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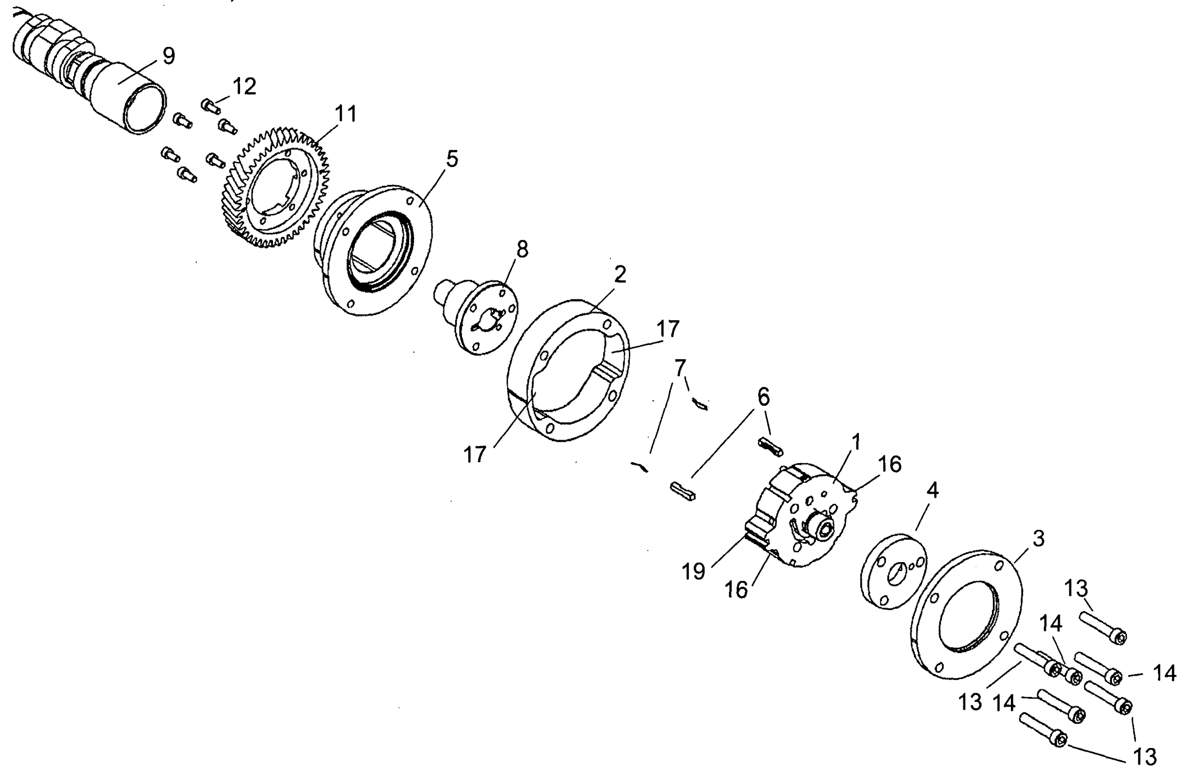
(54) **Camshaft incorporating variable camshaft timing phaser rotor**

(57) In a VCT system, the rotor of a phaser is integral to a shaft such as a camshaft. The lobes on the camshaft are also integral to the camshaft. The axial dimension and the radial dimension of the resultant rotor-cam shaft-cam lobes combination are reduced.

Fig. 1 (Prior Art)



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Description

FIELD OF THE INVENTION

[0001] The invention pertains to the field of camshaft disposition within an internal combustion engine. More particularly, the invention pertains to camshaft incorporating variable camshaft timing (VCT) phaser rotor.

BACKGROUND OF THE INVENTION

[0002] The performance of an internal combustion engine can be improved by the use of dual camshafts, one to operate the intake valves of the various cylinders of the engine and the other to operate the exhaust valves. Typically, one of such camshafts is driven by the crankshaft of the engine, through a sprocket and chain drive or a belt drive, and the other of such camshafts is driven by the first, through a second sprocket and chain drive or a second belt drive. Alternatively, both of the camshafts can be driven by a single crankshaft powered chain drive or belt drive. Engine performance in an engine with dual camshafts can be further improved, in terms of idle quality, fuel economy, reduced emissions or increased torque, by changing the positional relationship of one of the camshafts, usually the camshaft which operates the intake valves of the engine, relative to the other camshaft and relative to the crankshaft, to thereby vary the timing of the engine in terms of the operation of intake valves relative to its exhaust valves or in terms of the operation of its valves relative to the position of the crankshaft.

[0003] Consideration of information disclosed by the following U.S. Patents, which are all hereby incorporated by reference, is useful when exploring the background of the present invention.

[0004] U.S. Patent No. 5,002,023 describes a VCT system within the field of the invention in which the system hydraulics includes a pair of oppositely acting hydraulic cylinders with appropriate hydraulic flow elements to selectively transfer hydraulic fluid from one of the cylinders to the other, or vice versa, to thereby advance or retard the circumferential position on of a camshaft relative to a crankshaft. The control system utilizes a control valve in which the exhaustion of hydraulic fluid from one or another of the oppositely acting cylinders is permitted by moving a spool within the valve one way or another from its centered or null position. The movement of the spool occurs in response to an increase or decrease in control hydraulic pressure, P_c, on one end of the spool and the relationship between the hydraulic force on such end and an oppositely direct mechanical force on the other end which results from a compression spring that acts thereon.

[0005] U.S. Patent No. 5,107,804 describes an alternate type of VCT system within the field of the invention in which the system hydraulics include a vane having lobes within an enclosed housing which replace the oppositely acting cylinders disclosed by the aforementioned U.S. Patent No. 5,002,023. The vane is oscillatable with respect to the housing, with appropriate hydraulic flow elements to transfer hydraulic fluid within the housing from one side of a lobe to the other, or vice versa, to thereby oscillate the vane with respect to the housing in one direction or the other, an action which is effective to advance or retard the position of the camshaft relative to the crankshaft. The control system of this VCT system is identical to that divulged in U.S. Patent No. 5,002,023, using the same type of spool valve responding to the same type of forces acting thereon.

[0006] U.S. Patent Nos. 5,172,659 and 5,184,578 both address the problems of the aforementioned types of VCT systems created by the attempt to balance the hydraulic force exerted against one end of the spool and the mechanical force exerted against the other end. The improved control system disclosed in both U.S. Patent Nos. 5,172,659 and 5,184,578 utilizes hydraulic force on both ends of the spool. The hydraulic force on one end results from the directly applied hydraulic fluid from the engine oil gallery at full hydraulic pressure, P_s. The hydraulic force on the other end of the spool results from a hydraulic cylinder or other force multiplier which acts thereon in response to system hydraulic fluid at reduced pressure, P_c, from a PWM solenoid. Because the force at each of the opposed ends of the spool is hydraulic in origin, based on the same hydraulic fluid, changes in pressure or viscosity of the hydraulic fluid will be self-negating, and will not affect the centered or null position of the spool.

[0007] U.S. Patent No. 5,289,805 provides an improved VCT method which utilizes a hydraulic PWM spool position control and an advanced control method suitable for computer implementation that yields a prescribed set point tracking behavior with a high degree of robustness.

[0008] In U.S Patent No. 5,361,735, a camshaft has a vane secured to an end for non-oscillating rotation. The camshaft also carries a timing belt driven pulley which can rotate with the camshaft but which is oscillatable with respect to the camshaft. The vane has opposed lobes which are received in opposed recesses, respectively, of the pulley. The camshaft tends to change in reaction to torque pulses which it experiences during its normal operation and it is permitted to advance or retard by selectively blocking or permitting the flow of engine oil from the recesses by controlling the position of a spool within a valve body of a control valve in response to a signal from an engine control unit. The spool is urged in a given direction by rotary linear motion translating means which is rotated by an electric motor, preferably of the stepper motor type.

[0009] U.S. Patent No. 5,497,738 shows a control system which eliminates the hydraulic force on one end of a spool resulting from directly applied hydraulic fluid from the engine oil gallery at full hydraulic pressure, P_s, utilized by previous embodiments of the VCT system.

The force on the other end of the vented spool results from an electromechanical actuator, preferably of the variable force solenoid type, which acts directly upon the vented spool in response to an electronic signal issued from an engine control unit ("ECU") which monitors various engine parameters. The ECU receives signals from sensors corresponding to camshaft and crankshaft positions and utilizes this information to calculate a relative phase angle. A closed-loop feedback system which corrects for any phase angle error is preferably employed. The use of a variable force solenoid solves the problem of sluggish dynamic response. Such a device can be designed to be as fast as the mechanical response of the spool valve, and certainly much faster than the conventional (fully hydraulic) differential pressure control system. The faster response allows the use of increased closed-loop gain, making the system less sensitive to component tolerances and operating environment.

[0010] U.S. Patent No. 5,657,725 shows a control system which utilizes engine oil pressure for actuation. The system includes a camshaft that has a vane secured to an end thereof for non-oscillating rotation therewith. The camshaft also carries a housing which can rotate with the camshaft but which is oscillatable with the camshaft. The vane has opposed lobes which are received in opposed recesses, respectively, of the housing. The recesses have greater circumferential extent than the lobes to permit the vane and housing to oscillate with respect to one another, and thereby permit the camshaft to change in phase relative to a crankshaft. The camshaft tends to change direction in reaction to engine oil pressure and/or camshaft torque pulses which it experiences during its normal operation, and it is permitted to either advance or retard by selectively blocking or permitting the flow of engine oil through the return lines from the recesses by controlling the position of a spool within a spool valve body in response to a signal indicative of an engine operating condition from an engine control unit. The spool is selectively positioned by controlling hydraulic loads on its opposed end in response to a signal from an engine control unit. The vane can be biased to an extreme position to provide a counteractive force to a unidirectionally acting frictional torque experienced by the camshaft during rotation.

[0011] U.S. Patent No. 6,247,434 shows a multi-position variable camshaft timing system actuated by engine oil. Within the system, a hub is secured to a camshaft for rotation synchronous with the camshaft, and a housing circumscribes the hub and is rotatable with the hub and the camshaft and is further oscillatable with respect to the hub and the camshaft within a predetermined angle of rotation. Driving vanes are radially disposed within the housing and cooperate with an external surface on the hub, while driven vanes are radially disposed in the hub and cooperate with an internal surface of the housing. A locking device, reactive to oil pressure, prevents relative motion between the housing and the hub. A controlling device controls the oscillation of the housing relative to the hub.

[0012] U.S. Patent No. 6,250,265 shows a variable valve timing system with actuator locking for an internal combustion engine. The variable camshaft timing system is comprised of a camshaft with a vane secured to the camshaft for rotation with the camshaft but not for oscillation with respect to the camshaft. The vane has a circumferentially extending plurality of lobes projecting radially outwardly therefrom and is surrounded by an annular housing that has a corresponding plurality of recesses each of which receives one of the lobes and has a circumferential extent greater than the circumferential extent of the lobe received therein to permit oscillation of the housing relative to the vane and the camshaft while the housing rotates with the camshaft and the vane. Oscillation of the housing relative to the vane and the camshaft is actuated by pressurized engine oil in each of the recesses on opposed sides of the lobe therein, the oil pressure the recesses being preferably derived in part from a torque pulse in the camshaft as it rotates during its operation. An annular locking plate is positioned coaxially with the camshaft and the annular housing and is moveable relative to the annular housing along a longitudinal central axis of the camshaft between a first position, where the locking plate engages the annular housing to prevent its circumferential movement relative to the vane and a second position where circumferential movement of the annular housing relative to the vane is permitted. The locking plate is biased by a spring toward its first position and is urged away from its first position toward its second position by engine oil pressure, to which it is exposed by a passage leading through the camshaft, when engine oil pressure is sufficiently high to overcome the spring biasing force, which is the only time when it is desired to change the relative positions of the annular housing and the vane. The movement of the locking plate is controlled by an engine electronic control unit either through a closed loop control system or an open loop control system.

[0013] U.S. Patent No. 6,263,846 shows a control valve strategy for vane-type variable camshaft timing system. The strategy involves an internal combustion engine that includes a camshaft and hub secured to the camshaft for rotation therewith, where a housing circumscribes the hub and is rotatable with the hub and the camshaft, and is further oscillatable with respect to the hub and camshaft. Driving vanes are radially inwardly disposed in the housing and cooperate with the hub, while driven vanes are radially outwardly disposed in the hub to cooperate with the housing and also circumferentially alternate with the driving vanes to define circumferentially alternating advance and retard chambers. A configuration for controlling the oscillation of the housing relative to the hub includes an electronic engine control unit, and an advancing control valve that is responsive to the electronic engine control unit and that regulates engine oil pressure to and from the advance chambers. A retarding control valve responsive to the electronic engine control unit regulates engine oil pressure to and from the retard chambers. An advancing passage communicates engine oil pressure between the advancing control valve and the advance chambers, while a retarding passage communicates engine oil pressure between the retarding control valve and the retard chambers.

[0014] U.S. Patent No. 6,311,655 shows multi-position variable cam timing system having a vane-mounted locking-piston device. An internal combustion engine having a camshaft and variable camshaft timing system, wherein a rotor is secured to the camshaft and is rotatable but non-oscillatable with respect to the camshaft is described. A housing circumscribes the rotor and is rotatable with both the rotor and the camshaft. The housing is further oscillatable with respect to both the rotor and the camshaft between a fully retarded position and a fully advanced position. A locking configuration prevents relative motion between the rotor and the housing, and is mounted within either the rotor or the housing, and is respectively and releasably engageable with the other of either the rotor and the housing in the fully retarded position, the fully advanced position, and in positions therebetween. The locking device includes a locking piston having keys terminating one end thereof, and serrations mounted opposite the keys on the locking piston for interlocking the rotor to the housing. A controlling configuration controls oscillation of the rotor relative to the housing.

[0015] U.S. Patent No. 6,374,787 shows a multi-position variable camshaft timing system actuated by engine oil pressure. A hub is secured to a camshaft for rotation synchronous with the camshaft, and a housing circumscribes the hub and is rotatable with the hub and the camshaft and is further oscillatable with respect to the hub and the camshaft within a predetermined angle of rotation. Driving vanes are radially disposed within the housing and cooperate with an external surface on the hub, while driven vanes are radially disposed in the hub and cooperate with an internal surface of the housing. A locking device, reactive to oil pressure, prevents relative motion between the housing and the hub. A controlling device controls the oscillation of the housing relative to the hub.

[0016] U.S. Patent No. 6,477,999 shows a camshaft that has a vane secured to an end thereof for non-oscillating rotation therewith. The camshaft also carries a sprocket that can rotate with the camshaft but is oscillatable with respect to the camshaft. The vane has opposed lobes that are received in opposed recesses, respectively, of the sprocket. The recesses have greater circumferential extent than the lobes to permit the vane and sprocket to oscillate with respect to one another. The camshaft phase tends to change in reaction to pulses that it experiences during its normal operation, and it is permitted to change only in a given direction, either to advance or retard, by selectively blocking or permitting the flow of pressurized hydraulic fluid, preferably engine oil, from the recesses by controlling the position of a spool within a valve body of a control valve. The sprocket has a passage extending therethrough the passage extending parallel to and being spaced from a longitudinal axis of rotation of the camshaft. A pin is slidable within the passage and is resiliently urged by a spring to a position where a free end of the pin projects beyond the passage. The vane carries a plate with a pocket, which is aligned with the passage in a predetermined sprocket to camshaft orientation. The pocket receives hydraulic fluid, and when the fluid pressure is at its normal operating level, there will be sufficient pressure within the pocket to keep the free end of the pin from entering the pocket. At low levels of hydraulic pressure, however, the free end of the pin will enter the pocket and latch the camshaft and the sprocket together in a predetermined orientation.

[0017] In some VCT systems, a phaser having a rotor needs to be rigidly affixed to a camshaft and angularly adjustable in relation to other parts of the phaser.

[0018] Referring to Fig. 1, an exploded view of a prior art VCT device or phaser is depicted. A rotor 1 is fixedly positioned on the camshaft 9, by means of mounting flange 8, to which it and rotor front plate 4 is fastened by screws 14. The rotor 1 has a diametrically opposed pair of radially outwardly projecting vanes 16, which fit into recesses 17 in the housing body 2. The inner plate 5, housing body 2, and outer plate 3 are fastened together around the mounting flange 8, rotor 1 and rotor front plate 4 by screws 13, so that the recesses 17 holding the vanes 16, enclosed by outer plate 3 and inner plate 5, form fluid-tight chambers. The timing gear 11 is connected to the inner plate 5 by screws 12. Collectively, the inner plate 5, housing body 2, outer plate 3 and timing gear 11 will be referred to herein as the "housing".

[0019] Japanese Patent publication number 04209912(A), entitled: "Valve System Of Engine" teaches an improved apparatus having a simplified structure with improved supporting rigidity by holding the hub of a variable valve timing mechanism on a camshaft end part by a means of a cylindrical shaft member to fasten the hub by means of a fastening member, and bearing-supporting the shaft member on a cylinder head.

[0020] The use of a hub on a variable valve timing mechanism to fasten the same onto a camshaft is known. Japanese Patent 04209912 (A) teaches a simplified structure having improved supporting rigidity by holding the hub of a variable valve timing mechanism on a camshaft end part by a means of a cylindrical shaft member to fasten the hub by means of a fastening member, and bearing-supporting the shaft member on a cylinder head. The structure of the device is as follows. In a V typed engine 1 provided with a DOHC valve system, gears 7, 8 provided between cams are arranged on respective one end parts of an intake side camshaft 2 and an exhaust side camshaft 3 so as to engage each other as a driving wheel provided between the cams. A variable valve timing mechanism 20 is arranged inside the boss part 7a of the gear 7 provided between the cams of the intake side. A cylindrical shaft member 17a for holding the hub 21 of the variable valve timing mechanism 20 is provided on the center part of the gear 7 provided between the cams of the intake side, and the shaft member 17 is installed by a jointing member 18 jointed on the camshaft 2. The journal part 17a of the shaft member 17 is bearing-supported on a front end bearing part 5a mounted in the forward of the gear chamber 9 of a cylinder head 4.

[0021] The use of brazing in forming a camshaft is known. Japanese Patent 60021195 (A) teaches a device that has a joined camshaft consisting of joint members and a shaft member joined to the strength equivalent to the strength of the base metal by subjecting the shaft part of the camshaft consisting of a steel material and fitting members such as cam members, journal members, etc. formed of a cast iron to join by copper brazing in a furnace. The device includes a shaft part 2 consisting of a hollow or solid steel material and separately manufactured fitting members made of a cast iron such as cam members 4, journal members 5, etc. are disposed in prescribed positions and are joined under the following conditions: The shaft part 2 and the above-described fitting members are joined by brazing in a furnace for ≥15min in a temp. range of 1,090W1,150°C non- oxidizing atmosphere. It is necessary in this case to maintain the hardness of the cast iron fitting members within a 130W320Hv range. The joint strength between the fitting members and the shaft member is thus made equivalent to or higher than the strength of the base metal. However, no rotor of a VCT phaser is involved herein.

[0022] The forming of cam lobes by means of swaging is known. European patent EP0313985B1 teaches a method of making a camshaft from a blank having a cam shape, the configuration of the camshaft with the cams and the bearings being moulded into the blank by swaging and circular kneading by means of tool segments which at least partially surround the blank and exert radial compressive forces thereon and thus alter the shape and the cross section of the blank, characterized in that, in a first step, the cam-shaped blank is given an at least approximately circular shape by preforming by means of forging or hammering in the region of the bearings of the camshaft, and that subsequently, in a second step, the configuration of the camshaft with the cams and the bearings is molded by swaging and circular kneading by means of tool elements which at least partially surround the blank and exert radial compressive forces thereon and thus alter its shape and cross section both in the region of the bearings and in the remaining regions of the camshaft. However, no rotor of a VCT phaser is involved herein.

[0023] However, in virtually all VCT technology applications, the VCT units such as a phaser need to be downsized in order to reduce packaging requirements. The form factor that limits the axial and radial package of a VCT needs to be suitably reduced. Further, the use of a more permanent means of affixing the rotor of a phaser to the camshaft will allow for reduction in the radial packaging requirements.

[0024] Typically in a VCT assembly, a pilot is needed for locating the VCT system. Additional fasteners are required in the assembly; elaborate hydraulic seals are required for the rotor, camshaft. in addition, the cam lobe are separated into independent pieces. As can be seen, the separated and independent nature of the assembly necessarily entails mounting of the same and its concomitant adjustments. Therefore, it is desirable to have a single piece rotor-camshaft-cam lobe assembly.

SUMMARY OF THE INVENTION

[0025] In a VCT device, a single piece rotor-cam shaft-cam lobe assembly is provided.

[0026] In a VCT device, an actuator, instead of being placed at the rotor end of the single piece rotor-cam shaft-cam lobe member, is placed at the opposite end.

[0027] A VCT device, which provides a rotor that is machined out of a single piece of material in which camshaft and cam lobe are also formed thereon.

[0028] In a VCT device, alignment of bearing surfaces is improved in that no inter-member alignment of bearing surface is involved for the present single piece rotor-cam shaft-cam lobe member.

[0029] In a VCT device of a motor cycle engine, the extra space taken by the actuator is eliminated by having the same placed at the opposite end of the camshaft.

[0030] In a VCT device, a back plate having a cam shaped inner opening is provided for facilitating its mounting of the backing plate.

[0031] In a VCT device, permanent means of affixing part of the VCT device onto a shaft is provided.

[0032] In a VCT device, a set of non-reversible means of affixing part of the VCT device onto a shaft is provided.

[0033] In VCT systems, the rotor of a phaser is permanently, non-reversibly affixed onto a camshaft.

[0034] A VCT device having reduced form factors are provided. The reduced form factors include axial reduction and radial reduction.

[0035] A VCT device free from area on its frontal face for receiving connecting members such as bolt or screws is provided.

[0036] Accordingly, a device is provided, which includes: a first end having a rotor with a hollow space positioned at the center disposed to rotate relative to a housing; and a rotating shaft, integral to the rotor, having a plurality of lobes thereon terminating to a second end, the rotating shaft being made of the same material as the rotor.

[0037] Accordingly, a VCT system is provided. The system includes: a phaser having a housing and a rotor; and a device. The device includes: a first end having the rotor with a hollow space positioned at the center disposed to rotate relative to the housing; and a rotating shaft, integral to the rotor, having a plurality of lobes thereon terminating to a second end, the rotating shaft being made of the same material as the rotor.

BRIEF DESCRIPTION OF THE DRAWING

[0038]

Fig. 1 shows an exploded view of a prior art VCT device.

Fig. 2 shows a frontal view of a prior art rotor.

Fig. 2A shows a frontal view of the rotor of the present invention.

Fig. 3 shows a first perspective view of the preferred embodiment of the present invention.

Fig. 4 shows a second perspective view of the preferred embodiment of the present invention.

Fig. 5 shows an alternative embodiment of the present invention.

Fig. 6 shows a more detailed blow up view of the single piece rotor-cam shaft-cam lobe member of Fig. 5.

Fig. 7 shows a perspective view of the single piece rotor-cam shaft-cam lobe member of Fig. 5.

Fig. 8 shows a sectional view of the single piece rotor-cam shaft-cam lobe member of Fig. 5.

Fig. 9 shows an alternative of single piece rotor-cam shaft-cam lobe member of Fig. 5.

Fig. 10 shows a first means of connection of the present invention.

Fig.11 shows a second means of connection of the present invention.

Fig.12 shows a third means of connection of the present invention.

Fig. 13 shows a fourth means of connection of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0039] It is desirable to suitably shorten the axial length of a VCT device such as a phaser by eliminating mounting flange 8 that is mounted onto a shaft such as the camshaft 9. As can be seen, by eliminating flange 8, the axial length of the VCT device is shortened in that some axial dimensional contribution in length of flange 8 is reduced. Flange 8 has openings or holes for accommodating or receiving connecting members such as screws 14 for connecting portions of the phaser such as the rotor 1 onto camshaft 9. New means for connecting portions of the phaser such as the rotor 1 onto camshaft 9 is disclosed infra. Further, it is desirable to suitably reduce dimensionally the radial size of the VCT device by eliminating fasteners such as screws 14. Thereby region 18 can be eliminated. By eliminating region 18, the radial dimension of the VCT device can be reduced.

[0040] Referring to Fig. 2, frontal view 10 of a prior art rotor is shown. In the present figure, three lobes 16 are shown. All the rest of the features and parts herein the present figure are substantially similar to that of Fig. 1. A region 18 is provided for accommodating the screws 14. Region 18 is limited by two concentric circles (in broken line) having a common center. Openings 14a are distributed within region 18 for allowing the screws 14 to pass through for fastening purposes. For example, as shown in Fig. 1, screws 14 transpose through rotor 1 and fasten themselves onto flange 8.

[0041] Referring to Fig. 2A, a frontal face view 10a of the rotor 1a of the present invention is shown. Frontal view 10a is substantially identical to frontal view 10 of Fig. 2 except that region 18 is eliminated. As can be appreciated, the elimination of region 18 causes a reduction of radial dimension of rotor 1a in that the area of the front face of rotor 1a is smaller as compared with that of the rotor 1 of Figs 1 and 2.

[0042] Vanes 16 are provided that may have similar or different size as that of Fig. 2. Further, the number of vanes 16 per rotor 1a may be any natural number or positive integer. In addition, an opening 19 is provided for the coupling of rotor 1a with a shaft such as camshaft 9 of Fig. 1.

[0043] Figs. 3 and 4 depict perspective views of the present invention. Referring to Fig. 3, a first perspective view of the VCT device, in part, is shown. The VCT device comprises rotor 1a which constitutes part of a phaser. Rotor 1a has opening 19 formed substantially at the center of rotor 1a. Rotor 1a is connected to a first end of the camshaft 9, which has cam lobes 22 at a distance to the first end respectively. Rotor 1a is connected to camshaft 9 without the use of screws 14 and the flange 8 of the prior art phaser device shown in Figs. 1 and 2. The rotor 1a and camshaft 9 are connected together in a non-reversible means described infra. As can be seen, the functional portion of what is indicated as flange 8 in Fig. 1 is now incorporated in the camshaft/phaser component in Figs 3 and 4.

[0044] Referring to Fig. 4, a second perspective view of the VCT device of Fig. 3 is shown. Note that flange 8 of Fig. 1 or other interposing members of prior art is eliminated. Therefore, the axial length of the device along the length of camshaft 9 is shortened.

[0045] Referring to Fig. 5, an alternative embodiment of the present invention is shown. A camshaft 9a and a rotor 1b are integrally connected together. Rotor 1b has slots 26 disposed to receive vanes (not shown) preferably made of steel. In other words, the vanes, instead of formed as an extension of the rotor or formed integrally with the rotor, the vanes are separate parts that needs to be inserted into slots 26 in the rotor 1b.

[0046] Referring to Figs 6-9, a detailed description of single piece rotor-cam shaft-cam lobe assembly of the present invention is shown.

[0047] Referring to Fig. 6, a more detailed blow up view of a single piece rotor-cam shaft-cam lobe member 38 is shown. In single piece rotor-cam shaft-cam lobe member 38, cam lobes 22, camshaft 9a, and rotor 1b are formed out of a single piece or member. For example, single piece rotor-cam shaft-cam lobe member 38 is machined out of a single metal or alloy piece. Slots 26 are located on the outer circumference of rotor 1b for the accommodation of vanes 40 having vane springs 42 interposed therebetween. Vanes 40 are disposed to oscillate within cavities 43 formed within sprocket housing 44. A check valve 46 is provided within rotor 1b for controlling control fluid flowing unidirectionally within a passage, wherein a segment of which is formed within the single piece rotor-cam shaft-cam lobe member 38. A lock pin 48 is provided for locking sprocket housing 44 and rotor 1b into a fixed angular relationship. An accompanying spring pin 49 and lock pin spring 50 are provided for coupling to lock pin 48. A sleeve 52 having a sleeve slot 54 is disposed to fit in the opening 19. A backing plate 56 is provided to cover the back portion of the rotor 1b and sprocket housing 44 unit to contain control fluid within the VCT system. Backing plate 56 has a cam shaped inner openings 57 for allowing the same to traverse through the cam lobes 22 before reaching the desired location for the final assembly.

[0048] Referring to Fig. 7, a perspective view of the VCT assembly is shown. The single piece rotor-cam shaft-cam lobe member 38 including camshaft 9a, rotor 1b, and cam lobes 22 are shown. At the rotor 1b end of single piece rotor-cam shaft-cam lobe member 38, sprocket housing 44 is disposed to be engagable with single piece rotor-cam shaft-cam lobe member 38 for adjusting an angular relationship. Lock pin 48 with its accompanying lock pin spring 50 are disposed to be positioned in sprocket housing 44 as shown for stopping or rigidly fixing an angular relationship of the phaser assembly. Pulse wheel 58 is provided to be coupled to the sprocket housing 44 as shown. Pulse wheel 58 includes teeth 59 for generating pulses as wheel 58 turns. A retaining element 60 is disposed about the center of pulse wheel 58 for fitting in the sleeve slot 54 of sleeve 52.

[0049] Referring to Fig. 8, a sectional view of the VCT assembly is shown. Note that single piece rotor-cam shaft-cam lobe member 38 that comprises rotor 1b, camshaft 9a, and cam lobes 22 are formed out of a single piece of material. Single piece rotor-cam shaft-cam lobe member 38 may be made out of a single piece machined alloy material. Spool valve 62 is substantially disposed within the rotor 1b portion of single piece rotor-cam shaft-cam lobe member 38 and having spool spring 64 placed at the inner end of sleeve 52. Control fluid passages 66 are formed within single piece rotor-cam shaft-cam lobe member 38 for facilitating the controlled flow of control fluid flowing therein. Sprocket housing 44 and backing plate 56 are mounted on the VCT assembly as shown.

[0050] Referring to Fig. 9, an alternative of the present invention is shown. In this alternative embodiment, actuator 70, instead of being placed at the rotor 1b end of the single piece rotor-cam shaft-cam lobe member 38, is place at the opposite end. A hollow tube 72 is formed within the single piece rotor-cam shaft-cam lobe member 38 for accommodating a set of force transmitting members in the transmission of force from actuator 70 to spool valve 62 and then to spool spring 64 which is anchored on a seat (not shown). This causes the displacement of spool valve 62 in which controlled fluid are controlled in such a way that an angular relationship is adjusted or maintained. The set of force transmitting members comprises a first ball joint 74a, a second ball joint 74b, a first force transmitting segment 76a, a second force transmitting segment 76b, and a third force transmitting segment 76c. The spool valve 62 and spool spring 64 are placed within sleeve 52. Control fluid pressure is maintained within the hollow tube 72. There exits a balancing force with the hollow tube 72 as a result of control fluid pressure therein. Further the hollow tube nature of hollow tube 72 necessarily reduces the mass of single piece rotor-cam shaft-cam lobe member 38. Further, because of the hollow nature of hollow tube 72, single piece rotor-cam shaft-cam lobe member 38 may be made of materials of higher stiffness than a non-hollow member. In addition, actuator 70 may be a type of solenoid such as variable force solenoid (VFS). One advantage of placing actuator 70 on the on the opposite side as shown herein is that for a two cylinder motor cycle engine, the extra space taken by the actuator 70 may impede the operation and comfort of the vehicle driver.

[0051] As can be seen, the present invention may provide a rotor that is machined out of a single piece of material in which camshaft and cam lobe are also formed thereon. This way, the alignment of bearing surfaces is improved in that no inter-member alignment of bearing surface is involved for the present single piece rotor-cam shaft-cam lobe member 38. Further, the load capability of the bearings is improved as well. For example, the rotor 1b sprocket housing 44 bearing surface is improved in that no flange is required. In addition, check valve 46 may be placed within the single piece rotor-cam shaft-cam lobe member 38 assembly including the camshaft 9a. Also note that cam shaped inner opening 57 of backing plate 56 possesses a unique shape for facilitating its mounting in that cam lobes 22 need to be traversed before the eventual mounting of backing plate 56.

[0052] In addition, some features such as check valves seats, etc. may be machined integral onto the face of the rotor 1b or other portions of rotor-cam shaft-cam lobe member 38. Furthermore, the number of cam lobes is not limited to two.

[0053] By way of an example, the present invention teaches method and apparatus to apply VCT technology to desired applications such as connecting parts of a phaser on a first end of a camshaft. The relevant size of units such as rotor 1a size must be downsized in order to reduce packaging requirements. One factor that limits the axial and radial package of prior art product is the bolt circle diameter that affixes the phaser rotor to the end of the camshaft. In other words, region 18 of Fig. 2 affects or increases the dimension of a phaser, camshaft combination device. Further, the use of a more permanent means of affixing the rotor to the camshaft is desirable in that a reduction in the radial packaging requirements is achieved. The permanent means can be a non-reversible way to affix rotor 1a onto camshaft 9 in that once the two pieces, rotor 1a or rotor 1b and camshaft 9, are rigidly affixed to each other; the end product is generally a fixed thing in that taking the thing apart once they are rigidly affixed onto each other tends to render the whole thing useless. By way of a counter example, the prior art uses screws 14 (in Fig. 1) for non-permanently affixing rotor 1 onto camshaft 9, which is undesirable in that area 18 and flange 8 are required. Area 18 and flange 8 are undesirable because they increase the dimension of an end product such as the phaser. The dimension increases include both an axial increase via the introduction of flange 8, and the radial increase via the introduction of area 18. The present invention teaches the reduction of both the axial dimension and the radial dimension of a VCT device by eliminating both the flange 8 and area 18. As radial package space is reduced, the phaser components can then be pulled under the sprocket which also reduces the required axial package space. The bearing surface for the sprocket would also be incorporated into the end of the camshaft.

[0054] The rotor and bearing surface could be affixed onto the end of the camshaft in a number of ways. The means of affixing the rotor to the end of the camshaft would include but not be limited to the following 5 scenarios.

1 PRESSING THE ROTOR ONTO A STRAIGHT HUB

[0055] By pressing the rotor onto a straight hub at one end of camshaft, rotor such as rotor 1a or rotor 1b may be permanently affixed onto camshaft 9. As can be seen, no extra connecting members such as screw 14 or flange 8 is needed herein. By way of an example, camshaft 9 may have one end 30 disposed to be fitted into opening 19 of rotor 1a as shown in Fig. 10.

[0056] Hub is referred to as a cylindrical projection on the end of the camshaft onto which the inner diameter of the phaser is pressed. As shown in Fig. 10, the region around end 30 is a hub.

2. PRESSING THE ROTOR ONTO A HUB USING A STRAIGHT SPLINE ON ONE COMPONENT AND A HELICAL SPLINE ON THE SECOND COMPONENT

[0057] This second means of irreversible connection is similar to the first means in that the rotor is pressed upon a hub of a camshaft. The difference is that one component such as the rotor may have an opening 19, wherein an inside surface of opening 19 of the rotor 1a may be lined with straight spline. Whereas another component such as the camshaft 9 may have one end 30a may have a non-straight spline such as a helical spline. By way of an example, as shown in Fig. 11, by pressing the rotor 1a onto a hub using a straight spline 32 and a helical spline 34 on the one end 30a.

3. BRAZING THE ROTOR ONTO THE CAMSHAFT

[0058] Brazing the rotor onto the camshaft is another means to irreversibly affix the rotor such as rotor 1a onto a camshaft 9. Any known means of brazing is contemplated by the present invention.

4. SWAGING THE ROTOR ONTO THE CAMSHAFT

[0059] Rotor can also be swaged onto the camshaft. For example, referring to Fig. 12, by swaging the rotor 1a onto a first end 30b of the camshaft 9, the irreversible connection of rotor and camshaft is achieved. First end 30b, which may or may not have an internal opening 19a is first inserted or placed into opening 19 of the rotor 1a.

[0060] As can be appreciated, swaging is a process that is used to reduce or increase the diameter of tubes or rods such as a camshaft. Swaging may be done by placing camshaft 9 inside a die that applies compressive force by hammering radially. In addition, swaging can be achieved by placing a mandrel inside the internal opening 19a and applying radial compressive forces on the outer diameter. As can be appreciated, the inner diameter can be a different shape, for example the internal opening 19a may be a hexagon, and the resultant outer diameter after swaging can still be substantially circular.

[0061] To apply swaging, the existence of internal opening 19a is helpful, but not necessary. The net result is to permanently or irreversibly affix the rotor and the camshaft.

5. BALLIZING THE ROTOR ONTO THE CAMSHAFT WHERE THE CAMSHAFT IS A HOLLOW COMPONENT

[0062] Referring to Fig. 13, wherein the camshaft is formed such that opening 19a transcend or is formed throughout the camshaft structure, ballizing may be a means of permanently or irreversibly affixing rotor 1a onto camshaft 9. Initially, shaft 9 is place within rotor 1a such that a first end 30c of camshaft 9 is within opening

19 of the rotor 1a. A ball 32 made of materials such as a tungsten carbide speeds through opening 19a of camshaft 9 at a desired speed along a direct such as direction 34. Note that the direction of travel for ball 32 may be the reverse of direction 34. In other words, the direction of travel may be 180 degrees of direction 34. Therefore, by ballizing the rotor onto the camshaft where the camshaft is a hollow component, the net result is achieved in that the rotor and the camshaft is permanently or irreversibly affixed together.

[0063] Alternatively, the rotor and bearing surface may also be machined as part of the camshaft itself. Fig. 5 depicts such an alternative. In other words, a single member can include a rotor, a bearing surface, and a camshaft. It is noted that in some cases, the camshaft can be considered an extension of the phaser. Or the camshaft may be considered as an extension of the rotor. This is especially true in cases wherein less cam lobes are involved. Therefore, it necessarily is more convenient to machine the rotor and the camshaft out of one piece of material. It is further noted that cam lobe may not be machined out of one piece of material.

[0064] It is noted that in the preferred embodiment, the rotor is connected to a camshaft. However, the present invention contemplates the coupling or connecting of the rotor of a phaser onto any driving or driven shaft. For example, the rotor may be coupled to a crank shaft, or to any camshaft whether the camshaft is a driving or driven shaft.

[0065] The following are terms and concepts relating to the present invention.

[0066] It is noted the hydraulic fluid or fluid referred to supra are actuating fluids. Actuating fluid is the fluid which moves the vanes in a vane phaser. Typically the actuating fluid includes engine oil, but could be other hydraulic fluid. The VCT system of the present invention may be a Cam Torque Actuated (CTA)VCT system in which a VCT system that uses torque reversals in camshaft caused by the forces of opening and closing engine valves to move the vane. The control valve in a CTA system allows fluid flow from advance chamber to retard chamber, allowing vane to move, or stops flow, locking vane in position. The CTA phaser may also have oil input to make up for losses due to leakage, but does not use engine oil pressure to move phaser. Vane is a radial element actuating fluid acts upon, housed in chamber. A vane phaser is a phaser which is actuated by vanes moving in chambers.

[0067] There may be one or more camshaft per engine. The camshaft may be driven by a belt or chain or gears or another camshaft. Lobes may exist on camshaft to push on valves. In a multiple camshaft engine, most often has one shaft for exhaust valves, one shaft for intake valves. A "V" type engine usually has two camshafts (one for each bank) or four (intake and exhaust for each bank).

[0068] Chamber is defined as a space within which vane rotates. Chamber may be divided into advance chamber (makes valves open sooner relative to crankshaft) and retard chamber (makes valves open later relative to crankshaft). Check valve is defined as a valve which permits fluid flow in only one direction. A closed loop is defined as a control system which changes one characteristic in response to another, then checks to see if the change was made correctly and adjusts the action to achieve the desired result (e.g. moves a valve to change phaser position in response to a command from the ECU, then checks the actual phaser position and moves valve again to correct position). Control valve is a valve which controls flow of fluid to phaser. The control valve may exist within the phaser in CTA system. Control valve may be actuated by oil pressure or solenoid. Crankshaft takes power from pistons and drives transmission and camshaft. Spool valve is defined as the control valve of spool type. Typically the spool rides in bore, connects one passage to another. Most often the spool is located on center axis of rotor of a phaser.

[0069] Differential Pressure Control System (DPCS) is a system for moving a spool valve, which uses actuating fluid pressure on each end of the spool. One end of the spool is larger than the other, and fluid on that end is controlled (usually by a Pulse Width Modulated (PWM) valve on the oil pressure), full supply pressure is supplied to the other end of the spool (hence *differential* pressure). Valve Control Unit (VCU) is a control circuitry for controlling the VCT system. Typically the VCU acts in response to commands from ECU.

[0070] Driven shaft is any shaft which receives power (in VCT, most often camshaft). Driving shaft is any shaft which supplies power (in VCT, most often crankshaft, but could drive one camshaft from another camshaft). ECU is Engine Control Unit that is the car's computer. Engine Oil is the oil used to lubricate engine, pressure can be tapped to actuate phaser through control valve.

[0071] Housing is defined as the outer part of phaser with chambers. The outside of housing can be pulley (for timing belt), sprocket (for timing chain) or gear (for timing gear). Hydraulic fluid is any special kind of oil used in hydraulic cylinders, similar to brake fluid or power steering fluid. Hydraulic fluid is not necessarily the same as engine oil. Typically the present invention uses "actuating fluid". Lock pin is disposed to lock a phaser in position. Usually lock pin is used when oil pressure is too low to hold phaser, as during engine start or shutdown.

[0072] Oil Pressure Actuated (OPA) VCT system uses a conventional phaser, where engine oil pressure is applied to one side of the vane or the other to move the vane.

[0073] Open loop is used in a control system which changes one characteristic in response to another (say, moves a valve in response to a command from the ECU) without feedback to confirm the action.

[0074] Phase is defined as the relative angular position of camshaft and crankshaft (or camshaft and another camshaft, if phaser is driven by another cam). A phaser is defined as the entire part which mounts to cam. The phaser is typically made up of rotor and housing and possibly spool valve and check valves. A piston phaser is a phaser actuated by pistons in cylinders of an internal combustion engine. Rotor is the inner part of the phaser, which is attached to a camshaft.

[0075] Pulse-width Modulation (PWM) provides a varying force or pressure by changing the timing of on/off pulses of current or fluid pressure. Solenoid is an electrical actuator which uses electrical current flowing in coil to move a mechanical arm. Variable force solenoid (VFS) is a solenoid whose actuating force can be varied, usually by PWM of supply current. VFS is opposed to an on/off (all or nothing) solenoid.

[0076] Sprocket is a member used with chains such as engine timing chains. Timing is defined as the relationship between the time a piston reaches a defined position (usually top dead center (TDC)) and the time something else happens. For example, in VCT or VVT systems, timing usually relates to when a valve opens or closes. Ignition timing relates to when the spark plug fires.

[0077] Torsion Assist (TA)or Torque Assisted phaser is a variation on the OPA phaser, which adds a check valve in the oil supply line (i.e. a single check valve embodiment) or a check valve in the supply line to each chamber (i.e. two check valve embodiment). The check valve blocks oil pressure pulses due to torque reversals from propagating back into the oil system, and stop the vane from moving backward due to torque reversals. In the TA system, motion of the vane due to forward torque effects is permitted; hence the expression "torsion assist" is used. Graph of vane movement is step function.

[0078] VCT system includes a phaser, control valve (s), control valve actuator(s) and control circuitry. Variable Cam Timing (VCT) is a process, not a thing, that refers to controlling and/or varying the angular relationship (phase) between one or more camshafts, which drive the engine's intake and/or exhaust valves. The angular relationship also includes phase relationship between cam and the crankshafts, in which the crank shaft is connected to the pistons.

[0079] Variable Valve Timing (VVT) is any process which changes the valve timing. VVT could be associated with VCT, or could be achieved by varying the shape of the cam or the relationship of cam lobes to cam or valve actuators to cam or valves, or by individually controlling the valves themselves using electrical or hydraulic actuators. In other words, all VCT is VVT, but not all VVT is VCT.

[0080] Accordingly, it is to be understood that the embodiments of the invention herein described are merely illustrative of the application of the principles of the invention. Reference herein to details of the illustrated embodiments are not intended to limit the scope of the claims, which themselves recite those features regarded as essential to the invention.

Claims

1. A device, comprising:

a first end having a rotor (1b) with a hollow space (19) positioned at the center disposed to rotate relative to a housing (44); and

a rotating shaft (9a), integral to the rotor (1b), having a plurality of lobes(22) thereon and terminating to a second end, the rotating shaft (9a) being made of the same material as the rotor (1b).

2. The device of claim 1 further comprising at least one separate vane (40) for affixing onto a notch (26) on the outer circumference of the rotor (1b).

3. The device of claim 1 or 2, further comprising a back plate (56) disposed to be attached to the backside of the rotor (1b) having a lobe shaped opening (57) for facilitating the plate (56) to traverse past the plurality of lobes (22).

4. The device of claim 1, 2 or 3, wherein the rotor (1b) and the shaft (9a) are machined out of a single piece member (38).

5. The device of any one of claims 1 to 4, wherein the plurality of lobes (22) are made of the same material as the shaft (9a).

6. The device of claim 1, 2 or 3, wherein the device is machined out of a single piece member resulting in having the rotor (1b), the shaft (9a), and the plurality of lobes (22) thereon.

7. The device of any one of claims 1 to 6, wherein the hollow space (19) is disposed to accommodate a control valve (62) for controlling the flow of a controlling liquid.

8. The device of any one of claims 1 to 7, wherein an actuator (70) is disposed to engage a control valve (62) in the hollow space (19) of the rotor (1b) at the second end via an opening thereon via a hollowed space (72) within the rotating shaft (9a).

9. The device of any one of claims 1 to 8, wherein an actuator (70) is disposed to engage a control valve in the hollow space (19) of the rotor (1b) at the first end.

10. The device of any one of claims 1 to 9, wherein the device is a phaser.

11. The device of any one of claims 1 to 10, wherein the rotating shaft (9a) is a camshaft.

12. A VCT system comprising:

a phaser having a housing (2, 44) and a rotor (1, 1a, 1b); the rotor being included in a device as claimed in any one of claims 1 to 9.

13. In a VCT system having a phaser coupled to a shaft (9, 9a), which can be a driving or driven shaft, an arrangement wherein:

a rotor (1a) of the phaser is irreversibly connected to one end of the shaft (9) and free of any region (18) having openings (14a) for accommodating independent fastening members (14) such as screws, whereby the axial and radial dimension of the apparatus is reduced.

14. A method for coupling part of a VCT device to a shaft (9), comprising the steps of:

providing a phaser having a rotor (1)rotating in relation to an opposite part of the phaser (2), wherein the phaser is axially reduced by eliminating at least one part (18) of the phaser; and

irreversibly, connecting the rotor (1) to the shaft (9).

15. The arrangement of claim 13 or method of claim 15, wherein the rotor (1) is irreversibly connected to one end of the shaft (9) by pressing the rotor (1) onto a straight hub (30); pressing the rotor (1) onto a hub using a straight spline (32) on an inside surface of the rotor and a helical spline (30a) on a corresponding surface of the shaft or vice versa; brazing the rotor onto the shaft (9); swaging the rotor onto the shaft; or ballizing the rotor (1) onto the shaft where the shaft is a hollow component.

16. The arrangement of claim 13 or method of claim 14, wherein the rotor (1) is machined as part of the shaft (9).

Fig. 1 (Prior Art)

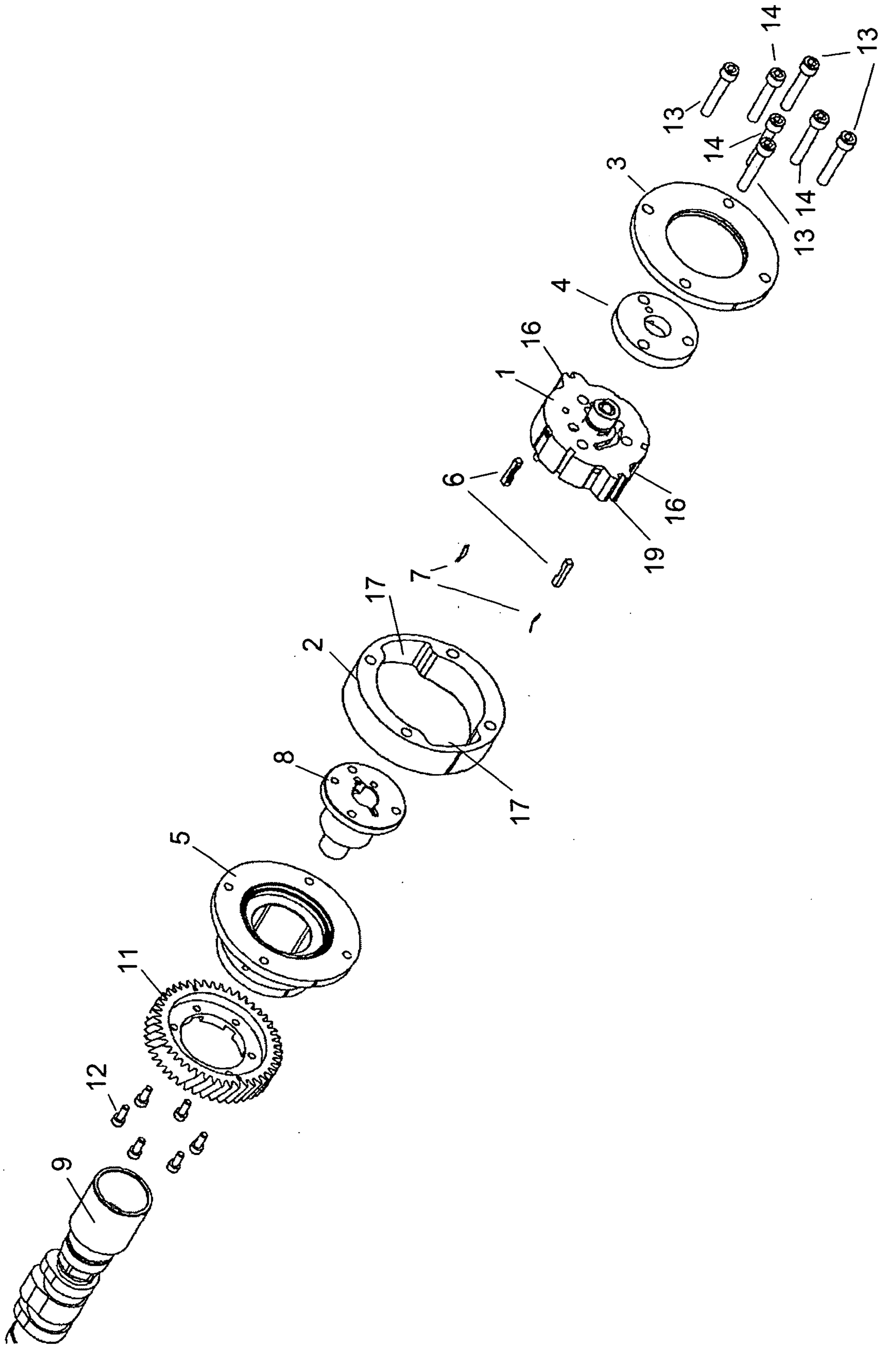


Fig. 2 (Prior Art)

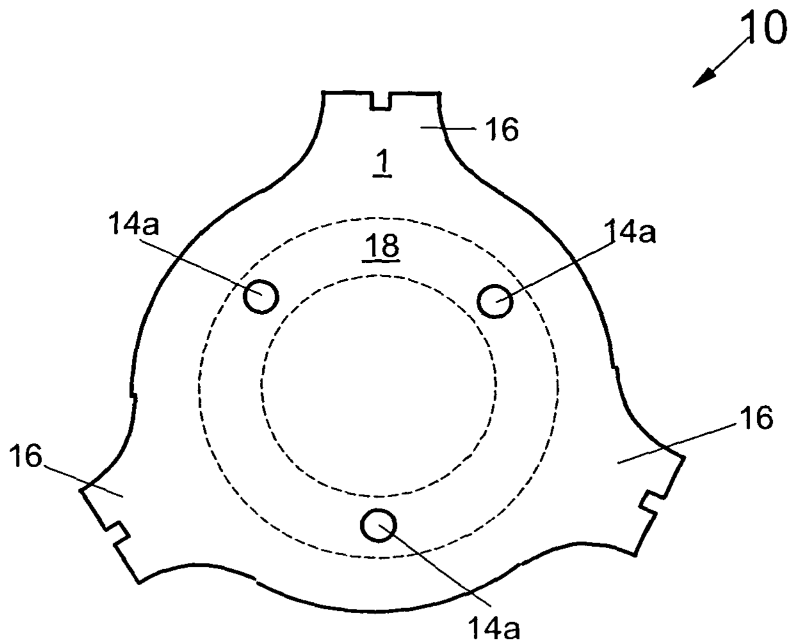


Fig. 2A

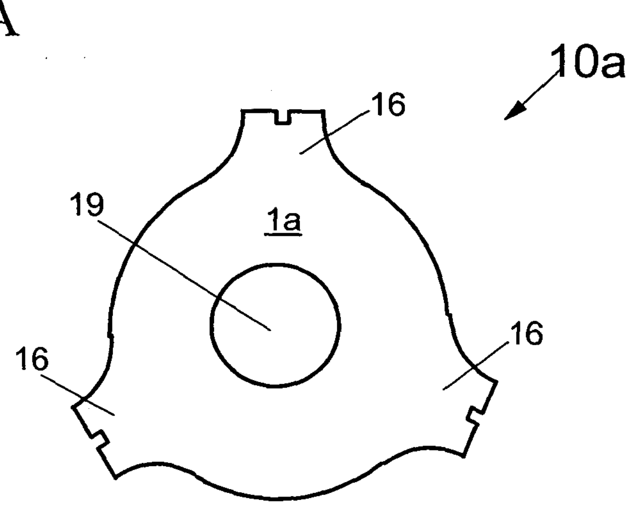


Fig. 3

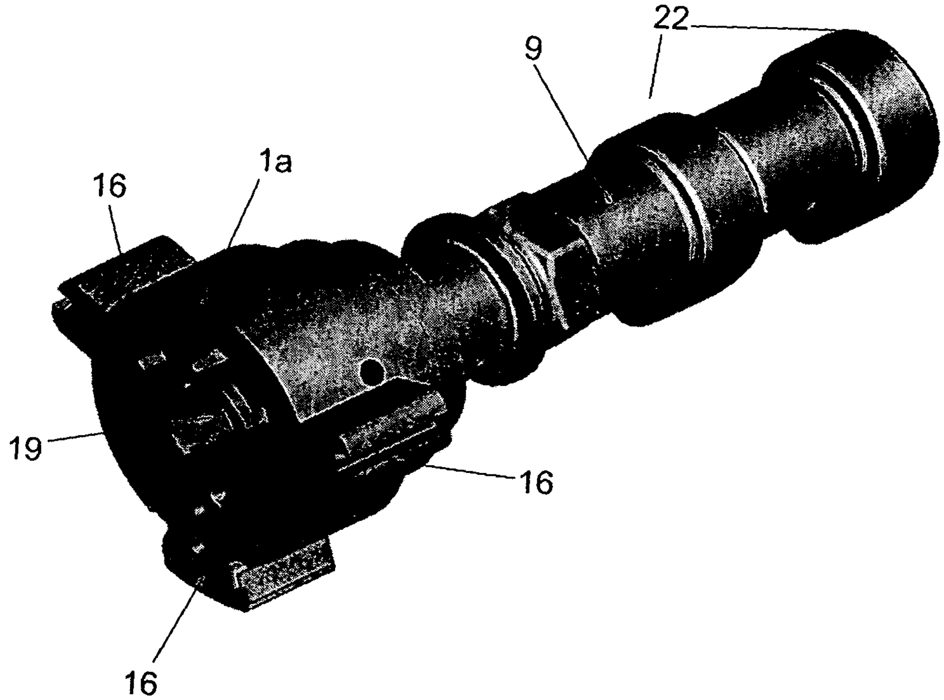


Fig. 4

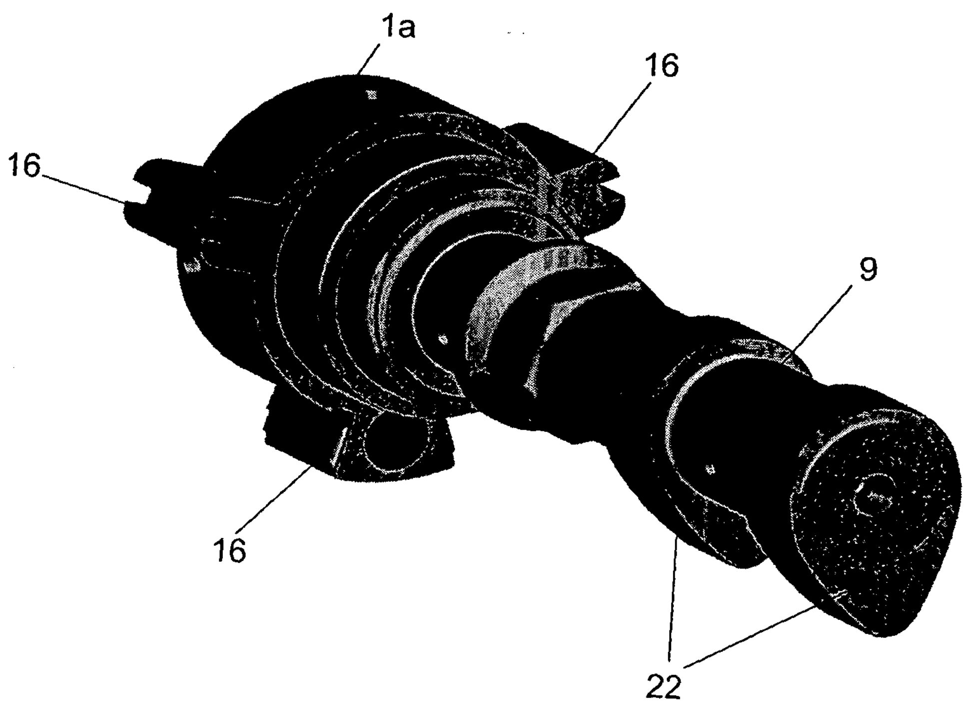


Fig. 5

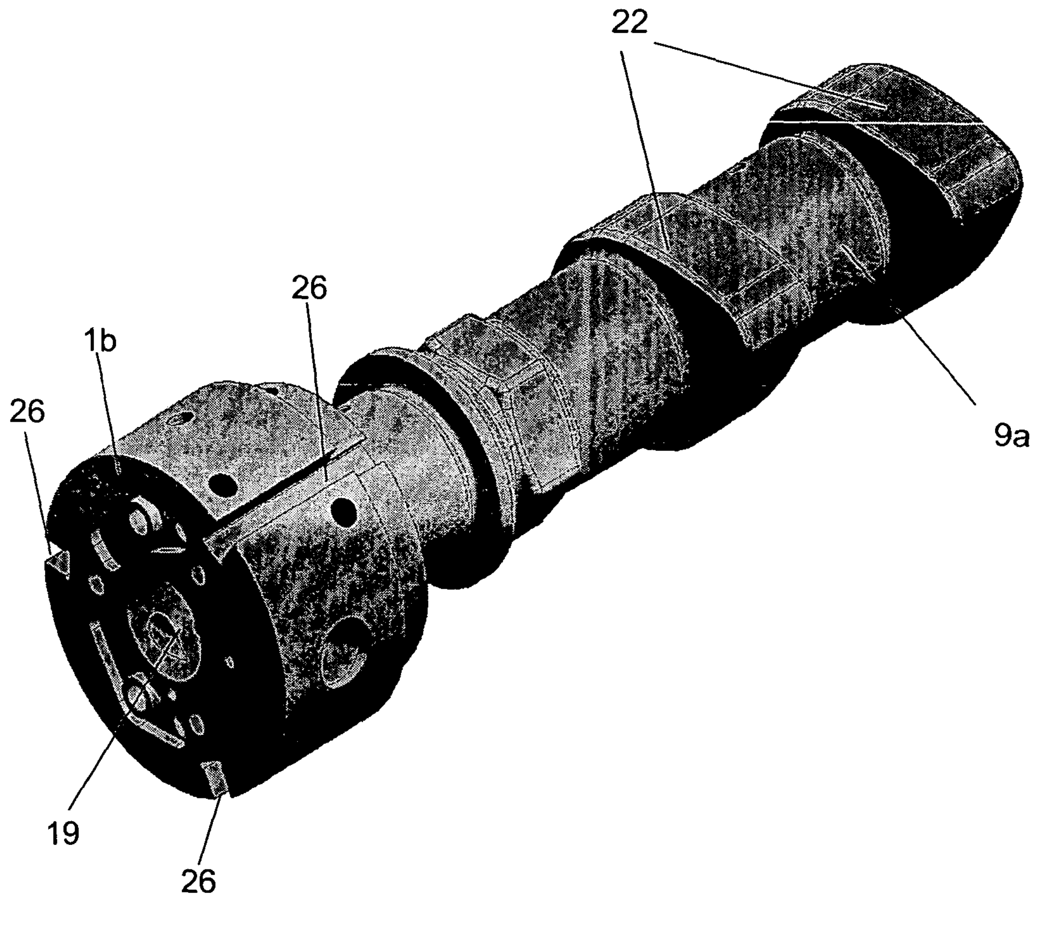


Fig. 6

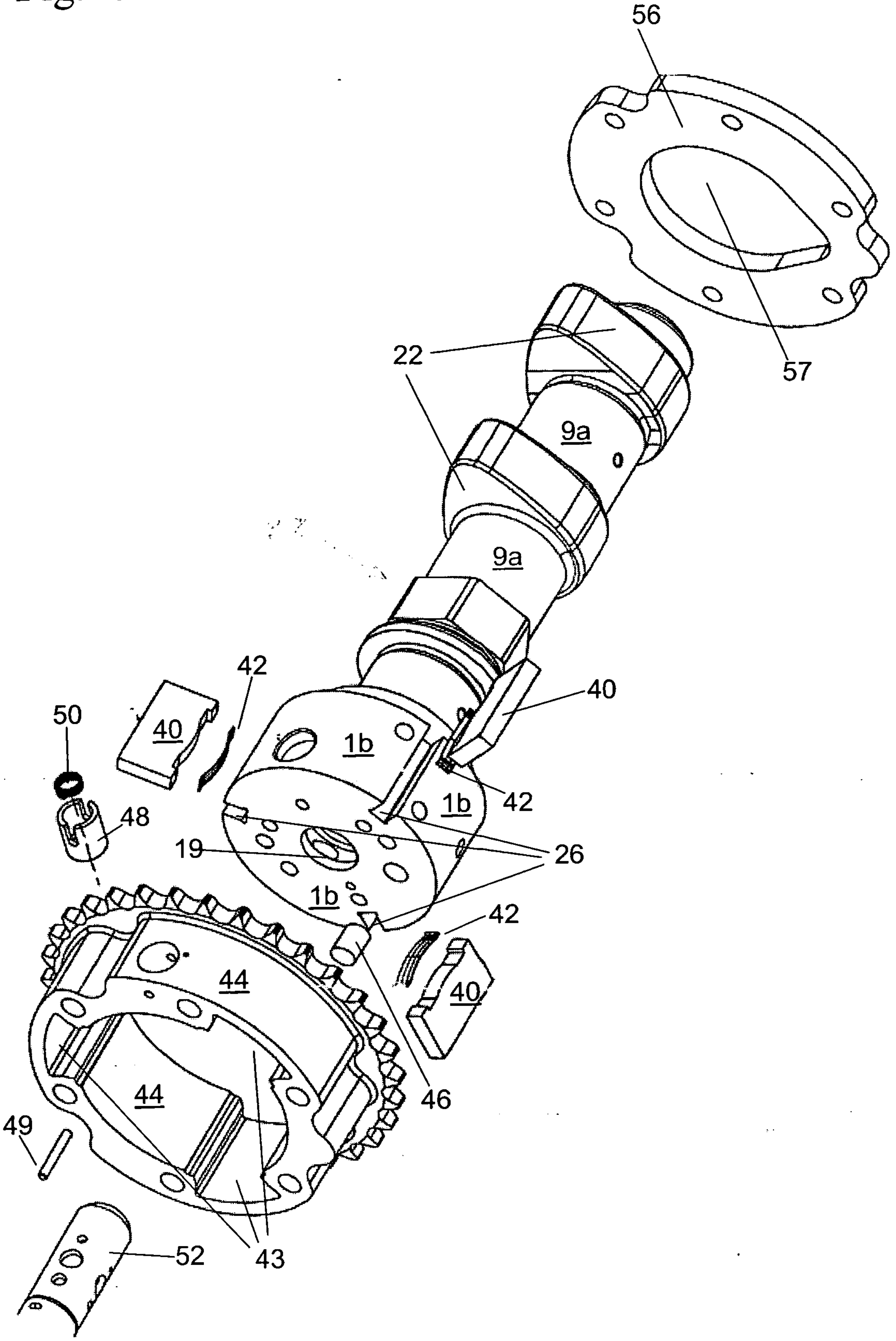
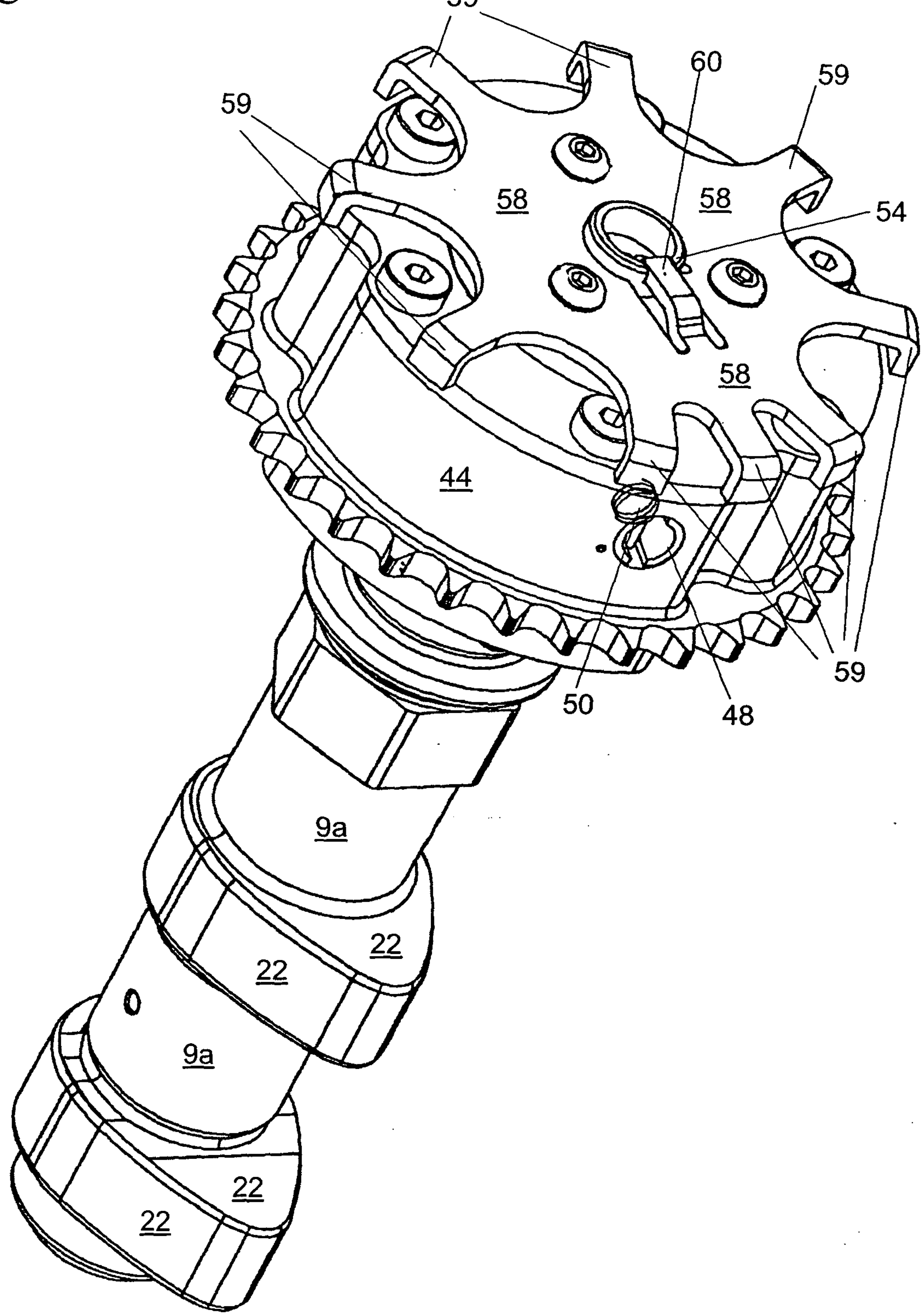


Fig. 7



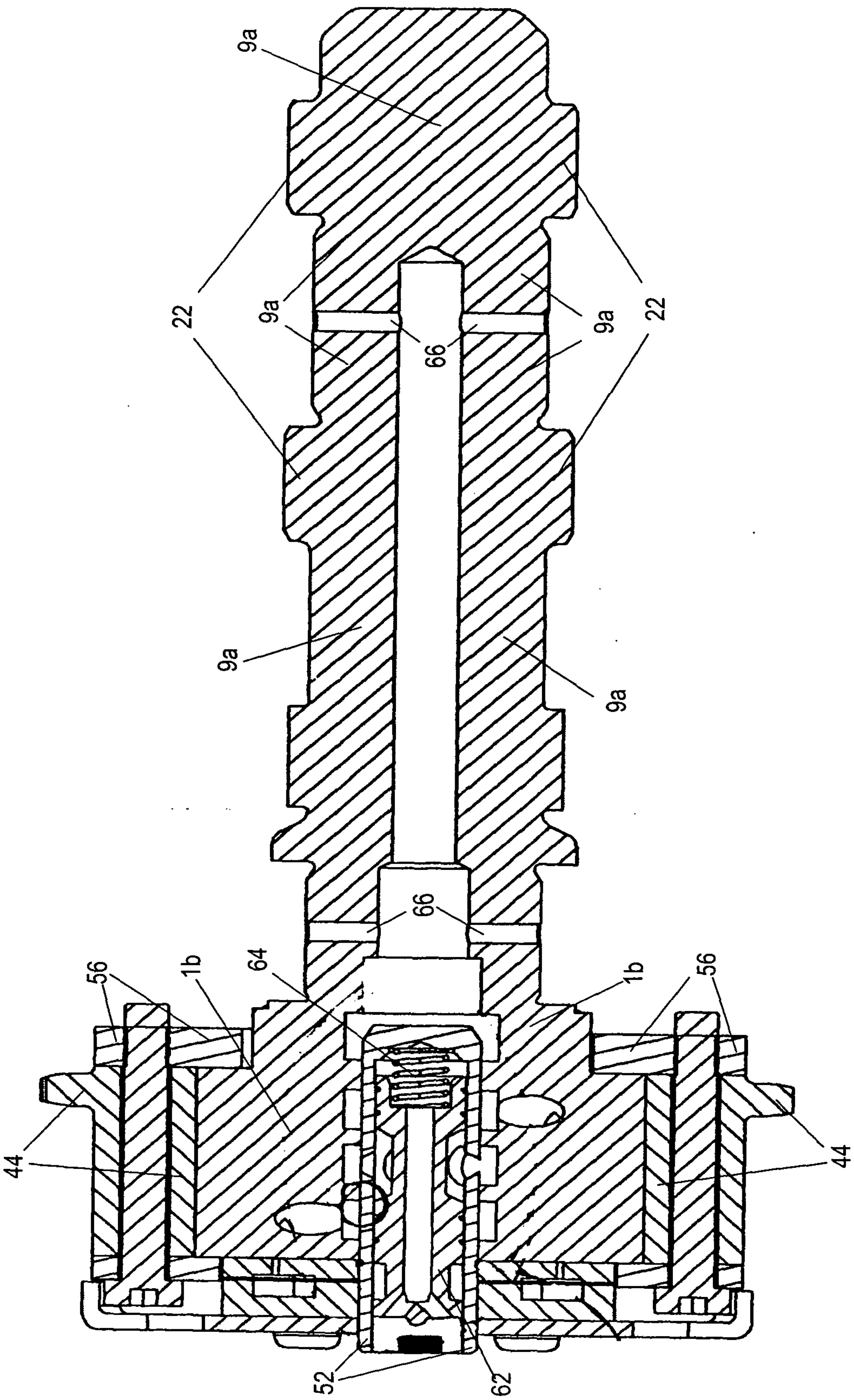


Fig. 8

Fig.9

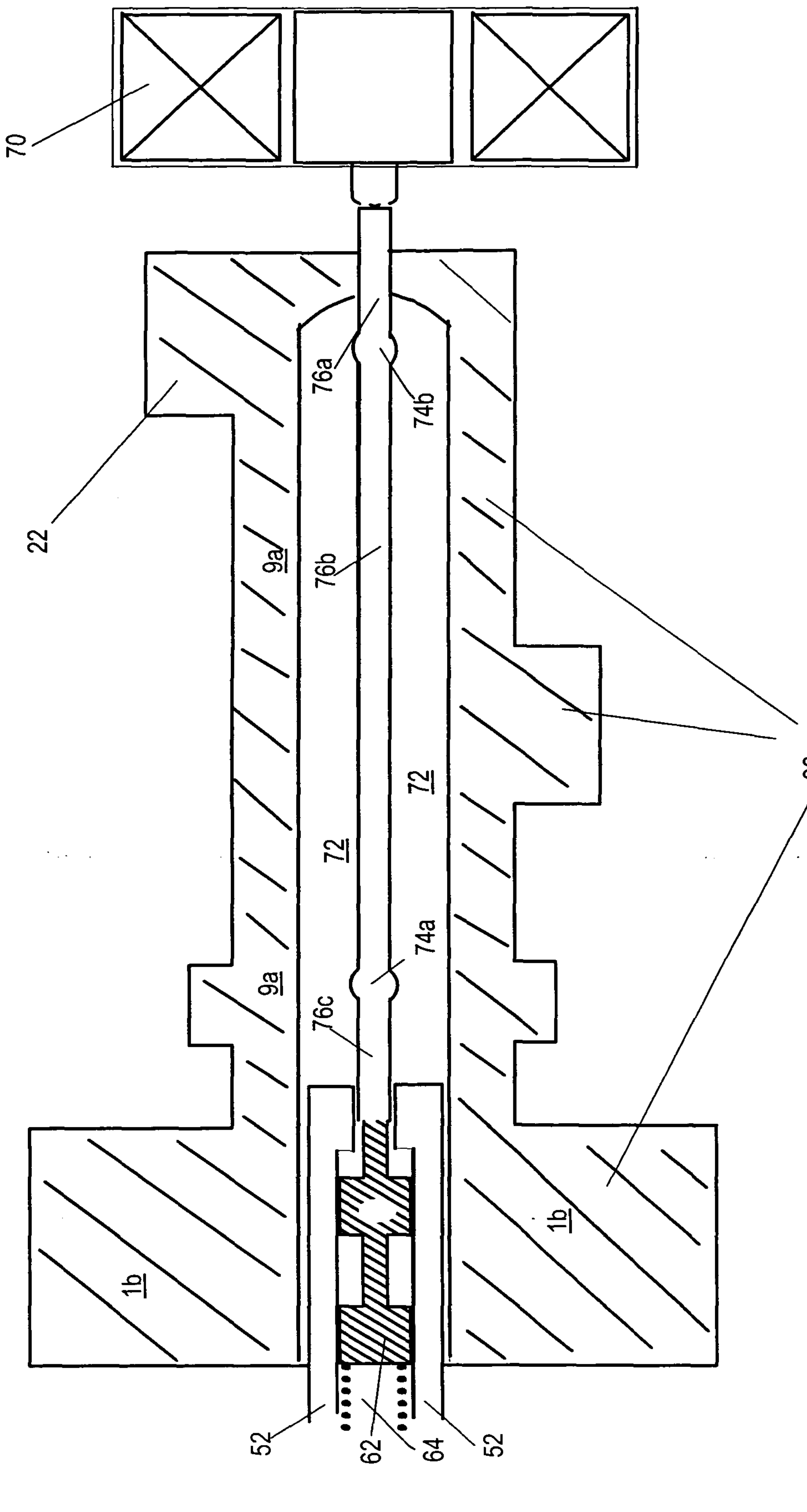


Fig. 10

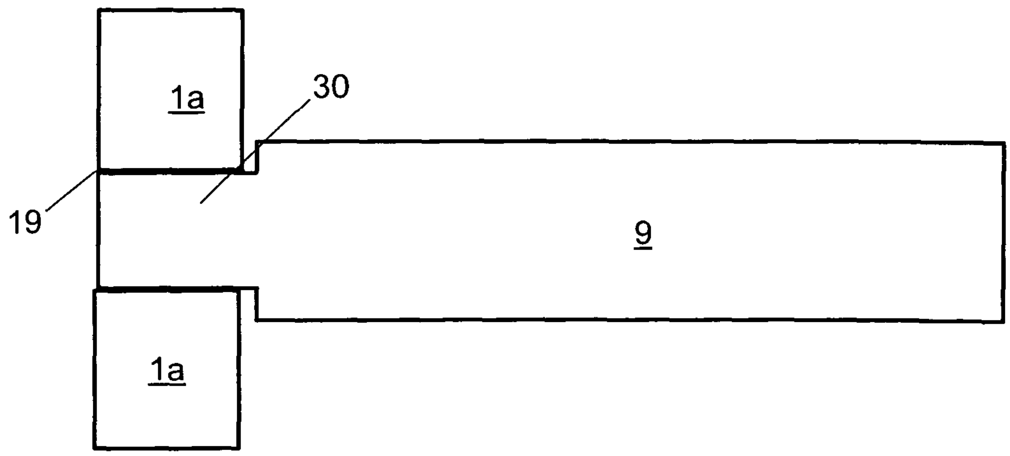


Fig. 11

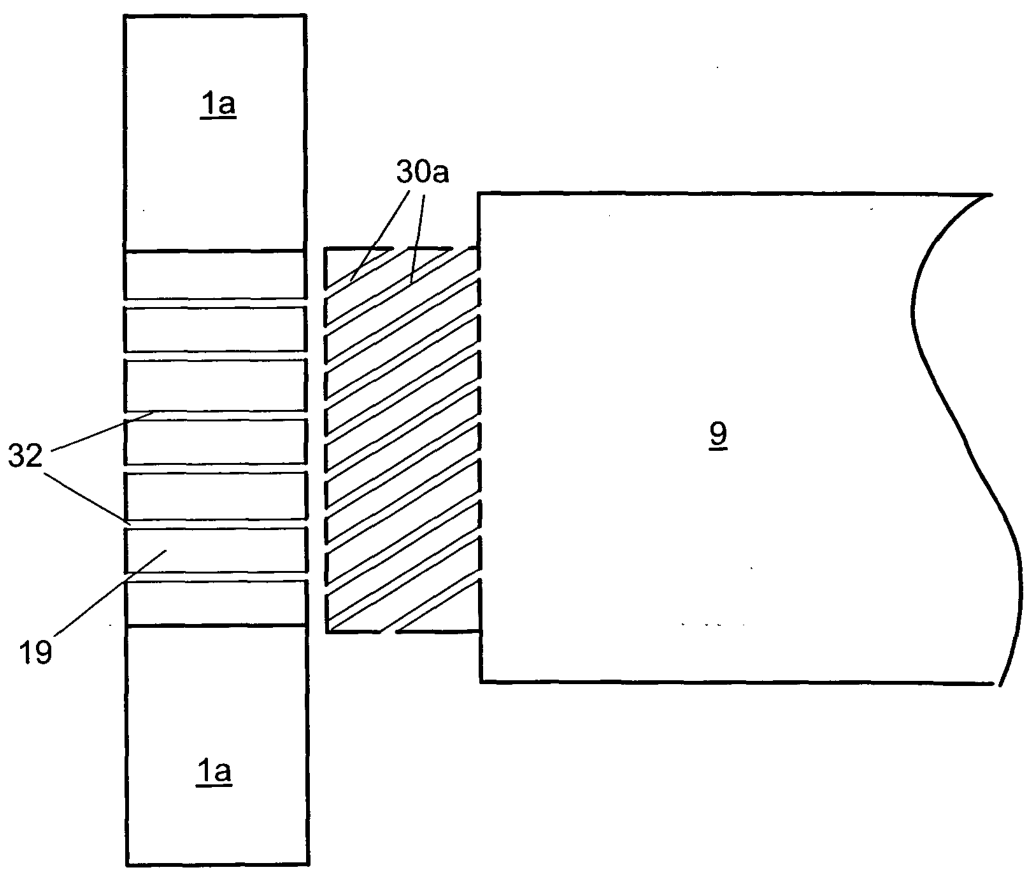


Fig. 12

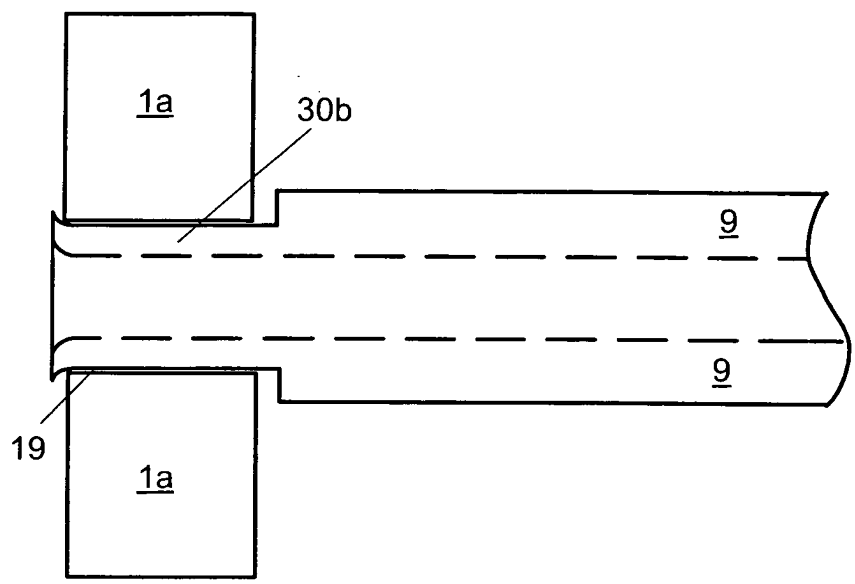


Fig. 13