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(54) **Control mechanism for cam phaser**

(57) A VCT phaser (10) having a mechanical feedback in which no elaborate sensors and its concomitant electronic control loop is required. The phaser (10) has centerly mounted spool valve (20) controlling the flow of control fluid such that when a command positions the same at a predetermined position, passages (86,88) within the phaser (10) adjusts to a desired position through the mechanical feedback.

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Description

FIELD OF THE INVENTION

[0001] The invention pertains to the field of mechanical feedback. More particularly, the invention pertains to control mechanism for a cam phaser having a center mounted spool with two helical slots.

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. 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 system comprising a variable camshaft timing system that includes 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 recesses 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 in such recess 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 discloses 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 discribed. A housing circumscribes the rotor, is rotatable with both the rotor and the camshaft, and 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 extends parallel to and is 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 is 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 enters the pocket and latches the camshaft and the sprocket together in a predetermined orientation.

[0017] U.S. Patent No. 6,477,999 shows a line control arrangement includes a valve timing controller generating a predetermined valve timing variable control signal according to an engine speed of a vehicle; and an oil controlling driver generating a rotational force in a predetermined direction according to the valve timing variable control signal received from the valve timing controller to form a corresponding advance line and a corresponding retard line. The line control arrangement for a continuously variable valve timing system reduces noise generated by operation of an oil controlling driver.

[0018] Furthermore, camshaft phaser is well known. However, known phasers are typically controlled much differently. For example, U.S. patent number 5,507,245 by Melchior, has disclosed a mechanical feedback including one of the driving and driven parts of the coupling is connected to a cylinder and the other to a piston which delimit therebetween two antagonistic chambers. The chambers have a substantially constant volume, and are filled with a practically incompressible hydraulic liquid, and are interconnected through two unidirectional circuits which have opposite directions and each a substantially constant volume. A distributing device is so arranged as to either bring into action one or the other of the unidirectional circuits, or to neutralize both of them.

[0019] In addition, it is known to have an electronic feedback loop involving sensors sensing the positions of shafts such as camshaft or crankshaft in a VCT system. For example, pulse wheels are rigidly affixed onto the shafts for the sensors sensing purposes. The sensed pulses are in turn processed into information wherein derived positional information of a rotor or vane in relation to a housing is used to control a control valve (spool) which in turn is used to control a phase relationship. Typically, the spool valve comprises two lands thereon for stopping fluid communications as desired.

SUMMARY OF THE INVENTION

[0020] In a VCT phaser, a mechanical feedback mechanism is provided for at least one vane to oscillate within a cavity free from electronics such as cam sensors.

[0021] In a VCT phaser comprising a housing and a rotor, the rotor having a control valve which is rigidly coupled to the housing.

[0022] The present invention provides a means to control a cam phaser. The cam phaser may be either a cam torque actuated phaser (CTA), or a torque actuated (TA) phaser or an oil pressure actuated phaser (OPA).

[0023] The present invention provides a center-mounted spool or control valve, which is located rotationally to a housing. The spool has two helical slots which serve to regulate the flow to the advance and retard chambers. Axial displacement of the spool allows either the advance or retard chambers to communicate with a common chamber. This results in the rotor displacing rotationally until the common chamber no longer communicates with either the advance or retard chambers. At this point a new equilibrium in terms of rotational position for the rotor relative to the housing/spool is reached. Displacements of the rotor from the null position are counteracted by the common chamber communicating to either the advance and retard chambers. Therefore the rotational position is directly related to the axial position of the center spool.

[0024] Accordingly, a phaser is provided, which includes a housing having at least one cavity therein; a rotor having at least one vane oscillating within the at least one cavity of the housing, the rotor being disposed to engage the housing, or rotate relative the housing, the cavity being divided into an advance chamber and a retard chamber by the at least one vane; and disposed to translationally move within an opening of the rotor along a substantially straight line, the control valve having at least two openings for selectively controlling fluid flow among a set of passages within the phaser for control fluid to occupy either the advance chamber or the retard chamber; at the outer surface of the control valve, a helical slot having at least one side, wherein a non-zero angle exists between the at least one side and the substantially straight line, the helical slot having an opening for facilitating fluid flow between chambers; thereby as the control valve moves along the substantially straight line the vane position within the cavity is controlled.

[0025] Accordingly, a method is provided which comprises the steps of: providing a housing having at least one cavity therein; providing a rotor having at least one vane oscillating within the at least one cavity of the housing, the rotor being disposed to engage the housing, or rotate relative the housing, the cavity being divided into an advance chamber and a retard chamber by the at least one vane; providing a control valve disposed to translationally move within an opening of the rotor along a substantially straight line, the control valve having at least two openings for selectively controlling fluid flow among a set of passages within the phaser for control fluid to occupy either the advance chamber or the retard chamber; at the outer surface of the control valve, providing a helical slot having at least one side, wherein a non-zero angle exists between the at least one side and the substantially straight line, the helical slot having an opening for facilitating fluid flow between chambers; and translationally moving the control valve along the substantially straight line a predetermined distance for controlling the position of the vane within the cavity of the housing.

BRIEF DESCRIPTION OF THE DRAWING

[0026]

Fig. 1 shows a phaser assembly of the present invention.

Fig. 2 shows a side view of the phaser of the present invention.

Fig. 3 shows a perspective view of the phaser of the present invention.

Fig. 4 shows a top view of the phaser of the present invention.

Fig. 5 shows a schematic of the present invention.

Fig. 5A shows a first detailed portion of Fig. 5.

Fig. 5B shows a second detailed portion of Fig. 5.

Fig. 6 shows an exemplified phaser of the present invention in a first dynamic state.

Fig. 6A shows the shape or formation of helical slot (52) in a first dynamic state.

Fig. 7 shows an exemplified phaser of the present invention in a second dynamic state

Fig. 7A shows the shape or formation of helical slot (52) in a second dynamic state.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0027] This section includes the descriptions of the present invention including the preferred embodiment of the present invention for the understanding of the same. It is noted that the embodiments are merely describing the invention. The claims section of the present invention defines the boundaries of the property right conferred by law.

[0028] Referring to Fig. 1-7, a phaser (10) assembly is shown in part. Phaser (10) comprises a sprocket (12), a rotor (14), a housing (16), a back plate (18), and a spool (20) or control valve. A pair of check valves (22) is provided (only one shown). Sprocket (12) comprises a teeth structure (24) circumferentially formed upon the circumference thereof. Sprocket (12) further comprises an inner portion (26) that is substantially of cylindrical shape formed at the center of the same. Inner portion (26) comprises a center opening (28) forming a hollow cylinder at the center for accommodating spool (20). Sprocket (12) has a key (27) of an elongated shape that protrudes from inner portion (26) into center opening (28) for slidably engaging a notch (30) formed axially on the circumference of spool (20). Sprocket (12) further includes a set of inner openings (29) (only three shown) on inner portion (26) for accommodating the maintenance of a set of coupling elements to affix rotor (14) onto a third member such as a camshaft (not shown). Sprocket (12) further has a set of outer openings (51) (only six shown) for affixing the same onto housing (16) and back plate (18).

[0029] Rotor (14) comprises a center opening of a substantially cylindrical shape disposed to allow for the axial movement of spool (20) in that spool (20) can slide axially along an axis (34). Furthermore, rotor (14) can rotate in relation to spool (20) by frictionally engaging an inner surface (32) with an outer surface of spool (20) along axis (34). Rotor (14) further comprises a first vane (36) and a second vane (38) with each vane formed diametrically opposing or relative to the other vane. Second vane (38) has an opening therein disposed for receiving check valve (22).

[0030] Housing (16) encloses rotor (14). A pair of cavities (40) is formed diametrically opposing each other for accommodating first vane (36) and second vane (38) to oscillate therein. Circumferentially between cavities (40), housing (16) has a set of openings (42). Openings (42) have identical numbers as that of outer openings (51) on back plate (18). Housing (16) further has an inner bearing surface (46) for rotably coupling with an outer surface (48) of rotor (14).

[0031] Back plate (18) has a center opening having a diameter that is less than the diameter of rotor (14) between the center thereof and outer surface (48) for contributing to the closure of a set of passages (86, 88) for fluid communication between chambers defined within cavities (40) and delimited by first vane (36) or second vane (38). In other words, part of the back plate (18), along with portions of the rotor (14) forms passages (86, 88). Back plate (18) further has a set of openings (51) having identical numbers as that of opening (42) or outer openings (51).

[0032] Spool (20) comprises a pair of helical slots (52) (only one shown) which serve to regulate the flow to the advance and retard chambers. Helical slots (52) function as a conduit for the selective fluid communications between the chambers defined by cavities (40) and subdivided by first vane (36) and second vane (38). Spool (20) is disposed to have an actuator (not shown) having a suitable force exerted upon a first end thereof, and an elastic member (also not shown) having a corresponding suitable force exerted upon a second or opposite end in a known manner.

[0033] Referring specifically to fig. 2, a side view of the assembled phaser (10) is shown. At the first end of phaser (10) along line axis (34), is sprocket (12) with its teeth structure (24) and inner portion (26). Note that teeth structure (24) is disposed to engage a chain such as an engine timing chain (not shown). Housing (16) is mounted onto sprocket (12). Typically, housing (16) is rigidly connected to sprocket (12) by some connecting means such as screws. Portions of sprocket (12) form a side wall of cavities (40). Back plate (18) is mounted onto housing (16). Similarly, back plate (18) is rigidly connected to housing (16) by some connecting means such as screws. Portions of back plate (18) also form a side wall of cavities (40).

[0034] Spool (20) is disposed at the center of phaser (10). Spool (20) can translationally move along axis (34). In addition, spool (20) can simultaneously rotate within the inner bearing surfaces of rotor (14). It should be noted that spool (20) is connected to sprocket (12) by notch (30) and key (27). Therefore, spool (20) rotates in unison with sprocket (12) yet spool (20) can still translationaly slide along axis (34).

[0035] Referring specifically to Fig. 3, a perspective view of phaser (10) is shown. As can be seen, key (27) of inner portion (26) is connected to notch (30) of spool (20), with spool (20) located within center opening (28) of inner portion (26). Through key (27) and notch (30), sprocket (12) and spool (20) are disposed to engage each other and rotate in unison together for a predetermined angular relationship between sprocket (12) and rotor (14). As shown earlier, rotor (14) has an inner bearing surface which rotates with the outer bearing surface of spool (20). By way of an example, phaser (10) is a cam phaser mounted on one end of a camshaft with rotor (14) rigidly affixed onto the one end. Spool (20) of sprocket (12) is coupled to a crankshaft by means of a timing chain. An angular adjustment can be achieved by relative movements of sprocket (12) in relation to rotor (14). According to the present invention, the angular adjustment is accomplished by moving spool (20) translationally along axis (34) relatively to the other members of phaser (10). By positioning spool (20) at a plurality of predetermined positions along axis (34), a mechanical feedback or self-adjustment mechanism (details shown infra) adjusts the angular relationship between the camshaft and the crankshaft.

[0036] Referring specifically to Fig. 4, an elevated perspective view of phaser (10) is shown. Note the inner openings (29) facilitate the three screws (54) going through rotor (14). It is noted that Fig. 4 merely shows a special case of the angular relationship between sprocket (12) and rotor (14), in which inner openings (29) of sprocket (12) happens to permit a top view of screws (54). Screws (54) are not affixed onto sprocket (12), but instead screws (54) are affixed onto rotor (14) which rotates relative to sprocket (12). Therefore, at other angular relationships, screws (54) may only be partially shown or not shown at all. Also note the inner portion (26) of spool (20) located inside a cylindrical hollow (58) of spool (20). Further, the present figure shows another view of key (27) of sprocket (12) disposed to engage and rotate with spool (20) by way of key (27) engaging notch (30) of spool (20). In addition, opening (60) may be used to rigidly affix sprocket (12) onto housing (16).

[0037] Referring specifically to Fig. 5, a schematic depicting the present invention is provided. Cavities (40) each being subdivided into an advance chamber A and a retard chamber R by first vane (36) and similarly subdivided by second vane (38) respectively. In addition, the advance chamber A of one of the cavities (40) is coupled to and in fluid communication with the advance chamber A of the other cavities (40). Similarly, the retard chamber R of one of the cavities (40) is coupled to and in fluid communication with the retard chamber R of the other cavities (40). A third chamber or common passage (62) is formed within rotor (14) having a first end (64) and a second end (66). First end (64) is always in fluid communication with a passage (68) in spool (20) via helical slot (52). Second end (66) is formed as a result in which common passage (62) extends from rotor (14) toward second vane (38). A pair of check valves (70) is provided to selectively permit control fluid to flow either to the advance chamber A of second vane (38), or the retard chamber R of second vane (38).

[0038] Retard chamber R of first vane (36) is deposed to be selectively coupled to the advance chamber of second vane (38) through passages and controlled by helical slot (52) of spool (20). Passage (72) is interposed between retard chamber R of first vane (36) and helical slot (52) of spool (20). Similarly, advance chamber A of first vane (36) is deposed to be selectively coupled to the retard chamber of second vane (38) through passage and controlled by helical slot (52) of spool (20). Passage (74) is interposed between advance chamber A of first vane (36) and helical slot (52) of spool (20). Preferably, when retard chamber R of first vane (36) is selected to be in fluid communication with advance chamber of second vane (38) through passage and controlled by helical slot (52) of spool (20), advance chamber A of first vane (36) is not in fluid communication with the retard chamber of second vane (38).

[0039] Symbol AB defines a region wherein detailed operation of the fluid flow is shown (see specifically Fig. 5A and 5B). As spool (20) moves translationaly along axle axis (34), helical slot (52) are formed such that control fluid from either advance chamber A of first vane (36) is permitted to flow therefrom toward retard chamber R of second vane (38), or alternatively retard chamber R of first vane (36) is permitted to flow therefrom toward advance chamber A of second vane (38).

[0040] Referring specifically to Fig. 5A, a first detailed depiction of Fig. 5 is shown. A first control fluid path (80) is formed which allows control fluid to flow from passage (72) to passage (64) via passage (68) of spool (20). No fluid flows out of passage (74) because the shape of helical slot (52) of spool (20) prevents any fluid flow therethrough.

[0041] Referring specifically to Fig. 5B, a second detailed depiction of Fig. 5 is shown. A second control fluid path (82) is formed which allows control fluid to flow from passage (74) to passage (64) via passage (68) of spool (20). No fluid flows out of passage (72) because the shape of helical slot (52) of spool (20) prevents any fluid flow therethrough.

[0042] A practical example of the present invention is shown in Figs. 6-7A. Referring to Fig. 6, an exemplified phaser of the present invention in a first dynamic state is shown. Housing (16) encloses sprocket (12) having second vane (38) and first vane (36) each oscillating within cavities (40) respectively. Rotor (14) has first groove 86 facilitating fluid communication between the two retard chambers. Rotor (14) further has a second groove 88 facilitating fluid communication between the two advance chambers. Spool (20) is disposed at the center of rotor (14). Due to the shape of helical slot (52) of spool (20), first end (64) of rotor (14) is in constant fluid communication with passage (68) of spool (20) in its entire range of translational movement. Whereas, Due to the shape or formation of helical slot (52) of spool (20), passage (74) is in fluid communication with passage (68), but passage (72) of rotor (14) is not in communication with first end (64) due to the shape of helical slot (52).

[0043] Referring to Fig. 6A, the shape or formation of helical slot (52) is shown. Helical slot (52) is a hollowed out portion or region of spool (20) thereon its outer surface. Helical slot (52) has six sides. Two of the six sides, specifically side (90) and side (92), possess a pair of non-zero angles in relation to the generally symmetrical shape of spool (20). In other words, angle θ_1 and angle θ_2 are of a non-zero value. Further, side (90) and side (92) are of a sufficient length to be at least longer than the diameter of passage (72) or passage (74) respectively. It is noted or repeated herein that, unlike passage (68) which is part of or formed within spool (20), passage (72) and passage (74) are not part of spool (20) but a part of rotor (14) formed diametrically at about opposite positions in a cylindrical hollow at the center thereof for accommodating spool (20). Helical slot (52) is formed so that either passage (68) and passage (74), or passage (68) and passage (72) are respectively in fluid communication with each other. When spool (20) moves translationally back and forth along axis (34), either passage (68) and passage (74), or passage (68) and passage (72) are permitted to communicate. Therefore, fluid from either retard chamber flows toward advance chamber or vice versa. The result is that rotor (14) rotates in relation to housing (16). The amount of movement or the duration spool (20) stays at a predetermined position in relation to rotor (14) determines the angle or phase of the rotation between rotor (14) and housing (16).

[0044] As can be seen, an actuator (not shown) acting upon one side of spool (20) and an elastic member (also not shown) reacting on the opposite side of spool (20) can cause and adjust the movement or the duration spool (20) staying at the predetermined position in relation to rotor (14). Therefore, a controller (not shown) that controls the actuation and adjustment of the actuator can be used to predetermine the phase relationship between rotor (14) and housing (16). Therefore, path (82) is active and path (80) is not.

[0045] Referring to Fig. 7, an exemplified phaser of the present invention in a second dynamic state is shown. Housing (16) encloses sprocket (12) having second vane (38) and first vane (36) each oscillating within cavities (40) respectively. Rotor (14) has first groove 86 facilitating fluid communication between the two retard chambers. Rotor (14) further has a second groove 88 facilitating fluid communication between the two advance chambers. Spool (20) is disposed at the center of rotor (14). Due to the shape of helical slot (52) of spool (20), first end (64) of rotor (14) is in constant fluid communication with passage (68) of spool (20) in its entire range of translational movement. Whereas, due to the shape or formation of helical slot (52) of spool (20), passage (74) is in fluid communication with passage (68), but passage (72) of rotor (14) is not in communication with first end (64) due to the shape of helical slot (52). Therefore, path (80) is active and path (82) is not.

[0046] Referring to Fig. 7A, the shape or formation of helical slot (52) is shown. helical slot (52) is a hollowed out portion of spool (20) having six sides. Two of the six sides specifically side (90) and side (92) possess a pair of non-zero angles in relation to the generally symmetrical shape of spool (20). In other words, angle θ_1 and angle $\theta 2$ are of a non-zero value. Further, side (90) and side (92) are of a sufficient length to at least longer than the diameter of passage (72) or passage (74) respectively. It is noted or repeated herein that, unlike passage (68) which is part of or formed within spool (20), passage (72) and passage (74) is not part of spool (20) but a part of rotor (14) formed diametrically at about opposite positions in a cylindrical hollow at the center thereof for accommodating spool (20). Helical slot (52) is formed so that only passage (68) and passage (74), or passage (68) and passage (72) are respectively in fluid communication. When spool (20) moves translationally back and forth along axis (34), either passage (68) and passage (74), or passage (68) and passage (72) are permitted to communicate. Therefore, fluid from either retard chamber flows toward advance chamber or vice versa. The result is that rotor (14) rotates in relation to housing (16). The amount of movement or the duration spool (20) stays at a predetermined position in relation to rotor (14) determines the angle or phase of the rotation between rotor (14) and housing (16).

[0047] As can be seen, an actuator (not shown) acting upon one side of spool (20) and an elastic member (also not shown) reacting on the opposite side of spool (20) can cause and adjust the movement or the duration spool (20) staying at the predetermined position in relation to rotor (14). Therefore, a controller (not shown) that controls the actuation and adjustment of the actuator can be use to predetermine the phase relationship between rotor (14) and housing (16).

[0048] The following are terms and concepts relating to the present invention.

[0049] 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 separate 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.

[0050] 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).

[0051] 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.

[0052] 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.

[0053] 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.

[0054] 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.

[0055] 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.

[0056] 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.

[0057] 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.

[0058] 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.

[0059] 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.

[0060] 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.

[0061] 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 crankshaft is connected to the pistons.

[0062] 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.

[0063] The present invention provides a means to control a cam phaser. The present invention is suitable for either a cam torque actuated phaser, TA phaser or oil pressure actuated phaser. By utilizing a center-mounted spool which is located rotationally to the housing as the control valve, the spool has two helical slots which serve to regulate the flow to the advance and retard chambers. Axial displacement or translational movement of the spool allows either the advance or retard chambers to communicate with the common chamber such as common passage (62) of rotor (14). This results in the rotor displacing rotationally until the common chamber no longer communicates with either the advance or retard chambers. At this point a new equilibrium rotational position for the rotor relative to the housing/spool is reached. Displacements of the rotor from the null position are counteracted by the common chamber communicating to either the advance and retard chambers. Therefore the rotational position is directly related to the axial position of the center spool.

[0064] The center spool can be positioned with or actuated upon by such actuators as a variable force solenoid, step motor of by a pressure/force balance (a pressure on one side of the spool reacting against a spring), etc.

[0065] 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 phaser, comprising:

   a housing having at least one cavity therein;

   a rotor having at least one vane oscillating within the at least one cavity of the housing, the rotor being disposed to engage the housing, or rotate relative to the housing, the cavity being divided into an advance chamber and a retard chamber by the at least one vane; and

   a control valve disposed to translationally move within an opening of the rotor along a substantially straight line, the control valve having at least two openings for selectively controlling fluid flow among a set of passages within the phaser for control fluid to occupy either the advance chamber or the retard chamber;

   at the outer surface of the control valve, a helical slot having at least one side, wherein a non-zero angle exists between the at least one side and the substantially straight line, the helical slot having an opening for facilitating fluid flow between chambers; thereby as the control valve moves along the substantially straight line the vane position within the cavity is controlled.

2. The phaser of claim 1, wherein the vane has a vane cavity disposed to have at least one check valve placed therein.

3. The phaser of claim 1 or 2, further comprises means for limiting the control valve to move along the substantially straight line.

4. The phaser of claim 1, 2 or 3, further comprising a sprocket rigidly affixed to the housing and disposed to rotate in unison with the housing.

5. A method comprising the steps of:

   providing a housing having at least one cavity therein;

   providing a rotor having at least one vane oscillating within the at least one cavity of the housing, the rotor being disposed to engage the housing, or rotate relative the housing, the cavity being divided into an advance chamber and a retard chamber by the at least one vane;

   providing a control valve disposed to translationally move within an opening of the rotor along a substantially straight line, the control valve having at least two openings for selectively controlling fluid flow among a set of passages within the phaser for control fluid to occupy either the advance chamber or the retard chamber;

   at the outer surface of the control valve, providing a helical slot having at least one side, wherein a non-zero angle exists between the at least one side and the substantially straight line, the helical slot having an opening for facilitating fluid flow between chambers; and

   translationally moving the control valve along the substantially straight line a predetermined distance for controlling the position of the vane within the cavity of the housing.

6. The method of claim 5, wherein the vane has a vane cavity disposed to have at least one check valve placed therein.

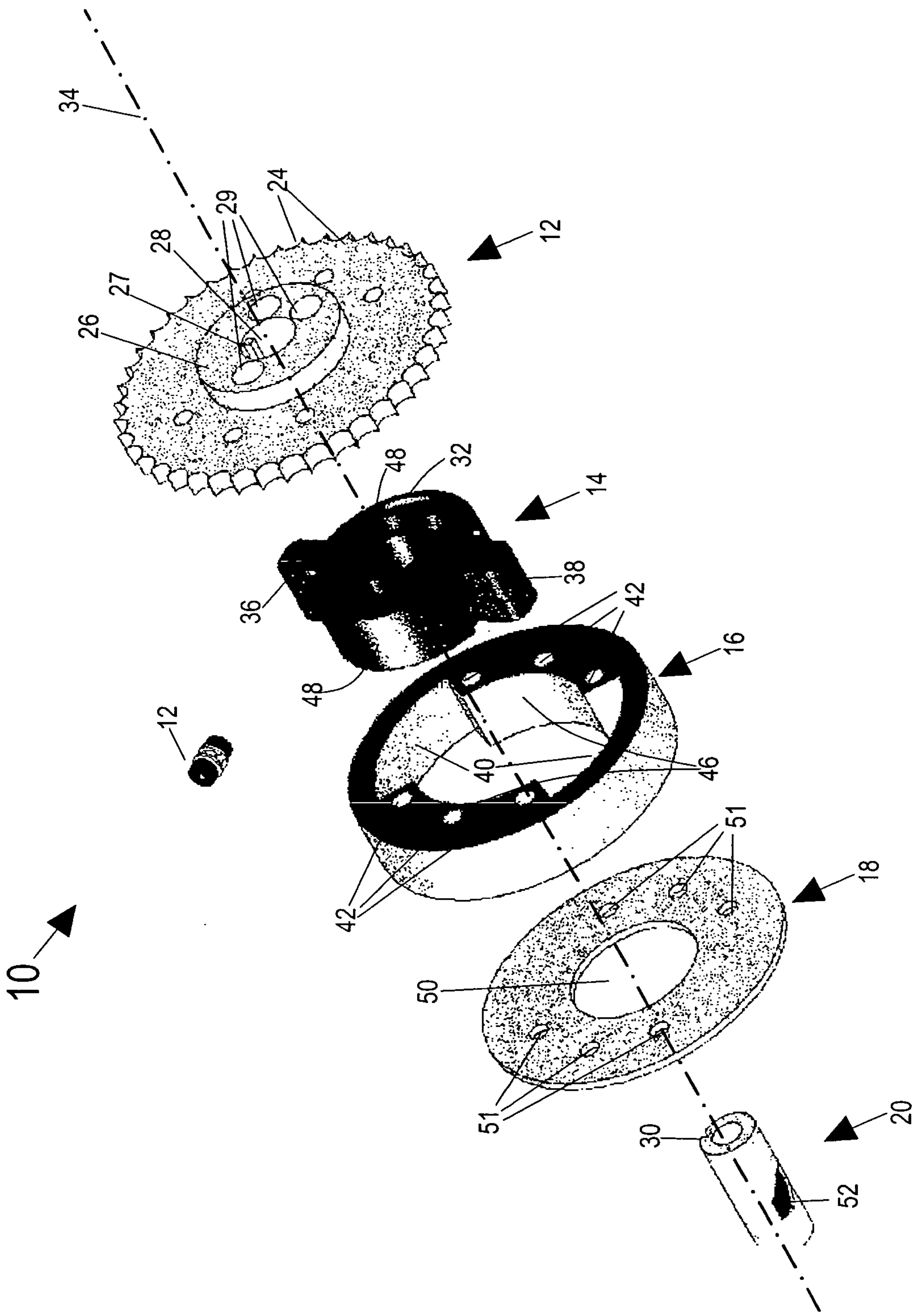
7. The method of claim 5 or 6 further comprising the step of providing a means for limiting the control valve to move along the substantially straight line.

8. The method of claim 5, 6 or 7 further comprising the step of providing a sprocket rigidly affixed to the housing and disposed to rotate in unison with the housing.

9. The phaser of any one of claims 1 to 4 or the method of any one of claims 5 to 8, wherein a back plate is rigidly affixed onto the housing and rotor for containing control fluid within the phaser.

10. A phaser comprising a housing with at least one cavity divided by a vane of a rotor to form advance and retard chambers, and a passage for conducting fluid between the chambers under control of a valve, the control valve being guided to move axially relative to

    the housing and the rotor being rotatable relative to the valve, wherein the valve has a slot with an axially inclined edge and forming part of said passage, the inclined edge being arranged for co-operation with a rotor opening whereby the axial position of the valve determines the rotational position of the rotor.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52

Fig. 1

Fig. 2

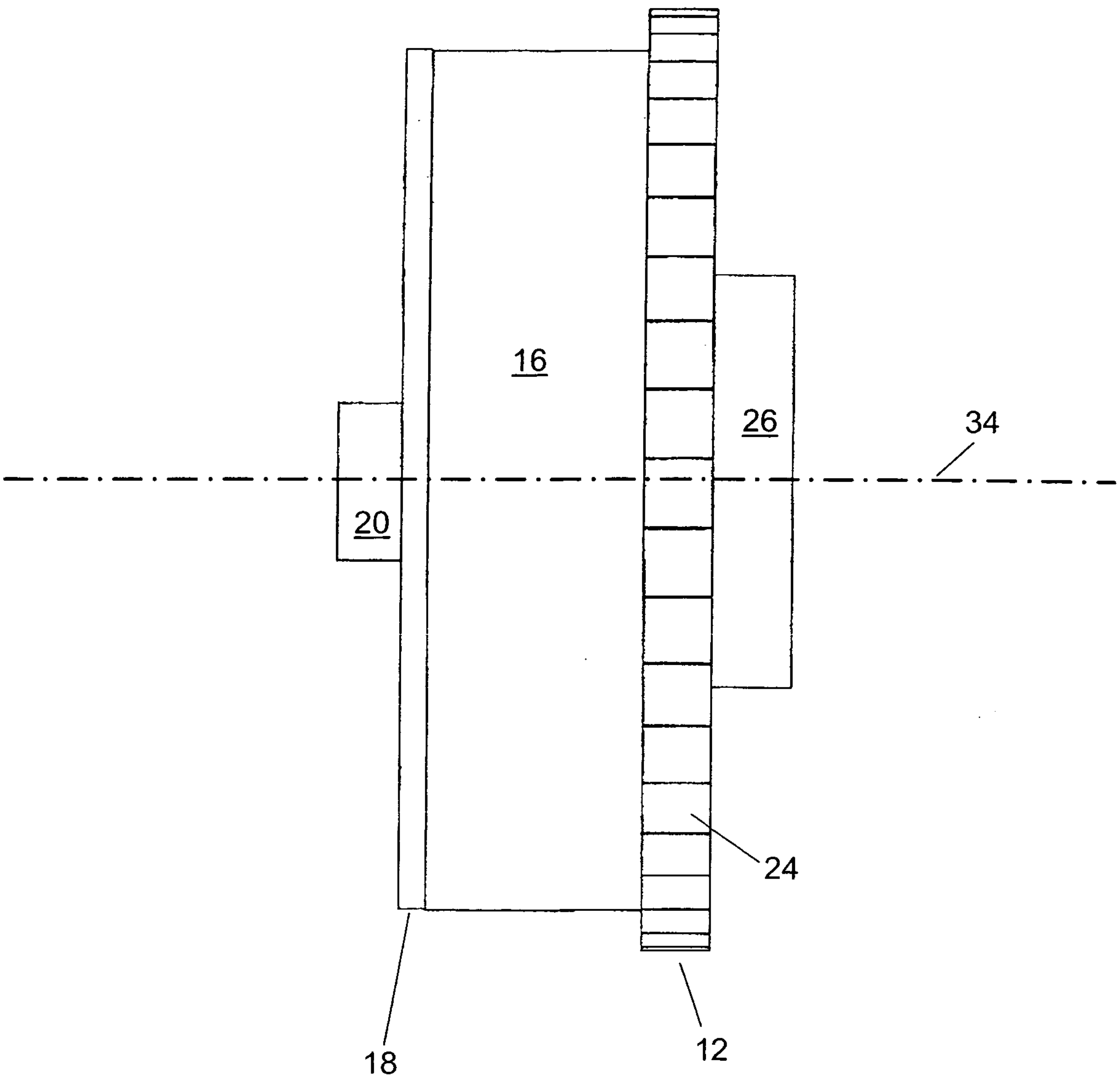

Fig. 3

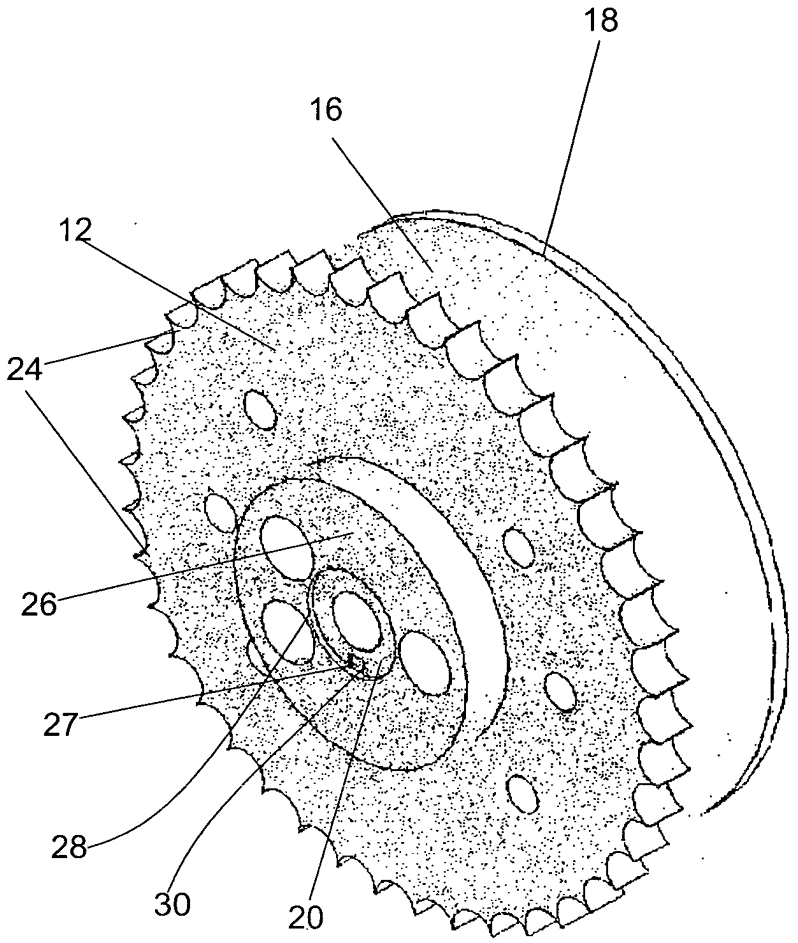

Fig. 4

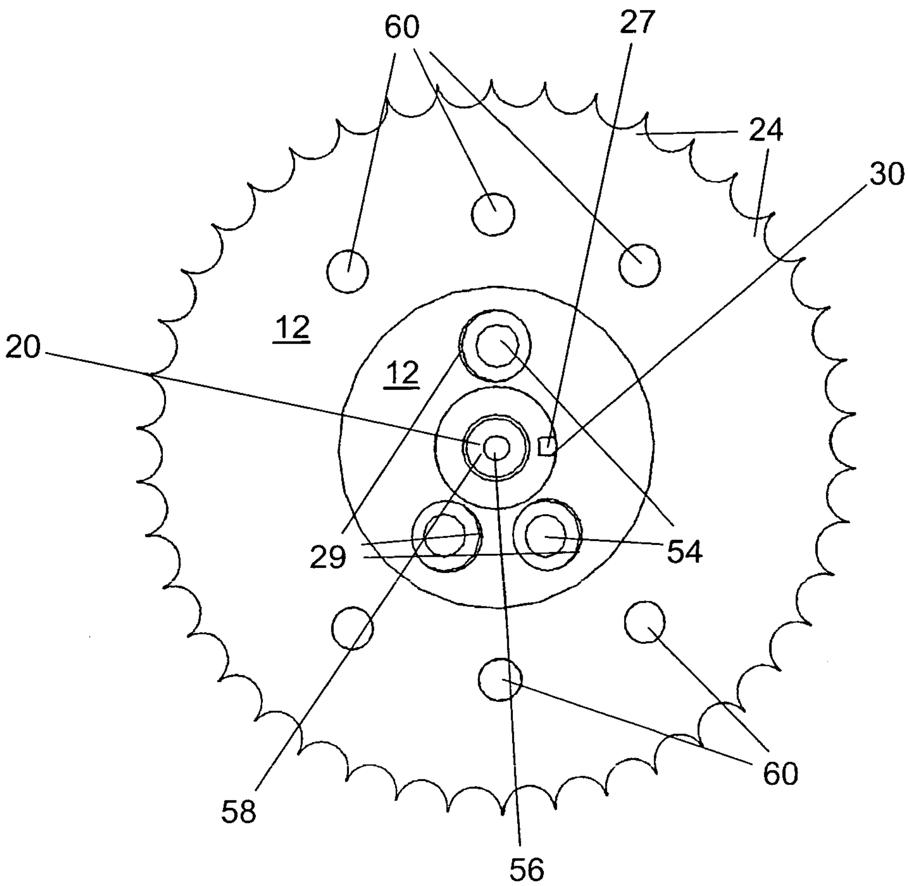

Fig. 5

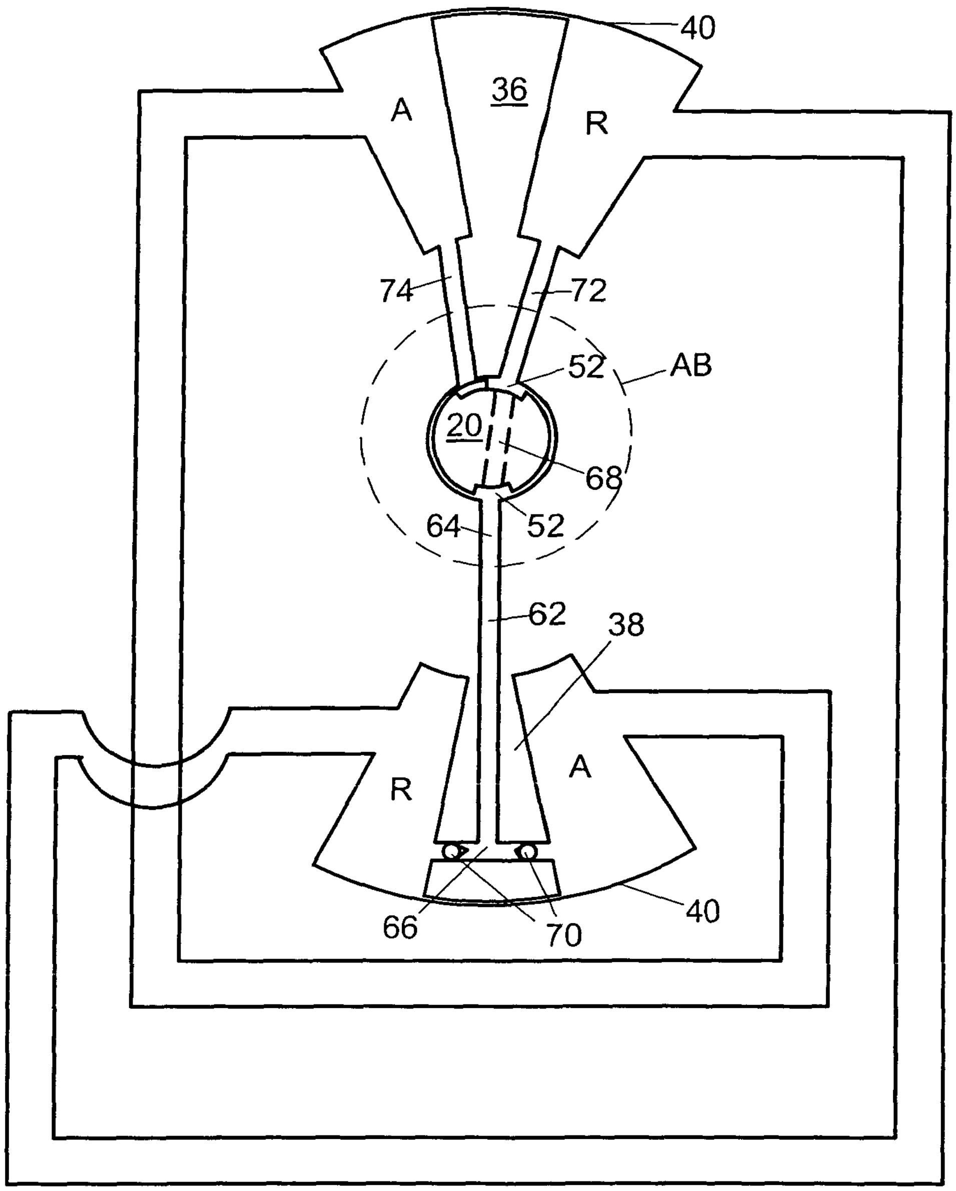

Fig. 5A

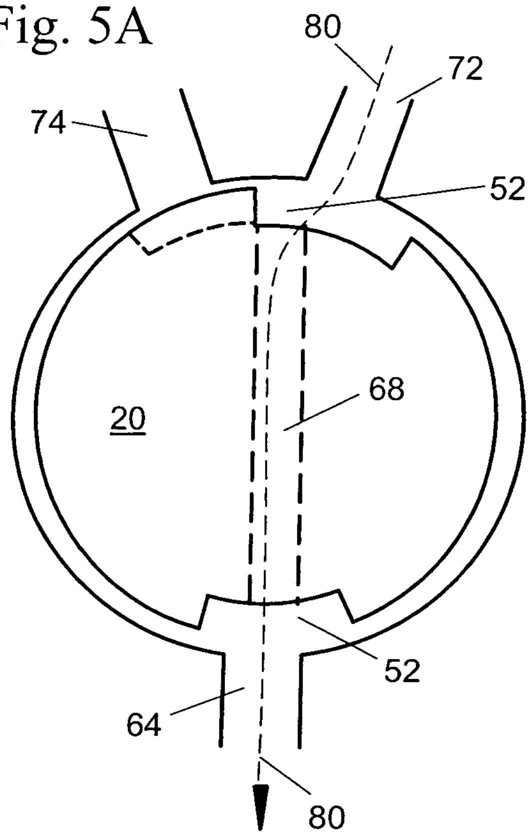

Fig. 5B

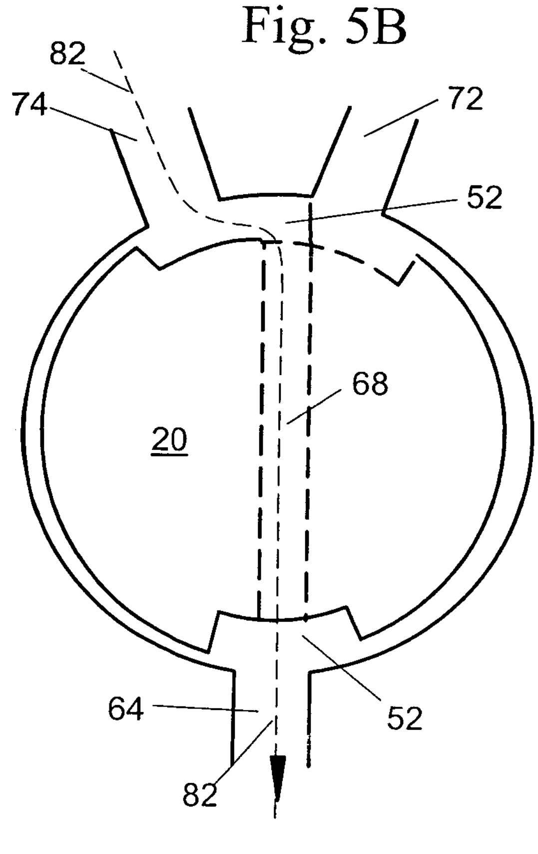

Fig. 6

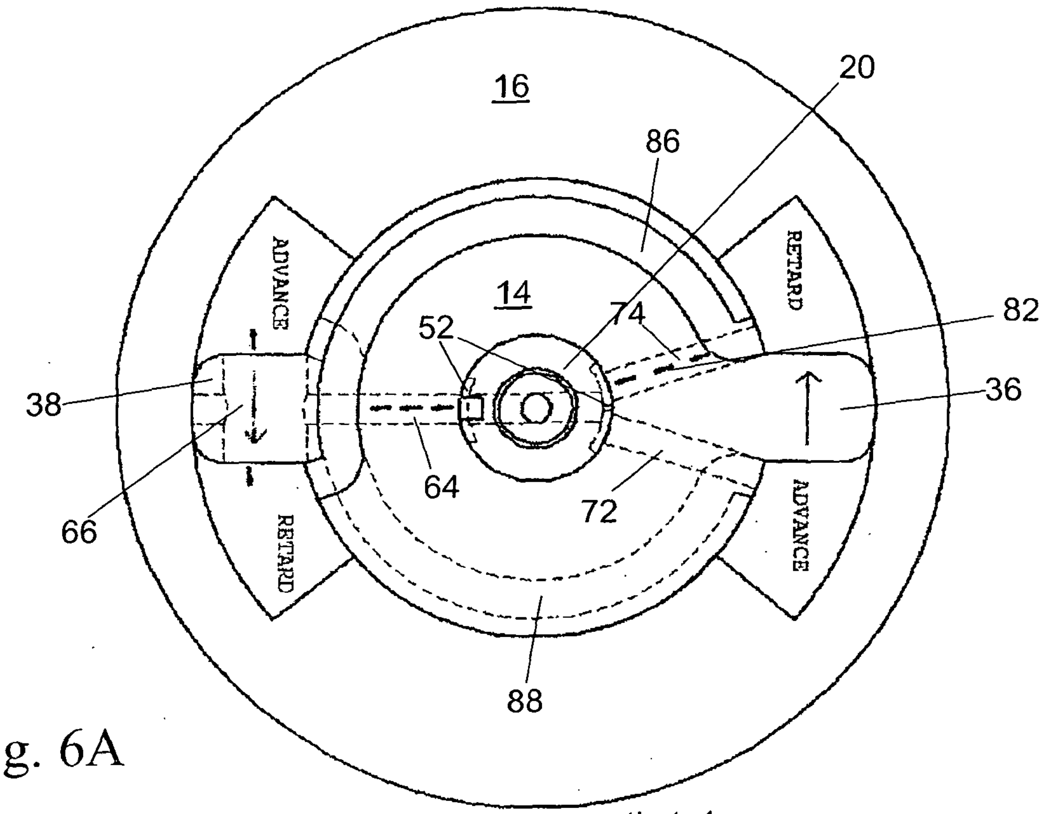
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Fig. 6A

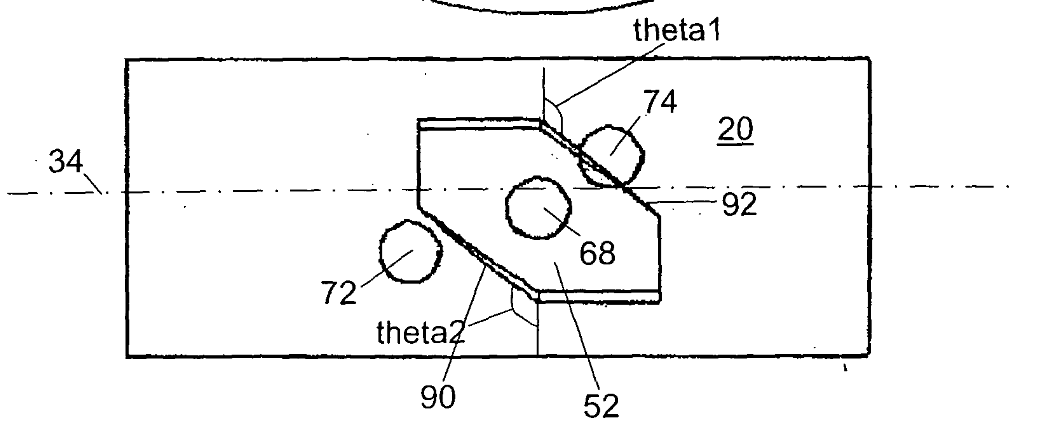
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Fig. 7

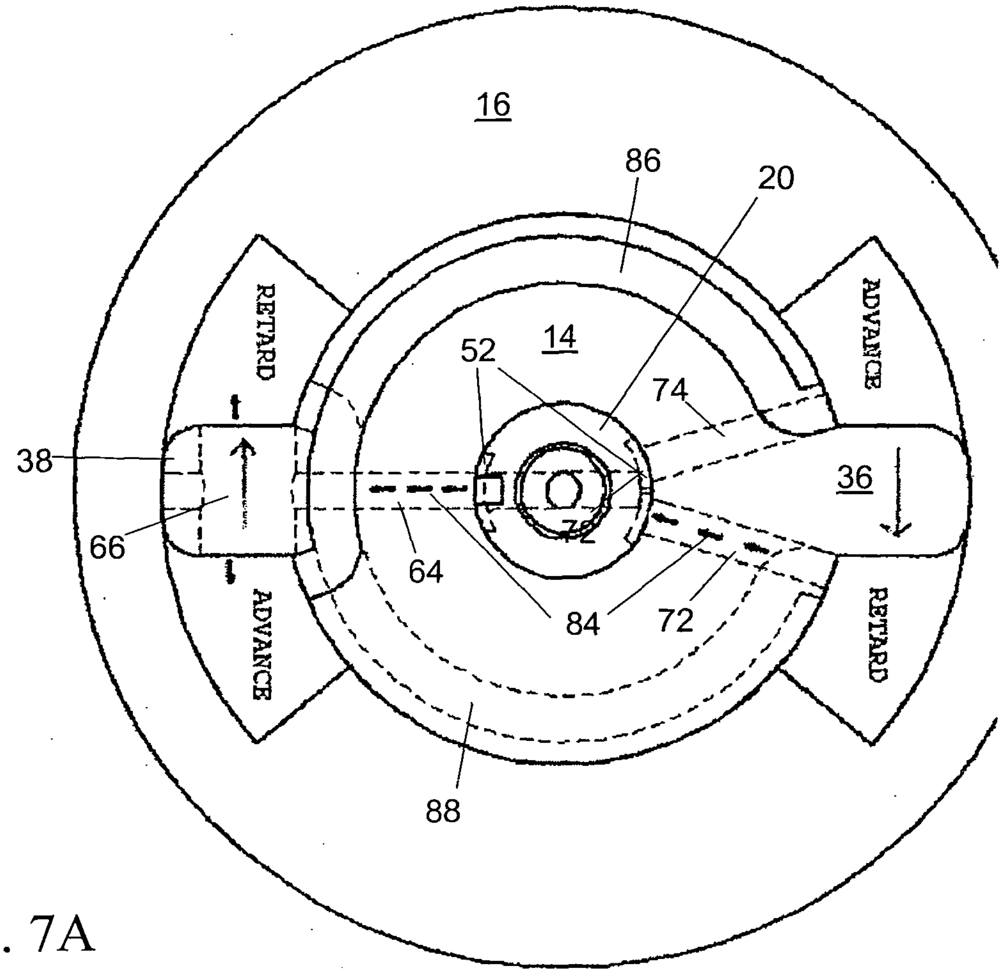
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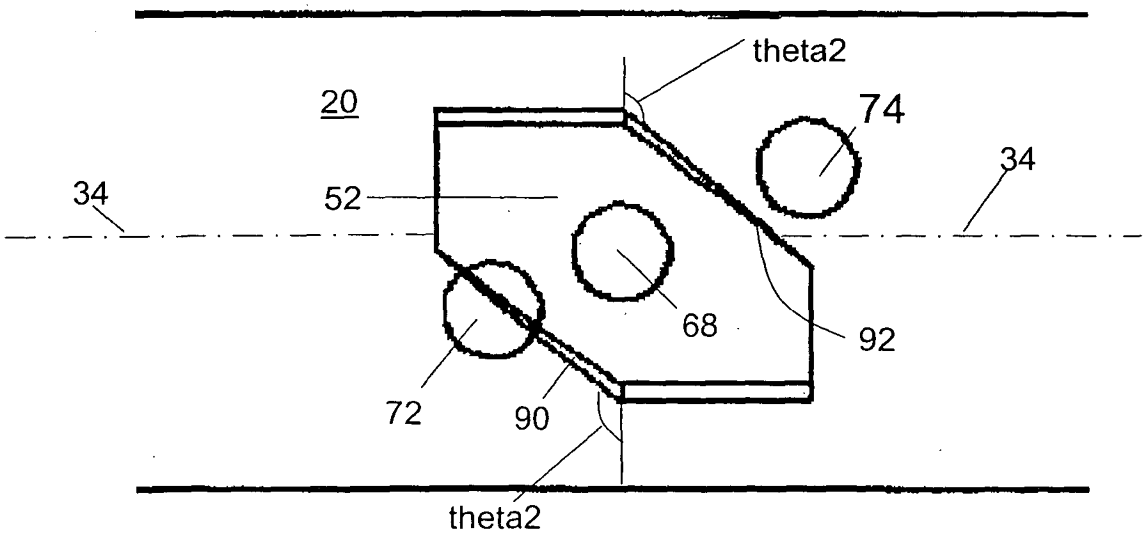
Fig. 7A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