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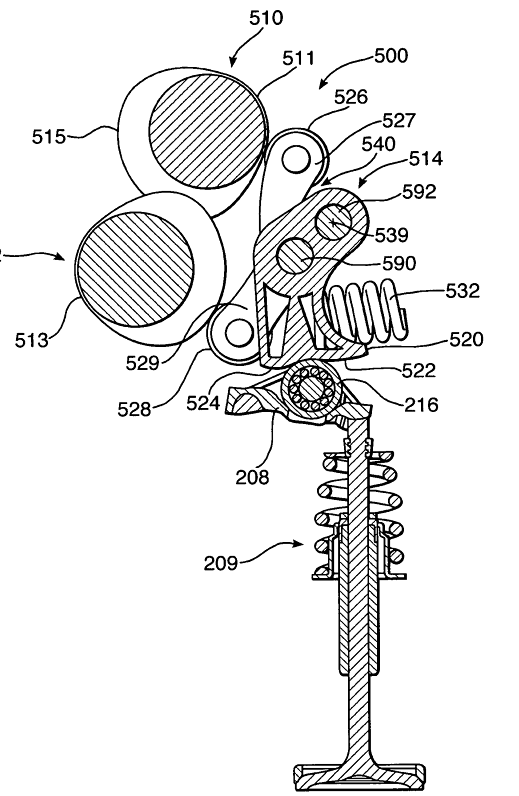
(54) **Phaser-actuated continuously variable valve actuation system with lost motion capability**

(57) A system for continuously varying actuation of a valve in an internal combustion engine including a first cam for opening the valve, a second cam for closing the valve, and an oscillating rocker arm continuously engaging each of the first cam, the second cam, and the valvetrain, with the aid of a lost motion spring. The cams are disposed on first and second camshafts that are geared together. The first camshaft gear is driven by the engine crankshaft and thus is phase-invariant. The second camshaft gear is rotationally mounted on the second camshaft and supports the stator of a camshaft phaser. The phaser rotor is mounted to the second camshaft. Varying the rotor position varies the phase of the second cam and thus varies lift and closing timing of the valve. The system is useful in improving the performance of both spark-ignited and compression-ignited engines.

Fig.13.



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Description

TECHNICAL FIELD

[0001] The present invention relates to the actuation of combustion valves in internal combustion engines; more particularly, to mechanisms for variable actuation of combustion valves; and most particularly, to a system for continuously variable valve actuation.

BACKGROUND OF THE INVENTION

[0002] One of the drawbacks inhibiting the introduction of a gasoline or Diesel Homogeneous Charge Compression Ignited (HCCI) engine in production has been the lack of a simple, cost effective and energy efficient Variable Valvetrain Actuation (VVA) system to vary intake events. Many electro-hydraulic and electro-mechanical (magnetic) "camless" VVA systems have been proposed for gasoline or Diesel HCCI engines, but while these systems may consume less or equivalent actuation power at low engine speeds, they typically require significantly more power than a conventional fixed-lift and fixed-duration valvetrain system to actuate at mid and upper engine speeds. Moreover, the cost of these "camless" systems can approach the cost of an entire conventional engine itself.

[0003] As the cost of petroleum continues to rise from increased global demands and limited supplies, the fuel economy benefits of internal combustion engines will become a central issue in their design, manufacture, and use at the consumer level. In high volume production applications, applying a continuously variable valvetrain system to just the intake side of a gasoline engine can yield significant fuel economy benefits on Federal Test Procedure - USA (FTP) or New European Driving Cycle (NEDC) driving schedules, based on simulations and vehicle testing. HCCI type combustion processes have promised to make the gasoline engine nearly as fuel efficient as a conventional, 4-stroke Diesel engine, yielding even higher gains over conventional (non-VVA) gasoline engines for these same driving schedules. The HCCI engine could become strategically important to America and other countries dependent on a gasoline based transportation economy.

[0004] Likewise, the use of a continuously variable valvetrain for at least the intake side of a Diesel engine has been identified as a potential means to reduce the size and cost of future exhaust aftertreatment systems and a way to restore the lost fuel economy that these systems presently impose. By varying the duration of intake lift events, potential Miller cycle-type fuel economy gains are feasible. Also, with VVA on the intake side, the effective compression ratio can be varied to provide a high ratio during startup and a lower ratio for peak fuel efficiency at highway cruise conditions. Without intake side VVA, compression ratios must be compromised in a tradeoff between these two extremes.

[0005] Exhaust side VVA can improve the torque response of a Diesel engine. Varying exhaust valve opening times can permit faster transitions with the turbocharger, reducing turbo lag. Exhaust VVA can also be used to expand the range of engine operation where pulse turbo-charging can be effective. Furthermore, varying exhaust valve opening times can be used to raise exhaust temperatures under light load conditions, significantly improving NOx adsorber efficiencies.

[0006] VVA devices for variably controlling the actuation of poppet valves in the cylinder head of an internal combustion engine are well known.

[0007] Referring to Published United States Patent Application Nos. 2007/0125329 and 2007/0125330, the relevant disclosures of which are incorporated herein by reference, an electromechanical VVA system is disclosed for variably controlling the opening, lift, and closing of poppet valves in the cylinder head of an internal combustion engine for one or more banks of engine valves. Using a single electrical rotary actuator per bank of valves to control the device, the valve lift events can be varied for either the exhaust or intake banks. The device comprises a hardened steel rocker subassembly for each valve or valve pair pivotably disposed on a control shaft between the engine camshaft and the engine roller finger follower. The control shaft itself may be displaced about a pivot axis outside the control shaft to change the angular relationship of the rocker subassembly to the camshaft, thus changing the valve opening, closing, and lift. A plurality of control shafts for controlling a plurality of valve trains for a plurality of cylinders in an engine bank may be assembled linearly to define a control crankshaft for all the valves in the engine bank. The angular positions of the control shafts for the plurality of cylinders may be tuned by mechanical means with respect to each other to optimize the valve timing of each cylinder in a cylinder bank. The valve actuation energy comes from a conventional mechanical camshaft that is driven by a belt or chain, as in the SSCR device disclosed in US Patent No. 5,937,809. An electrical, controlling actuator attached to the control shaft receives its energy from the engine's alternator. The disclosed device can easily be applied to the intake camshaft of a gasoline engine for low cost applications, or to the intake and/or exhaust camshafts of a Diesel or a gasoline HCCI engine.

[0008] A shortcoming of the disclosed system is that the timing of valve opening and valve closing cannot be independently controlled; e.g., valve opening timing cannot be held constant while varying valve closing timing. Also, valve lift cannot be controlled independently of valve opening and valve closing.

[0009] What is needed in the art is a simplified VVA mechanism that can vary the closing timing of a valve independently of the opening timing and valve lift.

[0010] What is further needed in the art is such a VVA mechanism that can also hold a combustion valve open for an extended and variable length of time as may be desired.

[0011] What is still further needed in the art is such a VVA mechanism that can also provide 100% lost motion for complete valve deactivation as may be desired.

[0012] It is a principal object of the present invention to provide fixed opening timing, variable closing timing, and variable or full lift amplitude in a bank of engine valves, especially intake valves.

SUMMARY OF THE INVENTION

[0013] Briefly described, a system in accordance with the invention for continuously varying actuation of a valve in a valvetrain in an internal combustion engine comprises a first cam lobe for opening the valve, the first cam lobe having a first base circle portion and a first working portion; a second cam lobe for closing the valve, the second cam lobe having a second base circle portion and a second working portion; and an oscillating rocker arm having first, second, and third working elements and being disposed among and continuously engaging each of the first cam lobe in contact with the first working element, the second cam lobe in contact with the second working element, and the valvetrain in contact with the third working element, with the aid of a lost motion spring. The cams are disposed on first and second camshafts that are geared together. The first (opening) camshaft gear is driven by the engine crankshaft and thus is phase-invariant. The second (closing) camshaft gear is rotationally mounted on the second camshaft and supports the stator of a camshaft phaser. The phaser rotor is mounted to the second camshaft. Varying the rotor position varies the phase of the second cam lobe and thus varies lift and closing timing of the combustion valve. The system is useful in improving the performance of both spark-ignited and compression-ignited engines.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] The present invention will now be described, by way of example, with reference to the accompanying drawings, in which:

FIG. 1 is an elevational drawing of a prior art valvetrain equipped with VVA means, showing the VVA in maximum lift position and the valve in the fully closed position;

FIG. 2 is a drawing like that shown in FIG. 1, showing the prior art VVA in maximum lift position and the valve in the fully open position;

FIG. 3 is a graph showing a family of lift curves for a valvetrain equipped with prior art VVA means as shown in FIGS. 1 and 2;

FIG. 4 is an elevational cross-sectional view of a first embodiment of the invention comprising a floating pivot arrangement for an oscillating rocker cam;

FIG. 5 is an isometric view of a dual-acting subassembly comprising identical oscillating rocker arms;

FIG. 6 is an isometric view of a full mechanism in accordance with elements shown in FIGS. 4 and 5 for actuating first and second valvetrains;

FIG. 7 is an isometric view showing the full mechanism of FIG. 6 mounted in a mounting block for installation into an engine head;

FIG. 8 is an isometric view showing geared relationship between a valve-opening camshaft and a valve-closing camshaft;

FIG. 9 is an end view of the assembly shown in FIG. 8;

FIG. 10 is a set of variable valve lift curves showing the effect of advancing the closing cam phaser that can be flexible in design of profile depending on engine application;

FIG. 11 is a set of variable valve duration curves showing the effect of retarding the closing cam phaser;

FIG. 12 is an elevational cross-sectional view of four stages of actuation of the embodiment shown in FIG. 4;

FIG. 13 is an elevational cross-sectional view of a second embodiment of the invention comprising a fixed pivot arrangement for an oscillating rocker cam; and

FIG. 14 is a subassembly for the second embodiment shown in FIG. 13 for operating dual valves; and

FIG. 15 is an assembly for the second embodiment like that shown in FIG. 6 for the first embodiment.

[0015] Corresponding reference characters indicate corresponding parts throughout the several views. The exemplifications set out herein illustrate two preferred embodiments of the invention, and such exemplifications are not to be construed as limiting the scope of the invention in any manner.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0016] The benefits and advantages of a VVA system in accordance with the present invention may be better appreciated by first considering a relevant prior art VVA system for varying valve opening timing, valve closing timing, and valve lift.

[0017] Referring to FIGS. 1 through 3, a prior art VVA valvetrain system 100, substantially as disclosed in Published United States Patent Application No. 2007/0125329, includes a control shaft assembly 1 shown at the intake valve camshaft 2 of an inline 4-cylinder engine which may be spark-ignited or compression-ignited. Control shaft assembly 1 manages an engine's gas exchange process by varying the angular position of the control shaft assembly. In FIGS. 1 and 2, system 100 is shown in its full engine load position. In FIG. 1, the input camshaft is on its base circle portion, and in FIG. 2, the input camshaft is at its peak lift point. High lift events with full duration are produced by the system whenever the control shaft arms 3 are in the nearly vertical position indicated in FIGS. 1 and 2. However, when control shaft assembly 1 is rotated through an angle clockwise on axis 17a from its full load position, such as would be desirable under light engine load conditions, for example through about 27.5°, assembly 1 produces minimal lift events with reduced duration (also see curve 30 in FIG. 3). In this position, control shaft rocker pivot pins 9 are in their closest proximity to input camshaft 2, causing rocker roller 7 to oscillate just right of the centerline 7a of camshaft 2. Likewise, when control shaft assembly 1 is in the light load position, finger follower roller 17 spends most of its time on base circle portion 12 of output cam profile, just barely reaching opening flank 16 of the profile whenever rocker roller 7 is aligned with nose portion 22 of input camshaft lobe 4. In such configuration, assembly 1 produces short and shallow lift events, which minimizes gas flow to the engine. Variably rotating control shaft assembly 1 to intermediate rotational positions between full engine load position and minimum engine load position produces the remaining lift curves (not numbered) within the family depicted in FIG. 3 between curves 30,32.

[0018] As noted above, two significant shortcomings of the just-described prior art invention are a) an inability to keep a constant valve opening timing while varying the valve closing timing, and b) an inability to vary the duration of a fully open valve lift. In addition, this prior art does not permit total valve deactivation via lost motion as may be desired.

[0019] The present invention comprises a new VVA mechanism that provides increased functionality and a simpler, more cost-effective actuator system.

[0020] Functionality of this mechanism makes it suitable to either gasoline or Diesel applications. Gasoline engines require variation in intake valve lift and duration to control the amount of air entering a cylinder during an intake event; whereas, Diesel engines utilizing HCCI require variation in intake valve opening duration with fixed (full) lift to vary the effective compression ratio of the engine during an intake event. The intake valve opening position remains fixed (no inherent phasing) for all lift/duration and duration only variations; however, peak lift advances when the mechanism is used to vary both lift and duration (as for gasoline engine operation). This is an engine requirement for Diesel operation to avoid piston/valve interference.

[0021] Gasoline engine control strategy is simplified in that the intake cam phaser control algorithm does not need to compensate for intake valve opening variation with changes in lift.

[0022] Phasing in the present invention may take advantage of inexpensive prior art employing an electric or hydraulic cam phaser, rather than a DC motor/worm and worm gear arrangement.

[0023] It will be seen that in any arrangement employing a single cam for both opening and closing a valve, the timing of the opening cannot be separated from the timing of the closing because the opening cam flank and the closing cam flank are in fixed relationship on the same cam lobe. The only way to separate the two functions and provide independent control is to provide two cams for each valve (or valve pair): an opening cam and a closing cam. Thus, as described below, a VVA system in accordance with the present invention includes dual dwell camshafts for the opening and the closing. This means that there are two constant radius sections per camshaft: a base radius and a peak nose radius. The duration of the respective radii and the angular relationship between the two camshafts has a significant impact on the performance and function of the device and on an engine thus equipped.

[0024] Referring to FIG. 4, a cross-section is shown of a first preferred embodiment 200 in accordance with the invention.

[0025] A conventional combustion valve 202 is seated in a valve seat 204 by a valve return spring 206. Valve 202 is actuated by a conventional roller finger follower 208 pivotably mounted conventionally on a hydraulic lash adjuster (not shown). These elements define a prior art valvetrain 209.

[0026] A valve opening cam 210 and a valve closing cam 212 are spaced apart from each other and from roller finger follower 208. Each cam 210,212 comprises a base circle portion 211, 213 respectively, having a minimum radius, and a working portion 215,217, respectively having a larger radius which may be variable. Each cam 210,212 further comprises respective ramp portions 219,221 between their respective base circle and working portions.

[0027] A novel oscillating rocker arm 214 comprises a first or intermediate roller 226 defining a first working element that engages valve closing cam 212; a second or outer roller 228 defining a second working element that engages valve opening cam 210; and a rocker cam surface 220 defining a third working element having a base radius portion 222 and a working cam portion 224 that engages the roller 216 of roller finger follower 208. Oscillating rocker arm 214 thus floats among valve opening cam 210, valve closing cam 212, and roller finger follower 208, and is urged into continuous contact therewith by a lost motion spring 232. A guide block 230 includes a surface for guiding the motion of oscillating rocker arm 214 along a predetermined path.

[0028] The oscillating rocker arm 214 is similar in function to those found in some other prior art continuously variable valve train mechanisms. A novel feature of the present oscillating rocker arm 214 is the use of a constant radius base radius portion 222 extending into a working curve of working cam portion 224. This type of curve is determined typically by kinematics from the desired lift profile. The present system, however, does not require such a curve: a simpler more linear contour will also work but provides less satisfactory kinematics/dynamics for the system. The constant radius base radius portion is important in that it is the feature providing lost motion for the device. Its duration is determined by the amount of angular stroke of the oscillating rocker cam (see discussion below respecting FIG. 12). The present mechanism will not provide any lift unless both the opening cam and the closing cam are both in contact with their respective rollers on a part of the cams other than their base circle portion.

[0029] Many internal combustion engines are provided with dual intake valves and dual exhaust valves. Thus, a mechanism in accordance with the invention is also adaptable for use with such dually-provided valve sets, as is now described.

[0030] Referring to FIGS. 5 through 7, a dual-acting mechanism 250 comprises identical oscillating rocker arms 214 mounted on a common shaft 234 extending through rollers 226 and a separating roller 236 that rides on a curved surface 238 in guide block 230. This arrangement permits the axis 239 of rollers 226,236 to "float" in two dimensions as roller 236 moves along surface 238 as required during actuation of mechanism 250. In FIG. 6, a full mechanism 260 for actuating first and second valvetrains 209 includes first and second opening cams 210 mounted on an opening camshaft 262, first and second closing cams 212 mounted on a closing camshaft 264, and a dual lost motion spring 232. Mechanism 250 is disposed among the cams 210,212 and valvetrains 209 as shown. FIG. 7 shows mechanism 260 assembled into a mounting block 266, including bearing caps 268 for closing camshaft 264, for assembly to an engine head 270. Similar bearing caps for opening camshaft 262 are present but not visible.

[0031] Referring to FIGS. 8 and 9, in a preferred embodiment 272 for positively associating the rotary motions of camshafts 262,264, the camshafts preferably are provided with meshed helical gears 274,276, respectively. In accordance with the present invention, opening camshaft gear 274 is driven conventionally by an engine crankshaft and turns once every two revolutions thereof for a four-stroke engine; thus the valve-opening timing is invariant relative to crankshaft angle. An angular phasing device 278 of embodiment 272, for selectively varying the angular relationship between a driven member and a driving member, such as for example a cam phaser which may be of any type but preferably is either vane/hydraulic or electrical, is mounted to closing camshaft gear 276, with its driving member 280 mounted to gear 276 and its driven member 282 mounted for rotation with closing camshaft 264. Thus, the timing of valve closing may be varied by varying the rotary position of phasing device 278 in known fashion. Of course, within the scope of the present invention, the two camshafts may be controllably and variably driven independently by any desired means capable of holding the valve opening timing invariant while varying the phase of the valve closing.

[0032] The benefits of a continuously variable valve actuation system in accordance with the invention are apparent in FIGS. 10 and 11.

[0033] FIG. 10 shows a family of valve lift curves extending from minimum lift curve 330 to maximum lift curve 332. Also referring to FIGS. 4, 8 and 9, maximum lift curve 332 defines a neutral position of the closing camshaft 264 as controlled by phasing device 278 wherein closing cam 212 begins closing the valve as soon as full lift is achieved. Compare these curves to the prior art curves shown in FIG. 3. Unlike the curves shown in FIG. 3, the opening crank angle is constant for all valve lifts, which are varied from maximum lift curve 332 to minimum lift curve 330 by advancing the phase of the closing camshaft from the neutral position. The change in duration of lift exhibits and one-to-one ratio with the change in phase angle, i.e., a 1 cam degree increase or decrease in phase angle results in a corresponding 1 cam degree increase or decrease in duration of valve opening. Note that locus of lift peaks (curve 333) is non-linear and is affected by the opening and closing cam lobe profile designs, and also varies with variation in closing timing. Cam profile design depends on the target full lift profile as well as obtaining the desired low lift profile that will fall with the phaser's authority. Such a Continuously Variable Valve Lift (CVVL) system is highly useful for fueling a gasoline engine, which benefits from variation in valve lift and duration to control the amount of air entering a cylinder during an intake event. As noted above, maintaining a fixed valve opening timing removes one variable in the valve control algorithms.

[0034] FIG. 11 shows a family of valve lift duration curves extending from zero peak duration 430 to maximum peak duration 432. Again, referring to FIGS. 4, 8 and 9 zero peak duration curve 430 defines a neutral position of the closing camshaft 264 as controlled by phasing device 278 wherein closing cam lobe 212 begins closing the valve as soon as full lift is achieved. Thus, curve 430 in FIG. 11 is identical to curve 332 in FIG. 10. By retarding the phase of the closing camshaft, the valve may be held open by the opening cam for an extended period of time. For the case shown in FIG. 11, each curve between curves 430 and 432 represents a 10 cam degree phase retardation by phasing device 278. Thus, a Continuously Variable Valve Duration (CVVD) system in accordance with the invention can maintain maximum valve lift over a significant period of time. As noted above, this is highly useful in Diesel engines utilizing HCCI, which allows variation in effective compression ratio of an engine during an intake event.

[0035] Referring now to FIG. 4 and 12, four different Stages (12a-12d) are shown during operation of first embodiment 200. Note that the opening and closing camshafts counter-rotate because they are geared together as shown in FIG. 8. Of course, it is not a requirement of the present invention that the camshafts counter-rotate. Note further the reference lines 402,404, representing respectively valve fully closed (no lift) and valve fully open (maximum lift).

[0036] In Stages 12a and 12b, closing cam 212 is on its working portion 217. This is required for a lift event to occur because the closing cam governs the position in space of pivot axis 239 about which opening roller 228 and rocker cam surface 220 must pivot.

[0037] In Stage 12a, opening cam 210 is on its base circle portion 211 and rocker cam surface 220 is on its base circle portion 222, so the valve remains closed.

[0038] In Stage 12b, the cams have each rotated approximately 60° from Stage 12a, such that opening cam 210 is now on its working portion 215. The position of pivot axis 239 is unchanged because closing cam 212 is still on its working portion 217. Oscillating rocker arm 214 is thus pivoted about axis 239, causing rocker cam surface 220 to be moved along roller 216 on working cam portion 224of rocker cam surface 220, thus causing the valve to be opened.

[0039] In Stage 12c, the cams have each rotated approximately 60° from Stage 12b, such that closing cam 212 is now entering its base circle portion 213. Although opening cam lobe 210 is still on its working portion 215, the rotation of closing cam 212 to its base circle portion 213 has caused pivot axis 239 to be moved such that the opening cam 210 can no longer open the valve. Variable lift curves such as those shown in FIG. 10 are generated by advancing the phase of the closing cam to begin closing the valve before the opening valve lift has been completed. Conversely, lift curves such as those shown in FIG. 11 are generated by retarding the phase of the closing cam to hold the valve open for a longer time.

[0040] Stages 12a and 12c demonstrate a fundamental property of the system which is both unique and practical. In both stages, the oscillating rocker's cam profile is contacting the roller finger follower roller 216 at the very end of base radius (lost motion) portion 222, or alternatively just before the working portion 224 of the rocker cam surface 220. In Stage 12a, closing cam 212 is contacting on its working portion 217 and opening cam 210 is contacting on its base circle portion 211. For the mechanism to function properly, the same must be true in Stage 12c wherein the opening cam 210 is on its working portion 215 and the closing cam 212 is on its base circle portion 213. This is essentially what provides the lost motion for the mechanism and allows both cams to stay in contact with the oscillating rocker arm at all times.

[0041] In Stage 12d, the cams 210,212 continue to rotate, opening cam 210 moving to its base circle portion 211 in lost motion. The cams will continue to rotate through another approximately 180°, with the valve remaining closed, to return to Stage 12a and the beginning of another valve opening event.

[0042] By judicious placement of the lengths and phases of the working portions in opening and closing cams 210,212, and by providing a phasing device 278 having a larger range of authority, for example, 60 cam degrees or greater, it is possible by phasing the closing cam to provide complete valve deactivation as may be useful in, for example, engine braking of a vehicle.

[0043] Referring now to FIGS. 13 through 15, a second preferred embodiment 500 in accordance with the invention is shown. Components are highly analogous to those shown for first embodiment 200 in FIGS. 4 through 6 and are numbered analogously in the 500 series, the principal difference being that the pivot axis of an oscillating rocker arm is fixed rather than floating, as in the first preferred embodiment 200.

[0044] A valve opening cam 510 and a valve closing cam 512 disposed respectively on camshafts 562, 564 are spaced apart from each other and from roller finger follower 208 (prior art valvetrain 209 is unchanged). Each cam 510, 512 comprises a base circle portion 511, 513 respectively, having a minimum radius, and a working portion 515, 517, respectively having a larger radius which may be variable.

[0045] An oscillating rocker arm 514 engages the roller 216 of roller finger follower 208 and includes a rocker cam surface 520 having a base radius portion 522 and a working cam portion 524. An intermediate link 540 comprises a first roller 526 disposed on a first arm 527 engaging valve opening cam 510, and a second roller 528 disposed on a second arm 529 engaging valve closing cam 512. Intermediate link 540 pivots on an intermediate pivot shaft 590, and both oscillating rocker arm 514 and intermediate pivot shaft 590 rotate about a fixed pivot shaft 592 having a pivot axis 539, in contact with valve opening cam 510, valve closing cam 512, and roller finger follower 208, and is urged into continuous contact therewith by a lost motion spring 532.

[0046] While the invention has been described by reference to various specific embodiments, it should be understood that numerous changes may be made within the spirit and scope of the inventive concepts described. Accordingly, it is intended that the invention not be limited to the described embodiments, but will have full scope defined by the language of the following claims.

Claims

1. A system for variably actuating a combustion valve in a valvetrain in an internal combustion engine, comprising:

a) a first cam for opening said valve, said first cam having a first base circle portion and a first working portion;

b) a second cam for closing said valve, said second cam having a second base circle portion and a second working portion;

c) an oscillating rocker arm having first, second, and third working elements and being disposed among and continuously engaging each of said first cam in contact with said first working element, said second cam in contact with said second working element, and said valvetrain in contact with said third working element; and

d) a phasing device for varying the phase of at least one of said first and second cam lobes to vary actuation of said combustion valve.

2. A system in accordance with Claim 1 further comprising a lost motion spring disposed against said oscillating rocker arm for maintaining said continuous engagement.

3. A system in accordance with Claim 1 wherein said third working element includes a cam surface for engaging said valvetrain.

4. A system in accordance with Claim 3 wherein said cam surface includes a cam surface base circle portion and a cam surface working portion.

5. A system in accordance with Claim 1 wherein said second working portion must be engaged with said oscillating rocker arm to permit said first working portion to open said valve.

6. A system in accordance with Claim 1 wherein said first working portion must be engaged with said oscillating rocker arm to permit said second base circle portion to close said valve.

7. A system in accordance with Claim 1 wherein the phase of at least one of said first and second cams is sufficiently adjustable to prevent said first working portion and said second working portion from being engaged simultaneously with their respective first and second working elements, thus preventing any valve activation during operation of said engine.

8. A system in accordance with Claim 1 wherein said phasing device comprises:

a) a first camshaft supportive of said first cam;
b) a second camshaft supportive of said second cam; and
c) a camshaft phaser disposed on at least one of said first and second camshafts.

9. A system in accordance with Claim 8,
wherein said first camshaft is operatively connected to a crankshaft of said engine to rotate at one-half the crankshaft rotational speed, and
wherein said camshaft phaser is disposed on said second camshaft to variably alter the phase relationship of said second cam to said first cam.

10. A system in accordance with Claim 9, further comprising:

a) a first gear fixed to said first camshaft; and
b) a second gear rotationally disposed on said second camshaft and meshed with said first gear,

wherein a driving member of said camshaft phaser is connected to said second gear for rotation therewith such that said driving member turns synchronously with said first camshaft and said crankshaft, and
wherein a driven member of said camshaft phaser is connected to said second camshaft such that changing the phase relationship of said driven member to driving member causes a phase change between said first and second camshafts.

11. A system in accordance with Claim 1 wherein said oscillating rocker arm oscillates about a floating axis.

12. A system in accordance with Claim 11 wherein said floating axis is coincident with an axis of said second working element.

13. A system in accordance with Claim 1 wherein said oscillating rocker arm oscillates about a fixed axis.

14. A system in accordance with Claim 13 further comprising;

a) an intermediate shaft extending through said oscillating rocker arm; and
b) a fixed shaft extending through said oscillating rocker arm and including said fixed axis.

15. A system in accordance with Claim 1 wherein said first and second working elements are rollers disposed in said oscillating rocker arm.

16. A system in accordance with Claim 1,
wherein said internal combustion engine includes a second valvetrain and combustion valve operative in parallel with said claimed valvetrain and combustion valve, and
wherein said system further comprises a parallel-operating first cam, second cam, and oscillating rocker arm operatively linked to said claimed first cam, second cam, and oscillating rocker arm, respectively.

17. A system in accordance with Claim 1,
wherein said valvetrain includes a poppet valve seat, a poppet valve head and stem, a valve return spring, and a roller finger follower operatively disposed against said valve stem, and
wherein said third working element is engaged with said roller finger follower.

18. A system in accordance with Claim 1 wherein said first cam and said second cam are rotational in opposite directions.

19. A system in accordance with Claim 1 wherein said first cam lobe and said second cam are rotational in the same direction.

20. An internal combustion engine comprising:

a system for variably actuating a combustion valve in a valvetrain in said engine, wherein said system includes,
a first cam for opening said valve, said first cam having a first base circle portion and a first working portion,
a second cam for closing said valve, said second cam having a second base circle portion and a second working portion,
an oscillating rocker arm having first, second, and third working elements and being disposed among and continuously engaging each of said first cam in contact with said first working element, said second cam in contact with said second working element, and said valvetrain in contact with said third working element, and
a phasing device for varying the phase of at least one of said first and second cams to vary actuation of said combustion valve.

21. An internal combustion engine in accordance with Claim 20
wherein said engine is selected from the group consisting of spark-ignited and compression-ignited.

22. An internal combustion engine in accordance with Claim 21
wherein said spark-ignited engine is operated in a mode selected from the group consisting of Continuous Variable Valve Lift and Continuous Variable Valve Duration.

23. An internal combustion engine in accordance with Claim 21
wherein said compression-ignited engine is operated in a Continuous Variable Valve Duration mode.

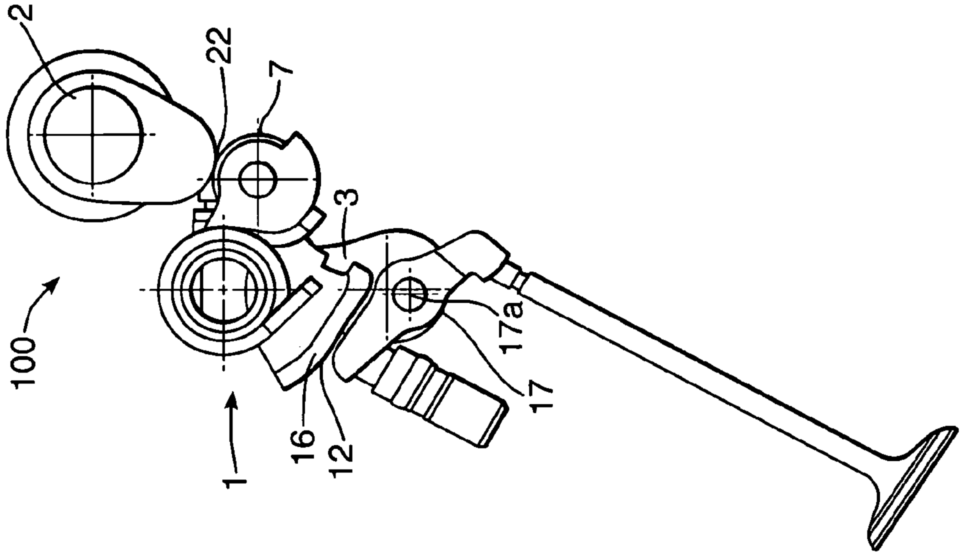

Fig.2.
(Prior Art)

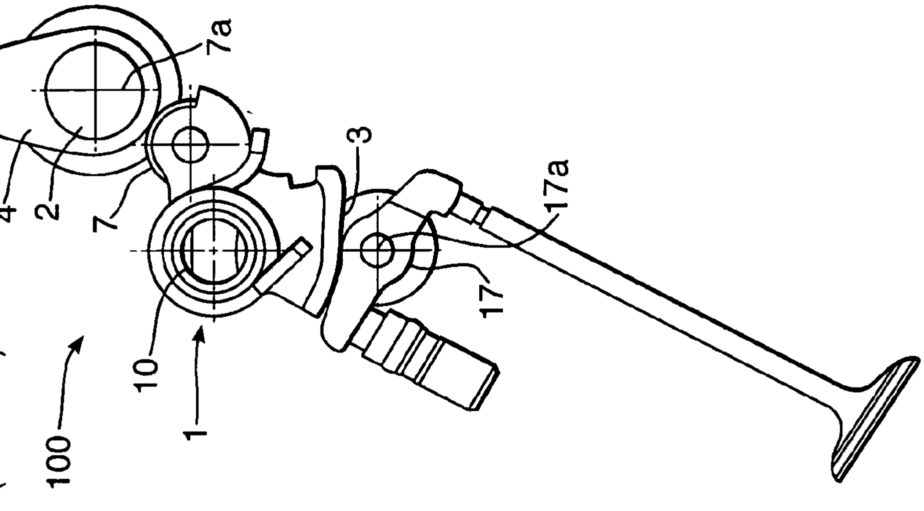

Fig.1.
(Prior Art)

Fig.3.
(Prior Art)

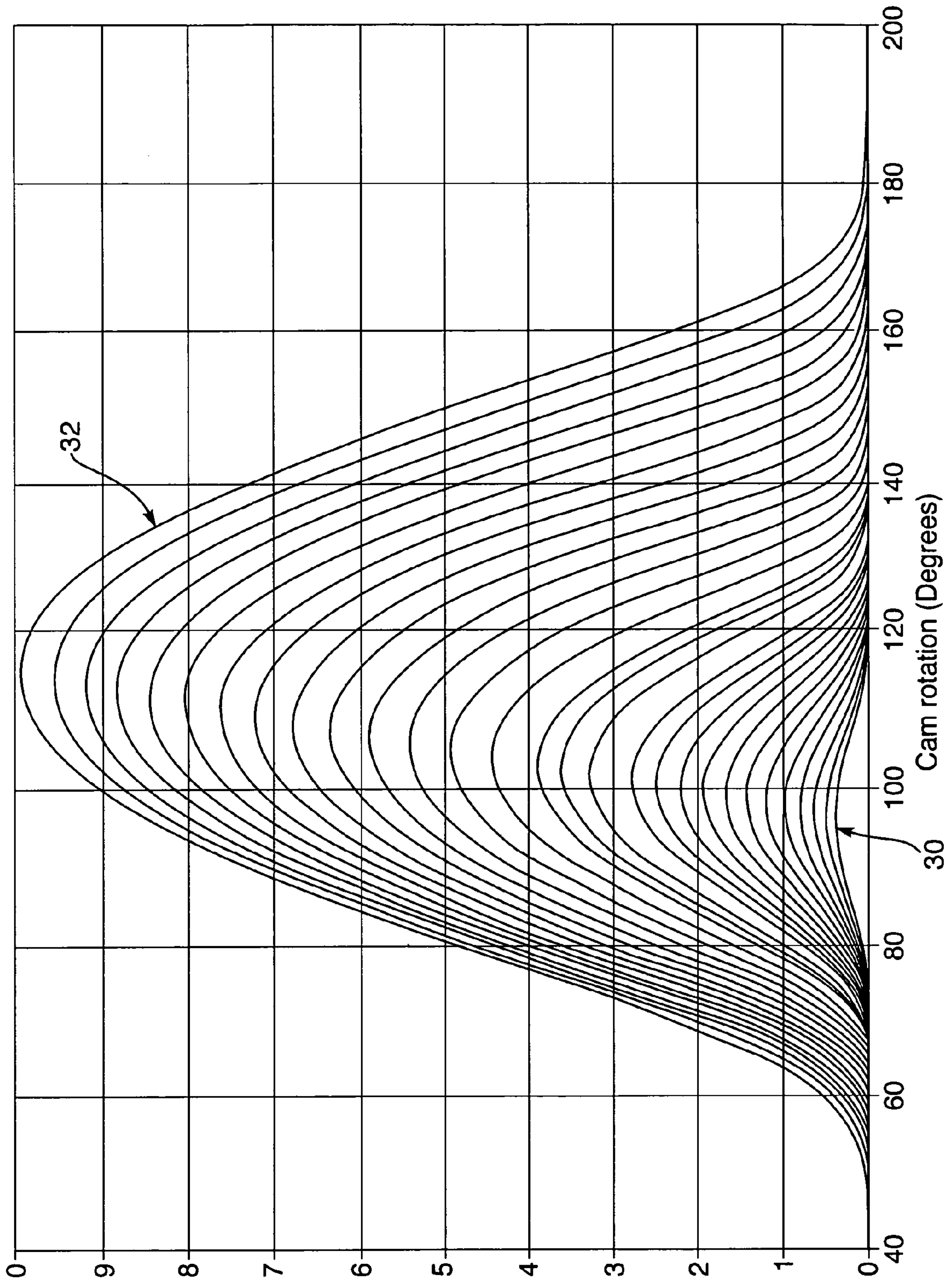

Fig.4.

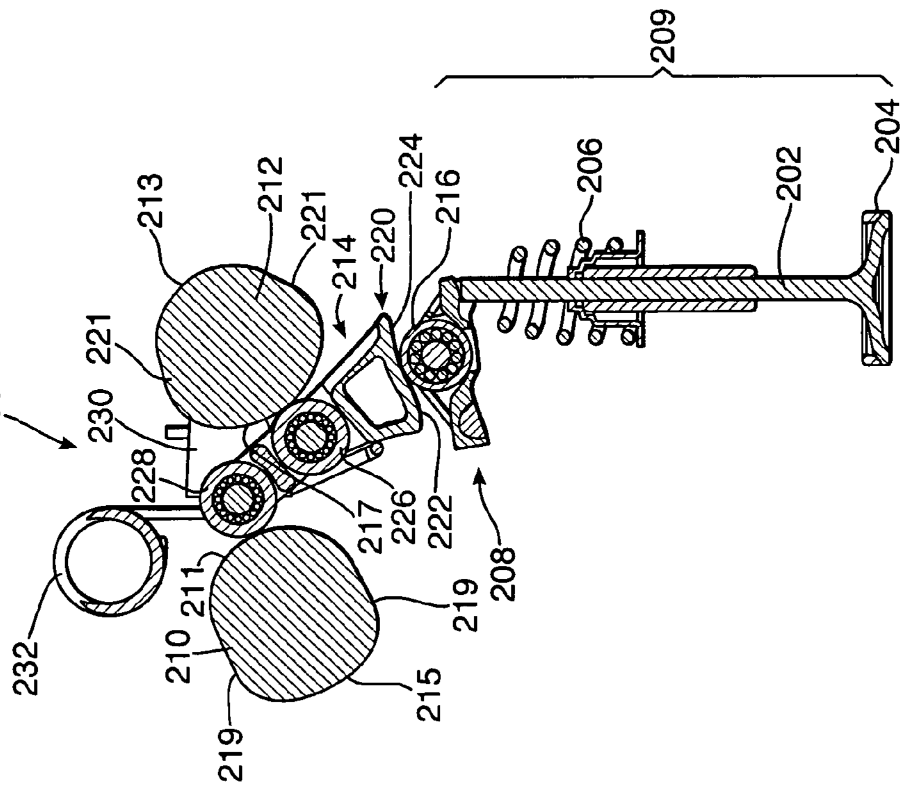
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Fig.5.

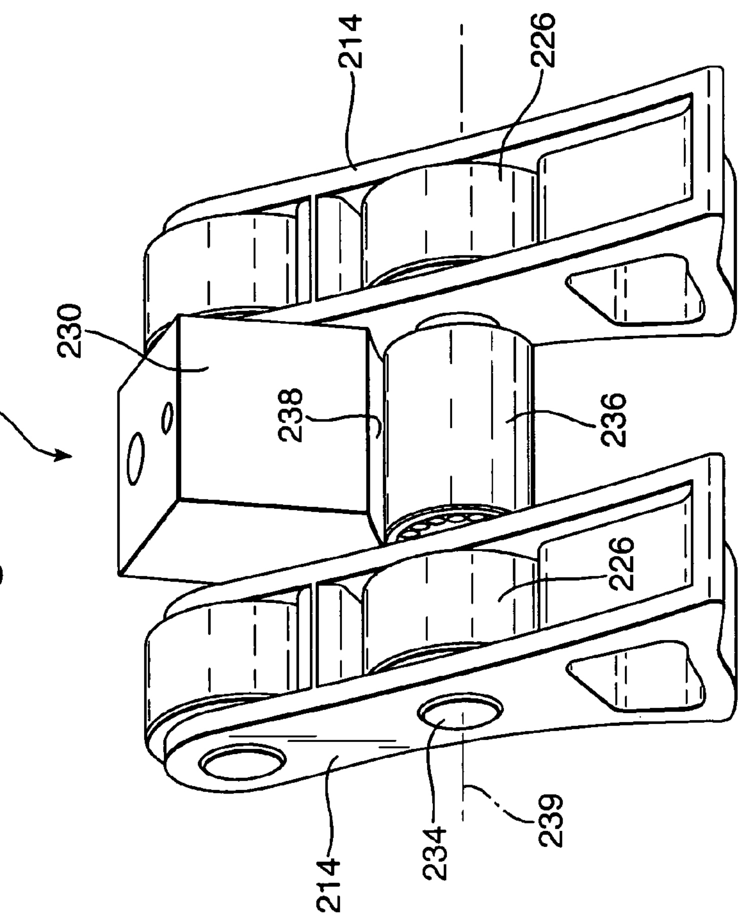
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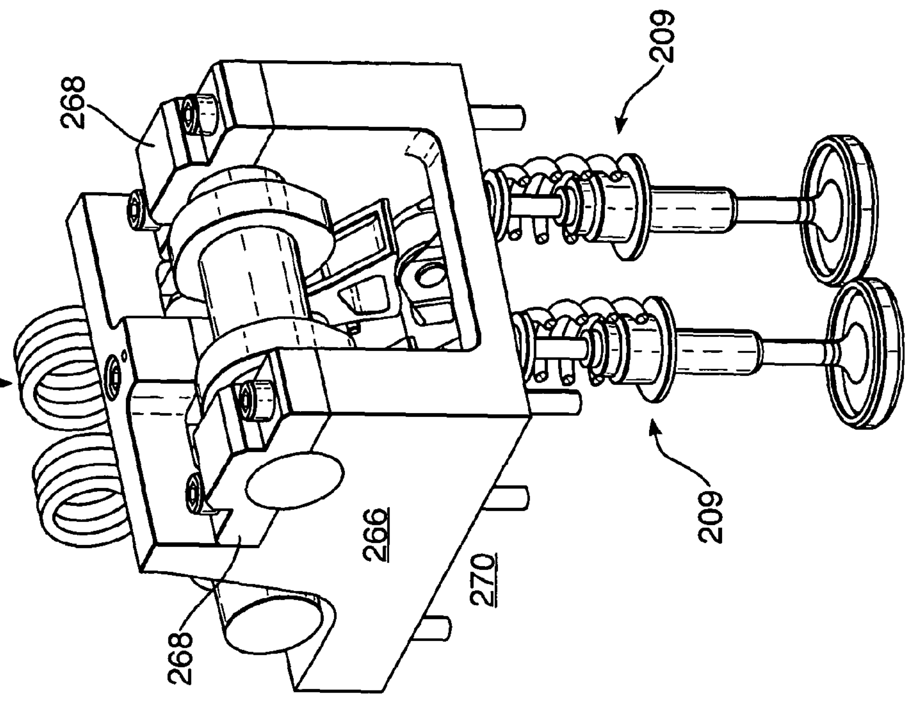
Fig.7.



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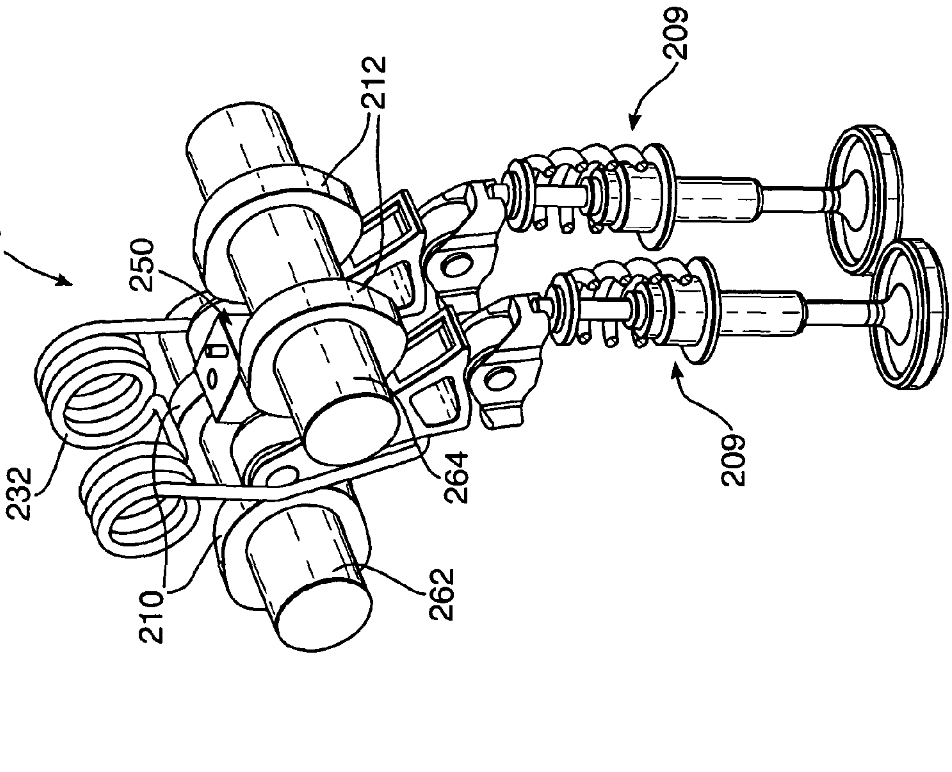


Fig.8.

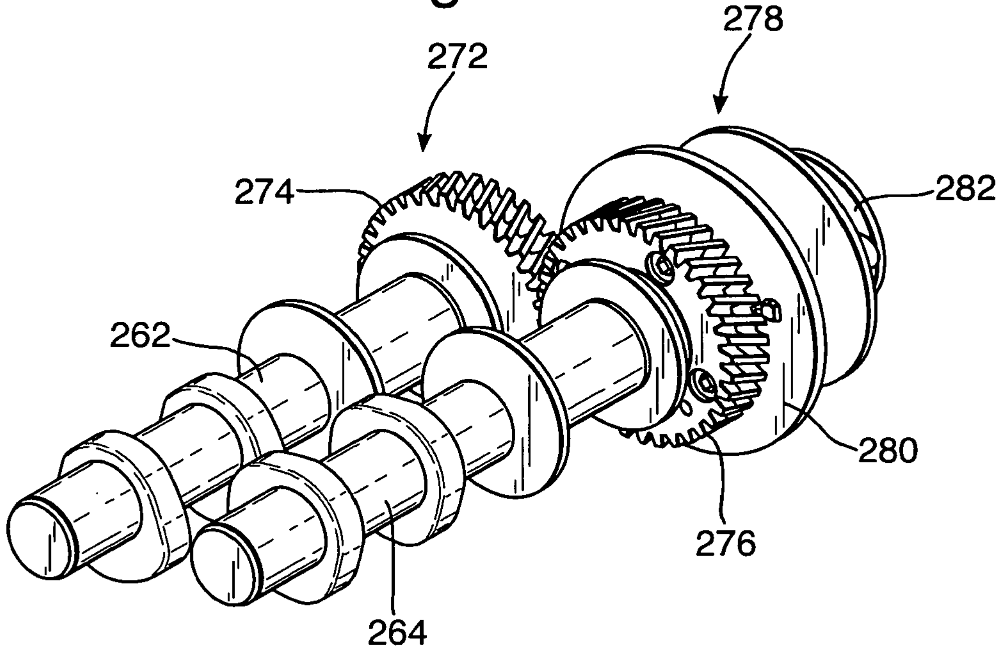


Fig.9.

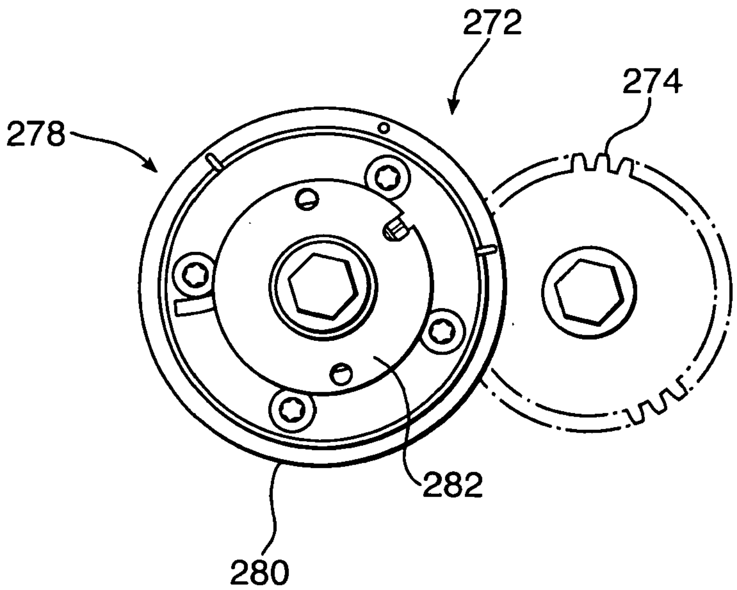
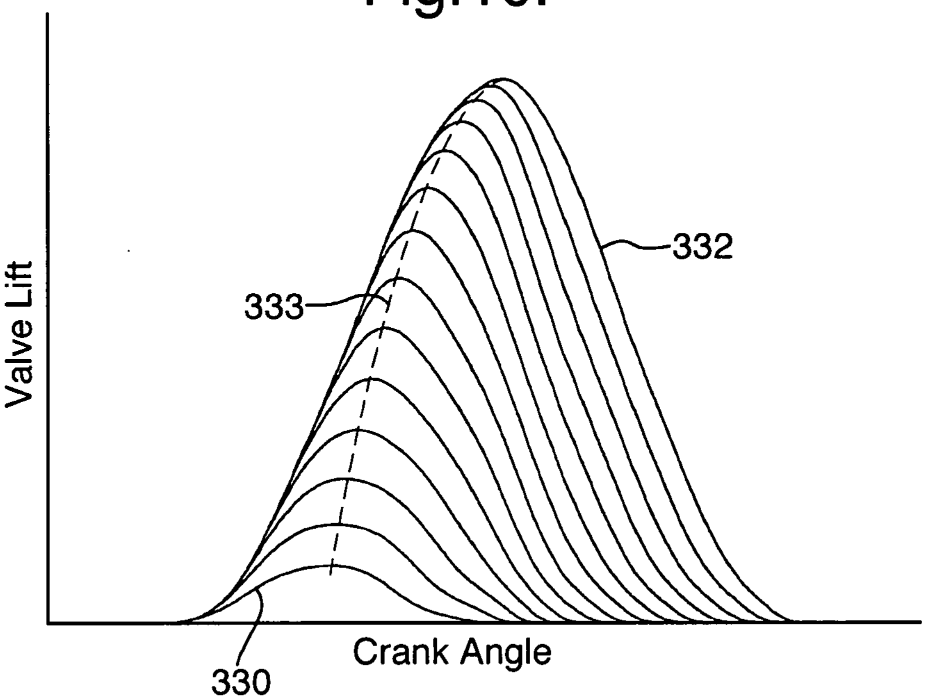


Fig.10.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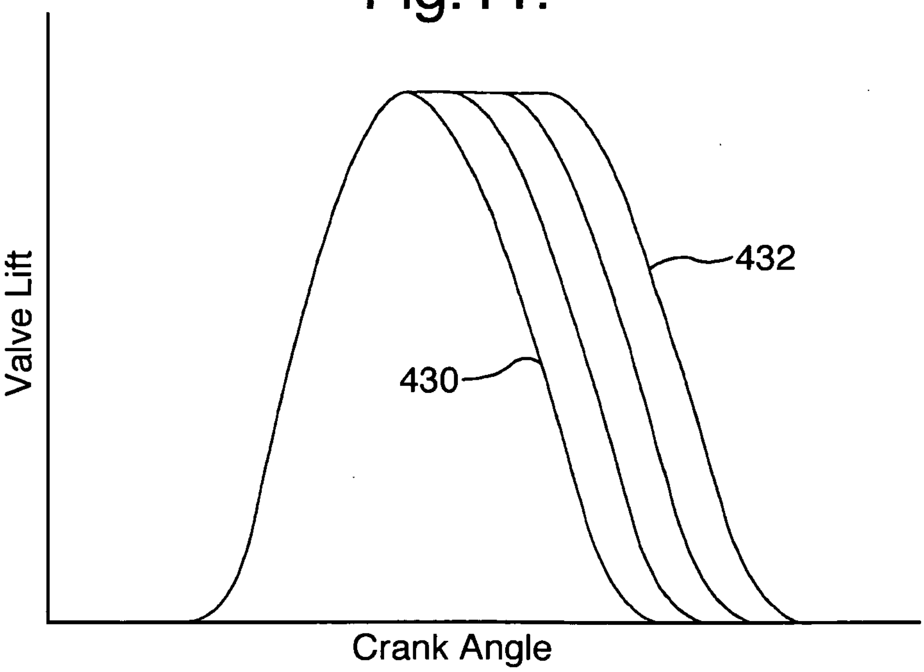
Crank Angle

Fig.11.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Crank Angle

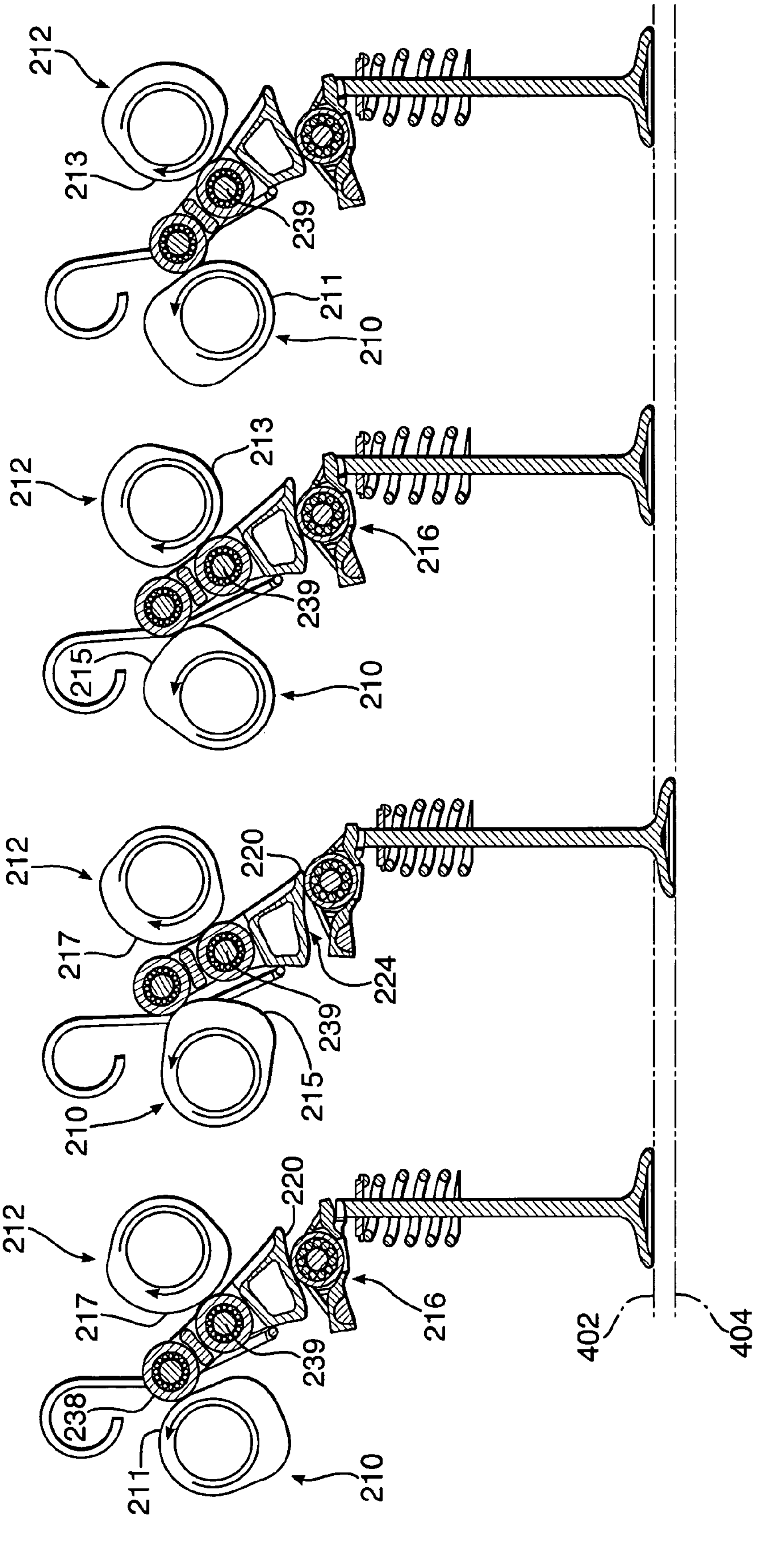


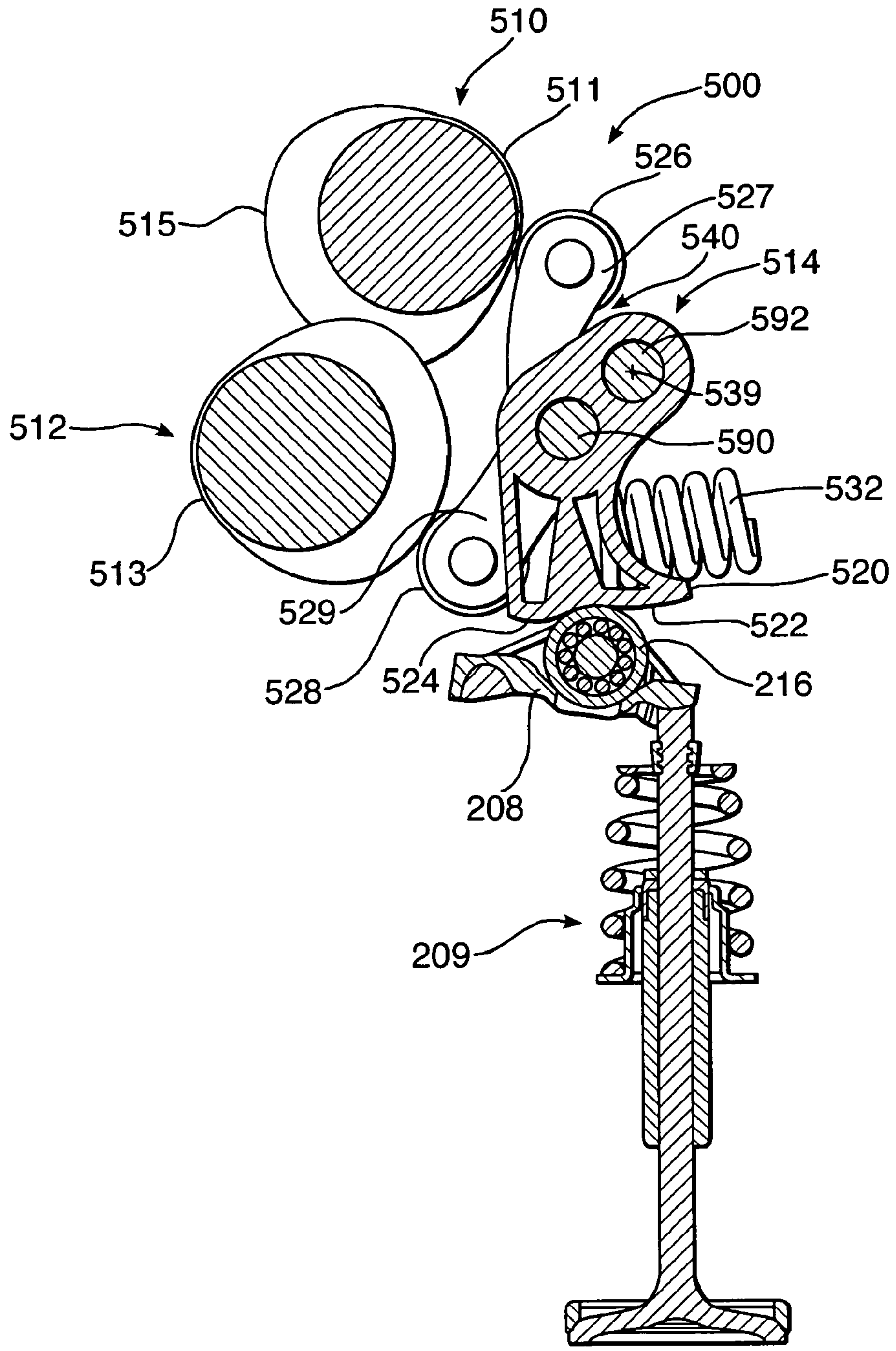
Fig.12a.

Fig.12b.

Fig.12c.

Fig.12d.

Fig.13.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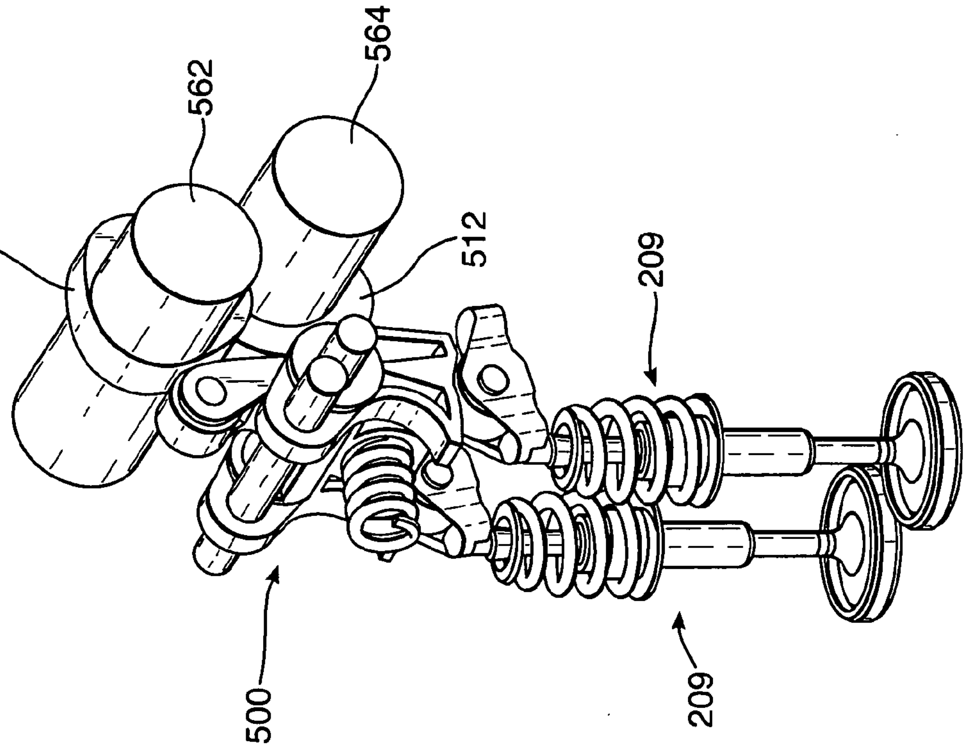
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Fig.15.

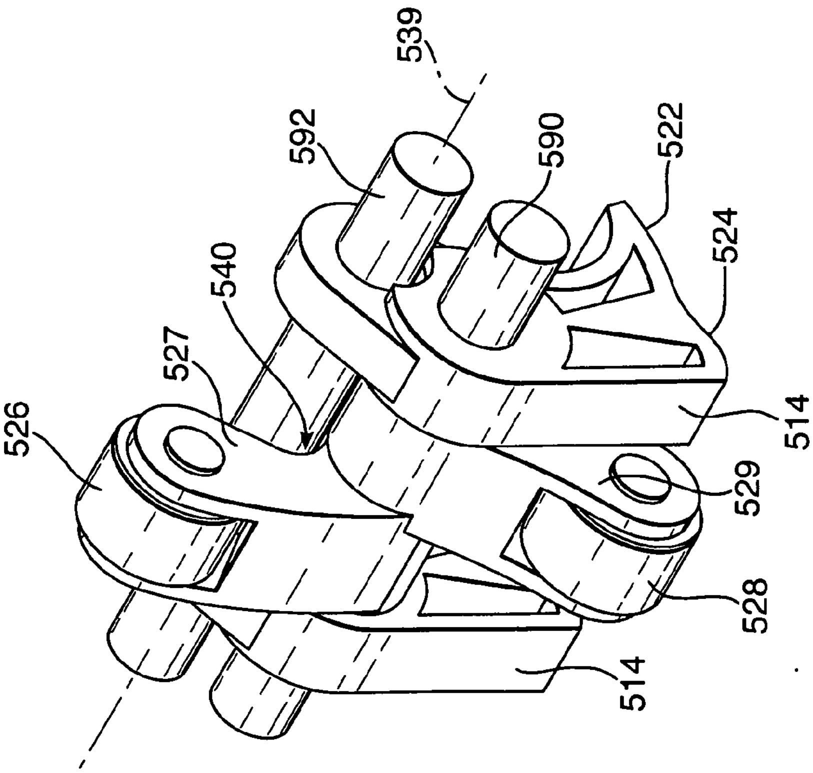
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Fig.14.

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 20070125329 A **[0007] [0017]**
- US 20070125330 A **[0007]**
- US 5937809 A **[0007]**