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(54) **Injection pump systems and methods of operation**

(57) The present invention relates to an injection pump system (1). An injection pump (3) is provided for supplying high pressure fuel. A low pressure fuel line (5) is provided in fluid communication with an inlet of the injection pump (3). A high pressure fuel line (7) is provided in fluid communication with an outlet of the injection pump (3) and a fuel rail. A control valve (27) is provided for controlling filling of the injection pump (3). The injection pump system is provided with a control unit for controlling operation of the control valve (27). The control unit is configured to close the control valve (27) to inhibit the supply of fuel to the injection pump when the rail pressure is within a target pressure range. The invention also relates to a method of operating an injection pump system. An aspect of the invention also relates to a fuel injection system.

tion pump system is provided with a control unit for controlling operation of the control valve (27). The control unit is configured to close the control valve (27) to inhibit the supply of fuel to the injection pump when the rail pressure is within a target pressure range. The invention also relates to a method of operating an injection pump system. An aspect of the invention also relates to a fuel injection system.

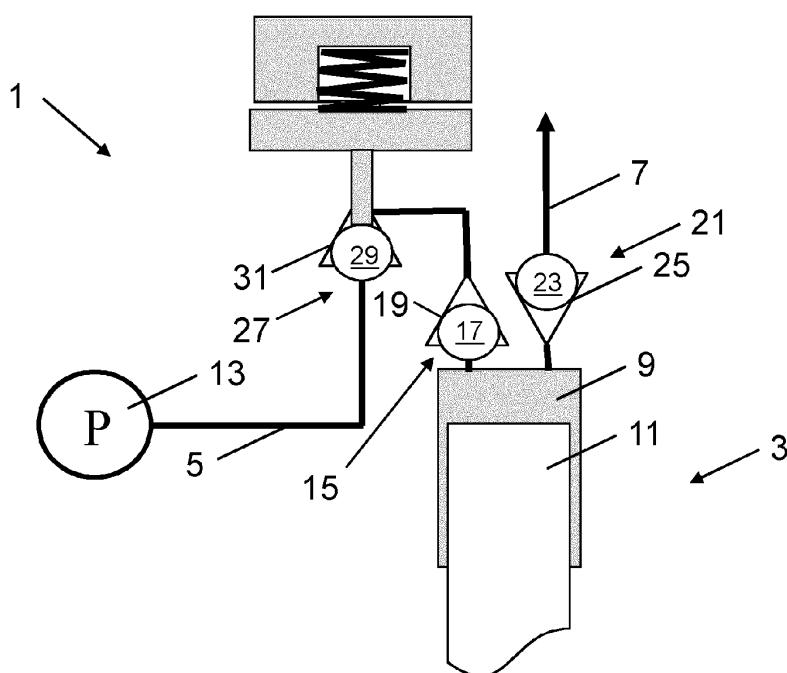


FIG. 1

Description

TECHNICAL FIELD

[0001] The present invention relates to an injection pump system for a fuel injection system. The invention also relates to a method of operating an injection pump system. Aspects of the invention also relate to a fuel injection system.

BACKGROUND OF THE INVENTION

[0002] It is known to provide fuel injection systems with a common fuel rail which supplies high pressure fuel to an array of injection nozzles for injection into the combustion chambers of an internal combustion engine. This technique is common in diesel fuel systems for automotive applications. To provide improved efficiency, the operating pressure of the fuel can be greater than 2000 bar and as high as 3000 bar. The fuel is supplied from a low pressure reservoir and pressurised by an injection pump which pumps the fuel into the fuel rail. The injection pump comprises a plunger which reciprocates inside a pump chamber. The plunger draws a fill volume of fuel into the injection pump when it retracts and then pressurises the fuel when it advances to complete a pump cycle.

[0003] In order to control the rail pressure (i.e. the pressure of fuel in the fuel rail) it is known to meter the volume of fuel introduced into the fuel rail during each pump cycle. The metering can be performed by an inlet metering valve or an outlet metering valve.

[0004] Typical inlet metering valves comprise a restrictor which strangles the flow of fuel into the injection pump, thereby controlling the flow rate when the plunger retracts. The fill volume is determined by the degree of flow strangulation. Traditional inlet metering valves provide a slow response and use partial filling of the pumping chamber to match pressure and delivery demand.

[0005] Outlet metering valves allow the pumping chamber to be filled on every stroke and the supply to the fuel rail is controlled by metering how much fuel is spilt back to fill during the pumping stroke. The outlet metering valve can be switched at any time during the stroke and it is possible to have pumping strokes which do not generate pressure. The outlet metering valve is positioned in a high pressure fuel line and this forces a compromise between high pressure design, actuator performance and packaging.

[0006] It has been proposed to include a fast acting outlet metering valve in the high pressure outlet line. The pump chamber fills on every stroke, but fuel is only delivered on strokes when the outlet metering valve is actuated. There are several disadvantages associated with these techniques. For example, when the valve is closed it is subjected to seating forces proportional to the valve area and the rail pressure which mean that it is desirable to keep the valve diameter relatively small. Yet for hydraulic reasons, it is necessary to use sufficiently large

valve lift and/or high spring loads.

[0007] Accordingly, to actuate the outlet metering valve requires significant electromagnetic energy at a large gap. These operating requirements result in an upper limit to how often the valve can be actuated without overheating.

[0008] It is against this background that the present invention has been conceived. Embodiments of the invention may provide an injection pump system, a fuel injection system and a method of operating an injection pump system. Other aims and advantages of the invention will become apparent from the following description, claims and drawings.

SUMMARY OF THE INVENTION

[0009] Aspects of the present invention relate to an injection pump system, a fuel injection system and a method of operating an injection pump system.

[0010] In a further aspect, the present invention relates to an injection pump system comprising:

- an injection pump for supplying high pressure fuel;
- a low pressure fuel line in fluid communication with an inlet of said injection pump and a high pressure fuel line in fluid communication with an outlet of said injection pump and a fuel rail;
- a control valve for controlling filling of the injection pump; and
- a control unit for controlling operation of the control valve;

wherein the control unit is configured to close said control valve to inhibit the supply of fuel to said injection pump when the rail pressure is within a target pressure range.

[0011] The control unit, in use, can operate the control valve such that fuel is delivered to the injection pump only when required to maintain the fuel in the fuel rail within a target pressure range. At least at low operating loads, the rail pressure can be maintained within the target pressure range without introducing low pressure fuel into the injection pump in every operating cycle of the injection pump. Thus, the injection pump can operate to pump pressurised fuel to the fuel rail only on selected strokes whilst maintaining the rail pressure (i.e. the fuel pressure within the fuel rail) within the target pressure range. The injection pump can continue to operate irrespective of the status of the control valve.

[0012] Providing a control valve in accordance with the present invention can enable improved high pressure design with improved actuator performance and greater flexibility for packaging. It relies on only filling the pumping chamber when it is required to maintain rail pressure. There may be an increase in rail pressure ripple (due to increased variation in the rail pressure) but it is believed that this is offset by efficiency and/or noise benefits. The injection pump system can provide improved efficiency through not having to use energy (and the associated

generation of heat and noise) to compress the top of the fuel volume even when only a little fuel is needed to be pumped. This can also reduce the operating noise of the injection pump system as the fuel can be pumped only on selected strokes. The operation of the control valve can be randomised to reduce the likelihood of resonance noise.

[0013] The control valve can comprise a solenoid actuator, for example an electrically activated solenoid actuator such as an electromagnetic solenoid. The control valve can be provided in the low pressure fuel line. This can allow a larger diameter valve to be employed requiring a lower lift and potentially also a lower spring load. This configuration may provide improved electromagnetic efficiency and allow the control valve to be operated at higher frequency. The control valve can operate at least once during each pump cycle. A solenoid actuator can provide fast response controls.

[0014] The control valve can provide ON/OFF control which either enables low pressure fuel to be supplied to the injection pump or prevents the supply of low pressure fuel. The control valve can operate without having to strangle the flow to control metering. In a preferred embodiment, the injection pump can either pump a full chamber or pump no volume at all. The injection pump can continue to reciprocate irrespective of whether fuel is present in the pump chamber. The control valve can control whether low pressure fuel is introduced into the pump chamber.

[0015] The control unit can be configured to open the control valve to supply fuel to said pump when required to maintain the rail pressure within said target pressure range. When the control valve is open, fuel can be supplied from the low pressure fuel line to the injection pump. The low pressure fuel is pressurised and pumped to the fuel rail via the high pressure fuel line.

[0016] The target pressure range could be pre-defined. Alternatively, the control unit can be configured to determine the target pressure range dynamically. For example, the target pressure range can be determined based on an operational loading of a combustion engine connected to the injection pump system. The control unit could be configured to look up the target pressure range based on one or more operating parameters. The control unit could, for example, access a stored look-up table.

[0017] The target pressure range could comprise an upper and lower operating threshold. Alternatively, the target pressure range could comprise a minimum operating threshold.

[0018] The control unit could be configured to measure the fuel pressure, for example using a pressure sensor in the fuel rail. Alternatively, or in addition, the control unit can calculate the rail pressure based on the volume of fuel pumped into the fuel rail less the volume expelled during injection cycles.

[0019] The control unit can receive fuel injection data, for example from a fuel injection control unit, indicating the volume of fuel to be expelled from the fuel rail. The

control unit can thereby predict the pressure of the fuel in the fuel rail and control the operation of the control valve based on the predicted pressure.

[0020] The control unit could be incorporated into a fuel injection control unit.

[0021] A pump inlet valve can be provided between the control valve and the injection pump. The pump inlet valve can be a one-way valve which isolates the control valve from high pressure fuel. The control valve can thereby be provided in a low pressure circuit. A pump outlet valve can be located in the high pressure line between the injection pump and the fuel rail. The pump inlet valve can be a one-way valve suitable for permitting the flow of fuel into the injection pump. The pump outlet valve can be a one-way valve for permitting the flow of fuel out of the injection pump.

[0022] The control valve can be biased towards an open position.

[0023] The control valve can be selectively operated in either an open or closed state. In other words, the control valve can provide digital operation corresponding to flow and no-flow operating states. If the control valve is open throughout the intake stroke of the injection pump, a uniform volume of fuel can be drawn into the pump during each operating cycle. The control valve does not meter the volume of fuel into the injection pump by restricting the flow of fuel into the pumping chamber. The volume retraction of the plunger, in sympathy with the cam during the period the control valve is open, represents the volume of fuel introduced into the pumping chamber. If a metered volume of fuel is required, the timing of the opening and/or closing of the control valve can be controlled by the control unit. The timing of the opening and/or closing of the control valve can be controlled relative to the initiation and/or termination of the intake stroke of the injection pump. The control valve could be opened and closed during the intake stroke, if required. In particular, the state of the control valve can change from closed to open; and/or change from open to closed during the intake stroke. This part stroke fuel metering is particularly attractive at idle, where the rail ripple from full stroke pumping can be detrimental. This technique for controlling the metering of the fuel supplied to the injection pump is believed to be patentable independently.

[0024] In a further aspect, the present invention relates to an injection pump system comprising:

- an injection pump for supplying high pressure fuel to a fuel rail;
- a low pressure fuel line in fluid communication with an inlet of said injection pump and a fuel rail in fluid communication with an outlet of said injection pump;
- a control valve for controlling filling of the injection pump; and
- a control unit for controlling operation of the control valve;

wherein the control unit is configured to control when the control valve is opened and/or closed to meter the volume of fuel supplied to the injection pump.

[0025] A metered volume of fuel can be supplied to the injection pump by controlling the period of time or angle of cam rotation during which the control valve is open. The control unit can be configured to open the control valve during a portion of an intake cycle of the injection pump. The control valve can be opened before or during the intake cycle. The control valve can be closed during the intake cycle or during a pumping cycle.

[0026] The control valve can be provided in the low pressure fuel line. Moreover, the control valve can be operatively isolated from high pressure fuel in the injection pump system. In other words, the control valve can be isolated from high pressure fuel and the associated operational loads. A one-way valve can be provided between said control valve and the injection pump to isolate the control valve.

[0027] In a still further aspect, the present invention relates to a method of operating an injection pump which is in fluid communication with a low pressure fuel line and a fuel rail; a control valve being provided in the low pressure fuel line for controlling filling of the injection pump; wherein the method comprises controlling when the control valve is opened and/or closed to meter the volume of fuel supplied to the injection pump. The control valve can be closed during a portion of an intake cycle of the injection pump to meter the volume of fuel supplied to the injection pump.

[0028] The control valve can be provided in the low pressure fuel line. The control valve can be operatively isolated from high pressure fuel in the injection pump system. For example, a one-way valve can be provided between the control valve and the injection pump. The control valve can thereby be provided in a low pressure circuit. Improved control can be achieved if the control valve is controlling low pressure fuel, rather than high pressure fuel.

[0029] In a still further aspect, the present invention relates to a method of operating an injection pump system comprising an injection pump in fluid communication with a low pressure line and a high pressure line connected to a fuel rail; the method comprising:

operating a control valve to control the filling of said injection pump;

wherein the control valve is closed to inhibit the supply of fuel to the injection pump when the rail pressure is within a target pressure range; and, when the rail pressure drops below said target pressure range, opening the control valve to supply fuel to the injection pump.

[0030] The rail pressure can be maintained within said target pressure range. At least when operating at low loads, it is not necessary for the injection pump to supply high pressure fuel to the fuel rail during every operating cycle. Rather, the injection pump can supply high pres-

sure fuel to the fuel rail intermittently. The control valve can be provided in the low pressure fuel line.

[0031] The control valve can be opened and/or closed during an intake cycle of said injection pump to meter the volume of low pressure fuel supplied to the injection pump. This technique is believed to be independently patentable.

[0032] The method(s) described herein can be machine-implemented. The method described herein can be implemented on a computational device comprising one or more processors, such as an electronic microprocessor. The processor(s) can be configured to perform computational instructions stored in memory or in a storage device. The device described herein can comprise one or more processors configured to perform computational instructions.

BRIEF DESCRIPTION OF THE DRAWINGS

[0033] Embodiments of the present invention will now be described, by way of example only, with reference to the accompanying figures, in which:

Figure 1 shows a schematic representation of an injection pump system in accordance with an embodiment of the present invention; and

Figure 2 shows a schematic representation of a control valve for the injection pump system according to a first embodiment of the present invention; and

Figure 3 shows a schematic representation of a control valve for the injection pump system according to a second embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0034] An injection pump system 1 in accordance with the present invention is illustrated in Figure 1. The injection pump system 1 is arranged to supply high pressure fuel to a fuel rail of a fuel injection system for a combustion engine (not shown). The injection pump system 1 is primarily intended for use in diesel applications for pumping diesel fuel.

[0035] The injection pump system 1 comprises an injection pump 3 which is arranged in fluid communication with a low pressure inlet line 5 and a high pressure outlet line 7. The injection pump 3 comprises a housing which defines a pump chamber 9 in which a plunger 11 reciprocates. The plunger operates in a pumping cycle consisting of a pumping stroke in which the plunger 11 is advanced into the pump chamber 9 to pressurise the fuel; and an intake stroke in which the plunger 11 is retracted to draw fuel into the pump chamber 9. The plunger 11 is actuated by a rotating camshaft (not shown) having at least one lobe. The pumping chamber 9 is only filled when fuel is required to maintain the pressure in the rail.

[0036] The low pressure inlet line 5 is in fluid communication with a low pressure fuel reservoir 13, for example a low pressure fuel pump for supplying fuel from a fuel

tank. A one-way inlet valve 15 is provided in the low pressure inlet line 5 to inhibit the return of fuel from the injection pump 3 to the low pressure inlet line 5. The inlet valve 15 comprises an inlet valve member 17 which is biased by a first spring member (not shown) to a closed position in which the inlet valve member 17 is located in an inlet valve seat 19, thereby preventing low pressure fuel entering the pump chamber 9. When the pressure differential between the low pressure inlet line 5 and the pump chamber 9 is sufficient to overcome the biasing force of the first spring member, the inlet valve member 17 is unseated and the inlet valve 15 opens allowing low pressure fuel to enter the pump chamber 9.

[0037] The high pressure outlet line 7 is in fluid communication with a fuel rail (not shown) for the injection pump system 1. A one-way outlet valve 21 is provided in the high pressure outlet line 7 to inhibit the return of fuel from the high pressure outlet line 7 to the injection pump 3. The outlet valve 21 comprises an outlet valve member 23 which is biased by a second spring member (not shown) towards a closed position in which the outlet valve member 23 is located in an outlet valve seat 25, thereby preventing fuel exiting the pump chamber 9. When the pressure differential between the pump chamber 9 and the high pressure outlet line 7 is sufficient to overcome the biasing force of the second spring member, the outlet valve member 23 is unseated and the outlet valve 21 opens allowing high pressure fuel to enter the high pressure outlet line 7.

[0038] The inlet and outlet valves 15, 21 are positioned as close to the pumping chamber 9 as possible to minimise the compressed volume at the top of the plunger 11 pumping stroke to help improve efficiency. In addition, minimising the pressurised volume can reduce the torque reversal as the volume depressurises at the top of pumping stroke and hence can also reduce associated pump noise.

[0039] A control valve 27 is provided in the low pressure inlet line 5, between the fuel reservoir 13 and the inlet valve 15, to control the supply of low pressure fuel to the pump chamber 9. The control valve 27 thereby controls the filling of the injection pump 3. The control valve 27 is operable in an ON/OFF (i.e. flow/no-flow) state selectively to supply fuel to the injection pump 3.

[0040] A control valve 27 in accordance with a first embodiment of the present invention is shown schematically in Figure 2. The control valve 27 is provided in the low pressure inlet line 5 and the direction of flow of fuel from the low pressure reservoir 13 is illustrated by an arrow A. The control valve 27 comprises a control valve member 29 biased towards a control valve seat 31 by a third spring member 33. An electromagnetic solenoid actuator 35 is arranged to provide energise-close functionality (i.e. the solenoid actuator 35 is energised to close the control valve 27). The solenoid actuator 35 comprises an electromagnetic coil 36 which actuates a circular plate shaped armature 37 coupled to a displacement member 39 arranged to act on the control valve member 29. A

fourth spring member 41 is provided for biasing the circular plate shaped armature 37 and the displacement member 39 to an advanced position in which the control valve member 29 is unseated from the control valve seat 31, thereby opening the control valve 27. When the solenoid actuator 35 is energised, the displacement member 39 is retracted and the control valve member 29 seats in the control valve seat 31, thereby closing the control valve 27 (as shown in Figure 2). In this state, no fuel is drawn into the pumping chamber 9 during plunger 11 retraction. The biasing force applied by the fourth spring member 41 is greater than that applied by the third spring member 33 such that the control valve 27 is biased to an open position when the solenoid actuator 35 is not energised.

[0041] A target pressure range is defined for the fuel pressure in the fuel rail (referred to herein as the rail pressure) based on the operating conditions including speed and load of the combustion engine. A control unit (not shown) is provided to control the operation of the control valve 27 to maintain the rail pressure within the target pressure range. By controlling the operation of the control valve 27 to supply fuel to the pump chamber 9 only when it is required, the rail pressure can be maintained within the target pressure range. The control unit can measure the pressure in the fuel rail and control the control valve 27 based on the measured pressure. Alternatively, or in addition, the control unit could use fuel injection data, for example from the fuel injection system, to predict when the rail pressure will fall below the specified target pressure range. The control unit can also utilise engine speed and load data, for example from an engine control unit, to determine the target pressure range.

[0042] The operation of the injection pump system 1 will now be described in more detail.

[0043] The fuel reservoir 13 provides a low pressure fuel supply to the injection pump system 1. The control valve 27 positioned in the low pressure inlet line 5 selectively controls the supply of fuel to the injection pump 3. When the control valve 27 is open, the injection pump 3 draws low pressure fuel into the pump chamber 9 from the low pressure inlet line 5 during an intake stroke and expels high pressure fuel into the high pressure line 7 during a pump stroke. When the control valve 27 is closed, the injection pump 3 is not supplied with low pressure fuel and the pumping cycle is performed with the pump chamber 9 substantially empty. Accordingly, high pressure fuel is not pumped to the high pressure outlet line 7.

[0044] The control of the control valve 27 is performed by the control unit to maintain the rail pressure within the target pressure range. The target pressure range can, for example, specify a minimum pressure threshold. The target pressure range can change dynamically in response to changes in the operating speed and load parameters of the combustion engine. The control unit can receive engine load data from the engine control unit. The control unit can also use fuel injection data from the

fuel injection system to predict when high pressure fuel should be introduced into the fuel rail to maintain the target pressure range.

[0045] When the rail pressure is within the target pressure range, the control unit closes the control valve 27 to prevent the supply of fuel to the injection pump 3. With the control valve 27 closed, the injection pump 3 does not draw low pressure fuel into the pump chamber 9 during the intake stroke and the subsequent pumping stroke does not pump fuel into the high pressure line 7.

[0046] When the rail pressure falls below the target pressure range, the control unit opens the control valve 27 to enable the supply of fuel to the injection pump 3. The control valve 27 can be opened during the pumping stroke of the injection pump 3 since the inlet valve 15 will prevent high pressure fuel returning through the low pressure inlet line 5. With the control valve 27 open, the injection pump 3 draws low pressure fuel into the pump chamber 9 during the intake stroke and the subsequent pumping stroke pressurises the fuel in the pump chamber 9 and pumps it into the high pressure line 7. The rail pressure is thereby increased and returned to the target pressure range.

[0047] At least at light operating conditions, it is possible to maintain an acceptable rail pressure whilst only filling the pumping chamber 9 occasionally. The efficiency of the injection pump 9 can be improved as there is less wasted energy due to fewer strokes with compressed fuel at the top of the plunger stroke. Moreover, torque reversals due to decompression can be reduced and, hence, noise can be reduced at light load when pump noise is typically most obtrusive.

[0048] By locating the control valve 27 in the low pressure fuel inlet line 5 (which is a low pressure circuit) the control valve member 29 can have a larger diameter without excessive seat force. The valve lift can be lowered which allows a smaller solenoid actuator 35 to be utilised. At maximum speeds, with maximum flow across the control valve seat 31, any tendency to self-close will result in incomplete filling so limiting the risk of overpressure. The spring bias provided by the third spring 33 can be minimised to ensure that filling is enabled below the maximum speed of normal operation. The larger diameter control valve member 29, lower lift and lower spring load can provide improved electromagnetic efficiency and hence enable the solenoid actuator 35 to be operated at higher frequency.

[0049] The volume of fuel delivered from the pump can be very accurately calibrated based on incremental numbers of pump strokes. This can help to provide rapid response and failure mode detection.

[0050] The present invention may result in a variation in the rail pressure (so-called rail pressure ripple) which may be in the region of 200 bar. It is believed that rail pressure ripple can be reduced and light load efficiency improved by using high frequency pumping with smaller plungers or shorter strokes.

[0051] The control valve 27 is not configured to control

the rate of fuel flow to the injection pump 3. Rather, the injection pump system 1 controls the filling of the pump chamber 9 by controlling the timing of the opening and/or closing of the control valve 27. The present embodiment maintains the control valve 27 open throughout the intake stroke of the injection pump 3. However, the control unit could be configured to control the operation of the control valve 27 to meter the low pressure fuel supplied to the injection pump 3. For example, the control valve 27 could be opened after the intake stroke has been initiated, or closed before it has been completed. By controlling the timing of the opening and/or closing of the control valve 27, a metered supply of low pressure fuel could be supplied to the pump chamber 9. This method and the associated apparatus is believed to be patentable independently.

[0052] A second control valve 43 in accordance with a second embodiment of the present invention will now be described with reference to Figure 3. The second control valve 43 is intended to replace the control valve 27 according to the first embodiment of the present invention. The second control valve 43 locates in the low pressure inlet line 5 to control the supply of low pressure fuel to the pump chamber 9. The direction of flow of the low pressure fuel is illustrated by a pair of arrows B in Figure 3.

[0053] The second control valve 43 comprises a second electromagnetic solenoid actuator 45 arranged to provide energise-open functionality (i.e. the second solenoid actuator 45 is energised to open the second control valve 43). The second solenoid actuator 45 actuates a second control valve member 47 biased towards a second control valve seat 49 by a fifth spring member 51. When energised, an electromagnetic coil 53 in the solenoid actuator 45 retracts a second circular plate shaped armature 55 coupled to the second control valve member 47, thereby opening the second control valve 43 (as shown in Figure 3). When the solenoid actuator 45 is not energised, the fifth spring member 51 advances the second control valve member 47 to a seated position in the second control valve seat 49, thereby closing the second control valve 43.

[0054] The second control valve 43 can be balanced when in the de-energised state. The spring force applied by the fifth spring member 51 can be minimised, thereby reducing the magnetic power required at large gap (i.e. when the second circular plate shaped armature 55 is displaced from the electromagnetic coil 53). Restriction across the second control valve seat 49 (for example, caused by the second control valve member 47) will tend to cause a pressure drop across the second control valve seat 49 at high flow rates which can close the second control valve 43. A small gap is maintained between the electromagnetic coil 53 and the second circular plate shaped armature 55 to reduce the actuating force required to overcome the closing force caused by the pressure drop in the fuel.

[0055] It is considered that the digital inlet metering valve described herein has particular application with

concentric valve arrangements, for example of the type described in the Applicant's co-pending applications EP 2287462 and EP 2302194. The contents of these published applications are incorporated herein in their entirety. More specifically, the embodiment illustrated in Figures 4 and 5 of EP 2302194 is believed to be particularly well suited for use in conjunction with the apparatus and techniques described herein and the description and figures relating to this embodiment are explicitly incorporated herein by reference.

[0056] It will be appreciated that various changes and modifications can be made to the design described herein without departing from the spirit and scope of the present invention. For example, the pattern of filling the pump chamber 9 can be randomised to reduce the likelihood of drive resonance and to further reduce perceived noise.

Claims

1. An injection pump system comprising:

an injection pump for supplying high pressure fuel;
a low pressure fuel line in fluid communication with an inlet of said injection pump and a high pressure fuel line in fluid communication with an outlet of said injection pump and a fuel rail;
a control valve for controlling filling of the injection pump; and
a control unit for controlling operation of the control valve;

wherein the control unit is configured to close said control valve to inhibit the supply of fuel to said injection pump when the rail pressure is within a target pressure range.

2. An injection pump system as claimed in claim 1, wherein the control unit is configured to open said control valve to supply fuel to said pump to maintain the rail pressure within said target pressure range.

3. An injection pump system as claimed in claim 1 or claim 2, wherein the target pressure range is defined dynamically.

4. An injection pump system as claimed in any one of claims 1, 2 or 3, wherein the control unit is configured to estimate the rail pressure.

5. An injection pump system as claimed in claim 4, wherein the control unit is configured to estimate the fuel pressure based on the volume of fuel to be expelled from the fuel rail.

6. An injection pump system as claimed in any one of

the preceding claims further comprising a pump inlet valve located between the control valve and the pump; and/or a pump outlet valve located in the high pressure line.

7. An injection pump system as claimed in any one of the preceding claims, wherein the control valve is biased towards an open position; or a closed position.

8. An injection pump system as claimed in any one of the preceding claims, wherein a uniform volume of fuel is drawn into the pump during each pump cycle when the control valve is open.

9. An injection pump system comprising:

an injection pump for supplying high pressure fuel;
a low pressure fuel line in fluid communication with an inlet of said injection pump and a high pressure fuel line in fluid communication with an outlet of said injection pump;
a control valve for controlling filling of the injection pump; and
a control unit for controlling operation of the control valve;

wherein the control unit is configured to control when the control valve is opened and/or closed to meter the volume of fuel supplied to the injection pump.

10. An injection pump system as claimed in claim 9, wherein a one-way valve is provided between said control valve and the injection pump.

11. A fuel injection system comprising an injection pump system as claimed in any one of the preceding claims.

12. A method of operating an injection pump system comprising an injection pump in fluid communication with a low pressure line and a high pressure line connected to a fuel rail; the method comprising:

operating a control valve to control the filling of said injection pump;

wherein the control valve is closed to inhibit the supply of fuel to the injection pump when the rail pressure is within a target pressure range; and, when the rail pressure drops below said target pressure range, opening the control valve to supply fuel to the injection pump.

13. A method of operating an injection pump which is in fluid communication with a low pressure fuel line and a high pressure fuel line; a control valve being pro-

vided in the low pressure fuel line for controlling filling of the injection pump; wherein the method comprises controlling when the control valve is opened and/or closed to meter the volume of fuel supplied to the injection pump.

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- 14.** A method as claimed in claim 13, wherein, during an intake cycle of said injection pump, the state of the control valve changes from closed to open and/or changes from open to closed.

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- 15.** A method as claimed in claim 12, 13 or 14, wherein the control valve is operatively isolated from high pressure fuel in the injection pump system.

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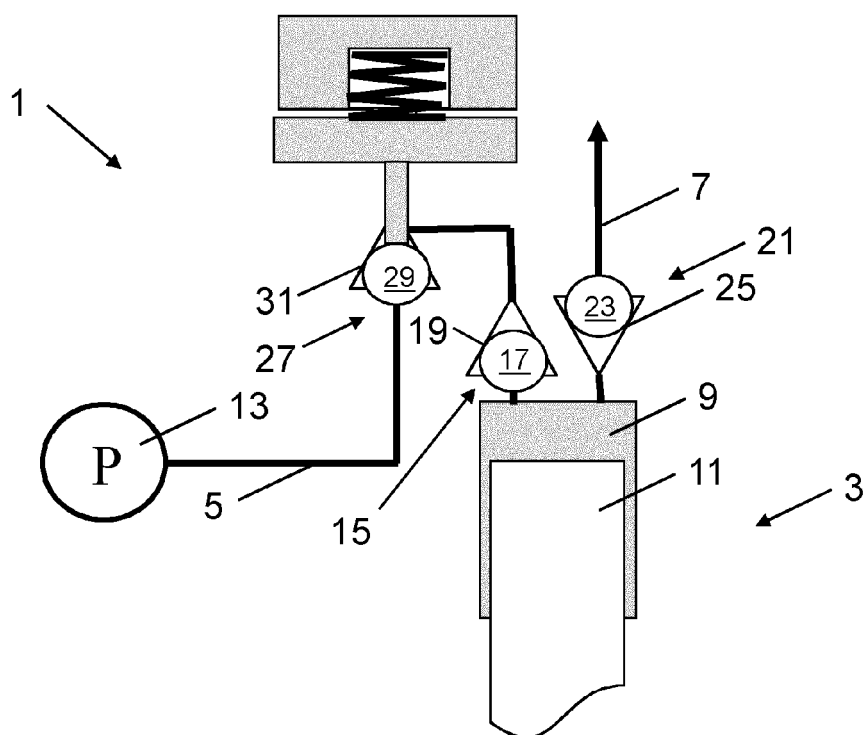
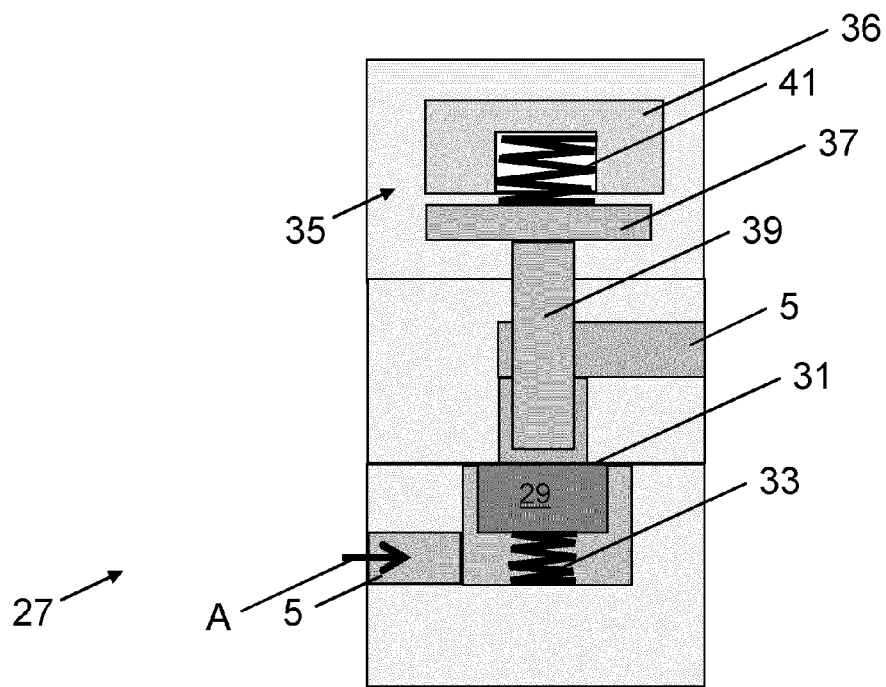
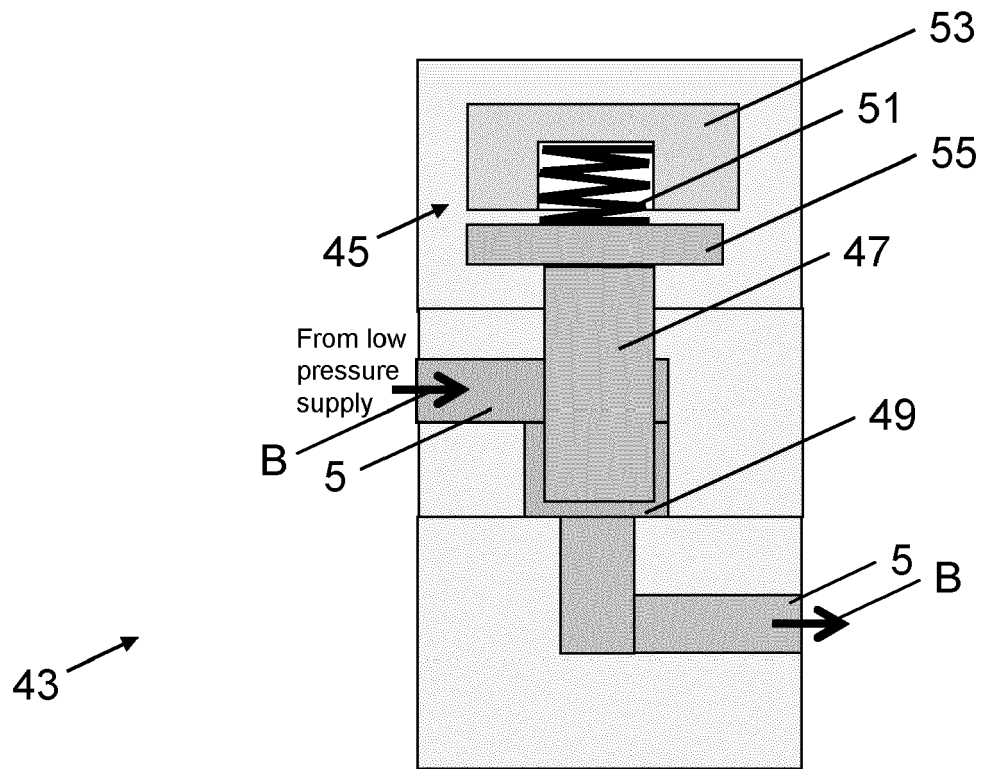


FIG. 1



Fast response valve for use in the low pressure feed to the pumping chamber

FIG. 2



Fast response valve for use in the low pressure feed to the pumping chamber

FIG. 3



EUROPEAN SEARCH REPORT

Application Number
EP 12 16 3322

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	EP 2 042 720 A1 (MAGNETI MARELLI POWERTRAIN SPA [IT] MAGNETI MARELLI SPA [IT]) 1 April 2009 (2009-04-01) * paragraphs [0016] - [0037]; figure 1 * -----	1-15	INV. F02M59/20 F02M59/36 F02M63/02 F02M59/46
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X	EP 1 469 190 A1 (DENSO CORP [JP]) 20 October 2004 (2004-10-20) * paragraphs [0036], [0037]; figures * -----	1-4,6-15	
			TECHNICAL FIELDS SEARCHED (IPC)
			F02M
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 2 October 2012	Examiner Godrie, Pierre
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