, the shaft member is configured by pivotably fitting an inner camshaft into an outer camshaft made up of a pipe member; the first cam is disposed in an outer periphery of the outer camshaft, and the second cam is disposed to be pivotable around an axis of the outer camshaft; and a phase of the second cam is variable on the basis of the first cam in response to a relative displacement of the outer camshaft and the inner camshaft.

**[0013]** The variable valve device for an internal combustion engine according to claim 1 or 2, as claimed in claim 3, the first cam is formed to have a cam width dimension that is larger than a cam width of a camshaft having a cam that forms an integral part of a shaft member applied in an internal combustion engine of the same model.

## Advantageous Effect of the Invention

**[0014]** According to the variable valve device for an internal combustion engine claimed in claim 1, contact area between the cam faces of the first and second cams and the cam-contact portions of the tappet and the rocker is maintained even in a misaligned state. This makes it possible to retain adequate lubrication, prevent an increase in friction and local wear in the contact portions, and reduce a maximum value of the bias load created by misalignment, which is applied onto the sliding surface of the second cam and that of the shaft member.

**[0015]** With a simple structure, therefore, it is possible to enhance the resistance against misalignment of the cam to be varied in phase.

**[0016]** According to the variable valve device for an internal combustion engine claimed in claim 2, the outer camshaft is made up of the pipe member having a low flexural rigidity. It is then possible to disperse the force applied from the second cam to the outer camshaft by using the second cam having a large cam width dimension.

**[0017]** According to the variable valve device for an internal combustion engine claimed in claim 3, the first and second cams have respective optimum cam widths, and can effectively respond to misalignment caused by split change. It is therefore possible to effectively prevent a deterioration in response and local wear resulting from friction increase.

## Brief Description of the Drawings

**[0018]**

FIG. 1 is a plan view showing an internal combustion engine equipped with a variable valve device according to a first embodiment of the invention;

FIG. 2 is a sectional view of the variable valve device, taken along line I- I of FIG. 1;

FIG. 3 is a sectional view of a camshaft in which a cam forms an integral part;

FIG. 4 is an exploded perspective view showing a configuration of each part of the variable valve device;

FIG. 5 is a line graph showing a variable property of the variable valve device;

FIG. 6 includes views for explaining a difference in a contact state between the cam and a tappet, which is caused by a change in cam width; and

FIG. 7 is a plan view showing a main part of a second embodiment of the invention.

## Mode of Carrying out the Invention

**[0019]** The present invention will be described below with reference to a first embodiment shown in FIGS. 1 to 6.

**[0020]** FIG. 1 is a plan view of a reciprocal engine (hereinafter, referred to as engine), for example, of a multi-cylinder type. FIG. 2 shows a cross-section taken along line I- I of FIG. 1. In FIG. 2, 1 represents a cylinder block of the engine, and 2 represents a cylinder head installed in a head of the cylinder block 1.

**[0021]** In the cylinder block 1, a plurality of cylinders 3 (only one of them is shown) are formed along an anteroposterior direction of the engine as shown in FIGS. 1 and 2. The cylinders 3 contain respective pistons 4, which are split from a crankshaft (not shown) via a con rod (not shown), so that the pistons 4 are capable of making reciprocating motion.

**[0022]** A combustion chamber 5 is formed under a lower face of the cylinder head 2 correspondingly to each of the cylinders 3. In the combustion chamber 5, a pair of intake ports 7 (two) that intakes air and a pair of exhaust ports (not shown) that exhausts air are open. Each of the intake ports 7 is provided with a pair of intake valves 10 (two) whose stem ends are each attached with a bottomed cylinder-shaped tappet 9 (driven member). A spherical crowning (cam-contact face) formed in a top face 9a of the tappet 9 faces an upper portion of the cylinder head 2. Likewise, each of the exhaust ports (not shown) is provided with a pair of exhaust valves (not shown) having tappets, and a valve base end faces the upper portion of the cylinder head 2. The intake ports 7 and the exhaust ports (not shown) are opened/closed by the intake valves 10 and the exhaust valves (not shown), respectively. Although not shown, an ignition plug is also provided to each of the combustion chambers 5.

**[0023]** An intake-side valve system 6a that is driven by shaft output of the crankshaft and an exhaust-side valve system 6b are disposed side by side on the upper portion of the cylinder head 2. A predetermined combustion cycle (including four processes, namely, intake process, compression process, expansion process and exhaust process) is repeated in the cylinders 3. The exhaust-side valve system 6b of the valve systems 6a and 6b has a configuration using, for example, a common camshaft 13 shown in FIG. 3. The camshaft 13 is a camshaft in which an exhaust cam forms an integral part, and more specifically, in which an exhaust cam 12 for a plurality of cylinders is formed integrally with a shaft 13a (shaft member) by machining. The camshaft 13 is rotatably installed to extend in a direction that the cylinders 3 are aligned and brings the cam faces of the exhaust cams 12 into contact with the crownings (not shown) of the tappets' top faces. In this way, the cam displacement of the exhaust cams 12 is transmitted to the exhaust valves (not shown).

**[0024]** The intake-side valve system 6a also uses a camshaft that is configured by assembling separate parts as shown in FIG. 4 unlike the exhaust-side camshaft 13, or a camshaft 14 having a so-called assembled cam structure. The camshaft 14 is used to configure a split-type variable valve device 15 as shown in FIG. 12.

**[0025]** In other words, the shaft member of the camshaft 14 is formed of a double shaft 17 (corresponding to the shaft member of the present invention) in which an inner camshaft 17b made of a solid shaft member serving as a control member is swingably contained in an outer camshaft 17a made of a pipe member, for example, as shown in FIGS. 2 and 4. The double shaft 17 is disposed along the direction in which the cylinders 3 are aligned in the same manner as with the exhaust-side camshaft 13. One of end portions (one side) of the double shaft 17, that is, one of end portions of the outer camshaft 17a is pivotably supported by a bearing 18a that is set in one of end portions (one side) of the cylinder head 2 through a bracket 37 that is attached to an end of the outer camshaft 17a. A middle portion of the outer camshaft 17a is rotatably supported by a middle bearing 18b that is set between the tappets 9. This way, the shafts 17a and 17b are concentrically rotatable. The outer camshaft 17a and the inner camshaft 17b are displaceable relative to each other due to clearance.

**[0026]** The outer camshaft 17a is provided with a pair (two) of intake cams 19 corresponding to the pair of intake valves 10 of each cylinder. Each of the intake cams 19 is configured by assembling a fixed cam 20 (corresponding to the first cam of the present invention) that determines a base phase and a cam lobe 22 (which is a movable cam and corresponds to the second cam of the present invention) located on a movable side.

**[0027]** To be specific, the fixed cam 20 on a base side is disposed in an outer periphery corresponding to one of the tappets of the outer camshaft 17a, for example, the tappet 9 on the left side in the drawing. The fixed cam 20 is formed of a plate cam, and is fixed by being fitted, and more specifically, press-fitted to the outer side of the outer camshaft 17a. A cam face 20a formed in an outer circumferential surface of the fixed cam 20 comes into contact with the top face 9a provided with the crowning of the left-side tappet 9. The cam displacement of the fixed cam 20 is thus transmitted to the left-side intake valve 10b.

**[0028]** The cam lobe 22 has a cam nose 22a formed of a plate cam. The cam nose 22a is interlocked with a portion for securing stability, that is, a hollow boss 22b. The entire cam lobe is thus configured. The cam nose 22a and the boss 22b are fitted to the outer side of the outer camshaft 17a to be pivotable (displaceable) in a circumferential direction. The cam nose 22a is disposed immediately above the right-side tappet 9. A cam face 22c formed in an outer circumferential surface of the cam nose 22a comes into contact with the top face 9a provided with the crowning of the right-side tappet 9. The cam displacement of the cam nose 22a is thus transmitted to the right-side intake valve 10a.

**[0029]** The boss 22b and the inner camshaft 17b are interlocked with each other by using a connecting member, that is, for example, a press-fit pin 24 press-fitted to run through the double shaft 17 in a diametrical direction while allowing the relative displacement of the inner and outer shafts 17a and 17b. This interlock enables the cam nose 22a (cam lobe 22) to displace relative to the fixed cam 20. More specifically, a hole that allows the press-fit pin 24 to escape, for example, a pair of long holes 26 extending in a retard direction is formed in a circumferential wall of the outer camshaft 17a, through which the press-fit pin 24 penetrates as shown in FIG. 4. The inner camshaft 17b is thus displaceable relative to the outer camshaft 17a. This enables the cam nose 22a to be variable from the phase of the fixed cam 20 serving as a base to a retard phase to a great degree. Reference numerals 14a and 14b in FIG. 4 represent a press-fit hole formed in the inner camshaft 17b and a press-fit hole formed in a circumferential wall of the boss 22b, respectively.

**[0030]** A cam-phase changing mechanism 25 that displaces the inner and outer shafts 17a and 17b relative to each other is mounted on one of the end portions of the double shaft 17. The variable valve device 15 is thus configured, in which the cam phase of the cam lobe 22 is changeable on the basis of the fixed cam 20.

**[0031]** For example, as shown in FIGS. 2 and 4, the cam-phase changing mechanism 25 has a pivot vane structure in which a vane portion 34 whose shaft portion 32 has a plurality of vanes 33 radially projecting from an outer periphery thereof is pivotably contained in a cylindrical housing 31 including a plurality of retard chambers 30 arranged in a circumferential direction, and the vanes

33 partition the inside of the retard chambers 30. A timing sprocket 39 is disposed in an outer periphery of the housing 31. The sprocket 39 is interlocked with a crankshaft (not shown) through a timing chain 40 together with a timing sprocket 13a mounted on the end of the exhaust-side camshaft 13. The housing 31 is interlocked with a bracket 37 (shown in FIG. 2) located at the end of the outer camshaft 17a by using a fixing bolt 36. The shaft portion 32 of the vane portion 34 is interlocked with a shaft end of the inner camshaft 17b by using a fixing bolt 38. When the vanes 33 make a pivoting displacement within the retard chamber 30, the inner camshaft 17b is displaced relative to the outer camshaft 17a.

**[0032]** The cam phase of the cam nose 22a is aligned with the cam phase of the fixed cam 20 serving as a base by a biasing force of a return spring member 42 (shown only in FIG. 2) that is set to bridge between the housing 31 and the vane portion 34. Each of the retard chambers 30 is connected to an oil control valve 44 (hereinafter, referred to as OCV 44) and a hydraulic supplier 45 (that is formed, for example, of a device having an oil pump for supplying oil) through various oil passages 43 (partially shown in FIG. 2) formed in the housing 31, the bracket 37 and the bearing 18a. In the intake-side camshaft 14, when oil is supplied into the retard chambers 30, split change is carried out, which displaces the cam nose 22a from the fixed cam 20 in the retard direction.

**[0033]** Split change will be described below. The shaft output from the crankshaft is transmitted through the timing chain 40, the timing sprocket 39, the housing 31 and the bracket 37 to the outer shaft 17a, to thereby rotate the fixed cam 20 and open/close the left-side intake valve 10b through the tappets 9. At this time point, if the hydraulic pressure is supplied from the OCV 44 to advance chambers (not shown) located on the opposite side to the retard chambers 30, the cam nose 22a is aligned with the cam phase of the fixed cam 20 as seen in a state shown by line A of FIG. 5 in consort with the biasing force of the return spring member 42. As a result, the right-side intake valve 10a is opened/closed while maintaining the same phase as the left-side fixed cam 20. When the hydraulic pressure of the hydraulic supplier 45 is supplied through the OCV 44 into the retard chambers 30, the vanes 33 are displaced from an initial position towards the retard side within the retard chambers 30 along with the output of the hydraulic pressure. At this time point, due to the control on the output of the hydraulic pressure, for example, after the vanes 33 are displaced halfway within the retard chambers 30, the inner camshaft 17b is displaced halfway in the retard direction. The displacement is transmitted through the press-fit pin 24 to the cam lobe 22 and displaces the cam nose 22a in the retard direction. By so doing, the opening/closing timing of the left-side intake valve 10b serving as a base is unchanged as seen in a state shown by line B of FIG. 5, and only the opening/closing timing of the right-side intake valve 10a is changed. In short, the right-side intake valve 10a is opened/closed according to a cam profile of the cam nose 22a in the middle of the opening/closing period of the left-side intake valve 10b. As a result of the control on the output of hydraulic pressure, if the vanes 33 are displaced to a most retarded position, the left-side intake valve 10b stays unchanged in opening/closing timing as seen in a state shown by line C of FIG. 5, whereas the right-side intake valve 10a is opened/closed with most retarded timing as compared to the left-side intake valve 10b while maintaining the opening/closing timing overlapped with that of the left-side intake valve 10b. The opening periods of the right- and left-side intake valves 10 are varied within a range from a shortest opening period $\alpha$ to a longest opening period $\beta$ according to the condition of the engine (split change).

**[0034]** The variable valve device 15 that displaces the phase of the cam lobe 22 relative to the fixed cam 20 has a unique problem because of the pivotability of the cam lobe 22.

**[0035]** Unlike the fixed cam 20, the cam lobe 22 combined with the double shaft 17 is required to be capable of making a pivoting motion in the outer circumferential surface of the outer camshaft 17a. To this end, there is microscopic clearance necessary for the pivoting motion of the cam lobe 22 between the cam lobe 22 and the outer camshaft 17a. The clearance is added with component tolerance of the cam lobe 22 and the outer camshaft 17a and erection tolerance at the time of combining the cam lobe 22 and the outer camshaft 17a. The cam nose 22a is therefore easy to displace in a wide range, and the cam face 22c is prone to be fluctuated (unstable). As shown in FIG. 6(a), the cam face 22c is likely to be misaligned relative to the cam axis center.

**[0036]** In the states shown by lines B and C of FIG. 5, misalignment occurs because a valve lift load is applied with time lag. In a common camshaft in which a cam forms an integral part of a shaft member, if there is a cam journal between a first cam located in a fixed cam position and a second cam located in a cam lobe position, the first and second cams are almost the same in valve lift and timing, the valve lift load is applied uniformly over the width of the cam journal. This prevents an increase in misalignment. In the variable valve device 15, however, when the fixed cam 20 as the first cam and the cam lobe 22 as the second cam are displaced in phase, a large misalignment takes place because the valve lift load is applied with time lags to the front and rear of the cam journal 18b in the width direction of the cam journal 18b.

**[0037]** If the misalignment of the cam face 22c takes place as shown in FIG. 6 (a), there might be contact between the top face 9a provided with the crowning that is the determined position of the cam-contact face of the tappet 9. Occasionally, valve lift is not carried out according to the cam that is designed. If this happens, the cam face 22c is reduced in contact area with respect to the cam-contact portion of the tappet 9 as shown in FIG. 6 (a) and is applied with high load. This makes it impossible to maintain adequate lubrication, which triggers an increase in friction and local wear in the contact portion.

**[0038]** Away from the idea that the fixed cam 20 and the corresponding cam nose 22a are identical in cam width, cam width dimension a of the cam face 22c of the cam nose 22a that varies phases is increased larger than cam width dimension b of the cam face 20a of the fixed cam 20 as shown in FIGS. 1, 2 and 4. The cam width dimensions are differentiated from each other in this manner. The cam face 22c of the cam nose 22a is formed to have a larger cam width than the cam face 20a of the fixed cam 20 (a>b).

**[0039]** This makes it possible, as shown in FIG. 6(b), to avoid contact between the top face 9a provided with the crowning of the cam-contact face of the tappet 9 and the cam-width end portion of the cam nose 22a even if misalignment takes place. The contact area with respect to the top face 9a (cam-contact portion) is maintained even in a misaligned state. Consequently, the load applied to the contact portions of the cam nose 22a and the top face 9a is dispersed, and the maximum load is also lowered. The same applies to the misalignment that occurs in response to split change, namely, the misalignment that takes place when the valve lift load is applied with time lags to the front and rear of the cam journal in the width direction of the cam journal.

**[0040]** If the cam width of the cam nose 22a is increased, an allowable range with respect to the misalignment in the cam face 22c of the cam nose 22a is increased. Furthermore, the cam nose 22a itself is increased in stability, which prevents an effect of the clearance and erection tolerance for the pivoting motion of the cam nose 22a.

**[0041]** With a simple structure, therefore, it is possible to enhance the resistance against misalignment of the cam to be varied in phase. For this reason, the camshaft 14 can be combined with the cylinder head 2 as with the conventional cam (FIG. 2), and thus eliminates the necessity of performing a time-consuming alignment work and improving precision in component machining at the prior stage (machining precision is not required). Furthermore, the maximum value of the bias load applied onto the sliding face of the cam nose 22a (second cam) and that of the outer camshaft 17a (shaft member), which is caused by misalignment, is reduced. It is therefore possible to prevent a deterioration in response and local wear resulting from friction increase. Since the inclination of the cam nose 22a is prevented by increasing the cam width dimension, the friction and local wear attributable to the instability of the cam nose 22a are prevented from taking place, and appropriate variable performance is secured. In addition, since the valve lift as designed can be obtained, there is no performance decrement and no degradation of NVH (Noise, Vibration and Harshness). As the outer camshaft 17a is made of the pipe member having a low flexural rigidity, if the cam nose 22a is increased in cam width, the force transmitted from the cam nose 22a to the outer camshaft 17a is dispersed, and appropriate variable performance can be retained.

**[0042]** As shown in FIG. 1, the cam width dimension b of the fixed cam 20 is larger than the cam width dimension of a camshaft having a cam that forms an integral part of a shaft member, which is used in an engine of the same model, that is, for example, the cam width dimension c of the cam face of the exhaust cam 12 of the camshaft 13 having the exhaust cam 12 that forms an integral part of the shaft 13a shown in FIG. 3 or the cam width dimension, not shown, of a cam face of an intake cam of an intake camshaft that forms an integral part of an intake cam used in a series of engines of the same model, which do not perform split change (a>c and b>c). If these cam width dimensions are set at the respective optimum values, even the fixed cam 20 configured by being combined with separate parts is not affected by erection tolerance, and it is possible to respond to the misalignment caused by split change.

**[0043]** Needless to say, the above advantages can be likewise obtained in the case where the crowning of the cam-contact face of the tappet 9 is provided to the cam face 22c side.

**[0044]** FIG. 7 shows a second embodiment of the invention.

**[0045]** The second embodiment is formed by applying the present invention to a variable valve device 50 that is added with a function of integrally varying the phase of the fixed cam 20 and that of the cam lobe 22, unlike the variable valve device 15 in which a phase-changing device 25 is attached to one of end portions of the double shaft 17 (shaft member), which includes the fixed cam 20 (first cam) and the cam lobe 22 (second cam) combined together as seen in the first embodiment.

**[0046]** In the variable valve device 50, the phase-changing mechanism 25 having the same structure as the first embodiment is connected to one of end portions of the double shaft 17 (shaft member) formed by combining the fixed cam 20 (first cam) and the cam lobe 22 (second cam), that is, for example, the end on the rear side of the engine, and a second phase-changing mechanism 51 having a pivot vane structure such as VVT (Variable Valve Timing) is connected to the end on the front side of the engine, whereby the phase of the fixed cam 20 and that of the cam lobe 22 are integrally varied on the basis of the integral pivot displacement of the outer camshaft 17 and the inner camshaft 17b, apart from the phase change by relative displacement of the outer camshaft 17a and the inner camshaft 17b.

**[0047]** If the present invention is applied to the variable valve device 50, the same advantage as in the first embodiment is provided. Referring to FIG. 7, constituents identical to those of the first embodiment are provided with the same reference marks, and descriptions thereof are omitted.

**[0048]** This is the end of the description of the variable valve device for an internal combustion engine according to the invention, but the invention is not limited to the above-described embodiments.

**[0049]** For example, the embodiments employ the structure in which cam displacement is transmitted to the tappets to drive the valves. Instead of this, however, the invention may be applied to a structure in which cam displacement is transmitted to another driven member, that is, for example, a rocker member, thereby driving the valves. In case of driving the valves by using the rocker member, it can be considered to employ a structure that includes a cam-contact face on the cam side of the rocker member and a bifurcated valve-driving section on the valve side of the rocker member, and drives a plurality of valves by means of a single cam. In this case, cam width dimension denotes a per-valve dimension that is obtained by dividing actual cam width by the number of driving valves (=actual cam shaft/the number of driving valves).

**[0050]** The invention may be applied to a variable valve device, not shown, which changes the phases of a pair of exhaust cams relative to each other, instead of being applied to the variable valve device that changes the phases of a pair of intake cams relative to each other as in the embodiments.

**[0051]** The engine to be applied may be one having a valve system in which the variable valve device is combined with the structure that drives valves by means of a camshaft whose cam is integrally formed.

## Reference Signs

**[0052]**

- 10 a pair of intake valves
- 12 exhaust cam
- 13 exhaust-side camshaft
- 14 intake-side camshaft
- 15 variable valve device
- 17 double shaft (shaft member)
- 17a outer camshaft
- 17b inner camshaft
- 19 intake cam
- 20 fixed cam (first cam)
- 20a cam face of a fixed cam
- 22a cam nose (second cam)
- 22c cam face of a cam nose
- 25 cam-phase changing mechanism
- a cam width of a cam nose
- b cam width of a fixed cam

## Claims

**1.** A variable valve device for an internal combustion engine, which varies valve phases of a pair of intake valves or valve phases of a pair of exhaust valves, which is provided to each cylinder, comprising:

a shaft member that is driven by crank output of an internal combustion engine;
a first cam that is disposed in the outside of the shaft member and has a cam face that drives one of the pair of intake valves or one of the pair of exhaust valves;
a second cam that is disposed in the outside of the shaft member to be displaceable in a circumferential direction and has a cam face that drives the other intake valve or the other exhaust valve; and
a cam-phase changing mechanism that changes a phase of the second cam relative to the first cam,
wherein the cam face of the second cam is formed to have a cam width dimension that is larger than a cam width of the cam face of the first cam.

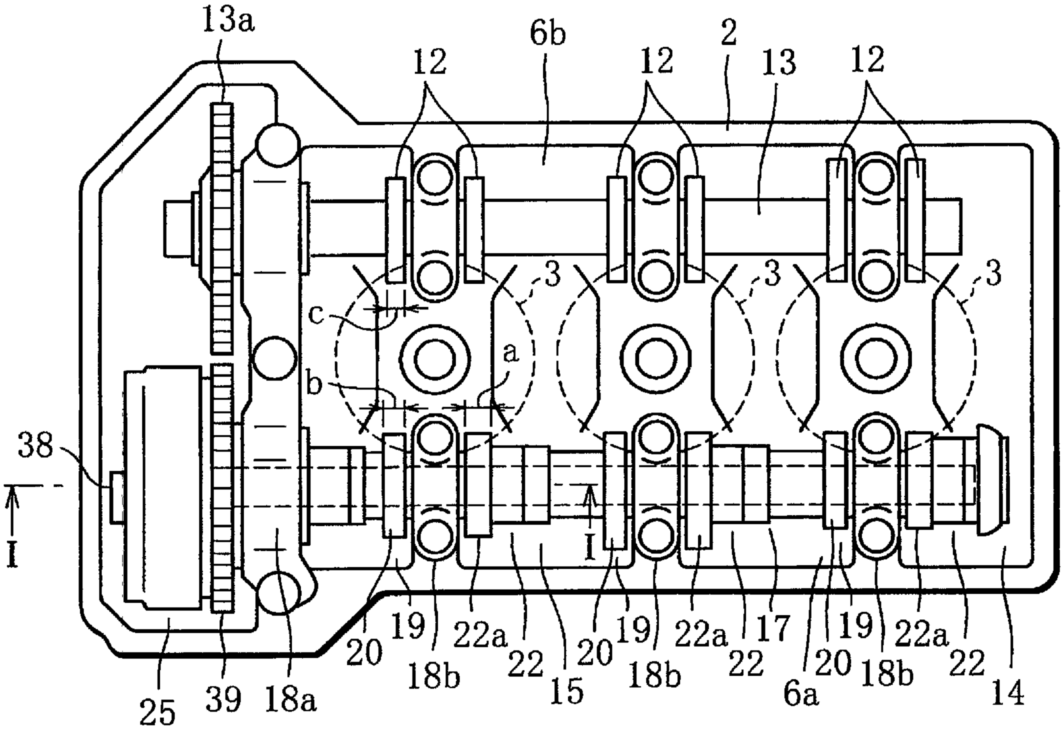
**2.** The variable valve device for an internal combustion engine according to claim 1, wherein:

the shaft member is configured by pivotably fitting an inner camshaft into an outer camshaft made up of a pipe member;
the first cam is disposed in an outer periphery of the outer camshaft, and the second cam is disposed to be pivotable around an axis of the outer camshaft; and
a phase of the second cam is variable on the basis of the first cam in response to a relative displacement of the outer camshaft and the inner camshaft.

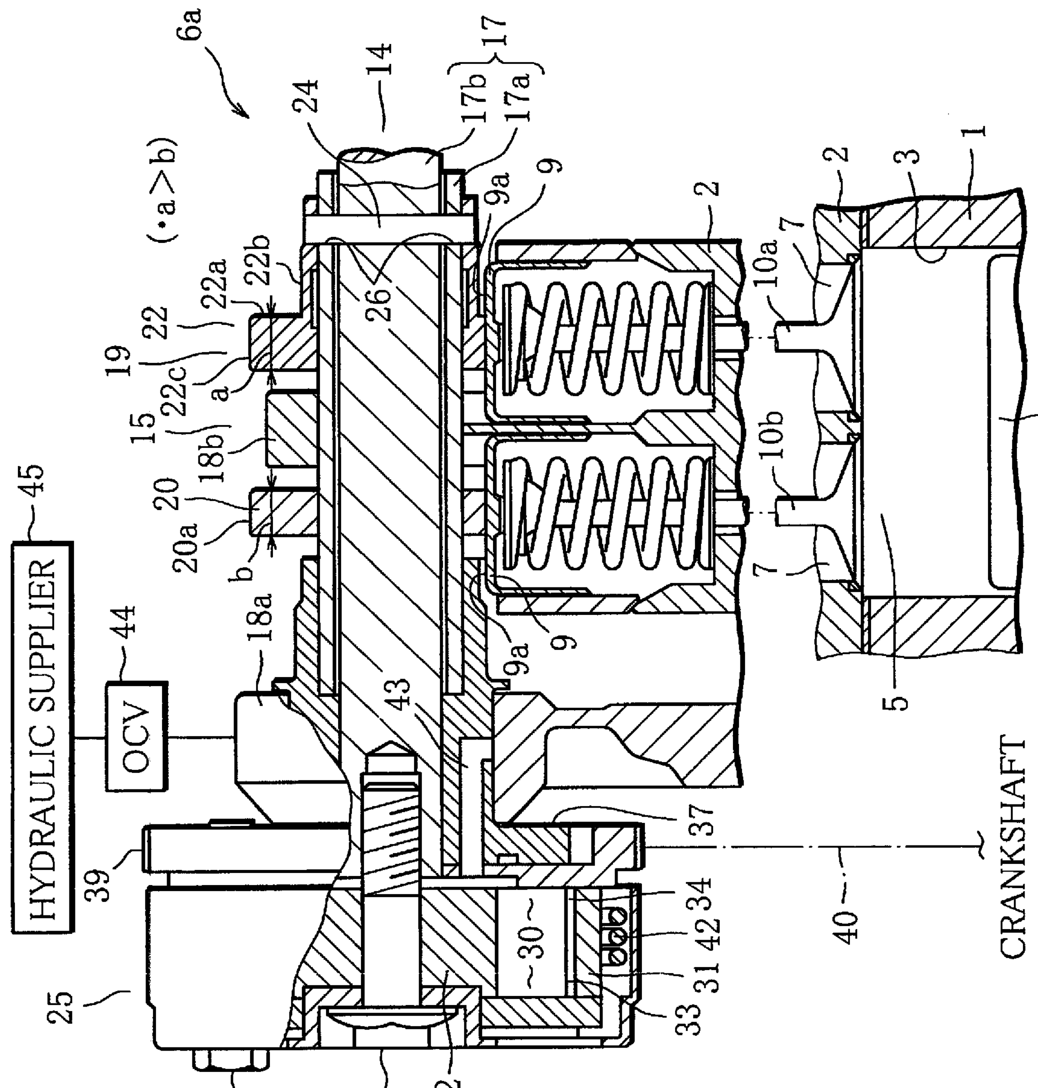
**3.** The variable valve device for an internal combustion engine according to claim 1 or 2, wherein:

the first cam is formed to have a cam width dimension that is larger than a cam width of a camshaft having a cam that forms an integral part of a shaft member applied in an internal combustion engine of the same model.

FIG. 1




$\begin{pmatrix} \cdot a > b \\ \cdot a > c \\ \cdot b > c \end{pmatrix}$



HYDRAULIC SUPPLIER
OCV
CRANKSHAFT
(•a>b)
6a
14
17
17a
17b
24
26
2
1
3
4
5
7
9
9a
10a
10b
15
18a
18b
19
20
20a
22
22a
22b
22c
a
b
25
30
31
32
33
34
36
37
38
39
40
42
43
44
45


FIG. 2

FIG. 3

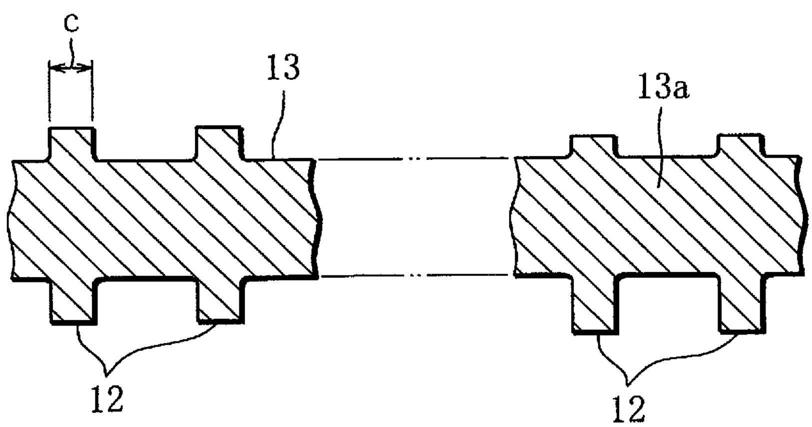


FIG. 4

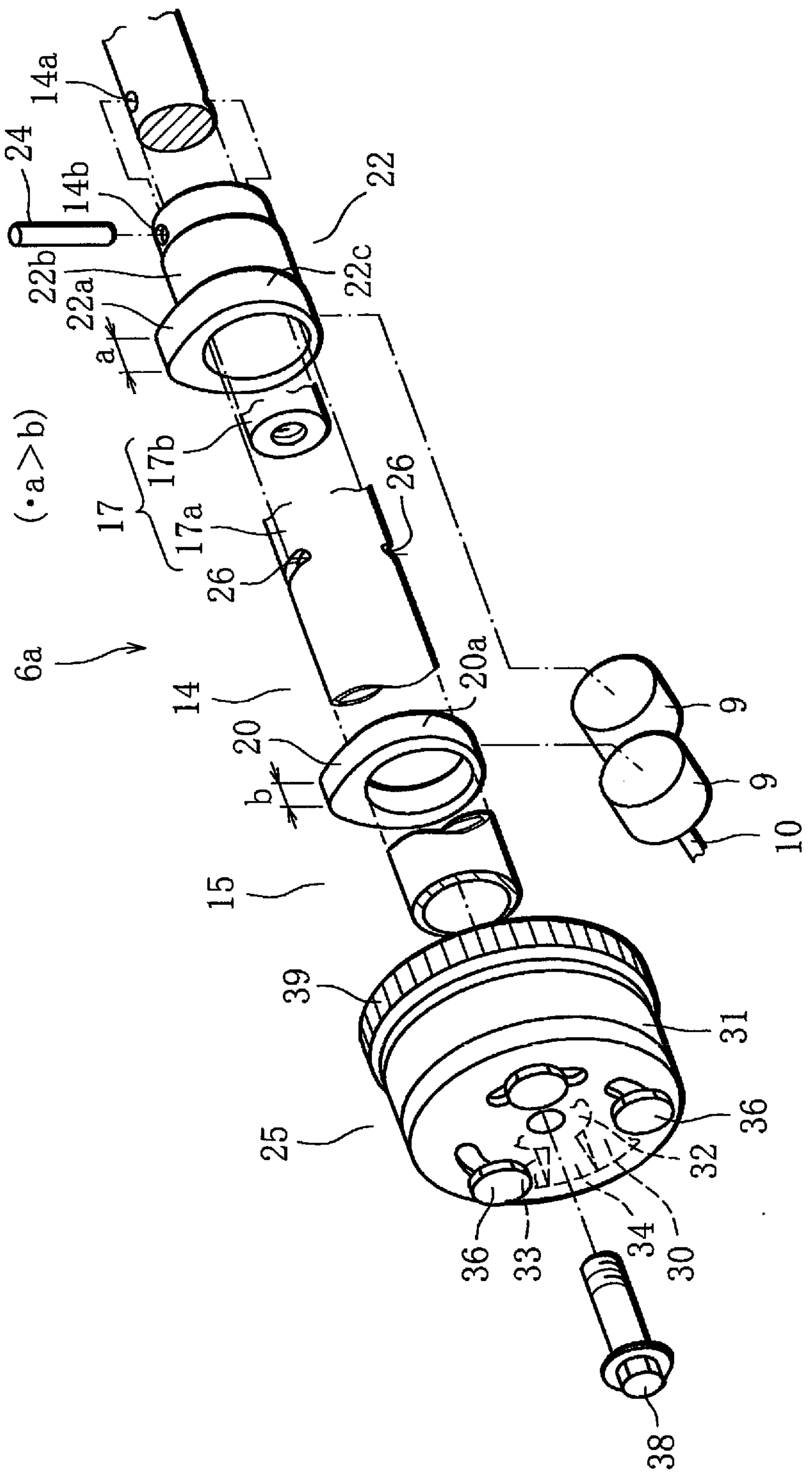

6a
(·a>b)
14a
24
14b
22b
22a
a
22
22c
17b
17
17a
26
26
14
20a
20
b
9
9
10
15
39
31
25
36
32
36
33
34
30
38

FIG. 5

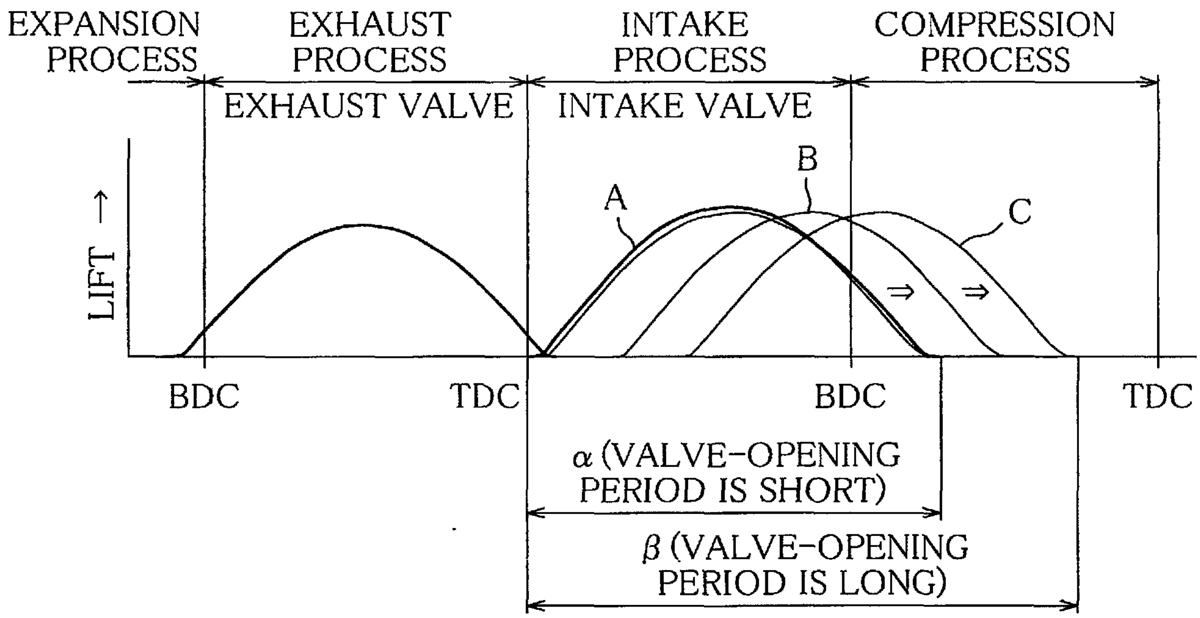

EXPANSION PROCESS
EXHAUST PROCESS
INTAKE PROCESS
COMPRESSION PROCESS
EXHAUST VALVE
INTAKE VALVE
LIFT →
A
B
C
BDC
TDC
BDC
TDC
α (VALVE-OPENING PERIOD IS SHORT)
β (VALVE-OPENING PERIOD IS LONG)

FIG. 6

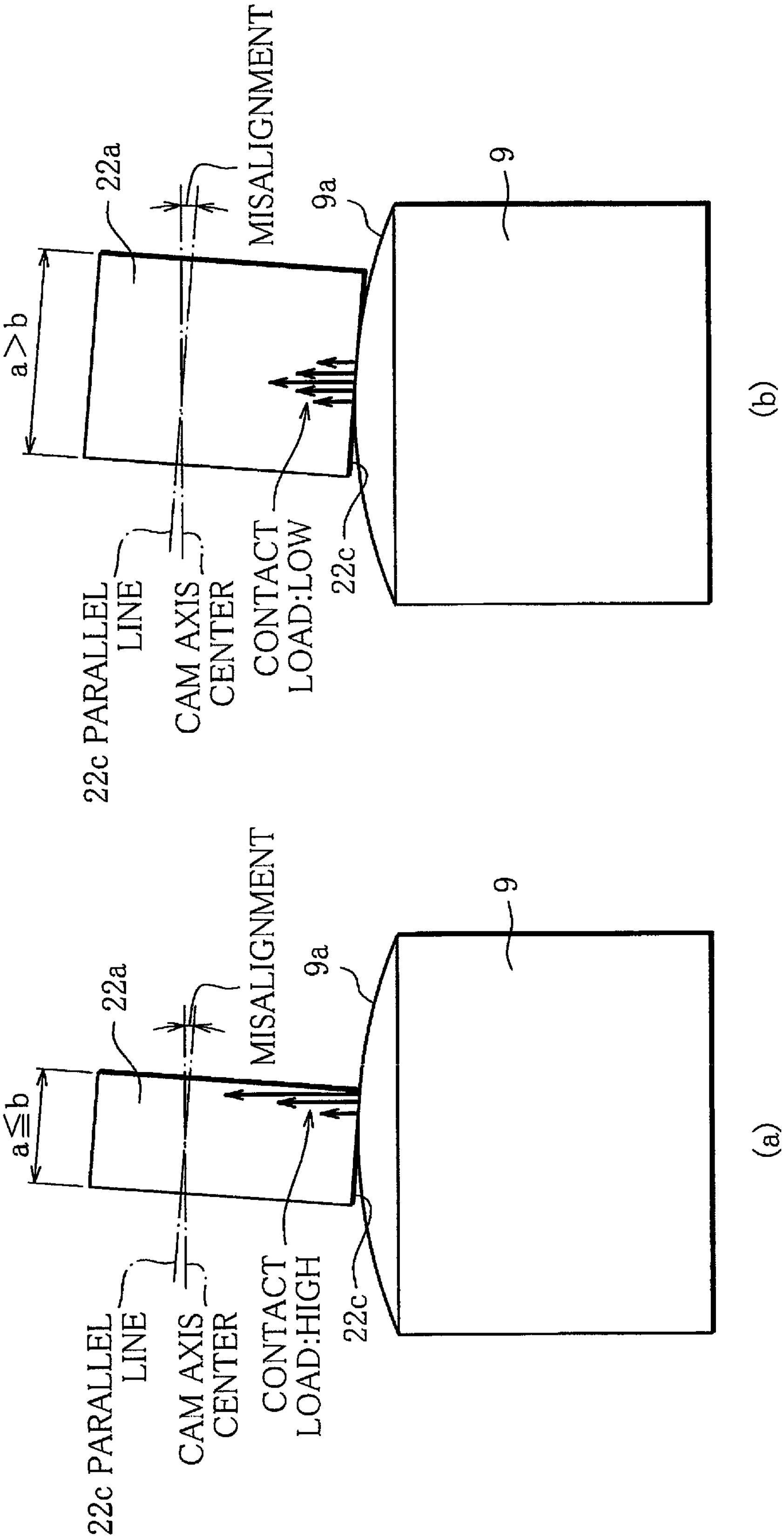
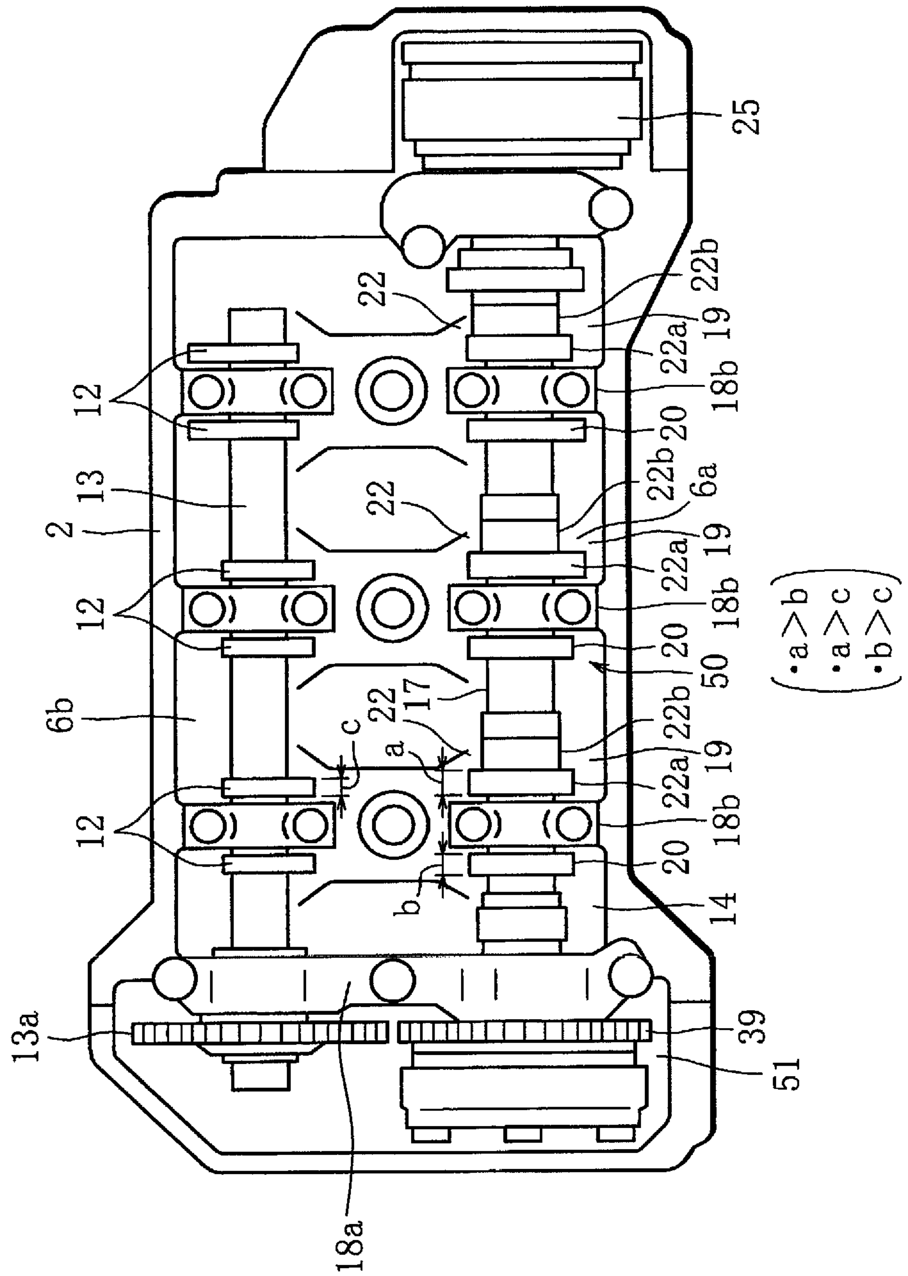

a>b
22a
MISALIGNMENT
9a
9
22c PARALLEL LINE
CAM AXIS CENTER
CONTACT LOAD:LOW
22c
(b)
a≦b
22a
MISALIGNMENT
9a
9
22c PARALLEL LINE
CAM AXIS CENTER
CONTACT LOAD:HIGH
22c
(a)

FIG. 7


25
22
22b
19
22a
18b
20
6a
50
17
a
b
c
14
39
51
13a
18a
12
13
2
6b
•a>b
•a>c
•b>c

**INTERNATIONAL SEARCH REPORT**

International application No.
PCT/JP2010/070799

A. CLASSIFICATION OF SUBJECT MATTER
*F01L1/04*(2006.01)i, *F01L1/34*(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)
F01L1/04, F01L1/34

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 | 1996-2011 |
| Kokai Jitsuyo Shinan Koho | 1971-2011 | Toroku Jitsuyo Shinan Koho | 1994-2011 |

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. |
|---|---|---|
| A | JP 2009-144522 A (Honda Motor Co., Ltd.), 02 July 2009 (02.07.2009), claims 1 to 3; fig. 1 to 12 (Family: none) | 1-3 |
| A | JP 2000-213315 A (Unisia Jecs Corp.), 02 August 2000 (02.08.2000), fig. 2 to 3 (Family: none) | 1-3 |
| A | JP 2005-140010 A (Mitsubishi Motors Corp.), 02 June 2005 (02.06.2005), paragraph [0043]; fig. 2 & US 2005/0098128 A1 & DE 102004053807 A & KR 10-2005-0043682 A & CN 1614201 A | 1-3 |

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

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"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 05 January, 2011 (05.01.11) | 01 March, 2011 (01.03.11) |

| Name and mailing address of the ISA/ | Authorized officer |
|---|---|
| Japanese Patent Office | |
| Facsimile No. | Telephone No. |

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**INTERNATIONAL SEARCH REPORT**

International application No.
PCT/JP2010/070799

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| A | JP 2005-326023 A (NSK Ltd.), 24 November 2005 (24.11.2005), paragraphs [0011] to [0014]; fig. 1 to 2, 9 to 10 (Family: none) | 1-3 |
| A | JP 10-169423 A (Yamaha Motor Co., Ltd.), 23 June 1998 (23.06.1998), paragraph [0028] & US 6053135 A & US 5924396 A & EP 908604 A1 & EP 834647 A1 | 1-3 |
| P,A | JP 2010-168948 A (JTEKT Corp.), 05 August 2010 (05.08.2010), paragraph [0005] (Family: none) | 1-3 |

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## REFERENCES CITED IN THE DESCRIPTION

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- JP 2009144521 A **[0006]**
- JP 2009144522 A **[0006]**