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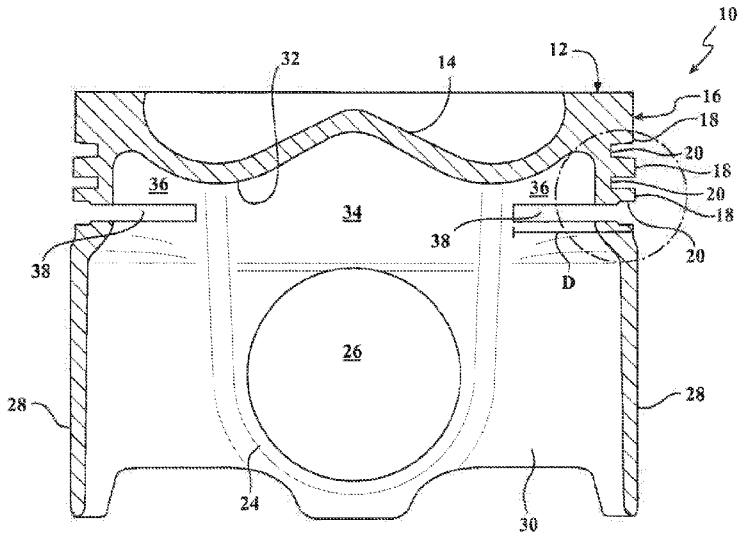

FIG. 4

(57) Abstract: A galleryless piston including a ring belt with three ring grooves is provided. Each ring groove is formed by an uppermost wall and a lower wall spaced from one another by a back wall. A pair of pin bosses depend from the upper wall and pair of skirt panels depend from the ring belt and are coupled to the pin bosses by struts, An inner undercrown region is surrounded by the skirt panels and the struts and the pin bosses. A pair of outer pockets extend along the undercrown surface, and each outer pocket is surrounded by a portion of the ring belt and one of the pin bosses and the struts coupling the one pin boss to the skirt panels. The third ring groove includes an oil drain slot extending through the back wall to the outer pockets of the piston for conveying cooling oil.

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GALLERYLESS PISTON WITH SLOTTED RING GROOVE

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This U.S. utility patent application claims priority to U.S. provisional patent application no. 62/302,396, filed March 2, 2016, and U.S. utility patent application no. 15/445,317, filed February 28, 2017, the content of which are incorporated herein by reference in their entirety.

BACKGROUND OF THE INVENTION

1. Technical Field

[0002] This invention relates generally to pistons for internal combustion engines, and methods of manufacturing the pistons.

2. Related Art

[0003] Engine manufacturers are encountering increasing demands to improve engine efficiencies and performance, including, but not limited to, improving fuel economy, reducing oil consumption, improving fuel systems, increasing compression loads and operating temperatures within the cylinder bores, reducing heat loss through the piston, improving lubrication of component parts, decreasing engine weight and making engines more compact, while at the same time decreasing the costs associated with manufacture.

[0004] While desirable to increase the compression load and operation temperature within the combustion chamber, it remains necessary to maintain the temperature of the piston within workable limits. Also, achieving an increase in the compression load and operation temperature comes with a tradeoff in that these desirable "increases" limit the degree to which the piston compression height, and thus, overall piston size and mass can be decreased. This is particularly troublesome with typical piston constructions having a closed or partially closed cooling gallery to reduce the operating temperature of the piston. The cost to manufacture pistons having upper and lower parts joined together along a bond joint to

form the closed or partially closed cooling gallery is generally increased due to the joining process used to bond the upper and lower parts together. Further, the degree to which the engine weight can be reduced is impacted by the need to make the aforementioned "cooling gallery" pistons from steel so they can withstand the increase in mechanical and thermal loads imposed on the piston.

[0005] Recently, single piece steel pistons without a cooling gallery have been developed and can be referred to as "galleryless" pistons. Such pistons provide for reduced weight, reduced manufacturing costs, and reduced compression height. The galleryless pistons are either spray cooled by a cooling oil nozzle, lightly sprayed for lubrication only, or are not sprayed with any oil. Due to the absence of the cooling gallery, such pistons typically experience higher temperatures than pistons with a conventional cooling gallery. High temperatures can cause oxidation or overheating of an upper combustion surface of the steel piston, which can then cause successive piston cracking and engine failures. High temperatures can also cause oil degradation along an undercrown area of the piston, for example underneath a combustion bowl where the cooling or lubrication oil is sprayed. Another potential problem arising due to high temperatures is that the cooling oil can create a thick layer of carbon in the area where the cooling or lubrication oil is in contact with the piston undercrown. This carbon layer can cause overheating of the piston with potential cracking and engine failure.

SUMMARY

[0006] One aspect of the invention provides a piston which can be galleryless, can provide a reduced weight, and can operate at a reduced temperature, which contributes to improved thermal efficiency, fuel consumption, and performance of an engine. The piston comprises an upper wall including an undercrown surface exposed from an underside of the piston, and a ring belt depending from the upper wall and extending circumferentially around

a center axis of the piston. The ring belt includes a plurality of ring grooves extending circumferentially around the center axis and each formed by an uppermost wall and a lower wall spaced from one another by a back wall. The piston further includes a pair of pin bosses depending from the upper wall, and pair of skirt panels depending from the ring belt and coupled to the pin bosses by struts. An inner undercrown region extends along the undercrown surface and is surrounded by the skirt panels and the struts and the pin bosses. A pair of outer pockets extend along the undercrown surface, and each outer pocket is surrounded by a portion of the ring belt and one of the pin bosses and the struts coupling the one pin boss to the skirt panels. One of the ring grooves including an oil drain slot extending through the back wall to at least one of the outer pockets of the piston for conveying cooling oil therethrough.

[0007] Another aspect of the invention provides a method of manufacturing a piston. The method includes providing a body including an upper wall, the upper wall including an undercrown surface exposed from an underside of the piston, a ring belt depending from the upper wall and extending circumferentially around a center axis of the piston, the ring belt including a plurality of ring grooves extending circumferentially around the center axis and each formed by an uppermost wall and a lower wall spaced from one another by a back wall, a pair of pin bosses depending from the upper wall, a pair of skirt panels depending from the ring belt and coupled to the pin bosses by struts, an inner undercrown region extending along the undercrown surface and surrounded by the skirt panels and the struts and the pin bosses, a pair of outer pockets extending along the undercrown surface, each outer pocket being surrounded by a portion of the ring belt and one of the pin bosses and the struts coupling the one pin boss to the skirt panels. The method further includes forming an oil drain slot extending through the back wall of one of the ring grooves to at least one of the outer pockets.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] These and other aspects, features and advantages of the invention will become more readily appreciated when considered in connection with the following detailed description and accompanying drawings, in which:

[0009] Figure 1 is a bottom view of a galleryless piston which can include an oil drain slot according to an example embodiment;

[00010] Figure 2 is a side view of a galleryless piston including an oil drain slot in a third ring groove according to an example embodiment;

[00011] Figure 3 is another side view of the galleryless piston of Figure 2;

[00012] Figure 4 is a side cross-sectional view of a galleryless piston including an oil drain slot in a third ring groove according to another example embodiment;

[00013] Figure 4A is an enlarged view of the ring belt of Figure 4; and

[00014] Figure 5 is another side cross-sectional view of the galleryless piston of Figure 4.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

[00015] Figures 1-5 illustrate views of a piston 10 constructed in accordance with example embodiments of the invention for reciprocating movement in a cylinder bore or chamber (not shown) of an internal combustion engine, such as a modern, compact, high performance vehicle engine, for example. The piston 10 has a reduced weight and operates at a reduced temperature, which contributes to improved thermal efficiency, fuel consumption, and performance of the engine.

[00016] As shown in the Figures, the piston 10 has a monolithic body formed from a single piece of metal material, such as steel. The monolithic body can be formed by machining, forging or casting, with possible finish machining performed thereafter, if desired, to complete construction. Accordingly, the piston 10 does not have a plurality of parts joined together, such as upper and lower parts joined to one another, which is

commonplace with pistons having enclosed or partially enclosed cooling galleries bounded or partially bounded by a cooling gallery floor. To the contrary, the piston 10 is "galleryless" in that it does not have a cooling gallery floor or other features bounding or partially bounding a cooling gallery. A bottom view of the galleryless piston 10 is shown in Figure 1, side views of the galleryless piston according to another embodiment are shown in Figures 2 and 3; and cross-sectional views of the galleryless piston according to yet another embodiment are shown in Figures 4 and 5.

[00017] The body portion, being made of steel or another metal, is strong and durable to meet the high performance demands, i.e. increased temperature and compression loads, of modern day high performance internal combustion engines. The steel material used to construct the body can be an alloy such as the SAE 4140 grade or different, depending on the requirements of the piston 10 in the particular engine application. Due to the piston 10 being galleryless, the weight and compression height of the piston 10 is minimized, thereby allowing an engine in which the piston 10 is deployed to achieve a reduced weight and to be made more compact. Further yet, even though the piston 10 is galleryless, the piston 10 can be sufficiently cooled during use to withstand the most severe operating temperatures.

[00018] The body portion of the piston 10 has an upper head or top section providing an upper wall 12. The upper wall 12 includes an upper combustion surface 14 that is directly exposed to combustion gasses within the cylinder bore of the internal combustion engine. In the example embodiment, the upper combustion surface 14 forms a combustion bowl, or a non-planar, concave, or undulating surface around a center axis A.

[00019] A ring belt 16 depends from the upper wall 12 and extends around a circumference and along an outer diameter of the piston 10. The ring belt 16 includes a plurality of lands 18 separated from one another by ring grooves 20a, 20b, 20c. In the example embodiment, the piston 10 includes only three of the ring grooves 20a, 20b, 20c,

including a first ring groove 20a, a second ring groove 20b, and a third ring groove 20c. Of all of the ring grooves 20a, 20b, 20c, the first ring groove 20a is disposed closest to the upper combustion surface 14 and the third ring groove is disposed farthest from the upper combustion surface.

[00020] As best shown in Figure 4A, each ring groove 20a, 20b, 20c is formed between an uppermost wall 21 and a lower wall 23 spaced from one another by a back wall 25. The back wall 25 extends generally parallel to or longitudinally along the center axis A of the piston 10, and the uppermost and lower walls 21, 23 extend perpendicular or at an angle relative to the center axis A. The ring grooves 20a, 20b, 20c can have various different dimensions, but in the example embodiments, the back wall 25 of each ring groove 20a, 20b, 20c has a length l extending from the uppermost wall 21 to the lower wall 23 and parallel to the center axis A of the piston 10, and the back wall 25 of each ring groove 20a, 20b, 20c is located a distance d extending radially from the adjacent lands 18. The length and distance of the back walls 25 from the adjacent lands 18 of the piston 10 is typically constant around the entire circumference of the piston 10. The piston 10 of the example embodiments includes three ring grooves 20a, 20b, 20c, but the piston 10 could alternatively include another number of ring grooves 20a, 20b, 20c.

[00021] The piston 10 further includes a pair of pin bosses 24 depending generally from an undercrown surface 32, inwardly of the ring belt 16. The pin bosses 24 and providing a pair of spaced pin bores 26 which are longitudinally spaced from the undercrown surface 32. The piston 10 also includes a pair of skirt panels 28 depending from the ring belt 16 and located diametrically opposite one another. The skirt panels 28 are coupled to the pin bosses 24 by struts 30.

[00022] The undercrown surface 32 of the piston 10 is formed on an underside of the upper wall 12, directly opposite the upper combustion surface 14 and radially inwardly of the

ring belt 16. The undercrown surface 32 is preferably located at a minimum distance from the combustion bowl and is substantially the surface on the direct opposite side from the combustion bowl. The undercrown surface 32 is defined here to be the surface that is visible, excluding any pin bores 26, when observing the piston 10 straight on from the bottom. The undercrown surface 32 is generally form fitting to the combustion bowl of the upper combustion surface 14. The undercrown surface 32 is also openly exposed, as viewed from an underside of the piston 10, and it is not bounded by an enclosed or partially enclosed cooling gallery, or any other features tending to retain oil or a cooling fluid near the undercrown surface 32.

[00023] The undercrown surface 32 of the piston 10 has greater a total surface area (3-dimensional area following the contour of the surface) and a greater projected surface area (2-dimensional area, planar, as seen in plan view) than comparative pistons having a closed or partially closed cooling gallery. This open region along the underside of the piston 10 provides direct access to oil splashing or being sprayed from within the crankcase directly onto the undercrown surface 32, thereby allowing the entire undercrown surface 32 to be splashed directly by oil from within the crankcase, while also allowing the oil to freely splash about the wrist pin (not shown), and further, significantly reduce the weight of the piston 10. Accordingly, although not having a typical closed or partially closed cooling gallery, the generally open configuration of the galleryless piston 10 allows optimal cooling of the undercrown surface 32 and lubrication to the wrist pin joint within the pin bores 26, while at the same time reducing oil residence time on the surfaces near the combustion bowl, which is the time in which a volume of oil remains on the surface. The reduced residence time can reduce unwanted build-up of coked oil, such as can occur in pistons having a closed or substantially closed cooling gallery. As such, the piston 10 can remain "clean" over extended use, thereby allowing it to remain substantially free of build-up.

[00024] The undercrown surface 32 of the piston 10 of the example embodiment is provided by several regions of the piston 10, including an inner undercrown region 34 and outer pockets 36, which are best shown in Figure 1. A first portion of the undercrown surface 32 located at the center axis A is provided by the inner undercrown region 34. The inner undercrown region 34 is surrounded by the pin bosses 24, skirt panels 28, and struts 30. The 2-dimensinional and 3-dimensional surface area of the undercrown surface 32 provided by the inner undercrown region 34 is typically maximized so that cooling caused by oil splashing or being sprayed upwardly from the crankcase against the exposed surface can be enhanced, thereby lending to exceptional cooling of the piston 10. In the example embodiments, the undercrown surface 32 of the inner undercrown region 34 is concave, when viewed from the bottom, such that oil can be channeled during reciprocation of the piston 10 from one side of the piston 10 to the opposite side of the piston 10, thereby acting to further enhance cooling of the piston 10.

[00025] A second region of the undercrown surface 32 is provided by the outer pockets 36 which are located outwardly of the pin bosses 24. Each outer pocket 36 is surrounded by a portion of the ring belt 16, one of the pin bosses 24, and the struts 30 coupling the one pin boss 24 to the adjacent skirt panels 28.

[00026] To improve cooling of the outer pockets 36 and thus the overall temperature of the piston 10 during operation, an oil drain slot 38 extends through the back wall 25 of one of the ring grooves 20a, 20b, 20c, as shown in Figures 2-5. The oil drain slot 38 is typically cut into the ring groove 20a, 20b, 20c around the entire circumference of the piston 10, for example by a machining process. In the example embodiments, the oil drain slot 38 is formed in the third ring groove 20c located third from the top of the piston 10. Alternatively, the oil drain slot 38 could be formed in another one of the ring grooves 20a or 20b. The oil drain slot 38 has a length L extending longitudinally between the uppermost wall 21 and the lower wall 23

of the ring groove 20a, 20b, 20c, and the oil drain slot 38 typically has a length L ranging from 40 to 100% of the length l (i.e. axial width or vertical height) of the back wall 25 of the ring groove 20a, 20b, 20c it is draining. In the example embodiments, the length L and the distance D of the oil drain slot 38 is constant around the entire circumference of the piston 10. However, the dimensions of the oil drain slot 38 can vary.

[00027] The oil drain slot 38 extends continuously in the radial direction from the adjacent lands 18 of the ring belt 16 to at least one of the outer pockets 36 along a portion or portions of the circumference of the piston 10. The oil drain slot 38 also extends continuously from the adjacent lands 18 of the ring belt 16 to the inner undercrown region 34 along at least one portion of the circumference of the piston 10. Thus, the oil drain slot 38 provides an opening to the outer pockets 36 and to the inner undercrown region 34, which allows oil to drain away from the ring grooves 20a, 20b, 20c, and from the oil drain slot 38 to the outer pockets 36.

[00028] However, the oil drain slot 38 does not extend to the outer pockets 36 and inner undercrown region 34 around the entire circumference of the piston 10. The oil drain slot 38 extends from the adjacent lands 18 and the third ring groove 20c to the pin bosses 24, or to the struts 30 located between the pin bosses 24 and skirt panels 28, along portions of the circumference of the piston 10. In the example embodiments, the oil drain slot 38 extends radially from the third ring groove 20c to the inner undercrown region 34 along a portion of the circumference of the piston 10, extends radially from the third ring groove 20c to opposite sides of each one of the pin bosses 24 and engages opposite sides of each pin boss 24. Thus in the example embodiment, the lower wall 23 of the third ring groove 20c with the oil drain slot 38 is connected to the uppermost wall 21 of the third ring groove 20 and the remainder of the ring belt 16 by the back wall 25 at only four locations around the circumference of the piston 10.

[00029] The piston 10 designed according to the present invention is able to achieve improved cooling of the outer pockets 36, compared to galleryless pistons without the oil drain slot 38 in the ring belt 16, by allowing for an increase in drainage of oil away from the ring grooves 20a, 20b, 20c and into the outer pockets 36.

[00030] The galleryless steel piston 10 also has a reduced mass and reduced temperature during operation in an internal combustion engine, which contributes to improved thermal efficiency, fuel consumption, and performance of the engine. Since the piston 10 is free of a closed cooling gallery along the undercrown surface 32, the piston 10 thus has a reduced weight and related costs, relative to pistons including a closed cooling gallery. The combination of the galleryless design and the steel material allows the oil drain slot 38 to be larger than oil drainage features used in comparative pistons, which leads to improve oil drainage compared to other piston designs. Further, the additional cooling oil provided to the outer pockets 36 assists in cooling of the outer pockets 36 and thus reduces the overall temperature of the piston 10.

[00031] Another aspect of the invention provides a method of manufacturing the galleryless piston 10 for use in the internal combustion engine. The body portion of the piston 10, which is typically formed of steel, can be manufactured according to various different methods, such as forging or casting. The body portion of the galleryless piston 10 can also comprise various different designs, and examples of the possible designs are shown in Figures 1-5.

[00032] The method further includes providing the oil drain slot 38 in the ring belt 16 of the piston 10 which extends through the back wall 25 of one of the ring grooves 20a, 20b, 20c. The oil drain slot 38 can be formed by machining or cutting into the ring belt 16 after forging or casting the monolithic body portion of the piston 10. However, the oil drain slot 38 could be formed by other methods.

[00033] Many modifications and variations of the present invention are possible in light of the above teachings and may be practiced otherwise than as specifically described while within the scope of the following claims. It is contemplated that all features of all claims and of all embodiments can be combined with each other, so long as such combinations would not contradict one another.

CLAIMS

1. A piston, comprising:

an upper wall including an undercrown surface exposed from an underside of said piston,

a ring belt depending from said upper wall and extending circumferentially around a center axis of said piston,

said ring belt including a plurality of ring grooves extending circumferentially around said center axis and each formed by an uppermost wall and a lower wall spaced from one another by a back wall;

a pair of pin bosses depending from said upper wall,

a pair of skirt panels depending from said ring belt and coupled to said pin bosses by struts,

an inner undercrown region extending along said undercrown surface and surrounded by said skirt panels and said struts and said pin bosses,

a pair of outer pockets extending along said undercrown surface,

each outer pocket being surrounded by a portion of said ring belt and one of said pin bosses and said struts coupling said one pin boss to said skirt panels, and

one of said ring grooves including an oil drain slot extending through said back wall to at least one of said outer pockets of said piston.

2. The piston of claim 1, wherein said ring grooves of said ring belt include a first ring groove and a second ring groove and a third ring groove, said first ring groove and said second ring groove and said third ring groove are the only ring grooves present in said piston, and said third ring groove includes said oil drain slot.

3. The piston of claim 1, wherein said oil drain slot extends radially from said ring groove to said inner undercrown region along at least one portion of a circumference of said piston.

4. The piston of claim 1, wherein said oil drain slot extends radially to at least one of said pin bosses and/or at least one of said struts along at least one portion of a circumference of said piston.

5. The piston of claim 1, wherein said oil drain slot extends radially from said ring groove to opposite sides of each one of said pin bosses.

6. The piston of claim 1, wherein said lower wall of said ring groove including said oil drain slot is connected to said uppermost wall of said ring groove by said back wall at only four locations around a circumference of said piston.

7. The piston of claim 1, wherein said oil drain slot extends radially from said ring groove to both of said outer pockets along portions of a circumference of said piston, said oil drain slot extends radially from said ring groove to said inner undercrown region along portions of said circumference of said piston, said oil drain slot extends radially from said ring groove to opposite sides of each one of said pin bosses along portions of said circumference of said piston, and said lower wall of said ring groove including said oil drain slot is connected to said uppermost wall of said ring groove by said back wall at only four locations around said circumference of said piston.

8. The piston of claim 1, wherein said back wall of said ring groove including said oil drain slot has a length extending from said uppermost wall to said lower wall, said oil drain slot has a length extending between said uppermost wall and said lower wall, and said length of said oil drain slot ranges from 40% to 100% of said length of said back wall.

9. The piston of claim 1, wherein said back walls of said ring grooves extend parallel to said center axis of said piston, and said uppermost and lower walls of said ring grooves extend perpendicular or at an angle to said center axis of said piston.

10. The piston of claim 1, wherein said back wall of each one of said ring grooves has a length extending from said uppermost wall to said lowermost wall, said length of said back wall is constant around a circumference of said piston, said back wall of each one of said ring grooves is located a distance radially from adjacent lands of said ring belt, and said distance is constant around said circumference of said piston.

11. The piston of claim 1 including a body formed of a single piece of steel, said body including said upper wall, said ring belt, said pin bosses, and said skirt panels.

12. The piston of claim 1, wherein said undercrown surface is not bounded by an enclosed or partially enclosed cooling gallery or any other feature tending to retain fluid.

13. The piston of claim 1, wherein said inner undercrown region is located at said center axis and is surrounded by said pin bosses and said skirt panels and said struts, and said outer pockets are located outwardly of said pin bosses.

14. The piston of claim 1 including a body formed of a single piece of steel,

said body does not have a cooling gallery floor or other features bounding or partially bounding a cooling gallery,

said body includes said upper wall presenting an upper combustion surface,

said upper combustion surface is a non-planar surface around said center axis,

said ring belt extends around a circumference of said piston,

said ring belt includes a plurality of lands spacing said ring grooves from one another,

said pin bosses are disposed inwardly of said ring belt and provide a pair of laterally spaced pin bores surrounding a pin bore axis and spaced longitudinally from said undercrown surface,

said pair of skirt panels are located diametrically opposite one another,

said undercrown surface is disposed radially inwardly of said ring belt,

a first portion of said undercrown surface is provided by said inner undercrown region and a second portion of said undercrown surface is provided by said outer pockets,

said inner undercrown region is located at said center axis and is surrounded by said pin bosses and said skirt panels and said struts,

said undercrown surface located in said inner undercrown region is concave when viewed from said underside of said piston,

said outer pockets are located outwardly of said pin bosses,

said ring grooves include a first ring groove and a second ring groove and a third ring groove,

said first ring groove and said second ring groove and said third ring groove are the only ring grooves present in said piston,

said first ring groove is disposed closest to said upper combustion surface and said third ring groove is disposed farthest from said combustion surface,

said back walls of said ring grooves extend parallel and longitudinally along said center axis of said piston,

said uppermost and lower walls of said ring grooves extend perpendicular or at an angle to said center axis of said piston,

said back wall of each one of said ring grooves has a length extending from said uppermost wall to said lowermost wall and parallel to said center axis of said piston,

said length of each one of said back walls is constant around said circumference of said piston,

said back wall of each one of said ring grooves is located a distance radially from said adjacent lands,

said distance is constant around said circumference of said piston,

said third ring groove of said ring belt includes said oil drain slot extending through said back wall of said third ring groove to both of said outer pockets,

said oil drain slot has a length extending longitudinally between said uppermost wall and said lower wall of said third ring groove,

said length of said oil drain slot ranges from 40% to 100% of said length of said back wall of said third ring groove,

said oil drain slot extends radially from said third ring groove to said outer pockets along portions of said circumference of said piston,

said oil drain slot extends radially from said third ring groove to said inner undercrown region along portions of said circumference of said piston,

said oil drain slot extends radially from said third ring groove to opposite sides of each one of said pin bosses along portions of said circumference of said piston, and

15. A method of manufacturing a piston, comprising the steps of:

providing a body including an upper wall, the upper wall including an undercrown surface exposed from an underside of the piston, a ring belt depending from the upper wall and extending circumferentially around a center axis of the piston, the ring belt including a plurality of ring grooves extending circumferentially around the center axis and each formed by an uppermost wall and a lower wall spaced from one another by a back wall, a pair of pin bosses depending from the upper wall, a pair of skirt panels depending from the ring belt and coupled to the pin bosses by struts, an inner undercrown region extending along the undercrown surface and surrounded by the skirt panels and the struts and the pin bosses, a pair of outer pockets extending along the undercrown surface, each outer pocket being surrounded by a portion of the ring belt and one of the pin bosses and the struts coupling the one pin boss to the skirt panels, and

forming an oil drain slot extending through the back wall of one of the ring grooves to at least one of the outer pockets.

16. The method of claim 15, wherein the step of forming the oil drain slot includes machining or cutting into the ring belt.

17. The method of claim 15, wherein the body is a single piece of material, and the step of providing the body includes forging or casting the body.

18. The method of claim 15, wherein the ring grooves of the ring belt include a first ring groove and a second ring groove and a third ring groove, the first ring groove and the second ring groove and the third ring groove are the only ring grooves present in the piston, and the third ring groove includes the oil drain slot extending through the back wall thereof.

19. The method of claim 15, wherein the oil drain slot extends radially from the ring groove to both of the outer pockets along portions of a circumference of the piston, the oil drain slot extends radially from the ring groove to the inner undercrown region along portions of the circumference of the piston, the oil drain slot extends radially from the ring groove to opposite sides of each one of the pin bosses along portions of the circumference of the piston, and the lower wall of the ring groove including the oil drain slot is connected to the uppermost wall of the ring groove by the back wall at only four locations around the circumference of the piston.

20. The method of claim 15, wherein the oil drain slot extends radially from the ring groove to the inner undercrown region along at least one portion of a circumference of the piston.

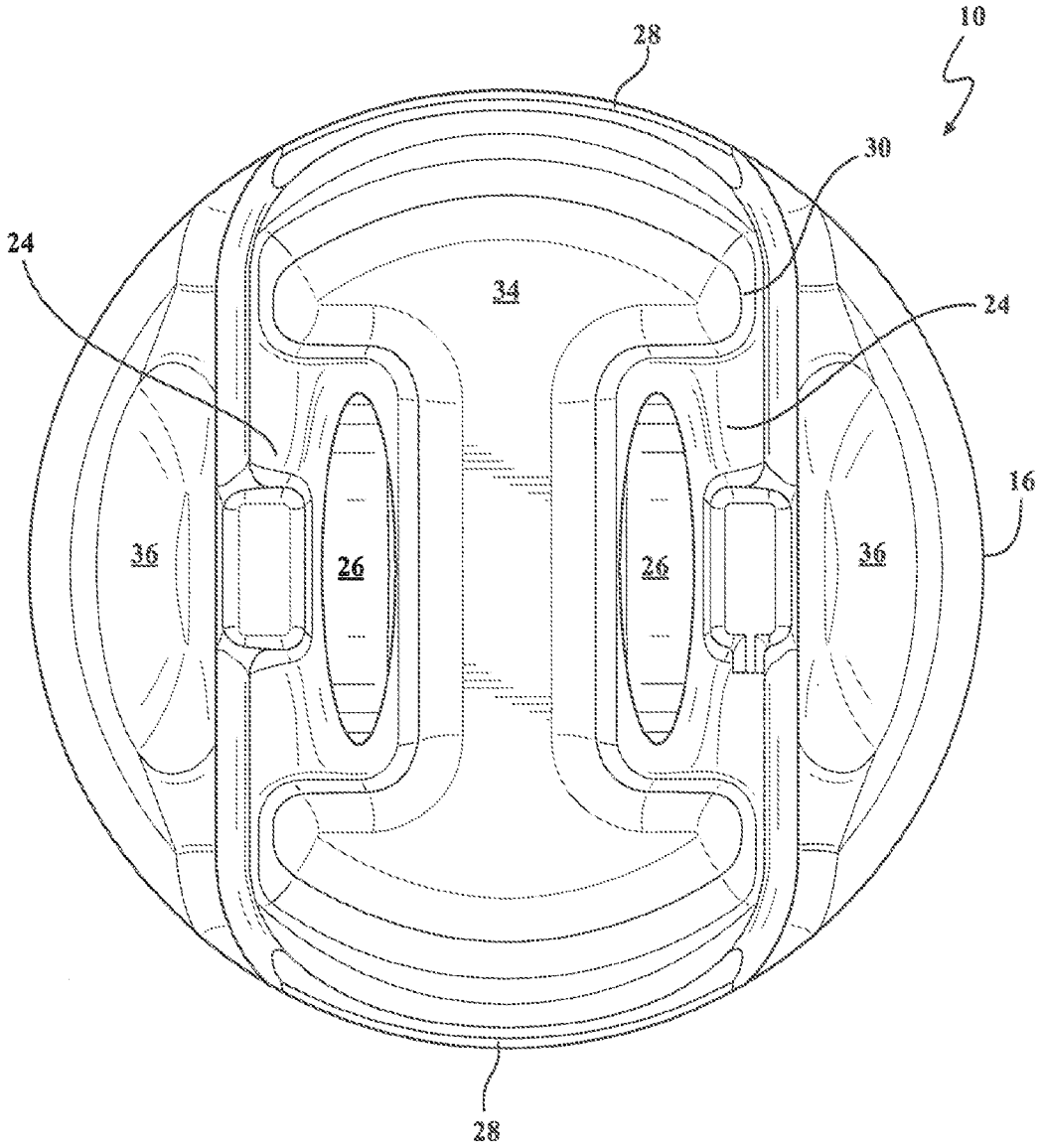

FIG. 1

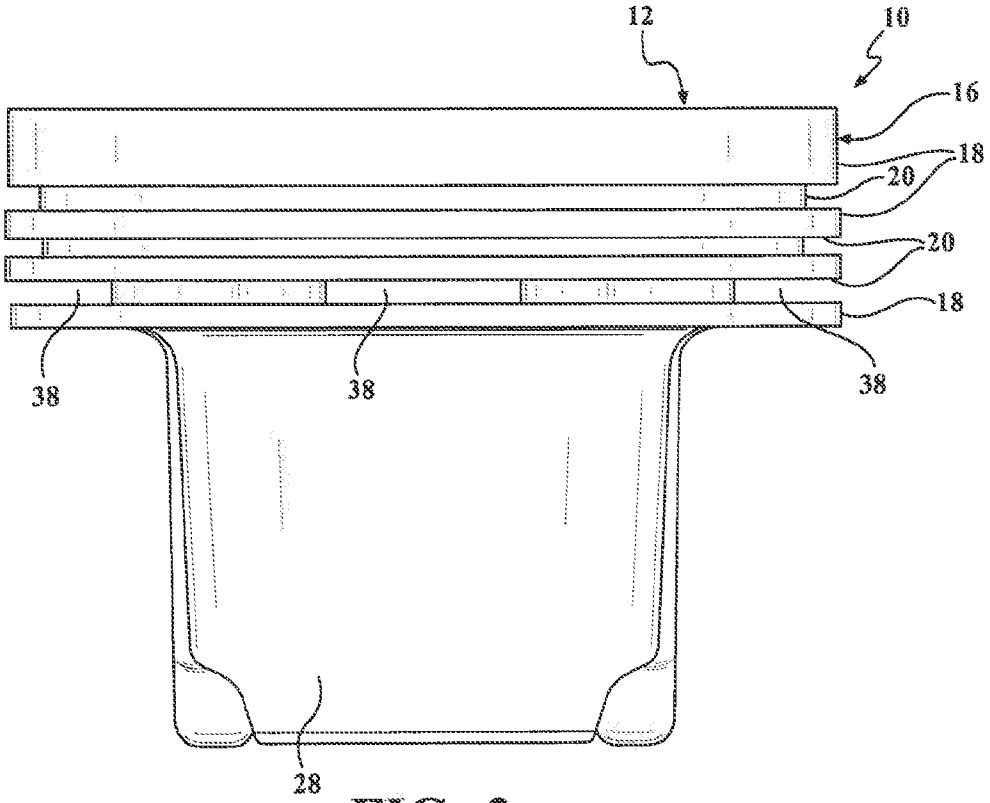
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FIG. 2

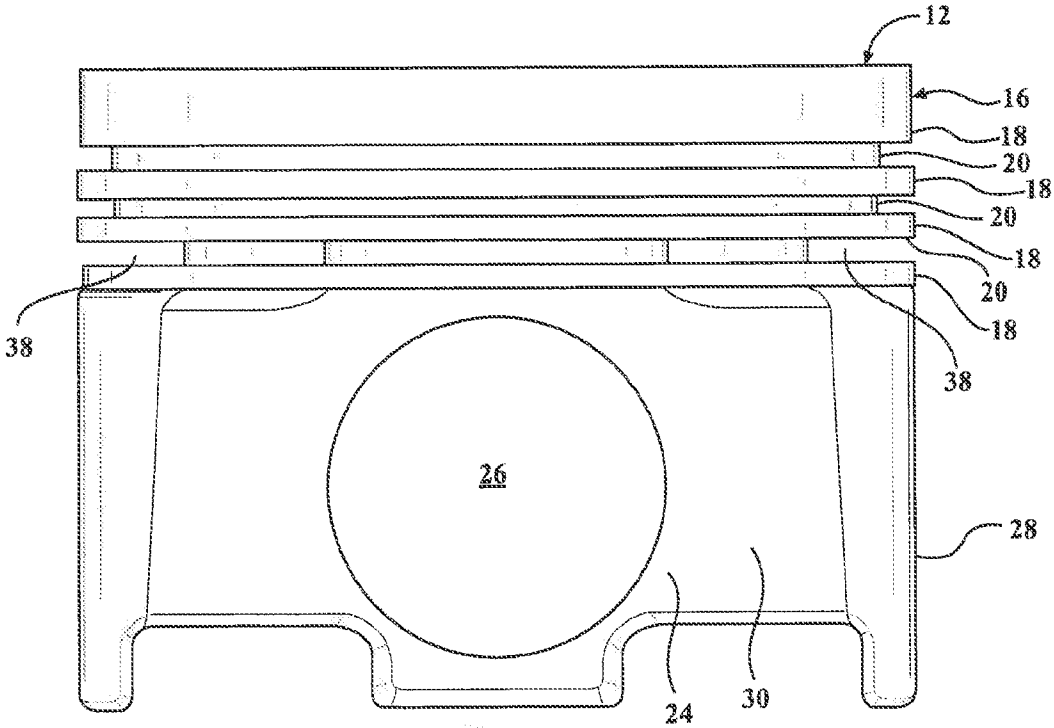
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FIG. 3

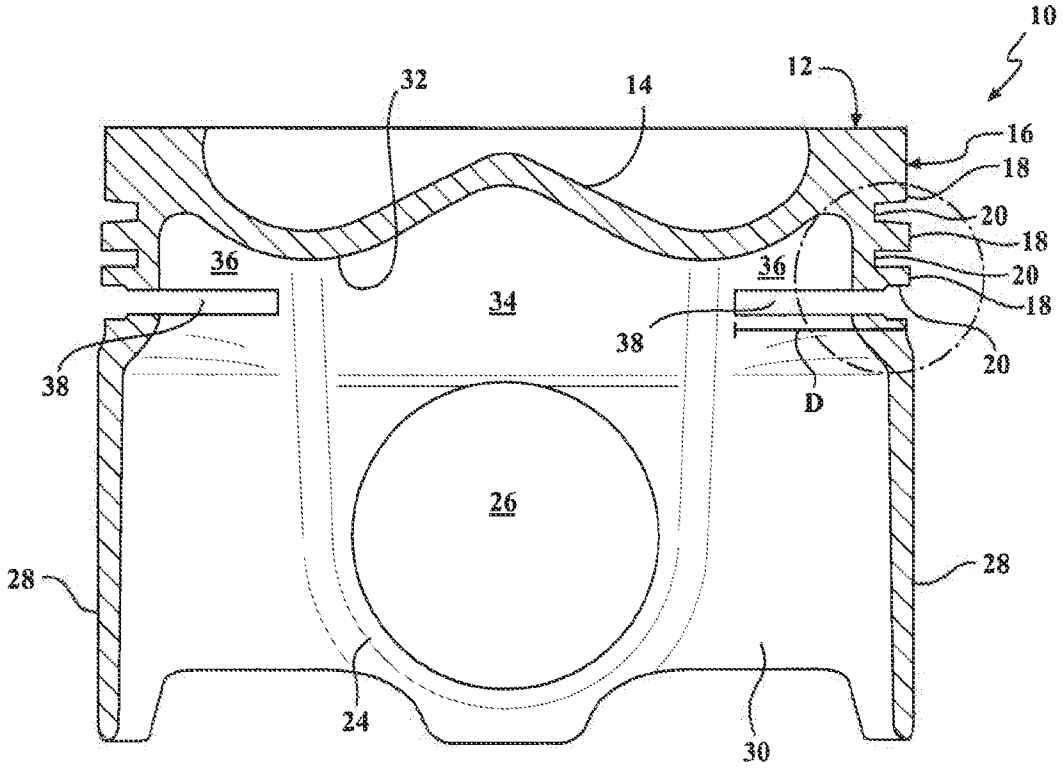
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FIG. 4

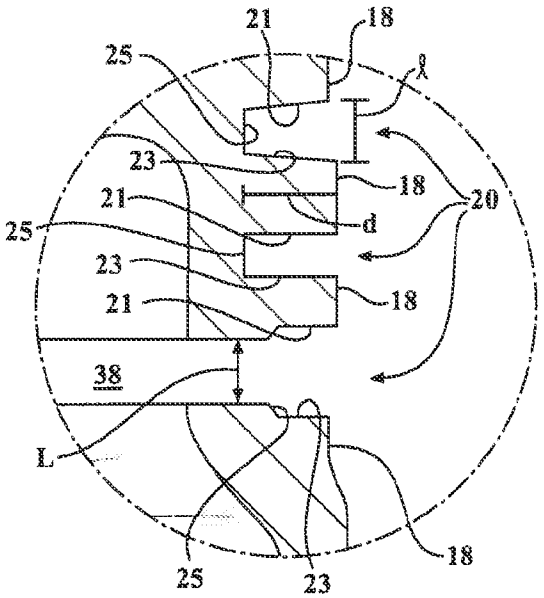
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FIG. 4A

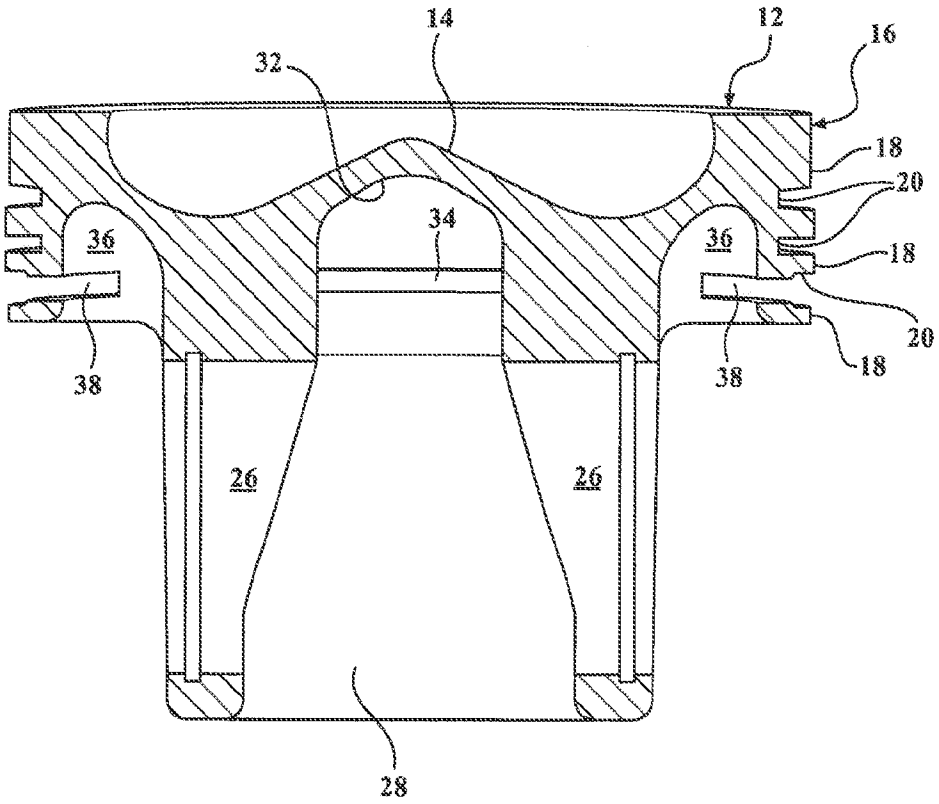

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/020127

A. CLASSIFICATION OF SUBJECT MATTER
INV. F02F3/20
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F02F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2004 353546 A (HITACHI UNISIA AUTOMOTIVE LTD) 16 December 2004 (2004-12-16) abstract figures 9-10	1-20
X	JP 2008 144658 A (MAZDA MOTOR) 26 June 2008 (2008-06-26) abstract figures	1,9-13, 15-18,20
A	WO 2007/025686 A1 (KS KOLBENSCHMIDT GMBH [DE]; BUSCHBECK RALF [DE]; SPERMANN JOHANNES [DE) 8 March 2007 (2007-03-08) figure 3	1-20

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
8 May 2017	16/05/2017

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Matray, J

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INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/020127

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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A	JP H09 242605 A (UNISIA JECS CORP) 16 September 1997 (1997-09-16) abstract figures	1-20
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
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