(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 4 209 671 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
12.07.2023 Bulletin 2023/28

(21) Application number: **23150815.1**

(22) Date of filing: **09.01.2023**

(51) International Patent Classification (IPC):
F02F 1/00 *(2006.01)*

(52) Cooperative Patent Classification (CPC):
F02F 1/004; F02F 2001/006

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA
Designated Validation States:
KH MA MD TN

(30) Priority: **10.01.2022 GB 202200257**

(71) Applicant: **Caterpillar Energy Solutions GmbH**
68167 Mannheim (DE)

(72) Inventor: **Guisasola, Inigo**
68167 Mannheim (DE)

(74) Representative: **Nordmeyer, Philipp Werner**
df-mp Dörries Frank-Molnia & Pohlman
Patentanwälte Rechtsanwälte PartG mbB
Theatinerstraße 16
80333 München (DE)

(54) **CYLINDER LINER WITH SCRAPER EDGE BUT WITHOUT SCRAPER RING**

(57) The present invention pertains to a cylinder liner for a cylinder of a combustion engine and a method for producing a cylinder liner as well as a combustion engine comprising at least one cylinder with a corresponding cylinder liner, in particular to improve stiffness and fatigue strength of the cylinder liner and/or to reduce pressure differences between a combustion chamber and an upper part of a piston. Accordingly, a cylinder liner (10) for a cylinder of a combustion engine is suggested, which comprises a longitudinally extending wall, wherein an inner diameter of the wall defines a bore (12) configured for receiving a piston and wherein the wall defines a protrusion (14) extending into the bore (12) and beyond the wall in a radially inward direction. An upper wall portion (16) directly adjacent to the protrusion (14) and extending to a combustion region end portion of the cylinder liner (10) comprises an inner diameter (18) that is larger than an inner diameter (22) of a bottom wall portion (20) directly adjacent to the protrusion (14) and extending to an opposing end portion of the cylinder liner (10).

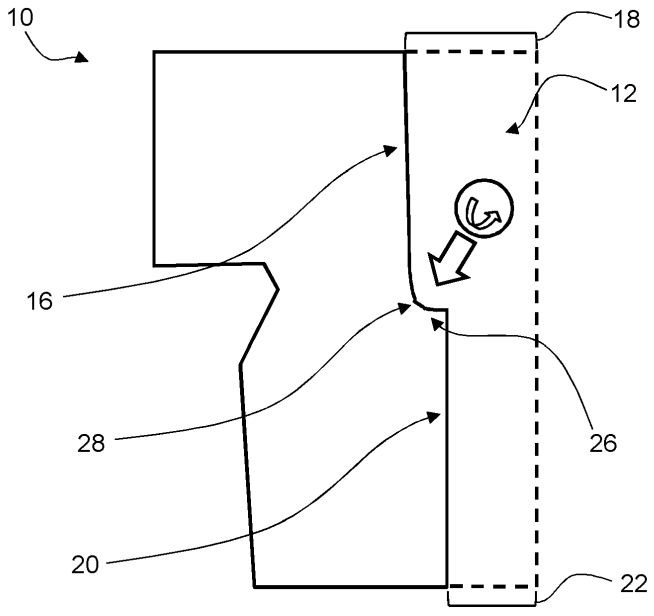

Fig. 1

EP 4 209 671 A1

Description

Technical Field

[0001] The present invention pertains to a cylinder liner for a cylinder of a combustion engine and a method for producing a cylinder liner as well as a combustion engine comprising at least one cylinder with a corresponding cylinder liner, in particular to improve stiffness and fatigue strength of the cylinder liner and/or to reduce pressure differences between a combustion chamber and an upper part of a piston.

Technological Background

[0002] Cylinder liners are commonly used in cylinders of a combustion engine in order to ensure proper functioning of a piston received therein, in particular by providing a sliding functionality during reciprocal action of the piston. Such cylinder liners generally comprise a fire ring or scraper ring, which extend from a top portion of the cylinder liner towards the intended position. The generally large dimensions of such scraper ring result in a significant reduction of the material thickness of the cylinder liner, since an accordingly dimensioned recess is provided. Furthermore, the thickness of the cylinder liner is generally already reduced at the level of an outer recess for mounting the cylinder liner in a respective cylinder. Common recesses hence significantly reduce the stiffness of the cylinder liner and result in an increase of stresses, which increase the risk of fatigue cracks that hence reduce the longevity and durability of the cylinder liner.

[0003] Furthermore, the dimensioning of the ring-shaped element and a corresponding recess results in pressure differences, e.g. a loss of pressure, between an adjacent combustion area and the piston, e.g. at the top land thereof. These pressure differences are considered to be further detrimental for the material strength and furthermore reduce the functionality of the piston.

[0004] Accordingly, there is a need to improve the structural stability of the cylinder liner, in particular in the region of the scraper ring.

Summary of the invention

[0005] Starting from the prior art, it is an objective to provide a new and inventive cylinder liner for a cylinder of a combustion engine and a method to produce such cylinder. In particular, it may be an objective to provide a cylinder liner with improved stiffness and fatigue strength and/or which reduces pressure differences between a combustion chamber and an upper part of a piston.

[0006] This objective is solved by means of a cylinder liner for a cylinder of a combustion engine with the features of claim 1. Preferred embodiments are set forth in the present specification, the Figures as well as the dependent claims.

[0007] Accordingly, a cylinder liner for a cylinder of a combustion engine is suggested, which comprises a longitudinally extending wall, wherein an inner diameter of the wall defines a bore configured for receiving a piston and wherein the wall defines a protrusion extending into the bore and beyond the wall in a radially inward direction. An upper wall portion directly adjacent to the protrusion and extending to a combustion region end portion of the cylinder liner comprises an inner diameter that is larger than an inner diameter of a bottom wall portion directly adjacent to the protrusion and extending to an opposing end portion of the cylinder liner.

[0008] Furthermore, a method of producing a cylinder liner is suggested, comprising the steps of:

- honing a wall of a cylinder liner defining a bore for receiving a piston; and
- subsequently rolling a portion of the wall so as to form an indent in said wall portion defining an enlarged inner diameter of the bore, wherein the rolling is performed such that the forming of the indent results in the formation of a protrusion extending into the bore and beyond the wall in a radially inward direction, wherein the protrusion is formed directly adjacent to the indent.

[0009] Furthermore, a combustion engine is suggested, which comprises at least one cylinder having a cylinder liner according to the invention.

Brief description of the drawings

[0010] The present disclosure will be more readily appreciated by reference to the following detailed description when being considered in connection with the accompanying drawings in which:

Figure 1 shows a schematic longitudinal section of a top portion of a cylinder liner prior to the formation of a protrusion;
Figure 2 shows a detailed section of the cylinder liner according to Figure 1 with a formed protrusion;
Figure 3 shows a detailed depiction of an alternative protrusion;
Figure 4 shows a detailed depiction of another alternative protrusion; and
Figure 5 schematically depicts a method for providing a protrusion for a cylinder liner having an alternative wall configuration.

Detailed description of preferred embodiments

[0011] In the following, the invention will be explained in more detail with reference to the accompanying figures. In the Figures, like elements are denoted by identical reference numerals and repeated description thereof may be omitted in order to avoid redundancies.

[0012] In Figure 1 a cylinder liner 10 for a cylinder of a combustion engine is shown in a schematic depiction and along a longitudinal section prior to the formation of a protrusion. The cylinder liner 10 is only shown for a top portion, wherein a combustion area may be present at the top end. The cylinder liner 10 may hence extend further towards a bottom end section, e.g. a gear section of a combustion engine. The cylinder liner 10 is formed of a solid material, preferably steel and is shaped and dimensioned so as to provide a liner for a cylinder of a combustion engine, wherein a corresponding outer recess (shown on the left side) and a top flange or annular portion is present to facilitate the mounting of the cylinder liner 10 in a cylinder.

[0013] The cylinder liner 10 is essentially formed as a longitudinally extending wall, which defines a continuous inner cavity formed as a bore 12, which is indicated with the dashed lines. The bore 12 is configured and adapted to receive and accommodate a piston of the combustion engine therein in a reciprocal arrangement. In Figure 1, the longitudinal section only depicts one radial end towards a longitudinal axis, which is delimited by the right dashed line in the Figure. Accordingly, the cylinder liner 10 is symmetrically formed and may be mirrored along said line to form an essentially cylindrical bore 12 and wall.

[0014] The wall of the cylinder liner 10 furthermore comprises a step 26, which connects an upper wall portion 16 and a bottom wall portion 20 via an inner radius 28. The step 26 extends in a radial direction and essentially corresponds to a difference between the inner diameter 18 of the upper wall portion 16 and the inner diameter 22 of the bottom wall portion 20. As shown in Figure 1, the step 26 and, in particular, the inner radius 28 may be processed by means of rolling, as indicated with the corresponding symbols and arrowheads.

[0015] Figure 2 shows a detailed section of the cylinder liner 10 according to Figure 1 with a formed protrusion 14. As shown, the protrusion 14 extends radially inwards beyond the wall, defining a protruding length 15, which may e.g. be between 0.05 mm and 0.20 mm, e.g. about 0.10 mm. The protrusion 14 extends from the step 26, which has been accordingly deformed. The protrusion 14 is dimensioned as a scraper ring for a piston to be received in the bore. The protrusion 14 itself may hence form a ring-shaped element and defines a scraper edge 30, such that the provision of a separate scraper ring, which is commonly inserted in a corresponding recess of the cylinder liner, is no longer necessary. The scraper edge 30, i.e. a cokes scraper ring or fire ring, may ensure that deposits on the piston are not accumulated along the circumference thereof, so as to avoid clogging and impaired movement of the piston. To facilitate such function, the protrusion 14 hence extends into the bore 12 and beyond the wall in a radially inward direction. The wall hence forms a scraper edge and renders a separate scraper ring fully obsolete.

[0016] Furthermore, an indent 24 is provided, which is also formed by means of the rolling of the wall of the cylinder liner 10, in particular the inner radius 28 thereof. The indent 24 defines an indent depth 25, which extends beyond the inner diameter 18 of the upper wall portion 16. Accordingly, an increased inner diameter is provided directly above the protrusion 14. The increased inner diameter 18, 25 of the upper wall portion 16 and indent 24 directly above the protrusion 14 ensure that pressure differences may be reduced or essentially omitted.

[0017] This is further facilitated by the enlarged inner diameter 18 of the upper wall portion 16 as a whole, which provides that pressure differences at the protrusion 14 and an adjacent piston may be minimized, which may be advantageous to reduce the risk of fatigue cracks.

[0018] Figure 3 shows a detailed depiction of an alternative protrusion 14, wherein a radial end face has been processed, e.g. by turning, so as to define a truncated protrusion 14 having predefined dimensions, in particular a predefined height in the longitudinal direction and predefined protruding length in the radial direction. The truncated end face may provide further structural stability of the protrusion 14 and its corresponding function and may optionally also be rounded towards the upper wall portion 16.

[0019] Figure 4 shows a further detailed depiction of another alternative protrusion 14, wherein the inner diameter of the protrusion 14 gradually decreases from the step towards the bottom wall portion 20. Such shape may be further advantageous for reducing pressure differences or losses towards the edge portion 30 and the adjacent piston or top land thereof in the mounted state. The surface of the protrusion 14 extending from the step 26 or indent 24 may e.g. be flush with the surface of the step 26 or indent 24 facing the bore 12 to further optimize the flow and pressure conditions at the level of the protrusion 14.

[0020] In Figure 5 a method for providing a protrusion for a cylinder liner 10 having an alternative wall configuration is schematically depicted. In this configuration, the method or rolling step thereof is performed to a portion of an essentially continuous wall, i.e. having an essentially continuous inner diameter, which portion is then deformed by the rolling step, such that a corresponding protrusion is formed that extends radially inward from the wall and only the deformed portion, e.g. a formed indent, comprises the enlarged inner diameter directly above the protrusion.

[0021] It will be obvious for a person skilled in the art that these embodiments and items only depict examples of a plurality of possibilities. Hence, the embodiments shown here should not be understood to form a limitation of these features and configurations. Any possible combination and configuration of the described features can be chosen according to the scope of the invention.

[0022] This is in particular the case with respect to the following optional features which may be combined with some or all embodiments, items and/or features mentioned before in any technically feasible combination.

[0023] A cylinder liner for a cylinder of a combustion engine is provided.

[0024] Such cylinder liner comprises a longitudinally extending wall, wherein an inner diameter of the wall defines a bore configured for receiving a piston and wherein the wall defines a protrusion extending into the bore and beyond the wall in a radially inward direction. An upper wall portion directly adjacent to the protrusion and extending to a combustion region end portion of the cylinder liner comprises an inner diameter that is larger than an inner diameter of a bottom wall portion directly adjacent to the protrusion and extending to an opposing end portion of the cylinder liner.

[0025] The protrusion particularly extends in a circumferential manner, such that the protrusion may form a ring-shaped element protruding into the bore, preferably within a single plane.

[0026] The increase in the inner diameter directly above the protrusion has the advantage that pressure differences in this region may be minimized. Since pressure differences may adversely affect the material strength of the cylinder liner, the increase in the inner diameter may hence result in an improved fatigue strength, such that the occurrence of cracks or risk thereof may be significantly reduced.

[0027] In this regard, the cylinder liner may be configured to receive a corresponding piston in a reciprocal manner, such that an upper end of the piston, e.g. a piston head, may be received along the upper wall portion of the cylinder liner, for example, after a compression stroke. Due to the increased inner diameter directly above the protrusion, the space between the upper portion or top land of the piston and the upper wall portion of the cylinder liner is hence larger than the space between the piston and the other wall portions of cylinder liner. The minimized pressure difference in this region is hence particularly advantageous upon combustion of a combustible mixture in the adjacent combustion chamber, resulting in a movement of the piston towards the bottom wall portion, e.g. a gear end portion of the cylinder.

[0028] Furthermore, due to the fact that the protrusion is formed of the wall, i.e. integrally or monolithically formed therewith, no further components or adjustments to the wall are required to ensure that the protrusion is maintained at the intended position. Accordingly, common recesses to insert a protrusion or ring-shaped element at the functionally intended position, may be omitted. Thereby, the thickness of the cylinder liner may be improved and further undesirable mechanical stresses may be avoided, such that the fatigue strength of the cylinder liner may be significantly improved. This is particularly the case at a region, where the cylinder liner already comprises a reduced thickness, e.g. at the level of an outer recess for mounting of the cylinder liner into a respective cylinder.

[0029] Preferably, the protrusion is dimensioned as a scraper ring for a piston to be received in the bore. The protrusion itself may hence form a ring-shaped element defining a scraper edge, such that the provision of a separate scraper ring, which is commonly inserted in a corresponding recess of the cylinder liner, is no longer necessary. The scraper ring, i.e. a cokes scraper ring or fire ring may ensure that deposits on the piston are not accumulated along the circumference thereof, so as to avoid clogging and impaired movement of the piston. To facilitate such function, the protrusion hence extends into the bore and beyond the wall in a radially inward direction. The wall hence forms a scraper edge and renders a separate scraper ring fully obsolete. The increased inner diameter of the upper wall portion directly above the protrusion thereby still ensures that pressure differences may be reduced or essentially omitted.

[0030] A portion of the upper wall portion being directly adjacent to the protrusion may comprise an indent extending at least partially in the radial direction and having a larger inner diameter than the upper wall portion extending from said indent towards the combustion region end portion. In other words, a cavity may be provided directly above the protrusion and a depth of the cavity into the wall may exceed the remaining radial extension or inner diameter of the upper wall portion. The indent hence ensures that pressure differences or losses may be counteracted directly at the level of the protrusion, e.g. at the level of the scraper ring.

[0031] Preferably, the indent is a rolled indent of the wall and the protrusion is formed by the indent. By means of rolling, the local stresses within the wall of the cylinder liner are modified, resulting in a change of shape of the material of the wall. By means of the rolling, such stresses may hence result in the formation of the protrusion, which may be accordingly optimized in terms of size, shape and structural characteristics that would not be available using other techniques such as milling or turning. The rolling is hence particularly advantageous, since it may further increase the fatigue strength at the level of the protrusion and of the protrusion itself. While the indent is formed in such a manner that an increase of the inner diameter is provided, i.e. in a radial direction, the indent may also, additionally and at least partially, form a depression in a longitudinal direction, if desirable for the formation of the protrusion.

[0032] The enlarged inner diameter may be provided at least at the level directly adjacent to the protrusion. Preferably, the inner diameter of the entire upper wall portion is larger than the inner diameter of the entire bottom wall portion. Thereby, pressure differences at the level of the protrusion may be further reduced, which is further advantageous to improve the fatigue strength of the cylinder liner and reduce the risk of fatigue cracks.

[0033] To provide such difference between the inner diameter of the upper wall portion and the inner diameter of the bottom wall portion, the protrusion may extend from a step between the upper wall portion and the bottom wall portion. Such step may be formed in an essentially radial direction, but may also extend, at least partially, in a longitudinal direction, e.g. in an oblique manner. Pref-

erably, the step may comprise the indent at the outer radial end while comprising or forming the protrusion at the inner radial end, such that the indent and protrusion are essentially at the same level in a longitudinal direction. For example, the step may comprise an inside radius, which is rolled so as to form a deformation of the step, resulting in both the indent and the protrusion.

[0034] A variety of shapes may be provided for the protrusion, depending on the required functionality of the protrusion and a geometry and size of an adjacent piston in the mounted state. Preferably, the protrusion comprises a conical shape, a V-shape, a pyramid-shape, a triangular shape, or a right trapezoid shape in a longitudinal section of the cylinder liner. Accordingly, the protrusion may form a scraper edge for an adjacent piston, wherein the edge performs the function of a scraper ring.

[0035] Alternatively, or in addition, the protrusion may be truncated and/or may define an edge surface at a portion of the protrusion defining a minimum inner diameter of the cylinder liner. As described above, the edge surface may be particularly advantageous for use as a scraper ring and may e.g. have a blade shape or barb shape in a longitudinal section of the cylinder liner. Such shape may furthermore provide a self-sharpening function. A truncated end of the protrusion may be advantageous to increase the longitudinal dimension of the portion of the protrusion that may be brought into contact with other components, e.g. cokes deposits or a moving element, so as to increase the robustness of the protrusion and corresponding functionality.

[0036] A ratio between the protruding length of the protrusion extending beyond the wall and a height of the protrusion in the longitudinal direction may be 1:1 to 1:5, preferably 1:1 to 1:3. For example, the protruding length beyond the wall into the bore may be between 0.05 mm and 0.25 mm whereas the height of the protrusion may be essentially the same or larger, e.g. between 0.1 mm and 0.35 mm, for example. These dimensions may vary depending on the combustion engine and the required functionality or robustness.

[0037] Although the upper wall portion may be formed having an essentially continuous inner diameter, the inner diameter of the upper wall portion may also gradually increase in a direction facing away from the protrusion. The upper wall portion may at least partially comprise a conical shape, funnel shape, concave shape, and/or parabolic shape in a longitudinal section of the cylinder liner.

[0038] Thereby, a further flow and/or pressure optimization may be provided and an even larger inner diameter may be implemented, at least partially, for the upper wall portion. The gradual increase may be a linear, curvilinear and/or essentially stepless increase, which is further beneficial for optimizing the flow and/or pressure conditions.

[0039] The preferred shape may be advantageous to further reduce any potentially occurring pressure differences and avoid the presence of steps, which may be adverse for optimizing the flow and pressure conditions at the upper portion of the cylinder liner.

[0040] Furthermore, a combustion engine is suggested, preferably a gas engine, comprising at least one cylinder fitted with a cylinder liner as described in the above.

[0041] For each cylinder, a piston may be provided, which is received within the respective cylinder liner. In order to facilitate the mounting of the piston, the piston is preferably mounted from the bottom side, e.g. a gear end of the cylinder. For mounting the piston from a top side of the cylinder, a device may be required that temporarily biases the protrusion without plastic deformation and/or facilitates the insertion of a piston.

[0042] According to a further aspect, a method of producing a cylinder liner is suggested, comprising the steps of:

- honing a wall of a cylinder liner defining a bore for receiving a piston; and
- subsequently rolling a portion of the wall so as to form an indent in said wall portion defining an enlarged inner diameter of the bore, wherein the rolling is performed such that the forming of the indent results in the formation of a protrusion extending into the bore and beyond the wall in a radially inward direction, wherein the protrusion is formed directly adjacent to the indent.

[0043] The protrusion may be subsequently turned so as to provide a predefined minimum inner diameter of the bore defined by protrusion and/or a predefined radial end surface of the protrusion. Preferably, the method provides a cylinder liner according to the invention.

[0044] The rolling is advantageously performed after the honing step of the cylinder liner, such that the formation of debris material at the protrusion may be avoided. As described above, the rolling step may induce local stresses at the corresponding wall portion, not only resulting in the protrusion, but which may furthermore be advantageous in terms of fatigue strength. The application of such particular stresses and distributions is not possible when performing other method steps, such as milling, and may significantly reduce production time of the protrusion.

[0045] Furthermore, an optional turning step may e.g. provide that the shape of the protrusion may be truncated according to predefined dimensions. For example, the turning step may provide that an essentially conical shape is provided with a flat or rounded surface directly adjacent to a piston received in the cylinder liner, wherein fitting tolerances may be considered, also during operation of the combustion engine.

[0046] Although the cylinder liner preferably comprises an upper wall portion having an enlarged inner diameter in its entirety, the method may also be performed to a portion of an essentially continuous wall, i.e. having an essentially continuous inner diameter, which portion is then deformed by the rolling step, such that only the deformed portion comprises the enlarged inner diameter.

Industrial Applicability

[0047] With reference to the Figures, a cylinder liner for a cylinder of a combustion engine and a method for producing a cylinder liner as well as a corresponding combustion engine equipped with such cylinder liner are suggested. The suggested cylinder liner as mentioned above is applicable in a variety of engines, such as gas engines, wherein undesirable pressure differences may occur at the region of the scraper ring or fire ring, resulting in fatigue cracks. The geometry and mechanical aspects concerning the recess receiving such scraper ring furthermore reduce the stiffness and induce stresses in the material, which directly affects the longevity of the cylinder liner. The disclosed cylinder liner may be mounted into existing cylinders or may replace current cylinder liners as a replacement or retrofit part, which may be exchanged e.g. upon or prior to overhaul or prior to use. The cylinder liner according to the invention reduces the need for separate scraper rings. The method furthermore provides an improved method that facilitates manufacturing of the cylinder liner with fewer steps while improving the structural stability of the cylinder liner and provides that the cylinder liner and a scraper ring may be formed from a single part.

List of reference numerals

[0048]

10	Cylinder liner
12	Bore
14	Protrusion
15	Protruding length
16	Upper wall portion
18	Inner diameter
20	Bottom wall portion
22	Inner diameter
24	Indent
25	Indent depth
26	Step
28	Inner radius
30	Edge

Claims

1. A cylinder liner (10) for a cylinder of a combustion engine, comprising a longitudinally extending wall, wherein an inner diameter of the wall defines a bore (12) configured for receiving a piston and wherein the wall defines a protrusion (14) extending into the bore (12) and beyond the wall in a radially inward direction and wherein an upper wall portion (16) directly adjacent to the protrusion (14) and extending to a combustion region end portion of the cylinder liner (10) comprises an inner diameter (18) being larger than an inner diameter (22) of a bottom wall portion (20) directly adjacent to the protrusion (14) and extending to an opposing end portion of the cylinder liner (10).

2. The cylinder liner (10) according to claim 1, wherein the protrusion (14) is dimensioned as a scraper ring for a piston to be received in the bore (12).

3. The cylinder liner (10) according to claim 1 or 2, wherein a portion of the upper wall portion (16) being directly adjacent to the protrusion (14) comprises an indent (24) extending at least partially in the radial direction and having a larger inner diameter than the upper wall portion (16) extending from said indent (24) towards the combustion region end portion.

4. The cylinder liner (10) according to claim 3, wherein the indent (24) is a rolled indent of the wall and the protrusion (14) is formed by the indent (24).

5. The cylinder liner (10) according to any of the preceding claims, wherein the inner diameter (18) of the entire upper wall portion (16) is larger than the inner diameter (22) of the entire bottom wall portion (20).

6. The cylinder liner (10) according to claim 5, wherein the protrusion (14) extends from a step (26) between the upper wall portion (16) and the bottom wall portion (20).

7. The cylinder liner (10) according to any of the preceding claims, wherein the protrusion (14) comprises a conical shape, a V-shape, a pyramid-shape, a triangular shape, or a right trapezoid shape in a longitudinal section of the cylinder liner (10).

8. The cylinder liner (10) according to any of the preceding claims, wherein the protrusion (14) is truncated and/or defines an edge (30) surface at a portion of the protrusion (14) defining a minimum inner diameter of the cylinder liner (10).

9. The cylinder liner (10) according to any of the preceding claims, wherein a ratio between the protruding length (15) of the protrusion (14) extending beyond the wall and a height of the protrusion (14) in the longitudinal direction is 1:1 to 1:5, preferably 1:1 to 1:3.

10. The cylinder liner (10) according to any of the preceding claims, wherein the inner diameter (18) of the upper wall portion (16) gradually increases in a direction facing away from the protrusion (14).

11. The cylinder liner (10) according to any of the preceding claims, wherein the upper wall portion (16) at least partially comprises a conical shape, funnel shape, concave shape, and/or parabolic shape in a

longitudinal section of the cylinder liner (10).

12. A combustion engine, comprising at least one cylinder having a cylinder liner (10) according to any of the preceding claims.

13. A method of producing a cylinder liner, comprising the steps of:

- honing a wall of a cylinder liner defining a bore for receiving a piston; and
- subsequently rolling a portion of the wall so as to form an indent in said wall portion defining an enlarged inner diameter of the bore, wherein the rolling is performed such that the forming of the indent results in the formation of a protrusion extending into the bore and beyond the wall in a radially inward direction, wherein the protrusion is formed directly adjacent to the indent.

14. The method according to claim 13, wherein the protrusion is subsequently turned so as to provide a predefined minimum inner diameter of the bore defined by protrusion and/or a predefined radial end surface of the protrusion.

15. The method according to claim 13 or 14, wherein the method provides a cylinder liner according to any of the preceding claims.

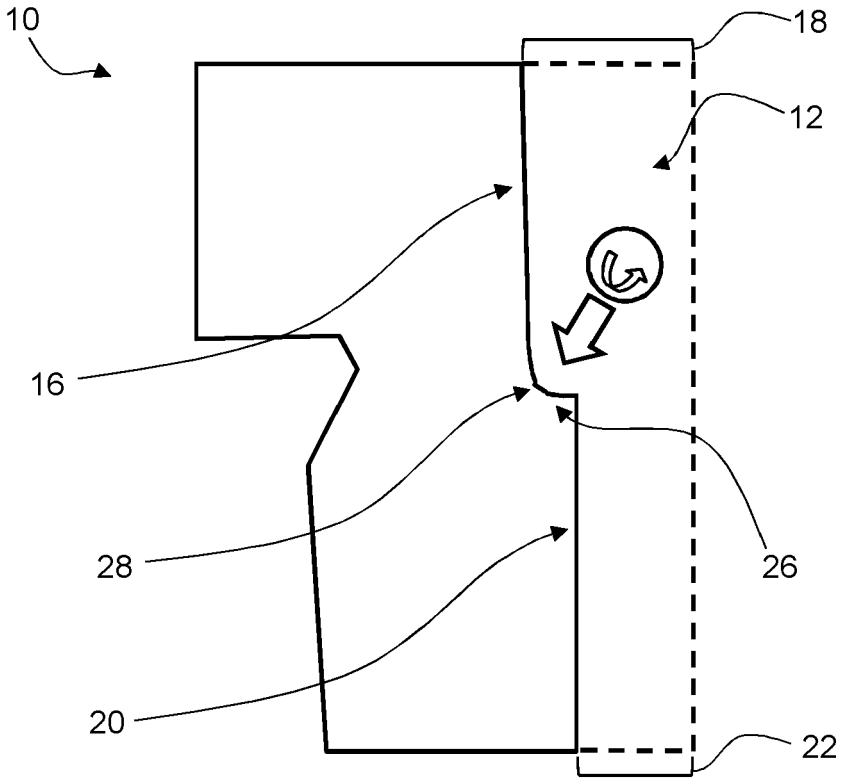

Fig. 1

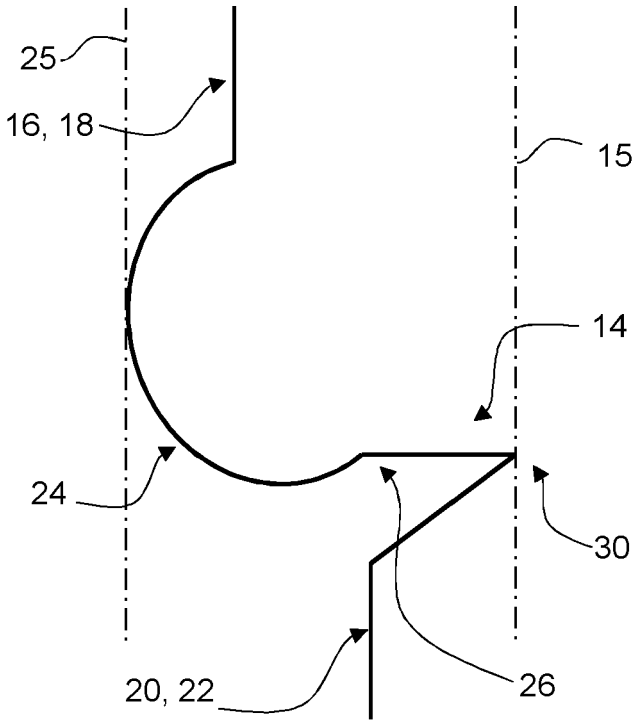

Fig. 2

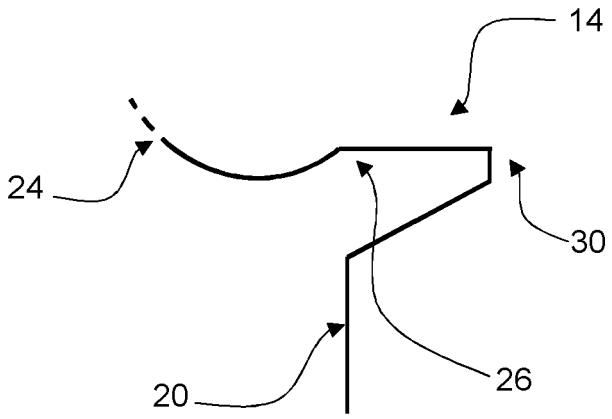

Fig. 3

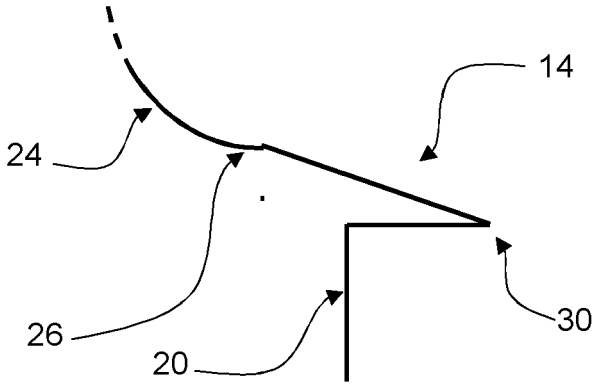

Fig. 4

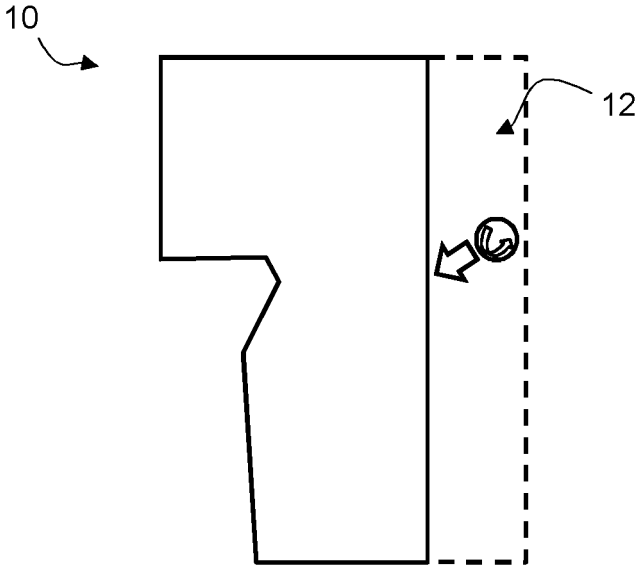

Fig. 5

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 23 15 0815

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	DE 197 43 627 A1 (MTU FRIEDRICHSHAFEN GMBH [DE]) 15 April 1999 (1999-04-15) * column 2, lines 43-63 * * figure 1 * -----	1-4,7-15 5,6	INV. F02F1/00
Y	DE 198 11 780 C1 (DAIMLER CHRYSLER AG [DE]) 26 August 1999 (1999-08-26) * column 2, line 66 - column 3, line 11 * * figures * -----	5,6	
A	WO 2021/166278 A1 (MITSUBISHI HEAVY IND ENGINE & TURBOCHARGER LTD [JP]) 26 August 2021 (2021-08-26) * figure 8 * -----	1-15	

TECHNICAL FIELDS SEARCHED (IPC)
F02F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	26 May 2023	Matray, J

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 23 15 0815

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

26-05-2023

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 19743627 A1	15-04-1999	NONE	
DE 19811780 C1	26-08-1999	NONE	
WO 2021166278 A1	26-08-2021	CN 114981533 A	30-08-2022
		EP 4074953 A1	19-10-2022
		JP 2021131028 A	09-09-2021
		KR 20220104828 A	26-07-2022
		US 2023026354 A1	26-01-2023
		WO 2021166278 A1	26-08-2021

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82