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(54) **INTERNAL COMBUSTION ENGINE PROVIDED OF A PISTON COOLING SYSTEM**

(57) Lubricating and cooling system for an internal combustion engine, the combustion engine comprising a piston reciprocated with a respective cylinder, the piston comprising an inner cooling passage (C) having at least an inlet (IP) and an outlet (OP), the system comprising an auxiliary oil circuit with an auxiliary pump (AP) sucking oil from said oil sump to feed at least one piston nozzle(s) (NZ), a main oil circuit with a respective main pump (MP) for sucking oil from said oil sump to feed oil to remaining engine oil consumers (CB-RA, CM, CR). The main circuit comprises a main cooler (MC) and the auxiliary circuit comprises an auxiliary cooler (AC) separated and thermally independent from the main cooler.

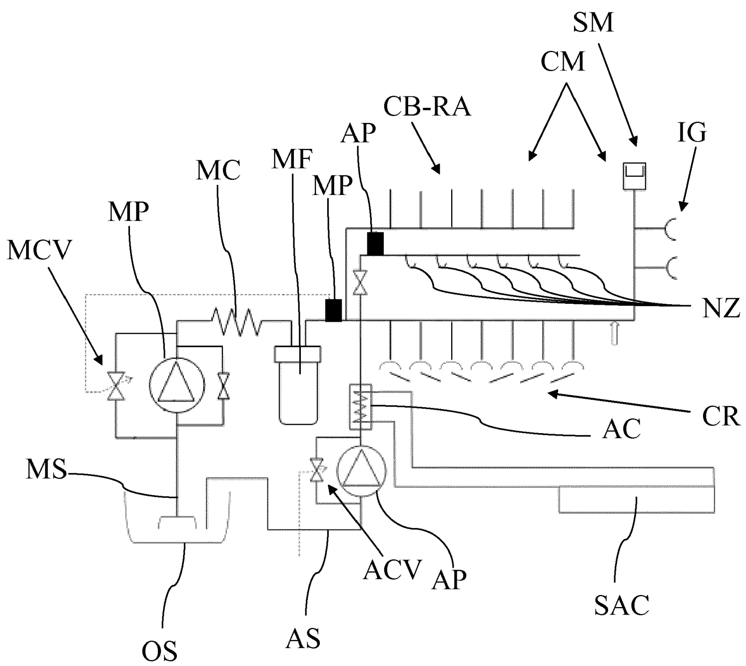

Fig. 1

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Description

Field of the invention

[0001] The present invention relates to the field of the cooling and lubricating systems of the internal combustion engines. In particular, the present invention relates to the specific aspect of the cooling of engine pistons.

Description of the prior art

[0002] The engine oil circuit has two different tasks to cool certain components, to lubricate other components and to lubricate and cool further components.

[0003] The engine pistons belong to the first of the above categories, being components that, as such, request only cooling. Instead, all the piston connections: the piston pin, the piston pin bore, the conrod small end, etc.. need lubrication more that cooling.

[0004] WO2010002293 describes a piston cooling system of a combustion engine. In particular, the scheme disclosed comprises a nozzle affixed to an internal wall of the combustion engine in order to face a lower face of an engine piston.

[0005] With upper face of the piston is intended the surface of the piston intended to compress the air/fuel charge, while for lower face is intended the surface of the piston opposite to the upper face. This wording is held irrespective to the spatial orientation of the engine cylinder.

[0006] WO2010002293 discloses also the possibility to separate the piston oil cooling circuit from the others by means of a separate pump. The solution disclosed in WO2010002293 could be subject to further improvements.

Summary of the invention

[0007] The main object of the present invention to provide a piston cooling system for an internal combustion engine capable to assure an efficient piston cooling with a really lower energetic impact.

[0008] The main principle of the invention is to exploit a separate oil circuit to cool the engine piston(s) with a corresponding separate pump, with respect to the remaining and "traditional" engine lubricating circuit, and to introduce a cooler on such separate oil circuit in order to reduce the oil flow needed to cool the engine piston(s) due to a lower oil temperature injected towards the lower face of the engine piston.

[0009] In particular, this cooler on the separate oil circuit is thermally independent from the main cooler of the "traditional" engine lubricating circuit. This means that the heat is released to the ambient in an independent way and not through a common intermediate vectoring medium, such as the engine water.

[0010] The combustion engine thus comprises also a water coolant circuit to cool the cylinder jacket(s) and the engine head. Such water coolant circuit comprises as usual a water pump and a radiator. The water coolant circuit is preferably connected to a coach radiator in order to heat, especially during winter, the coach of the vehicle belonging the internal combustion engine according to the present invention.

[0011] According to the present description with "main circuit" is meant the principal and "traditional" oil circuit encompassing substantially all the oil consumers of an internal combustion engine, such as those requiring oil for lubrication and/or actuation such as the bearings, including the crankshaft bearings and the turbine bearings, and the valves including the camshaft and rocker bearings and also the actuators to command the valves, for example to operate the engine braking, and so on. Instead, with "auxiliary oil circuit" is intended the above separate oil circuit to cool the engine piston(s), with respect to the main one, including an auxiliary pump sucking the engine oil from a common engine oil sump/tank, an auxiliary cooler capable to cool the oil sucked by the auxiliary pump and at least one nozzle affixed to an engine cylinder wall so as to hit on opening of a cooling passage realized in the body piston.

[0012] The task to cool a piston represents the most thermal stress for the engine oil, therefore, shifting towards lower values the thermal operation range reduces oil-aging effects.

[0013] According to a first embodiment of the invention, no oil filters are encompassed by said auxiliary circuit, thus it is of the filter-less type, in view of the fact that the piston cooling is not sensitive to impurities such as metal filings.

[0014] According to another embodiment of the invention, the lower oil temperature permits to reduce the flow of the oil itself, with savings in terms of energy spent to circulate and pressurize the oil.

[0015] According to a further embodiment of the invention that can be combined with the above embodiments, the oil nozzle(s) is sized so as to produce a laminar fluid jet filling the piston cooling passage during only a proximal relative position of the piston with respect to the nozzle and not continuously as carried out in the known engines.

[0016] Indeed, the oil pressure can be further reduced to a "very low oil pressure", by leading to very low pumping power requirements for piston cooling.

[0017] Even if the piston cooling passage is not modified to retain an increased oil quantity, the lower temperature of the oil jet is capable to cool properly the piston even if the latter is not continuously re-filled of fresh oil.

[0018] An auxiliary circuit with a separate pump and a separate cooler in combination with a laminar jet develops a synergistic effect, avoiding a heavy modification of the piston cooling passage. Therefore, the retaining means, usually arranged at the inlet port(s) and outlet port(s) of the piston cooling passage can be left unchanged. On another hand, such combination permits also a further pumping energy reduction that is amplified by a complete lacking of filtering elements on the auxiliary oil circuit. According to another embodiment of the invention, not only the piston nozzle but also the turbocharger bearings and eventually the engine primary distribution gear jets, intended to drive the oil pump(s), PTO, injection pump, steering pump, camshaft, are fed by the auxiliary circuit. Said bearings are really subjected to high thermal stresses; therefore, the auxiliary circuit represents a dedicated circuit for thermal stressed components of the engine as a whole. When the turbocharger bearings are provided of oil from the auxiliary oil circuit an auxiliary filter is foreseen in the auxiliary circuit in order to avoid bearings damaging.

[0019] According to a further embodiment, only the piston nozzles are served by the auxiliary oil circuit and during engine brake actuation, the oil is diverted from the auxiliary circuit to the main circuit in order to suddenly pressurize the main gallery of the main circuit. This sudden pressurization helps the main circuit to better serve switching means operating on the camshaft/rocker arms and eventually further components in order to actuate said engine brake or another timing strategy.

[0020] The main lubricating circuit can be pressurized by the auxiliary pump also before the engine cranking, namely when the main pump usually driven by the crankshaft is still. Thus, the auxiliary pump is switched on and the diverting means are activated once the ignition is on and before engine cranking by helping the lubrication of bearings and of other components in a condition where, usually, such components are stressed due to the lacking of oil pressurization. Thus, the diverting means are switched off after engine cranking.

[0021] Preferably, the activation of the auxiliary pump and of the diverting means is also contemporary with or consequent of the on-board services activation, such us the fuel pump. With the exception of said temporarily short circuit between the two circuits is actuated due to such oil diversion means, the sole point in common between the main and auxiliary circuits is the oil sump or the oil tank in case the lubricating circuit is of the dry type.

[0022] These and further objects are achieved by means of the attached claims, which describe preferred embodiments of the invention, forming an integral part of the present description.

Brief description of the drawings

[0023] The invention will become fully clear from the following detailed description, given by way of a mere exemplifying and non-limiting example, to be read with reference to the attached drawing figures, wherein:

- Fig. 1 shows schematically an example of implementation of the present invention,
- Fig. 2 shows crank angle/piston speed of a combustion engine, where the pseudo-sinusoidal curve developed by the up/down travelling of the piston is compare with two horizontal quotas, one corresponding to the height reached by a known oil jet and one corresponding to the height reached by the oil jet of one embodiment of the present invention,
- Fig. 3 shows a longitudinal section of a piston according to the present invention, in an operative condition in which the piston is far from the nozzle and the oil jet does not reach a corresponding inlet opening of the cooling piston passage.

[0024] The same reference numerals and letters in the figures designate the same or functionally equivalent parts. According to the present invention, the term "second element" does not imply the presence of a "first element", first, second, etc.. are used only for improving the clarity of the description and they should not be interpreted in a limiting way.

Detailed description of the preferred embodiments

[0025] The present invention is here described with the help of figures 1 - 3.

[0026] A volumetric internal combustion engine, as usual, comprises a piston reciprocated with a respective cylinder. A lubricating and cooling system is implemented either to cool the pistons or also to lubricate other "oil consumers". The piston (Fig.3) comprises an inner cooling passage C having at least an inlet IP and an outlet OP, while a piston nozzle NZ of the cooling system is arranged in order to hit said inlet IP, so as to make the oil circulating within the piston inner cooling passage.

[0027] After its work, the oil, as usual, falls in an oil sump OS where the oil is collected or in case of dry oil circuit, the oil is collected in a dedicated oil tank.

[0028] According to the present invention, an auxiliary oil circuit (Fig.1) with an auxiliary pump AP sucks oil from the oil sump/tank to feed only the piston nozzles NZ cooling the engine piston, while a main oil circuit with a respective main pump MP sucks oil from the same oil sump/tank to feed oil to the remaining engine oil consumers CB-RA, CM, CR with the sole exception of the piston nozzles NZ.

[0029] In addition, the main circuit comprises a main cooler MC while the auxiliary circuit comprises an auxiliary cooler AC separated and thermally independent from the main cooler.

[0030] Preferably, the auxiliary cooler is refreshed by the ambient air directly or indirectly through an intermediate vectoring medium. According to figure 1, the auxiliary cooler AC is a thermal exchanger between the engine oil directed to the piston nozzles and an intermediate vectoring medium circulating in a secondary circuit, where the heat is released to the ambient through the vectoring medium/ambient air exchanger SAC. However, an indirect cooling of the oil directed to the piston nozzle is not mandatory.

[0031] It is clear, from figure 1, that the main cooler MC and the auxiliary cooler AC are thermally independent, so said vectoring medium of the auxiliary cooler is not the engine cooling water.

[0032] The engine oil consumers, served by the main oil circuit, can be

- Command means CM including camshaft bearings CB and rocker arms RA, and switching means SM for vary cylinder valve timing actuation,
- eventually idler gears
- air compressor bearings
- turbocharger bearings
- gears
- PTO (Power Take Off).

[0033] Preferably, the auxiliary oil circuit is not provided of filter, because the cooling of the piston does not require oil filtration.

[0034] According to a preferred embodiment of the invention, the auxiliary pump AP is provided with bypass means connecting the pump inlet with the pump outlet through a controllable auxiliary valve ACV, so as the pump control is handled through said controllable auxiliary valve ACV. Alternatively, the auxiliary pump could be a variable flow pump or even an electric pump, whose speed can be controlled according to the heat to be drained by the pistons.

[0035] According to another preferred embodiment that can be combined with the above ones, the auxiliary circuit comprises an auxiliary pressure sensor AP arranged between on outlet of the auxiliary pump and the piston nozzles NZ, and a control unit, preferably the engine control unit, controls the auxiliary pump on the basis of a pressure signal generated by the auxiliary pressure sensor. According to another preferred embodiment of the invention, even combinable with the others herewith described, the control unit controls the pumps so that the oil fed by the auxiliary pump is proportional to the power delivered by the respective combustion engine and/or the oil fed by main pump is proportional to the engine speed. The main pump could have a variable displacement or could be electric or could have a fixed displacement coupled with a controllable bypass circuit capable to control the oil flow similar to that disclosed about the auxiliary pump.

[0036] Preferably, such controls are actuated by varying the target pressures within the respective main galleries of the main and auxiliary circuits.

[0037] According to another embodiment of the invention, not represent in figure 1, but that can be easily implemented in the same example, diverting means are arranged between the two circuits (main and auxiliary), in order to divert the oil from the auxiliary pump to the main circuit, preferably in a point upstream of the main filter in order to quickly increase the main circuit pressure. In other words, the piston nozzles are shut off for a short time interval just before the activation of switching means SM capable to vary the the activation of the cylinder valves, for example for engine brake or internal EGR, and so on. Such short time is, for example, between 0.3 to 1 second and in general depends on the engine operating point. Therefore, this oil diversion is actuated when switching means act on the cylinder valves command means, so the oil pressure increases suddenly within the main oil circuit, by making faster the dynamics of the switching means. In the following, with command means CM are intended, in general, the means controlling the cylinder valves, rocker arms/finger follower, camshaft, etc. and the relative switching means SM capable to vary the timing of the valve actuation according to an auxiliary strategy, such as engine brake or internal EGR and so on.

[0038] Immediately after the activation of the engine control means CM, the piston cooling is restored, thus the oil circulated by the auxiliary circuit is driven to the piston oil jets.

[0039] This strategy leads to energy savings since a smaller main pump can be used.

[0040] According to a preferred embodiment of the invention, also this "oil diversion" from the auxiliary circuit to the main circuit is actuated for a short time when the engine brake function or the internal EGR or other similar strategies are activated/deactivated , namely during transition between two or more valve operating strategy.

[0041] The time interval duration of the oil diversion depends on the dynamics of the switching means SM involved in the switching operation, however said 0.3 - 1 second should be enough.

[0042] In addition, the piston nozzles NZ and the auxiliary pump can be sized and controlled in order to produce a laminar oil jet. The meaning of "laminar" is well known to the skilled person in the art that knows the Reynolds numbers. Furthermore, the "laminar" concept is disclosed also in US2008017139 or in US2004040520.

[0043] If the oil jets are maintained at laminar (or near laminar) conditions, the piston inner cooling passage could be fed of fresh oil intermittently, namely, when the piston is in a proximal position with respect to the corresponding piston nozzle.

[0044] The delivery of piston cooling oil at very low oil pressure implies low pumping power, while ensuring a sufficient quantity of oil reaching the piston gallery.

[0045] Figure 2 shows also the quota Q reached by the oil jet J ejected by the nozzle NZ. It is clear, from figure 1, that the condition depicted is so that such jet does not reach the inlet opening IP, the piston having a higher speed than the oil jet.

[0046] Figure 2 shows a comparison of the effects of the reduction of the oil pressure.

[0047] The pseudo-sinusoidal curve indicates the piston speed vs crank angle.

[0048] The lowering of the oil pressure implies a lowering of the quota or altitude reached by the oil jet J.

[0049] Such lowering is virtually shown through the thick downwardly oriented arrow.

[0050] The portions of pseudo-sinusoidal curve over the stroke/dot line indicates crank angles - or time intervals by considering the engine speed -, where the oil jet does not hit the cooling inlet opening IP and, vice versa, the portions under such stroke/dot line indicates crank angles where the oil jet does hit the cooling inlet opening IP. The oil flow can be designed in order to guarantee the overall correct flow kg/kWh by accounting for the pseudo-sinusoidal curve over the stroke/dot.

[0051] Therefore, the oil flow can be reduced because independently cooled, and in addition, the oil can be ejected by the nozzle at low pressure, by obtaining at least a near laminar flow. It is well known that with the expression "near laminar flow" is intended Re<4000, while a laminar flow is characterized by Re<2300.

[0052] It is clear that, in order to maintain the oil pressure low, the nozzle inner surfaces are smooth pipes and that, accounting for the oil viscosity and density the laminar jet can be obtained by varying the nozzle opening diameter and the oil velocity, through the Reynolds formula.

[0053] For example, with an oil pressure of about 0.1 bar at the nozzle and with a nozzle outlet diameter of about 6 mm, the jet flow becomes even laminar with Re < 2130.

[0054] This means that there is minimal spray dispersion and the target, namely the piston cooling inlet opening (or bore), could be hit with a high efficiency. On the other side, this means to reduce drastically the energy needed to pump the oil.

[0055] This example, applies preferably to a 350 kW 6 cylinder engine.

[0056] In general, it is preferred to maintain the oil pressure between 0.1 and 1.5 bar with a preferred interval of 0.1 - 0.5 bar and the nozzle outlet diameters are between 4 - 8 mm.

[0057] Due to the separate cooling of the oil within the auxiliary circuit it is also possible to slightly increase the oil pressure to 2 bars [This appears to be contradictory]. For example, with a nozzle outlet diameter of about 3mm and oil pressure 2 bar, 0W20 viscosity 23 mm2/s at 60°C it is possible to maintain a laminar regime, still cooling a 350 kW 6 cylinder engine pistons.

[0058] Figure 3 shows schematically a longitudinal section of an engine piston P with its upper surface US and lower surface BS. It could also integrate at least a portion of the engine combustion chamber CC. In addition it is generally axially symmetric, but it is not mandatory that also the eventual combustion chamber portion CC is axially symmetric.

[0059] A cooling circuit C is integrated within the piston by forming an annular conduct with at least on inlet opening IP and an output opening OP.

[0060] It should be understood that more cooling circuits can be obtained by partitioning the said annular conduct.

[0061] A nozzle NZ is fixed with an internal part of the engine body in a lower position in order not to interfere with the piston travel.

[0062] The nozzle ejects engine lubricating oil towards the inlet opening IP.

[0063] Both the inlet opening and the outlet opening are provided with oil retention means, as for example tubular elements DK projecting within the cooling circuit C and forming a kind of dike suitable to refrain a certain volume of oil form falling into the engine oil sump.

[0064] By means of the present invention, a number of advantages are achieved. A separate cooling circuit is installed for piston cooling with low pressure to minimize pumping energy. The cooling oil is at low temperature, preferably at 40° instead of the typical 90 - 100°C. This enables a further reduction of oil flow and/or reduction of oil aging.

[0065] According to another embodiment of the invention, also the turbocharger bearings are supplied by the auxiliary circuit. Then the cooling circuit is equipped with a separate auxiliary filter.

[0066] Many changes, modifications, variations and other uses and applications of the subject invention will become apparent to those skilled in the art after considering the specification and the accompanying drawings which disclose preferred embodiments thereof. All such changes, modifications, variations and other uses and applications which do not depart from the scope of the invention are deemed to be covered by this invention.

[0067] It should be understood that all the single features and/or embodiments can be combined between each other. In addition, the features disclosed in the prior art background are introduced only in order to better understand the invention and not as a declaration about the existence of known prior art. Therefore, also the features described in the prior art background can be considered in combination with those mentioned in each embodiment of the detailed description.

[0068] Further implementation details will not be described, as the man skilled in the art is able to carry out the invention starting from the teaching of the above description.

Claims

1. Internal combustion engine comprising

- a water cooling circuit to cool a cylinder jacket and an engine comprising a coolant pump to recirculate water coolant and a coolant radiator,
- a lubricating and cooling system and

two or more oil consumers, wherein at least one oil consumer needs oil for lubrication and/or actuation (CB-RA, CM, CR), such as bearings, switching means for varying valve timing and/or engine brake, and at least one piston reciprocated with a respective cylinder, needing oil for cooling, the piston comprising an inner cooling passage (C) having at least an inlet (IP) and an outlet (OP), the system comprising at least one piston nozzle(s) (NZ) arranged in order to hit said inlet (IP) and an oil sump/tank (OS) where the oil is collected; the combustion engine being

characterized in comprising

- an auxiliary oil circuit with an auxiliary pump (AP) sucking oil from said oil sump/tank to feed at least one piston nozzle(s) (NZ),
- a main oil circuit with a respective main pump (MP) for sucking oil from said oil sump to feed oil to said at least one oil consumer needing oil for lubrication and/or actuation (CB-RA, CM, CR),

and **in that** said main circuit comprises a main cooler (MC) and said auxiliary circuit comprises an auxiliary cooler (AC) separated and thermally independent from said main cooler
and **in that** said main and auxiliary circuits, according to a first operating condition, share only said oil sump/tank.

2. System according to claim 1, wherein said auxiliary cooler is refreshed by the ambient air directly or indirectly through an intermediate vectoring medium.

3. System according to claim 2, wherein, said vectoring medium is different and separated from said engine cooling water.

4. System according to any of previous claims, wherein said engine oil consumers (CB-RA, CM, CR), supplied by the main circuit, comprise at lest one of:

- Command means (CM) including camshaft bearings (CB), rocker arms (RA), and switching means (SM) for vary cylinder valve timing actuation,
- eventually idler gears
- air compressor bearings
- turbocharger bearings
- gears
- PTO (Power Take Off).

5. System according to any of previous claims from 1 to 3, wherein said internal combustion engine is provided with a turbocharger and said auxiliary circuit feed also oil to the turbocharger bearings and/or to the gear jets and wherein said engine oil consumers (CB-RA, CM, CR), supplied by the main circuit, comprise at lest one of:

- Command means (CM) including camshaft bearings (CB) and rocker arms (RA), and switching means (SM) for vary cylinder valve timing actuation,
- eventually idler gears
- air compressor bearings
- turbocharger bearings
- gears
- PTO (Power Take Off).

6. System according to any of the previous claims, wherein said auxiliary oil circuit is a filter-less type.

7. System according to any of the previous claims, wherein said auxiliary pump (AP) is provided with bypass means connecting a pump inlet with a pump outlet through a controllable auxiliary valve (ACV), so as the pump control is handled through said controllable auxiliary valve (ACV).

8. System according to any of previous claims, wherein said auxiliary circuit comprises an auxiliary pressure sensor (AP) arranged between on outlet of the auxiliary pump and said at least one piston nozzle(s) (NZ), and wherein said auxiliary pump is controlled on the basis of a pressure signal of said auxiliary pressure sensor and/or on the engine speed/load.

9. System according to claim 8, wherein the oil fed by the auxiliary pump is proportional to a power delivered by the respective combustion engine, while the oil fed by main pump is proportional to the engine speed.

10. System according to any of previous claims, further comprising diverting means to divert the oil from the auxiliary pump to the main circuit in order to quickly increase the pressure of the main circuit according to a second operating condition or pressurize the main circuit according to a third operating condition.

11. System according to claim 10, further comprising control means configured to activate said diverting means according to said second operating condition defined when switching means (SM) are activated in order to vary cylinder valve timing and/or engine braking.

12. System according to claim 10 or 11, wherein said third operating condition is defined when the ignition is on AND before the internal combustion engine cranking and wherein said control means are configured to deactivate said diverting means after combustion engine cranking.

13. System according to any of the previous claims, wherein said at least one piston nozzle(s) (NZ) and said auxiliary pump are sized and controlled in order to produce a laminar oil jet.

14. System according to claim 13, wherein said laminar jet hit said inlet (IP) of the piston inner cooling passage (C) alternately, only when the piston is in a proximal position with respect to the at least one piston nozzle.

15. Terrestrial vehicle provided with the combustion engine of any of previous claims from 1 to 14.

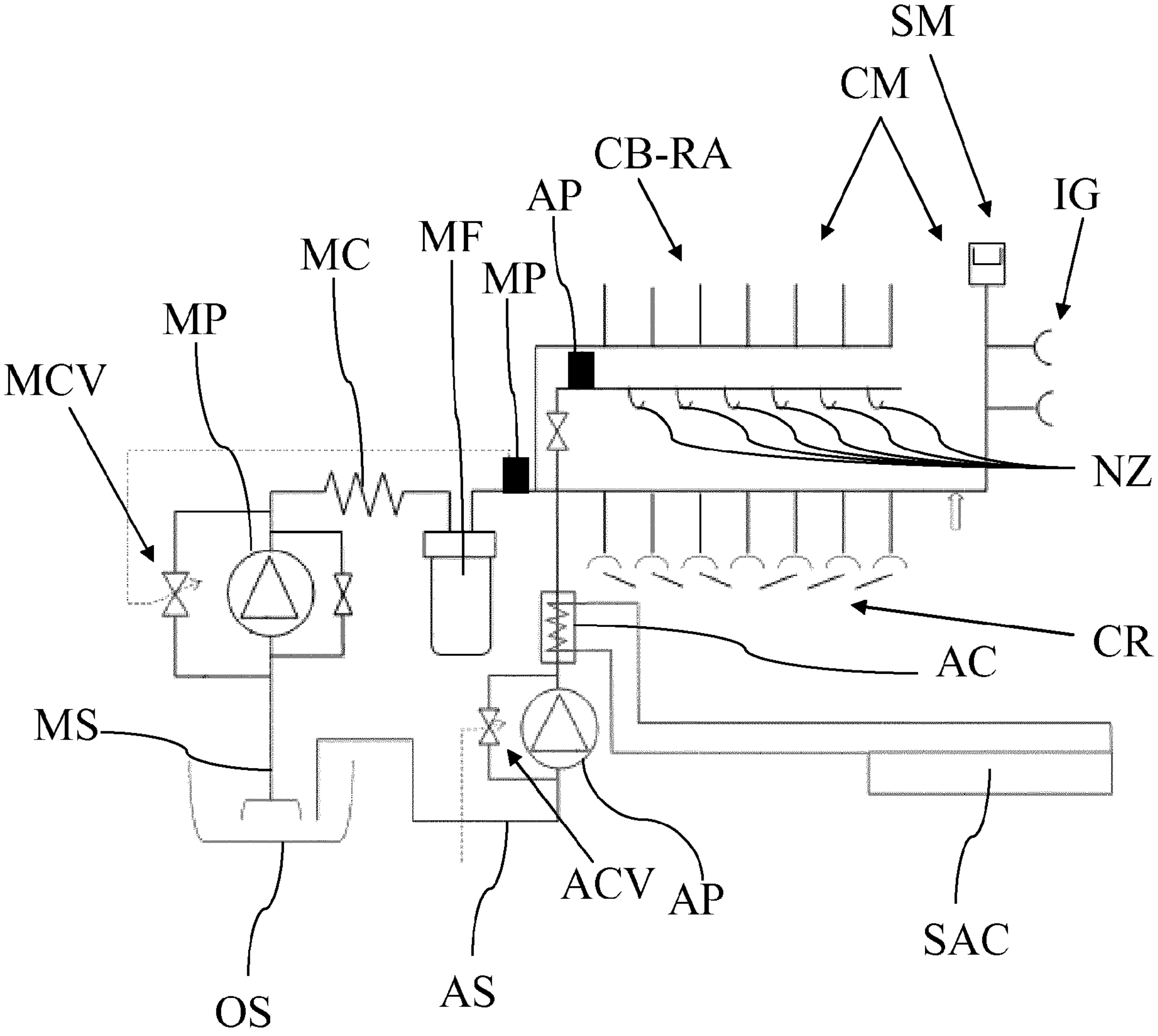
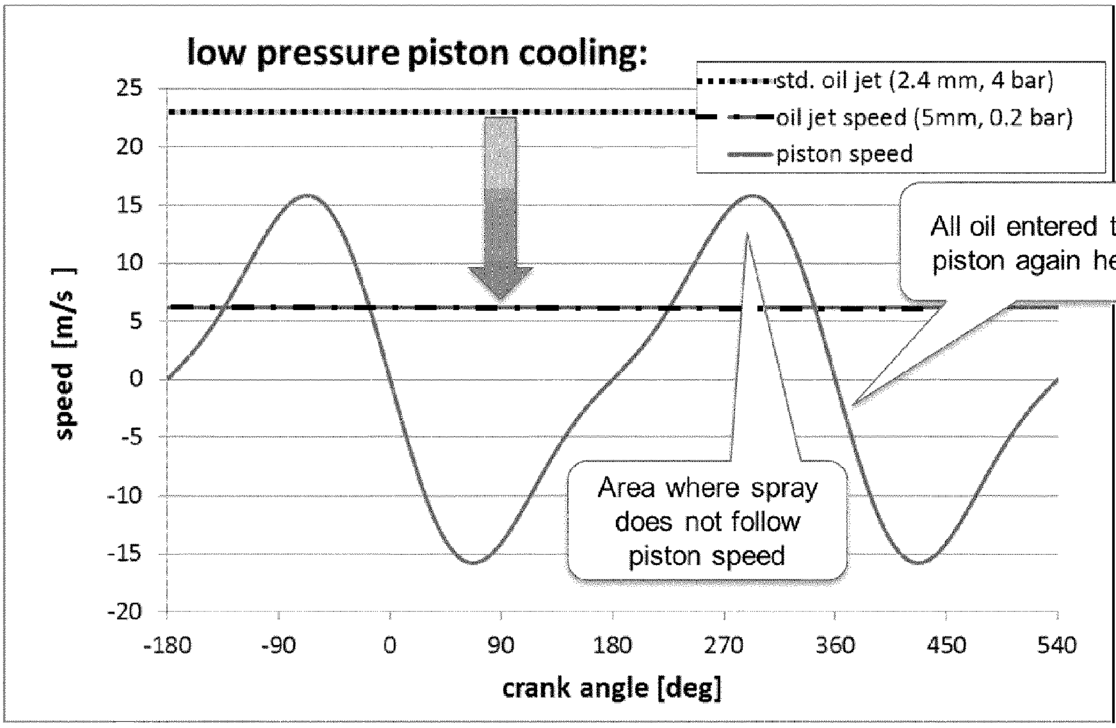


Fig. 1



low pressure piston cooling:
std. oil jet (2.4 mm, 4 bar)
oil jet speed (5mm, 0.2 bar)
piston speed
All oil entered the piston again here
Area where spray does not follow piston speed
speed [m/s]
25
20
15
10
5
0
-5
-10
-15
-20
-180
-90
0
90
180
270
360
450
540
crank angle [deg]

Fig. 2

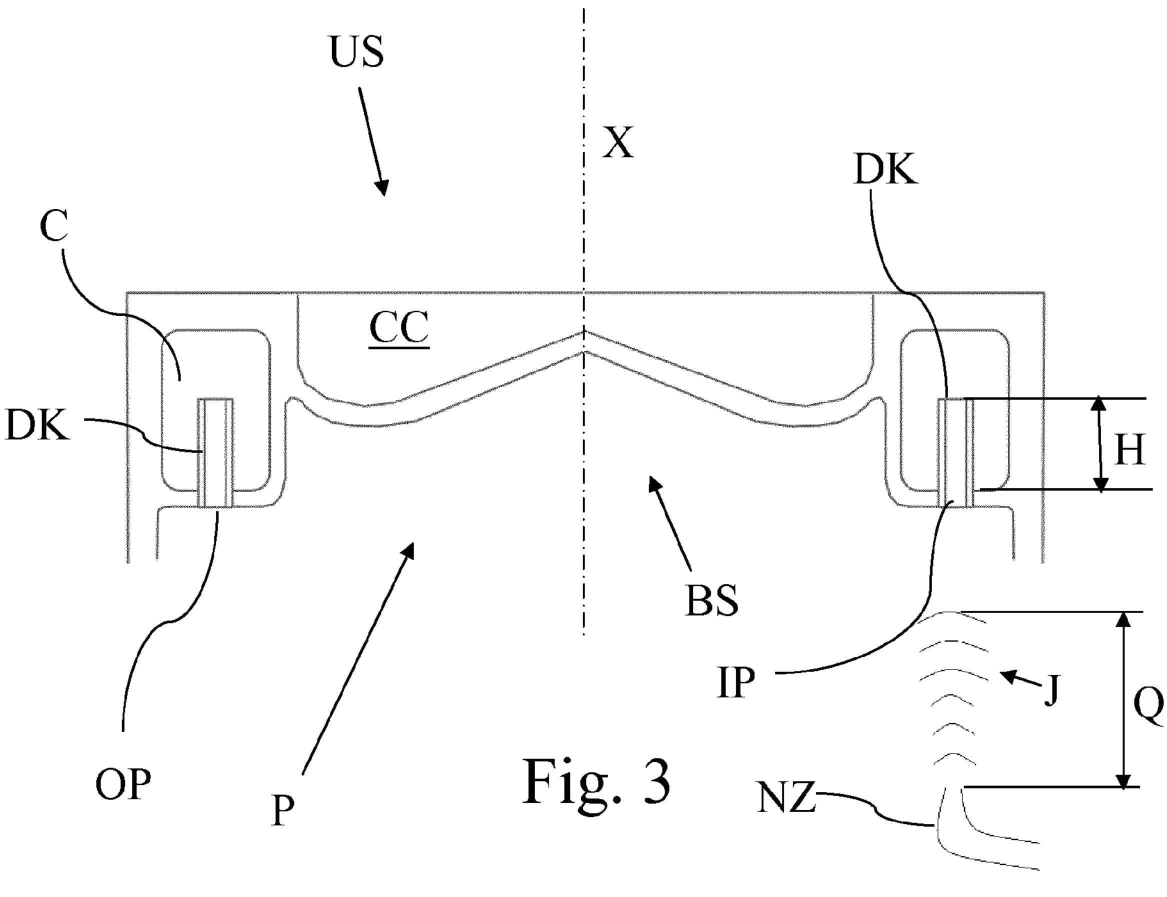


Fig. 3

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EUROPEAN SEARCH REPORT

Application Number
EP 16 19 1620

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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A	DE 103 22 304 A1 (DAIMLER CHRYSLER AG [DE]) 2 December 2004 (2004-12-02) * figure 1 * -----	1-15	TECHNICAL FIELDS SEARCHED (IPC) F01P F01M F02F

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	19 January 2017	Schwaller, Vincent

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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