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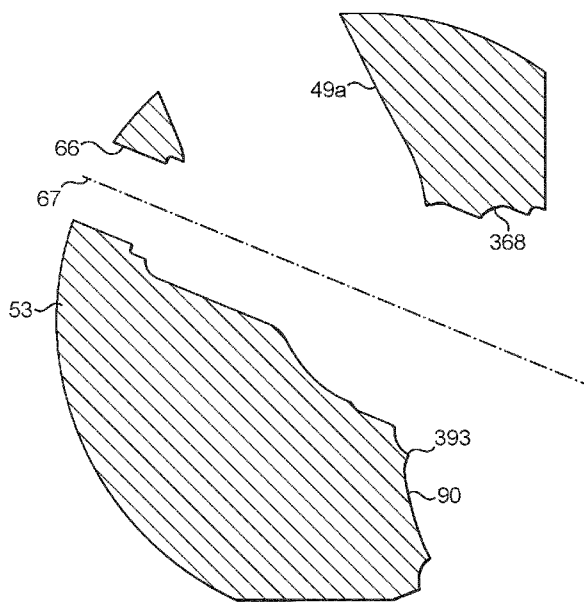


FIG. 6

(57) Abstract: A casting for an internal combustion engine comprising an air inlet opening and/or an exhaust outlet opening located in a combustion chamber. The air inlet opening (393) and/or the exhaust outlet opening form the outermost edge of an air inlet and/or exhaust outlet throat (368) which extend into the casting away from the opening(s). A portion of the air inlet and/or exhaust outlet throat is radially symmetrical about a central axis (67), and the cross-section of the throat in a plane perpendicular to the central axis comprises a radiused or a stepped profile. A method of manufacturing a component for an internal combustion engine comprising machining a radiused or stepped throat profile into a casting and laser cladding of the machined profile.



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A casting for an internal combustion engine

TECHNICAL FIELD

5 The present disclosure relates to a casting for an internal combustion engine, to a method of manufacturing a component for an internal combustion engine, to an internal combustion engine, and to a vehicle with such an engine.

BACKGROUND

10 It is known to provide cylinder heads for internal combustion engines having valve seats upon which poppet valves rest when the valves are closed during engine operation. The cylinder head is typically formed of aluminium as it is durable and can be easily cast and machined. Nonetheless, the valve seats are typically exposed to high temperatures and friction due to repeated contact with the poppet valves and thus need to exhibit greater wear resistance than
15 other portions of the cylinder head.

Traditionally, and as described in US 3285235 A, valve seats are provided with valve seat inserts to prevent excessive wear and breakage of the valve seat. However, such valve seat inserts have a number of well documented drawbacks resulting from the different coefficients of thermal expansion and thermal conductivity between the material of the cylinder head and
20 the material of the valve insert.

Patent application US 4723518 A describes laying a copper alloy upon the valve seat surface using a laser cladding technique to improve the wear resistance of the valve seat to remove the need for a valve seat insert.

It is against this background that the present invention has been made.

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SUMMARY OF THE INVENTION

Aspects and embodiments of the invention provide a cylinder head for an engine, an engine, and a vehicle with such an engine. The engine may be suitable for use with fuels including gasoline, diesel, hydrogen, LPG or any other suitable combustible fuel. The engine may be a
30 lean-burn engine.

According to an aspect of the present invention there is provided a casting for an engine, the casting comprising an air inlet opening located in a combustion chamber, wherein the air inlet opening comprises the outermost edge of an air inlet throat which extends into the casting

away from the air inlet opening, wherein a portion of the air inlet throat is radially symmetrical about a central axis, and wherein the cross-section of the air inlet throat in a plane which passes through the central axis and the edge of the air inlet throat comprises a radiused or a stepped profile.

5

The casting may comprise an exhaust outlet opening located in the combustion chamber, wherein the exhaust outlet opening comprises the outermost edge of an exhaust outlet throat which extends into the casting away from the exhaust outlet opening, wherein a portion of the exhaust outlet throat is radially symmetrical about a second central axis, and wherein the cross-section of the exhaust outlet throat in a plane which passes through the second central axis and the edge of the exhaust outlet throat comprises a radiused or a stepped profile.

10

Providing a radiused or a stepped profile at the air inlet throat and/or the exhaust outlet throat is advantageous to the quality of any subsequent a laser cladding process. Depending on the composition of the laser cladding material and the precise laser cladding process used, the machined profile can be tuned to facilitate the application of a high quality wear resistant cladding.

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Optionally, the cross-section of the air inlet throat, and/or the exhaust outlet throat where present, comprises a concave radiused profile. It has been found that a concave radiused profile is advantageous to the application of a high quality wear resistant cladding.

20

The cross-section of the air inlet throat, and/or the exhaust outlet throat where present, may optionally comprise a radiused profile having a radius of between 1mm and 5mm. Optionally, between 2.5mm and 3.5mm. It has been found that a concave radiused profile of about 3mm is advantageous to the application of a high quality wear resistant cladding.

25

In one example, the casting is a cylinder head casting, wherein the combustion chamber comprises a combustion chamber recess which extends into the cylinder head casting away from a bottom surface of the cylinder head casting, wherein the combustion chamber recess comprises a combustion chamber roof surface, and wherein the air inlet opening, and the exhaust outlet opening where present, are located in the combustion chamber roof surface.

30

In another aspect, the present invention provides a method of manufacturing a component for an engine, the method comprising providing a casting, wherein the casting comprises a combustion chamber having an air inlet opening located therein, the method of manufacturing comprising machining an air inlet throat at the air inlet opening, wherein the machined air inlet

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throat extends into the casting, and wherein a portion of the machined air inlet throat is radially symmetrical about a central axis, wherein the cross-section of the machined air inlet throat in a plane which passes through the central axis and the edge of the machined air inlet throat comprises a radiused profile. In one example, the casting comprises a cylinder head casting.

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The casting may comprise an exhaust outlet opening located in the combustion chamber and the method of manufacturing may comprise machining an exhaust outlet throat at the exhaust outlet opening, wherein the machined exhaust outlet throat extends into the casting, and wherein a portion of the machined exhaust outlet throat is radially symmetrical about a second central axis, wherein the cross-section of the machined exhaust outlet throat in a plane which passes through the second central axis and the edge of the machined exhaust outlet throat comprises a radiused profile.

10

A cladding may be applied to the machined air inlet throat, and/or the machined exhaust outlet throat where present, using a laser cladding process. Laser cladding can advantageously be applied to the inlet and/or exhaust throat to provide a wear resistant material at a position of high wear.

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Optionally the cladding may be a Nickel Aluminium (NiAl) cladding, optionally comprising Chromium Carbide (CrC) as a hardening additive.

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A laser hardening process may optionally be used after the laser cladding process to further improve wear performance.

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Optionally a portion of the cladding may be removed in a second machining process to form a valve seat.

In a further aspect, the present invention provides an engine comprising a casting as described above.

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In a still further aspect, the present invention provides a vehicle comprising an engine as described above.

35 BRIEF DESCRIPTION OF THE DRAWINGS

One or more embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 shows a vehicle in which the invention may be used;

Figure 2 shows a cross section of portion of a cylinder block and cylinder head;

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Figure 3 shows a detailed cross-sectional view of the air inlet side of the cylinder head of Figure 2;

Figure 4 shows a plan view of the underside of the cylinder head of Figure 2;

10

Figure 5 shows a plan view of the underside of the cylinder head in the “as cast” condition;

Figure 6 shows a detailed cross-sectional view of the air inlet side of the cylinder head after an intermediate machining step has been completed;

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Figure 7 shows a detailed view of the machined surface of Figure 6;

Figure 8a shows cladding depths achieved on a first curved machined profile;

20 Figure 8b shows cladding depths achieved on a second curved machined profile;

Figure 9 shows a detailed cross-sectional view of the air inlet side of the cylinder head after an alternative intermediate machining step has been completed;

25 Figure 10 shows a detailed view of the machined surface of Figure 9;

Figure 11a shows cladding depths achieved on a stepped machined profile; and

Figure 11b shows cladding depths achieved on the curved machined profile;

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DETAILED DESCRIPTION

Figure 1 shows a vehicle 100 in which the invention may be used. In this example, the vehicle 100 is a car, but the invention is equally applicable to other vehicles driven by an internal combustion engine 110. In this vehicle 100, the internal combustion engine 110 is positioned in the front and coupled to a drivetrain to drive the front and/or rear wheels of the vehicle 100. The energy needed for driving the vehicle 100 is provided by burning fuel in the engine's

cylinders and let the cylinder pistons drive a crankshaft that is mechanically connected to the vehicle's drivetrain.

Figure 2 shows a cross section of a portion of an engine block 52 and a cylinder head 53 of the engine 110. The engine block 52 comprises a cylinder 57 which houses a piston 54 shown near bottom dead centre (BDC) in Figure 2. The cylinder head 53 comprises a combustion chamber 50 which extends into the cylinder head 53 away from a bottom surface 58 of the cylinder head. A head gasket 80 is located between the engine block 52 and bottom surface 53. The cylinder head 53 is typically made of a cast aluminium alloy which is machined in critical areas to ensure geometrical accuracy.

Referring additionally to Figure 4, a pair of air inlet passages 49a, 49b open into the combustion chamber 50 on an air inlet side of the combustion chamber. The air inlet passages 49a, 49b provide a path for a flow of air to the combustion chamber 50 in use. A pair of exhaust outlet passages 56a, 56b open into the combustion chamber 50 on an exhaust outlet side of the combustion chamber. The exhaust outlet passages 56a, 56b provide an exhaust path for the combustion products exiting the combustion chamber 50 in use.

The air inlet passages 49a, 49b terminate at respective air inlet openings 91a, 91b located in the roof surface 90 of the combustion chamber 50, and the exhaust outlet passages 56a, 56b terminate at respective exhaust outlet openings 92a, 92b located in the roof surface 90 of the combustion chamber 50. The cross sections of Figures 2 and 3 are taken along section A-A of Figure 4 which passes through air inlet opening 91a and exhaust outlet opening 92a.

The combustion chamber roof surface 90 extends into the cylinder head 53 away from the bottom surface 58. The intersection between the combustion chamber roof surface 90 and the bottom surface 58 comprises a combustion chamber opening 86 in the bottom surface 58.

Referring once again to Figure 2, an inlet poppet valve 51 controls the opening and closing of the air inlet passage 49a, and an exhaust poppet valve 55 controls the opening and closing of the exhaust outlet passage 56a. The inlet valve 51 and the exhaust valve 55 are shown in the closed position in Figure 2.

Figure 3 shows a close-up of the air inlet 51 of Figure 2 in an open position. The air inlet valve 51 comprises a bottom surface 61 that faces the combustion chamber 50 and a tapered top surface 62 that faces the air inlet passage 49a. The air inlet valve 51 is provided at the end of a valve stem 63 which is moveable within a valve guide insert 65 located within a valve guide

opening 66 in the cylinder head 53. The valve guide insert 65 and the valve guide opening 66 share a common axis 67 along which the valve stem 63 moves in use. The inlet valve 51 is arranged to move by controlling the position of the valve stem 63. The inlet valve 51 may be moved between a closed state (Figure 2) for closing off the combustion chamber inlet and an opened state (Figure 3) wherein air can flow from the air inlet passage 49a into the combustion chamber 50.

The air inlet passage 49a extends into the cylinder head 53 away from the air inlet opening 91a. The portion of the air inlet passage 49a located proximate the air inlet opening 91a comprises an inlet throat 68. The inlet throat 68 comprises a tapered flat surface 71 which forms a seat for the top surface 62 of the inlet valve 51 such that when the inlet valve 51 is in the closed position, the tapered top surface 62 of the inlet valve 51 seats on the tapered flat surface 71 to seal the air inlet 49a. At least the flat surface 71 of the inlet throat 68 is radially symmetrical about the central axis 67 of the valve guide opening 66.

The tapered flat surface 71 which forms the valve seat may be provided in a valve seat insert or may be machined directly into a wear resistant cladding which has been applied to the throat area 68 of the inlet passage 49a prior to machining of the flat valve seat surface 71.

The exhaust poppet valve 55 (Figure 2) has substantially the same construction and operation as the air inlet valve 51 described above. The exhaust outlet valve 55 moves along exhaust valve axis 69 in use to open and close the exhaust outlet passages 56a, 56b. The skilled person will appreciate that the features and construction of the air inlet valve 51, and its seating surface 71, can equally be applied to the exhaust outlet valve 55.

Figure 5 shows a plan view of the bottom surface 58 of the cylinder head 53 in the "as cast" condition. That is to say before any machining processes have been carried out. In the "as cast" condition, the cylinder head 53 comprises a combustion chamber recess 180 which extends into the cylinder head 53 away from the bottom surface 58 and which comprises a roof surface 390. The roof surface 390 of the recess 180 is machined to form the roof surface 90 of the combustion chamber 50 of the completed cylinder head. In the example of Figure 4, the whole of the surface 390 of the cast recess 180 is machined away to form the combustion chamber roof surface 90. However, in other embodiments some of the cast roof surface 390 may remain after the machining processes are complete so that part of the finished combustion chamber roof surface 90 comprises sections of the original cast roof surface 390.

The air inlet passages 49a, 49b open into the cast roof surface 390 at air inlet openings 391a, 391b, and the exhaust outlet passages 56a, 56b open into the cast roof surface 390 at exhaust outlet openings 392a, 392b. It is clear that the air inlet openings 391a, 391b and the exhaust outlet openings 392a, 392b in the roof surface 390 of the “as cast” combustion chamber recess 180 will have a different shape to the air inlet openings 91a, 91b and the exhaust outlet openings 92a, 92b in the machined roof surface 90 of the combustion chamber 50. However, for the purpose of this description, both are referred to as “air inlet openings” and “exhaust outlet openings” respectively and refer to the opening in the roof surface 90 of the machined combustion chamber 50, or the roof surface 390 of the cast combustion chamber recess 180, as the case may be. In addition, as discussed below, there may be an intermediate machining step in which a specific profile is machined into the throat portion of the air inlet passages 49a, 49b and/or the exhaust outlet passages 56a, 56b before a cladding layer is applied and subsequently machined to form the final valve seat profile. In such cases, the openings in the chamber roof surface 90, or the cast roof surface 390, are still referred to as “air inlet openings” and “exhaust outlet openings” regardless of the fact that they will be cladded and further machined in subsequent manufacturing processes.

It is well known in the art of laser cladding that the conditions and parameters used during the laser cladding process are critical to the weld quality and durability of the resulting laser clad material. In particular, it is important to reduce voids and porosity in the laser clad material which may lead to failure of the laser clad material in use. It is also important to minimise the heat affected zone (HAZ) thereby reducing the dilution rate in order to avoid incorporating an alloying layer between the cladding material and the material of the cylinder head 53. It is also important to ensure that the geometric characteristics of the laser clad material, such as thickness and length, are sufficient to ensure that the correct geometry can be achieved when machining the valve seat surface 71 into the laser clad material.

One factor that can affect the quality and geometric characteristics of the laser clad material is the surface profile to which the laser cladding process is applied. To investigate possible beneficial pre-clad surface profiles, the following investigations were undertaken.

Investigation 1: Nickel Aluminium (NiAl) cladding applied to a radiused profile.

Figure 6 shows a cross-sectional view through an air inlet 49a of a cylinder head casting 53 before any cladding material has been applied. In this example, the air inlet 49a meets the roof 90 of the combustion chamber 50 at air inlet opening 393. The region of the air inlet 49a proximate the air inlet opening 393 defines a throat, or air inlet throat, 368 which extends into

the cylinder head casting 53 away from the air inlet opening 393. The throat 368 has a radiused profile in a plane which passes through the central axis of the throat 368 and the edge, which may be called the outermost edge, of the throat 368. In Figure 6 it can be seen that the central axis of the throat 368 corresponds to the valve guide axis 67.

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In investigation 1, two radii for the throat 368 were tested, a radius of 3mm and a radius of 1.5mm. Figure 7 shows a schematic view of the throat 368 in which the two test radii are schematically illustrated by R3 and R1.5 respectively.

10 Nickel Aluminium (NiAl) cladding was applied to both test throat profiles in a laser cladding process. Figure 8a and Figure 8b show plots of the resulting cladding height above the pre-clad throat profile position R3 and R1.5 respectively. It will be understood by the person skilled in the art that the pre-clad profiles R3 and R1.5 do not exist after the cladding has been applied since the material of the cylinder head casting 53 is melted into the laser cladding material at
15 the heat affected zone.

Figures 8a and 8b each show four plot lines for measurements of cladding height taken at 90° angles around the throat 368. Each plot also shows a target line 300 indicating the height of the final valve seat above the pre-clad profiles R3 and R1.5. As can be seen in Figures 8a and
20 8b, the throat 368 with the 3mm radiused profile resulted in cladding most closely matching the target line 300 for Nickel Aluminium (NiAl) cladding.

The cladding of each test piece was subjected to a laser hardening (re-melting) process and the results were compared to the “as welded” cladding. Here it was found that the re-melting
25 process had little effect on the cladding height, but micrographs of the cladding material revealed increased melting of the material of the cylinder head casting 53 in both test pieces and increased porosity in the 3mm radius test piece. For the “as welded” samples, the electron micrographs revealed no obvious porosity issues within the cladding or at the interface of the cladding and the material of the cylinder head casting 53.

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Investigation 2: Nickel Aluminium with Chromium Carbide hard phase (NiAl-CrC) cladding applied to a 3mm radiused profile and to a stepped profile.

In Investigation 2, two profiles for the throat 368 were tested, a radiused profile of 3mm as described above for Investigation 1, and a stepped profile as shown in Figures 9 and 10
35 described below.

Figure 9 shows a cross-sectional view through an air inlet 49a having a throat 368 with a stepped profile 369, and Figure 10 shows a schematic view of the stepped profile 369. As before, the air inlet 49a meets the roof 90 of the combustion chamber 50 at air inlet opening 393. The region of the air inlet 49a proximate the air inlet opening 393 defines a throat 368 which extends into the cylinder head casting 53 away from the air inlet opening 393. The throat 368 has a stepped profile 369 in a plane which passes through the central axis of the throat 368 and the edge of the throat 368. In Figure 9 it can be seen that the central axis of the throat 368 corresponds to the valve guide axis 67. The stepped profile 369 comprises two steps 370a, 370b (Figure 10). It is envisioned that other numbers of step may be used.

Nickel Aluminium – Chromium Carbide (NiAl – CrC) cladding was applied to both test throat profiles in a laser cladding process. Figure 11a and Figure 11b show plots of the resulting cladding height above the pre-clad throat profile 369 and R3 respectively. As above, it will be understood by the person skilled in the art that the pre-clad profiles do not exist after the cladding has been applied since the material of the cylinder head casting 53 is melted into the laser cladding material at the heat affected zone.

Figures 11a and 11b each show four plot lines for measurements of cladding height taken at 90° angles around the throat 368. Each plot also shows a target line 300 indicating the height of the final valve seat above the pre-clad profiles. As can be seen in Figures 11a and 11b, both test profiles resulted in cladding height above the target line 301 for Nickle Aluminium – Chromium Carbide (NiAl – CrC) cladding.

The cladding of each test piece was subjected to a “double pass” cladding process and the results were compared to the “single pass” cladding. Here it was found that the double pass process showed low variation between the weld profile and the cladding height for the stepped profile test piece, whereas for the radiused test piece the double pass cladding showed undulations near the centre of the cladding which reduced cladding depth. Micrographs of the “single pass” cladding material revealed that the step of the stepped profile had been melted away and that there were regions of porosity. For the radiused profile test piece, the electron micrograph of the “single pass” showed no evidence of porosity.

Investigation 3: Transition Zone.

The transition zone, or heat affected zone (HAZ), was measured from electron micrographs of the cladded materials. For the 1.5mm radiused profile Nickel Aluminium (NiAl) cladded workpiece of Investigation 1, and for the stepped profile Nickel Aluminium – Chromium

- Carbide (NiAl-CrC) clad workpiece of Investigation 2, the HAZ varied between 150 and 200µm in depth giving a dilution rate of 12%. For the 3mm radiused profile Nickel Aluminium – Chromium Carbide (NiAl-CrC) clad workpiece of Investigation 2 the depth of the HAZ was measured at approximately 35µm giving a dilution rate of 2%. An EDX elemental map of the 3mm radiused profile Nickel Aluminium – Chromium Carbide (NiAl-CrC) clad workpiece of Investigation 2 showed a clear distinction between the cladding and base material of the cylinder head casting indicating minimal dilution of compositional elements between the base material and the cladding.
- 10 The above description has been given in the context of a cylinder head to be used in conjunction with a cylinder block as is well known in the art. However, the skilled person will be aware of other internal combustion engine constructions having combustion chamber air inlets and exhaust outlets located elsewhere than in the roof of a combustion chamber recess located in a cylinder head, for example, side valve engine designs. It will be clear to the person skilled in the art that the above disclosure is equally applicable to other internal combustion engine designs and is not solely limited to internal combustion engines comprising air inlets and/or exhaust outlets located in a cylinder head.

CLAIMS

1. A casting for an internal combustion engine, the casting comprising an air inlet opening located in a combustion chamber, wherein the air inlet opening comprises the outermost edge of an air inlet throat which extends into the casting away from the air inlet opening, wherein a portion of the air inlet throat is radially symmetrical about a central axis, and wherein the cross-section of the air inlet throat in a plane which passes through the central axis and the edge of the air inlet throat comprises a radiused profile.
2. A casting as claimed in claim 1, comprising an exhaust outlet opening located in the combustion chamber, wherein the exhaust outlet opening comprises the outermost edge of an exhaust outlet throat which extends into the casting away from the exhaust outlet opening, wherein a portion of the exhaust outlet throat is radially symmetrical about a second central axis, and wherein the cross-section of the exhaust outlet throat in a plane which passes through the second central axis and the edge of the exhaust outlet throat comprises a radiused profile.
3. A casting as claimed in claim 1 or claim 2, wherein the cross-section of the air inlet throat, and/or the exhaust outlet throat where present, comprises a concave radiused profile.
4. A casting as claimed in any preceding claim, wherein the cross-section of the air inlet throat, and/or the exhaust outlet throat where present, comprises a radiused profile having a radius of between 1mm and 5mm.
5. A casting as claimed in claim 4, wherein the cross-section of the air inlet throat, and/or the exhaust outlet throat where present, comprises a radiused profile having a radius of between 2.5mm and 3.5mm.
6. A casting as claimed in any preceding claim, wherein the casting is a cylinder head casting, and wherein the combustion chamber comprises a combustion chamber recess which extends into the cylinder head casting away from a bottom surface of the cylinder head casting, wherein the combustion chamber recess comprises a combustion chamber roof surface, wherein the air inlet opening, and the exhaust outlet opening where present, are located in the combustion chamber roof surface.
7. A method of manufacturing a component for an internal combustion engine, the method comprising providing a casting, wherein the casting comprises a combustion chamber

having an air inlet opening located therein, the method of manufacturing comprising machining an air inlet throat at the air inlet opening, wherein the machined air inlet throat extends into the casting, and wherein a portion of the machined air inlet throat is radially symmetrical about a central axis, wherein the cross-section of the machined air inlet throat in a plane which passes through the central axis and the edge of the machined air inlet throat comprises a radiused profile.

8. A method of manufacturing as claimed in claim 7, wherein the casting comprises an exhaust outlet opening located in the combustion chamber, the method of manufacturing comprising machining an exhaust outlet throat at the exhaust outlet opening, wherein the machined exhaust outlet throat extends into the casting, and wherein a portion of the machined exhaust outlet throat is radially symmetrical about a second central axis, wherein the cross-section of the machined exhaust outlet throat in a plane which passes through the second central axis and the edge of the machined exhaust outlet throat comprises a radiused profile.

9. A method of manufacturing as claimed in claim 7 or claim 8, comprising applying a cladding to the machined air inlet throat, and/or the machined exhaust outlet throat where present, using a laser cladding process.

10. A method of manufacturing as claimed in claim 9, wherein the cladding is a Nickel Aluminium cladding, optionally comprising Chromium Carbide.

11. A method of manufacturing as claimed in claim 9 or claim 10, comprising using a laser hardening process after the laser cladding process.

12. A method of manufacturing as claimed in any one of claims 9 to 11, comprising removing a portion of the cladding in a second machining process to form a valve seat.

13. A method of manufacturing as claimed in any one of claims 7 to 12, wherein the casting comprises a cylinder head casting.

14. An internal combustion engine comprising a casting according to any one of claims 1 to 6.

15. A vehicle comprising an internal combustion engine according to claim 14.

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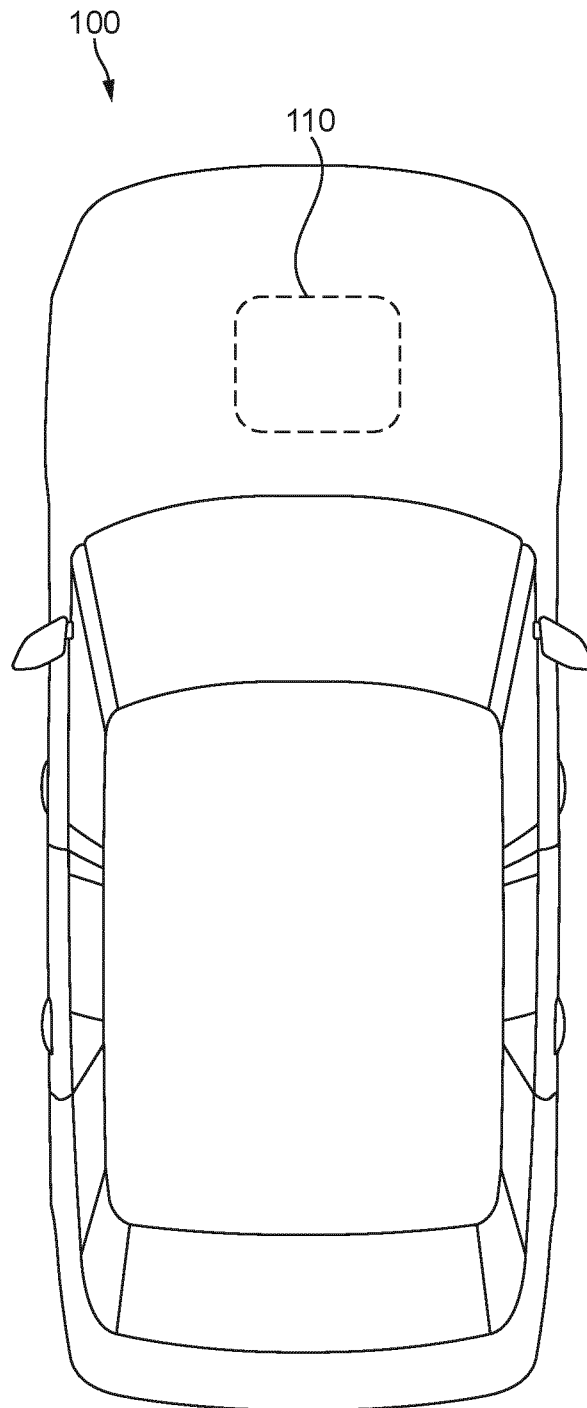


FIG. 1

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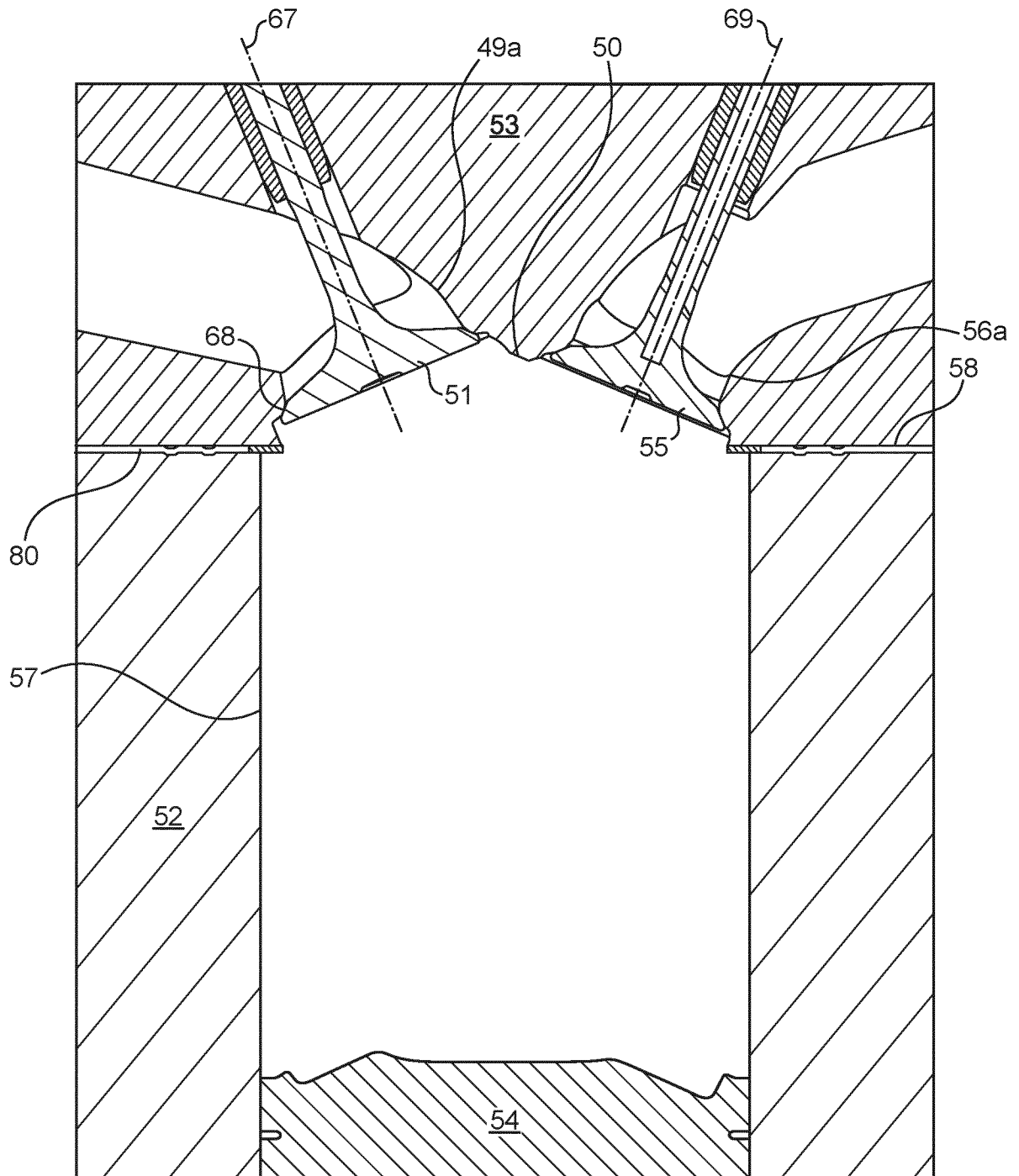


FIG. 2

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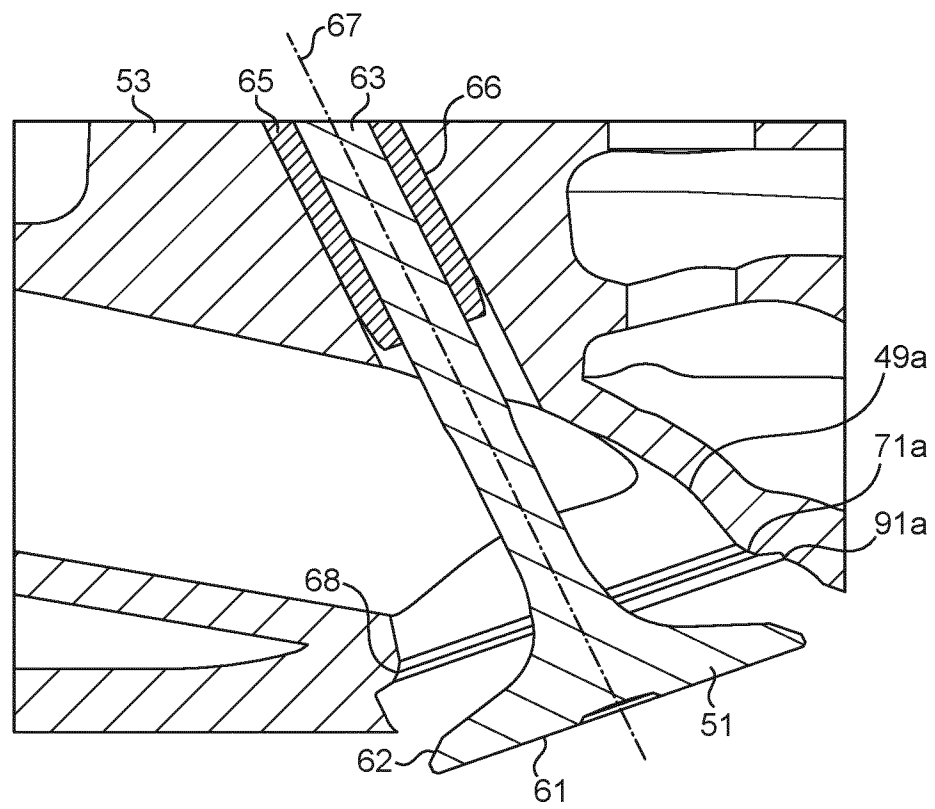


FIG. 3

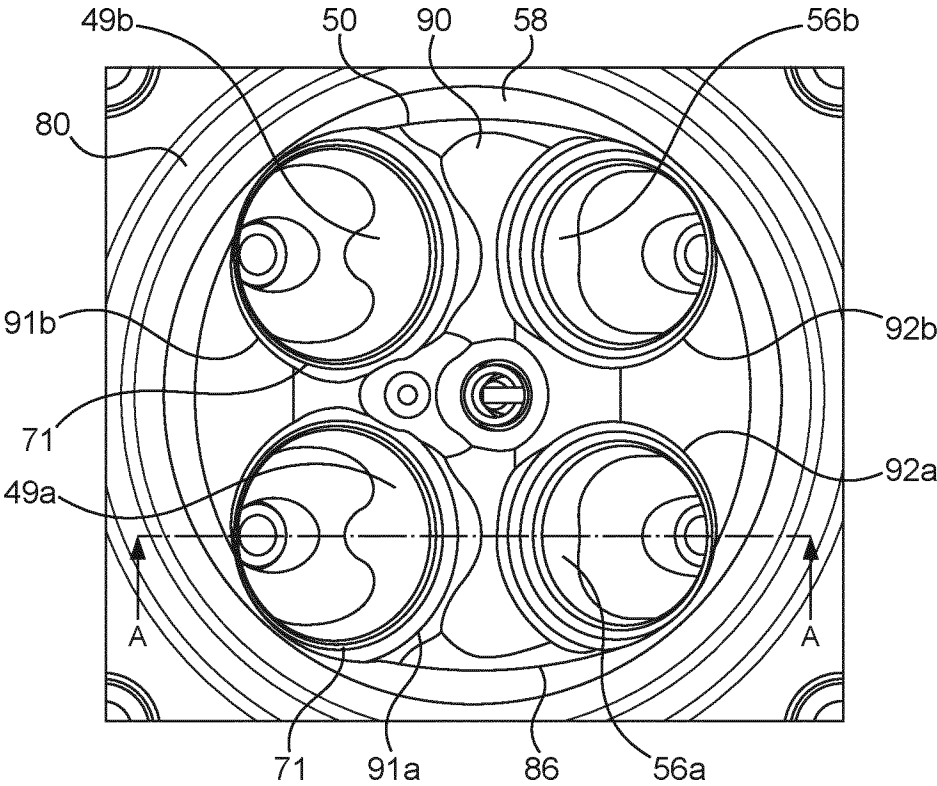


FIG. 4

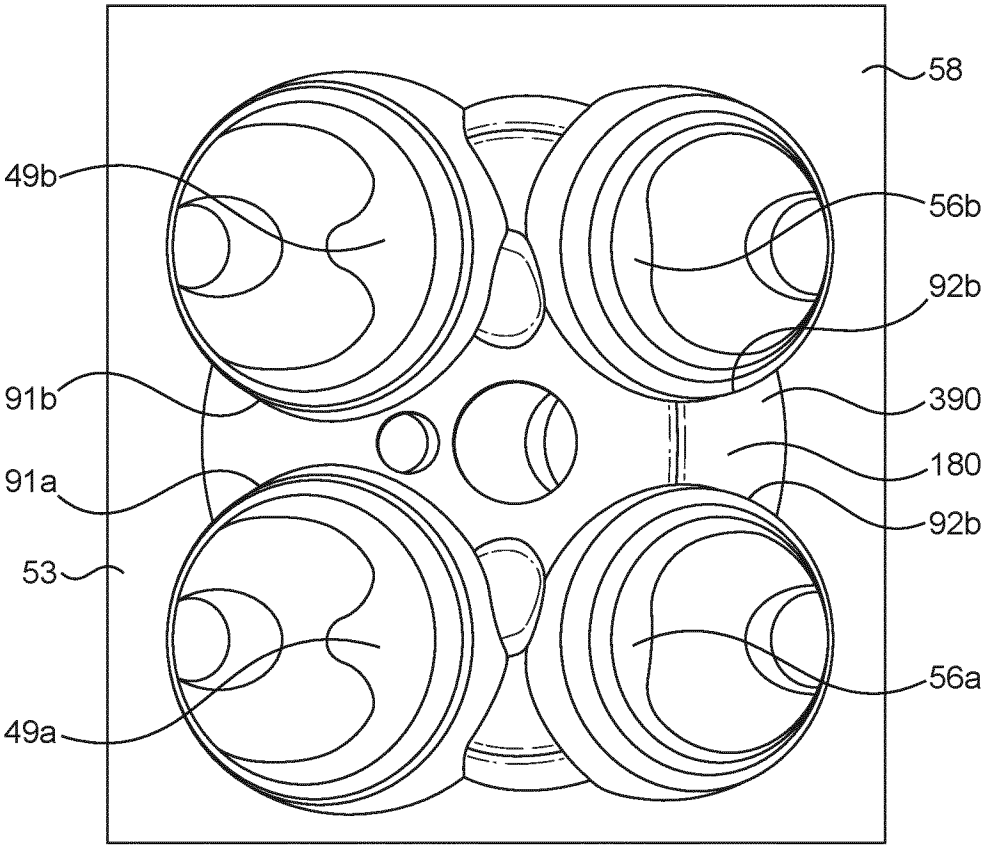


FIG. 5

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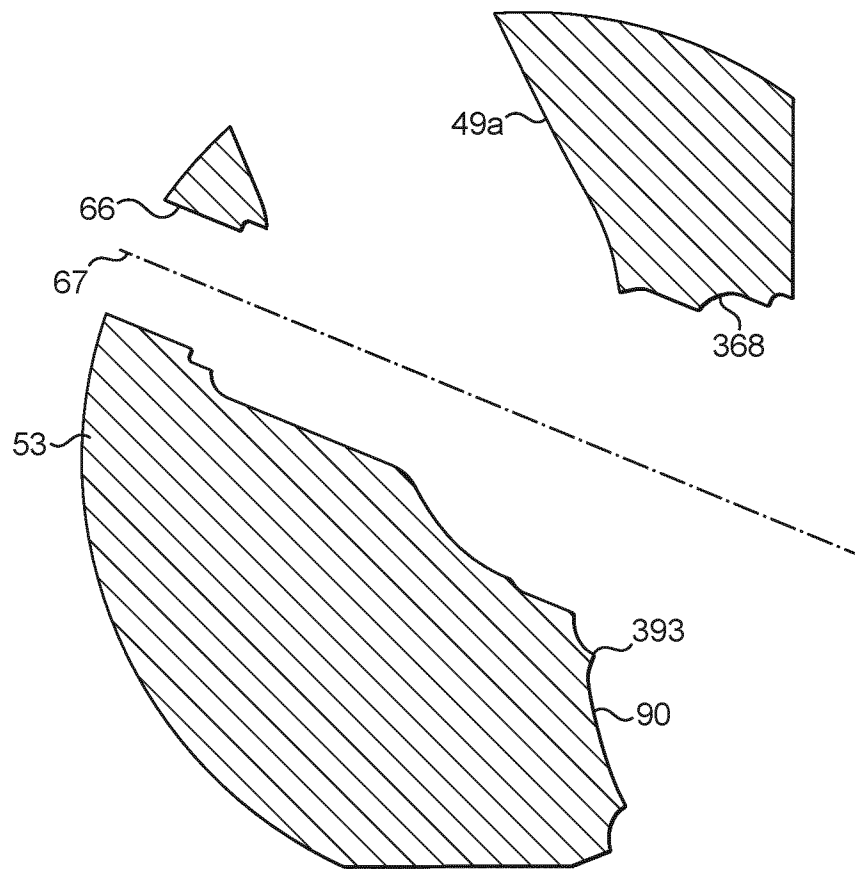


FIG. 6

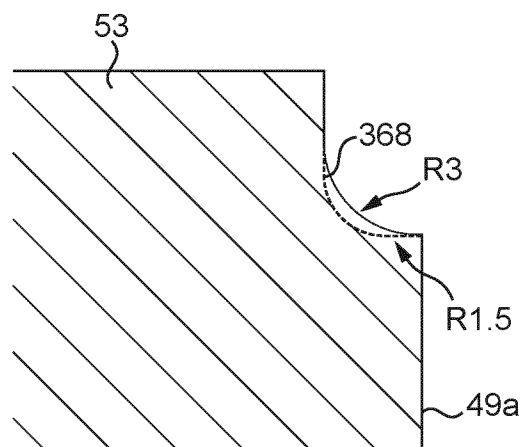


FIG. 7

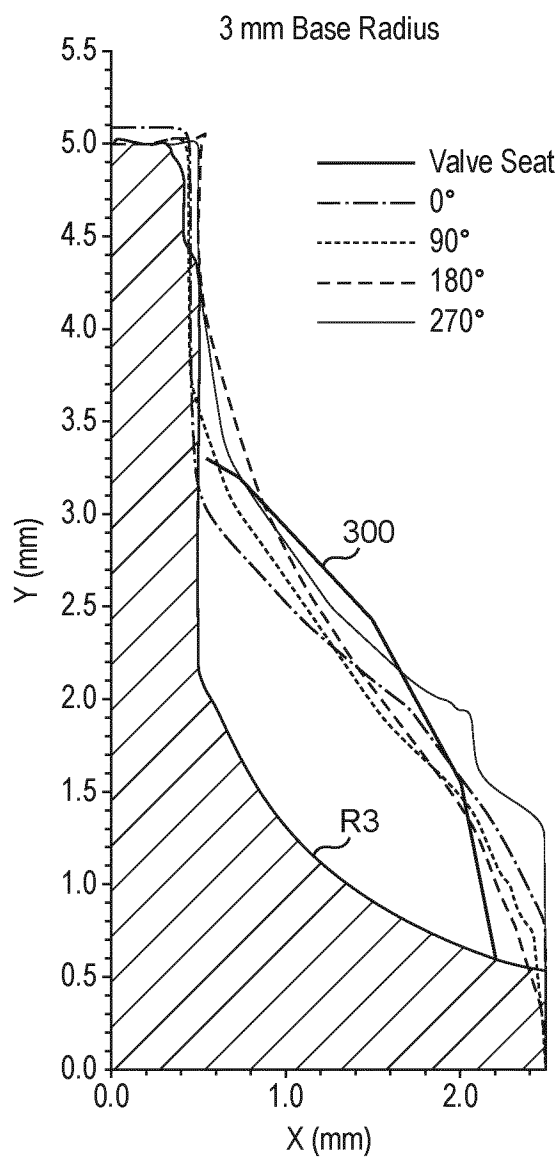


FIG. 8a

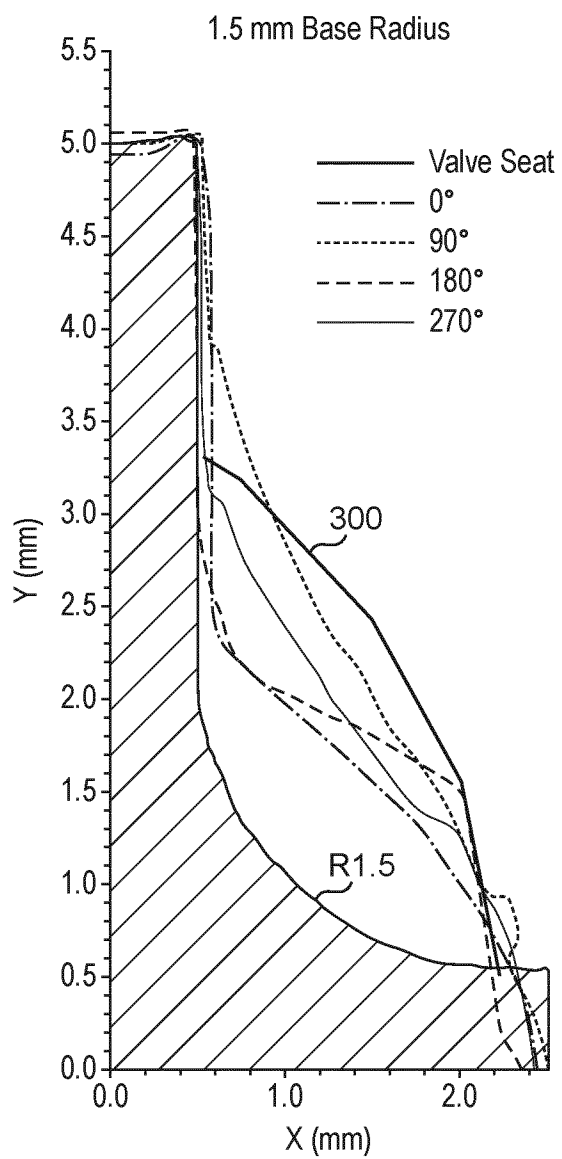


FIG. 8b

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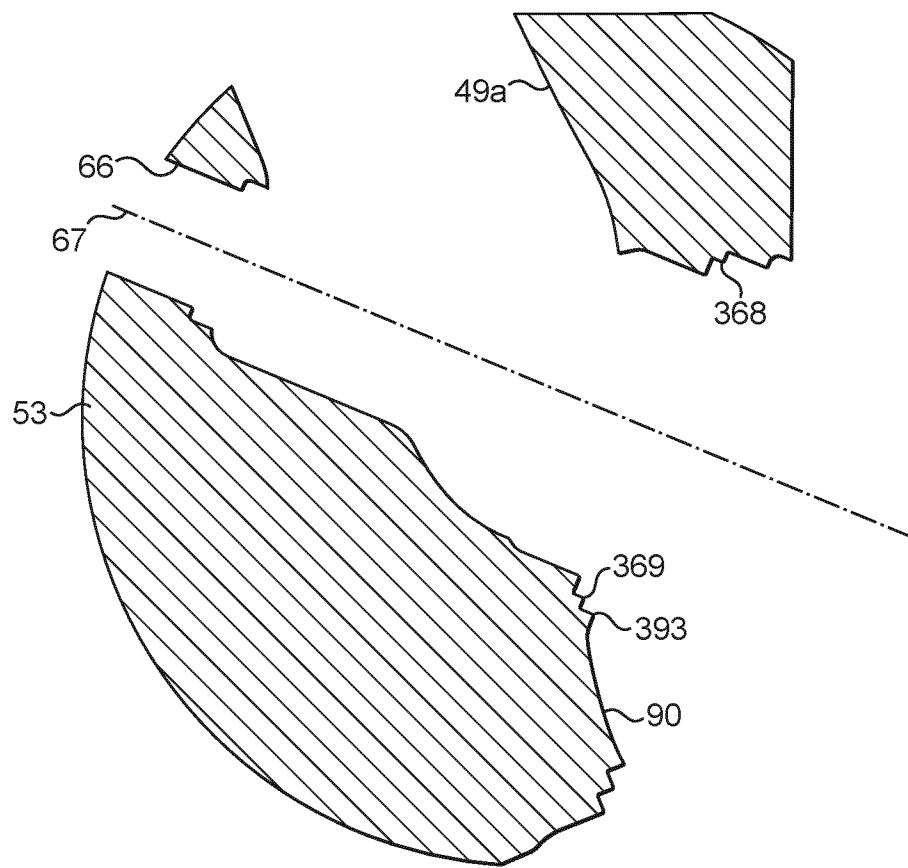


FIG. 9

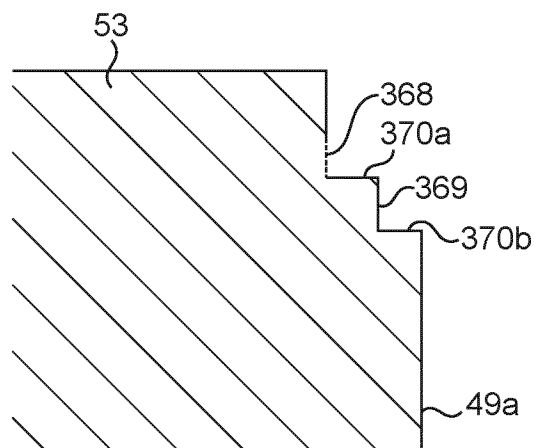


FIG. 10

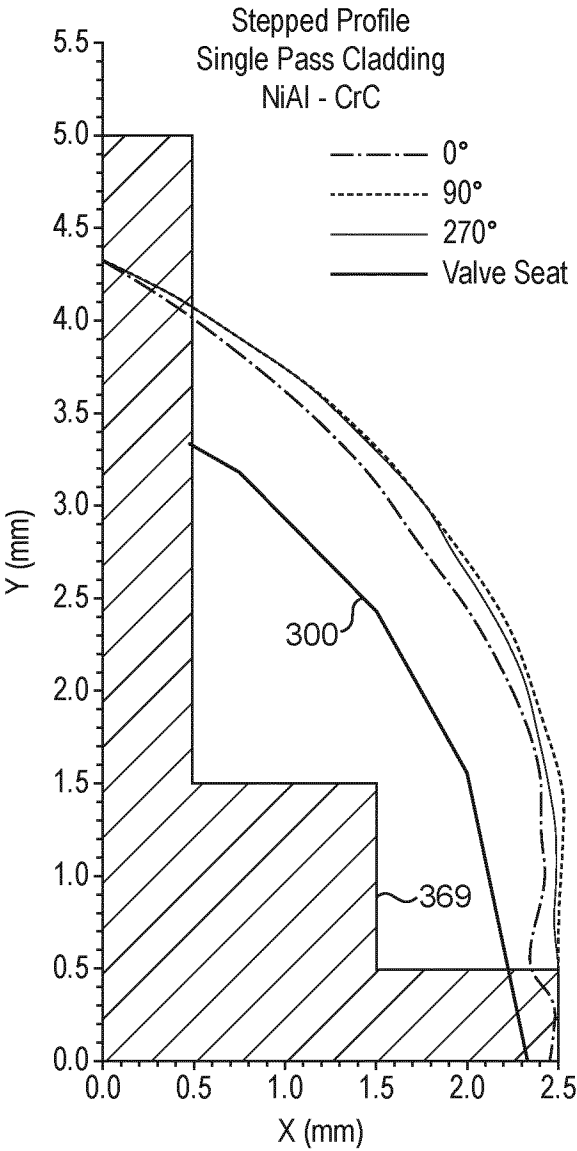


FIG. 11a

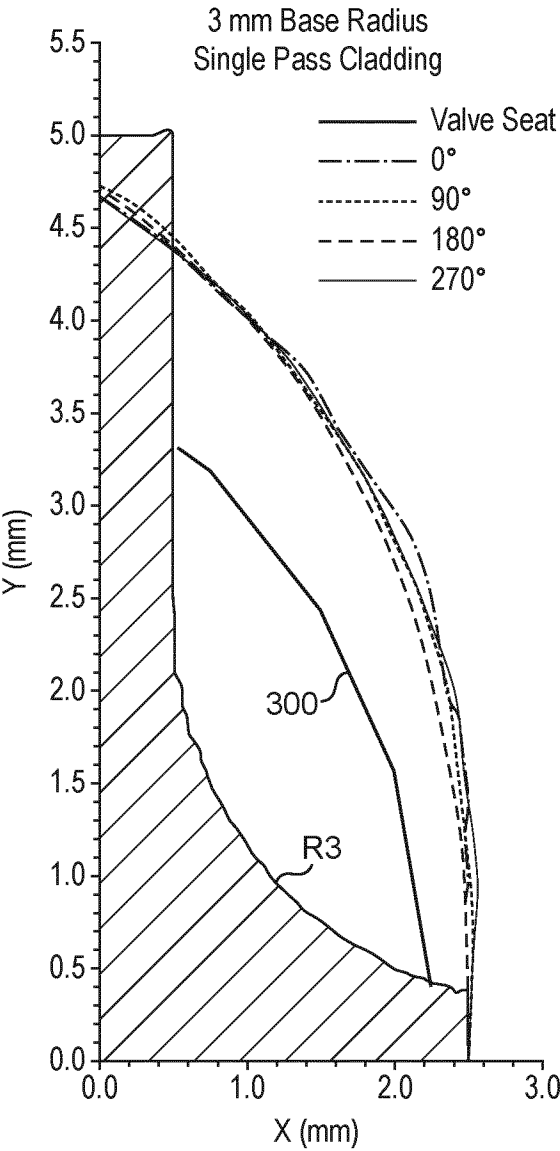


FIG. 11b

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2021/057922

A. CLASSIFICATION OF SUBJECT MATTER

INV. F02F1/42 B23K26/342 F01L3/04 F01L3/22
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F02F B23K F01L

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	JP H11 2154 A (NISSAN MOTOR) 6 January 1999 (1999-01-06)	1-9, 11-15
Y	figures 1-5 claim 11	10

X	JP H10 339117 A (NISSAN MOTOR) 22 December 1998 (1998-12-22)	1-4,6-9, 12-15
	figures paragraph [0031]	

X	JP 2010 230315 A (HONDA MOTOR CO LTD) 14 October 2010 (2010-10-14)	1-3,6-9, 12-15
	figures	

Y	DE 101 56 196 C1 (DAIMLER CHRYSLER AG [DE]) 2 January 2003 (2003-01-02)	10
	paragraph [0059]	

	-/-	



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

23 November 2021

Date of mailing of the international search report

02/12/2021

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INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2021/057922

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
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A	JP H08 224682 A (NISSAN MOTOR) 3 September 1996 (1996-09-03) paragraph [0020] -----	7
A	US 2018/272472 A1 (AOYAMA HIRONORI [JP] ET AL) 27 September 2018 (2018-09-27) figure 12 -----	1-15

INTERNATIONAL SEARCH REPORT

Information on patent family members

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