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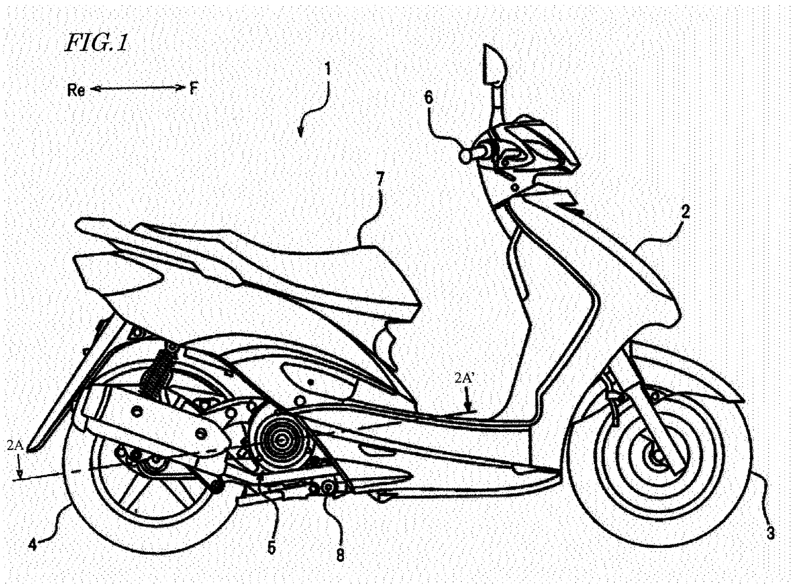
(54) **Air-cooling type internal combustion engine and saddled vehicle having the same**

(57) There is provided an air-cooling type internal combustion engine including a cylinder head body which has a cooling air duct with a sufficient cross-sectional area and which can be suitably molded by die casting.

An air-cooling type internal combustion engine according to the present invention includes a cylinder head body **100,** the cylinder head body **100** including: a plurality of cooling fins **10;** a cam chamber wall **20** defining a cam chamber **109;** a combustion chamber wall **30** defining a combustion chamber **110;** an intake duct **40** through which air intake into the combustion chamber **110** is to occur; an exhaust duct **50** through which exhaust from the combustion chamber **110** is to occur; and a cooling air duct **60** for allowing cooling air o pass through the cam chamber wall **20** and the combustion chamber wall **30.** The cylinder head body **100** is integrally molded from an aluminum alloy by die casting. The cylinder head body **100** further includes a cam chain chamber **70** for accommodating a cam chain **113.** When viewed in the cylinder axis direction **D1,** the exhaust duct **50** extends in such a manner that the exhaust duct **50** becomes more distant from the cam chain chamber **70** when going from the inlet side toward the outlet side, and the exhaust duct **50** is formed so that an axis **50x** of the exhaust duct **50** is linear.



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Description

BACKGROUND

1. Technical Field:

[0001] The present invention relates to an internal combustion engine, and more particularly to an air-cooling type internal combustion engine. Moreover, the present invention relates to a saddled vehicle having an air-cooling type internal combustion engine.

2. Description of the Related Art:

[0002] In recent years, for improved mileage, there is a desire to operate internal combustion engines at higher compression ratios. However, increasing the compression ratio is likely to allow the temperature near the top dead center of the piston to increase, thus inducing knocking.

[0003] In order to prevent such knocking, it is necessary to enhance the coolability of the cylinder head. Generally speaking, an air-cooling type internal combustion engine tends to have poorer coolability than that of a water-cooling type internal combustion engine. Thus, it may be said that a further enhancement in the coolability of the cylinder head is especially desired in air-cooling type internal combustion engines.

[0004] Therefore, it might be conceivable to provide a large number of thin cooling fins through molding the cylinder head by die casting. Japanese Laid-Open Patent Publication No. 2004-116464 (hereinafter, "Patent Document 1") discloses molding a cylinder head with cooling fins by die casting. Moreover, in the technique disclosed in Patent Document 1, when molding a cylinder head by die casting, previously-prepared liners are cast together to form an intake duct and an exhaust duct. In other words, the cylinder head contains separate members (i.e., a liner for intake duct formation and a liner for exhaust duct formation).

[0005] However, in the cylinder head disclosed in Patent Document 1, no cooling air duct is formed for allowing cooling air to come through. Therefore, even if the cylinder head of Patent Document 1 is used in an air-cooling type internal combustion engine, it is possible that sufficient coolability may not be obtained. Moreover, the difficulty to form an undercut shape (which is a shape that hinders release through a usual mold-opening maneuver when the molding is to be taken out of the die) by die casting makes it difficult to provide a cooling air duct having a sufficient cross-sectional area on a cylinder head which is molded by die casting.

[0006] Furthermore, in the case where liners are cast together as in Patent Document 1, misalignments of the liners may occur at die casting, thus causing misalignments of the intake duct and the exhaust duct, whereby the performance of the internal combustion engine may be deteriorated.

[0007] Therefore, it is preferable to form the intake duct and the exhaust duct without casting liners together during die casting, which would mean that cores must be used. In that case, however, misalignments of the cores may occur, which in itself may deteriorate the performance of the internal combustion engine.

SUMMARY

[0008] The present invention has been made in view of the above problems, and an objective thereof is to provide an air-cooling type internal combustion engine including a cylinder head body which has a cooling air duct with a sufficient cross-sectional area and which can be suitably molded by die casting.

[0009] An air-cooling type internal combustion engine according to the present invention comprises a cylinder head body, the cylinder head body including: a plurality of cooling fins; a cam chamber wall defining a cam chamber; a combustion chamber wall defining a combustion chamber; an intake duct through which air intake into the combustion chamber is to occur; an exhaust duct through which exhaust from the combustion chamber is to occur; and a cooling air duct for allowing cooling air to pass through between the cam chamber wall and the combustion chamber wall, wherein, the cylinder head body is integrally molded from an aluminum alloy by die casting; the cylinder head body further includes a cam chain chamber for accommodating a cam chain; and when viewed in a cylinder axis direction, the exhaust duct extends in such a manner that the exhaust duct becomes more distant from the cam chain chamber when going from an inlet side toward an outlet side and the exhaust duct is formed so that an axis of the exhaust duct is linear.

[0010] In one embodiment, the plurality of cooling fins include a cooling fin extending from an exhaust duct wall defining the exhaust duct.

[0011] In one embodiment, an inner peripheral surface of the exhaust duct has a surface roughness Rz of 30 μm or less.

[0012] In one embodiment, the cylinder head body further includes a plurality of bolt holes, into each of which a head bolt is to be inserted; one of the plurality of bolt holes is provided between the exhaust duct and the cam chain chamber; and a portion of the cooling air duct is located between the one bolt hole and the exhaust duct.

[0013] In one embodiment, the plurality of cooling fins are provided in such a manner that a total area of those cooling fins which are located on the combustion chamber side of an apex of the combustion chamber wall is greater than a total area of those cooling fins which are located on an opposite side of the combustion chamber from the apex of the combustion chamber wall.

[0014] In one embodiment, the plurality of cooling fins are provided so that, when viewed from an opposite side of the cylinder axis from the cam chain chamber, cylinder-axis-side edges of those cooling fins which are located on the combustion chamber side of the apex of the combustion chamber wall are closer to the cylinder axis than are cylinder-axis-side edges of those cooling fins which are located on an opposite side of the apex of the combustion chamber wall from the combustion chamber.

[0015] In one embodiment, a portion of the cooling air duct is defined by an exhaust duct wall defining the exhaust duct, the exhaust duct wall intersecting the cam chamber wall at an acute angle.

[0016] In one embodiment, the cam chamber wall has a thickness of not less than 1.5 mm and not more than 2.5 mm.

[0017] In one embodiment, a leading edge of each of the plurality of cooling fins has a thickness of not less than 1.0 mm and not more than 2.5 mm; and the plurality of cooling fins are disposed with a pitch of 7.5 mm or less.

[0018] In one embodiment, each of the plurality of cooling fins has a draft of not less than 1.0° and not more than 2.0°.

[0019] In one embodiment, the cylinder head body further includes a rib which is provided within the cooling air duct, the rib linking together the combustion chamber wall and the cam chamber wall.

[0020] In one embodiment, the rib is formed along a cooling air duct wall defining the cooling air duct.

[0021] In one embodiment, a circularity of a cross-sectional shape of the exhaust duct along a plane which is orthogonal to the axis of the exhaust duct is lower than a circularity of the shape of an outlet of the exhaust duct.

[0022] In one embodiment, the cross-sectional shape of the exhaust duct along the plane which is orthogonal to the axis of the exhaust duct is a substantial ellipse, and the shape of the outlet of the exhaust duct is a substantially perfect circle.

[0023] A saddled vehicle according to the present invention comprises an air-cooling type internal combustion engine of the above construction.

[0024] In the air-cooling type internal combustion engine according to the present invention, the exhaust duct of the cylinder head body extends in such a manner that the exhaust duct becomes more distant from the cam chain chamber when going from the inlet side toward the outlet side, whereby the space between the outlet of the exhaust duct and the cam chain chamber can be expanded. Therefore, it is easy to secure a sufficiently large cross-sectional area of the cooling air duct. This realizes a sufficiently high coolability. Moreover, in the internal combustion engine according to the present invention, the exhaust duct of the cylinder head body is formed so that its axis is linear. Therefore, exhaust resistance can be reduced, and a more efficient combustion is enabled. Furthermore, when molding the cylinder head body by die casting, the exhaust duct in its final shape can be formed with a die, which makes it unnecessary to employ subsequent machining to change the shape of the exhaust duct.

[0025] Typically, the plurality of cooling fins include those cooling fins which extend from the exhaust duct wall defining the exhaust duct. Since the exhaust duct is one place in the cylinder head body that is liable to high temperature, the cooling fins extending from the exhaust duct wall will allow for an improved cooling efficiency.

[0026] When the shape of the exhaust duct is designed so that its axis is linear, it is easy to form the exhaust duct by using a die, without using any cores. By forming the exhaust duct with a die, it is possible to make the surface roughness of the inner peripheral surface of the exhaust duct smaller than that when cores are used. More specifically, the surface roughness Rz (maximum height) of the inner peripheral surface of the exhaust duct can be made 30 μm or less, thus reducing exhaust resistance and improving the output power of the internal combustion engine. Furthermore, by also ensuring that the surface roughness Rz of the inner peripheral surface of the intake duct is 30 μm or less, intake resistance can be reduced to further improve the output power of the internal combustion engine.

[0027] When a bolt hole in which a head bolt is to be inserted is provided between the exhaust duct and the cam chain chamber, it is necessary that a portion of the cooling air duct be located (disposed) in a space which is narrower than that between the exhaust duct and the cam chain chamber (i.e., a space between the bolt hole and the exhaust duct). However, as described above, the exhaust duct extends in such a manner that the exhaust duct becomes more distant from the cam chain chamber when going from the inlet side toward the outlet side; therefore, a sufficiently large cross-sectional area of the cooling air duct can be ensured also between the bolt hole and the exhaust duct.

[0028] Preferably, the plurality of cooling fins are provided in such a manner that a total area of those cooling fins which are located on the combustion chamber side of an apex of the combustion chamber wall is greater than a total area of those cooling fins which are located on the opposite side of the apex of the combustion chamber wall from the combustion chamber. During the operation of the internal combustion engine, within the cylinder head body, the region which is on the combustion chamber side of the apex of the combustion chamber wall has a higher temperature than the region on the opposite side of the apex of the combustion chamber wall from the combustion chamber. Therefore, coolability can be efficiently improved by ensuring that a total area of the cooling fins located in the former region is greater than a total area of the cooling fins located in the latter region.

[0029] Moreover, it is preferable that the plurality of cooling fins are provided so that, when viewed from the opposite side of the cylinder axis from the cam chain chamber, edges (on the cylinder axis) of those cooling fins which are located on the combustion chamber side of an apex of the combustion chamber wall are closer to the cylinder axis than are edges (on the cylinder axis side) of those cooling fins which are located on the opposite side of the apex of the combustion chamber wall from the combustion chamber. Since the cylinder-axis-side edges of those cooling fins which are located on the combustion chamber side of the apex of the combustion chamber wall are closer to the cylinder axis than are the cylinder-axis-side edges of those cooling fins which are located on the opposite side of the apex of the combustion chamber wall from the combustion chamber, i.e., the edges of the latter cooling fins are more distant from the cylinder axis than are the edges of the former cooling fins, the cross-sectional area of the cooling air duct can be increased further.

[0030] When a portion of the cooling air duct is defined by an exhaust duct wall which defines the exhaust duct and which intersects the cam chamber wall at an acute angle, the following advantage is provided. Usually, when forming the shape of the cooling air duct with a die at die casting, the portion of the die that corresponds to the cooling air duct is shaped so as to protrude from any other portion. The tip end of a portion with such a protruding shape is liable to high temperature due to the heat of the melt. In particular, if there is any corner in the tip end, the corner may be eroded; therefore, generally, the tip end is to be designed so as to have a circular cross section. However, by allowing a portion of the cooling air duct to be defined by the exhaust duct wall intersecting the cam chamber wall at an acute angle, the cross-sectional area of the cooling air duct can be increased. In this case, the problem of erosion can be avoided because the cam chamber wall and the exhaust duct wall may both have a small thickness.

[0031] Preferably, the cam chamber wall has a thickness of 2.5 mm or less. When the thickness of the cam chamber wall is 2.5 mm or less, erosion of die corners can be prevented with greater certainty. However, if the thickness of the cam chamber wall is less than 1.5 mm, the compressive strength that is required of the cam chamber may not be adequately obtained, thus resulting in an insufficient resistance against flow stress occurring due to distortion; therefore, it is preferable that the thickness of the cam chamber wall is 1.5 mm or more.

[0032] In the air-cooling type internal combustion engine according to the present invention, the cylinder head body is molded by die casting; therefore, the thickness and pitch of the cooling fins can be reduced, thus improving coolability. Specifically, the thickness of the leading edge of each cooling fin may be not less than 1.0 mm and not more than 2.5 mm, and the plurality of cooling fins may be disposed with a pitch of 7.5 mm or less, whereby coolability can be improved.

[0033] Preferably, each of the plurality of cooling fins has a draft of 2.0° or less. By ensuring that the draft is as small as 2.0° or less, the interspace at the feet of the cooling fins can be increased, whereby coolability can be further improved. However, from the standpoint of facilitating release, it is preferable that the draft of each the plurality of cooling fins is 1.0° or more.

[0034] Preferably, the cylinder head body includes a rib which is provided within the cooling air duct, the rib linking together the combustion chamber wall and the cam chamber wall. Since the rib links together the combustion chamber wall and the cam chamber wall, the rib is able to transmit the heat of the combustion chamber wall to the cam chamber wall, thus enabling cooling with the lubricating oil in the cam chamber, whereby coolability can be improved. Moreover, the rib being provided within the cooling air duct also provides a cooling effect with the cooling air.

[0035] Note that the rib is preferably formed along the release direction used when the cylinder head body is molded by die casting. Therefore, the rib is preferably formed along the wall portion (cooling air duct wall) defining the cooling air duct.

[0036] Moreover, it is preferable that a cross-sectional shape of the exhaust duct along a plane which is orthogonal to the axis of the exhaust duct is a substantial ellipse, and that the shape of the outlet of the exhaust duct is a substantially perfect circle. Since the cross-sectional shape of the exhaust pipe is generally a substantially perfect circle, the shape of the outlet of the exhaust duct being a substantially perfect circle will prevent abrupt changes in the duct area, thus preventing deterioration in the performance of the internal combustion engine. When the exhaust duct extends in such a manner that the exhaust duct becomes more distant from the cam chain chamber when going from the inlet side toward the outlet side, if the cross-sectional shape of the exhaust duct along a plane which is orthogonal to the axis were a substantially perfect circle, it would be impossible to shape the outlet of the exhaust duct in a substantially perfect circle. In contrast, ensuring that the cross-sectional shape of the exhaust duct along a plane which is orthogonal to the axis is a substantial ellipse (i.e., so that the circularity of the cross-sectional shape of the exhaust duct along a plane which is orthogonal to the axis is lower than the circularity of the shape of the outlet of the exhaust duct) allows the outlet of the exhaust duct to be shaped in a substantially perfect circle.

[0037] According to the present invention, there is provided an air-cooling type internal combustion engine including a cylinder head body which has a cooling air duct with a sufficient cross-sectional area and which can be suitably molded by die casting.

[0038] Additional benefits and advantages of the disclosed embodiments will be apparent from the specification and Figures. The benefits and/or advantages may be individually provided by the various embodiments and features of the specification and drawings disclosure, and need not all be provided in order to obtain one or more of the same.

BRIEF DESCRIPTION OF THE DRAWINGS

[0039] FIG. **1** is a right side view schematically showing a motorcycle (saddled vehicle) **1** according to an embodiment of the present invention.

[0040] FIG. **2** is a cross-sectional view along line **2A-2A'** in FIG. **1.**

[0041] FIG. **3** is a diagram showing enlarged the vicinity of an engine (internal combustion engine) **101** which is shown in FIG. **2.**

[0042] FIG. **4** is a right side view of a portion of the engine **101.**

[0043] FIG. **5** is a cross-sectional left side view of the engine **101.**

[0044] FIG. **6** is an upper plan view schematically showing a cylinder head body **100** which is included in the engine **101** according to an embodiment of the present invention.

[0045] FIG. **7** is a bottom view schematically showing a cylinder head body **100** which is included in the engine **101** according to an embodiment of the present invention.

[0046] FIG. **8** is a front view schematically showing a cylinder head body **100** which is included in the engine **101** according to an embodiment of the present invention.

[0047] FIG. **9** is a rear view schematically showing a cylinder head body **100** which is included in the engine **101** according to an embodiment of the present invention.

[0048] FIG. **10** is a left side view schematically showing a cylinder head body **100** which is included in the engine **101** according to an embodiment of the present invention.

[0049] FIG. **11** is a right side view schematically showing a cylinder head body **100** which is included in the engine **101** according to an embodiment of the present invention.

[0050] FIG. **12** is a cross-sectional view schematically showing a cylinder head body **100** which is included in the engine **101** according to an embodiment of the present invention, along line **12A-12A'** in FIG. **11.**

[0051] FIG. **13** is a cross-sectional view schematically showing a cylinder head body **100** which is included in the engine **101** according to an embodiment of the present invention, along line **13A-13A'** in FIG. **7.**

[0052] FIG. **14** is a diagram schematically showing a plurality of cooling fins **10** of the cylinder head body **100.**

DETAILED DESCRIPTION

[0053] Hereinafter, with reference to the drawings, an embodiment of the present invention will be described. The present invention is not to be limited to the following embodiment.

[0054] FIG. **1** shows a saddled vehicle **1** according to the present embodiment. The saddled vehicle **1** shown in FIG. **1** is a motorcycle of a scooter type. Note that the saddled vehicle of the present invention is not limited to a scooter-type motorcycle **1.** The saddled vehicle of the present invention may be any other type of motorcycle, e.g., a so-called moped type, an off-road type, or an on-road type. Moreover, the saddled vehicle of the present invention is meant to be any arbitrary vehicle which a rider sits astraddle, without being limited to two-wheeled vehicles. The saddled vehicle of the present invention may be a three-wheeled vehicle or the like of a type whose direction of travel is changed as the vehicle body is tilted, or any other saddled vehicle such as an ATV (All Terrain Vehicle).

[0055] In the following description, the front, rear, right, and left are respectively meant as the front, rear, right, and left as perceived by the rider of the motorcycle **1.** Reference numerals **F, Re, R,** and **L** in the figures indicate front, rear, right, and left, respectively.

[0056] As shown in FIG. **1,** the motorcycle **1** includes a vehicle main body **2,** a front wheel **3,** a rear wheel **4,** and an engine unit **5** for driving the rear wheel **4.** The vehicle main body **2** includes handle bars **6** which are controlled by the rider, and a seat **7** on which the rider sits. The engine unit **5** is an engine unit of a so-called unit-swing type, and is supported by a body frame (not shown in FIG. **1)** so as to be capable of swinging around the pivot axis **8.** In other words, the engine unit **5** is supported by the body frame in a manner capable of swinging.

[0057] Next, with reference to FIG. **2** to FIG. **5,** the construction of the engine unit **5** of the motorcycle **1** will be described more specifically. FIG. **2** is a cross-sectional view along line **2A-2A'** in FIG. **1.** FIG. **3** is a diagram showing enlarged the vicinity of an engine **101** which is shown in FIG. **2.** FIG. **4** is a right side view of a portion of the engine **101.** FIG. **5** is a cross-sectional left side view of the engine **101.**

[0058] As shown in FIG. **2,** the engine unit **5** includes an engine (internal combustion engine) **101** and a V-belt type continuously variable transmission (hereinafter referred to as "CVT") **150.** Although the engine **101** and the CVT **150** integrally compose the engine unit **5** in the example illustrated in FIG. **2,** it will be appreciated that the engine **101** and the transmission may be separate.

[0059] The engine **101** is a single-cylinder engine having one cylinder. The engine **101** is a 4-stroke engine which sequentially repeats an intake step, a compression step, a combustion step, and an exhaust step. The engine **101** includes: a crankcase **102;** a cylinder block **103** which extends frontward (as used herein, "frontward" not only means frontward in the strict sense, i.e., a direction which is parallel to the horizon, but also encompasses directions which are inclined from the horizon) from the crankcase **102** and is coupled to the crankcase **102;** a cylinder head **104** which is connected in front of the cylinder block **103;** and a cylinder head cover **105** connected in front of the cylinder head **104.** A cylinder **106** is formed in the interior of the cylinder block **103.**

[0060] Note that the cylinder **106** may be formed of a cylinder liner or the like which is inserted in the main body (i.e., the portion of the cylinder block **103** excluding the cylinder **106)** of the cylinder block **103,** and may be made integral with the main body of the cylinder block **103.** In other words, the cylinder **106** may be made separable from the main body of the cylinder block **103,** or inseparable from the main body of the cylinder block **103.** A piston **107** is slidably accommodated in the cylinder **106.** The piston **107** is disposed so as to be capable of reciprocation between a top dead center **TDC** and a bottom dead center **BDC.**

[0061] The cylinder head **104** is overlaid on the cylinder block **103** so as to cover the cylinder **106.** The cylinder head **104** includes a cylinder head body **100** made of an aluminum alloy, a valve mechanism including a cam shaft **108,** an intake valve **161,** an exhaust valve **162,** and the like. The valve mechanism is accommodated in a cam chamber **109.** A portion **20** of the cylinder head body **100** that defines the cam chamber **20** is referred to as a cam chamber wall, as will be described later.

[0062] The cylinder head body **100,** the top face of the piston **107,** and the inner peripheral surface of the cylinder **106** together define a combustion chamber **110.** A portion **30** of the cylinder head body **100** that defines the combustion chamber **110** is referred to as a combustion chamber wall, as will be described later.

[0063] The piston **107** is linked to a crankshaft **112** via a con' rod **111.** The crankshaft **112** extends toward the left and the right, and is supported by a crankcase **102.** The cam shaft **108** is driven by a cam chain **113** which is connected to the crankshaft **112.** The cam chain **113** is accommodated in a cam chain chamber **70.**

[0064] In the present embodiment, the crankcase **102,** the cylinder block **103,** the cylinder head **104,** and the cylinder head cover **105** are separate pieces. However, they do not need to be separate pieces, and may be made integral as appropriate. For example, the crankcase **102** and the cylinder block **103** may be made integral, and the cylinder block **103** and the cylinder head **104** may be made integral. Moreover, the cylinder head **104** and the cylinder head cover **105** may be made integral.

[0065] As shown in FIG. **2,** the CVT **150** includes: a first pulley **151,** which is a driving pulley; a second pulley **152,** which is a drone pulley; and a V-belt **153** which is wound around the first pulley **151** and the second pulley **152.** The left end of the crankshaft **112** protrudes toward the left from the crankcase **102.** The first pulley **151** is attached to the left end of the crankshaft **112.** The second pulley **152** is attached to a main shaft **154.** The main shaft **154** is linked to a rear wheel shaft **155** via a gear mechanism not shown. A transmission case **156** is provided to the left of the crankcase **102.** The CVT **150** is accommodated in the transmission case **156.**

[0066] An electric generator **120** is provided on the right-hand portion of the crankshaft **112.** A cooling fan **121** is fixed at the right end of the crankshaft **112.** The cooling fan **121** rotates together with the crankshaft **112.** The cooling fan **121** is formed so as to suck air toward the left as it rotates. A shroud **130** is provided over the crankcase **102,** the cylinder block **103,** and the cylinder head **104.** The electric generator **120** and the cooling fan **121** are accommodated within the shroud **130.**

[0067] As shown in FIG. **4,** the engine **101** is an engine of a type such that the cylinder block **103** and the cylinder head **104** are elongated in the horizontal direction or in a direction which is slightly inclined from the horizontal direction so as to rise toward the front, i.e., a so-called transverse type engine. Reference numeral **L1** in the figure represents a line (cylinder axis) which passes through the center of the cylinder **106.** The cylinder axis **L1** extends in the horizontal direction or a direction slightly inclined from the horizontal direction. However, there is no particular limitation as to the direction of the cylinder axis **L1.** For example, the angle of tilt of the cylinder axis **L1** with respect to the horizontal plane may be 0° to 15°, or greater than that. Reference numeral **L2** in the figure represents the center line of the crankshaft **112.**

[0068] An intake pipe **141** is connected to an upper portion of the cylinder head **104.** An exhaust pipe **142** is connected to a lower portion of the cylinder head **104.** An intake duct **40** and an exhaust duct **50** are formed in the interior of the cylinder head **104.** The intake pipe **141** is connected to the intake duct **40,** whereas the exhaust pipe **142** is connected to the exhaust duct **50.** The intake valve **161** and the exhaust valve **162** are provided on the intake duct **40** and the exhaust duct **50,** respectively.

[0069] The engine **101** according to the present embodiment is an air-cooled engine, which is cooled with air. As shown in FIG. **2** to FIG. **4,** a plurality of cooling fins **114** are formed on the cylinder block **103.** The cooling fins **114** extend in a direction which is substantially orthogonal to the cylinder axis **L1.** As will be described later, a plurality of cooling fins **10** (see FIG. **8** to FIG. **10)** are also formed on the cylinder head body **100.**

[0070] The shroud **130** includes an inner member **131** and an outer member **132,** and is formed by assembling the inner member **131** and the outer member **132.** As shown in FIG. **4,** the inner member **131** and the outer member **132** are fixed with bolts **133.** The inner member **131** and the outer member **132** are made of a synthetic resin, for example.

[0071] A hole **131a** is formed in the inner member **131,** in which an ignition **115** such as a spark plug is to be inserted. An air inlet **132a** is formed in the outer member **132.** When the shroud **130** is attached to the engine unit **5,** the air inlet **132a** is at a position opposing the cooling fan **121** (see FIG. **3).** Reference numeral **F** in FIG. **4** indicates the outer periphery of the cooling fan **121,** whereas reference numeral **B** indicates the direction of rotation of the cooling fan **121.**

[0072] The shroud **130** is attached to the crankcase **102,** the cylinder block **103,** and the cylinder head **104,** and extends frontward so as to fit along the cylinder block **103** and the cylinder head **104.** The shroud **130** covers the right-hand portion of the crankcase **102,** the cylinder block **103,** and the cylinder head **104.** Portions of the shroud **130** also partly cover an upper portion and a lower portion of the cylinder block **103** and the cylinder head **104.**

[0073] When the cooling fan **121** rotates with the rotation of the crankshaft **112,** the air which is external to the shroud **30** is introduced into the shroud **30** through the air inlet **132a.** The air having been introduced into the shroud **30** is blown onto the cylinder block **103** and the cylinder head **104.** The cylinder block **103** and the cylinder head **104** are cooled by this air.

[0074] Next, with reference to FIG. **6** to FIG. **13,** the construction of the cylinder head body **100** included in the engine **101** of the present embodiment will be specifically described. FIG. **6** and FIG. **7** are an upper plan view and a bottom view schematically showing the cylinder head body **100.** FIG. **8** and FIG. **9** are a front view and a rear view schematically showing the cylinder head body **100.** FIG. **10** and FIG. **11** are a left side view and a right side view schematically showing the cylinder head body **100.** FIG. **12** is a cross-sectional view along line **12A-12A'** in FIG. **11,** and FIG. **13** is a cross-sectional view along line **8A-8A'** in FIG. **7.** The cylinder axis direction is indicated by arrow **D1** in some of the figures. It will be appreciated that the cylinder axis direction is a direction which is parallel to the cylinder axis **L1.** In the following description, it is assumed that the side of the cylinder head body **100** at which the intake pipe **141** is connected will be regarded as the front side of the cylinder head body **100.**

[0075] As shown in FIG. **6** to FIG. **13,** the cylinder head body **100** includes the plurality of cooling fins **10,** a cam chamber wall **20,** and a combustion chamber wall **30.** The cylinder head body **100** further includes the intake duct **40,** the exhaust duct **50,** and a cooling air duct **60.**

[0076] As shown in FIG. **8,** FIG. **9,** and FIG. **10,** the plurality of cooling fins **10** are provided on the outer side face (or more specifically, the left side face) of the cylinder head body **100,** and formed so as to protrude out of the cylinder head body **100** (i.e., so as to extend in a direction substantially orthogonal to the cylinder axis direction **D1).** Moreover, the plurality of cooling fins **10** are disposed at a predetermined pitch along the cylinder axis direction **D1.** The number of cooling fins **10** is not limited to what is shown herein.

[0077] The cam chamber wall **20** (shown in FIG. **6,** FIG. **10,** and FIG. **13)** defines the cam chamber **109.** The cam chamber **109** accommodates the valve mechanism, including the cam shaft **108.** The space existing between the cylinder head cover **105** attached to the upper portion of the cylinder head body **100** and the cam chamber wall **20** is the cam chamber **109.**

[0078] The combustion chamber wall **30** (shown in FIG. **7,** FIG. **10,** and FIG. **13)** defines the combustion chamber **110.** The combustion chamber **110** is a space created by the combustion chamber wall **30** of the cylinder head body **100,** the top face of the piston **107,** and the inner peripheral surface of the cylinder **106.** As shown in FIG. **7,** not only an intake port **40a** and an exhaust port **50a** described below, but also a plug hole **32** is formed in the combustion chamber wall **30.** The spark plug of the ignition **115** is attached in the plug hole **32.**

[0079] The intake duct **40** is a passage through which air intake into the combustion chamber **110** occurs. An opening **40a** of the intake duct **40** in the combustion chamber wall **30** is the intake port. As the intake valve **161** is moved up and down by the valve mechanism, the intake port **40a** is opened or closed. To an opening **40b** of the intake duct **40** at the opposite side from the combustion chamber wall **30** (located in the front of the cylinder head body **100),** the intake pipe **141** is connected.

[0080] The exhaust duct **50** is a passage through which exhaust from the combustion chamber **110** occurs. An opening **50a** of the exhaust duct **50** in the combustion chamber wall **30** is the exhaust port. As the exhaust valve **162** is moved up and down by the valve mechanism, the exhaust port **50a** is opened or closed. To an opening **50b** of the exhaust duct **50** at the opposite side from the combustion chamber wall **30,** the exhaust pipe **142** is connected.

[0081] Typically, the plurality of cooling fins **10** include those cooling fins **10** which extend from an exhaust duct wall defining the exhaust duct **50** (located on the relatively right-hand side in FIG. **10).** In the present embodiment, the plurality of cooling fins **10** further include those cooling fins **10** which extend from an intake duct wall defining the intake duct **40** (located on the relatively left-hand side in FIG. **10).**

[0082] The cooling air duct **60** (shown in FIG. **10** and FIG. **13)** is a passage for allowing cooling air to pass through between the cam chamber wall **20** and the combustion chamber wall **30.** As shown in FIG. **7,** an inlet **60a** of the cooling air duct **60** is located on the left side face of the cylinder head body **100,** whereas an outlet **60b** of the cooling air duct **60** is located on the right side face of the cylinder head body **100.** The cooling air **CA** which has been introduced by the cooling fan **121** into the shroud **130** is introduced through the inlet **60a** into the cooling air duct **60,** cools down the cylinder head body **100** as it passes through the cooling air duct **60,** and thereafter is discharged through the outlet **60b** to the exterior of the cylinder head body **100.**

[0083] The cylinder head body **100** is integrally molded from an aluminum alloy by die casting. As the aluminum alloy, ADC10 or ADC12 is suitably used, for example.

[0084] As shown in FIG. **6,** FIG. **7,** and FIG. **12,** the cylinder head body **100** further includes the cam chain chamber **70** for accommodating the cam chain **113.** The cam chain **113** is a member with which to drive the cam shaft **108** of the valve mechanism.

[0085] The exhaust duct **50** extends in such a manner that, when viewed in the cylinder axis direction **D1** (i.e., a direction which is perpendicular to the plane of the figure of FIG. **6,** FIG. **7,** and FIG. **12),** the exhaust duct **50** becomes more distant from the cam chain chamber **70** when going from the inlet (exhaust port **50a)** toward the outlet (opening **50b).** In other words, an axis **50x** of the exhaust duct **50** is inclined with respect to the front-rear direction of the cylinder head body **100.** Moreover, the exhaust duct **50** is formed so that, when viewed in the cylinder axis direction **D1,** its axis **50x** appears linear.

[0086] Moreover, as shown in FIG. **6,** FIG. **7,** and FIG. **12,** the cylinder head body **100** has a plurality of bolt holes **80a** to **80d,** into each of which a head bolt is inserted. The head bolts (which typically are stud bolts) inserted in the bolt holes **80a** to **80d** cause the cylinder head body **100** to be coupled to the cylinder block **103.**

Among the plural (i.e., 4 herein) bolt holes **80a** to **80d,** one bolt hole (the bolt hole which appears upper right in FIG. **6** and FIG. **12** and lower right in FIG. **7) 80a** is provided between the exhaust duct **50** and the cam chain chamber **70.** A portion of the cooling air duct **60** is located between this bolt hole **80a** and the exhaust duct **50.** Bosses **80** having the bolt holes **80a** to **80d** may be referred to as bosses for head bolts or bosses for stud bolts.

[0087] As mentioned earlier, the cylinder head body **100** of the engine (internal combustion engine) **101** according to an embodiment of the present invention is integrally molded by die casting. In other words, unlike the cylinder head of Patent Document 1, there are no liners, as separate members, being cast together in the cylinder head body **100.** Therefore, no misalignments of the intake duct **40** and the exhaust duct **50** will be caused by liner misalignments, so that deterioration in the performance of the engine **101** associated with misalignments of the intake duct **40** and the exhaust duct **50** can be prevented.

[0088] Moreover, since the exhaust duct **50** extends in such a manner that the exhaust duct **50** becomes more distant from the cam chain chamber **70** when going from the inlet side toward the outlet side, the space between the outlet of the exhaust duct **50** and the cam chain chamber **70** can be expanded. Therefore, it is easy to secure a sufficiently large cross-sectional area of the cooling air duct **60.** This realizes a sufficiently high coolability.

[0089] Furthermore, the exhaust duct **50** is formed so that its axis **50x** is linear. Thus, exhaust resistance can be reduced, and a more efficient combustion is enabled. Moreover, when molding the cylinder head body **100** by die casting, the exhaust duct **50** in its final shape can be formed with a die, which makes it unnecessary to employ subsequent machining to change the shape of the exhaust duct **50.**

[0090] From the standpoint of securing a sufficiently large cross-sectional area of the cooling air duct **60,** it is preferable that the axis **50x** of the exhaust duct **50** is inclined at a somewhat large angle with respect to the front-rear direction. Specifically, it is preferable that, when viewed in the cylinder axis direction **D1,** the axis **50x** of the exhaust duct **50** is inclined at an angle of 20° or more with respect to a line **L3** connecting the centers of the two bolt holes **80a** and **80b** that are located closer to the cam chain chamber **70** among the four bolt holes **80a** to **80d.** However, if the angle of tilt is too large, the exhaust resistance may become excessive; therefore, the angle of tilt is preferably 30° or less.

[0091] As in the present embodiment, when a certain bolt hole **80a** among the plurality of bolt holes **80a** to **80d** is provided between the exhaust duct **50** and the cam chain chamber **70,** it is necessary that a portion of the cooling air duct **60** be located (disposed) in a space which is narrower than that between the exhaust duct **50** and the cam chain chamber **70** (i.e., a space between the bolt hole **80a** and the exhaust duct **50).** However, as described above, the exhaust duct **50** extends in such a manner that the exhaust duct **50** becomes more distant from the cam chain chamber **70** when going from the inlet side toward the outlet side; therefore, a sufficiently cross-sectional area of the cooling air duct **60** can be ensured also between the bolt hole **80a** and the exhaust duct **50.**

[0092] When the shape of the exhaust duct **50** is designed so that its axis **50x** is linear, it is easy to form the exhaust duct **50** by using a die, without using any cores. By forming the exhaust duct **50** with a die, it is possible to make the surface roughness of the inner peripheral surface of the exhaust duct **50** smaller than that when cores are used. More specifically, the surface roughness Rz (maximum height) of the inner peripheral surface of the exhaust duct **50** can be made 30 μm or less, thus reducing exhaust resistance and improving the output power of the engine **101.** By also ensuring that the surface roughness Rz of the inner peripheral surface of the intake duct **40** is 30 μm or less, intake resistance can be reduced to further improve the output power of the engine **101.**

[0093] Preferably, the plurality of cooling fins **10** include those cooling fins **10** which extend from the exhaust duct wall defining the exhaust duct **50.** Since the exhaust duct **50** is one place in the cylinder head body **100** that is liable to high temperature, the cooling fins **10** extending from the exhaust duct wall will allow for an improved cooling efficiency. From the standpoint of ensuring a sufficiently high cooling efficiency, more specifically, the cooling fins **10** extending from the exhaust duct wall may extend at least from a portion of the exhaust duct wall that is located closer to the cylinder axis **L1** than is the boss (boss for stud bolt) **80** corresponding to the bolt hole (the closest bolt hole to the cooling fins **10** extending from the exhaust duct wall) **80c** (see FIG. **10).**

[0094] Now, among the plurality of cooling fins **10,** those cooling fins **10a** which are located on the combustion chamber **110** side of an apex of the combustion chamber wall **30** will be referred to as "first cooling fins", and those cooling fins **10b** which are located on the opposite side of the apex of the combustion chamber wall **30** from the combustion chamber **110** (i.e., so as to be closer to the cam chamber) will be referred to as "second cooling fins". In the present embodiment, as can be seen from FIG. **8,** FIG. **9,** and FIG. **10,** the plurality of cooling fins **10** are provided in such a manner that a total area of the first cooling fins **10a** is greater than a total area of the second cooling fins **10b.**

[0095] During the operation of the engine **101,** within the cylinder head body **100,** the region which is on the combustion chamber **110** side of the apex of the combustion chamber wall **30** has a higher temperature than the region on the opposite side of the apex of the combustion chamber wall **30** from the combustion chamber **110.** Therefore, coolability can be efficiently improved by ensuring that a total area of the first cooling fins **10a** located in the former region is greater than a total area of the second cooling fins **10b** located in the latter region.

[0096] Moreover, in the present embodiment, as shown in FIG. **10,** the plurality of cooling fins **10** are provided so that, when viewed from the opposite side of the cylinder axis **L1** from the cam chain chamber **70** (i.e., from a direction perpendicular to the plane of the figure of FIG. **10),** edges **10a1** of the first cooling fins **10a** on the cylinder axis **L1** side are closer to the cylinder axis **L1** than are edges **10b1** of the second cooling fins **10b** on the cylinder axis **L1** side. In other words, the edges **10b1** of the second cooling fins **10b** are more distant from the cylinder axis **L1** than are the edges **10a1** of the first cooling fins **10a.** This allows the cross-sectional area of the cooling air duct **60** to be increased further.

[0097] Furthermore, in the present embodiment, as shown in FIG. **10,** a portion of the cooling air duct **60** is defined by an exhaust duct wall **51** which defines the exhaust duct **50** and which intersects the cam chamber wall **20** at an acute angle. This provides the following advantage.

[0098] Usually, when forming the shape of the cooling air duct with a die at die casting, the portion of the die that corresponds to the cooling air duct is shaped so as to protrude from any other portion. The tip end of a portion with such a protruding shape is liable to high temperature due to the heat of the melt. In particular, if there is any corner in the tip end, the corner may be eroded; therefore, generally, the tip end is to be designed so as to have a circular cross section. However, as in the present embodiment, by allowing a portion of the cooling air duct **60** to be defined by the exhaust duct wall **51** intersecting the cam chamber wall **20** at an acute angle, the cross-sectional area of the cooling air duct **60** can be increased. In this case, the problem of erosion can be avoided because the cam chamber wall **20** and the exhaust duct wall **51** may both have a small thickness.

[0099] Preferably, the cam chamber wall **20** has a thickness of 2.5 mm or less. When the thickness of the cam chamber wall **20** is 2.5 mm or less, erosion of die corners can be prevented with greater certainty. However, if the thickness of the cam chamber wall **20** is less than 1.5 mm, the compressive strength that is required of the cam chamber **109** may not be adequately obtained, thus resulting in an insufficient resistance against flow stress occurring due to distortion; therefore, it is preferable that the thickness of the cam chamber wall **20** is 1.5 mm or more.

[0100] Moreover, in the present embodiment, the cylinder head body **100** is molded by die casting; therefore, the thickness and pitch of the cooling fins **10** can be reduced, thus improving coolability. Specifically, as shown in FIG. **14,** given a thickness t of the leading edge of each of the plurality of cooling fins **10,** and a pitch p of the plurality of cooling fins **10,** the thickness t of the leading edge of each cooling fin **10** may be not less than 1.0 mm and not more than 2.5 mm, and the plurality of cooling fins **10** may be disposed with a pitch p of 7.5 mm or less.

[0101] Preferably, each of the plurality of cooling fins **10** has a draft of 2.0° or less. By ensuring that the draft is as small as 2.0° or less, the interspace at the feet of the cooling fins **10** can be increased, whereby coolability can be further improved. However, from the standpoint of facilitating release, it is preferable that the draft of each of the plurality of cooling fins **10** is 1.0° or more.

[0102] Moreover, as shown in FIG. **10,** the cylinder head body **100** of the present embodiment further includes a rib **90** which is provided within the cooling air duct **60,** the rib **90** linking together the combustion chamber wall **30** and the cam chamber wall **20.** Since the rib **90** links together the combustion chamber wall **30** and the cam chamber wall **20,** the rib **90** is able to transmit the heat of the chamber wall **30** to the cam chamber wall **20,** thus enabling cooling with the lubricating oil in the cam chamber **109,** whereby coolability can be improved. Moreover, the rib **90** being provided within the cooling air duct **60** also provides a cooling effect with the cooling air **CA.**

[0103] Note that the rib **90** is preferably formed along the release direction used when the cylinder head body **100** is molded by die casting. Therefore, the rib **90** is preferably formed along the wall portion (cooling air duct wall) defining the cooling air duct **60.**

[0104] Moreover, it is preferable that a cross-sectional shape of the exhaust duct **50** along a plane which is orthogonal to the axis **50x** of the exhaust duct **50** is a substantial ellipse, and that the shape of the outlet **50b** of the exhaust duct **50** is a substantially perfect circle as shown in FIG. **9.** Since the cross-sectional shape of the exhaust pipe **142** is generally a substantially perfect circle, the shape of the outlet **50b** of the exhaust duct **50** being a substantially perfect circle will prevent abrupt changes in the duct area, thus preventing deterioration in the performance of the engine **101.** As has already been described, the exhaust duct **50** extends in such a manner that the exhaust duct **50** becomes more distant from the cam chain chamber **70** when going from the inlet side toward the outlet side; therefore, if the cross-sectional shape of the exhaust duct **50** along a plane which is orthogonal to the axis **50x** were a substantially perfect circle, it would be impossible to shape the outlet **50b** of the exhaust duct **50** in a substantially perfect circle. Ensuring that the cross-sectional shape of the exhaust duct **50** along a plane which is orthogonal to the axis **50x** is a substantial ellipse (i.e., so that the circularity of the cross-sectional shape of the exhaust duct **50** along a plane which is orthogonal to the axis **50x** is lower than the circularity of the shape of the outlet **50b** of the exhaust duct **50)** allows the outlet **50b** of the exhaust duct **50** to be shaped in a substantially perfect circle.

[0105] Furthermore, it is preferable to perform a shot blast treatment for any wall portion defining the cooling air duct **60** and the cam chain chamber **109,** and the outer side faces including the plurality of cooling fins **10.** Roughening achieved through a shot blast treatment will allow for an increased area of contact with the cooling air **CA,** thus enabling a further enhancement in coolability. Moreover, the cooling air duct **60** may also be deburred through the shot blast treatment.

[0106] Moreover, for further improvement in coolability, it would be preferable to provide cooling fins extending from the rib **90,** or perform a shot blast treatment for the rib **90.**

[0107] The internal combustion engine **101** according to an embodiment of the present invention is suitably used for various saddled vehicles such a motorcycles and ATVs (All Terrain Vehicles). It is also suitably used for electric generators or the like.

[0108] According to the present invention, there is provided an air-cooling type internal combustion engine including a cylinder head body which has a cooling air duct with a sufficient cross-sectional area and which can be suitably molded by die casting. An air-cooling type internal combustion engine according to the present invention provides excellent coolability of the cylinder head body, and is suitably used for various saddled vehicles such as motorcycles.

[0109] While the present invention has been described with respect to exemplary embodiments thereof, it will be apparent to those skilled in the art that the disclosed invention may be modified in numerous ways and may assume many embodiments other than those specifically described above. Accordingly, it is intended by the appended claims to cover all modifications of the invention that fall within the true spirit and scope of the invention.

Claims

1. An air-cooling type internal combustion engine comprising a cylinder head body, the cylinder head body including:

a plurality of cooling fins;
a cam chamber wall defining a cam chamber;
a combustion chamber wall defining a combustion chamber;
an intake duct through which air intake into the combustion chamber is to occur;
an exhaust duct through which exhaust from the combustion chamber is to occur; and
a cooling air duct for allowing cooling air to pass through between the cam chamber wall and the combustion chamber wall, wherein,
the cylinder head body is integrally molded from an aluminum alloy by die casting;
the cylinder head body further includes a cam chain chamber for accommodating a cam chain; and
when viewed in a cylinder axis direction, the exhaust duct extends in such a manner that the exhaust duct becomes more distant from the cam chain chamber when going from an inlet side toward an outlet side and the exhaust duct is formed so that an axis of the exhaust duct is linear.

2. The air-cooling type internal combustion engine of claim 1, wherein the plurality of cooling fins include a cooling fin extending from an exhaust duct wall defining the exhaust duct.

3. The air-cooling type internal combustion engine of claim 1 or 2, wherein an inner peripheral surface of the exhaust duct has a surface roughness Rz of 30 μm or less.

4. The air-cooling type internal combustion engine of any of claims 1 to 3, wherein,
the cylinder head body further includes a plurality of bolt holes, into each of which a head bolt is to be inserted;
one of the plurality of bolt holes is provided between the exhaust duct and the cam chain chamber; and
a portion of the cooling air duct is located between the one bolt hole and the exhaust duct.

5. The air-cooling type internal combustion engine of any of claims 1 to 4, wherein the plurality of cooling fins are provided in such a manner that a total area of those cooling fins which are located on the combustion chamber side of an apex of the combustion chamber wall is greater than a total area of those cooling fins which are located on an opposite side of the combustion chamber from the apex of the combustion chamber wall.

6. The air-cooling type internal combustion engine of any of claims 1 to 5, wherein the plurality of cooling fins are provided so that, when viewed from an opposite side of the cylinder axis from the cam chain chamber, cylinder-axis-side edges of those cooling fins which are located on the combustion chamber side of the apex of the combustion chamber wall are closer to the cylinder axis than are cylinder-axis-side edges of those cooling fins which are located on an opposite side of the apex of the combustion chamber wall from the combustion chamber.

7. The air-cooling type internal combustion engine of any of claims 1 to 6, wherein a portion of the cooling air duct is defined by an exhaust duct wall defining the exhaust duct, the exhaust duct wall intersecting the cam chamber wall at an acute angle.

8. The air-cooling type internal combustion engine of claim 7, wherein the cam chamber wall has a thickness of not less than 1.5 mm and not more than 2.5 mm.

9. The air-cooling type internal combustion engine of any of claims 1 to 8, wherein,
a leading edge of each of the plurality of cooling fins has a thickness of not less than 1.0 mm and not more than 2.5 mm; and

the plurality of cooling fins are disposed with a pitch of 7.5 mm or less.

10. The air-cooling type internal combustion engine of any of claims 1 to 9, wherein each of the plurality of cooling fins has a draft of not less than 1.0° and not more than 2.0°.

11. The air-cooling type internal combustion engine of any of claims 1 to 10, wherein the cylinder head body further includes a rib which is provided within the cooling air duct, the rib linking together the combustion chamber wall and the cam chamber wall.

12. The air-cooling type internal combustion engine of claim 11, wherein the rib is formed along a cooling air duct wall defining the cooling air duct.

13. The air-cooling type internal combustion engine of any of claims 1 to 12, wherein a circularity of a cross-sectional shape of the exhaust duct along a plane which is orthogonal to the axis of the exhaust duct is lower than a circularity of the shape of an outlet of the exhaust duct.

14. The air-cooling type internal combustion engine of claim 13, wherein the cross-sectional shape of the exhaust duct along the plane which is orthogonal to the axis of the exhaust duct is a substantial ellipse, and the shape of the outlet of the exhaust duct is a substantially perfect circle.

15. A saddled vehicle comprising the air-cooling type internal combustion engine of any of claims 1 to 14.

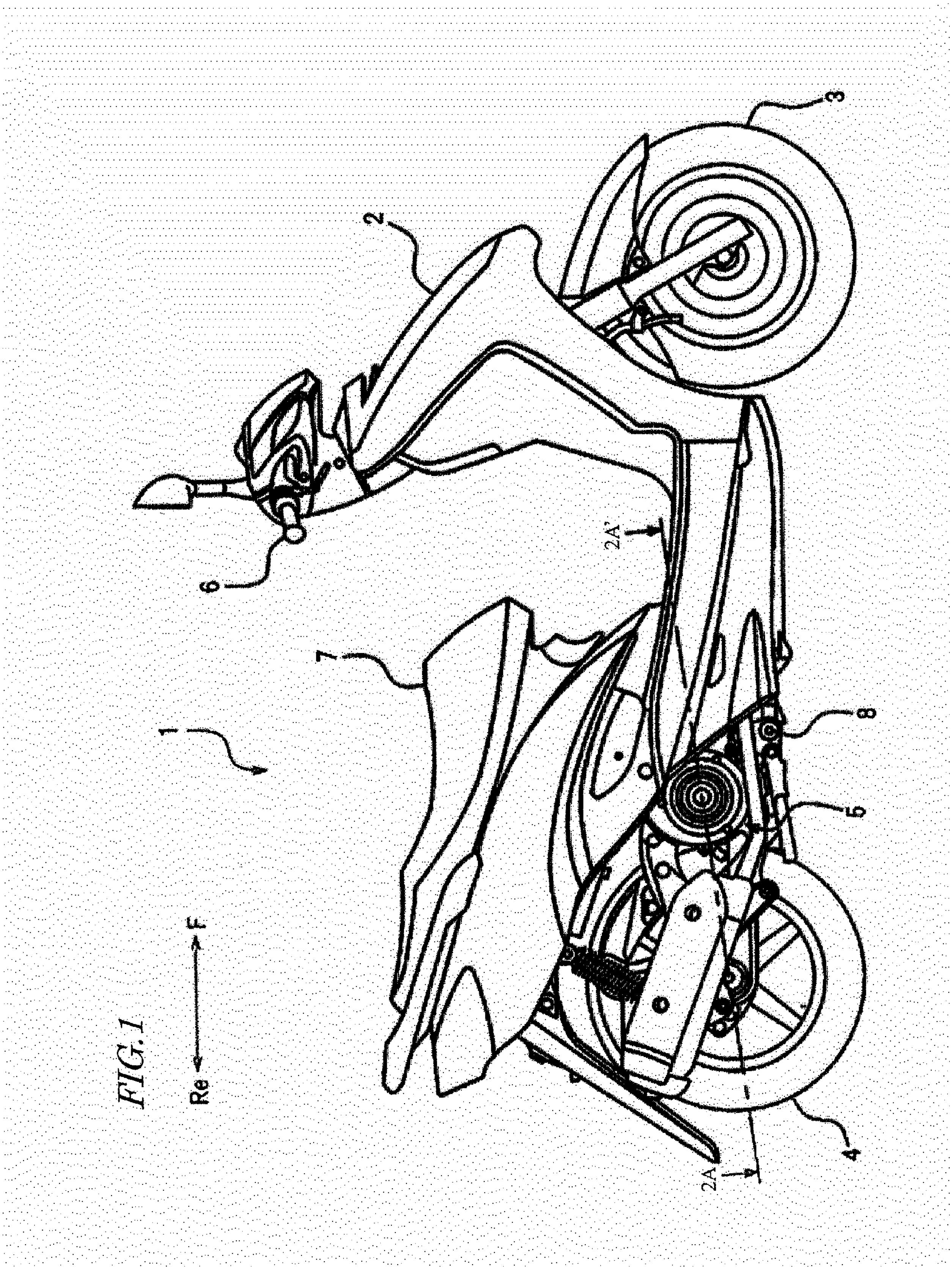
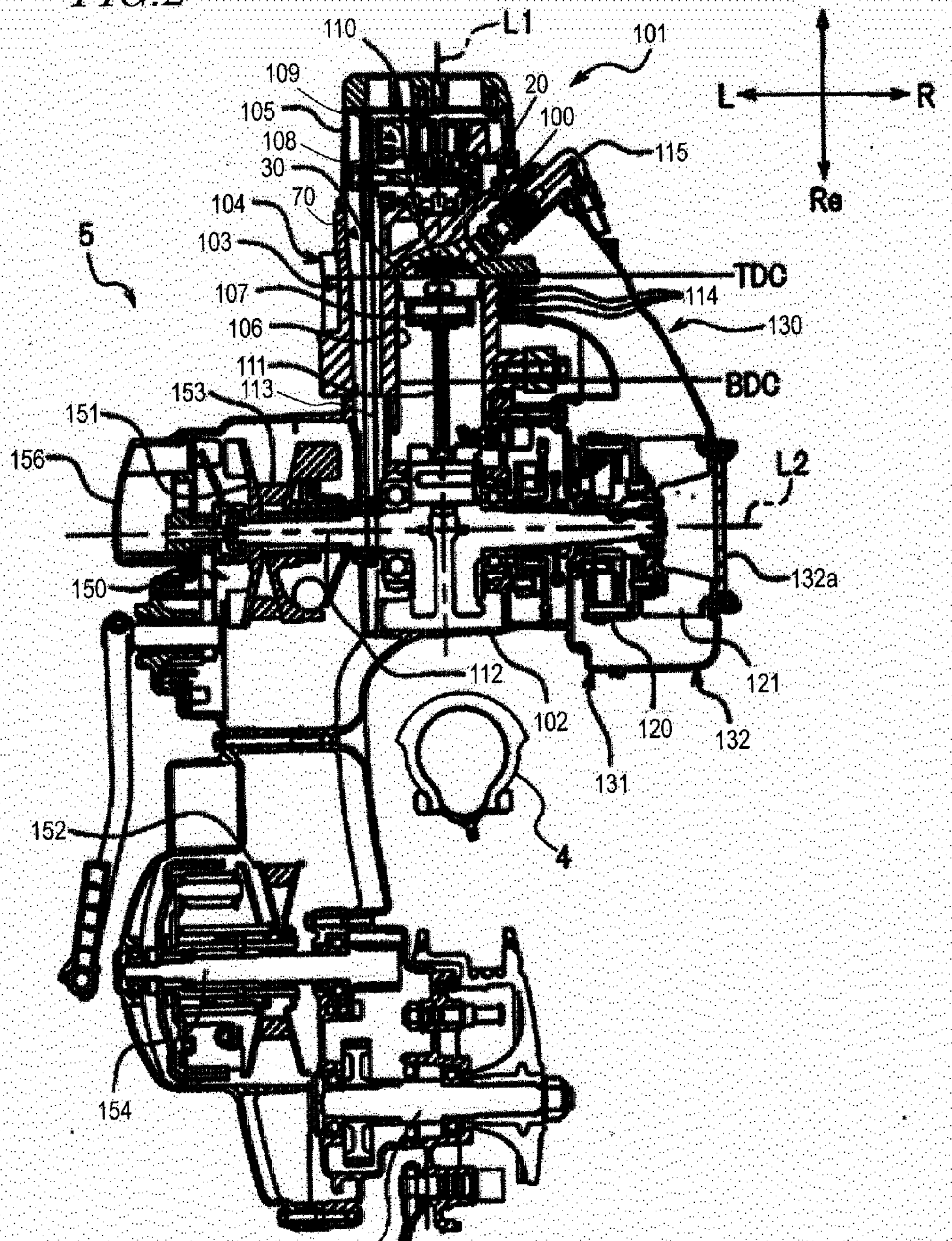


FIG.1

FIG.2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L1
101
F
L
R
Re
109
20
105
100
108
115
30
104
70
103
TDC
5
107
114
130
106
111
BDC
153
113
151
156
L2
132a
150
112
121
102
120
132
131
152
4
154
155

FIG.3

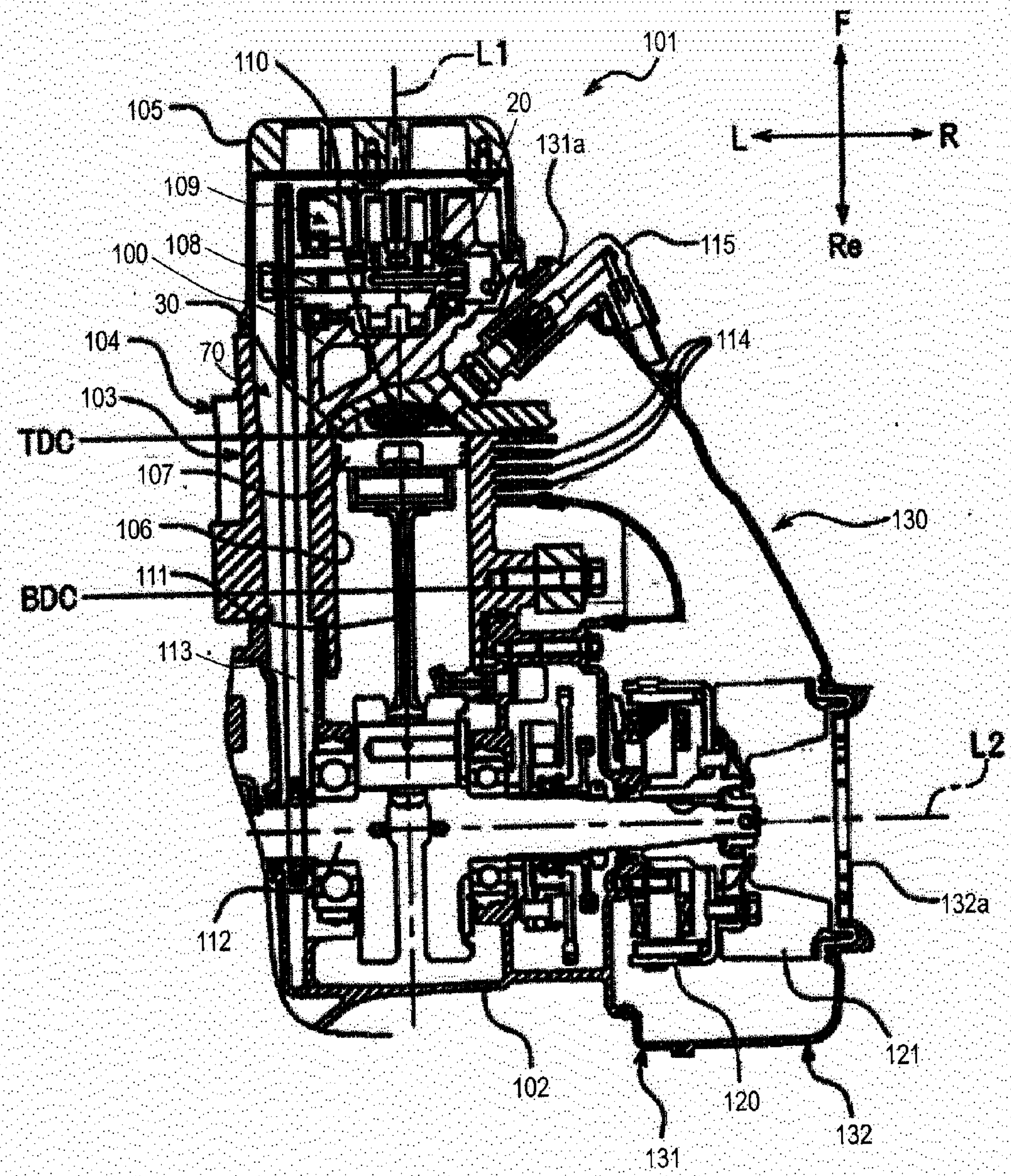

L1
101
110
20
105
131a
109
115
108
100
30
114
104
70
103
TDC
107
130
106
111
BDC
113
L2
132a
112
121
102
120
132
131
F
L
R
Re

FIG.4

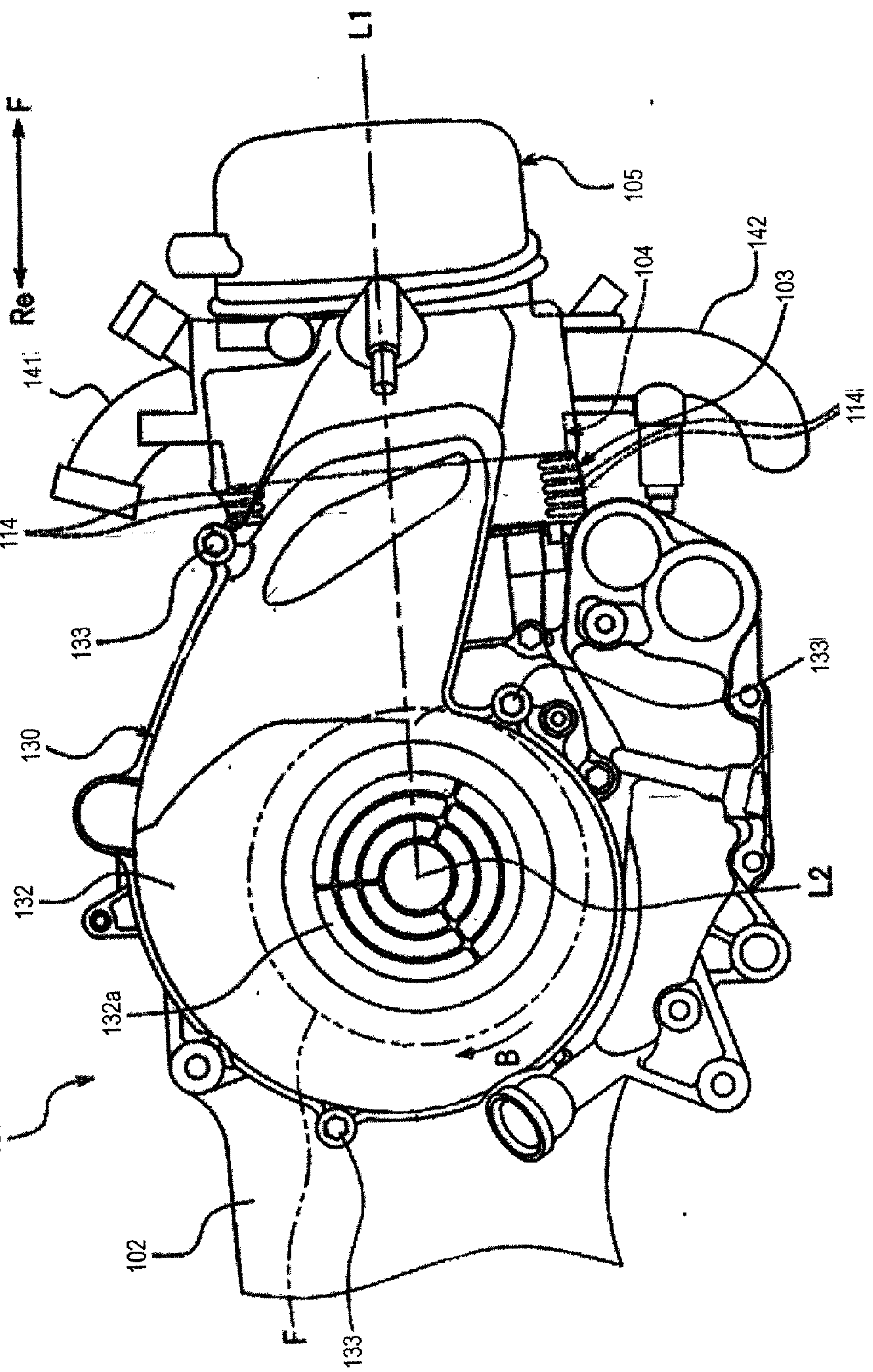
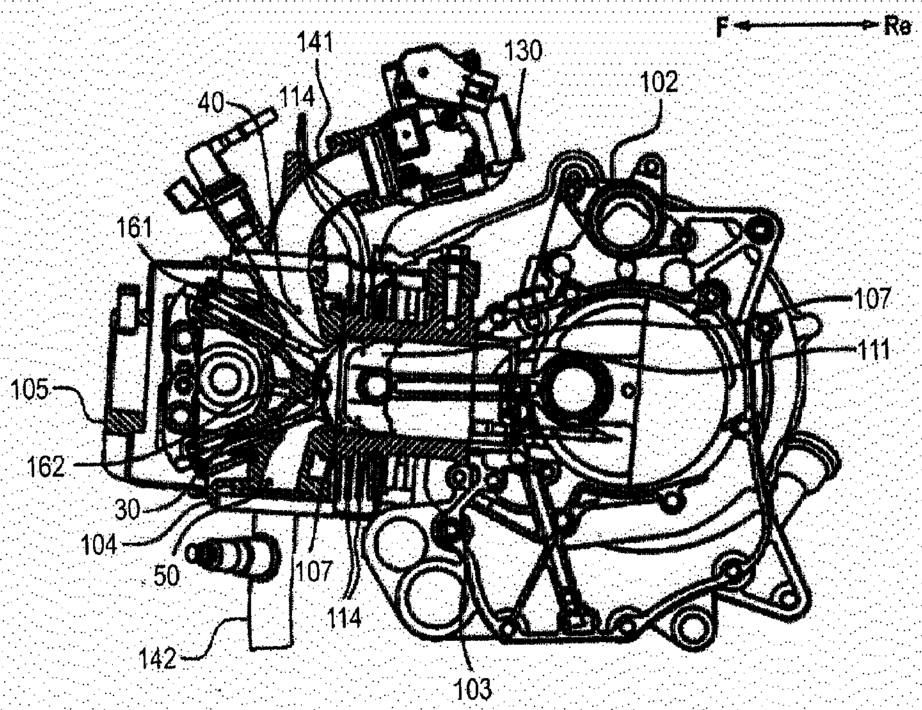


FIG.5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Re
141
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40
114
102
161
107
111
105
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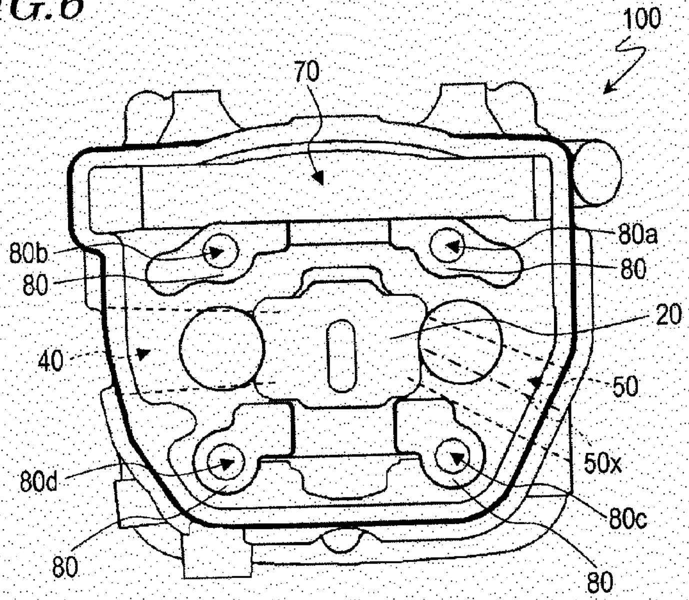
30
104
50
107
114
142
103

FIG.6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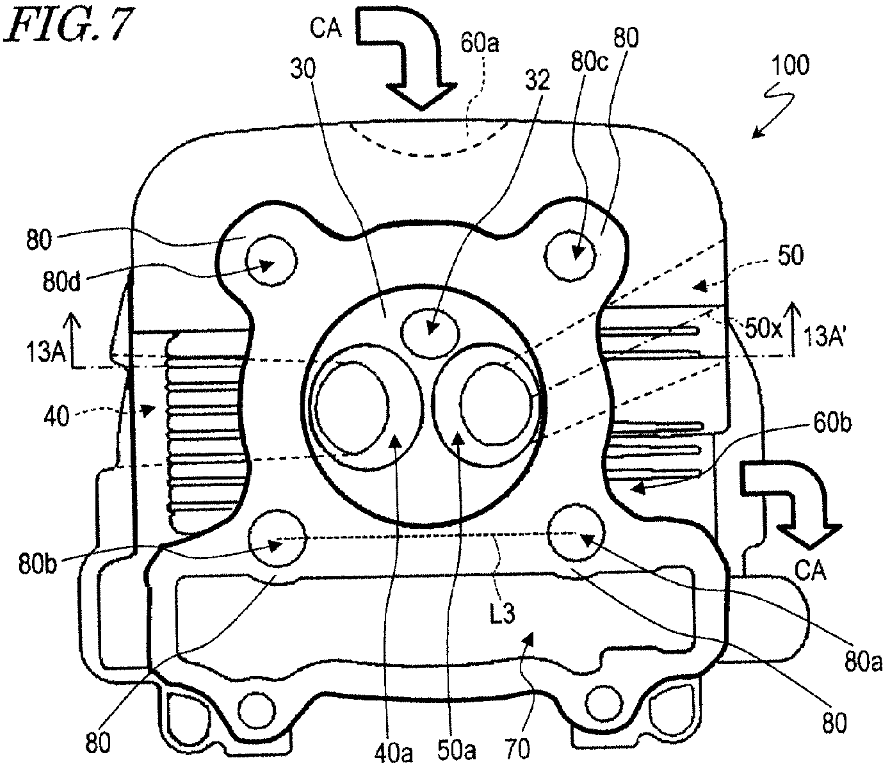
80b
80a
80
80
20
40
50
50x
80d
80c
80
80

FIG.7


CA
60a
30
32
80c
80
100
80
80d
50
13A
50x
13A'
40
60b
80b
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L3
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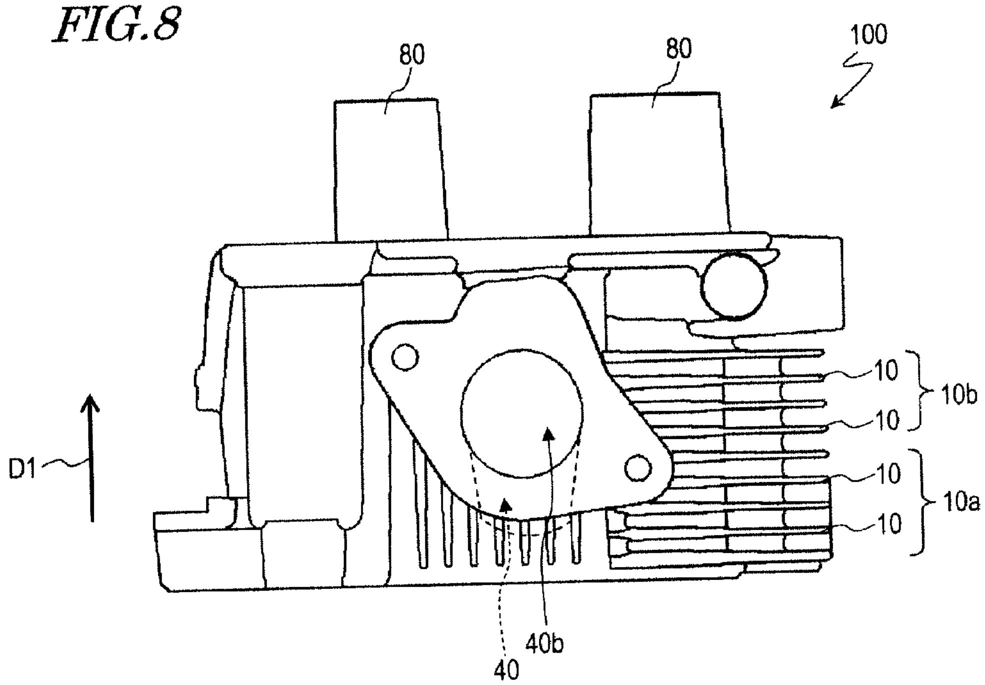
40a
50a
70
80

FIG.8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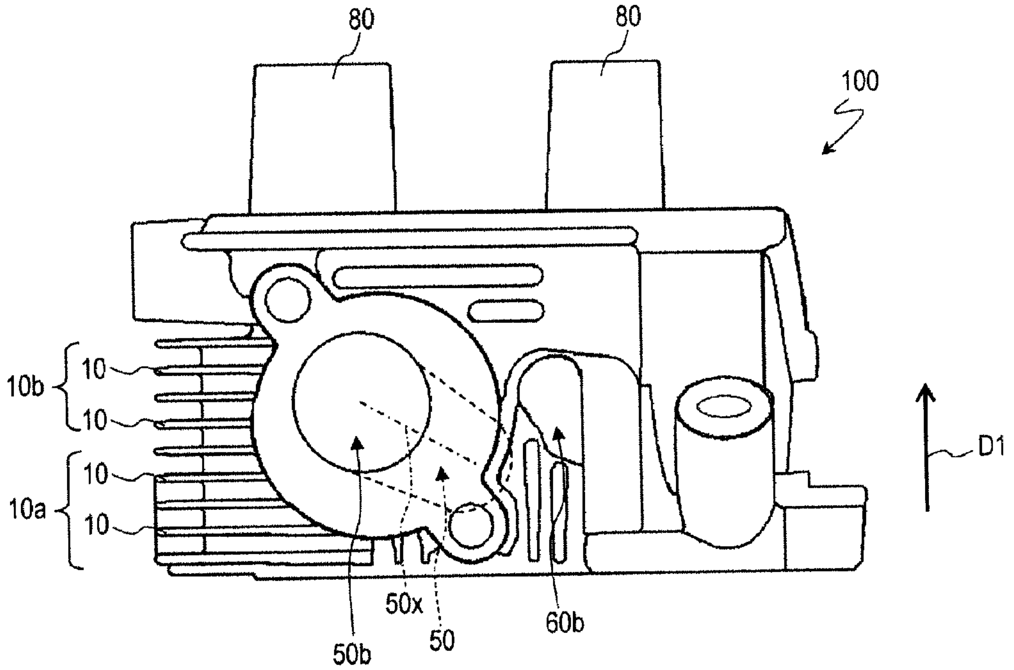
80
100
10
10b
10
D1
10
10a
10
40b
40

FIG.9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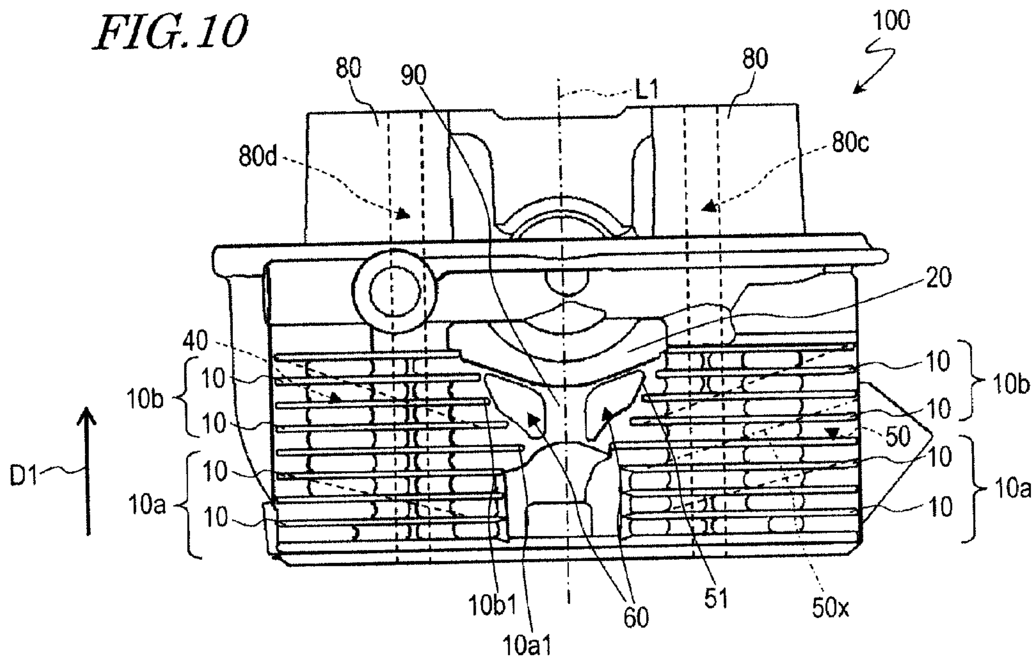
80
100
10b
10
10
10a
10
10
D1
50x
50
50b
60b

FIG.10


100
80
90
L1
80
80d
80c
20
40
10b
10
10
10
10b
10
50
D1
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10
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10a
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10b1
10a1
60
51
50x

FIG.11

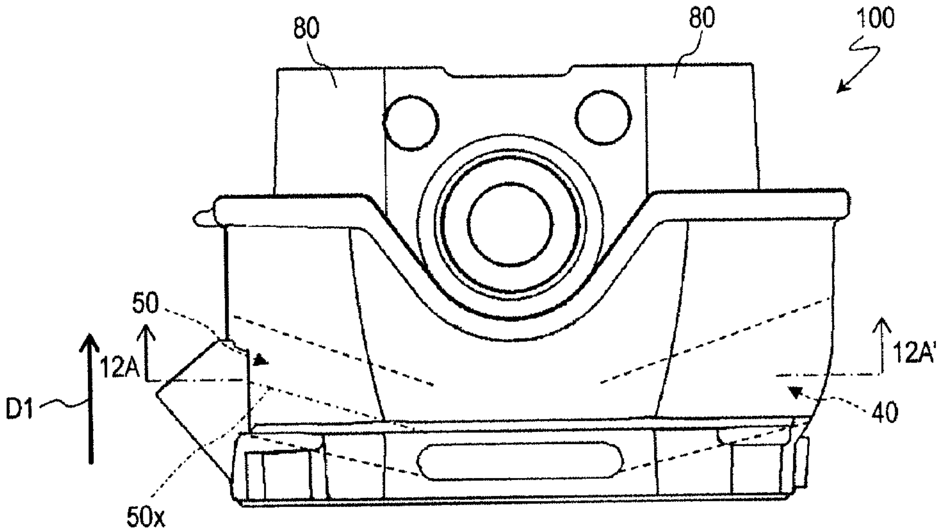


FIG.12

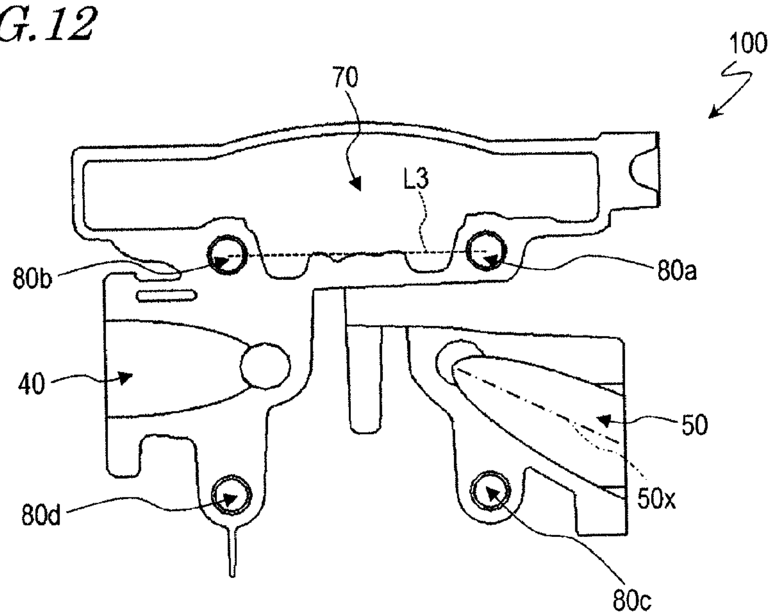


FIG.13

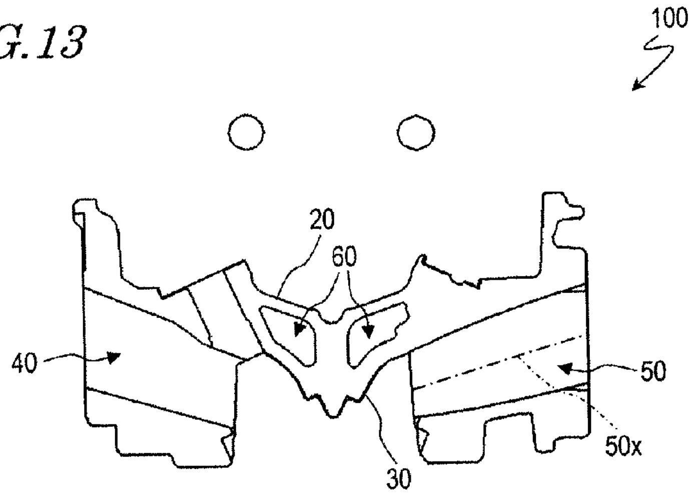
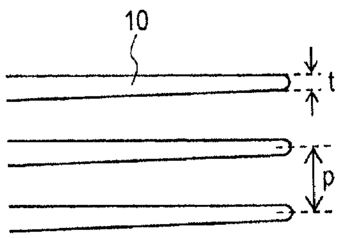


FIG.14



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EUROPEAN SEARCH REPORT

Application Number
EP 13 18 5284

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	EP 1 403 496 A1 (HONDA MOTOR CO LTD [JP]) 31 March 2004 (2004-03-31) * paragraph [0009] - paragraph [0019]; figures * -----	1-15	INV. F02F1/30 F02F1/32 F02F1/34
X	EP 2 410 164 A2 (KWANG YANG MOTOR CO [TW]) 25 January 2012 (2012-01-25) * paragraph [0016]; figure 7 * -----	1	
X	US 2012/160194 A1 (YANO TAKAHIRO [JP] ET AL) 28 June 2012 (2012-06-28) * paragraph [0047]; figure 5 * -----	1	

TECHNICAL FIELDS SEARCHED (IPC)

F02F

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	12 December 2013	Mouton, Jean

CATEGORY OF CITED DOCUMENTS

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12-12-2013

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 1403496 A1	31-03-2004	BR 0304160 A	31-08-2004
		CN 1497158 A	19-05-2004
		EP 1403496 A1	31-03-2004
		ES 2295513 T3	16-04-2008
		KR 20040026599 A	31-03-2004
		MX PA03008260 A	03-09-2004
		TW I221877 B	11-10-2004
EP 2410164 A2	25-01-2012	NONE	
US 2012160194 A1	28-06-2012	CN 102562250 A	11-07-2012
		JP 2012136971 A	19-07-2012
		US 2012160194 A1	28-06-2012

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REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 2004116464 A **[0004]**