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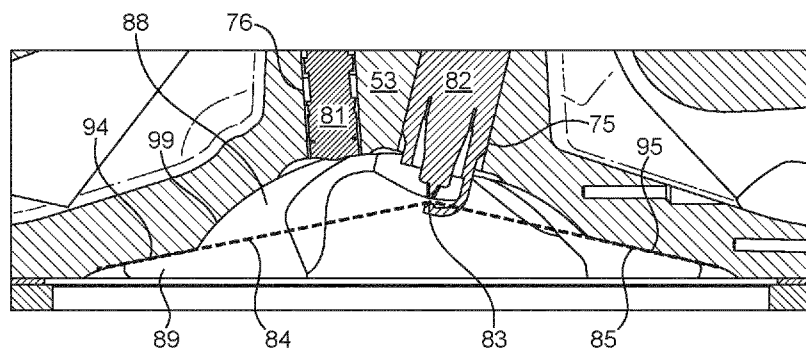


FIG. 5

(57) Abstract: A cylinder head (53) for a lean-burn gasoline engine comprising a combustion chamber (50) extending into the cylinder head (53) away from a gasket interface surface (58). The combustion chamber (50) comprises a combustion chamber roof surface (90) which has a central domed surface portion (99) and a sloped surface portion (94, 95) which comprises a substantially straight cross-section along a plane of symmetry (87) of the combustion chamber (50). In use, a spark plug seat (75) supports a spark plug (82) in a fixed position within the domed portion (88) of the combustion chamber (50) and the sloped surface portion (94, 95) of the combustion chamber roof is configured so that a geometric extension of the sloped surface portion is coincidental with the spark plug gap. The combustion chamber may also be configured so that the apex of a geometric extension (84, 85) of the sloped surface portion (94, 95) of the combustion chamber roof is located within a volume envelope that is described by a 360° rotation of the spark plug tip.



A cylinder head for a lean-burn gasoline engine

TECHNICAL FIELD

5 The present disclosure relates to a cylinder head for a lean-burn gasoline engine, to a lean-burn gasoline engine and to a vehicle with such an engine.

BACKGROUND

10 In classic internal combustion engines, gasoline burns best when it is mixed with air in proportions of around 14.7:1 ($\lambda = 1$) depending on the particular type of fuel. Most modern gasoline engines used in vehicles tend to operate at or near this so-called stoichiometric point for most of the time. Ideally, when burning fuel in an engine, only carbon dioxide (CO_2) and water (H_2O) are produced. In practice, the exhaust gas of an internal combustion engine also comprises significant amounts of carbon monoxide (CO), nitrogen
15 oxides (NO_x) and unburned hydrocarbons.

One possible route for increasing fuel efficiency is to burn the fuel with an excess of air. Burning fuel in such an oxygen-rich environment is usually called lean-burning. Typical lean-burn engines may mix air and fuel in proportions of, for example, 20:1 ($\lambda > 1.3$) or even
20 30:1 ($\lambda > 2$).

Advantages of lean-burn engines include, for example, that they produce lower levels of CO_2 and hydrocarbon emissions by better combustion control and more complete fuel burning inside the engine cylinders. The engines designed for lean burning can employ higher
25 compression ratios and thus provide better performance, more efficient fuel use and lower exhaust hydrocarbon emissions than conventional gasoline engines. Additionally, lean-burn modes help to reduce throttling losses, which originate from the extra work that is required for pumping air through a partially closed throttle. When using more air to burn the fuel, the throttle can be kept more open when the demand for engine power is reduced.

30 Lean burning of fuel does, however, also come with some technical challenges that have to be overcome for providing an engine that is suitable and optimised for efficiently burning hydrocarbons in an oxygen-rich environment. For example, if the mixture is too lean, the engine may fail to combust. Especially at low loads and engine speeds, reduced flammability
35 may affect the stability of the combustion process and introduce problems with engine knock. Further, a lower fuel concentration leads to less output. Because of such disadvantages, lean

burn is currently only used for part of the engine map and most lean-burning modern engines, for example, tend to cruise and coast at or near the stoichiometric point.

In order to enable the lean burning of fuel over a larger portion of the engine map, the engine needs to be designed in such a way to enable a large airflow into the combustion chamber and to ensure a reliable combustion process that will effectively burn all fuel, despite the oxygen rich conditions.

It is an aim of the present invention to provide an improved lean-burn gasoline engine.

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 lean-burn engine.

According to an aspect of the present invention there is provided a cylinder head for an engine, the cylinder head comprising:

- a substantially planar gasket interface surface;
- a combustion chamber extending into the cylinder head away from the gasket interface surface, wherein the combustion chamber comprises a combustion chamber roof surface having:
 - a central domed surface portion defining a central domed portion of the combustion chamber; and
 - a sloped surface portion defining a sloped portion of the combustion chamber, wherein the sloped surface portion comprises a substantially straight cross-section along a plane of symmetry of the combustion chamber, and
 - a spark plug seat configured to support a spark plug, in use, such that a spark gap of the spark plug is held in a substantially fixed position within the domed portion of the combustion chamber, wherein the sloped surface portion of the combustion chamber roof is configured so that a geometric extension of the sloped surface portion is coincidental with the spark plug gap in use.

The cylinder head configuration described above is advantageous as it promotes direction of the air and fuel mixture into the central domed portion of the combustion chamber, and towards the spark plug gap, as the piston of the engine approaches the sloped surface portions of the

combustion chamber roof as it moves towards top dead centre. This has been found to promote efficient burn of the air fuel mixture.

5 Optionally the sloped surface portion conforms to part of the surface of a cone which is a readily manufacturable shape which achieves the aim of directing the air fuel mixture towards the spark gap.

10 The cylinder head optionally comprises two sloped surface portions located on opposite sides of the combustion chamber. Since the air fuel mixture occupies the entirety of the cylinder and combustion chamber above the piston, it is beneficial to direct the air fuel mixture towards the spark gap from both sides of the combustion chamber.

15 The sloped surface portions may comprise a first sloped surface portion located adjacent a combustion chamber air inlet opening, and a second sloped surface portion located adjacent a combustion chamber exhaust outlet opening. The inlet and outlet openings are typically located on opposite sides of the combustions chamber.

20 In one example the combustion chamber comprises a pair of air inlet openings and a pair of exhaust outlet openings, wherein the first sloped surface portion is at least partially located between the pair of air inlet openings, and wherein the second sloped surface portion is at least partially located between the pair of exhaust outlet openings. This arrangement provides symmetry between adjacent sides of the combustion chamber.

25 Optionally the surface area of the first sloped surface portion is less than the surface area of the second sloped surface portion to accommodate the geometry of the combustion chamber.

30 The length of the first sloped surface portion along the plane of symmetry of the combustion chamber may optionally be less than the length of the second sloped surface portion along the plane of symmetry of the combustion chamber.

35 The first sloped surface portion may comprise an innermost edge at an interface between the first sloped surface portion and the central domed portion, and wherein the second sloped surface portion comprises an innermost edge at an interface between the second sloped surface portion and the central domed portion, wherein the length of the innermost edge of the first sloped surface portion is substantially equal to the length of the innermost edge of the second sloped surface portion.

In one example the innermost edge of the first sloped surface portion is located between the pair of air inlet openings no further towards the centre of the combustion chamber than the shortest possible line joining the outermost extremities of the air inlet openings, and wherein the innermost edge of the second sloped surface portion is located between the pair of exhaust outlet openings no further towards the centre of the combustion chamber than the shortest possible line joining the outermost extremities of the exhaust outlet openings.

Optionally the ratio of: the width of a projection of the combustion chamber onto a plane parallel to the gasket interface surface measured in a direction along the plane of symmetry of the combustion chamber; and the width of a projection of the central domed portion of the combustion chamber onto a plane parallel to the gasket interface surface measured in a direction along the plane of symmetry of the combustion chamber, is about 1.7:1.

The angle between the gasket interface surface and each sloped surface portion measured along the plane of symmetry of the combustion chamber are optionally substantially equal.

The combustion chamber roof surface may comprise concave curved portions located between an outermost edge of the combustion chamber and the or each sloped surface portion.

In one example the central domed portion of the combustion chamber may be elongated in a direction perpendicular to the plane of symmetry of the combustion chamber.

Optionally the spark plug seat comprises an opening in the central domed surface of the combustion chamber located such that it intersects the plane of symmetry of the combustion chamber.

The combustion chamber may optionally comprise a fuel injector seat opening in the central domed surface of the combustion chamber, wherein the fuel injector seat opening is located such that it intersects the plane of symmetry of the combustion chamber, wherein the fuel injector seat opening is positioned further towards the pair of air inlet openings than the spark plug seat opening.

In another aspect, the present invention provides a cylinder head for an engine, the cylinder head comprising:

a combustion chamber extending into the cylinder head, the combustion chamber comprising a combustion chamber roof surface having a sloped surface portion, wherein the sloped surface portion conforms to part of the surface of a cone; and

a spark plug seat configured to support the tip of a spark plug at a predetermined position within the combustion chamber in use, wherein the combustion chamber is configured so that the apex of a geometric extension of the sloped surface portion of the combustion chamber roof surface is located within a volume envelope that is described by a 360° rotation of the spark plug tip when the spark plug tip is supported at the predetermined position in the combustion chamber.

This arrangement promotes direction of the air and fuel mixture into the central domed portion of the combustion chamber, and towards the spark plug tip, as the piston of the engine approaches the sloped surface portions of the combustion chamber roof as it moves towards top dead centre. This has been found to promote efficient burn of the air fuel mixture.

In a further aspect the present invention provides an engine comprising a cylinder head as described above.

In a still further aspect the present invention provides an engine as described above, comprising a piston having a working surface configured to conform to at least part of the or each sloped surface portion of the combustion chamber roof surface in use.

In another aspect the present invention provides an engine as described above, wherein the gap between the sloped surface portion of the combustion chamber roof surface and the conforming part of the working surface of the piston is no less than 0.8mm and no more than 1.4mm when the piston is at top dead centre as measured when the engine is at substantially the same temperature as the environment.

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

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 an engine block and cylinder head with a piston shown at bottom dead centre;

5 Figure 3 shows a plan view of the roof surface of the combustion chamber of Figure 2;

Figure 4 shows a second cross section of the engine block and cylinder head of Figure 2 with the piston at top dead centre;

10 Figure 5 shows a magnified view of the cross section of Figure 4; and

Figure 6 shows a schematic drawing of the combustion chamber roof surface and piston of Figure 2 superimposed with an alternative combustion chamber roof surface geometry and alternative piston geometry.

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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 a lean-burn gasoline engine 110. In this vehicle 100, the lean-burn gasoline 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.

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Compared to classic internal combustion engines, the lean-burn engine 110 of this vehicle 100 burns the fuel with an excess of air in the air-fuel mixture. Typical lean-burn engines may mix air and fuel in proportions of, for example, 20:1 ($\lambda > 1.3$) or even 30:1 ($\lambda > 2$). Advantages of lean-burn engines include more efficient fuel use and lower exhaust hydrocarbon emissions than conventional gasoline engines.

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In order to enable the lean burning of fuel over a large portion of the engine map, the engine 110 is designed in such a way to enable a large air flow into the combustion chamber and a good mixing with the relatively small amount of fuel that is to be burnt to ensure a reliable combustion process that will effectively burn all fuel, despite the oxygen rich conditions.

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Figure 2 shows a cross section of a portion of an engine block 52 and a cylinder head 53. The engine block 52 comprises a cylinder 57 which houses a piston 54 shown at 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 gasket interface surface 58, which may be substantially planar. A head gasket 80 is located between the engine block 52 and cylinder head 53.

Referring additionally to Figure 3, a pair of air inlets 49a, 49b provide a path for a flow of air to the combustion chamber 50 in use, and a pair of exhaust outlets 56a, 56b provide an exhaust path for the combustion products exiting the combustion chamber 50 in use. The air inlets 49a, 49b connect to respective air inlet openings 91a, 91b located in the roof surface 90 of the combustion chamber 50, and the exhaust outlets 56a, 56b connect to respective exhaust outlet openings 92a, 92b located in the roof surface 90 of the combustion chamber 50. The first air inlet opening 91a and the first exhaust outlet opening 92a are located on a first side 93a of the combustion chamber 50, and the second air inlet opening 91b and the second exhaust outlet opening 92b are located on a second side 93b of the combustion chamber 50. The cross section of Figure 2 is taken along section A-A which passes through the first air inlet opening 91a and the first exhaust outlet opening 92a on the first side 93a of the combustion chamber 50.

Referring once again to Figure 2, an inlet valve 51 controls the opening and closing of the first air inlet opening 91a, and an exhaust valve 55 controls the opening and closing of the first exhaust outlet opening 92a. An equivalent inlet valve (not shown) controls the opening and closing of the second air inlet opening 91b, and an equivalent exhaust valve (not shown) controls the opening and closing of the second exhaust outlet opening 92b. The inlet valve 51 and the exhaust valve 55 are shown in the closed position in Figure 2.

A dotted line provides a simplified 2D representation of the preferred air flow path 59 into and through the combustion chamber 50 and cylinder 57 during the intake stroke. As noted above, the inlet valve 51 is shown in the closed position in Figure 2. The air flow path 59 is not possible with the inlet valve 51 in the closed position as shown. Nonetheless, the preferred air flow path 59 is shown for the purpose of illustration.

With the valve 51 and air inlet design of this embodiment, it is possible to create a tumble motion of the incoming air, first along the roof 90 of the combustion chamber 50 towards the opposite wall of the cylinder 57, under the outlet valves 55 that close off the exhaust outlet openings 92a, 92b, and then down along that opposite wall of the cylinder 57, back over the

top surface of the piston 54 and up along the other wall of the cylinder 57 in the direction of the inlet valves 51 again. This tumble is preferably kept in motion during the full intake stroke and at least a portion of the compression stroke of the piston 54 moving through the cylinder 57. The thus produced tumble helps to obtain an optimal distribution of air and fuel inside the cylinder 57 and combustion chamber 50 that can then break down in the latter stages of the compression stroke into turbulence to facilitate the subsequent combustion process. Wherein, in this context, "turbulence" refers to a flow state having chaotic changes in velocity and pressure and no necessarily clear flow directions as is well known in the art.

Figure 3 shows a plan view of the roof surface 90 of the combustion chamber 50 and Figure 4 shows a cross sectional view of the engine block 52 and cylinder head 53 along section B-B shown in Figure 3. Section B-B corresponds with the plane of symmetry 87 of the combustion chamber 50 such that every feature on the first side 93a of the combustion chamber 50 is a mirror image of every feature of the second side 93b of the combustion chamber 50.

The combustion chamber roof surface 90 extends into the cylinder head 53 away from the gasket interface surface 58. The intersection between the combustion chamber roof surface 90 and the gasket interface surface 58 comprises a combustion chamber opening 86 in the gasket interface surface 58. The pair of air inlet openings 91a, 91b, and the pair of exhaust outlet openings 92a, 92b are formed in the combustion chamber roof surface 90. For the avoidance of doubt, the internal surfaces of the air inlets 49a, 49b, and exhaust outlets 56a, 56b seen in Figure 3 do not form part of the combustion chamber roof surface 90.

As best shown in Figure 4, a central domed surface portion 99 of the combustion chamber roof surface 90 defines a central domed portion 88 of the combustion chamber 50. In this embodiment the central domed surface portion 99 is elongate such that it extends from one side of the combustion chamber 50 to the other in a direction substantially perpendicular to the plane of symmetry 87. In an alternative embodiment the central domed surface portion 99 may be substantially circular or oval in plan view. Note that the central domed surface portion 99 of the combustion chamber roof surface 90 is not a single smooth surface, but rather is a surface made up of a plurality of facets made by different machine cutters during manufacture or formed during casting of the cylinder head.

Two sloped surface portions 94, 95 of the combustion chamber roof surface 90 define a sloped portion 89 of the combustion chamber 50. In this embodiment the sloped surface portions 94, 95 each have a shape which conforms to the surface of a single cone. That is to say, the

sloped surface portions 94, 95 each form part of the surface of the same conical shape. In an alternative embodiments, each of the sloped surface portions 94, 95 may conform to the surface of two different conical shapes such that curvature and slope of the first sloped surface 94 does not match the slope and curvature of the second sloped surface 95. In a further alternative embodiment, the sloped surfaces 94, 95 may be planar with equal or different slopes depending on design choice. As best shown in Figure 4, the combustion chamber roof surface 90 between the sloped surface portions 94, 95 and the combustion chamber opening 86 comprises curved portions which extend from the sloped surface portions 94, 95 to the combustion chamber opening 86.

The skilled person will understand that whether the sloped surface portions 94, 95 conform to the surface of a cone, or whether they are planar, the cross sections of the sloped surface portions 94, 95 will be substantially straight along the plane of symmetry 87 of the combustion chamber 50.

A spark plug seat 75 and a fuel injector seat 76 are located in the cylinder head. Both the spark plug seat 75 and fuel injector seat 76 open into the domed surface portion 99 of the combustion chamber roof surface 90. The spark plug seat 75 opens into roof surface 90 at the approximate centre of the combustion chamber 50, and the fuel injector seat 76 opens into the roof surface 90 substantially adjacent to the spark plug seat opening further towards the air inlet openings 91a, 91b than the spark plug seat opening. Both the spark plug seat opening and the fuel injector seat opening are located substantially on the plane of symmetry 87 of the combustion chamber 50.

The spark plug seat 75 is configured so that the tip 78 of the spark plug 82 is supported towards the centre of the central domed portion 88 substantially on the plane of symmetry 87 of the combustion chamber 50. The fuel injector seat 76 is configured to support the tip 77 of the fuel injector 81 proximate the combustion chamber roof surface 90 substantially in line with the tip 78 of the spark plug 82.

Referring now to Figure 5, the slope of the sloped surface portions 94, 95 of the combustion chamber roof surface 90 along the plane of symmetry 87 is illustrated by dotted lines 84, 85. The dotted lines 84, 85 therefore represent a geometric extension of the sloped surface portions 94, 95 along the plane of symmetry 87. In this embodiment, the sloped surface portions 94, 95 have a shape which conforms to the surface of a cone which has its apex at the spark gap 83. The sloped surface portions 94, 95 are therefore configured so that the

spark gap 83 of the spark plug 82 is substantially coincidental with the geometric extension of the sloped surface portions 94, 95.

As discussed above, in an alternative embodiment the sloped surface portions 94, 95 do not conform to a single conical surface, but instead conform to two separate conical surfaces. In cases such as this the sloped surface portions 94, 95 may conform to conical surfaces each of which has its apex at the spark gap 83. Alternatively, one or both of the sloped surface portions 94, 95 may conform to conical surfaces which do not have an apex coincidental with the spark gap 83. In such cases, at least the geometric extension of the sloped surface portions along the plane of symmetry 87 of the combustion chamber 50 are coincidental with the spark gap 83.

In the further alternative discussed above, the sloped surface portions 94, 95 may be planar. In such cases, the geometric extension of the sloped surface portions along the plane of symmetry 87 of the combustion chamber 50 are coincidental with the spark gap 83. Planar sloped surface portions may have the same or different slopes.

The piston 54 comprises a working surface 79 which has a central scooped portion 140 and outer sloped portions 96, 97. As shown most clearly in Figure 4, the outer sloped portions 96, 97 of the working surface 79 conform to the shape of the sloped surface portions 94, 95 of the combustion chamber roof surface 90.

As discussed above, during the intake stroke of the piston 54, and during the early stages of the compression stroke of the piston 54, the air flow path tumbles as illustrated by the dotted line 59 in Figure 2. As the piston 54 moves through the later stages of the compression stroke this tumble airflow pattern breaks down into a turbulent flow which helps to maximise combustion efficiency and flame front speed. As the air and fuel mixture is compressed into the combustion chamber 50 by the rising piston 54, the air fuel mixture is forced into the central domed portion 88 of the combustion chamber 50 as the sloped portions 96, 97 of the working surface 79 approach the sloped surface portions 94, 95 of the combustion chamber roof surface 90; this is known as “squish”. Because the sloped surface portions 94, 95 slope towards the spark gap 83 of the spark plug 82, the air fuel mixture is directed towards the spark gap 83 where it is ignited by a spark just before the piston 54 reaches top dead centre.

The sloped surface portions 94, 95 of the combustion chamber roof 90 and the sloped portions 96, 97 of the working surface 79 of the piston 54 are configured so that the maximum separation between them when the piston 54 is at top dead centre is around 1.2 mm

(measured normal to the surfaces when the engine is cold). It has been found in practice that the gap between the sloped surface portions 94, 95 of the combustion chamber roof 90 and the sloped portions 96, 97 of the working surface 79 should be greater than about 0.8mm and less than about 1.4mm when the piston 54 is at top dead centre (measured normal to the surfaces when the engine is cold). A gap of less than about 0.8mm risks the piston 54 hitting the cylinder head 53, and a gap any greater than about 1.4mm results in poor combustion and insufficient "squish". The skilled person will understand that "cold" in the above description means substantially at the same temperature as the environment.

Specific characteristics of the embodiment shown in the Figures are described below by way of example with particular reference to Figure 3. The surface area of the first sloped surface portion 94 is less than the surface area of the second sloped surface portion 95, and the length of the first sloped surface portion 94 along the plane of symmetry 87 of the combustion chamber 50 is less than the length of the second sloped surface portion 95 along the plane of symmetry 87.

The length of the intersection 135 between the first sloped surface portion 94 and the central domed portion 99 of the combustion chamber roof surface 90, and the length of the intersection 136 between the second sloped surface portion 95 and the central domed portion 99 are substantially equal. The intersection 135 between the first sloped surface portion 94 and the central domed portion 99 is located further towards the combustion chamber opening 86 than the shortest possible line joining the outermost extremities of the air inlet openings 91a, 91b. The intersection 136 between the second sloped surface portion 95 and the central domed portion 99 is located further towards the combustion chamber opening 86 than the shortest possible line joining the outermost extremities of the exhaust outlet openings 92a, 92b.

The ratio of the width of the combustion chamber 50 in plan view measured along the plane of symmetry 87 and the width of the central domed portion 88 of the combustion chamber 50 measured in a direction along the plane of symmetry 87 is about 1.7:1.

Figure 6 shows a schematic drawing of the combustion chamber roof surface 90 with the piston 54 near top dead centre. An alternative combustion chamber roof surface 515 geometry with a conforming alternative piston geometry 510 is also shown superimposed with the piston 54 and combustion chamber roof surface 90.

The piston 510 has a wider central scooped portion 540 than the central scooped portion 140 of the piston 54 such that the edges of the central scooped portion 540 of the piston 510 are further towards the periphery of the piston 510 than the edges of the central scooped portion 140 of the piston 54. As a result, in order to maintain the minimum gap of between 0.8mm and 1.4mm between the sloped surface portions of the combustion chamber roof surface and the outer sloped portions of the working surface of the piston, the slope of the outer sloped portions 513, 514 of the working surface 79 of the piston 510 are steeper than the outer sloped portions 96, 97 of the working surface 79 of the piston 54. Consequently, the sloped surface portions 512, 516 of the combustion chamber roof surface 515 of the piston 510 are steeper than the sloped surface portions 94, 95 of the combustion chamber roof surface 90. As a result, the geometric extensions 517 of the sloped surface portions 512, 516 of the combustion chamber roof surface 515 have a common apex 518 at a different position to the common apex (at the spark gap 83) of the geometric extensions 84, 85 of the sloped surface portions 94, 95 of the combustion chamber roof surface 90. An increase of steepness 616 of about 1.6 degrees may be measurable between the geometric extensions 85 and 517. Other increases of steepness may be useful. Nonetheless, the apex 518 is located between the opening of the spark plug seat 75 in the combustion chamber roof 515 and the tip 78 of the spark plug 82 so that the air fuel mixture is directed towards the vicinity of the tip 78 of spark plug 82 where it is ignited by a spark just before the piston 510 reaches top dead centre.

As will be clear to a person skilled in the art, there are many possible configurations for a combustion chamber and associated piston and each particular engine geometry and fuel combination will require slightly different tuning of the working surface configuration and associated combustion chamber roof geometry. It has been found in practice that it is desirable for the "squish" to be aimed at the lower end of the spark plug in use. As demonstrated by the piston 510 described above, it is possible to aim the "squish" at a slightly different position in the space below the spark plug. It is preferable to aim the "squish" so that the apex of a geometric extension of the sloped surface portions of the combustion chamber roof surface are located within a volume envelope that is described by a 360° rotation of the spark plug 82 when the spark plug 82 is supported by the spark plug seat 76 in the combustion chamber 50. This envelope illustrated in Figure 6 by dotted line 640. It will be clear to the skilled person that the spark plug 82 does not actually rotate in its seat 76 in use, but rather is held in a predetermined position. However, the skilled person will understand that nonetheless, a notional 360° rotation of the spark plug 82 when the spark plug 82 is held at the predetermined position in the combustion chamber 50 will describe a defined volume.

- In the embodiment described above the outer sloped portions 512, 516 of the combustion chamber roof surface 515 conform to the shape of a single cone such that the geometric extensions 517 of the sloped surface portions 512, 516 have a common apex. In an alternative embodiment the sloped surface portions of the combustion chamber roof surface may conform to different cones which may share a common apex, or which may have different apex locations. In such cases the apex of the geometric extensions of the different conforming conical surfaces of the combustion chamber roof surface are nonetheless located within the volume 640 described by a 360° rotation of the spark plug 82.
- 10 Although the spark plug 82 and fuel injector 81 are shown in line along the plane of symmetry 87 of the combustion chamber 50, it will be appreciated that the spark plug 82 and fuel injector 81 may in other embodiments be located sided by side in a plane perpendicular to the plane of symmetry 87 or in any other suitable position.
- 15 It will be appreciated that various changes and modifications can be made to the present invention without departing from the scope of the present application.

CLAIMS

1. A cylinder head for a lean-burn gasoline engine, the cylinder head comprising:
a substantially planar gasket interface surface;
5 a combustion chamber extending into the cylinder head away from the gasket interface surface, wherein the combustion chamber comprises a combustion chamber roof surface having:
a central domed surface portion defining a central domed portion of the combustion chamber; and
10 a sloped surface portion defining a sloped portion of the combustion chamber, wherein the sloped surface portion comprises a substantially straight cross-section along a plane of symmetry of the combustion chamber, and
a spark plug seat configured to support a spark plug, in use, such that a spark gap of the spark plug is held in a substantially fixed position within the domed portion of the combustion chamber, wherein the sloped surface portion of the combustion chamber roof is
15 configured so that a geometric extension of the sloped surface portion is coincidental with the spark plug gap in use.
2. A cylinder head as claimed in claim 1, wherein the sloped surface portion conforms
20 to part of the surface of a cone.
3. A cylinder head as claimed in claim 1 or 2, comprising two sloped surface portions located on opposite sides of the combustion chamber.
- 25 4. A cylinder head as claimed in claim 3, wherein the sloped surface portions comprise a first sloped surface portion located adjacent a combustion chamber air inlet opening, and a second sloped surface portion located adjacent a combustion chamber exhaust outlet opening.
- 30 5. A cylinder head as claimed in claim 4, wherein the combustion chamber comprises a pair of air inlet openings and a pair of exhaust outlet openings, wherein the first sloped surface portion is at least partially located between the pair of air inlet openings, and wherein the second sloped surface portion is at least partially located between the pair of exhaust outlet openings.
- 35 6. A cylinder head as claimed in claim 5, wherein the surface area of the first sloped surface portion is less than the surface area of the second sloped surface portion.

7. A cylinder head as claimed in claim 6, wherein the length of the first sloped surface portion along the plane of symmetry of the combustion chamber is less than the length of the second sloped surface portion along the plane of symmetry of the combustion chamber.

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8. A cylinder head as claimed in any one of claims 5 to 7, wherein the first sloped surface portion comprises an innermost edge at an interface between the first sloped surface portion and the central domed portion, and wherein the second sloped surface portion comprises an innermost edge at an interface between the second sloped surface portion and the central domed portion, wherein the length of the innermost edge of the first sloped surface portion is substantially equal to the length of the innermost edge of the second sloped surface portion.

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9. A cylinder head as claimed in any one of claims 5 to 8, wherein the innermost edge of the first sloped surface portion is located between the pair of air inlet openings no further towards the centre of the combustion chamber than the shortest possible line joining the outermost extremities of the air inlet openings, and wherein the innermost edge of the second sloped surface portion is located between the pair of exhaust outlet openings no further towards the centre of the combustion chamber than the shortest possible line joining the outermost extremities of the exhaust outlet openings.

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10. A cylinder head as claimed in any one of claims 5 to 9, wherein the ratio of:
the width of a projection of the combustion chamber onto a plane parallel to the gasket interface surface measured in a direction along the plane of symmetry of the combustion chamber; and

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the width of a projection of the central domed portion of the combustion chamber onto a plane parallel to the gasket interface surface measured in a direction along the plane of symmetry of the combustion chamber, is about 1.7:1.

11. A cylinder head as claimed in any one of claims 3 to 10, wherein the angle between the gasket interface surface and each sloped surface portion measured along the plane of symmetry of the combustion chamber are substantially equal.

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12. A cylinder head as claimed in any preceding claim, wherein the combustion chamber roof surface comprises concave curved portions located between an outermost edge of the combustion chamber and the or each sloped surface portion.

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13. A cylinder head as claimed in any preceding claim, wherein the central domed portion of the combustion chamber is elongated in a direction perpendicular to the plane of symmetry of the combustion chamber.

5 14. A cylinder head as claimed in any preceding claim, wherein the spark plug seat comprises an opening in the central domed surface of the combustion chamber located such that it intersects the plane of symmetry of the combustion chamber.

10 15. A cylinder head as claimed in claim 14, wherein the combustion chamber comprises a fuel injector seat opening in the central domed surface of the combustion chamber, wherein the fuel injector seat opening is located such that it intersects the plane of symmetry of the combustion chamber, wherein the fuel injector seat opening is positioned further towards the pair of air inlet openings than the spark plug seat opening.

15 16. A cylinder head for a lean-burn gasoline engine, the cylinder head comprising:
a combustion chamber extending into the cylinder head, the combustion chamber comprising a combustion chamber roof surface having a sloped surface portion, wherein the sloped surface portion conforms to part of the surface of a cone; and
a spark plug seat configured to support the tip of a spark plug at a predetermined
20 position within the combustion chamber in use, wherein the combustion chamber is configured so that the apex of a geometric extension of the sloped surface portion of the combustion chamber roof surface is located within a volume envelope that is described by a 360° rotation of the spark plug tip when the spark plug tip is supported at the predetermined position in the combustion chamber.

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17. A lean-burn gasoline engine comprising a cylinder head as claimed in any one of claims 1 to 16.

30 18. A lean-burn gasoline engine as claimed in claim 17, comprising a piston having a working surface configured to conform to at least part of the or each sloped surface portion of the combustion chamber roof surface in use.

35 19. A lean-burn gasoline engine as claimed in claim 18, wherein the gap between the sloped surface portion of the combustion chamber roof surface and the conforming part of the working surface of the piston is no less than 0.8mm and no more than 1.4mm when the piston is at top dead centre as measured when the engine is at substantially the same temperature as the environment.

20. A vehicle comprising a lean-burn gasoline engine according to any one of claims 17 to 19.

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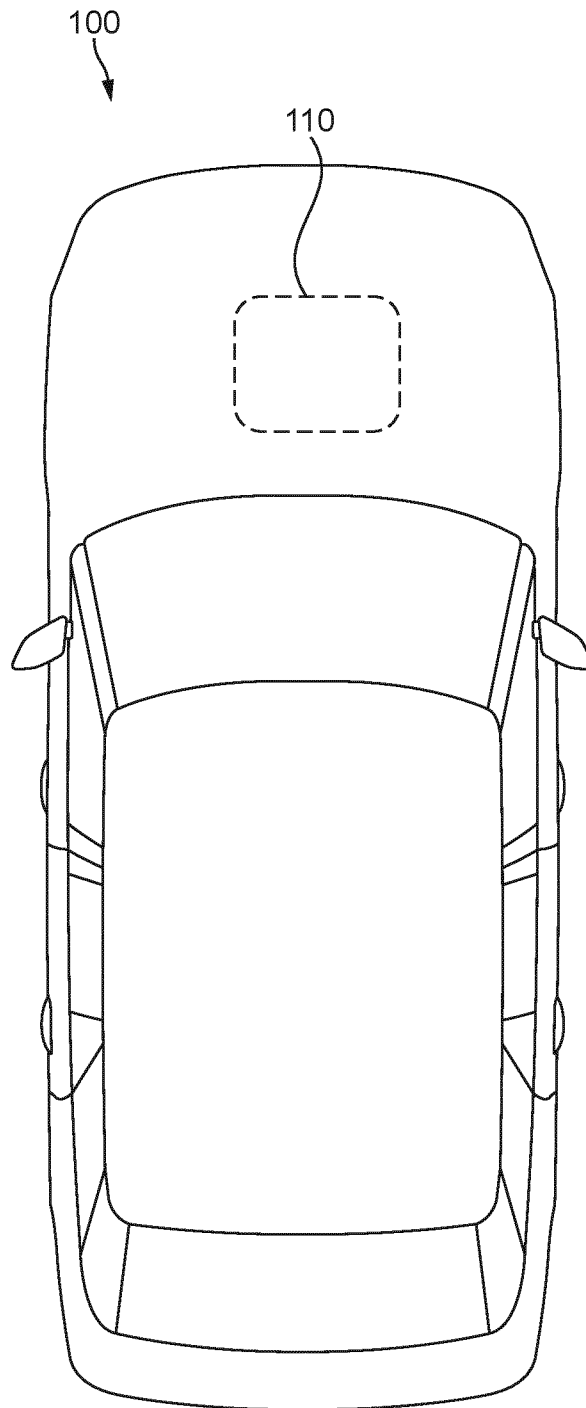


FIG. 1

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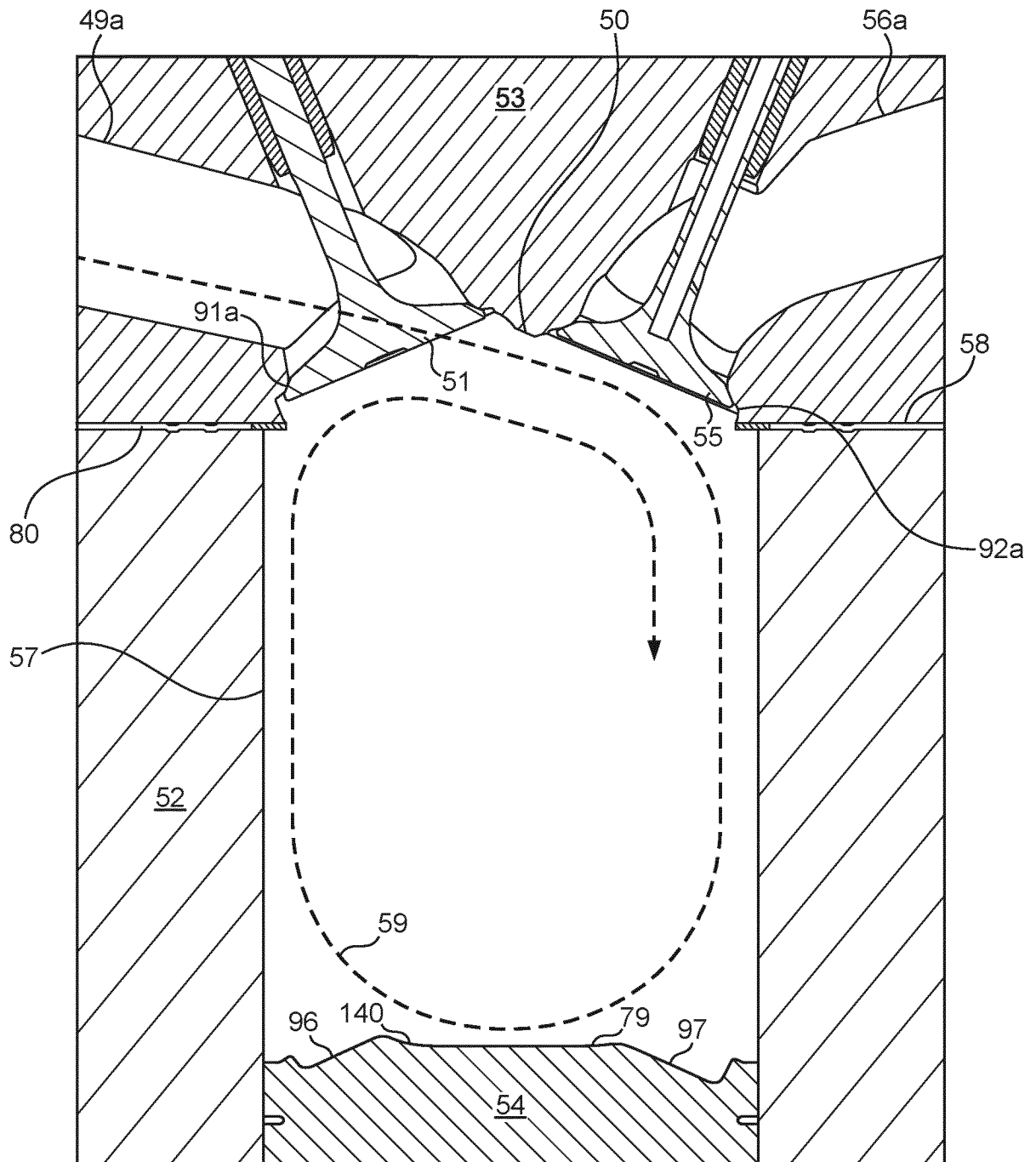


FIG. 2

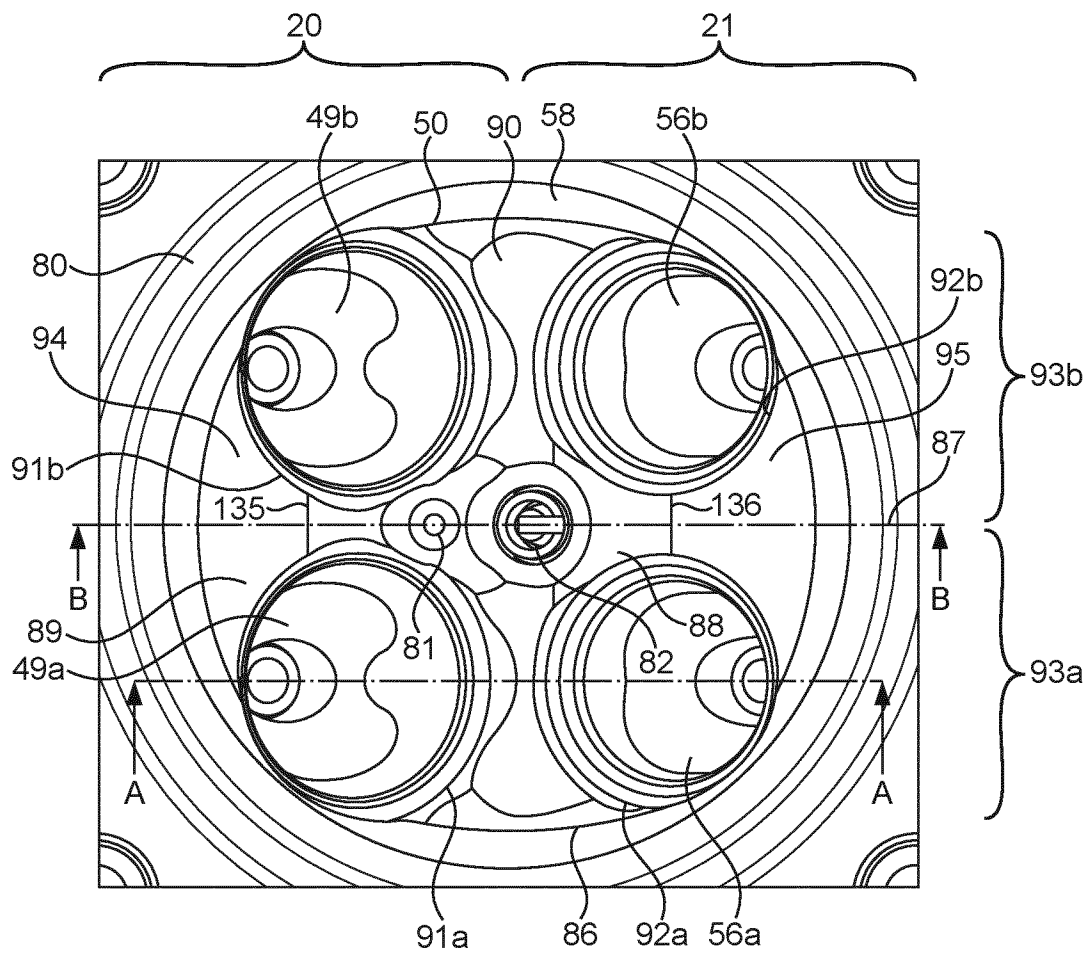


FIG. 3

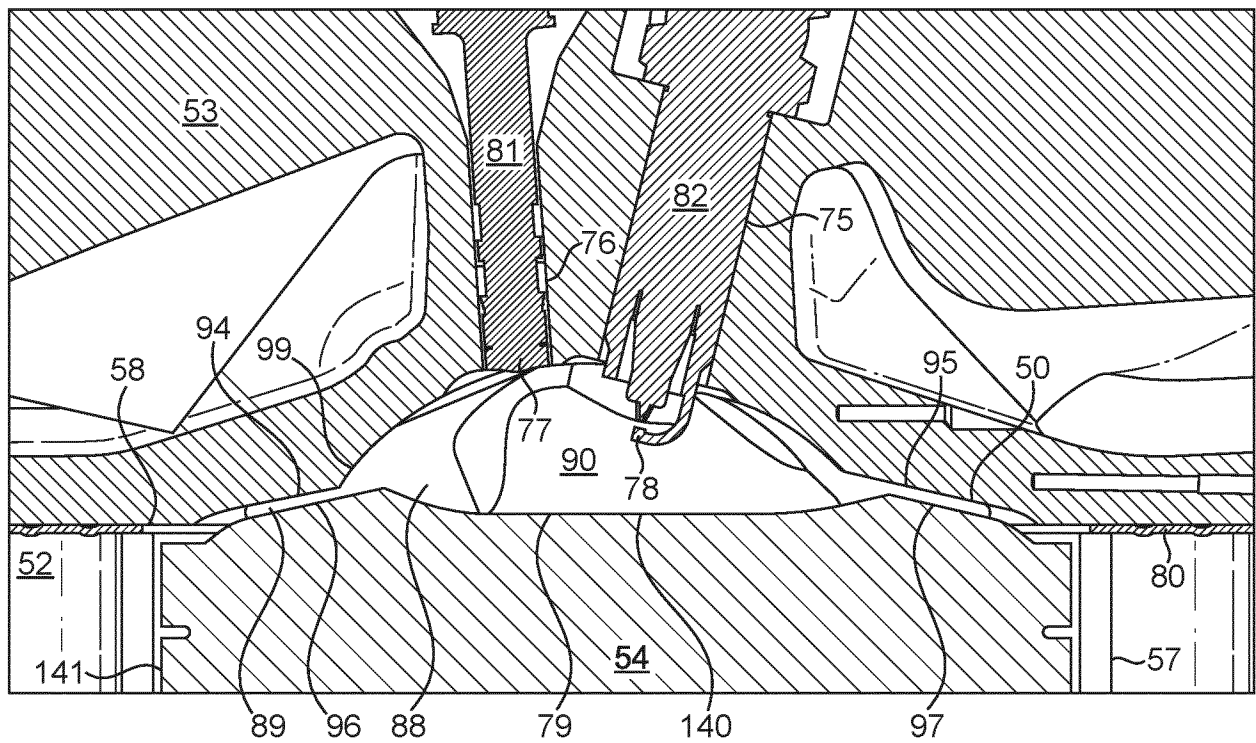


FIG. 4

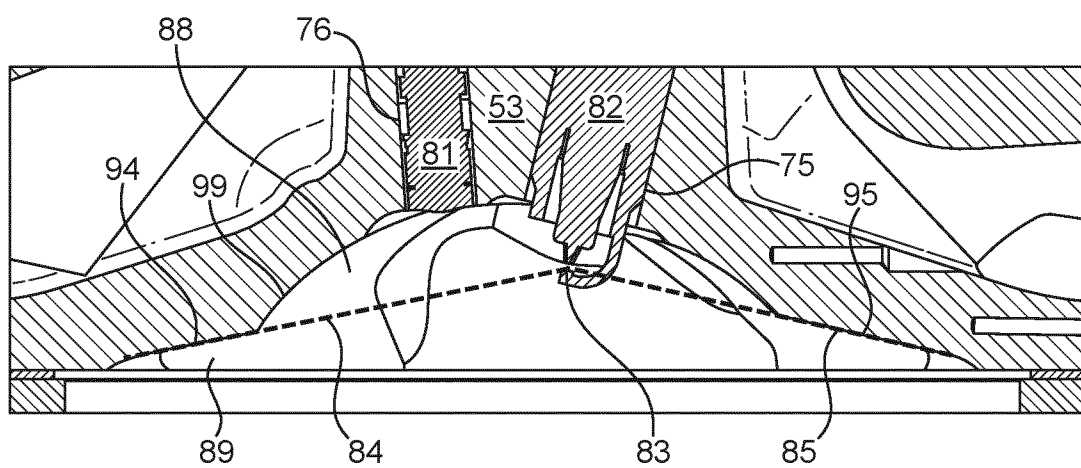


FIG. 5

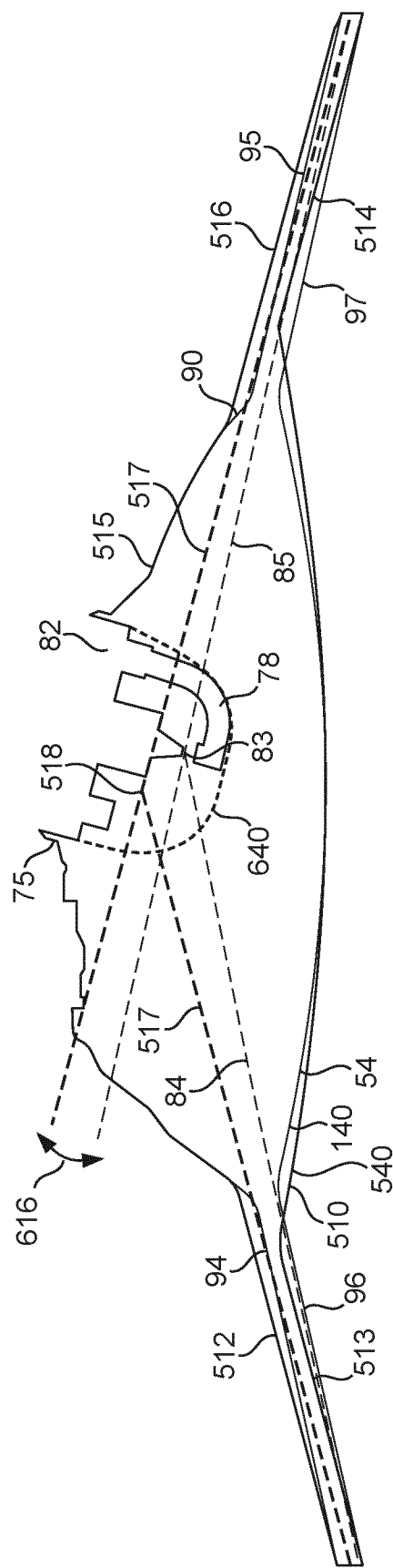


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2021/057928

A. CLASSIFICATION OF SUBJECT MATTER
INV. F02F1/24 F02B23/10
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 F02B

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 A	WO 2009/044225 A1 (KULYGIN VIKTOR IVANOVYCH [UA] ET AL.) 9 April 2009 (2009-04-09) figures	1-3,10, 11,14, 16-20 4-9,12, 13,15
X	----- US 5 522 354 A (SAKAMOTO NOBORU [JP] ET AL) 4 June 1996 (1996-06-04) figures -----	1,2,14



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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"P" document published prior to the international filing date but later than the priority date claimed

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

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Date of the actual completion of the international search

22 November 2021

Date of mailing of the international search report

30/11/2021

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2021/057928

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2009044225 A1	09-04-2009	UA 87733 C2 WO 2009044225 A1	10-08-2009 09-04-2009
US 5522354 A	04-06-1996	NONE	