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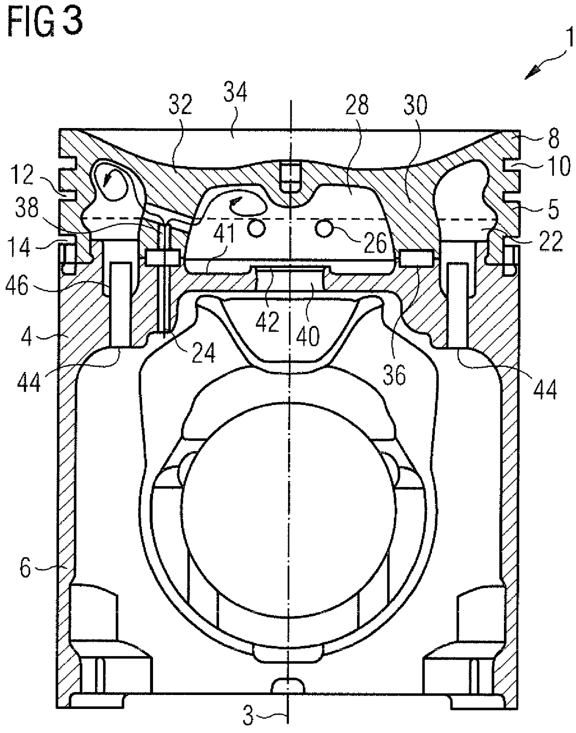
(54) PISTON WITH COOLING ARRANGEMENT

(57) A piston (1) for an engine (100) comprises a cooling arrangement that allows for an increased cooling efficiency of an outer peripheral wall (5) of a piston body (4) including a plurality of piston ring grooves (10, 12, 14). Lubricant is supplied to an outer plenum (22) formed adjacent to outer peripheral wall (5) via a cooling passage (26) that extends at an upwardly-inclined angle from a central plenum (28) towards the outer plenum (22). Lubricant that enters cooling passage (26) is imparted with a corresponding flow velocity component due to the upwardly-inclined orientation of cooling passage (26) prior to entering outer plenum (22) to flow along an inner surface of the same. A heat transfer between the lubricant and the inner surface of the outer plenum (22) is increased due to the resulting flow of lubricant.

FIG 3



EP 3 301 284 A1

Description

Technical Field

[0001] The present disclosure generally relates to a piston for an engine, in particular, to a piston with a cooling arrangement for cooling the same during operation of the engine.

Background

[0002] Generally, pistons of engines are configured to reciprocate within a cylinder liner of a cylinder. Lubricant between an inner circumference of the cylinder liner and an outer circumference (also referred to as piston skirt) of the piston facilitates lubrication and cooling of the piston and the cylinder liner during operation of the engine.

[0003] For example, US 4,577,595 discloses a piston for a reciprocating piston internal combustion engine including an annular cooling oil space which is supplied with cooling oil by way of an oil collecting device. The cooling oil can flow off toward a piston center by way of bores.

[0004] The present disclosure is directed, at least in part, to improving or overcoming one or more aspects of prior systems.

Summary of the Disclosure

[0005] According to an aspect of the present disclosure, a piston for an engine comprises a piston body having a longitudinal axis. At least one piston ring groove is formed in an outer peripheral wall of the piston body. An outer plenum is formed inside the piston body adjacent to the outer peripheral wall at a position corresponding to the at least one piston ring groove. A cooling inlet is configured to receive lubricant for cooling the piston body. At least one cooling passage is configured to receive lubricant supplied from the cooling inlet and supply the received lubricant to the outer plenum. The at least one cooling passage extends towards the outer peripheral wall at an upwardly-inclined angle with respect to the longitudinal axis and opens into the outer plenum.

[0006] According to another aspect of the present disclosure, an engine comprises at least one cylinder and an at least one piston as exemplarily disclosed herein, the piston being adapted to reciprocate within the at least one cylinder.

[0007] Other features and aspects of this disclosure will be apparent from the following description and the accompanying drawings.

Brief Description of the Drawings

[0008]

Fig. 1 is a schematic cross-sectional view of an exemplary engine;

Fig. 2 is a schematic drawing of an exemplary piston; and

Fig. 3 is cross-sectional view of a piston in accordance with the present disclosure.

Detailed Description

[0009] The following is a detailed description of exemplary embodiments of the present disclosure. The exemplary embodiments described herein and illustrated in the drawings are intended to teach the principles of the present disclosure, enabling those of ordinary skill in the art to implement and use the present disclosure in many different environments and for many different applications. Therefore, the exemplary embodiments are not intended to be, and should not be considered as, a limiting description of the scope of patent protection. Rather, the scope of patent protection shall be defined by the appended claims.

[0010] The present disclosure may be based in part on the realization that cooling of the piston and the piston rings is crucial in terms of robust engine operation. In particular, the region adjacent to an uppermost piston ring has to be maintained below a certain temperature level. Otherwise, coke from decomposing lube oil may form and accumulate in the crevices between the piston ring and the piston, eventually causing immobility of the ring and subsequent damage to the piston and the cylinder liner.

[0011] In particular, the present disclosure may be based at least in part on the realization that, when lube oil is supplied to a set of plenums and ducts inside a piston to transfer heat from critical regions to the lube oil, the lube oil will accumulate at the top of the plenums or ducts when the piston is moving downward. During this time, while the lube oil will be in contact with those regions of the piston that are important with respect to cooling, it has been recognized that the heat transfer from the piston to the lube oil is dependent on the lube oil motion on the surface to be cooled. In other words, when the lube oil flows along the surface to be cooled, more energy per unit area and unit time can be transferred compared to a non-flowing lube oil. Therefore, it has been realized that it is preferred to perform cooling by forced convection of the lube oil such that the lube oil flows along the surfaces to be cooled for enhanced cooling.

[0012] In this respect, the present disclosure is based at least in part on the realization that a continuous lube oil flow adjacent to the critical regions to be cooled can be obtained by utilizing an oil distribution passage that distributes oil to a plurality of transfer passages that are equally spread out along the circumference of the piston. A forced convection of the lube oil is achieved by an orientation of the transfer passages according to which the transfer passages provide the lube oil to an outer plenum of the piston under a slight angle, i.e., the transfer passages are upwardly-inclined with respect to the longitudinal axis of the piston. As a result, a continuous flow of lube oil, in particular, in the outer plenum, is obtained to provide enhanced cooling due to an improved heat transfer at the surfaces to be cooled.

[0013] The present disclosure may further be based on the realization that it may be advantageous to maintain a minimum lube oil level in the piston at all times. This provides an improved initial cooling due to oil remaining in the piston splashing against the upper region of the plenum when the piston is decelerating upon reaching the top dead center. It has been realized that this may be achieved by providing raised outlet passages at the bottom of the plenum, such that part of the lube oil in the plenum is prevented from leaving the plenum during the upward motion of the piston.

[0014] Further, the present disclosure may be based on the realization that cooling of the piston top may be adjusted in an appropriate manner by optimizing the lube oil distribution system, e.g., the volume of the distribution passage, the cross-sectional area of the same, the orientation and position of the transfer passages, and the like. Further, it has been realized that the volume of lube oil that is held in the distribution passage can be adjusted by providing raised inlets that are disposed above the lowest surface of the distribution passage. Accordingly, part of the lube oil will remain in the distribution passage as the piston moves upward.

[0015] In addition, the present disclosure may be based at least in part on the realization that it may be advantageous to increase the flow velocity of the lube oil in the distribution passage away from the position of the inlet to achieve a substantially constant mass flow along the circumference of the distribution passage such that each transfer passage receives substantially the same amount of lube oil during operation of the engine.

[0016] It is noted that a piston as exemplarily disclosed herein may be used in internal combustion engines, compressors, pumps and other machines comprising a piston with at least one piston ring groove and a piston ring (hereinafter referred to generally as engines). For the purposes of illustration, an exemplary piston is described in connection with an internal combustion engine in the following.

[0017] Referring to FIG. 1, an exemplary engine 100 includes an engine block 101 that at least partially defines a plurality of cylinders 102, a piston 1 slidably disposed within each cylinder 102, and a cylinder head 104 associated with each cylinder 102. Engine 100 further includes a plurality of inlet valves 106 and exhaust valves 108 associated with the plurality of cylinders 102, as well as an actuating mechanism 112 connected to, e.g., a cam shaft 114 of engine 100. Engine 100 may include features not shown, such as fuel systems, air systems, cooling systems, peripheries, drivetrain components, etc. Furthermore, engine 100 may be of any size, with any number of cylinders, and in any configuration ("V", in-line, radial, etc.). Engine 100 may be used to power any machine or other device, including locomotive applications, on-highway trucks or vehicles, off-highway trucks or machines, earth moving equipment, generators, aerospace applications, marine applications, pumps, stationary equipment, or other engine-powered applications, and run on any type of fuel, including gaseous fuel, gasoline, diesel, heavy fuel oil, etc.

[0018] Referring to Fig. 2, an exemplary piston 1 in a cylinder liner 2 of cylinder 102 is shown. Piston 1 and cylinder liner 2 may be arranged within engine block 101 of engine 100.

[0019] Piston 1 comprises a central longitudinal axis 3. Furthermore, piston 1 comprises a piston body 4 with a piston skirt 6, a piston top 8, and a plurality of piston rings. Piston 1 is connected via a piston rod 9 to a crankshaft (not shown) of the internal combustion engine, and is adapted to reciprocate in cylinder liner 2 during operation of the internal combustion engine.

[0020] Piston top 8 defines a combustion chamber 11 together with cylinder liner 2 and a cylinder head (not shown).

[0021] Piston skirt 6 defines an outer circumference of piston body 4. A plurality of piston ring grooves extends circumferentially around piston body 4 in piston skirt 6. Specifically, an upper piston ring groove 10, an intermediate piston ring groove 12 and a lower piston ring groove 14 are arranged in piston skirt 6. The lower piston ring groove 14 is arranged farthest from piston top 8 compared to the other piston ring grooves. In other words, in this exemplary embodiment, lower piston ring groove 14 is the lowermost piston ring groove, and upper piston ring groove 10 is the uppermost piston ring groove.

[0022] Each of a plurality of piston rings is arranged in a corresponding piston ring groove. Specifically, a compression ring 16 is arranged in upper piston ring groove 10, an intermediate ring 18 is arranged in intermediate piston ring groove 12, and an oil scraper ring 20 is arranged in lower piston ring groove 14.

[0023] Piston 1 further comprises a cooling arrangement configured to cool piston 1, in particular, piston top 8 and the region adjacent to piston ring grooves 10, 12, 14, which will be described in more detail below with reference to Fig. 3.

[0024] In some embodiments, a piston may comprise a different number of piston ring grooves and corresponding piston rings than shown in Figs. 1 and 2.

[0025] In some embodiments, an engine may comprise at least one cylinder, each cylinder having a piston as exemplarily disclosed herein. Each piston may be adapted to reciprocate within a corresponding cylinder.

[0026] Turning to Fig. 3, a cross-sectional view of a piston with a cooling arrangement in accordance with the present disclosure is shown.

[0027] As shown in Fig. 3, piston 1 includes an arrangement of passages and plenums within the same to circulate a lubricant such as lube oil during the reciprocating movement of piston 1 in the associated cylinder. As used herein, the term "plenum" refers to chambers or cavities (spaces) formed in piston body 4, to which lubricant is supplied to cool piston 1. In particular, an outer plenum

22 is formed inside piston body 4 adjacent to an outer peripheral wall 5 of piston skirt 6 at a position corresponding to piston ring grooves 10, 12, 14. Further, a central plenum 28 is formed at a center of piston body 4 and separated from outer plenum 22 by an annular partition wall 30. During downward movement of piston 1, lubricant accumulates in the upper region of plenums 22, 28 to cool the adjacent regions of piston 1, in particular, the regions adjacent to piston ring grooves 10, 12, 14 and a bottom 32 of a piston bowl 34 formed in piston top 8, as shown by the dashed line in Fig. 3. In the embodiment, the configuration of plenums 22, 28 is symmetrical, i.e. central plenum 28 is symmetrical with respect to longitudinal axis 3, and outer plenum 22 is an annular space extending around longitudinal axis 3 in the circumferential direction. It will be readily appreciated that, in other embodiments, different configurations of plenums 22, 28 may be used without departing from the present teachings.

[0028] Piston 1 further comprises at least one cooling inlet (duct or passage) 24 configured to receive lubricant for cooling piston body 4. In the exemplary embodiment, cooling inlet 24 is a passage that is provided in annular partition wall 30 and extends along longitudinal axis 3, i.e., vertically. More precisely, an opening of cooling inlet 24 is provided in a lower surface of annular partition wall 30 and receives lubricant that is sprayed upwards from a cooling nozzle (not shown) disposed below piston 1 at a position that corresponds to cooling inlet 24. Although a single cooling inlet 24 is shown in Fig. 3, it will be appreciated that any appropriate number of cooling inlets 24 may be provided and arranged along the circumferential direction of piston 1, for example, with equal distances from each other. Likewise, a corresponding number of cooling nozzles, for example, two cooling nozzles for two cooling inlets, may be provided.

[0029] The lubricant entering cooling inlet 24 flows through the same and reaches a circumferentially extending lubricant distribution passage 36. In the present embodiment, lubricant distribution passage 36 is formed as an annular space or cavity within annular partition wall 30 that extends in the circumferential direction. Lubricant distribution passage 36 is configured to distribute the lubricant entering via the one or more cooling inlets 24 in the circumferential direction.

[0030] A plurality of cooling intermediate passages 38 are fluidly connected to lubricant distribution passage 36 and extend therefrom to a corresponding plurality of cooling passages 26 formed in annular partition wall 30 to fluidly connect central plenum 28 to outer plenum 22. In the exemplary embodiment, each cooling intermediate passage 38 extends along longitudinal axis 3, i.e., vertically, from lubricant distribution passage 36. As shown in Fig. 3, the plurality of cooling passages 26 and the associated cooling intermediate passages 38 are equidistantly arranged in the circumferential direction. It should be noted that, while it is shown in Fig. 3 that cooling intermediate passage 38 is aligned with cooling inlet 24 in the circumferential direction, in other embodiments, cooling intermediate passage(s) 38 may be arranged at a position that is different from that of cooling inlet(s) 24.

[0031] Lubricant that has been distributed by lubricant distribution passage 36 enters cooling passages 26 via cooling intermediate passage 38. Cooling passage 26 extends from central plenum 28 to outer plenum 22 at an upwardly-inclined angle of less than 90 degrees with respect to longitudinal axis 3, for example, an angle of between 0° and 45°, preferably between 15° and 30°, or an angle of between 45° and 90°, preferably between 60° and 75°. As a result, lubricant entering cooling passage 26 via cooling intermediate passage 38 is imparted with a flow velocity component directed along cooling passage 26 upon entering central plenum 28 and outer plenum 22. Accordingly, upon entering central plenum 28 and outer plenum 22, the lubricant flows along the inner surfaces of the same in a manner that is shown by the flow lines in Fig. 3.

[0032] In particular, lubricant entering outer plenum 22 flows upward and outward along the inner surface of outer plenum 22, resulting in an increased heat transfer between bottom 32 of piston bowl 34 and outer peripheral wall 5 and the lubricant in outer plenum 22. Further, due to the flow, hot lubricant is displaced by relatively cool lubricant entering from cooling passage 26 to further increase the cooling efficiency. It will be appreciated that the arrangement of cooling passage 26 shown in Fig. 3 is particularly advantageous for outer plenum 22, because it facilitates the flow of lubricant to outer plenum 22 as piston 1 is moving downward. Therefore, by arranging cooling passage 26 as shown in Fig. 3, cooling of the critical regions of piston 1, in particular, the region adjacent to piston ring grooves 10, 12, 14 can be increased.

[0033] It will be appreciated that the amount of cooling of the central portion of piston top 8 and the outer peripheral portion of the same can be adjusted by appropriately setting the angle of extension of cooling passage 26. Further, although it is shown in Fig. 3 that cooling passage 26 extends through annular partition wall 30 along a straight line, it will be appreciated that in other embodiments cooling passage 26 may have a different configuration. For example, cooling passage 26 may extend at an upwardly-inclined angle from the opening of cooling intermediate passage 38 towards outer plenum 22, and may extend at a different angle towards central plenum 28, for example, substantially horizontally, or also at an upwardly-inclined angle.

[0034] Lubricant that has entered plenums 28, 22 and flowed along the respective inner surfaces exits central plenum 28 and outer plenum 22 via respective lubricant outlets 40, 44. In particular, a central lubricant outlet 40 is formed at the center of a bottom 41 of central plenum 28 and includes a central opening 42 that is opened towards an inside of central plenum 28. Likewise, a peripheral lubricant outlet 44, more precisely, a plurality of peripheral lubricant outlets 44, are fluidly connected to outer plenum 22 for discharging the lubricant from outer plenum 22 towards a lower end of piston body 4. In the exemplary embodiment, each peripheral lubricant outlet 44 is configured as a tube-like member 46, for example, made of metal, that is inserted into a bore formed in piston body 4 to extend along longitudinal axis 3.

[0035] As shown in Fig. 3, peripheral lubricant outlet 44 projects into outer plenum 22 such that an inlet opening of the same is disposed above a lowest portion (bottom surface) of outer plenum 22. In this manner, when lubricant is discharged from outer plenum 22 during upward motion of piston 1, part of the lubricant stored in outer plenum 22 remains therein. Accordingly, as piston 1 is subsequently decelerated upon reaching top dead center, the remaining part of lubricant moves upwards and splashes against the inner surface of outer plenum 22 to provide additional cooling, even before new lubricant is supplied to outer plenum 22 during the downward movement of piston 1.

[0036] Although not shown in Fig. 3, a similar configuration can be used for central lubricant outlet 40. In other words, in some embodiments, central opening 42 of lubricant outlet 40 may be disposed above bottom 41 of central plenum 28.

[0037] Likewise, although not shown in Fig. 3, in some embodiments, cooling inlet 24 may have an outlet opening into lubricant distribution passage 36, said outlet being arranged above a lowest portion of lubricant distribution passage 36. In this manner, part of the lubricant in lubricant distribution passage 36 remains in the same during upward movement of piston 1, and may be supplied to cooling intermediate passages 38 and cooling passages 26 during the subsequent downward movement of piston 1.

[0038] It will be appreciated that, in case a plurality of cooling passages are arranged at different distances from the position of cooling inlet 24 in the circumferential direction, a velocity of lubricant towards cooling passages 26 decreases with increasing distance from cooling inlet 24 in case lubricant distribution passage 36 has a constant cross-section. Therefore, in order to assure that the velocity of the lubricant flowing through lubricant distribution passage 36 remains substantially constant, a cross-section of the same may be varied. In particular, the cross-section of lubricant distribution passage 36 may decrease away from cooling inlet 24. For example, a bottom of lubricant distribution passage 36 may be raised as lubricant distribution passage 36 extends away from cooling inlet 24. It will be readily appreciated that many different configurations can be used to achieve a substantially constant flow velocity of lubricant in lubricant distribution passage 36, depending on the number and positions of cooling inlet 24 and/or cooling passages 26. In addition or as an alternative, in other embodiments, lubricant distribution passage 36 may have a downward slope away from cooling inlet 24, which may result in an increasing cross-section of the same, to enhance oil flow to cooling passages 26 as piston 1 approaches top dead center.

<u>Industrial Applicability</u>

[0039] Hereinafter, functionality of the cooling arrangement of piston 1 is described with reference to Figs. 2 and 3.

[0040] During operation of the internal combustion engine, piston 1 reciprocates in cylinder liner 2. Specifically, piston 1 reciprocates between a top dead centre (TDC) and a bottom top centre (BDC) in cylinder liner 2. As known by those skilled in the art, a velocity of piston 1 is constantly changing during upstroke and downstroke. For example, piston 1 decelerates before arriving at TDC and BDC, respectively.

[0041] As piston 1 reciprocates in cylinder liner 2, lubricant is supplied to the same from a plurality of cooling nozzles ejecting lubricant into piston body 4. In particular, the position and the number of the cooling nozzles may correspond to the position and the number of cooling inlets 24 formed in piston body 4. Accordingly, as piston 1 moves downward within cylinder liner 2, lubricant enters cooling inlet 24. The lubricant then flows into lubricant distribution passage 36 to be distributed along the circumference of piston 1. Via the plurality of cooling intermediate passages 38, lubricant enters the plurality of cooling passages 26, which are equidistantly arranged in the circumferential direction. Due to cooling passages 26 extending at an upwardly-inclined angle towards upper plenum 22, a corresponding flow velocity component is imparted on the lubricant flowing into outer plenum 22. Therefore, lubricant entering outer plenum 22 flows along the inner surface of the same, as shown by the flow lines in Fig. 3, to efficiently cool piston top 8 due to the increased heat transfer. Likewise, lubricant enters central plenum 28 to cool the inner surface of the same.

[0042] After cooling, hot lubricant is discharged from plenums 22, 28 during upward movement of piston 1. At this time, however, due to the raised configuration of lubricant outlet 44, part of the lubricant remains in outer plenum 22 even during the upward movement. Accordingly, as piston 1 is decelerated upon reaching TDC, this remaining lubricant splashes against the inner surface of outer plenum 22 to further cool the same.

[0043] With the cooling arrangement disclosed herein, a cooling efficiency of critical regions of piston body 4, in particular, outer peripheral wall 5 comprising piston ring grooves 10, 12, 14, can be increased due to the increased heat transfer of the lubricant that is flowing along the inner surface of outer plenum 22.

[0044] Although the preferred embodiments of this invention have been described herein, improvements and modifications may be incorporated without departing from the scope of the following claims.

Claims

1. A piston (1) for an engine (100), the piston (1) comprising:

a piston body (4) having a longitudinal axis (3);
at least one piston ring groove (10, 12, 14) formed in an outer peripheral wall (5) of the piston body (4);
an outer plenum (22) formed inside the piston body (4) adjacent to the outer peripheral wall (5) at a position corresponding to the at least one piston ring groove (10, 12, 14);
a cooling inlet (24) configured to receive lubricant for cooling the piston body (4); and
at least one cooling passage (26) configured to receive lubricant supplied from the cooling inlet (24) and supply the received lubricant to the outer plenum (22),
wherein the at least one cooling passage (26) extends towards the outer peripheral wall (5) at an upwardly-inclined angle with respect to the longitudinal axis (3) and opens into the outer plenum (22).

2. The piston (1) of claim 1, further comprising a central plenum (28) formed at a center of the piston body (4), the central plenum (28) being separated from the outer plenum (22) by a partition wall (30), for example, an annular partition wall (3),
wherein the at least one cooling passage (26) is formed in the partition wall (30).

3. The piston (1) of claim 2, wherein the at least one cooling passage (26) is formed in the partition wall (30) and extends between the central plenum (28) and the outer plenum (22).

4. The piston (1) of claim 2 or 3, wherein the cooling inlet (24) is formed in the partition wall (30), preferably, as a passage that extends parallel to the longitudinal axis (3).

5. The piston (1) of any one of claims 2 to 4, further comprising a circumferentially extending lubricant distribution passage (36) fluidly connected to the cooling inlet (24), wherein the at least one cooling passage (26) is fluidly connected to the lubricant distribution passage (36) by at least one corresponding cooling intermediate passage (38) formed in the annular partition wall (30).

6. The piston (1) of claim 5, comprising a plurality of cooling passages (26) and a plurality of corresponding cooling intermediate passages (38), wherein the plurality of cooling passages (26) and the plurality of cooling intermediate passages (26) are equidistantly arranged in the circumferential direction.

7. The piston (1) of claim 5 or 6, wherein the cooling inlet (24) has an outlet opening into the lubricant distribution passage (36), said outlet being arranged above a lowest portion of the lubricant distribution passage (36).

8. The piston (1) of any one of claims 5 to 7, wherein the lubricant distribution passage (36) extends in the circumferential direction with varying cross-section, preferably with a cross-section that decreases away from the cooling inlet (24).

9. The piston (1) of any one of claims 2 to 8, wherein the central plenum (28) includes a lubricant outlet (40) formed at a center of a bottom (41) of the central plenum (28).

10. The piston (1) of claim 9, wherein the lubricant outlet (40) includes a central opening (42) that is disposed above the bottom (41).

11. The piston (1) of any one of claims 1 to 10, further comprising a peripheral lubricant outlet (44) fluidly connected to the outer plenum (22) for discharging lubricant from the outer plenum (22) towards a lower end of the piston body (4).

12. The piston (1) of claim 11, wherein the peripheral lubricant outlet (44) projects into the outer plenum (22) such that an inlet opening of the same is disposed above a lowest portion of the outer plenum (22).

13. The piston (1) of claim 12, wherein the peripheral lubricant outlet (44) is configured as a tube-like member (46), for example, made of metal, inserted into a bore formed in the piston body (4).

14. The piston (1) of any one of claims 1 to 13, wherein the at least one cooling passage (26) extends towards the outer peripheral wall (5) at an upwardly-inclined angle of less than 90 degrees, for example, between 0° and 45°, preferably between 15° and 30°, or between 45° and 90°, preferably between 60° and 75°, with respect to the longitudinal axis (3).

15. An engine (100) comprising:

at least one cylinder (102); and
at least one piston (1) according to any one of claims 1 to 14 adapted to reciprocate within the at least one cylinder (102).

FIG 1

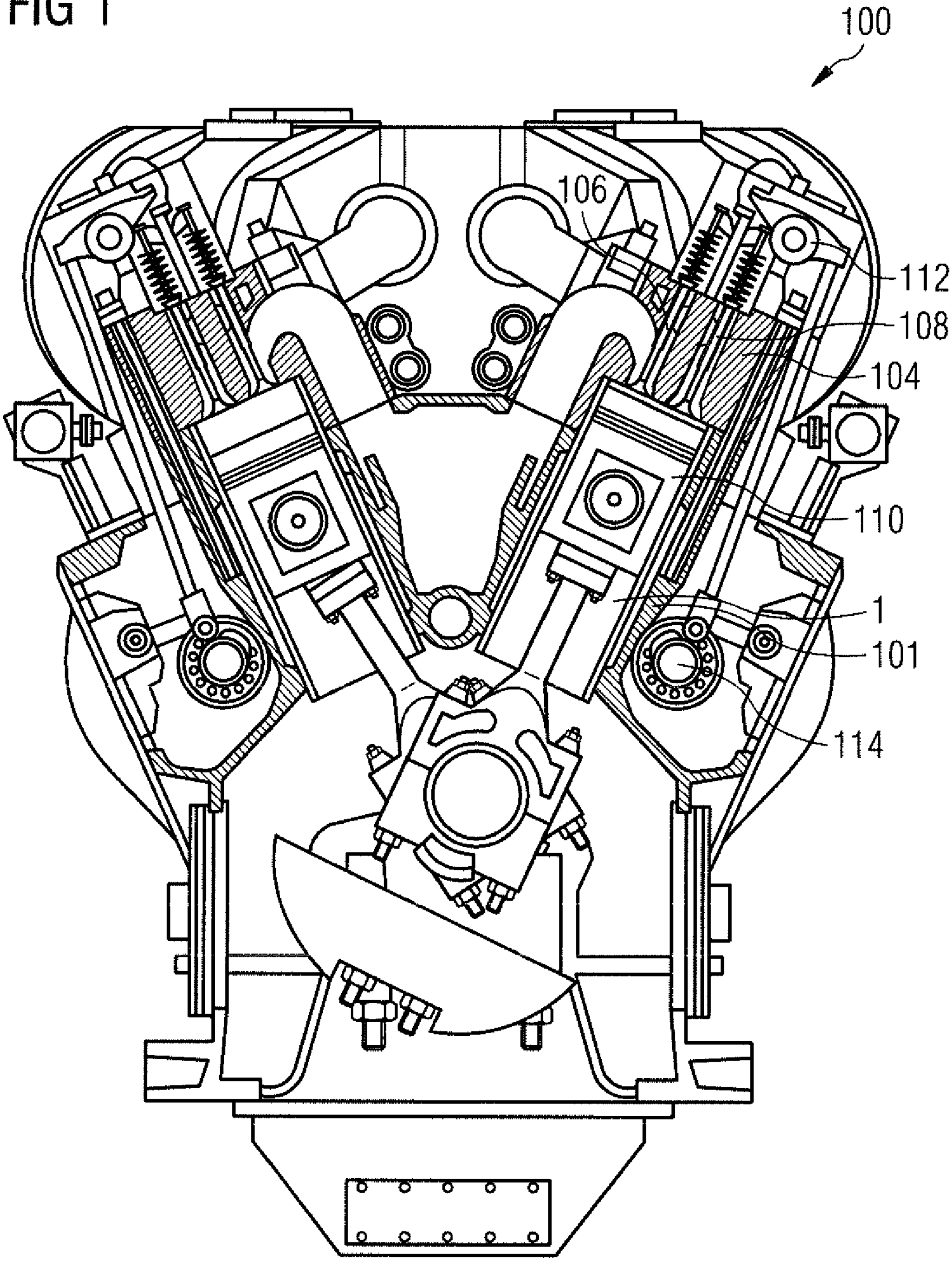


FIG 2

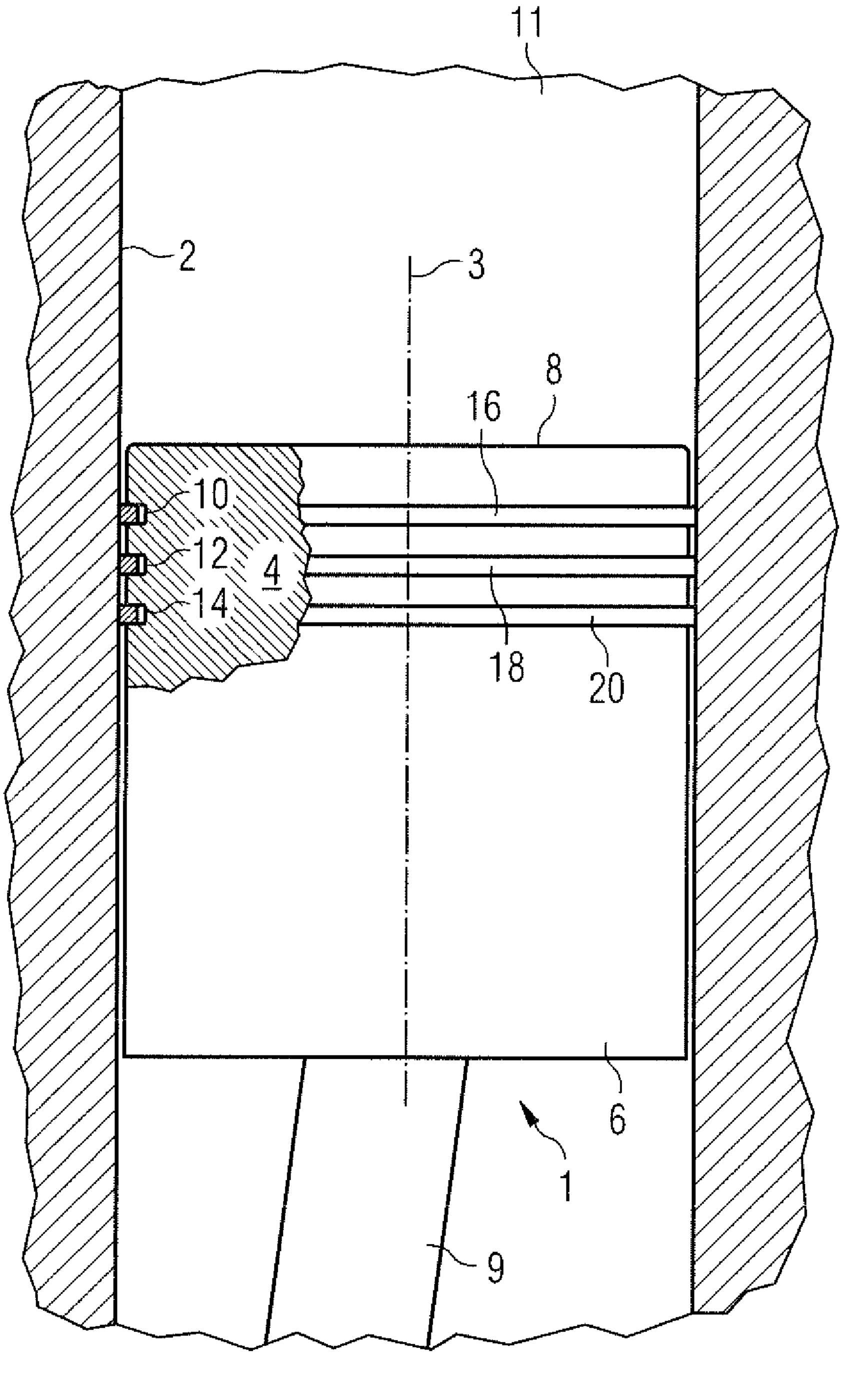
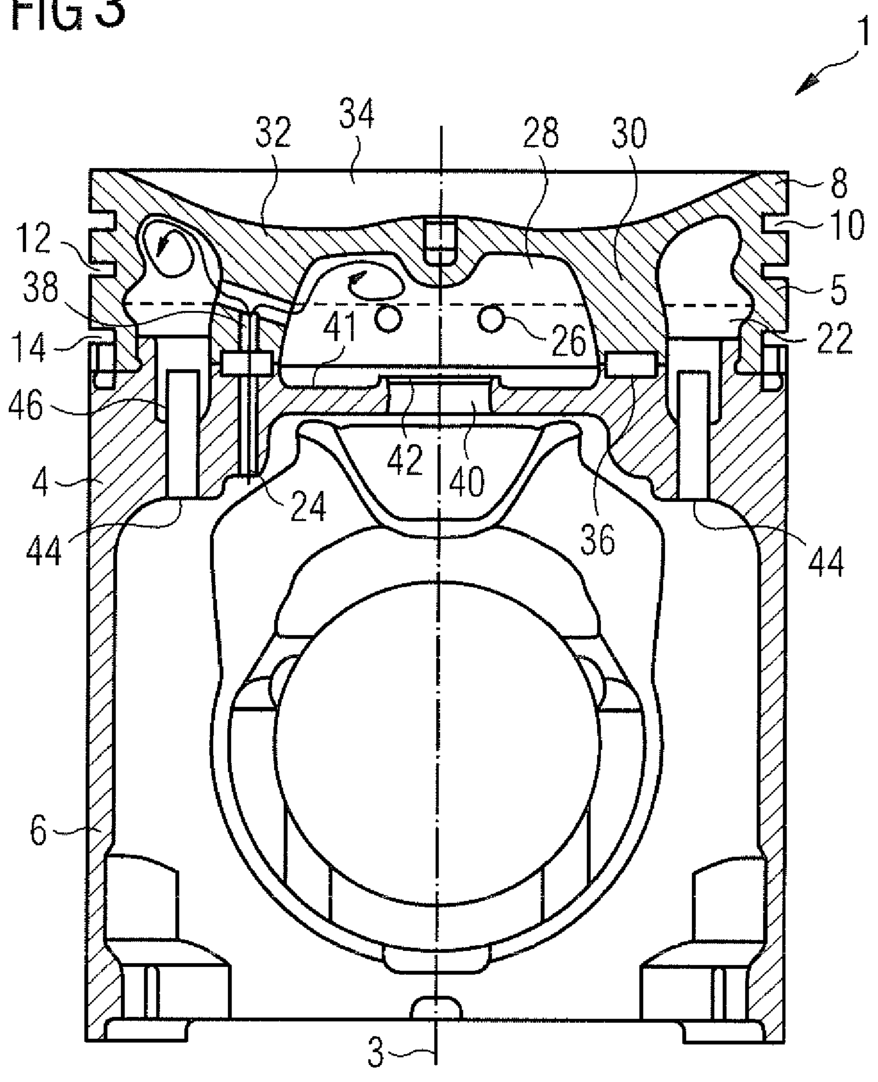


FIG 3



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EUROPEAN SEARCH REPORT

Application Number
EP 16 19 1417

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	9 March 2017	Matray, J

CATEGORY OF CITED DOCUMENTS

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Patent documents cited in the description

- US 4577595 A **[0003]**