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(54) Title: PISTON AND CONNECTING ROD RETENTION

(57) Abstract

A piston assembly is configured for high compressive loading, or arduous duty cycle, such as in a two-stroke, compression-ignition (diesel), internal combustion engine, and incorporates a (part-) spherical or (part-) cylindrical bearing (18, 22, 23, 42), between a piston (10) and a connecting rod (50) small end (64); a (part) closed, unitary retaining ring (40), with a threaded circumference (44), for piston mounting; and an aperture, of internal profile (45) allowing its installation, by passage over the connecting rod; or, alternatively, as a partially-closed loop, with a peripheral slot, laterally to accommodate the connecting rod.
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PISTON AND CONNECTING ROD RETENTION

The present invention relates to piston and connecting rod retention and/or connection, in a positive displacement, reciprocating piston-in-cylinder device - whether a pump or prime mover, such as an internal combustion engine.

TERMINOLOGY

The term 'retention' is used herein to embrace any form of (inter)connection, (inter)coupling, entrainment, joining, or (mutual) restraint.

Thus, for example, retention could inhibit elements, or joints and bearings therebetween, becoming wholly dis-connected or uncoupled - and thus independently movable.

Harmony and continuity of movement is important in translating the motion mode of one element into that of another element connected thereto.

Retention is a contributory factor to that end.

The terms 'upper' and 'lower' relate merely to relative (dis)positions of components, as shown in the diagrams.
In a working engine (or pump), components may be arranged in any appropriate disposition or orientation, as indeed may an engine as a whole, subject to preserving lubrication (such as oil feed and oil pressure), coolant supply, fuel feed and 'breathing' through intake and exhaust valving, ports and manifold ducting.

Moreover, the term 'small-end' refers to the end of the connecting rod that is connected to the piston.

Thus the small end need not necessarily be physically small, nor smaller than the so-called 'big end' of the connecting rod.

Similarly, the term 'big end' merely identifies a connection to the crankshaft - again not necessarily relative or absolute size.

PRIOR ART

The connecting rod assembly itself is also generally in two parts.

One part comprises a small end, shank, and upper big end bearing housing.

Another part comprises a connecting rod end cap, which forms the lower portion of a circular bearing housing for the big end bearing.

Suitable fasteners are installed to hold these elements together.

The joint between piston and connecting rod small end includes a bearing (surface) allowing relative (rotational) movement.

Whilst the piston is confined by its contact with cylinder walls - to at least a linear reciprocating motion within the cylinder - the nature and degree of freedom of relative movement admitted between piston and connecting rod (small end) joint, reflects the joint configuration.

The joint bearing surface must be adapted accordingly.

Thus a (part-)spherical joint allows both (connecting rod) articulation or tilting, and rotation of the piston about its axis.
This contrasts with a conventional cylindrical journal bearing of a so-called 'gudgeon' or 'wrist' pin joint, which allows tilting, but not rotation.

Generally, piston rotation tends to adopt a sporadic form, spreading wear around the cylinder wall circumference, rather than a continuous rotation, which could engender an adverse (localised, eg annular) wear mode.

More specifically, in a spherical joint, complementary opposed bearing surfaces are formed on:

- the small end of a connecting rod;
- the underside of a piston body; and
- the upper side of a piston retaining ring.

There is necessarily a small clearance between the various bearing surfaces of the piston and connecting rod assembly - to allow relative rotation, but to minimise relative axial movement.

Principal advantages of a substantially spherical, or part-spherical, joint bearing contact surface, compared to a more conventional (gudgeon or wrist) pinned joint, include:

- piston expansion is symmetrical about its longitudinal (reciprocating) axis, affording manufacturing simplification,
and smaller running clearances;

- piston skirt wear is spread more evenly around the entire piston (skirt) circumference - promoting longer piston service life; and

- the bearing area available for carrying principal compressive load can be increased - thus either reducing bearing loading, or increasing the load carrying capacity.

Hitherto, as with the particular art identified, (part-) spherical piston-connecting rod bearings have generally used a split (or multi-part) retaining ring, to allow installation within the piston and around the connecting rod.

Commonly, a further retaining ring is employed to hold this split ring to the piston body - as, for example, demonstrated in the disclosures of SAE Paper 960055, DE-A-4,308751, US-A-2,819,936.

In one variant in SAE Paper 960055, an entire (part-) spherical bearing surface is formed in the body of the piston, with no separate retaining ring.

The machining and assembly complexities attendant these solutions are unattractive for mass production.
According to one aspect of the present invention, a piston assembly comprises a piston fitted with a connecting rod, coupled thereto by a (pivot or swivel) joint, itself retained by a unitary (retaining or retention) ring.

Another aspect of the invention provides a unitary (retaining or retention) ring, for such a piston assembly.

The retaining ring could be configured as either a partly, or completely, closed loop.

In practice, the retaining ring would be installed upon, or within, a piston to lie generally transversely of the piston axis.

The retaining ring cross-section could be uniform, or (periodically) varied throughout its circumference - for example, providing a series of spaced bearing contact regions or 'lands', protruding or upstanding from a lesser ring cross-section. A certain symmetry of form may be desirable. An undulating, or corrugated, profile might be employed.

The retaining section could change orientation throughout its circumference - say, by twisting - provided again a symmetry of collective or cumulative bearing surfaces were preserved.
The overall retaining ring profile or contour could be flat, or - at least before installation - 'canted' or periodically 'wavy' - with corrugated forms providing contact lands.

Thus, for example, in a part-closed retaining ring (but distinct from the 'minor', arcuate ring segments of the art), opposite ends could lie in different planes.

A helical, or part-helical ring would be a case in point - again desirably providing a substantially symmetrical overall bearing geometry, if not of the whole ring, then localised contact lands.

The helix could be compacted into a flat, or at least flatter form, upon installation, providing a tight sprung fit, without the need for supplementary circlips or other fasteners.

Generally, a unitary retaining ring configuration represents a simplification in construction, manufacture and assembly - over the known multi-part ring art identified.

Preferably, the internal profile of such a unitary retaining ring, and the (complementary) external profile of the associated connecting rod, allow the ring to pass over the rod, - (even at its point of greatest cross-section, that is usually its big end) - with the big end bearing cap removed.
The retaining ring may be configured as a continuous closed loop, with an asymmetric internal aperture profile, to complement, or fit around, the connecting rod cross-section.

Alternatively, the retaining ring may be only partially closed - that is of less than 360 degrees circumferential span - for example, configured as a form of horseshoe (see Figure 5).

Such a partially-closed retaining ring need not pass over the connecting rod big end - but rather may be fitted laterally onto the connecting rod shank.

In either case, the component count is less than for a split retaining ring assembly of the known art identified.

Moreover, the surfaces to be machined are readily accessible and of relatively simple form.

Overall symmetry of piston and bearing configuration provide stable expansion characteristics, in turn promoting:

- low engine oil consumption; and

- reduced leakage ('blow-by') of working fluid.

These benefits tend to prevail throughout a long useful working life, since the ring grooves will not suffer the asymmetric distortions that occur with more conventional pinned joints.
Some means of positive mechanical entrainment between the retaining ring and piston (internal) wall is desirably employed for a secure inter-connection.

To this end, conveniently, the retaining ring has an external thread, to mate with a complimentary threaded internal bore in the piston wall.

Torque tool locating recesses, or modest protruding lugs, may be incorporated in the ring body, to facilitate tightening of the threaded inter-connection with the piston.

Alternatively, a circlip may be fitted beneath, or into a circumferential wall slot within, the retaining ring, in order to locate in a groove or ledge in the internal piston wall.

In another approach, several circumferentially-spaced, say, longitudinally-directed, threaded fasteners may be fitted to pass through the piston retaining ring into the body of the piston (crown).

Radial fasteners might be an alternative or supplementary approach, albeit not so readily installed or tightened.

A piston assembly with connecting rod retention according to the invention is compatible with engines needing high cylinder pressure capability, in order to minimise emissions and fuel consumption.
This compatibility arises largely through the increased bearing area, but also by improved stress distribution and minimal shape distortion.

Hitherto known pistons capable of withstanding the stresses produced in high pressure engines generally employ steel for the main structure.

Some examples would be:

- steel-crowned 'articulated' pistons;
- single-piece cast, or fabricated, steel pistons; and
- steel-crowned, composite pistons.

With the adoption of such robust steel pistons, very high bearing pressures are encountered, calling for advanced bearing materials or treatments - which tends to increase their cost.

In contrast, a piston with connecting rod retention of the present invention can be made at much lower cost (than steel) - preferably in aluminium alloy, although cast iron would also be well-suited.

The attendant large bearing area is particularly suitable for arduous duty - such as is experienced with two-stroke diesel engines.
Operationally, in a two-stroke combustion cycle, there is no load reversal - and so the small end bearing design is critical.

Additionally, since, in a two-stroke cycle engine, the load is always compressive in the connecting rod, the big end bearing itself may not need a (substantial confinement or retention) closure cap.

Similarly, in a two-stroke cycle engine, the main load-bearing part of a connecting rod big end circumference need only embrace an arc some 120 degrees or less.

Other preferred features of a piston assembly adopting piston and connecting rod retention according to the invention include:

- wear-resistant ring carrier material (eg Ni-resist);
- reduced top-land height;
- integral coolant gallery;
- ceramic fibre reinforcement.

Generally, the piston assembly will be of aluminium alloy, with a steel connecting rod - although any suitable material combination may be used.
Some particular embodiments of the invention will now be described, by way of example only, and with reference to the accompanying diagrammatic and schematic drawings, in which:

The invention will now be described with reference to the accompanying drawings, in which:

Figure 1 shows a cross-sectional view through a spherically-jointed, piston and connecting rod assembly according to the invention;

Figures 2A through 2D depict schematically part of an assembly sequence for fixing a retaining ring upon the connecting rod of the piston assembly of Figure 1;

Figure 3 shows an end view of a retaining ring of the assembly of Figures 1 and 2; and

Figure 4 shows a three-dimensional part cut-away, part-sectioned view of the spherical piston-connecting rod joint of Figures 1 through 3.

Figure 5 shows an end view of a 'horse shoe' retaining ring.

Referring to the drawings, a (spherically-jointed) piston and connecting rod assembly of Figure 1 includes a piston 10, fitted with a connecting rod 50.

The piston 10 has a hollow underside, bounded by a peripheral skirt 12, a ring belt 14,
a crown 16, a coolant gallery 20, and thread 30 upon an internal peripheral wall of the skirt 12.

The connecting rod 50 has a 'small end' 64 with a spherical, or rather part-spherical bearing surface 22, 23.

The small end bearing surface 22, 23 is constrained between complementary opposed (part-) spherical bearing surfaces 18, 42, respectively on the hollow underside of the piston crown and upper inner rim of unitary annular retaining ring 40.

The small end 64 is effectively retained in situ by the retaining ring 40.

An outer threaded circumference 44 of the retaining ring 40 mates with a complementary thread 30 on the internal circumference of the piston skirt 12.

The connecting rod 50 is in two parts, viz:

an upper part 60, including the small end 64, a shank 62 and an upper (say, half) portion of a 'big end' bearing housing 70; and a lower part, with an end closure, or retention bearing cap 80.

The (cylindrical) piston body is axial-symmetric - except for various ancillary internal (cast and/or drilled) passages, or oil-ways, for feeding and drainage of lubricating and coolant oil.
The piston depicted in this example, features integrated cooling provision - through an (optional) coolant gallery 20, located between the piston crown 16 and part-spherical bearing 18, with a supply and drainage path for oil.

However, the piston retention feature of the present invention is broadly applicable to pistons without such a gallery.

The piston retaining ring 40 is not axial-symmetric, as may be appreciated from the end view of Figure 3.

More specifically, an internal aperture 45 of the retaining ring 40 is profiled, with diametral cut-outs or notches, to complement the connecting rod local (rectangular) cross-section - which in turn varies somewhat along its length.

This allows passage of the retaining ring 40 - with some re-orientation relative to the connecting rod 50 - progressively over the connecting rod 50, in a particular way, or ways, such as depicted in Figures 2A through 2D.

Other contours for the aperture 45 - for example with non-diametral cut-outs - are possible, in order to provide the necessary local increase in breadth.

This in turn enables the retaining ring 40 to fit around (taken individually, in turn) the big end housing 70 and the lower part of the shank 62 of the connecting rod 50.
The ring 40, with the connecting rod held captive thereto, can then be installed within the piston 10.

When installing the ring 40, in order to gain purchase for rotation, use may be made of drain holes 46 as location points, in combination with a peg spanner (not shown).

In this way the necessary tightening torque can be applied, upon engaging the mating threads 30, 44 - thereby in turn fastening the ring 40 to the piston 10.

If (integrated) piston cooling is incorporated, oil passes from an engine oil pump, (not shown), through passages or oil-ways in the crankshaft (not shown), via the big end housing 70, up a central passage 68 of the connecting rod 50, to a chamber 27 formed (centrally) in the underside of the piston crown 16.

In one possible variation, transverse grooves 26 feed oil out to the passages 28 and also ensure ample lubrication of the spherical bearing surfaces 18, 22 between the (underside of the) piston 10 and the (upper portion of the) connecting rod 50 small end 64.

Oil passes through the passages 28, into the coolant gallery 20 and is vigorously shaken up and down by the reciprocating motion of the piston 10 - as it does so, collecting heat from the internal surfaces.
Oil then passes down the drain holes 24, escaping past the (part) spherical small end 64 of the connecting rod 50 and into a ring gallery 48, formed around the connecting rod small end 64.

The ring gallery 48 helps lubricate the (part-) spherical bearing surfaces 23, 42 between (the lower portion of the) small end 64 and (the upper portion) retaining ring 40.

More heat is collected here as the oil is shaken up and down in this space, before the oil escapes down the lower drain holes 46, formed in the piston retaining ring 40 and away into the crankcase.

Some oil will also escape over the small end bearing surface 23, lubricating it as it does so.

Refinements in coolant gallery configuration and localised collection and (re-)distribution between connecting rod and piston are disclosed in the Applicants' (unpublished) co-pending UK patent applications [nos. 9909034.2 & 9909033.4].

The sequence of views of Figures 2A through 2D shows how the connecting rod 50 can be passed through the piston retaining ring 40, and how its profiled aperture 45 is shaped to facilitate this, with some relative (re-)orientation.

For a robust engine, the big-end bearing must be of substantial diameter.
A connecting rod big end split perpendicularly to its shank axis would not then be able to pass through the piston retaining ring.

Conversely, a big end bearing of a smaller connecting rod that was split perpendicularly to its shank axis - and so which could pass through the retaining ring - would not be sufficiently substantial or robust to survive the loads in a heavy duty engine.

Overall, a particular aspect of the invention thus provides a piston and connecting rod assembly, in which a connecting rod small-end surface mates with a piston, the piston being retained upon the connecting rod, by a discrete, unitary retaining ring.

More particularly, the piston retaining ring and connecting rod are configured to allow the piston retaining ring to pass over the connecting rod big end, up its shank and hence to (en)trap and constrain the connecting rod small end, between complementary (part-spherical or part-cylindrical) bearing surfaces, formed respectively in the piston body and the retaining ring.

For operating conditions - such as those encountered in two-stroke, compression-ignition (diesel) engines - where working (combustion gas) loads are generally always compressive - that is such as to push the piston down onto the connecting rod - the features that retain the piston to the connecting rod do not need to be nearly as substantial as for, say, a four-stroke engine.
COMPONENT LIST

10 piston
12 skirt
14 ring belt
16 crown
18 (part-) spherical bearing surface (piston)
20 coolant gallery
22 (part-) spherical bearing surface (small end)
23 (part-) spherical bearing surface (small end)
24 drain hole
26 groove
27 chamber
28 passage
30 internal thread (piston skirt)
40 retaining ring
42 (part-) spherical bearing surface (retaining ring)
44 external thread (retaining ring)
45 profiled aperture
46 drainage hole
48 ring gallery
50 connecting rod
60 upper part
62 shank
64 small end (connecting rod)
68 passage (shank 62)
70 big end upper part bearing cap
CLAIMS:

1. A piston assembly, comprising a piston body (10), a connecting rod (50), and a piston retaining ring (40), of unitary construction, installed within, or upon, the piston body, to locate upon and retain the connecting rod small end (64).

2. A piston assembly, as claimed in Claim 1, incorporating a spherical, or part-spherical, (swivel) bearing (18, 22) joint, between the piston and the connecting rod small end, and a (swivel) bearing (23, 42), between the connecting rod small end and the retaining ring to admit of piston rotation about its axis.

3. A piston assembly, as claimed in Claim 1, incorporating a cylindrical, or part-cylindrical, bearing joint, between the piston and the connecting rod small end.

4. A piston assembly, as claimed in any of the preceding claims, incorporating a threaded interconnection between the piston body and the retaining ring.

5. A piston assembly, as claimed in any of the preceding claims, with a circlip installed to locate the retaining ring and locate in the piston internal wall.
6. A piston assembly, as claimed in any of the preceding claims, with a fastener or fasteners through both the retaining ring and the piston body.

7. A piston assembly, as claimed in any of the preceding claims, in which the piston is at least partly of aluminium alloy.

8. A piston assembly, as claimed in any of the preceding claims, in which the piston is at least partly of cast iron.

9. A piston assembly, as claimed in any of the preceding claims, wherein the retaining ring has an aperture, the aperture internal profile, - having regard to a connecting rod section - allowing its passage, over a big end and along the connecting rod, towards a small end.

10. A piston assembly, as claimed in any of the preceding claims, wherein the retaining ring is configured as a partially closed loop, (subtending, say, 300 degrees or more) with a slot, allowing installation laterally over a connecting rod shank.

11. A piston assembly, substantially as hereinbefore described, with reference to, and as shown in, the accompanying drawings.

12. A reciprocating piston-in-cylinder device, whether configured as an internal combustion engine or pump, incorporating a
piston assembly, as claimed in any of the preceding claims.

13. A reciprocating piston-in-cylinder device, incorporating a piston assembly, as claimed in any of Claims 1 through 11, configured as a two-stroke, compression-ignition (diesel) engine.

14. A unitary, closed or partially-closed, retaining ring, for a piston to connecting rod small end joint, of a piston assembly, as claimed in any of Claims 1 through 11.

15. A connecting rod with a (part-)cylindrical small end, for a piston to connecting rod small end joint, of a piston assembly, as claimed in any of Claims 1 through 11.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F16J1/22

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)
IPC 7 F16J

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

Electronic database consulted during the international search (name of database and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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| X        | US 4 459 900 A (LABOUFF GARY A)  
17 July 1984 (1984-07-17)  
cited in the application  
column 4, line 5-26  
figure A | 1,2,4,  
11,12,  
14,15 |
| X        | US 2 926 975 A (K.C. KARDE)  
1 March 1960 (1960-03-01)  
column 3, line 6-36  
column 3, line 53-59  
figures 1-3 | 1,2,5,  
11,12,  
14,15 |

Further documents are listed in the continuation of box C.  
Patient family members are listed in annex.

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