



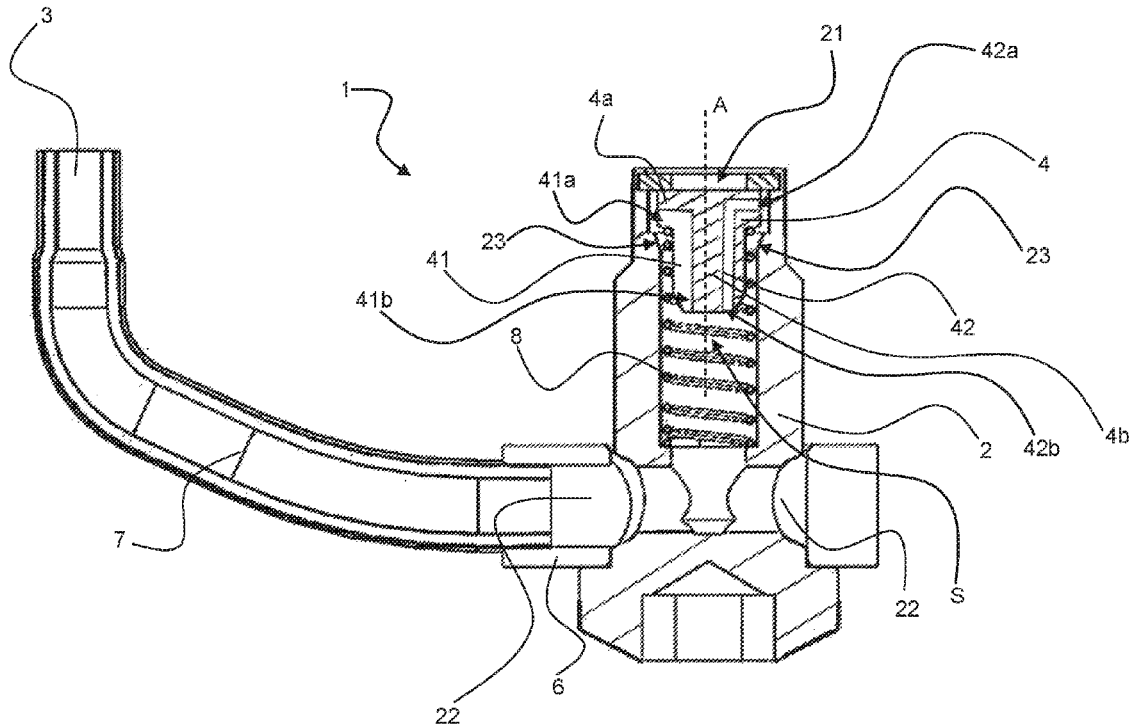
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(19) **United States**(12) **Patent Application Publication**
CANDELA et al.(10) **Pub. No.: US 2017/0130639 A1**(43) **Pub. Date: May 11, 2017**(54) **PISTON COOLING JET FOR AN INTERNAL COMBUSTION ENGINE****Publication Classification**(71) Applicant: **GM GLOBAL TECHNOLOGY OPERATIONS LLC**, Detroit, MI (US)(51) **Int. Cl.**
F01P 3/08 (2006.01)(72) Inventors: **Giorgio CANDELA**, Turin (IT); **Luca AGATAU**, Leini (TO) (IT)(52) **U.S. Cl.**
CPC **F01P 3/08** (2013.01)(73) Assignee: **GM GLOBAL TECHNOLOGY OPERATIONS LLC**, Detroit, MI (US)(57) **ABSTRACT**

A piston cooling jet for an internal combustion engine includes a body having a coolant duct extending between a coolant duct inlet and a coolant duct outlet fluidly connected to a coolant nozzle. The piston cooling jet includes a plunger having a plunger stem and a plunger head. The plunger is movable within the coolant duct of the body between a closing position that closes the coolant duct inlet and an opening position that opens the coolant duct inlet. The piston cooling jet further includes a biasing spring coupled to the plunger to bias it towards the closing position. A plunger coolant channel has an inlet at the plunger head and an outlet at the plunger stem, channeling coolant downstream of the plunger head when the plunger is in the opening position.

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Nov. 6, 2015 (GB) 1519640.5



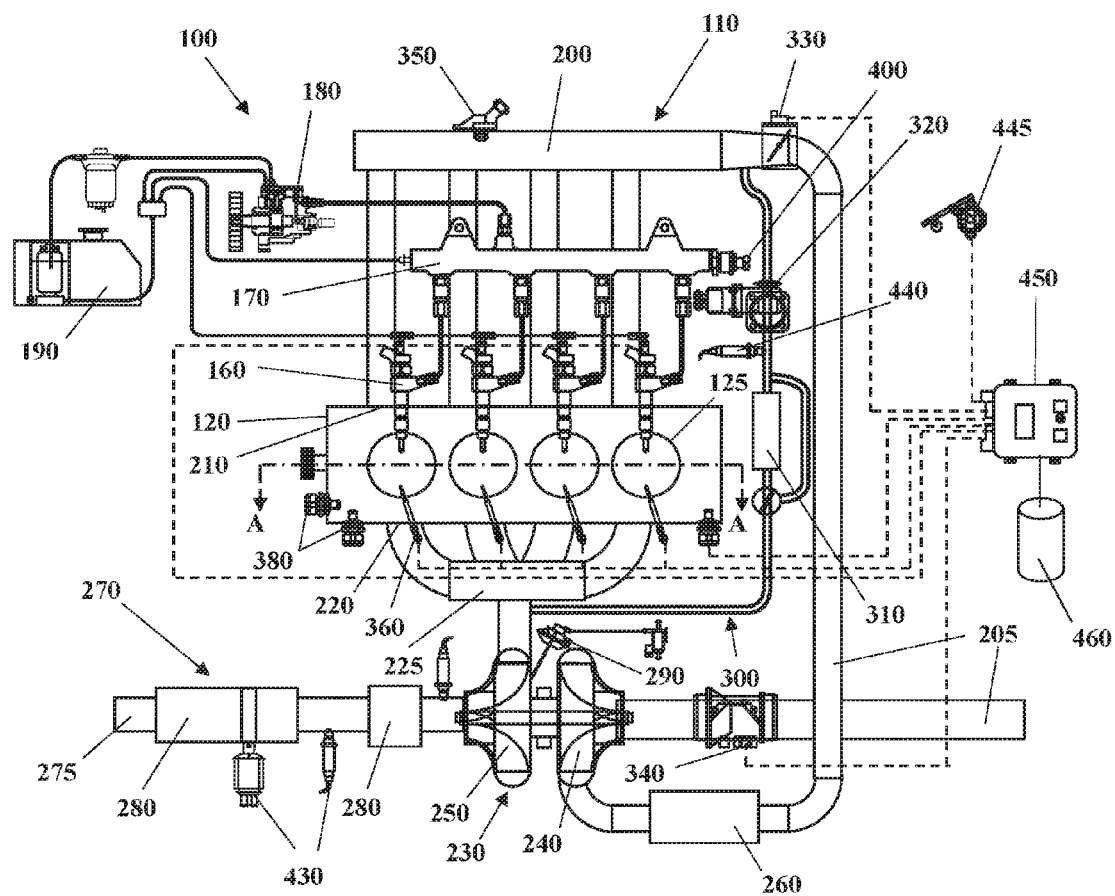


FIG.1

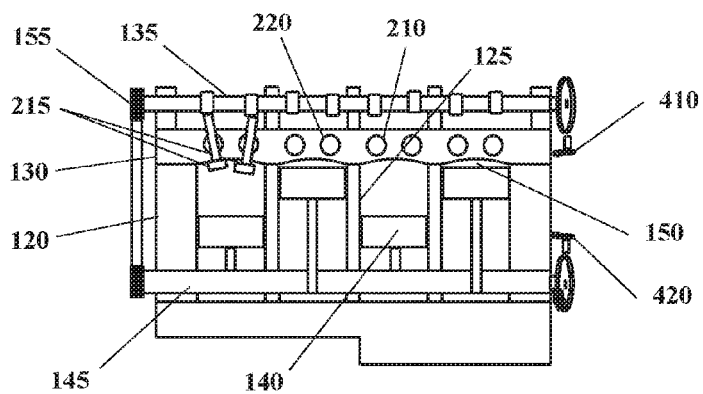


FIG.2

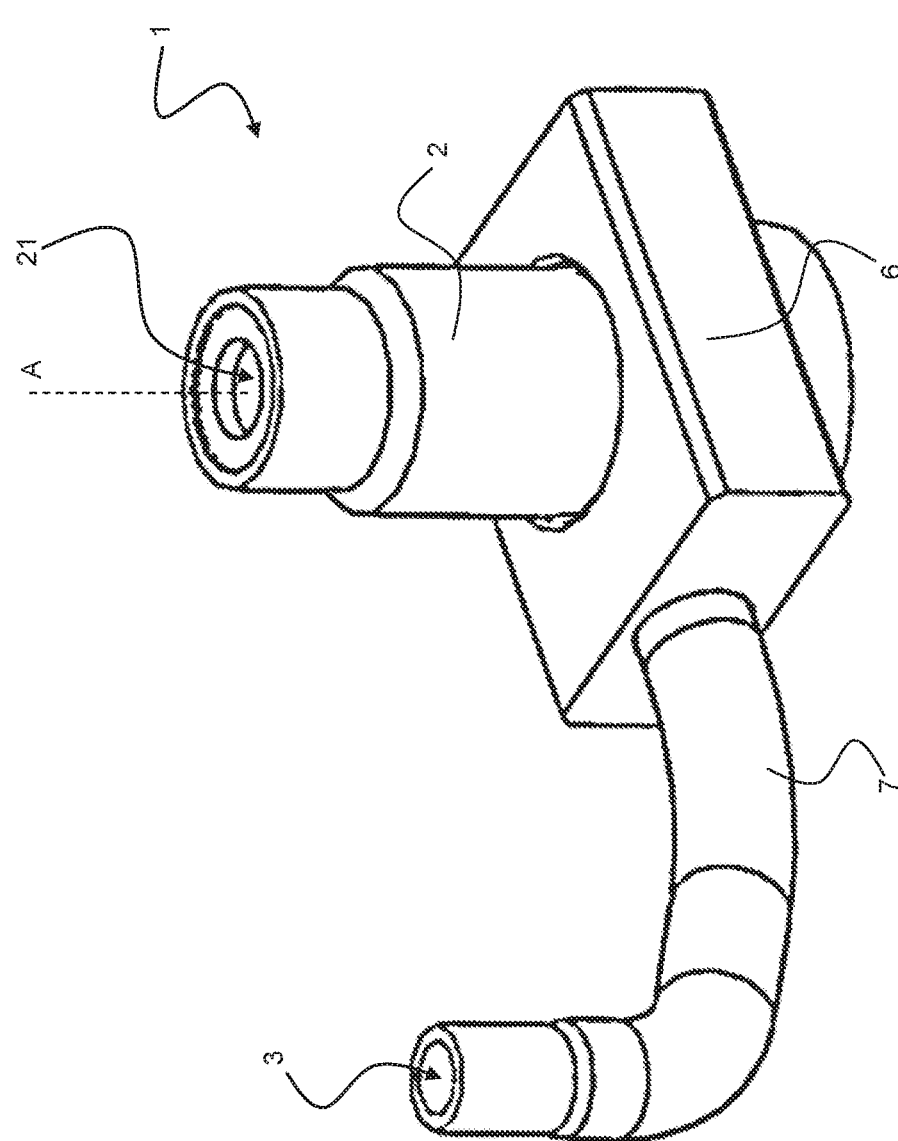


Fig. 3

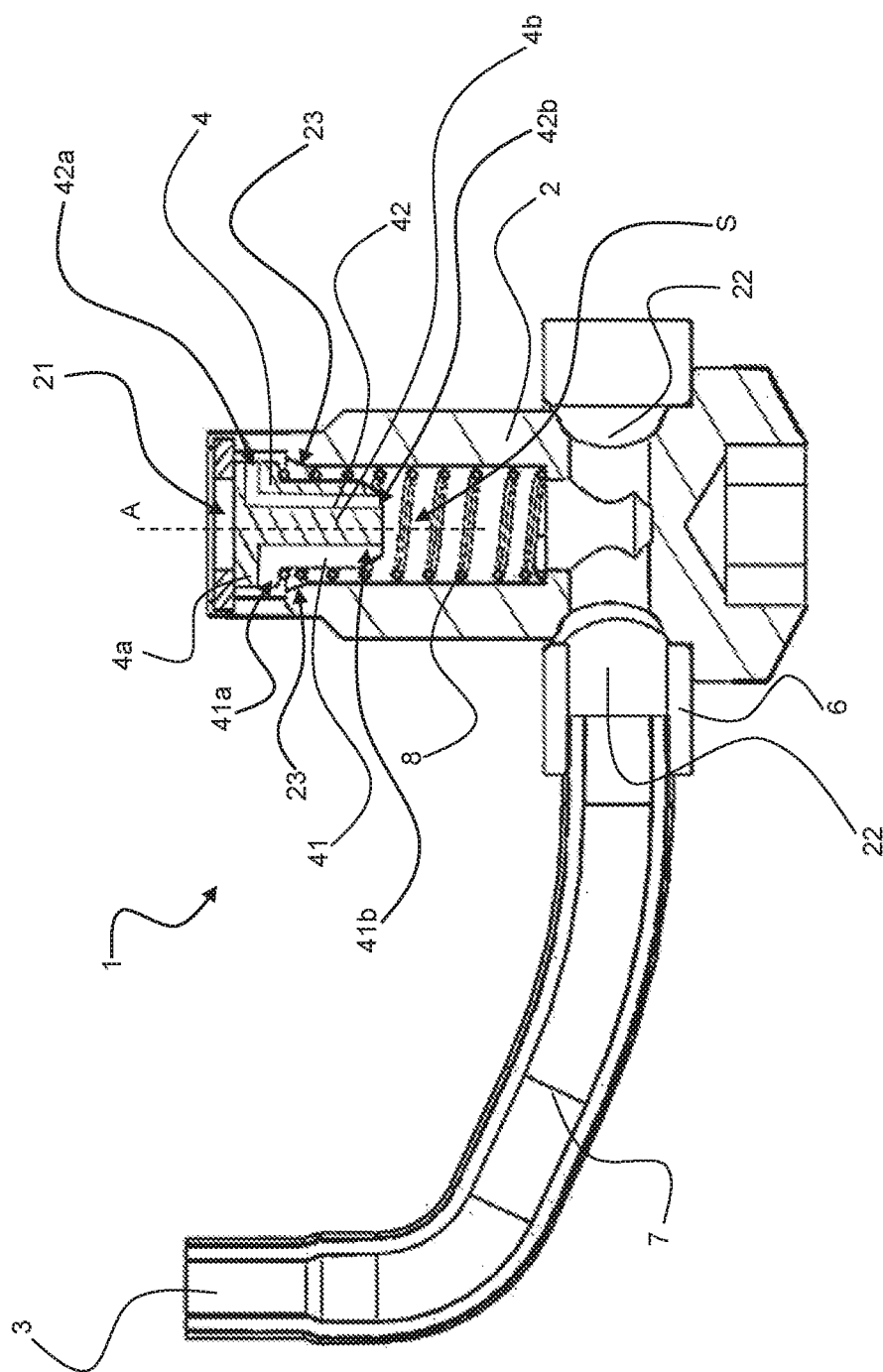
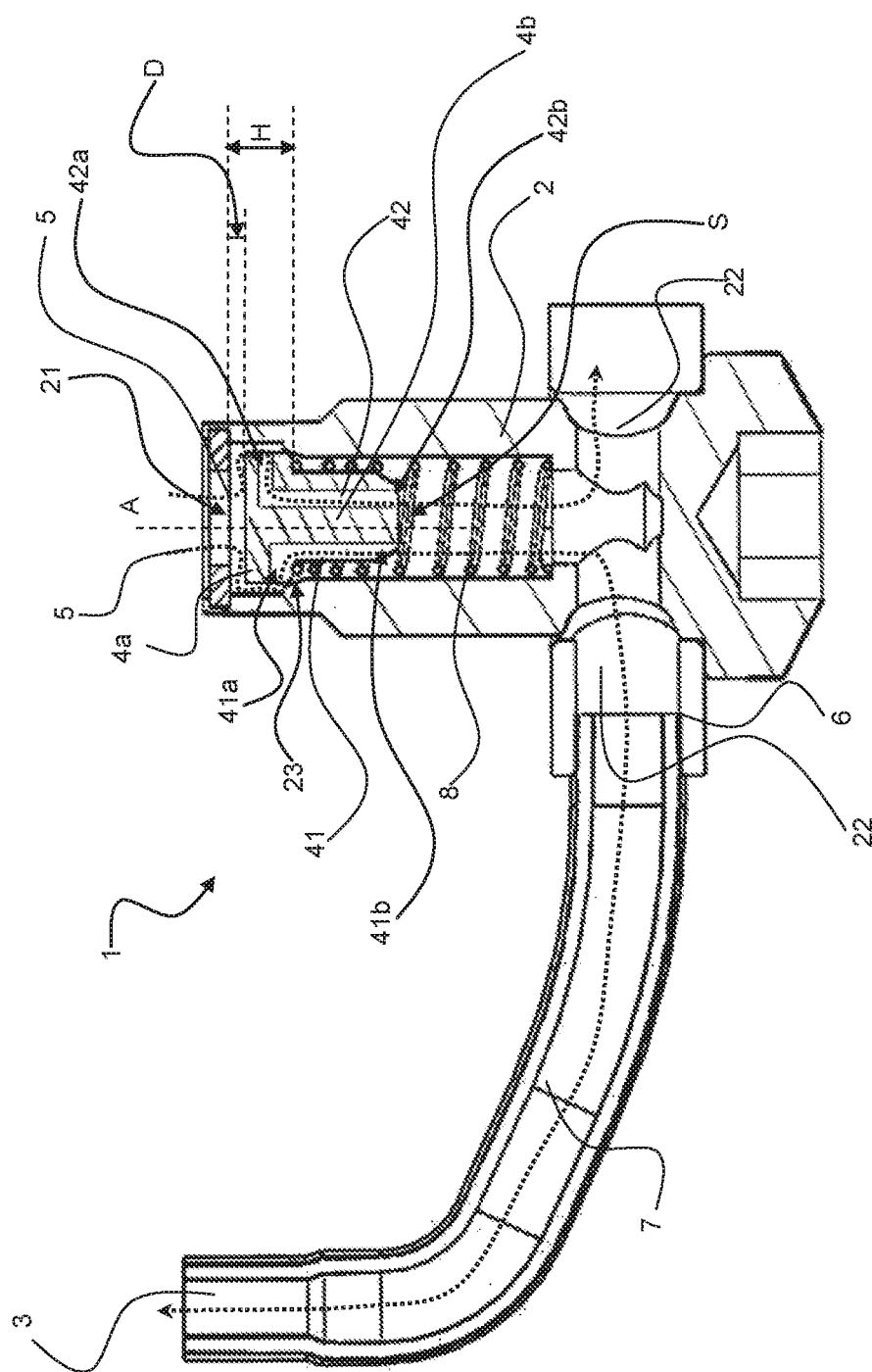


Fig. 4



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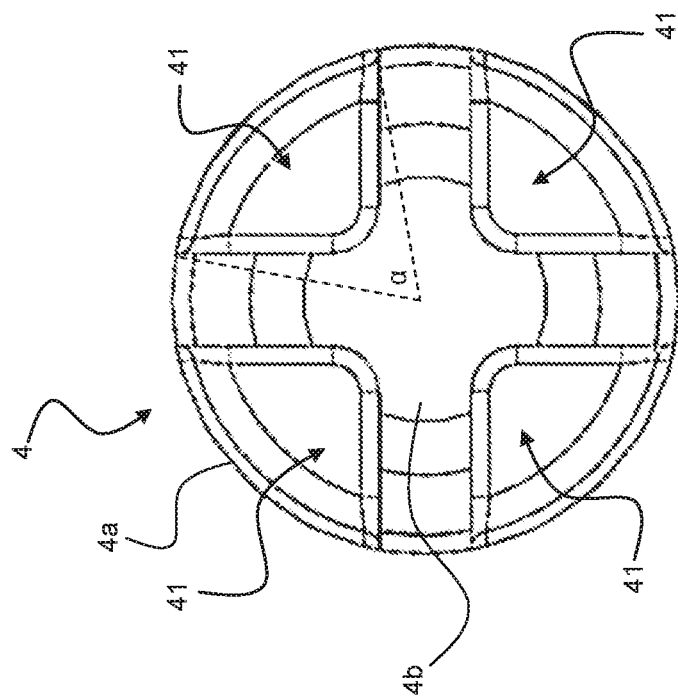


Fig. 6

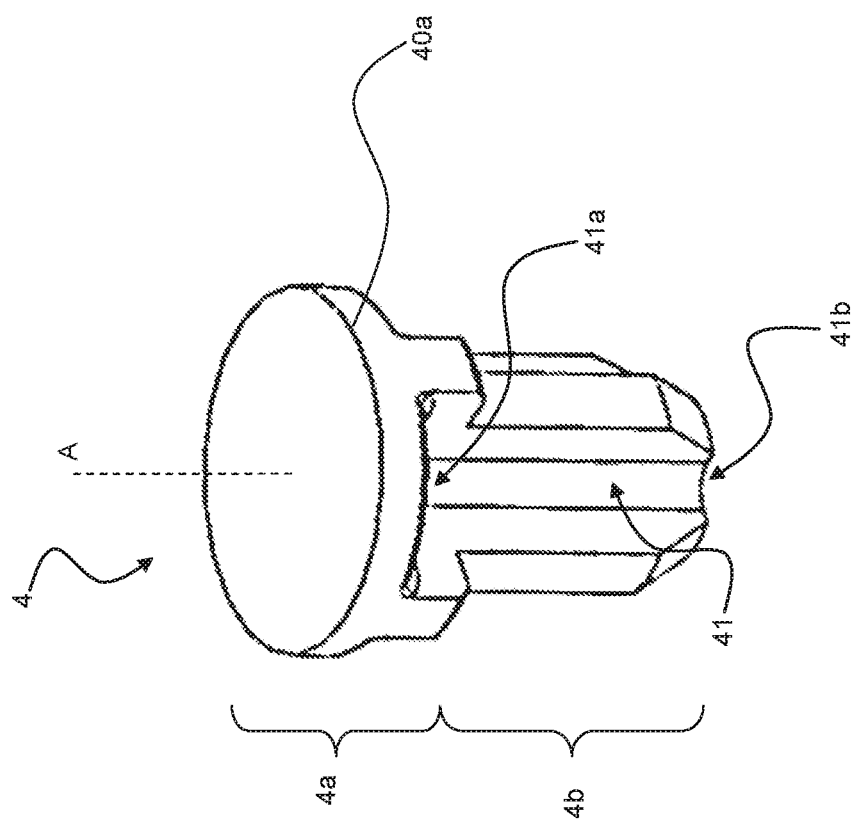


Fig. 7

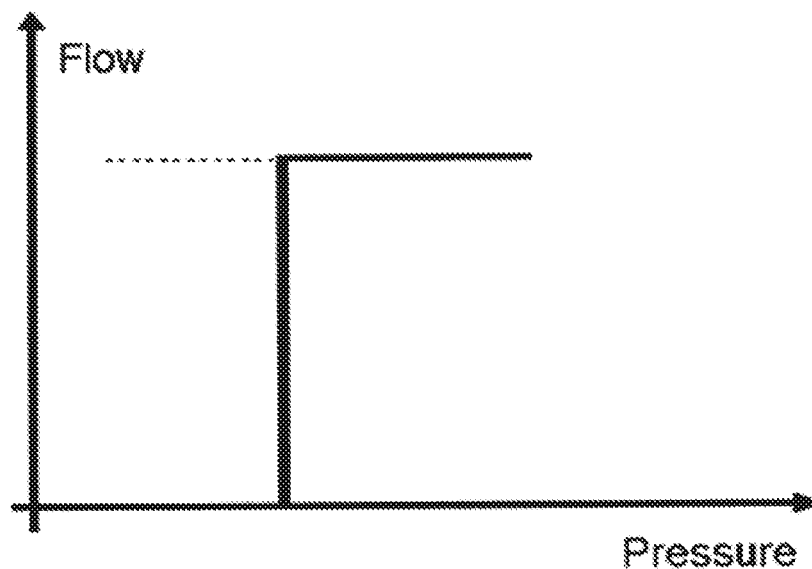


Fig. 8

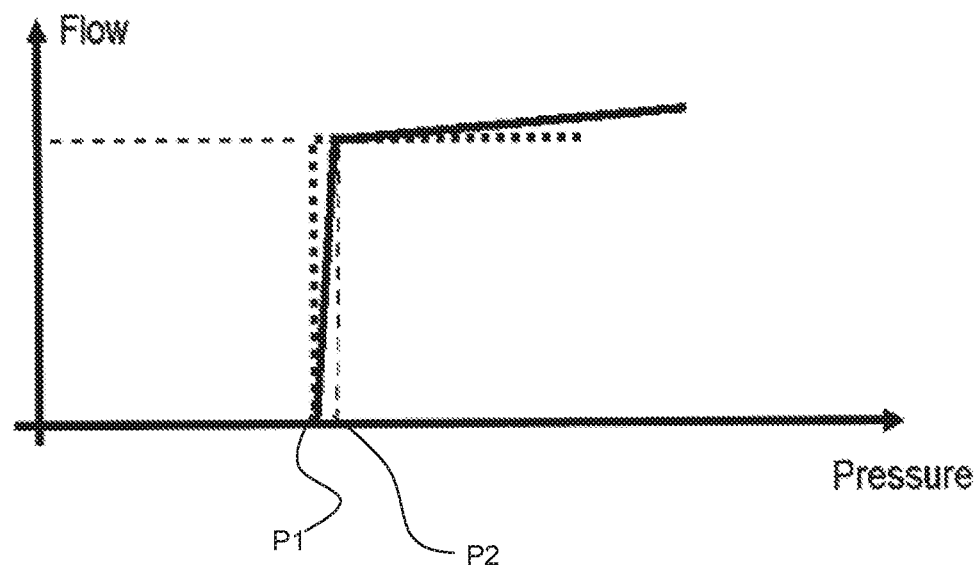


Fig. 9

PISTON COOLING JET FOR AN INTERNAL COMBUSTION ENGINE

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to Great Britain Patent Application No. 1519640.5, filed Nov. 6, 2015, which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

[0002] The present disclosure pertains to the cooling of the pistons of an internal combustion engine, and more particularly to piston cooling jets for an internal combustion engine.

BACKGROUND

[0003] An internal combustion engine (ICE) generally includes an engine block defining one or more cylinders, each provided with a reciprocating piston coupled to a crankshaft. A cylinder head closes the cylinders to define a combustion chamber for each cylinder, where injection and ignition of a fuel and air mixture cyclically occurs, causing the above mentioned reciprocating movement of the piston.

[0004] In order to improve the internal combustion engine performances, pistons are preferably cooled. Devices known as piston cooling jets (PCJs) are used to generate jets of oil onto the underside of the pistons. The oil may be used to absorb heat from the pistons and also to lubricate the cylinders of the internal combustion engine.

[0005] Piston cooling jets include a coolant inlet, which is typically opened and closed by a movable plunger reciprocating within the piston cooling jet. The piston cooling jet further includes a nozzle to direct the coolant towards the underside of the pistons in the cylinder of the engine block. The plunger is biased by a spring towards the coolant inlet, to close it. When a force generated by the coolant exceeds the biasing force of the spring, the plunger is moved away from the coolant inlet, so that coolant can flow within the piston cooling jet. The spring and the plunger are supported by a carrier within the piston cooling jet. When the coolant inlet is opened, the coolant flows laterally with respect to the carrier, so as to avoid contact between the coolant and the spring that may cause undesired turbulence within the coolant itself. Also, the carrier is designed and arranged within the piston cooling jets, so as to limit the maximum stroke of the plunger.

[0006] As a result, the coolant flow requirements are respected and also coolant consumption is limited. Moreover, the carrier acts as a stroke limiter to maintain the flow of coolant as constant as possible when the coolant pressure continues to be raised.

[0007] Furthermore, a balance between the performance improvements and the power required to operate the piston cooling jets and the fuel consumption (and consequently CO₂ emission) is achieved. In particular, the flow of coolant (viewed as a function of the coolant pressure) has a step-like behavior, which provides for an effective operation of the piston cooling jet.

[0008] However, the carrier is a relatively complex component. Also it is particularly difficult and complex to insert the carrier within the piston cooling jets. As a result, the piston cooling jets require a certain number of elements that are complex and timely to assemble, thus reducing the cost effectiveness of the piston cooling jet.

[0009] Accordingly, there is a need to provide a piston cooling jet composed of a reduced number of components that is simple to produce and to assemble in a cost-effective manner.

SUMMARY

[0010] According to an embodiment, a piston cooling jet for an internal combustion engine includes a body having a coolant duct extending between a coolant duct inlet and a coolant duct outlet that is fluidly connected to a coolant nozzle. The piston cooling jet includes a plunger provided with a plunger stem and with a plunger head. The plunger is movable within the coolant duct of the body between at least a closing position wherein the plunger head closes the coolant duct inlet and an opening position. The plunger head is at a distance from the coolant duct inlet to open the coolant duct inlet. The piston cooling jet further includes a biasing spring arranged within the coolant duct and coupled to the plunger to bias it towards the closing position. The plunger is provided with at least one plunger coolant channel having a channel inlet on the plunger head and a channel outlet on the plunger stem, channeling coolant downstream of the plunger head when the plunger is in the opening position.

[0011] As a result, the above mentioned step-like behavior of the flow of coolant can be achieved with a reduced number of simple components. Hence, the above mentioned advantages mentioned for the known complex piston cooling jets are achieved in a simpler and inexpensive manner.

[0012] According to an embodiment, at least part of the plunger coolant channel is a recess provided on the plunger stem and/or on the plunger head. In other words the plunger stem and/or the plunger head is provided with at least one recess defining at least part of the plunger coolant channel. This is a simple and effective manner to realize the above mentioned plunger coolant channel(s).

[0013] According to an embodiment, the plunger stem and/or the plunger head has a cross section substantially cross-shaped. In other words, at least part of the plunger coolant channel(s) is/are defined on the external surface of the plunger, and are parallel with respect to a longitudinal axis of the body. These particular shapes have proven to be particularly effective.

[0014] According to an embodiment, at least part of the plunger coolant channel is a duct provided within said plunger stem and/or said plunger head. In other words, the plunger stem and/or the plunger head is provided with at least one duct defining at least part of the plunger coolant channel. Therefore, at least part of the plunger coolant channel(s) is obtained by a duct passing inside the plunger. This allows an improved guidance of the coolant.

[0015] According to an embodiment, the biasing spring is a helical coil spring coupled to at least a portion of the lateral surface of the plunger stem and at least part of the plunger coolant channel is extending within the inner hollow space of the coil spring. By doing so, the coolant is channeled by the plunger coolant channel inside the inner hollow space of the spring thus avoiding undesired turbulence effects. In fact, the fluid is not directed towards the spring, which may cause turbulence in the flow of coolant.

[0016] According to an embodiment, the plunger is provided with a plurality of plunger coolant channels, preferably arranged symmetrically with respect to a plunger longitudinal axis. This allows managing an increased flow of

coolant. Also, it is simpler to make the system symmetric, so as to obtain a more regular flow of coolant.

[0017] According to an embodiment, a portion of the plunger coolant channel at the plunger head is arranged substantially perpendicular, or inclined, with respect to a plunger longitudinal axis. According to an embodiment, a portion of the plunger coolant channel at the plunger head is arranged substantially radially with respect to a plunger longitudinal axis. As a result, a good guidance of the flow of coolant is obtained.

[0018] According to an embodiment, a portion of the plunger coolant channel at the plunger stem is arranged substantially parallel with respect to the longitudinal axis. This allows obtaining a regular flow of fluid. Moreover, the fluid is not directed towards the spring, which may cause turbulence in the flow of coolant.

[0019] According to an embodiment, the plunger head is dimensioned so that, in the opening position, the plunger is distanced from the coolant duct inlet by a distance that is less than the height of the plunger head. In other words, the maximum stroke of the plunger is smaller than the height of the plunger head. As a result, the plunger reaches the abutting portion in short time (i.e. the plunger can switch between the closing position and the opening position in a short time). Also, in the opening position the space between the plunger head and the coolant duct inlet is filled in short time, so that the above mentioned step-like behavior of the flow of coolant can be achieved.

[0020] According to an embodiment, the coolant duct is provided with a plunger abutting portion that is contacted by the plunger head in the opening position of the plunger. Advantageously by providing the abutting portion for the plunger head on the coolant duct, and preferably on an inner surface of the coolant duct, it is possible to reduce the number of components of the piston cooling jet.

[0021] A further embodiment of the present disclosure provides for an internal combustion engine including a piston cooling jet according to one or more of the preceding aspects.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] The present disclosure will hereinafter be described in conjunction with the following drawing figures, wherein like numerals denote like elements.

[0023] FIG. 1 shows an exemplary embodiment of an automotive system including an internal combustion engine in which the fuel unit pump can be used;

[0024] FIG. 2 is a cross-section according to the plane A-A of an internal combustion engine belonging to the automotive system of FIG. 1;

[0025] FIG. 3 is a perspective view of a piston cooling jet according to an embodiment of the present disclosure;

[0026] FIG. 4 is a front sectional view of the piston cooling jet of FIG. 3, with the plunger in the closing position;

[0027] FIG. 5 is a view similar to FIG. 4, with the plunger in the opening position;

[0028] FIG. 5 is a bottom view of a plunger according to an embodiment of the present disclosure;

[0029] FIG. 7 is a perspective view of the plunger of FIG. 6;

[0030] FIG. 8 is schematic view of a desired and ideal behavior of the flow of coolant in a piston cooling jet; and

[0031] FIG. 9 is a schematic view of the actual behavior of the flow of coolant in a piston cooling jet according to an embodiment of the present disclosure.

DETAILED DESCRIPTION

[0032] The following detailed description is merely exemplary in nature and is not intended to limit the invention or the application and uses of the invention. Furthermore, there is no intention to be bound by any theory presented in the preceding background of the invention or the following detailed description.

[0033] Some embodiments may include an automotive system **100**, as shown in FIGS. 1 and 2, that includes an internal combustion engine (ICE) **110** having an engine block **120** defining at least one cylinder **125** having a piston **140** coupled to rotate a crankshaft **145**. A cylinder head **130** cooperates with the piston **140** to define a combustion chamber **150**. A fuel and air mixture (not shown) is disposed in the combustion chamber **150** and ignited, resulting in hot expanding exhaust gasses causing reciprocal movement of the piston **140**. The fuel is provided by at least one fuel injector **160** and the air through at least one intake port **210**. The fuel is provided at high pressure to the fuel injector **160** from a fuel rail **170** in fluid communication with a high pressure fuel pump **180** that increase the pressure of the fuel received from a fuel source **190**.

[0034] Each of the cylinders **125** has at least two valves **215**, actuated by the camshaft **135** rotating in time with the crankshaft **145**. The valves **215** selectively allow air into the combustion chamber **150** from the port **210** and alternately allow exhaust gases to exit through a port **220**. In some examples, a cam phaser **155** may selectively vary the timing between the camshaft **135** and the crankshaft **145**.

[0035] The air may be distributed to the air intake port(s) **210** through an intake manifold **200**. An air intake duct **205** may provide air from the ambient environment to the intake manifold **200**. In other embodiments, a throttle body **330** may be provided to regulate the flow of air into the manifold **200**. In still other embodiments, a forced air system such as a turbocharger **230**, having a compressor **240** rotationally coupled to a turbine **250**, may be provided. Rotation of the compressor **240** increases the pressure and temperature of the air in the duct **205** and manifold **200**. An intercooler **260** disposed in the duct **205** may reduce the temperature of the air. The turbine **250** rotates by receiving exhaust gases from an exhaust manifold **225** that directs exhaust gases from the exhaust ports **220** and through a series of vanes prior to expansion through the turbine **250**. The exhaust gases exit the turbine **250** and are directed into an exhaust system **270**. This example shows a variable geometry turbine (VGT) with a VGT actuator **290** arranged to move the vanes to alter the flow of the exhaust gases through the turbine **250**. In other embodiments, the turbocharger **230** may be fixed geometry and/or include a waste gate.

[0036] The exhaust system **270** may include an exhaust pipe **275** having one or more exhaust aftertreatment devices **280**. The aftertreatment devices may be any device configured to change the composition of the exhaust gases. Some examples of aftertreatment devices **280** include, but are not limited to, catalytic converters (two and three way), oxidation catalysts, lean NO_x traps, hydrocarbon adsorbers, selective catalytic reduction (SCR) systems, and particulate filters. Other embodiments may include an exhaust gas recirculation (EGR) system **300** coupled between the

exhaust manifold 225 and the intake manifold 200. The EGR system 300 may include an EGR cooler 310 to reduce the temperature of the exhaust gases in the EGR system 300. An EGR valve 320 regulates a flow of exhaust gases in the EGR system 300.

[0037] The automotive system 100 may further include an electronic control unit (ECU) 450 in communication with one or more sensors and/or devices associated with the ICE 110. The ECU 450 may receive input signals from various sensors configured to generate the signals in proportion to various physical parameters associated with the ICE 110. The sensors include, but are not limited to, a mass airflow and temperature sensor 340, a manifold pressure and temperature sensor 350, a combustion pressure sensor 360, coolant and oil temperature and level sensors 380, a fuel rail pressure sensor 400, a cam position sensor 410, a crank position sensor 420, exhaust pressure and temperature sensors 430, an EGR temperature sensor 440, and an accelerator pedal position sensor 445. Furthermore, the ECU 450 may generate output signals to various control devices that are arranged to control the operation of the ICE 110, including, but not limited to, the fuel unit pump 180, fuel injectors 160, the throttle body 330, the EGR Valve 320, the VGT actuator 290, and the cam phaser 155. Note, dashed lines are used to indicate communication between the ECU 450 and the various sensors and devices, but some are omitted for clarity.

[0038] Turning now to the ECU 450, this apparatus may include a digital central processing unit (CPU) in communication with a memory system 460, or data carrier, and an interface bus. The CPU is configured to execute instructions stored as a program in the memory system, and send and receive signals to/from the interface bus. The memory system 460 may include various storage types including optical storage, magnetic storage, solid state storage, and other non-volatile memory. The interface bus may be configured to send, receive, and modulate analog and/or digital signals to/from the various sensors and control devices.

[0039] Instead of an ECU 450, the automotive system 100 may have a different type of processor to provide the electronic logic, e.g. an embedded controller, an onboard computer, or any processing module that might be deployed in the vehicle.

[0040] With reference to FIGS. 3-7, a piston cooling jet 1 includes a body 2 and a nozzle 3. The body 2 includes a coolant duct 20 having a coolant duct inlet 21 and a coolant duct outlet 22 fluidly connected to the nozzle 3. A plunger 4 is movable in a reciprocating manner within the coolant duct 20 and is provided with a plunger longitudinal axis A.

[0041] The body 2 typically has an elongated shape, and is provided with a longitudinal axis that is parallel or coincident to the plunger longitudinal axis A (In the following reference will be made to the plunger longitudinal axis A). Generally, the body 2 is substantially cylindrical. The nozzle 3 is configured in a known manner to direct coolant 5 towards a piston 140 in operative condition. It should be noted the coolant is schematically shown in FIG. 5 by arrows 5 schematically showing its flow path.

[0042] The coolant duct 20 passes through the body 2. Typically, at least part of the coolant duct 20 is extending substantially axially with respect to the plunger longitudinal axis A. In an embodiment, the coolant duct inlet 21 is placed at one end of the body 2, and allows inlet of coolant 5 along a direction substantially parallel with respect to the plunger longitudinal axis A. In the shown embodiment, the coolant

duct 20 is provided with two coolant outlets 22. The coolant outlets 22 are oriented radially with respect to the plunger longitudinal axis A.

[0043] A coolant collector 6 is partially disposed around the body 2 to collect the coolant 5 exiting from the body and to direct it towards the nozzle 3. In particular, a pipe 7 carrying the nozzle 3 is coupled to the coolant collector 6.

[0044] The coolant duct 20 is further provided with a plunger abutting portion 23, configured to engage the plunger 4 (in particular the plunger head 4a of the plunger 4, better discussed below). Typically, the plunger abutting portion 23 is obtained by converging portion (considering the direction of flow of the coolant 5) of the coolant duct 20. In general, at the plunger abutting portion 23, the diameter of the cooling duct 20 is smaller than the maximum width of the plunger, so that movement of the plunger 4 is stopped by the plunger abutting portion 23, when the plunger 4 moves away from the coolant duct inlet 21. In general, the number and disposition of the coolant ducts inlet and outlet may vary with respect to what shown. Moreover, in other embodiments, the coolant collector 6 may be absent, e.g. a pipe 7 may be directly connected to a coolant duct outlet 22.

[0045] The plunger 4 is provided with a plunger head 4a and with a plunger stem 4b. Typically, the plunger head 4a has a greater width (and in general greater cross section) and a smaller height with respect to the width and the height of the plunger stem 4b. The plunger 4 is movable within the coolant duct 20 of the body 2 between at least a closing position (shown in FIG. 4) wherein the plunger head 4a closes the coolant duct inlet and an opening position (shown in FIG. 5) wherein the plunger head 4a reaches a plunger abutting portion 23 of the coolant duct 20, at a distance D from the coolant duct inlet 21.

[0046] According to an embodiment, the plunger head 4a is dimensioned so that, in the opening position, the plunger is distanced from the coolant duct inlet 21 by a distance D that is less than the height H of the plunger head 4a. As a result, the maximum stroke of the plunger 4 within the coolant duct 20 is short. In an embodiment, the plunger 4 reciprocates along a direction that coincides with (or at least is parallel with respect to) the plunger longitudinal axis A.

[0047] A biasing spring 8 is inserted within the coolant duct 20. In particular, biasing spring 8 is arranged within the coolant duct 20 so as to bias the plunger 4 in the closing position, i.e. towards the coolant duct inlet 21. As mentioned, in the closing position, the plunger 4, and in particular the plunger head 4a, contacts the cooling inlet 21 so as to close it. In other words, in the closing position, fluid tight engagement is obtained between the cooling inlet 21 and the plunger 4, in order to prevent coolant from entering within the body 2. Gaskets or other sealing members may be used at the cooling inlet 21 to help in providing the above mentioned fluid tight engagement.

[0048] According to an embodiment, the biasing spring 8 is typically dimensioned so that its external diameter substantially coincides with the diameter of the portion of the coolant duct 20 into which it is inserted, while the inner diameter of the biasing spring 8 substantially coincides with the maximum width of the plunger stem 4b. According to an embodiment, the plunger 4 is partially inserted within the biasing spring 8 so that the biasing spring 8 exerts its biasing force against the plunger head 4a. The external surface (or part of the external surface, as better discussed later) of the

plunger stem 4b contacts the biasing spring 8, so that tilting of the plunger 4 with respect to the biasing spring 8 is prevented.

[0049] The plunger 4 is provided with at least one plunger coolant channel 41, 42 allowing flow of coolant 5 within the coolant duct 20 downstream the plunger head 4a (considering the direction of flow of coolant 5, i.e. from the coolant duct inlet 21 towards the coolant duct outlet 22) when the plunger 4 is in the opening position. In particular, the plunger coolant channel(s) 41, 42 is/are provided with a channel inlet 41a, 42a and with a channel outlet 41b, 42b. The channel inlet 41a, 42a is arranged on the plunger head 4a, while the channel outlet 41b, 42b is arranged on the plunger stem 4b.

[0050] According to an embodiment, the channel inlet 41a, 42a is arranged so that the coolant 5 flows in the plunger coolant channel 41, 42 into the channel inlet 41a, 42a in a radial direction with respect to the plunger longitudinal axis A. The channel outlet 41b, 42b is arranged so that the coolant 5 leaves the plunger coolant channel 41, 42 substantially along a direction parallel with respect to the plunger longitudinal axis A.

[0051] The plunger coolant channel(s) 41, 42 may be arranged according to various configurations. In FIGS. 4 and 5 two possible embodiments are shown. In particular, a plunger coolant channel 41 (shown on the left portion of the plunger 4) may be obtained as a recess, e.g. a missing or cut-away portion on the external surface of the plunger 4. In another embodiment, a plunger coolant channel 42 (shown on the right portion of the plunger 4) may be obtained as a duct (or hole) within the plunger 4. Plunger coolant channel 41 configured as a recess allows the coolant to flow along the external surface of the plunger 4, while plunger coolant channel 42 configured as a duct allows the coolant to flow within the plunger 4.

[0052] In FIGS. 4 and 5, it is shown an embodiment where a plunger 4 is provided with two different kinds of plunger coolant channels 41, 42 (i.e. the two above discussed), but generally a single embodiment is provided with only one kind of plunger coolant channels. In FIGS. 6 and 7 an embodiment is shown wherein a plunger 4 is provided with four plunger coolant channels 41, configured as recesses on the external surface of the plunger 4. The plunger coolant channels 41 are evenly distributed along the external surface of the plunger 4, so that the plunger 4 is provided with two planes of symmetry, substantially orthogonal one to the other.

[0053] In more detail, the plunger head 4a is provided with a first portion 40a substantially cylindrical, acting as a shutter for the coolant duct inlet 21, and a second portion 40b provided with recesses to define the plunger coolant channels 41. The second portion 40b, viewed in cross section, is substantially cross shaped. The plunger stem 4b is also provided with recesses to define plunger coolant channels 41. As before, the cross section of the plunger stem 4b is substantially cross-shaped. Other embodiments (not shown) may be provided with different shaped and/or with a different number of recesses to define coolant channels 41.

[0054] In general, the plunger head 4a may be provided with recesses (or missing or cut-away portions) to define part of one or more channels 41 so that, at the recesses, flow of coolant 5 between the plunger 4 and the coolant duct 20 is allowed (typically along a direction substantially radial (or perpendicular) with respect to the plunger longitudinal axis

A). The remaining lateral surface of the plunger head 4a allows engagement with the plunger abutting portion 23. The plunger stem 4b may be provided with recesses to define the remaining part of the channel(s) 41 so that, at the recess(es), flow of coolant 5 is allowed between the plunger 4 and the biasing spring 8 (typically along a direction substantially parallel with respect to the plunger longitudinal axis A). The remaining portion of the lateral surface of the plunger stem 4b contacts the biasing spring 8.

[0055] More in detail, according to a possible embodiment, the biasing spring 8 is a helical coil spring coupled to at least a portion of the lateral surface of the plunger stem 4b and at least part of the plunger coolant channel 41, 42 is extending within the inner hollow space S of the coil spring. More in detail, the channel outlet 41b, 42b is provided within the inner hollow space of the plunger 4.

[0056] According to an embodiment, considering a cross section of the plunger 4 each of the plunger coolant channels 41 has an angular extension α of about 70 degrees. The maximum depth MD of the channel 41 is about $\frac{2}{3}$ the maximum width of the plunger stem 4b (i.e. the diameter of the plunger stem 4b). This provides a good balance between allowing a sufficient flow of coolant and allowing an effective engagement between the plunger head 4a and the plunger abutting portion 23.

[0057] As mentioned, in other embodiments, plunger coolant channels 42 may be configured as ducts within the plunger 4. At the plunger head 4a, the duct is preferably arranged substantially radially with respect to the longitudinal axis A, while at the plunger stem 4b the duct is preferably arranged substantially parallel to the plunger longitudinal axis. Different configurations, shapes and numbers of plunger coolant channels 42 may be used allowing flow of coolant downstream the plunger head 4a when the plunger 4 is in the opening position. In general, typically plunger coolant channels 42 allow inlet of coolant 5 within the plunger head 4a of the plunger 4, and outflow of coolant 5 from the plunger stem 4b of the plunger 4.

[0058] In different embodiments, a plunger coolant channel may be configured in part as a recess and in part as a duct. As an example, the portion of channels 41 shown in the figures may continue as a through duct within the plunger head 4a.

[0059] As mentioned, in general a plunger coolant channel according to an embodiment of the present disclosure allows flow of coolant downstream the plunger head 4a, i.e. it allows flow of coolant from upstream the plunger abutting portion 23 to downstream the plunger abutting portion 23. In other words, a plunger coolant channel according to an embodiment of the present disclosure allows the coolant to bypass the engagement between the plunger 4 and the plunger abutting portion 23.

[0060] During assembly, the piston cooling jet 1 is inserted into a coolant circuit of an automotive system 100, so that the coolant circuit provides coolant 5 at the coolant inlet duct 21. The piston cooling jet is arranged in the automotive system so that the nozzle can direct a flow of coolant 5 towards the underside of a piston 140 in the engine block 120 of the internal combustion engine 110 of the automotive system 100.

[0061] During operation, the plunger 4 is initially in the closing position, shown in FIG. 4, biased by the biasing spring 8. The plunger head 4a closes the coolant duct inlet 21, so that no coolant 5 is introduced into the coolant duct

20. This is shown in the graph of FIG. 9. When the pressure of the coolant 5 in the coolant circuit is below value P1 (i.e. the value needed to move the plunger 4 away from the coolant duct inlet 21), there is no flow of coolant 5.

[0062] When the pressure of coolant 5 in the coolant circuit exceeds the biasing force of the biasing spring 8, the plunger 4 is moved away from the coolant duct inlet 21. In this situation, the flow of coolant 5 is rapidly increased, until the space between the plunger 4 and the coolant duct inlet 21 is filled. In the graph of FIG. 9, this is shown by the rapid increase in the flow of coolant for values of pressure above value P1. Subsequently, the plunger head 4 reaches the plunger abutting portion 23, and thus the plunger 4 is stopped in the opening position, shown in FIG. 5.

[0063] When flow continuity within the piston cooling jet 1 has been established, i.e. when the space between the plunger 4 and the coolant duct inlet 21 is filled, the coolant 5 has reached a value of pressure P2. Subsequently, flow of coolant 5 is slowly increased proportionally to the increase of pressure above value P2, so that the flow of coolant is nearly constant when the values of pressure of the coolant exceed pressure value P2.

[0064] As mentioned, the stroke of the plunger is short and reduced space is formed between the plunger head 4a and the coolant duct inlet 21. As a result, short time is needed to fill the space between the plunger 4 and the coolant duct inlet 21, so that pressure of the coolant reaches a value of pressure P2 that is slightly different from pressure value P1. As a result, a substantially step like behavior (similar to the ideal step-like behavior of FIG. 8) can be achieved by the piston cooling jet 1 according to embodiments of the present disclosure.

[0065] While at least one exemplary embodiment has been presented in the foregoing detailed description, it should be appreciated that a vast number of variations exist. It should also be appreciated that the exemplary embodiment or exemplary embodiments are only examples, and are not intended to limit the scope, applicability, or configuration of the invention in any way. Rather, the foregoing detailed description will provide those skilled in the art with a convenient road map for implementing an exemplary embodiment, it being understood that various changes may be made in the function and arrangement of elements described in an exemplary embodiment without departing from the scope of the invention as set forth in the appended claims and their legal equivalents.

1-11. (canceled)

12. A piston cooling jet for an internal combustion engine comprising:

- a body having a coolant duct extending between a coolant duct inlet and a coolant duct outlet and fluidly connected to a coolant nozzle;
 - a plunger including a plunger stem, a plunger head and at least one plunger coolant channel having a channel inlet at the plunger head and a channel outlet at the plunger stem; and
 - a biasing spring arranged within the coolant duct and biasing the plunger towards the closing position;
- wherein the plunger is configured to move within the coolant duct between a closing position wherein the plunger head closes the coolant duct inlet and an opening position wherein the plunger head spaced from the coolant duct inlet to open the coolant duct for channeling coolant downstream of the plunger head.

13. The piston cooling jet according to claim 12, wherein at least part of the plunger coolant channel comprises a recess provided in at least one of the plunger stem or the plunger head.

14. The piston cooling jet according to claim 13, wherein at least one of the plunger stem or the plunger head comprising a cross-shaped cross section with respect to a plunger longitudinal axis.

15. The piston cooling jet according to claim 12, wherein at least part of the plunger coolant channel comprises a duct provided within at least one of said plunger stem or said plunger head.

16. The piston cooling jet according to claim 12, wherein said biasing spring comprising a coil spring coupled to at least a portion of a lateral surface of the plunger stem, wherein at least part of the plunger coolant channel extends within an inner hollow space of the coil spring.

17. The piston cooling jet according to claim 12, wherein the plunger comprising a plurality of plunger coolant channels.

18. The piston cooling jet according to claim 12, wherein a portion of the plunger coolant channel at the plunger head is arranged substantially perpendicular with respect to a plunger longitudinal axis.

19. The piston cooling jet according to claim 12, wherein a portion of the plunger coolant channel at the plunger head is inclined with respect to a plunger longitudinal axis.

20. The piston cooling jet according to claim 12, wherein a portion of the plunger coolant channel at the plunger stem is arranged substantially parallel with respect to a plunger longitudinal axis.

21. The piston cooling jet according to claim 12, wherein the plunger head is dimensioned so that, in the opening position, the plunger is distanced from the coolant duct inlet by a distance that is less than a height of the plunger head.

22. The piston cooling jet according to claim 12, wherein the coolant duct comprises a plunger abutting portion, the plunger head contacting said plunger abutting portion in said opening position.

23. An internal combustion engine comprising:

- an engine block defining a cylinder;
- a reciprocating piston disposed in the cylinder and coupled to a crankshaft;
- a cylinder head closing the cylinder to define a combustion chamber; and
- a piston cooling jet including a body having a coolant duct extending between a coolant duct inlet and a coolant duct outlet and fluidly connected to a coolant nozzle, a plunger including a plunger stem, a plunger head and at least one plunger coolant channel having a channel inlet at the plunger head and a channel outlet at the plunger stem, and a biasing spring arranged within the coolant duct and biasing the plunger towards the closing position;

wherein the plunger is configured to move within the coolant duct between a closing position wherein the plunger head closes the coolant duct inlet and an opening position wherein the plunger head spaced from the coolant duct inlet to open the coolant duct for channeling coolant downstream of the plunger head, through the coolant nozzle towards an underside of the pistons in the cylinder of the engine block.

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