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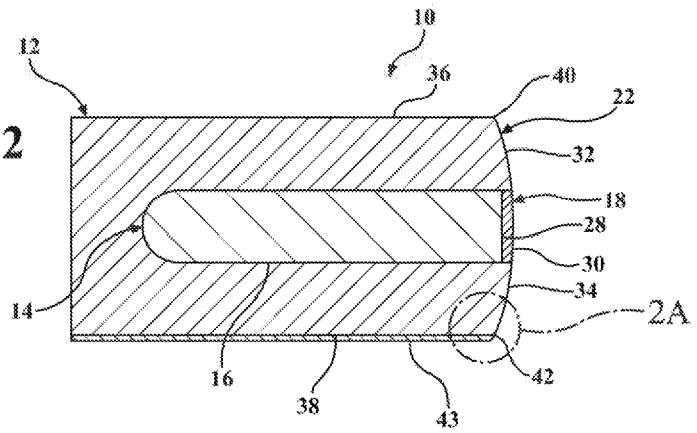
FIG. 2



(57) Abstract: A piston ring (10) providing improved performance during operation, including reduction in blowby gases and improved oil control, is provided. The piston ring (10) includes a rail (14) disposed in a recess (16) of a wire (12). The wire (12) presents a wire outer diameter surface (22), the rail (14) presents a rail outer diameter surface (28), and a coating (18) including diamond-like carbon is disposed on the rail outer diameter surface (28). The coating (18) is inlaid and thus an exposed sharp upper corner (40) is present between an upper portion (32) of the wire outer diameter surface (22) and an upper ring surface (36), and an exposed sharp lower comer (42) is present between a lower portion (34) of the wire outer diameter surface (22) and a lower ring surface (38).

WO 2020/180925 A1

PISTON RING WITH INLAID DLC COATING AND METHOD OF MANUFACTURING

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to U.S. Utility Patent Application Serial No. 16/291,832, filed March 4, 2019, the entire disclosure of which is incorporated herein by reference of its entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0002] The present invention is related generally to piston rings and methods of manufacturing piston rings.

2. Related Art

[0003] Internal combustion engine manufacturers are encountering increasing demands to improve engine efficiencies and performance, including, but not limited to, improving fuel economy, improving fuel combustion, reducing oil consumption, increasing the exhaust temperature for subsequent use of the heat, increasing compression loads within the cylinder bores, decreasing weight and making engines more compact. In order to satisfy one or more of these demands, many engine manufacturers have been employing advanced technologies to increase the temperature and pressure loads within the combustion chambers of their engines. Consequently, such pistons must be sealed to their respective cylinder bores with piston rings that are designed to withstand the increasingly extreme environment. Improvements to piston ring performance is desired.

SUMMARY

[0004] One aspect of the present invention provides a piston ring for a piston of an internal combustion engine. The piston ring provides for improved performance, specifically a reduction in blowby gases and improved oil control. The piston ring includes a wire formed of a metal material extending circumferentially around a center axis. The wire

presents a wire outer diameter surface which includes a recess. The piston ring also includes a rail formed of steel extending circumferentially around the center axis and disposed in the recess of the wire. The rail presents a rail outer diameter surface. A coating including diamond-like carbon is disposed on the rail outer diameter surface.

[0005] Another aspect of the invention provides a method of manufacturing a piston ring. The method comprises providing a rail formed of steel and extending circumferentially around a center axis, the rail presents a rail outer diameter surface. The method also includes disposing a coating including diamond-like carbon on the rail outer diameter surface. The method further includes providing a wire formed of a metal material and extending circumferentially around a center axis, and the wire presents a wire outer diameter surface which includes a recess. The method further includes disposing the rail in the recess of the wire.

[0006] Yet another aspect of the invention provides a piston assembly. The piston assembly comprises a piston body portion. At least one piston ring is disposed on the piston body portion. Each of the at least one piston ring includes a wire and a rail. The wire is formed of a metal material extending circumferentially around a center axis. The wire presents a wire outer diameter surface which includes a recess. A rail formed of steel extends circumferentially around the center axis and is disposed in the recess of said wire. The rail presents a rail outer diameter surface. A coating including diamond-like carbon is disposed on the rail outer diameter surface.

[0007] Another aspect of the invention includes a method of manufacturing a piston assembly. The method comprises providing a piston body portion; and disposing at least one piston ring on the piston body portion. Each of the at least one piston ring includes a wire formed of a metal material extending circumferentially around a center axis. The wire presents a wire outer diameter surface which includes a recess. A rail formed of steel and

extending circumferentially around the center axis is disposed in the recess of the wire. The rail presents a rail outer diameter surface. The method further includes disposing a coating including diamond-like carbon on the rail outer diameter surface.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] 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:

[0009] Figure 1 is top view of a piston ring according to an example embodiment;

[0010] Figure 2 is a cross-sectional view of the piston ring according to the example embodiment;

[0011] Figure 2A is an enlarged view of a portion of the piston ring of Figure 2; and

Figure 3 is a side view of a piston assembly including a piston ring according to an example embodiment.

DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0012] As shown in Figures 1-3, the invention provides a piston ring **10** for an internal combustion engine which is capable of providing improved performance during operation, including reduction in blowby gases and improved oil control. As shown in Figure 2, the piston ring **10** has a two-piece design including a wire **12** and a rail **14**. The rail **14** is disposed in a recess **16** of the wire **12**. A coating **18** including diamond-like carbon is disposed on the rail **12**.

[0013] The wire **12** is formed of a metal material and extends circumferentially around a center axis **A** between opposite wire ends **20**. A wire gap **26** is located between the wire ends **20**. The wire **12** presents a wire outer diameter surface **22** which includes the recess **16**.

[0014] The rail **14** is formed of steel and extends circumferentially around the center axis **A** between opposite rail ends **24**. A rail gap **27** is located between the rail ends **24**. Preferably, the rail ends **24** are circumferentially misaligned aligned with the wire ends **20**, and the rail gap **27** is circumferentially misaligned with the wire gap **26**. For example, as shown in Figure 1, the rail ends **24** and the rail gap **27** can be disposed 180 degrees from the wire ends **20** and the wire gap **26**. Thus, the wire gap **26** and the rail gap **27** are staggered. The rail **14** also presents a rail outer diameter surface **28**.

[0015] The coating **18** which includes diamond-like carbon can be referred to as a DLC coating. According to a preferred embodiment, the coating **18** is free of hydrogen. The coating **18** is disposed on the rail outer diameter surface **28**, and the coating **18** presents a coating outer diameter surface **30**. The coating **18** is preferably not disposed on the wire outer diameter surface **22** and thus a smaller axial higher of the ring **10** is coated, compared to rings with a coating on an entire outer diameter surface, which can increase the capacity of the DLC furnace.

[0016] As best shown in Figure 2, the wire outer diameter surface **22** and the coating outer diameter surface **30** are outermost surfaces of the piston ring **10**, and those surfaces are convex in shape. The wire outer diameter surface **22** includes an upper portion **32** spaced from a lower portion **34** by the coating outer diameter surface **30**. The rail outer diameter surface **28** is disposed radially inwardly of the upper portion **32** and the lower portion **34** of the wire outer diameter surface **22**. In the example embodiment, the coating outer diameter surface **30** is flush with the upper portion **32** and the lower portion **34** of the wire outer diameter surface **22**.

[0017] The wire **12** also presents an upper ring surface **36** and a lower ring surface **38** opposite the upper ring surface **36**. An upper corner **40** is located between the upper ring surface **36** and the upper portion **32** of the wire outer diameter surface **22**, and a lower corner

42 is located between the lower ring surface **38** and the lower portion **34** of the wire outer diameter surface **22**. The upper and lower corners **40, 42** of the wire **12** are sharp.

[0018] The coating **18** is not disposed on the corners **40, 42** of the wire **12**. Thus, the upper and lower corners **40, 42** remain exposed. Preferably, the coating **18** is spaced from the upper corner **40** by the upper portion **32** of the wire outer diameter surface **22**, and the coating **18** is spaced from the lower corner **42** by the lower portion **34** of the wire outer diameter surface **22**. When the piston ring **10** is used in an internal combustion engine, the exposed and uncoated sharp corners **40, 24** help to control the oil consumption and reduce blowby gases during operation.

[0019] To improve wear resistance, a layer **43** of chrome can be disposed on the lower ring surface **38**, as shown in Figure 2A. The chrome layer **43** could have a thickness of 5 microns. Alternatively, all surfaces of the wire **12** can be nitrided, so that nitrogen is diffused into the wire **12**.

[0020] Another aspect of the invention provides a method of manufacturing the piston ring **10**. The method generally comprises the steps of providing the rail **14**; disposing the coating **18** on the rail outer diameter surface **28**; providing the wire **12**; and disposing the rail **14** in the recess **16** of the wire **12**. The method can also include applying the layer **43** of chrome to the lower ring surface **38**, or nitriding all surfaces of the wire **12**.

[0021] Yet another aspect of the invention provides a piston assembly **44** including the two-piece DLC coated piston ring **10**. An example of the piston assembly **44** is shown in Figure 3. The piston assembly **44** of the example embodiment includes a piston body portion **46** which includes a crown **48** having a plurality of ring grooves **50** extending circumferentially around the center axis **A**. The piston assembly **44** includes at least one of the piston rings **10** disposed in one of the ring grooves **50**. In the example embodiment, the

piston ring **10** is disposed in a top one of the ring grooves **50**. The piston assembly **44** can also include other types of piston rings in the lower ring grooves **50**.

[0022] Another aspect of the invention provides a method of manufacturing the piston assembly **44**. The method includes providing the piston body portion **46**, disposing at least one of the piston rings **10** on the piston body portion **46**; and disposing the coating **18** including diamond-like carbon on the rail **14**.

[0023] Obviously, 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 contemplated that all features described 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 wire formed of a metal material extending circumferentially around a center axis;

said wire presenting a wire outer diameter surface which includes a recess;

a rail formed of steel extending circumferentially around said center axis and being disposed in said recess of said wire;

said rail presenting a rail outer diameter surface; and

a coating including diamond-like carbon disposed on said rail outer diameter surface.

2. A piston ring according to claim 1, wherein said wire presents an upper ring surface and a lower ring surface opposite said upper ring surface; said wire includes a upper corner between said upper ring surface and an upper portion of said wire outer diameter surface; said wire includes a lower corner between said lower ring surface and a lower portion of said wire outer diameter surface; said coating is spaced from said upper corner by said upper portion of said wire outer diameter surface; and said coating is spaced from said lower corner by said lower portion of said wire outer diameter surface.

3. A piston ring according to claim 2, wherein said upper and lower corners of said wire are exposed and are sharp.

4. A piston ring according to claim 1, wherein said wire extends circumferentially around said center axis between opposite wire ends; said rail extends circumferentially around said center axis between opposite rail ends; a wire gap is located between said wire ends; a rail gap is located between said rail ends; and said rail gap is circumferentially misaligned with said wire gap.

5. A piston ring according to claim 1, wherein said coating presents a coating outer diameter surface; and said wire outer diameter surface and said coating outer diameter are convex.

6. A piston ring according to claim 1, wherein said wire outer diameter surface includes an upper portion spaced from a lower portion by said coating outer diameter surface; said rail outer diameter surface is disposed radially inwardly of said upper portion and said lower portion of said wire outer diameter surface; and said coating outer diameter surface is flush with said upper portion and said lower portion of said wire outer diameter surface.

7. A piston ring according to claim 1, wherein a layer of chrome is disposed on said wire.

8. A piston ring according to claim 1, wherein nitrogen is diffused into said wire adjacent said wire outer diameter surface.

9. A piston ring according to claim 1, wherein said wire extends circumferentially around said center axis between opposite wire ends;

said rail extends circumferentially around said center axis between opposite rail ends;

a wire gap is located between said rail ends;

a rail gap is located between said wire ends;

said rail gap is circumferentially aligned with said wire gap;

said coating presents a coating outer diameter surface;

said wire outer diameter surface and said coating outer diameter surface are outermost surfaces of said piston ring;

said wire outer diameter surface and said coating outer diameter surface are convex;

said wire outer diameter surface includes an upper portion spaced from a lower portion by said coating outer diameter surface;

said rail outer diameter surface is disposed radially inwardly of said upper portion and said lower portion of said wire outer diameter surface;

said coating outer diameter surface is flush with said upper portion and said lower portion of said wire outer diameter surface;

said wire presents an upper ring surface and a lower ring surface opposite said upper ring surface;

said wire includes an upper corner between said upper ring surface and said upper portion of said wire outer diameter surface;

said wire includes a lower corner between said lower ring surface and said lower portion of said wire outer diameter surface;

said upper and lower corners of said wire are sharp;

said coating is spaced from said upper corner by said upper portion of said wire outer diameter surface;

said coating is spaced from said lower corner by said lower portion of said wire outer diameter surface;

said coating is not disposed on said upper and lower corners of said wire;

said upper and lower corners of said wire are exposed; and

said coating is free of hydrogen.

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

providing a rail formed of steel and extending circumferentially around a center axis, the rail presenting a rail outer diameter surface;

disposing a coating including diamond-like carbon on the rail outer diameter surface;

providing a wire formed of a metal material and extending circumferentially around a center axis, the wire presenting a wire outer diameter surface which includes a recess; and

disposing the rail in the recess of the wire.

11. A method according to claim 10, wherein the wire presents an upper ring surface and a lower ring surface opposite the upper ring surface; the wire includes an upper corner between the upper ring surface and an upper portion of the wire outer diameter surface; the wire includes a lower corner between the lower ring surface and a lower portion of the wire outer diameter surface; the coating is spaced from the upper corner by the upper portion of the wire outer diameter surface; and the coating is spaced from the lower corner by the lower portion of the wire outer diameter surface.

12. A method according to claim 10 including applying a layer of chrome to the wire.

13. A method according to claim 10 including nitriding the wire.

14. A piston assembly, comprising:

a piston body portion;

at least one piston ring disposed on said piston body portion;

each of said at least one piston ring including:

a wire formed of a metal material extending circumferentially around a center axis;

said wire presenting a wire outer diameter surface which includes a recess;

a rail formed of steel extending circumferentially around said center axis and being disposed in said recess of said wire;

said rail presenting a rail outer diameter surface; and

a coating including diamond-like carbon disposed on said rail outer diameter surface.

15. A piston assembly according to claim 14, wherein said wire extends circumferentially around said center axis between opposite wire ends; said rail extends circumferentially around said center axis between opposite rail ends; a wire gap is located between said wire ends; a rail gap is located between said rail ends; and said rail gap is circumferentially misaligned with said wire gap.

16. A piston assembly according to claim 14, wherein a layer of chrome is disposed on said wire.

17. A piston assembly according to claim 14, wherein said piston body includes a crown having a plurality of ring grooves extending circumferentially around said center axis; and each of said at least one piston ring is disposed in one of said ring grooves.

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

providing a piston body portion;

disposing at least one piston ring on the piston body portion;

each of the at least one piston ring including a wire formed of a metal material extending circumferentially around a center axis, the wire presenting a wire outer diameter surface which includes a recess, a rail formed of steel extending circumferentially around the center axis and being disposed in the recess of the wire, and the rail presenting a rail outer diameter surface; and

disposing a coating including diamond-like carbon on the rail outer diameter surface.

19. A method according to claim 18 including a plurality of the piston rings; wherein the wire extends circumferentially around the center axis between opposite wire ends; the rail extends circumferentially around the center axis between opposite rail ends; a

wire gap is located between the wire ends; a rail gap is located between the rail ends; and the rail gap is circumferentially misaligned with the wire gap.

20. A method according to claim 18 including applying a layer of chrome to the wire or nitriding the wire.

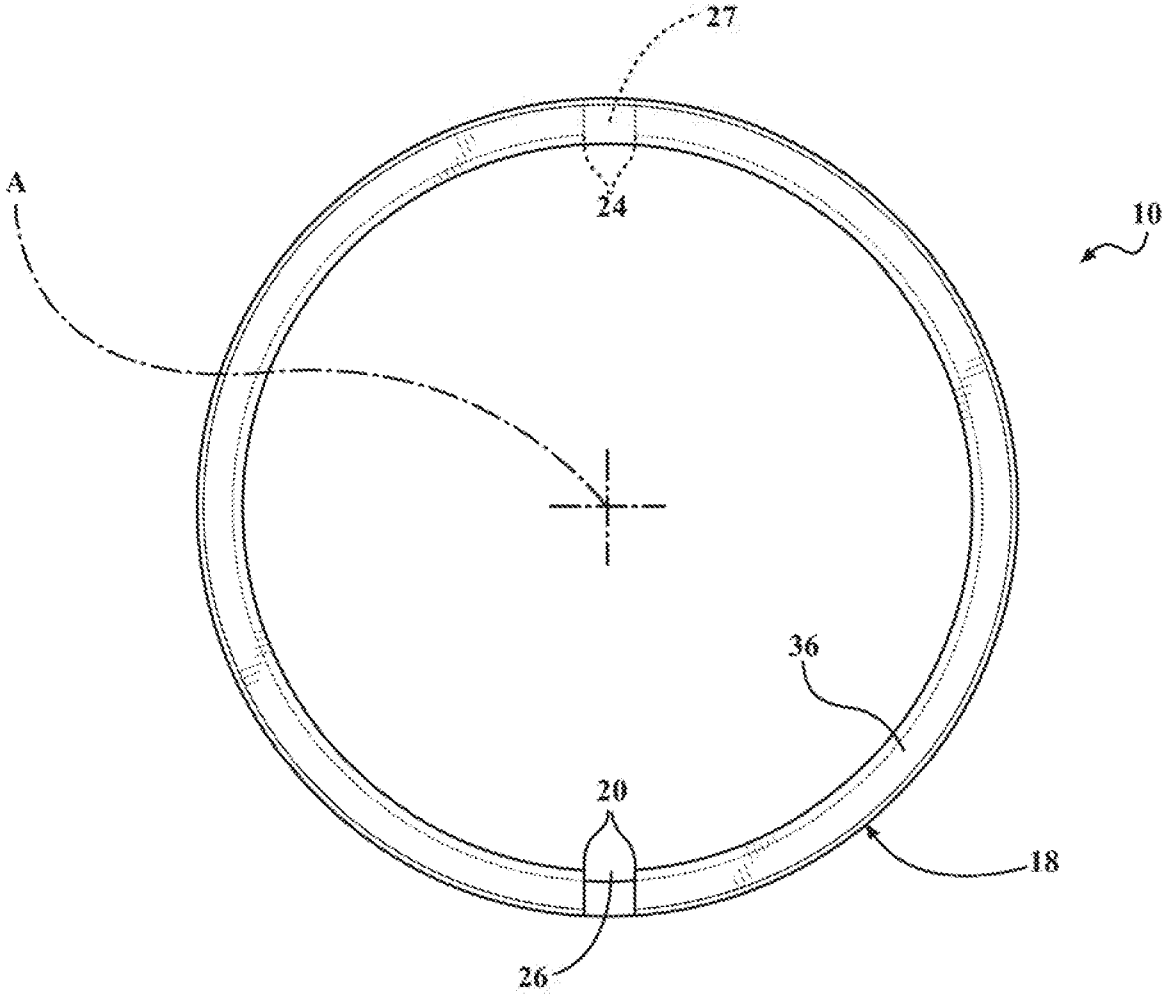


FIG. 1

FIG. 2

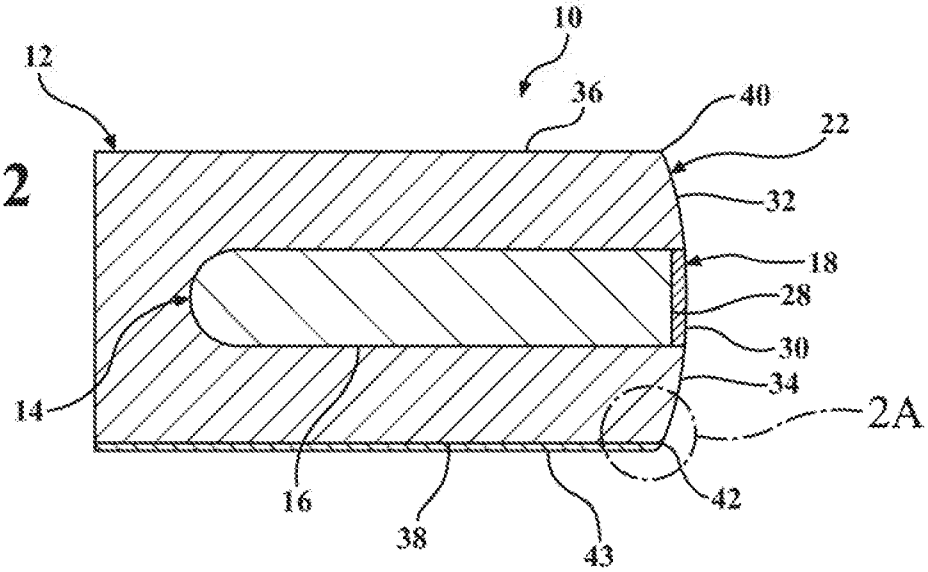
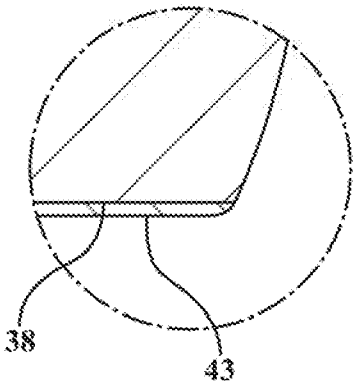


FIG. 2A



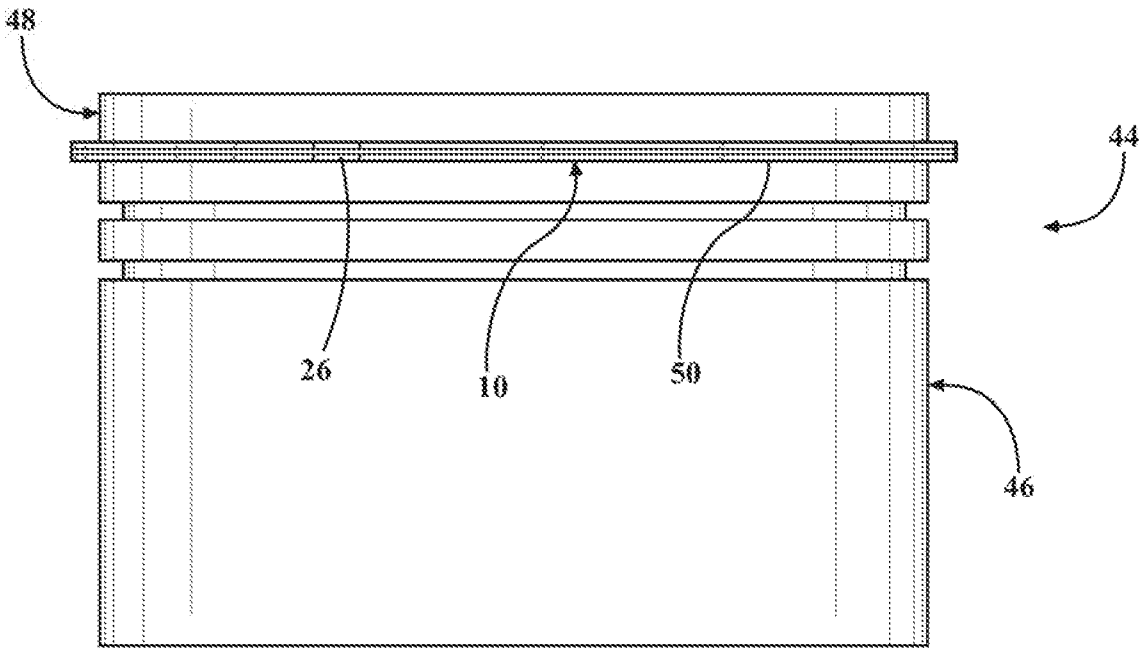


FIG. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2020/020880

A. CLASSIFICATION OF SUBJECT MATTER
INV. F16J9/20 F16J9/26
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)
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, 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	DE 10 2012 018706 B3 (FEDERAL MOGUL BURSCHEID GMBH [DE]) 12 December 2013 (2013-12-12) paragraphs [0026] - [0031] figures 1-3	1-20
A	FR 1 556 365 A (TEIKOKU PISTON RING KABUSHIKI KAISHA) 7 February 1969 (1969-02-07) page 2, column 1, lines 30-44 figure 4	7,12,16, 20
A	US 5 405 154 A (TSUCHIYA TAKESHI [JP] ET AL) 11 April 1995 (1995-04-11) column 3, lines 30-39 figures 1, 2, 4, 5	8,13,20

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

☒ See patent family annex.

* Special categories of cited documents :

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 June 2020	25/06/2020

Name and mailing address of the ISA/	Authorized officer
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1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2020/020880

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