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(54) **DRIVE CAM AND VALVE OPERATING DEVICE FOR ENGINE**

(57) Provided are a drive cam having an improved wear resistant sliding surface that gives the drive cam enhanced durability and a valve operating system in an engine with such a drive cam. The drive cam 13a of the present invention, made of a nitriding steel, has on its sliding surface, a hardened surface formed by nitrocarburizing wherein the hardened layer lies on top of the sliding surface. It is preferred that the driven mechanism 33 used in combination with the drive cam 13a has, in its sliding surface against which the drive cam slides, a chrome-plated layer and thereon a diamond-like carbon coating.

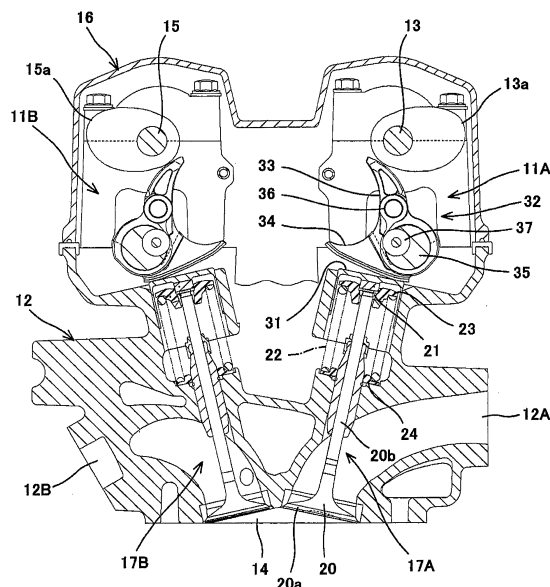


Fig. 1

Description

Patent Literature 1: JP- A- 2004- 204762

Patent Literature 2: JP- A- 2010- 156247

Patent Literature 3: JP- A- 2009- 103083

Technical Field

[0001] The present invention relates to a drive cam for use in a valve operating system in an engine and to an engine valve operating system including such a drive cam.

Background Art

[0002] A drive cam of the type that is configured to rotate in association with rotation of a crankshaft in a valve operating system in an engine is required to provide a higher degree of wear resistance so that the sliding surface of the drive cam against which a driven mechanism (for example, a rocker arm, a tappet et cetera) slides will not wear out. To this end, typical drive cams are conventionally made of chilled cast iron having high wear resistance. In addition, it has been well known in the art that with a view to achieving further improvement of the wear resistance, chilled cast iron is treated by various types of surface hardening processes. For example, in Patent Literature 1, there is disclosed a technique in which a sliding part such as a cam made of chilled cast iron is surface treated by a PVD process for formation of a hardened coating on top of the sliding part, thereby to achieve improvement in wear resistance. In addition, as such a surface hardening process, there is a conventional surface hardening process in which subsequently to formation of a drive cam by use of chilled cast iron, the drive cam is treated by nitrocarburizing. This nitrocarburizing process allows for diffusion and penetration of the nitrogen into the surface of the drive cam to form a compound layer and a hardened layer (a diffusion layer), whereby it is made possible to accomplish improvement in wear resistance.

[0003] Patent Literature 2 discloses a technique according to which the sliding surface of a rocker arm against which the drive cam slides in the engine valve operating system is chromized and then subjected to a two-stage polishing process, thereby to give the rocker arm improved wear resistance.

[0004] On the other hand, for example, Patent Literature 3 discloses a valve operating system of such a variable valve timing type that the rotation motion of a drive cam is converted by a pivot cam mechanism into the reciprocation motion of a valve and the pivot angle range of the pivot cam mechanism is changed, whereby to accomplish valve timing control in response to the engine speed.

Citation List**Patent Literature**

[0005]

Summary of Invention**Technical Problem**

[0006] Recent engines with high driving power output accompany an increase in the flow rate of air-fuel mixture and as a result, the amount of valve lift increases. Along with this, the pressure acting on the sliding surface tends to grow. Particularly in a valve operating system of the variable valve timing type, the pressing force exerted by the drive cam will increase in order that the valve is reciprocated. Therefore, the sliding frictional force occurring in the sliding surface of the drive cam increases. This produces the problem that the sliding surface of the drive cam tends to wear out extremely rapidly.

[0007] With the increase in pressure acting on the sliding surface of the drive cam, there is a need to provide improved wear resistance better than those achieved by conventional surface processing. In particular, for the case of a drive cam formed such that chilled cast iron is treated, at its top surface, by nitrocarburizing for formation of a compound layer and a hardened layer, the compound layer on top of the sliding surface tends to become separated upon application of a large surface pressure due to the fact that the compound layer on top of the cam surface is a hard but fragile layer. Even a slight separation of the compound layer easily gives rise to the development of a total separation thereof. If the separation of the compound layer proceeds, then the hardened layer will be exposed. This produces the problem that the drive cam decreases in wear resistance considerably due to the fact that the hardened layer made of chilled cast iron is low in wear resistance.

[0008] Therefore, an object of the present invention is to provide a drive cam with an improved wear resistant sliding surface that gives the drive cam enhanced durability and to provide a valve operating system with such a drive cam for use in an engine.

Solution to Problem

[0009] Bearing in mind the above-described problems with the prior art, the present invention was devised. The present invention accordingly provides a drive cam having a sliding surface and which drive cam rotates in association with rotation of a crank shaft in a valve operating system in an engine. The drive cam is characterized in that it comprises a nitriding steel and has on the sliding surface a hardened layer formed by nitrocarburizing, the hardened layer lying on top of the sliding surface.

[0010] In accordance with this configuration, the top of the sliding surface of the drive cam is comprised of the hardened layer and there is provided no compound layer formed by nitrocarburizing, whereby the problem of sep-

aration of the compound layer due to sliding of the drive cam can be avoided. Although the hardened layer formed by nitrocarburizing is exposed on the top of the sliding surface of the drive cam in the present invention, the hardened layer thus exposed is a hardened layer that is formed by performing nitrocarburizing not on conventional chilled cast iron but on nitriding steel. Therefore, the hardened layer of the present invention has enough hardness and thickness thereby exhibiting a considerably high level of wear resistance. As a result, the drive cam of the present invention according to the aforesaid configuration is improved significantly in wear resistance, as compared to conventional drive cams having atop thereof a compound layer formed by performing nitrocarburizing on the chilled cast iron.

[0011] Preferably, the drive cam of the present invention is manufactured such that subsequently to forming a hardened layer and a compound layer on the sliding surface by nitrocarburizing, the compound layer is removed. This method allows for easy manufacture of the drive cam of the present invention.

[0012] Preferably it is arranged such that the hardened layer is a layer having a Vickers hardness of 550HV100gf or greater and a thickness in a range of 100 to 300 micrometers. Because of this arrangement, the hardened layer exposed on top of the sliding surface of the drive cam comes to have enough hardness and thickness, thereby making it possible for the drive cam of the present invention to effect much better wear resistance.

[0013] Preferably, it is arranged such that the nitriding steel is a nitriding steel with a bainite structure formed therein. By subjecting such a nitriding steel to nitrocarburizing, there can be formed a hardened layer having enough hardness and thickness, thereby making it possible for the drive cam of the present invention to effect much better wear resistance.

[0014] The present invention relates also to a valve operating system in an engine. This valve operating system comprises: any one of the aforesaid drive cams; and a driven mechanism having a sliding surface in contact with the sliding surface of the drive cam and which driven mechanism is driven by sliding against the drive cam. This valve operating system employs a drive cam formed in accordance with the present invention. That is, since the sliding surface of the drive cam exhibits better wear resistance, this makes it possible that even if the engine is operated under rigorous conditions where the degree of frictional force applied to the drive cam is great, the valve operating system of the present invention is able to provide good durability.

[0015] Preferably, it is arranged such that there are formed in the sliding surface of the driven mechanism in the valve operating system a chrome-plated layer and thereon a diamond-like carbon coating. By providing the chrome-plated layer on the sliding surface of the driven mechanism, it is made possible to enhance the wear resistance of the driven mechanism. In addition, by provision of the diamond-like carbon coating on top of

the chrome-plated layer, it is made possible to accomplish improvement in seizure resistance that can be a problem when operated under rigorous conditions, while simultaneously making it possible to accomplish improvement in wear resistance.

[0016] Preferably, it is arranged such that the chrome-plated layer is formed by such polishing that it has a surface roughness (Rz) of 0.5 micrometers or smaller and that its period of corrugation of 0.1 micrometers or greater is 50 micrometers or greater. Because of this arrangement, the friction between the driven mechanism and the drive cam is reduced, whereby it becomes possible to control both the wear of the sliding surface of the driven mechanism and the wear of the sliding surface of the drive cam.

[0017] Preferably, it is arranged such that the diamond-like carbon coating is a metal-containing diamond-like carbon coating. Because of this arrangement, it is made possible to accomplish improvement in seizure resistance and improvement in wear resistance.

[0018] In the first embodiment of the present invention, the driven mechanism is a mechanism having a sliding surface in contact with the sliding surface of the drive cam and another sliding surface in contact with a tappet. In the valve operating system of the present embodiment, the drive cam and the driven mechanism such as a rock arm have respective sliding surfaces opposing each other and in addition the driven mechanism and the tappet have respective sliding surfaces opposing each other. In this embodiment, it is possible to accomplish the advantageous effects of the present invention.

[0019] Preferably, it is arranged such that in the first embodiment, the valve operating system is of the variable valve timing type. What is meant here by the "valve operating system of the variable valve timing type" is a system that comprises a drive cam which rotates in association with rotation of an engine crank shaft, a driven member in contact with the drive cam; a pivot member mounted to the driven member and which pivot member transmits the movement of the driven member to the tappet; and a relative position changing mechanism operable to make a change in relative position between the driven member and the pivot member. In such a valve operating system of the variable valve timing type, it is likely that the sliding surface of the drive cam will wear out due to the fact that the surface pressure against the sliding surface of the drive cam varies significantly. However, according to the present invention, the sliding surface of the drive cam will not wear out easily even in a valve operating system of the variable valve timing type, which is a preferable aspect.

[0020] In the second embodiment of the present invention, the driven mechanism includes a tappet with a sliding surface in direct contact with the sliding surface of the drive cam. In the valve operating system of the present embodiment, the tappet is in direct contact with the sliding surface of the drive cam and is equivalent to the driven mechanism. Also in this embodiment, the ad-

vantageous effects of the present invention can be accomplished.

Advantageous Effects of Invention

[0021] Thus, with the present invention, it becomes possible to improve the wear resistance of a sliding surface of a drive cam in an engine valve operating system thereby resulting in improvement in durability. Even when applied to a valve operating system of the variable valve timing type to be operated under rigorous conditions where the conventional drive cam tends to wear out in the sliding surface, the present invention achieves improvement in wear resistance thereby providing better durability.

Brief Description of Drawings

[0022]

Figure 1 is a cross sectional view showing a valve operating system of the variable valve timing type according to Embodiment 1 of the present invention and in addition showing its adjacent area;

Figure 2 is an enlarged cross sectional view conceptually showing an area in the vicinity of the surface of a nitriding steel after subjected to nitrocarburizing; Figure 3 is an enlarged cross sectional view conceptually showing an area in the vicinity of the top of the sliding surface of a drive cam according to the present invention; and

Figure 4 is a cross sectional view showing in a detached manner the major components of an engine valve operating system according to Embodiment 2 of the present invention.

Description of Embodiments

[0023] Hereinafter, a description will be given in regard to preferred embodiments of the present invention with reference to the drawing figures.

(Embodiment 1)

[0024] Figure 1 is a cross sectional view showing valve operating systems 11A, 11B in an engine and their adjacent area in Embodiment 1. As shown in Figure 1, the engine is of the double overhead camshaft (DOHC) type. The engine includes a cylinder head 12 which is provided with an intake port 12A and an exhaust port 12B, which ports are in fluid communication with a combustion chamber 14. There are arranged, above the cylinder head 12, an intake-side drive camshaft 13 and an exhaust-side drive camshaft 15, which camshafts are covered by a cylinder head cover 16. The drive camshafts 13, 15 are each coupled, through a rotation transmission mechanism (not shown) such as a chain or the like, to a crankshaft (not shown) of the engine so that each drive cam-

shaft rotates in association with rotation of the crankshaft. The cylinder head 12 is provided with an intake valve mechanism 17A operable to selectively open or close the combustion chamber 14 to the intake port 12A and an exhaust valve mechanism 17B operable to selectively open or close the combustion chamber to the exhaust port 12B. The intake valve mechanism 17A performs an open/close operation by the valve operating system 11A on the intake side whereas the exhaust valve mechanism 17B performs an open/close operation by the valve operating system 11B on the exhaust-side. The valve operating systems 11A, 11B are of the variable valve timing type. Because of the general similarity in configuration of the intake side (the valve mechanism 17A and the valve operating system 11A) and the exhaust side (the valve mechanism 17B and the valve operating system 11B), a description will be given representatively in regard to the intake side.

[0025] The intake valve mechanism 17A has a valve element 20. The valve element 20 includes a flange portion 20a for open/close of the intake port 12A and a stem member 20b extending upward from the flange portion 20a. There is formed, at the upper end of the stem member 20b, a groove. A cotter 21 is fitted into the groove. And, a spring retainer 23 is mounted to the cotter 21. And, a spring sheet 24 is mounted onto the upper surface of the cylinder head 12, and a valve spring 22 is interposed between the spring sheet 24 and the spring retainer 23. Therefore, the valve element 20 is biased upward by the valve spring 22, as a result of which the intake port 12A is closed. In addition, a tappet 31 is mounted onto the upper surface of the cotter 21.

[0026] The valve operating system 11A is provided with a drive camshaft 13 configured to rotate in association with rotation of the crankshaft of the engine, a drive cam 13a firmly fixed to the drive camshaft 13 and a pivot cam mechanism 32 which enters into contact with the drive cam 13a for transmitting the movement of the drive camshaft 13 to the tappet 31 of the intake valve mechanism 17A. The pivot cam mechanism 32 has a driven member 33 which enters into contact with the drive cam 13a, a pivot member 34 which pushes the tappet 31 of the intake valve mechanism 17A and a relative position changing mechanism operative to make a change in relative position between the driven member 33 and the pivot member 34. The relative position changing mechanism has a control shaft 35 which supports in a pivotable manner the pivot member 34, a coupling pin 36 which couples the driven member 33 to the pivot member 34 in an angularly displaceable manner, a roller 37 which is rotatably mounted to a part of the control shaft 35 so as to support the driven member 33 against the force exerted from the drive cam 13a and a driven spring (not shown) by which the driven member 33 is biased in the direction of the drive cam 13a. The control shaft 35 is angularly displaced by a motor (not shown), whereby there is made a change in relative positional relationship between the pivot member 34 and the driven member 33

in the circumferential direction around the control shaft 35. This makes it possible that the valve open time and the amount of lift of the valve element 20 can be varied.

[0027] The drive cam 13a is in contact with the driven member 33 of the pivot cam mechanism 32. In the present invention, the drive cam 13a is implemented by a drive cam comprising a nitriding steel formed into a predetermined shape by a forming process. The nitriding steel used in the present invention is a conventional nitriding steel and more specifically, it is a special steel intended for nitriding and therefore comprising an alloy of aluminium (Al) and chrome (Cr) with adequate additions of manganese (Mn), molybdenum (Mo) and vanadium (V) so as to facilitate formation of a hard surface layer. In the present invention, various types of nitriding steels may be used, but it is preferable to select from among them a nitriding steel with a bainite structure because of fast nitrocarburizing that allows for easy formation of a deeper hardened layer.

[0028] The nitriding steel that makes up of the drive cam 13a is treated, at least in its sliding surface against which the driven member 33 slides, by nitrocarburizing. As the nitrocarburizing process, gas nitrocarburizing, plasma nitrocarburizing, ion nitrocarburizing, tufftriding, nitrosulphurizing et cetera have been known in the art, and although their performance requirements are not limited to special conditions, it is preferred that the processing should be carried out 520 degrees Centigrade or lower in order to prevent the cam from strain resulting from high-temperature heat processing. The present embodiment employed a gas nitrocarburizing process.

[0029] By the nitrocarburizing process, nitrogen diffuses and penetrates into the surface of the nitriding steel thereby increasing the amount of nitrogen in the vicinity of the surface of the nitriding steel. As a result, there is formed as a topmost layer a compound layer made of nitride while there is formed, under the compound layer, a hardened layer formed by nitrogen diffusion. This layer structure is depicted in Figure 2. Referring to Figure 2, the hardened layer 52, i.e., a nitrogen diffused/penetrated layer, is formed on an unnitrided layer 53 free from diffusion and penetration of the nitrogen. Formed on the hardened layer 52 is the compound layer 51 made of nitride. The compound layer 51 constitutes a topmost layer.

[0030] The compound layer 51 is a topmost layer formed on top of the surface of the nitriding steel after treated by nitrocarburizing and which has a thickness falling within the range of from about several micrometers to about tens of micrometers. The compound layer 51 is compositionally a layer formed of a complex nitride made of iron, chrome et cetera. On the other hand, the hardened layer 52 is called a diffusion layer and which is formed immediately under the compound layer 51. There are formed no iron nitrides in the hardened layer 52. Therefore, the hardened layer 52 is either a layer in which nitrogen is just solid-dissolved or a complex layer formed such that nitrides of addition elements such as alumi-

um, chrome et cetera are diffused into a matrix in which nitrogen is solid-dissolved.

[0031] Generally, compound layers formed by nitrocarburizing are hard but fragile and accordingly susceptible to crack. Therefore, in the case of forming a drive cam employing a nitriding steel having as a topmost layer a compound layer, the compound layer tends to become separated by application of a surface pressure during operation therefore causing the problem with durability.

[0032] To cope with this problem, it is arranged that in the present invention, the surface of the nitriding steel constituting the drive cam 13a is treated by nitrocarburizing thereby forming a compound layer and a hardened layer. This is followed by removal of only the compound layer from the nitriding steel surface so that the hardened layer is exposed as a topmost layer. Such a hardened layer formed by nitrocarburizing on the nitriding steel has enough hardness and thickness and therefore exhibits a considerably high level of wear resistance. By the presence of such a hardened layer as a topmost layer on the sliding surface of the drive cam, the wear resistance of the drive cam is improved considerably. Referring to Figure 3, there is shown a layer structure in the surficial vicinity of the sliding surface of the drive cam according to the present invention. In Figure 3, the hardened layer 52 with diffusion and penetration of nitrogen is formed overlying the unnitrided layer 53 free from diffusion and penetration of nitrogen. However, the difference from Figure 2 is that the hardened layer 52 is exposed as a topmost layer and there is no formation of the compound layer 51 on the hardened layer 52.

[0033] It is preferred that the hardened layer formed as a topmost layer on the sliding surface of the drive cam according to the present invention is a layer that exhibits a Vickers hardness of 500HV100gf or greater. In addition, it is preferable that the hardened layer having such a hardness has a thickness falling within the range of from 100 to 300 micrometers. If the hardened layer combines both hardness and thickness as described above, it is made possible to provide further superior wear resistance. In addition, in the unnitrided layer, the Vickers hardness is substantially below 550 (for example, about 300) and therefore the hardness is poor.

[0034] The drive cam of the present invention can be manufactured by the following steps to be carried out in sequence which steps are:

- (1) a step in which a drive cam of nitriding steel is formed;
- (2) a step in which at least the sliding surface of the drive cam formed by the step (1) is treated by nitrocarburizing whereby to form a hardened layer and a compound layer; and
- (3) a step in which the compound layer is removed from the sliding surface so that hardened layer is exposed as a topmost layer on the sliding surface.

[0035] In the step (3), the method of removing the com-

pound layer from the sliding surface is not limited to a particular method. For example, it is possible to employ a conventional removal method such as mechanical polishing technique. In addition, in order to provide confirmation that the compound layer has been removed by a removal process, it is possible to employ a method for measuring the distribution of hardness at a cross section of the sliding surface or a method for observing a sectional structure of the sliding surface with the aid of an electron microscope.

[0036] The inventors of the present invention had prepared (i) four different types of drive cams having a sliding surface with a hardened layer and a compound layer formed thereon by nitrocarburizing and (ii) another four different types of drive cams having such a sliding surface that the compound layer is removed after the nitrocarburizing process so that the hardened layer is exposed as a topmost layer. All of these drive cams were subjected to rotational sliding testing under specific conditions. Then, the amount of wear of each of the drive cams was measured at five specific locations on top of the sliding surface. The results showed that at any of the measurement points on top of the sliding surface, the amount of wear was significantly reduced in the drive cams with their compound layers removed. The result that by removal of the compound layer, the amount of wear was reduced on average to more than half was obtained. This experimentally verified that by removal of the compound layer from on top of the sliding surface, the wear resistance of the sliding surface of the drive cam was improved significantly.

[0037] In addition, it was also confirmed that in the absence of removal of the compound layer, the wear resistance was worse, regardless of the thickness of compound layer. Stated in another way, there were prepared a drive cam with a sliding surface comprising a compound layer as a topmost layer having a thickness of 3 micrometers and another drive cam with a sliding surface comprising a compound layer having a thickness of 16 micrometers, and their amount of wear was measured in the way as described above. The resulting measurements showed that both of them had undergone considerable wear. This result confirmed that the wear resistance was not improved by reduction in thickness of the compound layer. As described above, the requirement for improving the wear resistance of the sliding surface of the drive cam is that the compound layer is removed for the hardened layer to be exposed.

[0038] Next, a description will be given in regard to the driven member 33 which is in contact with the drive cam 13a. The driven member 33 may be implemented by a driven member that is prepared using a formed body made of steel. More specifically, the formed body is treated at the top of its sliding surface (i.e., the sliding surface against which the drive cam slides) by chrome plating. The purpose of this chrome plating process is to provide better wear resistance.

[0039] However, the inventors of the present applica-

tion found out that the employment of a chromized driven member and a drive cam with removal of a compound layer for a hardened layer to be exposed as described above produced the problem that if operated in a valve operating system of the variable valve timing type in which the surface pressure varies wildly, the occurrence of seizure was likely and the resistance to seizure (the resistance to adhesion) was decreased accordingly. More specifically, the problem that the material on the surface of the drive cam was removed forcibly and then adhered to the surface of the driven member arose. It was estimated that this resulted from an intermetallic bond occurring between the hardened layer on the surface of the drive cam and the surface of the driven member. A typical conventional drive cam is provided, atop thereof, with a compound layer. Such a compound layer serves as a protective coat capable of preventing an intermetallic bond because it is a form of ceramic, and it is conceivable that the resistance to seizure has been considered out of the question. In the present invention, the compound layer is removed from on top of the surface of the drive cam, that is, the drive cam has now no protective coat thereon. Consequently, it was conceivable that under harsh operating conditions in a valve operating system of the variable valve timing type, the material of the drive cam came to adhere onto the top surface of the driven member.

[0040] In order to avoid such a problem with the seizure resistance, the inventors of the present application examined the possibility of additionally performing various types of surface treatments on the sliding surface of the chromized driven member (the sliding surface against which the drive cam slides). However, if tin plating, *Kanigen* (registered trademark) plating (electroless nickel plating), *Kanifron* (registered trademark) plating, or other like plating is employed as a surface treatment, the plated layer itself will become separated. This causes the sliding surface of the driven member to wear out thereby resulting in failing to achieve improvement in seizure resistance.

[0041] However, it was confirmed that if the sliding surface of the chromized driven member was additionally coated with a diamond-like carbon coating, this provided a significant improvement in seizure resistance when compared to the case of employing a driven member that was treated only by a chrome plating process.

[0042] Here, the evaluation of the seizure resistance was conducted based on the load when a seizure occurred (hereinafter referred to as the "seizure load"). There were prepared five sample driven members having thereon only a chrome-plated layer and their seizure load spread ranging from 10 to 70 kgf. There were variations causing instability and in addition, it was found that in three of the five sample driven members, their seizure load was 30 kgf or less, that is, their seizure resistant properties were insufficient. On the other hand, there were prepared another three sample driven members having, on a chrome-plated layer, a diamond-like carbon

coating and their seizure load fell within the range of 40 to 50 kgf, that is, their seizure resistant properties were good. In addition, it was found that their seizure resistance remained stable at high level. As described above, significant improvement in seizure resistance by formation of the diamond-like carbon coating was confirmed.

[0043] Besides the above-described improvement in seizure resistance, it was confirmed that the wear resistance of the surface of the drive cam was further improved. In other words, by employment of a driven member whose chrome-plated layer was coated with a diamond-like carbon coating, the amount of wear of the surface of the drive cam on which the hardened layer is exposed as a topmost surface is reduced to about half as compared to the case where there was employed a driven member having thereon only a chrome-plated layer.

[0044] As can be seen from the above, it is preferable, in terms of seizure resistance (adhesion resistance) and wear resistance, that in the sliding surface of the driven member (the sliding surface that enters into contact with the drive cam), the chrome-plated layer is coated with a diamond-like carbon coating. Accordingly, the present embodiment employs, as the driven member 33, a driven member having such a structure.

[0045] The diamond-like carbon coating in the driven member is not limited to any particular type of coating as long as it is formed of a coating of diamond-like carbon. Diamond-like carbon is an amorphous hard coating composed mainly of carbon. In the present invention, various type of conventionally known diamond-like carbon coatings may be used. However, it is preferable, in terms of toughness, adhesion to the chrome-plated layer and seizure resistance, to employ a metal-containing diamond-like carbon coating. The present embodiment employs a tungsten-containing diamond-like carbon.

[0046] The diamond-like carbon coating may range in thickness from about 1 to about 4 micrometres.

[0047] The chrome-plated layer formed under the diamond-like carbon coating is effective to improve the adhesion of the diamond-like carbon coating, while impeding separation of the diamond-like carbon coating from the driven member. Furthermore, it is also expected that even if the diamond-like carbon coating becomes separated under rigorous operating conditions, some degree of seizure resistance will be provided.

[0048] It is preferable for the chrome-plated layer to be pre-treated, at the sliding surface against which the drive cam slides, by a polishing process, similarly to as disclosed in Patent Literature 2 (JP-A-2010-156247). Owing to such polishing, the surface of the chrome-plated layer is controlled such that its surface roughness (R_z) is 0.5 micrometers or smaller and in addition, the period of corrugation of 0.1 micrometers or greater is 50 micrometers or greater. This reduces the friction between the driven member and the drive cam, thereby making it possible to control the friction in the sliding surface of the drive cam. Since the diamond-like carbon coating has an extremely high surface hardness, it is preferable that

the surface roughness of a chrome-plated layer prior to formation of a diamond-like carbon coating is precontrolled whereby to avoid the wear of the sliding surface of the drive cam due to the diamond-like carbon coating.

[0049] After the chrome-plated layer is polished in the way as described above, there is formed a diamond-like carbon coating. It is possible to employ a conventional technique to form a diamond-like carbon coating.

10 (Embodiment 2)

[0050] Figure 4 is a cross sectional view showing in a detached manner the major components of an engine valve operating system according to Embodiment 2 of the present invention. This embodiment is similar to Embodiment 1 but excludes the pivot cam mechanism 32, and therefore the drive cam 13a is in direct contact with the tappet 31.

[0051] The tappet 31 has on top of the sliding surface (the sliding surface against which the drive cam slides) of a formed body made of steel a chromed plated layer and thereon a diamond-like carbon coating. As is the case with the driven member 33 in Embodiment 1, this improves seizure resistance thereby enhancing the wear resistance of the drive cam to a further extent. The details of the chrome-plated layer and the diamond-like carbon coating are the same as in Embodiment 1.

[0052] Embodiment 2 is similar to Embodiment 1, with the exception that the pivot cam mechanism 32 is not provided and the tappet 31 has on top of its sliding surface a chrome-plated layer and a diamond-like carbon coating and in regard to the same points as Embodiment 1, their description is omitted here.

35 Industrial Applicability

[0053] As has been described above, the drive cam and the engine valve operating system of the present invention allow for control of the degradation of the sliding surface of the drive cam due to wear. Therefore, the present invention can find a wide range of application to engines for use in vehicles such as a motorbicycle and so on.

45 Reference Signs List

[0054]

11A, 11B	variable valve timing type valve operating system
12	cylinder head
13	intake-side drive camshaft
14	combustion chamber
15	exhaust-side drive camshaft

17A	intake valve mechanism			a driven mechanism having a sliding surface in contact with said sliding surface of said drive cam and which driven mechanism is driven by sliding against said drive cam.
17B	exhaust valve mechanism			
20	valve element	5		
31	tappet		6.	The valve operating system as set forth in claim 5, wherein there are formed in said sliding surface of said driven mechanism a chrome-plated layer and thereon a diamond-like carbon coating.
32	pivot cam mechanism	10		
33	driven member		7.	The valve operating system as set forth in claim 6, wherein said chrome-plated layer is formed by such polishing that it has a surface roughness (Rz) of 0.5 micrometers or smaller and that its period of corrugation of 0.1 micrometers or greater is 50 micrometers or greater.
34	pivot member			
35	control shaft	15		
36	coupling pin		8.	The valve operating system as set forth in claim 6, wherein said diamond-like carbon coating is a metal-containing diamond-like carbon coating.
37	roller	20		
51	compound layer		9.	The valve operating system as set forth in claim 5, wherein said driven mechanism is a mechanism having a sliding surface in contact with said sliding surface of said drive cam and another sliding surface in contact with a tappet.
52	hardened layer			
53	unnitrided layer	25		

Claims

1. A drive cam having a sliding surface and which drive cam rotates in association with rotation of a crank shaft in a valve operating system in an engine, wherein said drive cam comprises a nitriding steel and wherein said drive cam has on said sliding surface a hardened layer formed by nitrocarburizing, said hardened layer lying on top of said sliding surface. 30
2. The drive cam as set forth in claim 1, wherein said drive cam is manufactured such that subsequently to forming said hardened layer and a compound layer on said sliding surface by nitrocarburizing, said compound layer is removed. 40
3. The drive cam as set forth in claim 1, wherein said hardened layer is a layer having a Vickers hardness of 550HV100gf or greater and a thickness in a range of 100 to 300 micrometers. 45
4. The drive cam as set forth in claim 1, wherein said nitriding steel is a nitriding steel with a bainite structure formed therein. 50
5. A valve operating system in an engine, said valve operating system comprising: 55
 - a drive cam as set forth in any one of claims 1 to 4; and
10. The valve operating system as set forth in claim 9, further comprising, in addition to said drive cam, a driven member in contact with said drive cam; a pivot member mounted to said driven member and which pivot member transmits the movement of said driven member to said tappet; and a relative position changing mechanism operable to make a change in relative position between said driven member and said pivot member.

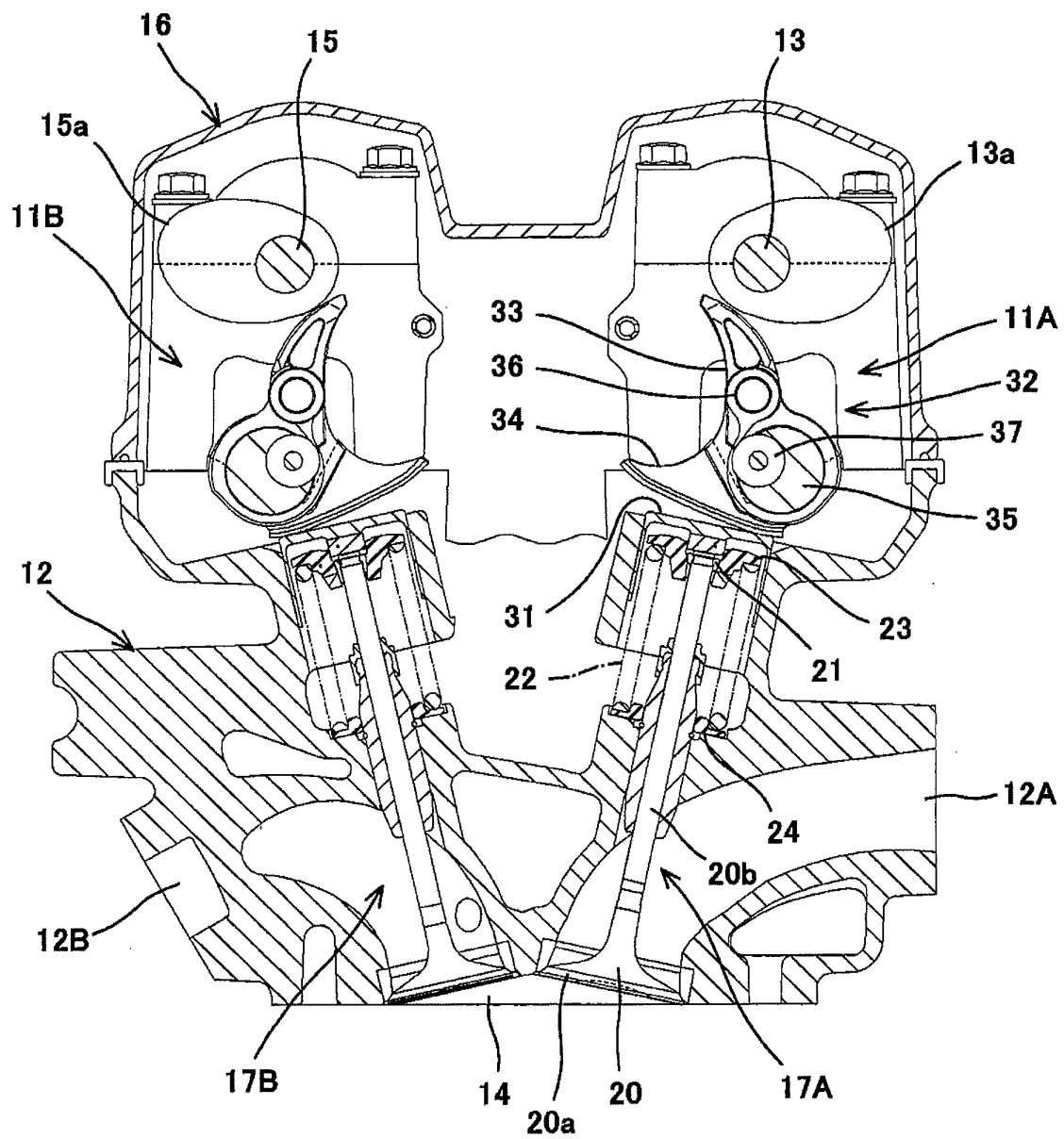


Fig. 1

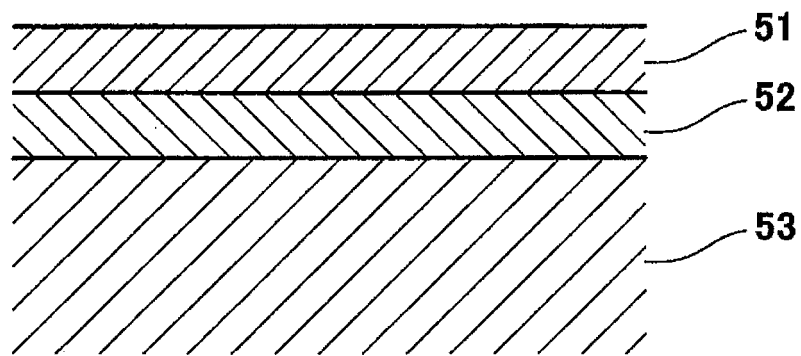


Fig. 2

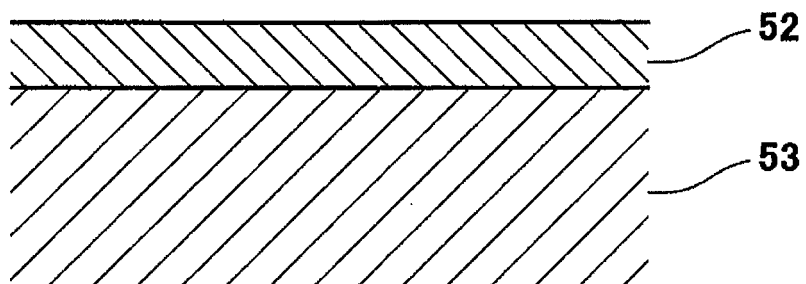


Fig. 3

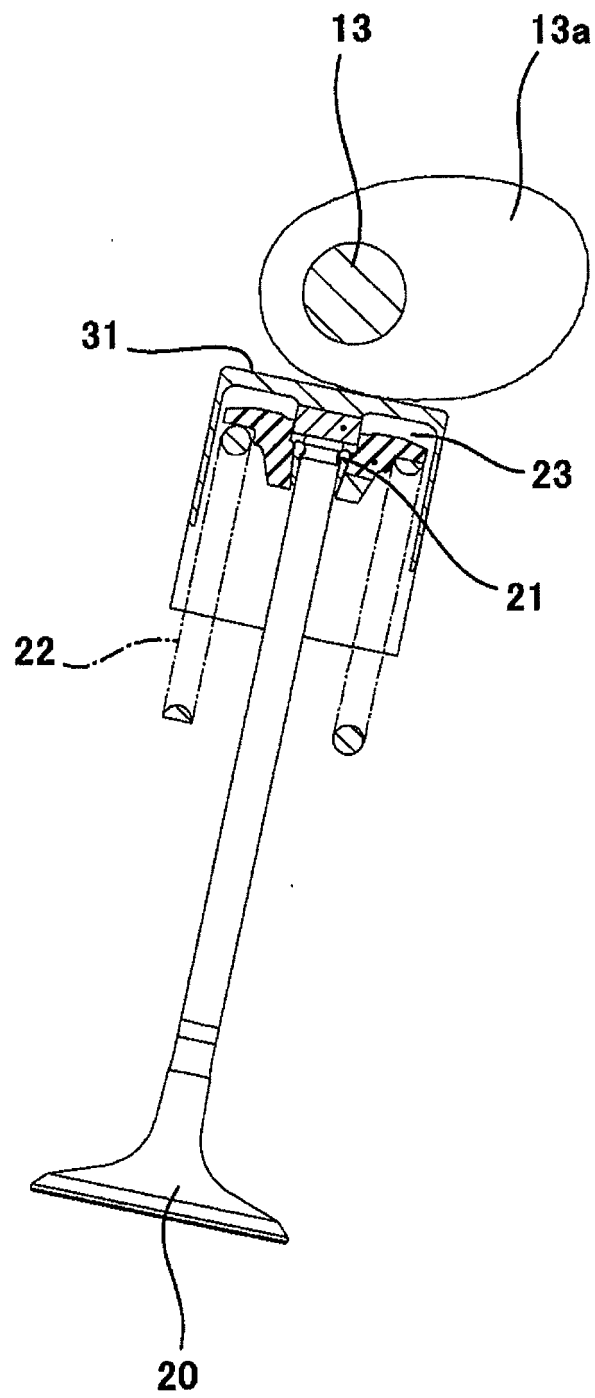


Fig. 4

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2011/006823

A. CLASSIFICATION OF SUBJECT MATTER

F01L1/04 (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

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	1996-2012
Kokai Jitsuyo Shinan Koho	1971-2012	Toroku Jitsuyo Shinan Koho	1994-2012

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.
X Y A	JP 63-167004 A (Musashi Seimitsu Industry Co., Ltd.), 11 July 1988 (11.07.1988), pages 2, 3; fig. 1 to 4 (Family: none)	1, 3 4, 5, 9, 10 2, 6-8
Y	WO 2005/021816 A1 (Sumitomo Metal Industries, Ltd.), 10 March 2005 (10.03.2005), claims; paragraphs [0001], [0002]; abstract & US 2006/096671 A1 & CN 1846010 A	4
Y	JP 11-12685 A (Kawasaki Steel Corp.), 19 January 1999 (19.01.1999), claims; paragraph [0001] (Family: none)	4

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

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search
27 February, 2012 (27.02.12)Date of mailing of the international search report
13 March, 2012 (13.03.12)Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

Facsimile No.

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2011/006823

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 2009-209711 A (Kawasaki Heavy Industries, Ltd.), 17 September 2009 (17.09.2009), paragraphs [0048], [0049]; fig. 4 to 7 & US 2009/0229552 A1 & EP 2098693 A1	5, 9, 10 6-8

Form PCT/ISA/210 (continuation of second sheet) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2004204762 A [0005]
- JP 2010156247 A [0005] [0048]
- JP 2009103083 A [0005]