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(54) **Digital inlet valve**

(57) A digital inlet valve (24) comprises a dynamically passive poppet valve (25) normally closed cooperating

with a piloted actuator (36) to stay open.

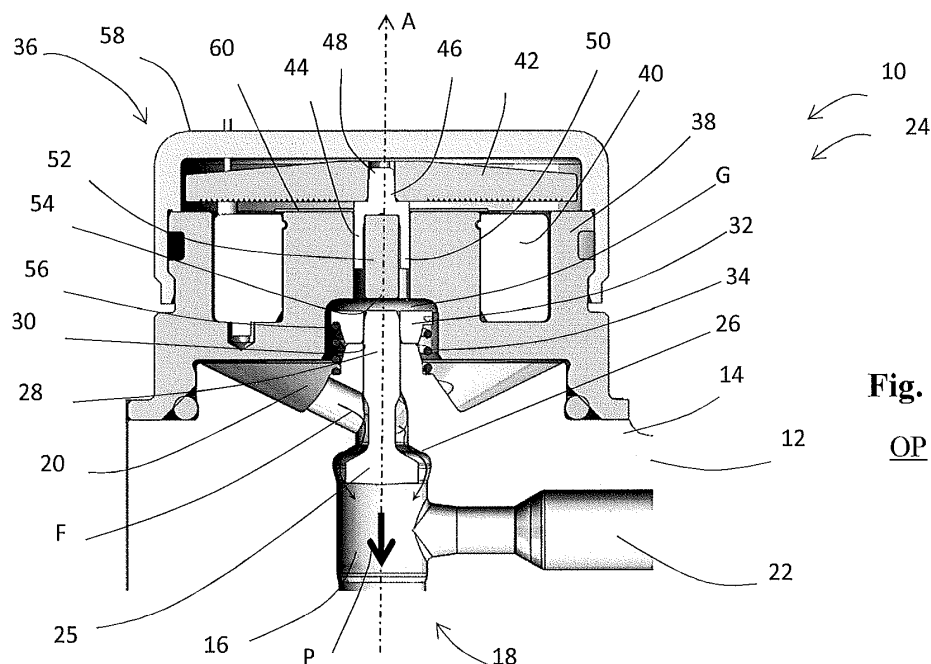


Fig. 1
OP

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Description

TECHNICAL FIELD

[0001] The present invention relates to a digital inlet valve for metering the fuel quantity entering the pumping chamber of a high pressure pump.

BACKGROUND OF THE INVENTION

[0002] In diesel fuel systems, high pressure pumps are provided with inlet metering valve that meters the flow of fuel that enters in a compression chamber wherein a piston reciprocally moves.

[0003] In a first filling phase, the piston moves so the free volume of the chamber increases, the valve opens and the fuel fills the chamber. In a subsequent compression phase, the piston moves to minimize said volume, the valve closes, and the fuel in the chamber is pressurized and is sent through an outlet toward the injectors. A spring permanently solicits the valve toward closing. The valve is either "passive" or "piloted". "Passive" means that the valve is only subject to the closing force of the spring, to the opening force due to aspiration during the filling phase or to the closing force due to compression of the fuel in the chamber. "Piloted" meaning its displacements are piloted by an electromagnetic actuator, providing the same function of fuel metering as a proportional flow control valve. A piloted valve is taught in application WO2012163892. To control the moves of the valve, the stem of the valve is fixed to the magnetic plunger of the actuator.

[0004] The piloted valve is difficult to assemble as several press fit operation have to be performed on the manufacturing assembly line. Consequently, it is not possible either to source the actuator as a separate kit. Another issue is that the displacements of the plunger and of the valve are equal while the actuator and the valve have their own design constraints obliging to compromise.

SUMMARY OF THE INVENTION

[0005] The present invention aims at solving the above mentioned problem by proposing a digital inlet valve of a hydraulic head of a high pressure pump of a diesel fuel injection system. The digital inlet valve comprises a poppet valve normally closed cooperating with a piloted actuator. The valve is dynamically passive and cooperates with the actuator to stay open. The actuator may be energized earlier so to help the opening during filling phase or to force the valve to stay open during pumping phase.

[0006] The hydraulic head has a body provided with a compression chamber in which opens an inlet and an outlet. The body is further provided with a bore extending along a main axis and in which is arranged the stem of the valve able to reciprocally slides between a closed position where the valve is in abutment against a seat surrounding the inlet and an open position where the

valve is at a distance from the seat enabling the fuel F to flow. An elastic member is arranged to permanently solicit the valve toward the closed position. The actuator is an electromagnetic actuator having an armature, a fixed coil piloting a movable magnetic core, the core is arranged to cooperate with the valve stem only to maintain the valve in the open position, the valve being passive when opening and when closing.

[0007] More precisely, the elastic member is a coil spring positioned around the valve stem and compressed between the body and, a spring seat fixed at the extremity of the stem.

[0008] Also the core is flat having a thick disc shape arranged transversally to the main axis.

[0009] The digital inlet valve further comprises an adjusting shim arranged between the core and the valve stem. The shim axially extends from an upward extremity fixed to the core to a downward extremity that contacts the valve stem only to maintain the valve in the open position.

[0010] In an alternative embodiment, the digital inlet valve further comprises a second elastic member permanently soliciting the core away from the valve stem.

[0011] More specifically, the second elastic member is a coil spring compressed between the armature and the core.

[0012] The invention is also related to a high pressure pump having a hydraulic head provided with a chamber in which a piston is reciprocally moving between an upward position where the volume of the chamber is minimized and the fluid in the chamber is compressed and a downward position where said volume is maximized. The pump comprises a digital inlet valve as described above and arranged on the hydraulic head to control the filling of the chamber.

[0013] The invention is further related to a process to control the operation of a high pressure pump, the process comprising the steps of:

- providing a high pressure pump as described above;
- depressurizing the chamber by downwardly displacing the piston so that the valve opens enabling the fuel to fill the chamber;
- energizing the actuator so to maintain the valve in the open position;
- stop energizing the actuator, the valve closing as being subject to the pressure inside the chamber, the fuel compressed being sent via the outlet.

[0014] The process can further comprise the step:

- maintain the valve open by continuing to energize the actuator at the beginning of the upward displacement of the piston so to control the volume of the chamber and send some fuel back into the inlet.
- stop energizing the actuator when the volume of the fuel in the chamber matches the fuel quantity needed, the valve closing as being subject to the pressure

inside the chamber, the fuel compressed being sent via the outlet.

[0015] The process can further comprising the step of:

- energizing the actuator during the depressurizing step so to force the valve in the open position before the depressurization is enough to open the valve.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] The present invention is now described by way of example with reference to the accompanying drawings in which:

- Figure 1 is a section of a digital inlet valve during a filling phase.
- Figure 2 is the valve of figure 1 at beginning of pumping phase.
- Figure 3 is the valve of figure 1 during the pumping phase.
- Figure 4 is an alternative embodiment of a digital inlet valve.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0017] The description shall utilize an orientation as set in the pictures. For clarity purposes and, words such as "top", "bottom", "up", "upward", "down" or "downward" may be utilized without any intention to limit the scope of the invention.

[0018] The subject matter of the present invention is a digital inlet valve 24 which embodiment will be described in reference to figure 1. In a diesel fuel injection system, the fuel F sprayed by the injectors is compressed in a high pressure pump 10.

[0019] The high pressure pump 10 of a diesel injection system comprises a hydraulic head 12 having a body 14 provided with a compression chamber 16 extending along a main axis A. In the chamber 16, a piston 18 reciprocally moves between a top position, where the free volume inside the chamber 16 is minimal, and a bottom position where said volume is maximized. At the top end of the chamber 16 opens an inlet 20 through which the fuel F may flow to fill the chamber 16. An outlet channel 22 transversally departs from the chamber 16 leading the fuel F toward the injectors. The inlet 20 is controlled by the digital inlet valve 24 comprising a poppet valve 25 that cooperates with a seat 26 surrounding the inlet 20. The valve 25 can be in an open position OP, at a distance from the seat 26 and then the fuel F can fill the chamber 16 or, the valve 25 can be in a closed position CP, in abutment in a complementary manner against the seat 26 so to prohibit any flow of the fuel F. From the valve 25 axially extends a stem 28 guided in a bore 30 of the body 14. The stem 28 protrudes from the bore 30 and extends up to an extremity where is fixed a spring seat 32. A coil spring 34 arranged around the stem 28 is com-

pressed between the spring seat 32 and another spring seat provided in the body 14 so to permanently axially pull the valve 25 upward toward the closed position CP.

[0020] The digital inlet valve 24 further comprises a flat electromagnetic actuator 36 that covers the hydraulic head 12. The actuator 36 comprises an armature 38 fixed to the head body 14, a coil 40 arranged in the armature 38 and a disc shape magnetic core 42 positioned above the coil 40. The armature 38 is further provided with an axial bore 44 through which is slidably engage a shaft 46 centrally fixed to the core 42. The shaft 46 is made of nonmagnetic material. It has an upward male extremity 48 engaged and fixed into a central hole of the core 42 and, a downward female extremity 50 in which is engaged and fixed the upper extremity of an adjusting shim 52, made as well from a nonmagnetic material, and which axially extends until a downward extremity 54. The axial bore 44 of the armature 36 downwardly opens in a cylindrical recess 56 wherein the valve stem 28 and the spring seat 32 can displace without contacting the armature 38. As can be observed on the figures the shaft 46, the shim 52 and the valve stem 28 are axially aligned. In an alternative construction, the shim could be removed and the shaft or the stem could be longer. The advantage to use a shim is to enable fine adjustment when assembling. Said adjustment in length can be done by presorting shims in classes of tolerance then by selecting an appropriate shim as a function of the stack up of the assembly. Alternatively, a fine small tolerance fine machining is an option to perform said adjustment while avoiding shim classes.

[0021] The armature 36 is covered by a cover 58 enclosing the core 42. On the upper face of the armature 38 is positioned a nonmagnetic thin washer 60 that prevents sticking effect of the core on the armature.

[0022] The operation of the valve 24 will now be described.

[0023] In a first phase represented on figure 1, the coil is not energized and the piston 18 moves downward as shown by arrow P. The valve 25 opens as it is subject to opening forces due to the depressurization of the chamber 16 and to the fuel F in the inlet 20, the opening force is superior to the closing force of the spring 34. The fuel F fills the chamber 16. When opening, the stem 28 loses contact with the downward extremity 54 of the shim 52 so a gap G is created between the shim and the stem.

[0024] In a second phase represented on figure 2, the coil 40 is energized, which is pictorially symbolized by a light storm, and the core 42 is downwardly attracted toward the coil 40 and consequently the downward extremity 54 of the shim comes in abutment against the upward extremity of the stem 28 and maintains the valve 25 open. The piston 18 has initiated its upward travel and some fuel F flow back from the chamber 16 toward the inlet 20.

[0025] In a third phase represented on figure 3, the coil 40 is no longer energized and the shim does not generate any force on the stem. The upward displacement of the piston 18 compresses the fuel F in the chamber 16 and,

the valve 25 closes as the compression generates on the valve 25 a closing force which adds to the force of the spring. The fuel F pressurized in the chamber 16 now flows to the outlet 22 toward the injectors. In a control alternative, the coil 40 remains energized at the beginning of the third phase in order to maintain the valve 25 in the open position OP. A certain quantity of fuel F is sent back via the inlet 20 until the volume remaining in the compression chamber 16 matches the fuel F quantity to be sent to the injectors. Then, the coil 40 is energized enabling the valve 25 to close CP.

[0026] With this construction the valve 25 is dynamically passive as to open or to close in only reacts to forces due to aspiration or compression. The coil is only energized to maintain the valve open.

[0027] A piloting alternative of the digital inlet valve consists in energizing the coil when the piston initiates its downward displacement so helping the valve to open as early as possible and optimizing the filling of the chamber.

[0028] In a design alternative represented figure 4, a second spring 62 is axially A arranged in an axial recess 64 upwardly open provided in the armature 38. The second spring 62 is around the upper portion of the shaft 46 and it is compresses between the bottom of said recess 64 and the core 42.

[0029] The second spring 62 has a low stiffness and its role is to help when moving from the open position OP to the closed position CP. Indeed in this phase of operation, the coil 40 is not energized and the spring 34, the "first spring" has to axially A push upward the all assembly of the valve 24, the spring seat 32, the shim 52, the shaft 46 and the core 42 and to overcome the inertia of this assembly which, at high speed, may be important.

[0030] The addition of the second spring 62 compensates for the inertia of the core 42, shaft 46 and shim 52 and does not affect the opening phase of the valve 25.

Claims

1. A digital inlet valve (24) of a hydraulic head (12) of a high pressure pump (10) of a diesel fuel injection system, comprising a poppet valve (25) normally closed cooperating with a piloted actuator (36) **characterized in that** the valve (25) is dynamically passive and cooperates with the actuator (36) to stay open.
2. A digital inlet valve (24) as set in the preceding claim wherein the hydraulic head (12) has a body (14) provided with a compression chamber (16) in which opens an inlet (20) and an outlet (22), the body (14) being further provided with a bore (30) extending along a main axis (A) and in which is arranged the stem (28) of the valve (25) able to reciprocally slides between a closed position (CP) where the valve (25) is in abutment against a seat (26) surrounding the

inlet (20) and, an open position (OP) where the valve (25) is at a distance from the seat (26) enabling the fuel (F) to flow, an elastic member (34) being arranged to permanently solicit the valve (25) toward the closed position (CP), the actuator (36) being an electromagnetic actuator (36) having an armature (38), a fixed coil (40) piloting a movable magnetic core (42), the core (42) being arranged to cooperate with the valve stem (28) only to maintain the valve (25) in the open position (OP), the valve (25) being passive when opening and when closing.

3. Digital inlet valve (24) as set in claim 2 wherein the elastic member is a coil spring (34) positioned around the valve stem (28) and compressed between the body and, a spring seat (32) fixed at the extremity of the stem (28).
4. Digital inlet valve (24) as set in any of the claims 2 or 3 wherein the core (42) is flat having a thick disc shape arranged transversally to the main axis (A).
5. Digital inlet valve (24) as set in any of the claims 2 to 4 further comprising an adjusting shim (52) arranged between the core (42) and the valve stem (28), said shim (52) axially extending from an upward extremity fixed to the core to a downward extremity (54) that contacts the valve stem (28) only to maintain the valve (25) in the open position (OP).
6. Digital inlet valve (24) as set in any of the claims 2 to 5 further comprising a second elastic member (62) permanently soliciting the core (42) away from the valve stem (28).
7. Digital inlet valve (24) as set in claim 6 wherein the second elastic member (62) is a coil spring (62) compressed between the armature (38) and the core (42).
8. High pressure pump (10) having a hydraulic head (12) provided with a chamber (16) in which a piston (18) is reciprocally moving between an upward position where the volume of the chamber is minimized and the fluid (F) in the chamber is compressed and a downward position where said volume is maximized, a digital inlet valve (24) as set in any of the preceding claims being arranged on the hydraulic head (12) to control the filling of the chamber (16).
9. Process to control the operation of a high pressure pump (10) comprising the steps of:
 - providing a high pressure pump as set in claim 8, the digital inlet valve (24) is as set in any of the claims 2 to 5;
 - depressurizing the chamber (16) by downwardly displacing the piston (18) so that the

valve (25) opens (OP) enabling the fuel (F) to fill the chamber (16);
- energizing the actuator (36) so to maintain the valve (25) in the open position (OP);
- stop energizing the actuator (36), the valve (25) closing (CP) as being subject to the pressure inside the chamber (16), the fuel (F) compressed being sent via the outlet (22).

10. Process as set in claim 9 further comprising the step of: 10

- maintain the valve (25) open (OP) by continuing energization of the actuator (36) at the beginning of the upward displacement of the piston (18) so to send some fuel (F) into the inlet (20). 15
- stop energizing the actuator (36) when the volume of the fuel (F) in the chamber (16) matches the fuel (F) quantity needed, the valve (25) closing (CP) as being subject to the pressure inside the chamber (16), the fuel (F) compressed being sent via the outlet (22). 20

11. Process as set in any of the claim 9 or 10 further comprising the step of: 25

- energizing the actuator (36) during the depressurizing step.

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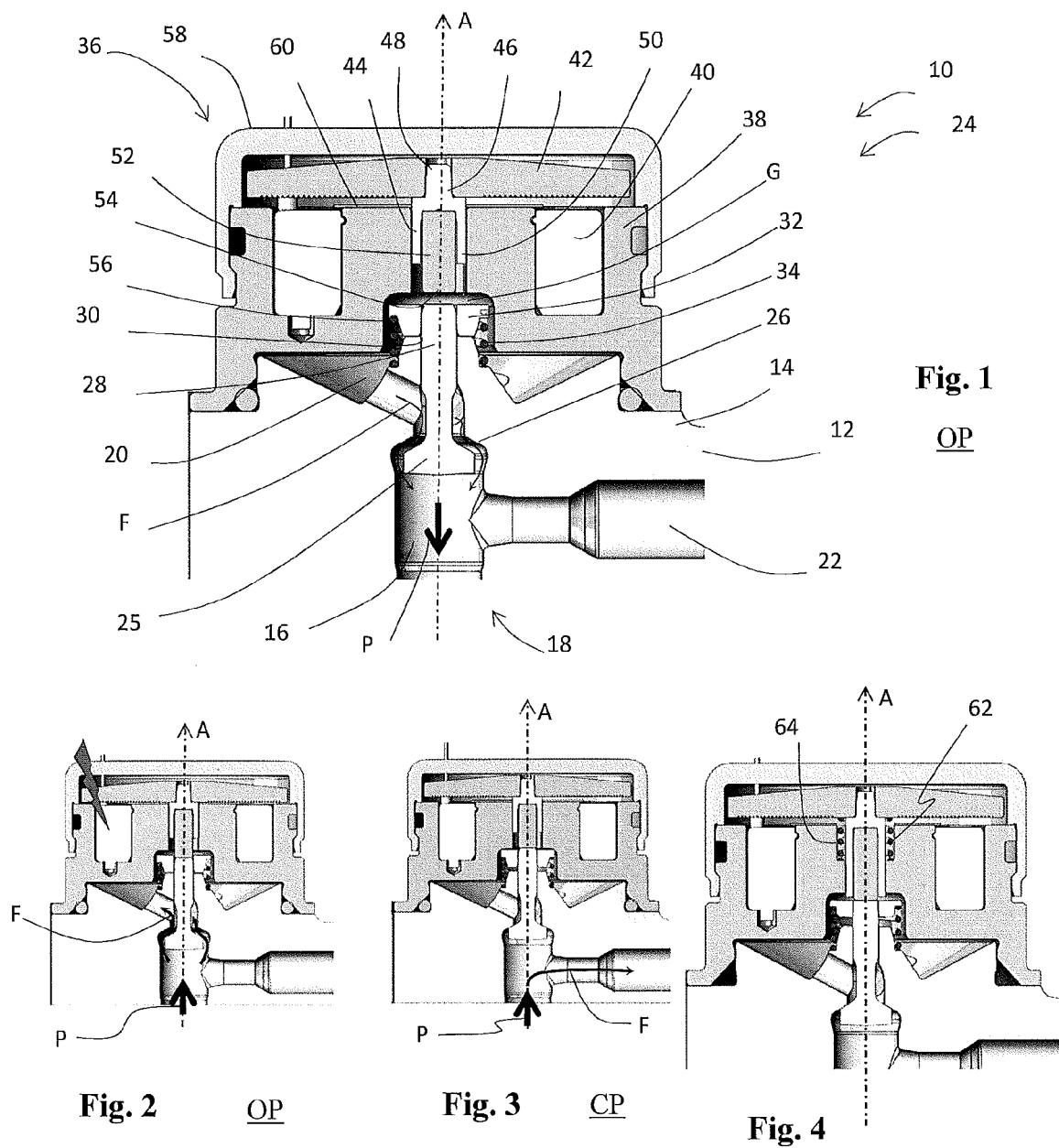
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Application Number
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X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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