ABSTRACT
An integral timing device for fuel injection pumps including a servo-actuated helically splined sleeve for varying the relative angular position of the pump drive shaft and the cam driven by the drive shaft which serves to reciprocate the pump plunger. The invention includes means for providing a positive trapping of the sleeve actuating fluid during the plunger injection interval to minimize the shifting of the cam towards a retard position and to reduce the pressure requirements of the device. In addition, means are provided for automatically retarding the pump timing during the starting of the engine.

11 Claims, 9 Drawing Figures
FUEL INJECTION PUMP TIMING DEVICE

The present invention relates generally to timing devices for fuel injection pumps and is particularly adapted for use as an internal timing device for single plunger, distributor type pumps.

The present invention is directed to improvements in fuel injection pump timing devices of the type shown in U. S. Pat. No. 3,050,964 (Hogemen et al.) assigned with the present application to a common assignee, which patent is hereby incorporated by reference. The present device is similar to that of the above patent and includes a centrifugal speed sensing means which by means of a servo mechanism adjusts the axial position of a splined sleeve between the pump drive shaft and plunger cam to change their angular relationship and hence the timing of the fuel injection. Important functional advantages are derived from the various structural improvements presently disclosed including the retarding of the timing during engine cranking and the prevention of cam shift during the injection interval.

To minimize the shifting of the cam during injection, the passages for the input flow of sleeve actuating fluid are formed by a plurality of slots in a non-rotating member which cooperate with an equal number of ports in a rotating member so located as to permit the passage of the high pressure actuating fluid into the sleeve chamber only between the pump injection intervals. The timing is automatically retarded for starting by providing spring means in the linkage controlling the centrifugal speed sensing means with the sleeve which will hold the sleeve in a retard position until the engine reaches a predetermined speed.

It is accordingly a first object of the present invention to provide an improved internal timing device for fuel injection pumps including means for minimizing the shifting of the pumping plunger cam during the injection interval of the plunger.

A further object of the invention is to provide a fuel injection pump timing device as described including means for automatically retarding the injection timing during cranking of the engine.

Additional objects and advantages of the invention will be more readily apparent from the following detailed description of embodiments thereof when taken together with the accompanying drawings in which:

FIG. 1 is a side elevational view of a fuel injection pump embodying the present invention with portions thereof broken away and in section to show interior details;

FIG. 2 is an enlarged sectional view of the portion of the pump of FIG. 1 shown therein in section;

FIG. 3 is a view similar to FIG. 2 but with the timing advanced in response to increased engine speed and with the helical splines of the cam and drive shaft partially shown in full;

FIG. 4 is a partial sectional view taken along line 4—4 of FIG. 3 showing the interruption of the sleeve actuating fluid passages during the injection interval;

FIG. 5 is a partial sectional view taken along line 5—5 of FIG. 3 showing the splined engagement of the sleeve with the cam and drive shaft;

FIG. 6 is a schematic phase diagram showing the timing of the servo mechanism fluid input with respect to the injection interval;

FIG. 7 is a view similar to FIG. 2 showing a modified embodiment of the invention (cam and enclosed mechanism only) including means for effecting an automatic retarding of the timing engine starting, the embodiment being shown in the starting retard position;

FIG. 8 is a partial view of the mechanism shown in FIG. 7 with the timing advanced to the 0° position; and

FIG. 9 is a graph showing the manner in which the pump timing is automatically varied by the embodiment of FIGS. 7 and 8 in accordance with pump speed to provide a timing retard during engine cranking.

Referring to the drawings and specifically FIG. 1 thereof, a fuel injection pump generally designated 10 embodying the present invention is generally similar to that disclosed in the above mentioned Hogemen patent and hence the details of the pump except for those portions with which the present invention is directly involved need not be described. The pump in brief includes a hydraulic head 12 within which a pump plunger is driven in reciprocation and rotation to sequentially inject fuel in metered amounts into the fuel outlets 14 which are connected by appropriate conduits to nozzles mounted in the engine.

The hydraulic head 12 is mounted in the pump housing 16 with the plunger thereof being driven by the pump drive shaft 18 as described below. The drive shaft 18 is coupled directly with the engine and may be driven at engine speed or a speed proportional to engine speed. A governor container within the governor housing 20 connected at one end to the pump housing 16 is driven indirectly as later described by the drive shaft 18 by means of the gear 22 which drives a similar gear 24 secured to the governor shaft 26. The engine speed is controlled by means of a linkage connected to the operating lever 23 in a conventional manner. Since the construction of the governor is conventional and not material to the present invention, the interior details are not shown.

The rotation of the pump plunger is effected by the gear 28 on the governor shaft 26 which meshes with the face gear 30 which is rotationally secured but axially slidable on the pump plunger.

Referring to FIG. 2, the pump drive shaft 18 rotates within the cam 32, the drive shaft being supported by the cam at bearing surfaces 34 and 36. The cam is rotatably supported within the housing 16 by bearings 38 and 40. A bearing liner 41 within the bearing 40 serves an important function to be presently described. The drive shaft 18 and cam 32 are secured and sealed within the housing by the retainer plate 42 which is secured to the housing 16 and includes appropriate seal means.

It will be noted that the gear 22 is an integral part of the cam. As described below, this feature insures a constant phase relation between the timing advance and the plunger rotation. The Hogeman structure does not coordinate the plunger rotation with timing advance, with a possible danger of hydraulic lock should be distribution channels fail to register properly during the injection interval.

The cam 32 includes a plurality of cam lobes 44 corresponding in number to the number of cylinders of the engine. The cam lobes 44 are adapted to engage the roller 46 of the tappet 48 which actuates the pump plunger in reciprocation. A return spring 50 (FIG. 1) maintains the contact of the roller 46 with the cam
lobes to insure the desired reciprocatory movement of the plunger.

The automatic timing device comprises means for varying the angular relationship of the drive shaft 18 and cam 32 automatically in accordance with the speed at which the pump is driven. For the most effective engine performance, it is necessary to advance the injection timing at higher speeds and to retard the timing during starting of the engine. This is accomplished in the present invention as in the above mentioned Hogeman patent by a centrifugal speed sensing device which controls a hydraulic servo mechanism. The servo mechanism actuates a sleeve 52 disposed between the cam 32 and drive shaft 18. The sleeve includes external helical splines 54 for cooperative engagement with similar interior splines 56 of the cam, and internal helical splines 59 which cooperate with the splines 58 of the drive shaft. Seal rings 60 and 61 axially spaced from the respective splines prevent servo fluid passage between the sleeve and the cam, or the sleeve and the drive shaft. A predetermined axial movement of the sleeve 52 will produce a change in the rotational angular relationship of the cam and the drive shaft. In the position shown in FIG. 2, the sleeve 52 is in the fully retarded position abutting the shoulder 62 of the cam. Since the range of timing adjustment might typically be 20°, this position is termed the position of 0° advance.

A pin 64 is radially secured to the sleeve 52 and passes through a helical slot 66 in the drive shaft 18 into the rod 68 which is slidable disposed in the axial bore 70 of the drive shaft 18. The position of the rod 68 will accordingly correspond to the position of the sleeve 52. A stem portion 72 of the rod 68 extends axially through a hollow valve member 74, also slidable disposed in the bore 70, and terminates in a spring seat 76 at its opposite end. A coil spring 78 extends in compression between the spring seat 76 and the end 80 of the valve member 74. A plurality of weights 82 are pivotally mounted at 84 to a spider 86 extending from the valve element 74 in such a manner as to cause a movement of the valve element toward the right as viewed in FIG. 2 upon the centrifugally effected outward movement of the weights. Such weight induced movement of the valve 74 is opposed by the compression spring 78, the spring rate of which is appropriately chosen to provide the required movement of the valve member with increasing speed of the pump. Shims 88 are applied to the spring seat 76 to create an initial spring force which must be overcome by the weight force before radial movement of the weights and hence movement of the valve member can occur.

The position of the valve member 74 controls the flow of high pressure sleeve actuating fluid, which in the present instance comprises oil from a source such as the engine lubrication system. The high pressure oil enters through ports 89 in the bearing 40 into an annulus 90 which distributes oil to the slots 92 in the bearing liner 41. A plurality of ports 94 in the cam connect the slots 92 with an annulus 96 in the bearing surface 36 adjacent the drive shaft 18. A plurality of equally spaced ports 98 in the drive shaft of a number equal to the number of lobes on the cam 52 extend radially to an annulus 100 opening into bore 76. As discussed in further detail below, the slots 92 in the bearing liner 41 and the ports 94 in the cam are cooperatively arranged so that the slots and ports are not in communication during the injection interval of the pump plunger thereby preventing any shifting of the cam with respect to the drive shaft.

The valve member 74 is characterized by a region 102 of reduced diameter which divides the member into two spaced lands 104 and 106. The position of shoulder 108 of the land 104 with respect to the annulus 100 of the drive shaft controls the flow of high pressure actuating oil into the region 102 of the valve. A plurality of radial ports 110 in the drive shaft connect the chamber formed by the drive shaft bore 70 and region 102 of the valve with the chamber 112 within which the splined sleeve 52 is disposed. Accordingly, when the land 104 of the valve member 74 is so positioned as to permit communication of the annulus 100 with the region 102 of the valve member, high pressure fluid will flow through the region 102 and ports 110 into the chamber 112 whereupon the sleeve 52 will be moved to the left as viewed in FIG. 2 as the fluid pressure overcomes the force of the spring 78.

An annulus 114 in the drive shaft is spaced from the annulus 100 exactly the same distance as the spacing of the valve member lands 104 and 106. A plurality of radial ports 116 in the land 106 permit oil to pass from the annulus 114 through the valve member into the hollow bore 118 thereof which it will be noted is of a diameter substantially larger than the diameter of the stem portion 72 of the rod 68, thus permitting the exhausing of the oil into the sump formed by the pump and governor housings. Oil may also drain past the rod 68 into drain bore 119 in the driven end of the drive shaft.

In operation, the timing device functions in a manner similar to that described in the above-cited Hogeman patent. With the pump drive shaft 18 connected with the engine to rotate at a speed equal or proportional to engine speed, the pump plunger will deliver metered quantities of fuel to the injection nozzle in accordance with the setting of the operating lever 23 which, acting through the governor, regulates the engine speed. At idling and relatively low speeds, the phase relationship of the drive shaft 18 with the cam 32 is in the normal 0° advance position shown in FIG. 2 wherein the sleeve 52 abuts the shoulder 62 of the cam. At such idling or low speeds, the weights 82 do not develop sufficient centrifugal force to overcome the opposing force of the spring 78 and the valve member 74 is accordingly disposed at its extreme leftward or closed position as in FIG. 2. In this position, the land 104 covers the annulus 100 thereby preventing high pressure fluid from reaching the sleeve chamber 112. At the same time, the land 106 is so positioned as to permit communication between the region 102 and the annulus 114 thereby permitting fluid to drain from the sleeve chamber 112 through ports 116.

As the speed of the engine and hence the pump is increased, the weights 82 overcome the force of spring 78 and in swinging outwardly move the valve member 74 to the right closing off the annulus 114 and at the same time opening the annulus 100 permitting a flow of high pressure fluid to enter the sleeve chamber 112 through the region 102 and ports 110. The pressurization of the chamber 112 moves the sleeve 52 to the left as shown in FIG. 3. The leftward movement of the
sleeve is substantially stabilized at a position dependent on the speed of operation of the engine by the linkage of the sleeve, pin 64 and the rod 68. Thus as the sleeve moves to the left, the rod 68 also moves to the left, further compressing the spring 78 and countereacting the centrifugally developed force of the weights 82. This movement of the rod 68 to the left serves to move the valve member 74 to the left thereby closing the annulus 100. For a given increased speed, the sleeve 52 will thus move to a predetermined position and the valve member 74 will become relatively stabilized as the spring force 78 and centrifugal force of the weights become balanced. By virtue of the helical splines on the sleeve 52 and the corresponding splines of the drive shaft and cam, the change in the timing relationship of the drive shaft and cam is automatically regulated in accordance with the speed of rotation of the pump.

Upon a further increase in the speed of engine operation, the weights will again move the valve member to admit fluid to the sleeve chamber 112 and move the sleeve to the left to establish a new advanced timing relation of the drive shaft and cam. Conversely, should engine speed decrease, the inwardly collapsing spring will allow the valve member 74 to move to the left, opening the main annulus 114 and draining the fluid in the chamber 112 to the sump, thus permitting movement of the sleeve to the right under the influence of the spring 78 acting through the rod 68 and pin 64. When the spring and weight forces are balanced, the valve member 74 will again reach a relatively stabilized position although a slight oscillation of the valve takes place even during constant speed operation.

Because of the greatly increased force transmitted through the cam during the plunger injection interval, there is a tendency for the cam to shift on the helical splines with respect to the drive shaft during the injection interval, especially during periods when the annuli 100 and 114 are in communication with the chamber 112. The tendency is for the sleeve 52 to be shifted to the right under the increased resistance during the injection interval and accordingly to produce a less advanced timing relationship than is required for optimum efficiency at a particular speed. Such a shifting is not as detrimental during the opening of the drain annulus 114 since this annulus is opened only during a retarding phase of operation which is hastened by the shifting tendency. However, during the opening of the annulus 100, such a shifting tendency runs counter to the timing advance being carried out.

By the present invention, such a shifting tendency is minimized during the time the valve member 74 is positioned to permit flow from the annulus 100. The structure provided to minimize the shifting comprises the slots 92 in the bearing liner 41 and their cooperative relationship with ports 94 of the cam. With reference to FIGS. 4 and 6, it will be observed that the ports 94 do not communicate with the slots 92 during the high pressure injection interval of the pump due to the selection of the length and angular relation of the slots with respect to the ports 94 and the cam lobes 44. There is accordingly a positive trapping of the sleeve actuating fluid in the sleeve chamber 112 during the injection interval. The fluid cannot escape past the sleeve due to the seal rings 60 and 61. In the view of FIG. 4, the ports 94 have just rotated out of communication with the slots 92 as the plunger has advanced to approximately 20° from bottom center. As shown in FIG. 6, the port closing occurs approximately 19° after bottom center at the same time as the port closing of the injection pump plunger. As indicated, the end of injection at maximum delivery occurs at approximately 34° and the ports 94 again communicate with the slots 92 at approximately top center which is 45° of shaft rotation from bottom center with a four lobe cam configuration.

The provision of the gear 22 on the cam rather than on the drive shaft as in the Hogeman U.S. Pat. No. 3,050,964 maintains a constant phase relation of the plunger reciprocation and rotation. Thus, as the timing is advanced or retarded by cam rotation, there is a corresponding rotation shift of the plunger. This allows at least theoretically an unlimited timing advance without danger of hydraulic lock.

A modified embodiment of the invention is shown in FIGS. 7 and 8 which includes essentially the same timing device described above with the addition of an arrangement for permitting a retarding of the timing below the 0° timing position during starting and low idling of the engine. Since the structure providing this function is contained wholly within the cam, only the cam and interior details of the modified embodiment are shown in FIGS. 7 and 8. The cam, drive shaft, sleeve, valve member and flyweight assembly are identical with the counterparts of the timing device described above and accordingly bear the same identifying numbers as do other identical elements.

Referring to FIG. 7, the rod 68 is at its left end of a different configuration than the rod 68 of the above described embodiment. The pin 64 secured to the sleeve 52 passes through an axial slot 130 in the hollow end portion 132 of the rod 68. A light spring 134 is mounted in compression in the hollow end 132 of the rod between a spring seat 136 and a piston 138 slidably disposed within the hollow bore of the rod and bearing against the pin 64. The spring 134 will accordingly urge the rod 64 and hence the sleeve 52 toward a retard position. With the engine stopped as shown in FIG. 7, the spring 134 imposes the sleeve 52 against the shoulder 62 of the cam, which in this embodiment is a timing position of −6° below the normal 0° advance position as illustrated in the graph of FIG. 9. A shoulder portion 140 of the rod 68 engages the left hand end of the valve member 74 in the stopped or idling position of the pump, and the spring 78 and shims 88 are selected so that the rod 68 remains with the shoulder 140 abutting the valve member until the pump reaches a speed of approximately 850 rpm, at which point the centrifugal force of the weights is sufficient to overcome the force of the compressed spring and to move the valve member out of engagement with the rod shoulder.

At speeds below 400 rpm, the force of spring 134 is greater than the centrifugal force of the weights 82 and the rod 64 and sleeve 52 will accordingly move to the fully retarded position shown in FIG. 7. At speeds between approximately 400 and 520 rpm, the centrifugal force of the weights is sufficient to compress the spring 134 and move the rod 68 and the valve member 74 to the right to open the annulus 100 and permit a fluid flow into the sleeve chamber 112, thereby advancing the timing as high as the 0° advance position illus-
trated in FIG. 8. At speeds between approximately 520 and 850 rpm, the sleeve remains in the position shown in FIG. 8 with the spring 134 fully compressed. Since the valve member 74 and rod 68 remain in abutting relationship in this speed range, there is no change in the timing relationship of the drive shaft and cam which remains at 0°. At speeds above 850 rpm, the timing advance is in direct proportion to increase speed as shown in FIG. 9.

While the several embodiments of the invention have been described in the setting of a single plunger distributor type pump, it will be apparent that the invention may also be used with other types of pumps wherein the angular relation of a plunger cam with respect to the cam drive shaft is selectively controlled.

Manifestly, changes in details of construction can be effected by those skilled in the art without departing from the spirit and the scope of the invention.

We claim:

1. In a fuel injection pump including a drive shaft, a pump plunger, a pump plunger actuating cam rotatably driven by said drive shaft, said cam driving said plunger radially away from said drive shaft during a portion of the cam rotation including the plunger injection interval, timing means for varying the relative angular relation of said drive shaft and cam, said timing means including a sleeve disposed between and operatively connected to said cam and said drive shaft, and hydraulic means for actuating said sleeve to vary the relation of said drive shaft and cam, hydraulic means including an input conduit for actuating fluid, the improvement comprising means for preventing the shifting of the cam comprises seal rings associated with said sleeve for preventing escape of actuating fluid from said sleeve chamber during the injection interval.

2. A fuel injection pump timing device comprising a drive shaft, a pump plunger actuating cam rotatably driven by said drive shaft, said cam being concentrically disposed in overlying rotateable relation with said drive shaft and operatively connected by helical splines to said cam and drive shaft, hydraulic means including conduit means for introducing pressurized fluid into said sleeve chamber to effect axial movement of said sleeve and a resultant variation of the timing relation of said drive shaft and cam, hydraulic means operatively connected with said hydraulic means for preventing the shifting of the cam with respect to the drive shaft during the plunger injection interval, said sensitive means comprising means for closing said sleeve actuating fluid conduit means during the injection interval, said sensitive means comprising means for preventing said escape of pressurized fluid along said sleeve during the injection interval.

3. The invention as claimed in claim 4 wherein said sleeve is disposed in a bearing member rotatably supporting said sleeve, and wherein said ports are disposed in said sleeve.

4. The invention as claimed in claim 4 wherein said means for preventing the shifting of the cam comprises means associated with said sleeve for preventing escape of fluid from said sleeve chamber during the injection interval.

5. The invention as claimed in claim 4 wherein said means for preventing the shifting of the cam comprises seal rings associated with said sleeve for preventing escape of fluid from said sleeve chamber during the injection interval.

6. The invention as claimed in claim 4 wherein said means for preventing the shifting of the cam comprises seal rings associated with said sleeve for preventing escape of fluid from said sleeve chamber during the injection interval.

7. A fuel injection pump timing device comprising a drive shaft, a pump plunger actuating cam rotatably driven by said drive shaft, said cam being concentrically disposed in overlying rotateable relation with said drive shaft and operatively connected by helical splines to said cam and drive shaft, hydraulic means including conduit means for introducing pressurized fluid into said sleeve chamber to effect axial movement of said sleeve and a resultant variation of the timing relation of said drive shaft and cam, hydraulic means including a valve slidably disposed in a coaxial bore within said drive shaft, centrifugal speed sensing means operatively connected with said valve to effect automatic control of said hydraulic means, a rod coaxial with said drive shaft and disposed within a concentric bore in said drive shaft and passing through a concentric bore of said sleeve, a first spring means extending between said sleeve and said rod opposing the centrifugal movement of said speed sensing means, and a second spring means associated with said rod adapted to urge said sleeve toward a timing retard position when said pump speed falls below a predetermined level.

8. The invention claimed in claim 7 including a radial pin secured to said sleeve and passing through an axial slot in said rod, said second spring means being connected with said rod to urge said pin and hence said sleeve against the force of fluid pressure in said sleeve chamber.

9. The invention claimed in claim 8 including means for preventing relative movement of said rod and valve during pump operation below a predetermined speed.

10. The invention claimed in claim 7 including means for conserving said conduit means for introducing pressurized fluid into said sleeve chamber during the injection of the pump plunger.

11. The invention as claimed in claim 10 including means associated with said sleeve for preventing escape of pressurized fluid along said sleeve during the injection interval.
UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,726,608 Dated April 10, 1973

Inventor(s) Norvan W. Bostwick et al

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 2, line 30, change "container" to --contained--;
line 38, change "nor" to --not--;
line 59, after "be" insert --the--.

Claim 7, line 31 after "drive shaft" insert --, a sleeve disposed in a chamber between said cam and drive shaft--.
Claim 10, line 61 after "injection" insert --interval--.

Signed and sealed this 20th day of November 1973.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.  RENE D. TEGTMeyer
Attesting Officer  Acting Commissioner of Patents