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(54) Title: COATED PISTON RING FOR AN INTERNAL COMBUSTION ENGINE

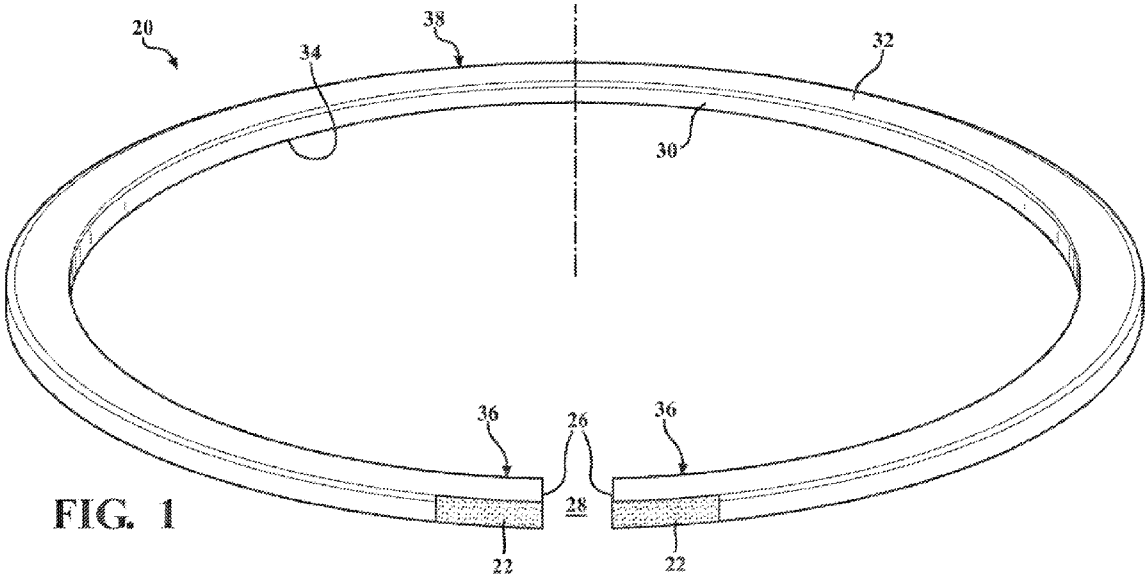

FIG. 1

(57) Abstract: A piston ring with a coated outer surface is provided. The coating is disposed on end sections of the outer surface adjacent a gap. Typically, a middle section of the outer surface located between the end sections is not coated. The coating can be formed of CrN or DLC, and the CrN coating can be applied by physical vapor deposition (PVD). The end sections of the outer surface, upon which the coating is applied, are rough. For example, the outer surface can be blasted or otherwise textured to achieve the rough surface. The rough surface retains oil and distributes stress better than a smooth surface, and thus reduces crazing and flaking of the coating.

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[Continued on next page]

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COATED PISTON RING FOR AN INTERNAL COMBUSTION ENGINE

CROSS-REFERENCE TO RELATED APPLICATIONS

The subject international patent application claims priority to and all the benefits of U.S. Utility Patent Application No. 16/564,852, filed on September 9, 2019, which is herein incorporated by reference in its entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates generally to a piston for an internal combustion engine, a piston ring for providing a seal between the piston and a cylinder wall of the engine, and methods of manufacturing the same.

2. Related Art

[0002] Typical internal combustion engines are provided with at least one piston assembly which reciprocates within a cylinder of an engine block. In general, each piston assembly includes a piston body with a plurality of ring grooves, each of which typically receives and operably supports a piston ring. In operation, the piston rings remain in the ring grooves and travel with their respective piston bodies in a reciprocating motion within cylinders of an engine block. Among other things, the pistons rings function to seal combustion gasses in a combustion chamber above the piston body, to transfer heat from the piston body to the cylinder wall, to restrict the passage of oil from the crank case to the combustion chamber and to provide a generally uniform oil film on the cylinder wall. Piston rings are oftentimes coated to improve performance and/or reduce wear and damage to the piston ring. However, over time, due to the harsh conditions of the engine, the coating can experience flaking and crazing.

SUMMARY

[0003] One aspect of the present invention provides a coated piston ring for a piston assembly of an internal combustion engine which is less prone to flaking and crazing. The piston ring comprises a ring body extending circumferentially around a center axis between opposite end surfaces, and the end surfaces of the ring body present a gap therebetween. The ring body has an outer surface facing away from the center axis, the outer surface includes end sections adjacent the end surfaces, and the end sections of the outer surface are rough. A coating is disposed on the end sections of the outer surface, and the coating includes chromium nitride (CrN) or diamond-like carbon (DLC).

[0004] Another aspect of the invention provides a piston assembly for an internal combustion engine. The piston assembly includes a piston body including at least one ring groove extending circumferentially around a center axis, and a ring body disposed in one of the at least one ring groove. The ring body extends circumferentially around the center axis between opposite end surfaces, and the end surfaces of the ring body present a gap therebetween. The ring body has an outer surface facing away from the center axis, the outer surface includes end sections adjacent the end surfaces, and the end sections of the outer surface are rough. A coating is disposed on the end sections of the outer surface, and the coating includes chromium nitride (CrN) or diamond-like carbon (DLC).

[0005] Yet another aspect of the invention provides a method of manufacturing a piston ring. The method comprises the steps of providing a ring body extending circumferentially around a center axis between opposite end surfaces, wherein the end surfaces present a gap therebetween, and the ring body has an outer surface facing away from the center axis. The method further includes texturing end sections of the outer surface located adjacent the end surfaces so that the end sections of the outer surface are rough; and

applying a coating to the rough end sections of the outer surface, wherein the coating includes chromium nitride (CrN) or diamond-like carbon (DLC).

[0006] Another aspect of the invention provides a method of manufacturing a piston assembly. The method comprises providing a piston body including at least one ring groove extending circumferentially around a center axis, and providing a ring body extending circumferentially around the center axis between opposite end surfaces. The end surfaces of the ring body present a gap therebetween, and the ring body has an outer surface facing away from the center axis. The method further includes texturing end sections of the outer surface adjacent the end surfaces so that the end sections of the outer surface are rough, applying a coating to the rough end sections of the outer surface, wherein the coating includes chromium nitride (CrN) or diamond-like carbon (DLC), and disposing the coated piston ring in one of the at least one ring groove of the piston body.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] These and other features and advantages of the present invention will be readily appreciated, as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

[0008] Figure 1 is a perspective view of a piston ring according to an exemplary embodiment;

[0009] Figure 2 is an enlarged cross-sectional view of the piston ring of Figure 1; and

[0010] Figure 3 is a sectional view of an internal combustion engine including a piston assembly with the piston ring of Figure 1 according to an exemplary embodiment.

DETAILED DESCRIPTION OF THE EXAMPLE EMBODIMENTS

[0011] An exemplary embodiment of a piston ring **20** for an internal combustion engine is shown in Figure 1. A coating **22** is disposed on rough sections of an outer surface **24** of the piston ring **20**. Due to the rough outer surface **24** beneath the coating **22**, the coating **22** less prone to crazing and flaking than comparative coatings on piston rings without the rough surface beneath the coating.

[0012] The piston ring **20** comprises a ring body extending circumferentially around a center axis **A** between opposite end surfaces **26**. The ring body is formed of metal, for example steel. The end surfaces **26** of the ring body present a gap **28** therebetween. Typically, the end surfaces **26** are parallel to the center axis **A**, but the end surfaces **26** could be disposed at an angle relative to the center axis **A**. The outer surface **24** of the ring body faces away from the center axis **A**, and the ring body includes an inner surface **30** facing toward the center axis **A**. A top surface **32** extends from the inner surface **30** to the outer surface **24** of the ring body, and a bottom surface **34** is spaced from the top surface **32** and extends from the inner surface **30** to the outer surface **24**. Typically, the inner surface **30** is parallel to the center axis **A** and the outer surface **24**, and the top surface **32** is perpendicular to the center axis **A** and parallel to the bottom surface **34**, but the surfaces could be disposed at different angles relative to one another.

[0013] The outer surface **24** of the ring body includes end sections **36** adjacent the end surfaces **26** and the gap **28**. The end sections **36** of the outer surface **24** are rough, and the coating **22** is disposed on at least the rough end sections **36** of the outer surface **24**. The end sections **36** are spaced from one another by a middle section **38** of the outer surface **24**. In the example embodiment shown in Figure 1, the middle section **38** is not coated with the coating **22**. In this embodiment, the end sections **36** of the outer surface **24** have a surface roughness greater than a surface roughness of the middle section **38**, and the middle section

38 of the outer surface **24** is considered to be smooth. However, in another embodiment, the entire outer surface **24**, including the middle section **38**, is coated with the coating **22**. The rough sections of the outer surface **24**, also referred to as textured surfaces, distribute stresses differently than smooth surfaces in a way that reduces flaking and crazing of the coating **22**. The rough sections of the outer surface **24** also create a surface area that retains more oil on the piston ring **20**.

[0014] The coating **22** applied to the end sections **36**, and possibly to the entire outer surface **24**, includes chromium nitride (CrN) or diamond-like carbon (DLC). The coating **22** may consist essentially of, or consist entirely of DLC or CrN. The coating **22** is formed of grains **46**, and due to the rough surface, the grains **46** of the coating **22** are disposed at angles relative to one another.

[0015] Another aspect of the invention provides a method of manufacturing the coated piston ring **20**. The method includes texturing the end sections **36** of the outer surface **24** located adjacent the end surfaces **26** of the ring body so that the end sections **36** of the outer surface **24** are rough; and applying the coating **22** to the rough end sections **36** of the outer surface **24**. The texturing step can include blasting the outer surface **24** with a solid material, such as sand, to form the rough surface.

[0016] The coating step typically includes physical vapor deposition, especially when the coating **22** includes CrN, but other methods can be used to apply the coating **22**. In the example embodiment, the middle section **38** includes no coating **22**, so the method includes applying none of the coating **22** to the middle section **38** of the outer surface **24**. For example, the method can include masking the middle section **38** of the outer surface **24** while applying the coating **22** to the end sections **36**, so that the coating **22** is only disposed on the end sections **36**. However, the coating **22** could be disposed on the entire outer surface **24**. The method can also include masking the middle section **38** of the outer

surface **24** while blasting or texturing the outer surface **24** in another manner, so that only the end sections **36** are textured. Alternately, the entire outer surface **24** could be rough, with or without the coating **22** on the middle section **38**.

[0017] The coated piston ring **20** is preferably disposed on a piston body to form a piston assembly **40** for an internal combustion engine. The piston body can have various different designs, but typically includes a crown **42** and a skirt **44** depending from the crown **42**. The piston body typically includes at least one ring groove extending circumferentially around the center axis **A**, and the piston ring **20** is disposed in one of the ring grooves. In the example embodiment, the crown **42** of the piston body includes a plurality of the ring grooves and at least one, and oftentimes more or all of the ring grooves, contain the piston rings **20**.

[0018] 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 claims. It is also 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

What is claimed is:

1. A piston ring, comprising:

a ring body extending circumferentially around a center axis between opposite end surfaces,

said end surfaces of said ring body presenting a gap therebetween,

said ring body having an outer surface facing away from said center axis,

said outer surface including end sections adjacent said end surfaces,

said end sections of said outer surface being rough,

a coating disposed on said end sections of said outer surface, and

said coating including chromium nitride (CrN) or diamond-like carbon (DLC).

2. The piston ring of claim 1, wherein said coating consists essentially of DLC or CrN.

3. The piston ring of claim 1, wherein end sections are spaced from one another by a middle section of said outer surface, and said middle section is not coated with said coating including CrN or DLC.

4. The piston of claim 1, wherein said end sections have a surface roughness greater than a surface roughness of said middle section of said outer surface.

5. The piston ring of claim 1, wherein said coating includes a plurality of grains disposed at angles relative to one another.

6. The piston ring of claim 1, wherein said coating includes CrN.

7. The piston ring of claim 6, wherein said coating is applied by physical vapor deposition.

8. The piston ring of claim 1, wherein said coating includes DLC.

9 The piston ring of claim 1, wherein said end surfaces of said ring body are parallel to said center axis,

said ring body has an inner surface facing toward said center axis,

said ring body has a top surface extending from said inner surface to said outer surface and a bottom surface spaced from said top surface and extending from said inner surface to said outer surface,

said inner surface is parallel to said center axis and said outer surface,

said top surface is perpendicular to said center axis and parallel to said bottom surface,

said ring body is formed of steel,

said end sections are spaced from one another by a middle section of said outer surface,

said middle section of said outer surface is not coated with said coating including CrN or DLC.

said end sections of said outer surface have a surface roughness which is greater than a surface roughness of said middle section,

said coating consists essentially of DLC or CrN, and

said coating includes a plurality of grains disposed at angles relative to one another.

10. A piston assembly for an internal combustion engine, comprising:

a piston body including at least one ring groove extending circumferentially around a center axis,

a ring body disposed in one of said at least one ring groove,

said ring body extending circumferentially around the center axis between opposite end surfaces,

said end surfaces of said ring body presenting a gap therebetween,

said ring body having an outer surface facing away from said center axis,

said outer surface including end sections adjacent said end surfaces,

said end sections of said outer surface being rough,

a coating disposed on said end sections of said outer surface, and

said coating including chromium nitride (CrN) or diamond-like carbon (DLC).

11. The piston assembly of claim 10, wherein said piston body includes a crown and a skirt depending from said crown, and said at least one ring groove is located in said crown.

12. A method of manufacturing a piston ring comprising the steps of:

providing a ring body extending circumferentially around a center axis between opposite end surfaces, the end surfaces presenting a gap therebetween, the ring body having an outer surface facing away from the center axis;

texturing end sections of the outer surface located adjacent the end surfaces so that the end sections of the outer surface are rough; and

applying a coating to the rough end sections of the outer surface, the coating including chromium nitride (CrN) or diamond-like carbon (DLC).

13. The method of claim 12 including applying the coating by physical vapor deposition.

14. The method of claim 13, wherein the coating includes CrN.

15. The method of claim 12, wherein the coating includes DLC.

16. The method of claim 12, wherein the end sections are spaced from one another by a middle section of the outer surface, and applying none of the coating to the middle section of the outer surface.

17. The method of claim 16, wherein the texturing step provides the end sections of the outer surface with a surface roughness which is greater than a surface roughness of the middle section.

18. The method of claim 12, wherein the end surfaces of the ring body are parallel to the center axis, the ring body has an inner surface facing toward the center axis, the ring body has a top surface extending from the inner surface to the outer surface and a bottom surface spaced from the top surface and extending from the inner surface to the outer surface, the inner surface is parallel to the center axis and the outer surface, the top surface is perpendicular to the center axis and parallel to the bottom surface, the ring body is formed of steel, the end sections are spaced from one another by a middle section of the outer surface which is not textured, the end sections have a surface roughness which is greater than a surface roughness of the middle section, the coating consists essentially of DLC or CrN, and the coating includes a plurality of grains disposed at angles relative to one another being applied to the outer surface; and applying none of the coating to the middle section of the outer surface.

19. A method of manufacturing a piston assembly comprising the steps of:

providing a piston body including at least one ring groove extending circumferentially around a center axis,

providing a ring body extending circumferentially around the center axis between opposite end surfaces, the end surfaces presenting a gap therebetween, the ring body having an outer surface facing away from the center axis,

texturing end sections of the outer surface adjacent the end surfaces so that the end sections of the outer surface are rough,

applying a coating to the rough end sections of the outer surface, the coating including chromium nitride (CrN) or diamond-like carbon (DLC), and

disposing the coated piston ring in one of the at least one ring groove of the piston body.

20. The method of claim 19, wherein the end sections are spaced from one another by a middle section of the outer surface, and applying none of the coating to the middle section of the outer surface.

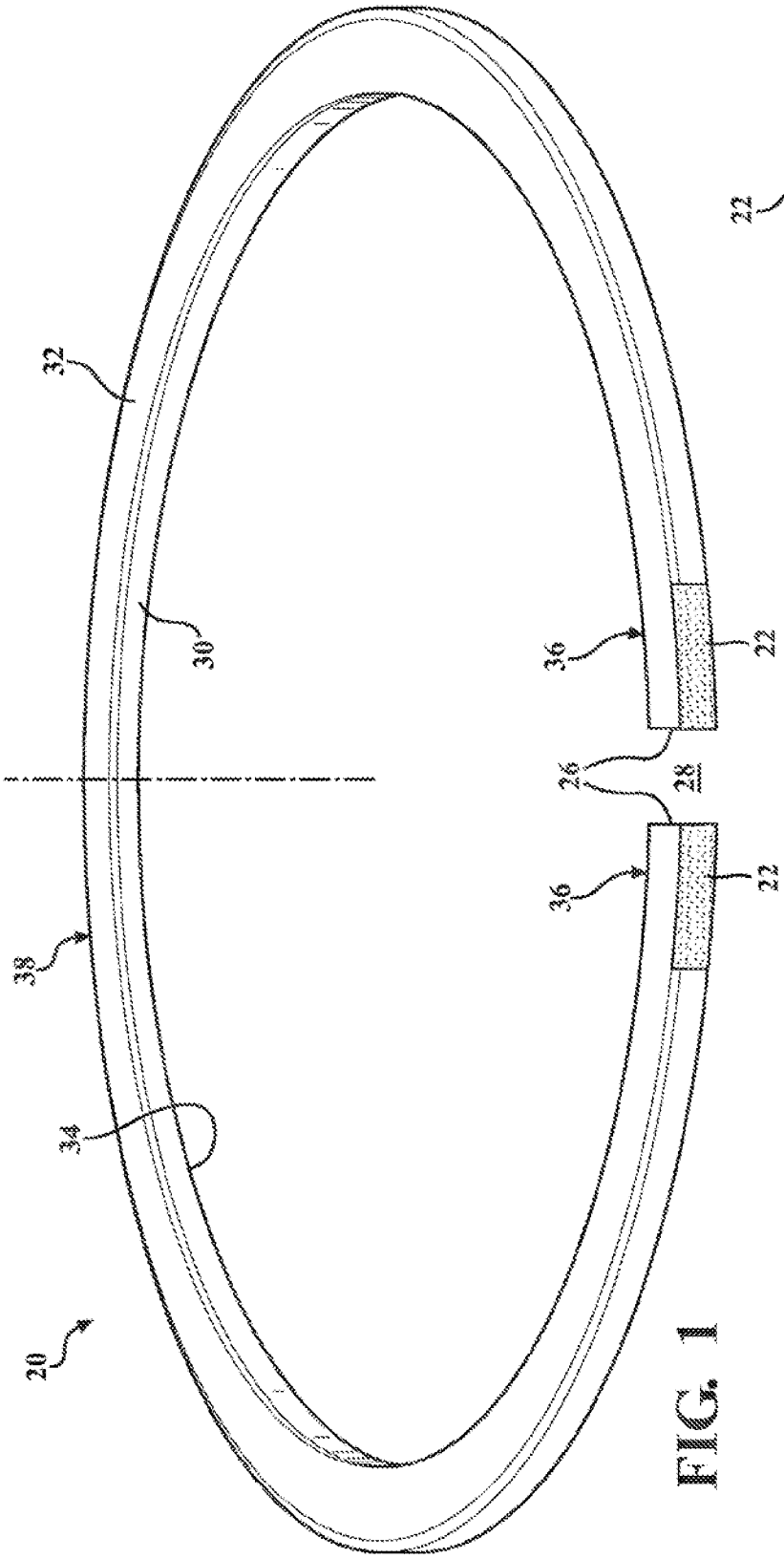

FIG. 1

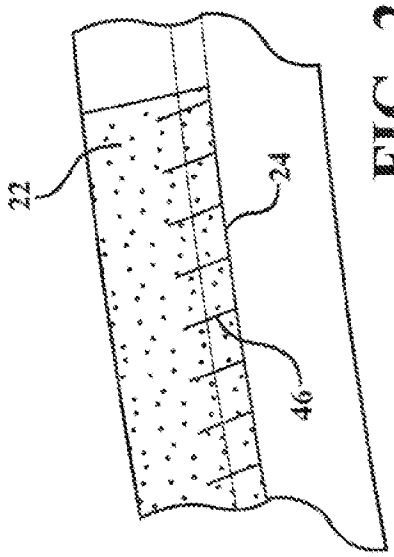

FIG. 2

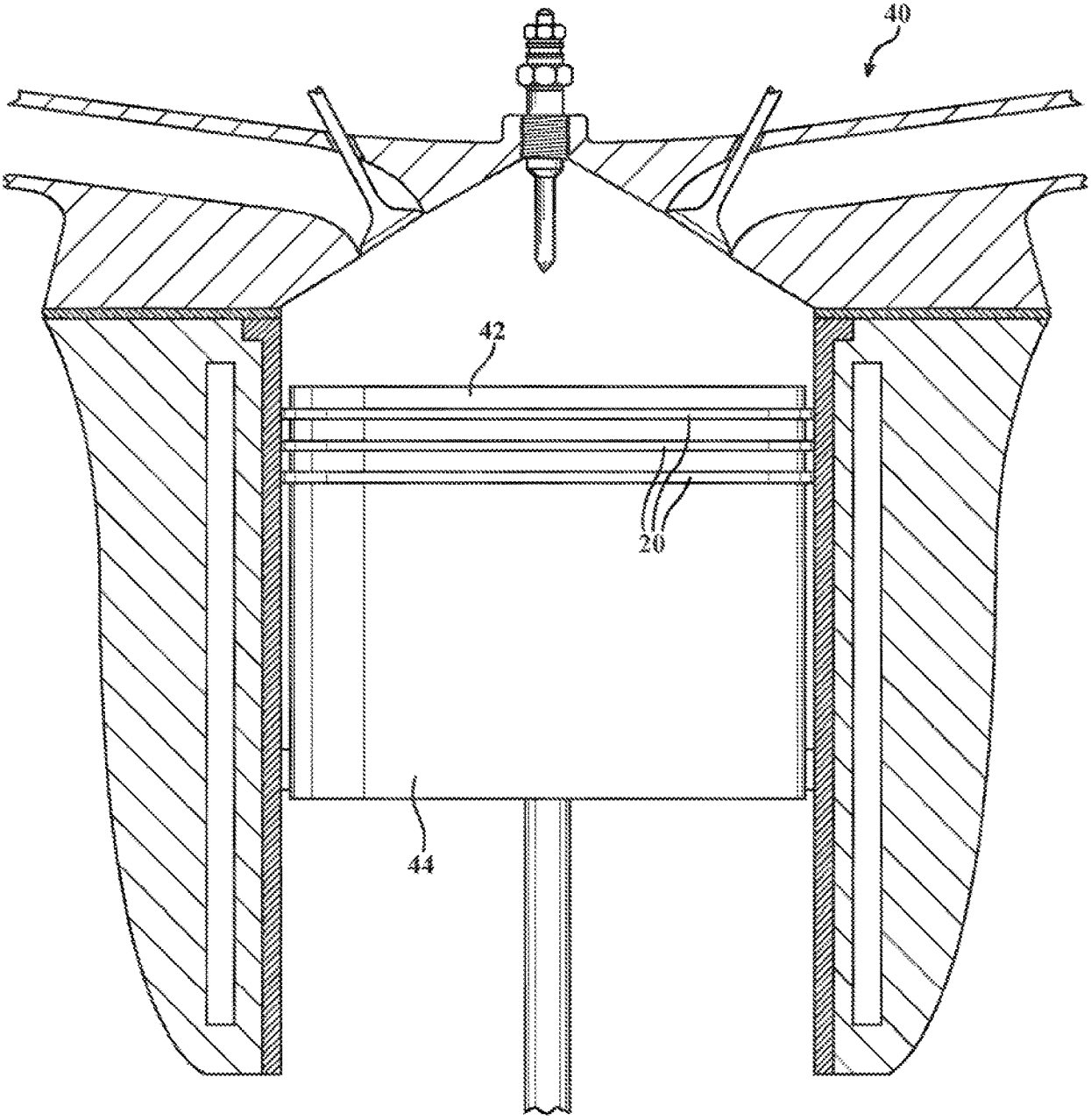

FIG. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2020/049828

A. CLASSIFICATION OF SUBJECT MATTER
INV. C23C28/04 C23C14/06 C23C30/00 F16J9/00
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)
C23C F16J

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2014/183180 A1 (MAHLE METAL LEVE SA [BR]; MAHLE INT GMBH [DE]) 20 November 2014 (2014-11-20) page 5; claims 1-6; figures 2, 3	1-20
A	WO 2018/220192 A1 (MAHLE INT GMBH [DE]) 6 December 2018 (2018-12-06) paragraphs [0018], [0019], [0030]; claims 1-19	1,8,10, 12,15,19
A	US 2013/075977 A1 (AN JEONG UK [KR]) 28 March 2013 (2013-03-28) claims 1-12	1,8,10, 12,15,19
A	US 2018/010689 A1 (TOTH JAMES R [US] ET AL) 11 January 2018 (2018-01-11) claims 1-24	1-20

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search	Date of mailing of the international search report
20 October 2020	28/10/2020

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2020/049828

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