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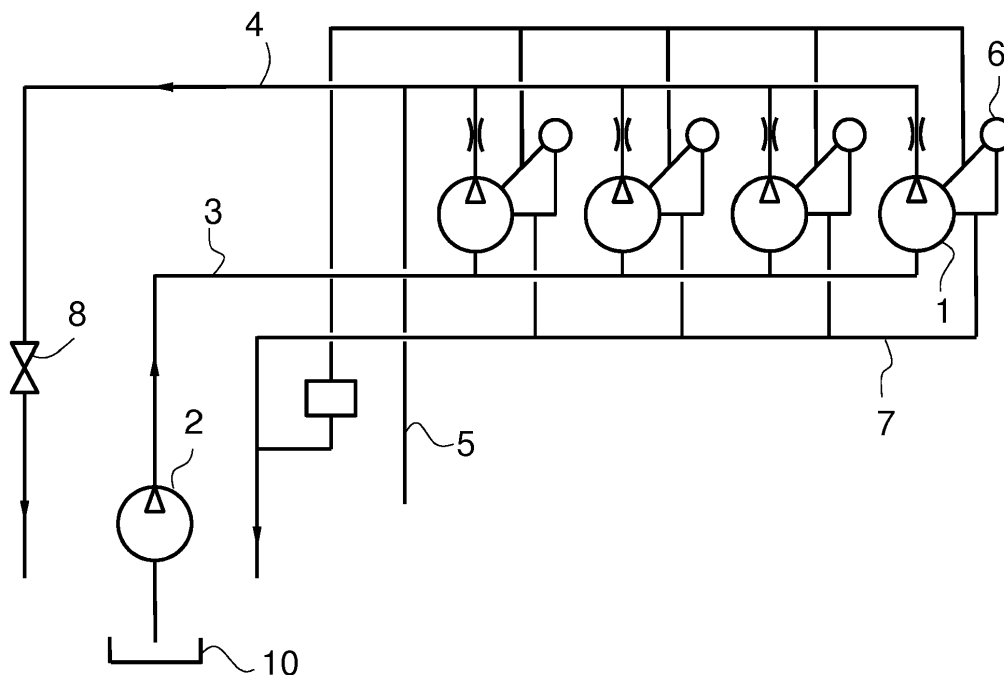
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(54) Fuel injection arrangement

(57) The fuel injection arrangement for a piston engine comprises a number of fuel injection pumps (1), a feed pump (2) for supplying fuel to the fuel injection pumps (1), a fuel supply line (3) connecting the fuel injection pumps (1) to the feed pump (2), and a return line

(4) for receiving excess fuel from the fuel injection pumps (1). The arrangement is provided with a branch line (5) having a first end and a second end, the first end being connected to the return line (4) and the second end being closed.

**FIG. 1****EP 3 032 086 A1**

Description**Technical field of the invention**

5 [0001] The present invention relates to a fuel injection arrangement for a piston engine in accordance with the preamble of claim 1.

Background of the invention

10 [0002] The fuel injection systems of compression ignition piston engines can be divided into common rail systems and systems that comprise a separate fuel injection pump for each cylinder of the engine. In common rail systems, fuel pressurized by a high-pressure pump is supplied into a storage, from which it can be fed to several cylinders of the engine. The amount of the injected fuel and the fuel injection timing is controlled by the fuel injectors, which are usually electrically controlled. In fuel injection systems with individual fuel injection pumps, each cylinder of the engine is provided
15 with an own fuel injection pump, which also controls the amount of the fuel to be injected and the fuel injection timing. The fuel injectors are opened by the pressure of the fuel. A feed pump supplies fuel to the fuel injection pumps. In the systems with individual fuel injection pumps, which are commonly called as jerk pumps, pressure peaks occur in the low pressure part of the fuel injection system, i.e. in the fuel supply line and in the return line that collects clean excess fuel from the fuel injection pumps.

20 [0003] Pressure peaks can be lowered by using large diameter pipes, but this is not always sufficient and often leads to a need to provide the pipes with pulsation dampers. Often several different pulsation dampers need to be used. This increases the costs and the need for service.

Summary of the invention

25 [0004] The object of the present invention is to provide an improved fuel injection arrangement for a piston engine. The fuel injection arrangement comprises a number of fuel injection pumps, each fuel injection pump being configured to inject liquid fuel into a cylinder of the engine, at least one feed pump for supplying fuel to the fuel injection pumps, a fuel supply line connecting the fuel injection pumps to the feed pump, and a return line for receiving excess fuel from
30 the fuel injection pumps. The characterizing features of the fuel injection arrangement according to the invention are given in the characterizing part of claim 1.

[0005] According to the invention, the fuel injection arrangement is provided with a branch line having a first end and a second end, the first end being connected to the return line and the second end being closed.

35 [0006] The arrangement according to the invention effectively reduces pulsations in the fuel injection system. The reliability of the engine and the lifetime of the components can thus be increased. The need for more expensive pulsation dampers can be avoided and manufacturing costs can thus be reduced. By means of stable low pressure piping, the feeding pressure and circulation flow can be reduced. This can lead to higher efficiency of the overall system.

[0007] The return line can be provided with pressure regulating means, in which case the branch line is connected to the return line upstream from the pressure regulating means. The pressure regulating means can be a pressure regulating
40 valve.

[0008] According to an embodiment of the invention, the inner diameter of the branch line is 30 to 200 percent of the inner diameter of the return line.

[0009] The length of the branch line can be selected using formula $LT = a/(4*f)$, where LT is the length of the branch line, a is the speed of sound in the fuel in the branch line and f is the firing frequency of the engine.
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Brief description of the drawings

[0010] Embodiments of the invention are described below in more detail with reference to the accompanying drawing, which shows a fuel injection arrangement according to an embodiment of the invention.
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Description of embodiments of the invention

[0011] In figure 1 is shown schematically a fuel injection system of a piston engine. The engine is a large internal combustion engine, such as a main or an auxiliary engine of a ship or an engine that is used at a power plant for producing
55 electricity. In the embodiment of figure 1, the fuel injection system is configured for a four-cylinder engine, but the invention is applicable to engines with any number of cylinders. In the embodiment of the figure, the cylinders are arranged in line, but the invention is also suitable for V-engines and other cylinder configurations. The fuel injection system of figure 1 is configured to inject liquid fuel directly into the cylinders of the engine. The fuel can be, for instance, light fuel oil (LFO),

heavy fuel oil (HFO), marine gas oil (MGO), crude oil or marine diesel oil (MDO). The engine can be provided with additional fuel injection systems, such as a gas injection system for introducing gaseous fuel into the engine and a pilot fuel injection system for introducing liquid pilot fuel into the cylinders when the engine is operated using a gaseous main fuel.

[0012] The fuel injection system of figure 1 comprises a number of fuel injection pumps 1. One fuel injection pump 1 is provided for each cylinder of the engine. The fuel injection pumps 1 are conventional fuel injection pumps, which are preferably cam-operated. The fuel injection pumps 1 can also be called as jerk pumps. Each fuel injection pump 1 is connected to a fuel injector 6, which is arranged to inject fuel directly into a cylinder of the engine. Each fuel injector 6 is provided with an injector needle, which is opened by the pressure produced by the fuel injection pump 1. As opposed to a common rail system, the fuel injectors are thus not electrically controlled, but the fuel injection timing and the amount of the injected fuel is determined by the fuel injection pumps 1. The injection pressure is typically 1000 to 1800 bar.

[0013] The fuel injection system is provided with a feed pump 2 for supplying fuel from a tank 10 to the fuel injection pumps 1. The feed pump 2 is a low-pressure pump that raises the pressure of the fuel to the range of 5 to 15 bar. A fuel supply line 3 connects the feed pump 2 to the inlets of the fuel injection pumps 1. During each cycle of a fuel injection pump 1, the fuel injection pump 1 takes in substantially the same amount of fuel. However, the amount of the fuel that is supplied to the fuel injector 6 depends on the load of the engine. The fuel injection system is provided with a return line 4 for receiving the excess fuel that is not supplied to the fuel injector 6. In the embodiment of figure 1, all the cylinders are connected to the same return line 4. However, more than one return lines 4 could be provided, for instance in a V-engine a separate return line 4 could be arranged for each bank of the engine. Via the return line 4, the excess fuel can be returned to the tank 10. The return line 4 comprises pressure regulating means 8. In the embodiment of the figure, the pressure regulating means is a pressure regulating valve 8. The pressure regulating valve 8 is a normally closed valve, which is arranged to open when a certain threshold pressure is exceeded. The opening pressure of the pressure regulating valve 8 can be adjusted. Typically, the nominal pressure in the return line 4 is kept in the range of 6 to 12 bar. With that nominal pressure, the actual pressure in the return line 4 typically varies in the range of 2 to 20 bar. Instead of the pressure regulating valve 8, a throttling device could be arranged in the return line 4 to regulate the pressure.

[0014] The fuel injection system is further provided with a leakage line 7. The leakage line 7 collects clean fuel leakage from the fuel injectors 6 and the fuel injection pumps 1. The clean leakage is caused by the clearances of the fuel injection pumps 1 and the fuel injectors 6 during normal operation of the engine. The clean fuel leakage can be returned to the tank 10. The engine is also provided with a separate leakage line for dirty fuel (not shown). Via the leakage line for dirty fuel, the fuel that is mixed with other substances can be collected to a separate tank.

[0015] For reducing pressure pulsations in the return line 4, the fuel injection system is provided with a branch line 5. The branch line 5 is a pipe, which in fluid communication with the return line 4 but closed at the opposite end. The branch line 5 has a first end and a second end. The first end of the branch line 5 is connected to the return line 4 on the upstream side of the pressure regulating valve 8. The branch line 5 is thus in fluid communication with the return line 4. The second end of the branch line 5 is closed.

[0016] The length of the branch line 5 is selected such that pulsations can be minimized. The length of the branch line 5 depends on the firing frequency. The suitable length for the pipe can be calculated by the following formula:

$$LT = a/(4*f), \quad (1)$$

where

LT is the length of the pipe [m],
a is the speed of sound in the pipe [m/s], and
f is the firing frequency [1/s].

[0017] The speed of sound in the branch line 5 can be calculated by the following formula:

$$a = (1/(p*(1/k+d\phi/tE)))^{1/2}, \quad (2)$$

where

p is the density of the fuel [kg/m³],

k is the bulk modulus of the fuel [N/m²],
 d is the inner diameter of the pipe [m],
 ϕ is a pipe restraint factor,
 t is the thickness of the pipe [m], and
 E is the Young's Modulus of the pipe [N/m²].

[0018] The branch line 5 does not need to be straight, but it can comprise bends. A suitable inner diameter for the branch line 5 is 30 to 200 percent of the inner diameter of the return line 4. The fuel injection system could comprise more than one branch lines 5. For instance, in a V-engine each bank of the engine could be provided with an own branch line 5.

[0019] It will be appreciated by a person skilled in the art that the invention is not limited to the embodiments described above, but may vary within the scope of the appended claims.

Claims

1. A fuel injection arrangement for a piston engine, the arrangement comprising

- a number of fuel injection pumps (1), each fuel injection pump (1) being configured to inject liquid fuel into a cylinder of the engine,
- at least one feed pump (2) for supplying fuel to the fuel injection pumps (1),
- a fuel supply line (3) connecting the fuel injection pumps (1) to the feed pump (2), and
- a return line (4) for receiving excess fuel from the fuel injection pumps (1),

characterized in that the fuel injection arrangement is provided with a branch line (5) having a first end and a second end, the first end being connected to the return line (4) and the second end being closed.

2. An arrangement according to claim 1, wherein the branch line (5) is connected to the return line (4) upstream from pressure regulating means (8).

3. An arrangement according to claim 2, wherein the pressure regulating means is a pressure regulating valve (8).

4. An arrangement according to any of the preceding claims, wherein the inner diameter of the branch line (5) is 30 to 200 percent of the inner diameter of the return line (4).

5. An arrangement according to any of the preceding claims, wherein the length of the branch line (5) is selected using formula $LT = a/(4 \cdot f)$, where LT is the length of the branch line (5), a is the speed of sound in the fuel in the branch line (5) and f is the firing frequency of the engine.

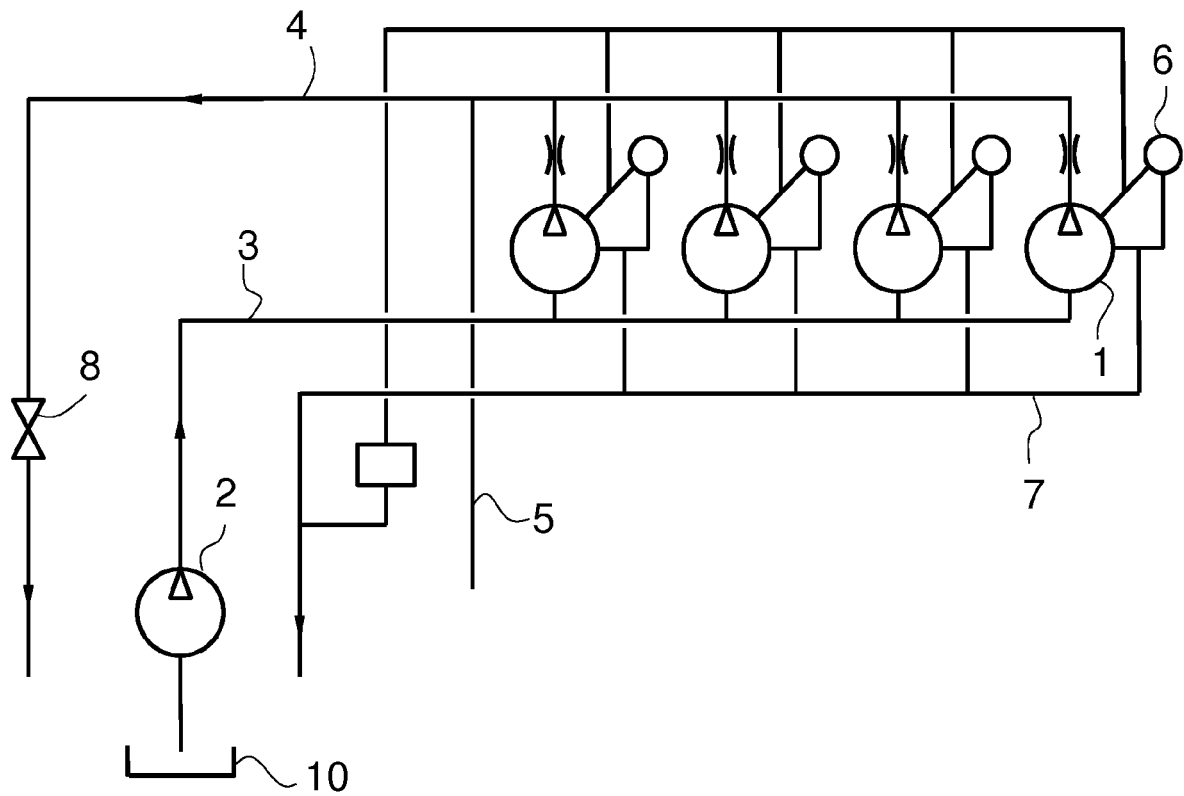


FIG. 1



EUROPEAN SEARCH REPORT

Application Number
EP 14 19 6724

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Place of search Munich		Date of completion of the search 15 May 2015	Examiner Godrie, Pierre
CATEGORY OF CITED DOCUMENTS 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			

EPO FORM 1503 03/82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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