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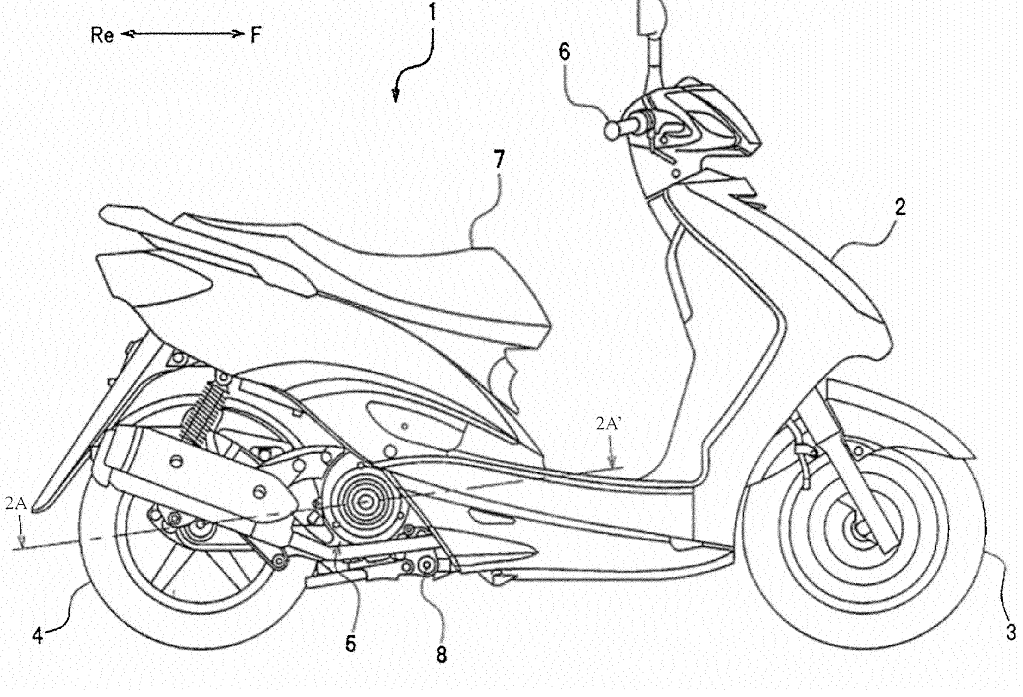
(54) **Forced air-cooling type internal combustion engine and saddled vehicle having the same**

(57) There is provided a forced air-cooling type internal combustion engine which excels in both castability and cooling efficiency of a cylinder head and/or a cylinder block.

A forced air-cooling type internal combustion engine **(101)** includes: a cylinder block **(103)** molded by casting; a cylinder head **(100)** molded by casting and overlaid on the cylinder block; a shroud **(130)** covering at least a portion of the cylinder block and at least a portion of the cylinder head; and a fan **(121)** for rotating to introduce air to the inside of the shroud. At least one of the cylinder block and the cylinder head includes a cooling fin (10) formed at least in a portion covered by the shroud and a cross fin (20) provided so as to cross the cooling fin, the cross fin being connected to the cooling fin. A thickness (**t'**) of the cross fin at a leading edge (**20a**) thereof is greater than a thickness (**t**) of the cooling fin at a leading edge thereof.

FIG.1



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Description

BACKGROUND

1. Technical Field:

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

2. Description of the Related Art:

[0002] Internal combustion engines for saddled vehicle are generally classified into the water-cooling type and the air-cooling type. The water-cooling type achieves cooling by using a coolant (such as water) as a medium, whereas the air-cooling type achieves cooling with air. In an air-cooling type internal combustion engine, a multitude of cooling fins are provided on the surface of the internal combustion engine for improving the cooling efficiency (see, for example Japanese Laid-Open Patent Publication No. 2010-159703 (hereinafter, "Patent Document 1").

[0003] Among air-cooling type internal combustion engines, natural air-cooling type internal combustion engines and forced air-cooling type internal combustion engines are known. The natural air-cooling type achieves cooling as the cooling fins receive air resistance during travel. The internal combustion engine disclosed in Patent Document 1 is a natural air-cooling type. On the other hand, in the forced air-cooling type, a fan is driven by the motive power of the internal combustion engine, such that the cooling fins receive the cooling air which is introduced by the fan to the inside of the shroud (cowling), whereby cooling is achieved.

[0004] The inventors have studied cooling fin structures that may be optimum for internal combustion engines of the forced air-cooling type. Specifically, the inventors have considered reducing the thickness and pitch of cooling fins (i.e., placing thin cooling fins at narrow interspaces) to provide as many cooling fins as possible on the cylinder head and the cylinder block, thus enhancing cooling efficiency. As a result, the inventors have found that disposing thin cooling fins at narrow interspaces may enhance cooling efficiency, but, when the cylinder head or cylinder block is molded through casting, melt permeability around the cooling fins may be lowered, thus possibly causing casting insufficiencies.

SUMMERY

[0005] The present invention has been made in view of the above problems, and an objective thereof is to provide a forced air-cooling type internal combustion engine which excels in both castability and cooling efficiency of a cylinder head and/or a cylinder block.

[0006] A forced air-cooling type internal combustion engine according to the present invention comprises: a cylinder block molded by casting; a cylinder head molded by casting and overlaid on the cylinder block; a shroud covering at least a portion of the cylinder block and at least a portion of the cylinder head; and a fan for rotating to introduce air to an inside of the shroud, wherein, at least one of the cylinder block and the cylinder head includes a cooling fin formed at least in a portion covered by the shroud and a cross fin provided so as to cross the cooling fin, the cross fin being connected to the cooling fin; and a thickness of the cross fin at a leading edge thereof is greater than a thickness of the cooling fin at a leading edge thereof.

[0007] In a preferred embodiment, between the cylinder block and the cylinder head, at least the cylinder head includes the cross fin.

[0008] In a preferred embodiment, the cross fin is at an angle of 45° or less with respect to an axis of rotation of the fan when viewed in a cylinder axis direction.

[0009] In a preferred embodiment, the cross fin overlaps with the combustion chamber when viewed in a cylinder axis direction.

[0010] A preferred embodiment further comprises a plurality of head bolts for coupling the cylinder block and the cylinder head, wherein, the plurality of head bolts include two head bolts that are located on the fan side of a cylinder axis; and the cross fin is located in part between the two head bolts.

[0011] In a preferred embodiment, the width of the cross fin along a cylinder axis direction is smaller at the leading edge of the cross fin than at a foot of the cross fin.

[0012] In a preferred embodiment, the thickness of the cross fin increases from the leading edge toward the foot of the cross fin.

[0013] In a preferred embodiment, the thickness of the cross fin increases toward the cylinder block.

[0014] In a preferred embodiment, a parting line of at least one of the cylinder block and the cylinder head is located between a center of the cooling fin and the leading edge of the cooling fin.

[0015] In a preferred embodiment, at least one of the cylinder block and the cylinder head includes a plurality of cooling fins; and, given a thickness t (mm) of each of the plurality of cooling fins at the leading edge and an interspace c (mm) between the leading edges of any two adjacent cooling fins among the plurality of cooling fins, the thickness t and the interspace c satisfy the relationships $t \leqq 3$ and $t \leqq c \leqq 3t$.

[0016] In a preferred embodiment, the thickness t further satisfies the relationship $1 \leqq t$.

[0017] In a preferred embodiment, the interspace c further satisfies the relationship $3 \leqq c$.

[0018] In a preferred embodiment, the cooling fin has a draft of not more than 1.0° and not less than 2.0°.

[0019] A saddled vehicle according to the present invention comprises a forced air-cooling type internal combustion engine of the above construction.

[0020] The internal combustion engine according to the present invention is a forced air-cooling type internal combustion engine having a shroud and a fan. Therefore, even when the thickness and pitch of the cooling fins are reduced (i.e., thin cooling fins are placed at narrow interspaces) in order to allow as many cooling fins as possible to be provided for an improved cooling efficiency, it is still possible to send sufficient cooling air through the gaps between adjacent cooling fins. Moreover, in the forced air-cooling type internal combustion engine according to the present invention, at least one of the cylinder block and the cylinder head includes not only cooling fins, but also cross fins which are provided so as to cross the cooling fins and which are connected to the cooling fins. The thickness of the cross fins at the leading edges is greater than the thickness of the cooling fins at the leading edges. Since such cross fins are provided, even if thin cooling fins are placed at narrow interspaces for an improved cooling efficiency, deterioration in melt permeability at casting can be prevented, thereby preventing casting insufficiencies. Thus, the forced air-cooling type internal combustion engine according to the present invention excels in both castability and cooling efficiency of the cylinder head and/or the cylinder block.

[0021] Preferably, between the cylinder block and the cylinder head, at least the cylinder head includes cross fins. Generally, a cylinder head is likely to have a more complicated shape than a cylinder block; therefore, if thin cooling fins are placed at narrow interspaces, melt permeability around the cooling fins is likely to be deteriorated. By providing the cross fins at least on the cylinder head, casting insufficiencies can be effectively prevented.

[0022] When the cross fins are provided at an angle of 45° or less with respect to an axis of rotation of the fan as viewed in the cylinder axis direction, the cross fins are unlikely to present resistance against the cooling air which is sent from the fan. Thus, deterioration in cooling efficiency due to the provision of the cross fins can be prevented.

[0023] Preferably, the cross fins overlap with the combustion chamber when viewed in the cylinder axis direction. In other words, it is preferable that the cross fins are connected to the combustion chamber wall defining the combustion chamber. When the cross fins are provided in this manner, the heat generated in the combustion chamber can be transmitted to the cooling fins via the cross fins, thereby improving the cooling efficiency.

[0024] Typically, the internal combustion engine according to the present invention includes a plurality of head bolts that couple the cylinder block and the cylinder head, the plurality of head bolts including two head bolts that are located on the fan side of the cylinder axis. Preferably, the cross fins are located in part between these two head bolts. Thus placed, the cross fins are close to the center of the combustion chamber, allowing more heat to be transmitted to the cooling fins via the cross fins; as a result, a further enhancement in cooling efficiency is achieved.

[0025] When the width of each cross fin along the cylinder axis direction is smaller at the leading edge of the cross fin than at the foot of the cross fin, it is possible to provide a large number of cooling fins at the leading edge side, while allowing at the foot side the cam chamber to be placed near the combustion chamber, thus downsizing the cylinder head. In other words, both coolability and downsizing are reconciled.

[0026] Preferably, the thickness of each cross fin increases from the leading edge toward the foot of the cross fin. The thickness of the cross fins thus being set allows more heat to be transmitted from the combustion chamber to the cooling fins.

[0027] Moreover, it is preferable that the thickness of the cross fins increases toward the cylinder block. The thickness of the cross fins thus being set allows more heat to be transmitted from the combustion chamber to the cooling fins.

[0028] Preferably, a parting line (i.e., the position at which the mold is parted in casting) of the cylinder block and/or the cylinder head is somewhere between the center and the leading edge of each cooling fin. When the parting line is at such a position, burrs at the parting line are easy to remove. On the other hand, if the parting line is somewhere between the center and the foot of each cooling fin, the deburring work will become difficult.

[0029] Preferably, the relationships $t \leqq 3$ and $t \leqq c \leqq 3t$ are satisfied by the thickness t (mm) of each of the plurality of cooling fins at the leading edge and the interspace c (mm) between the leading edges of any two adjacent cooling fins among the plurality of cooling fins. By placing thin cooling fins at narrow interspaces while satisfying these relationships, it becomes possible to provide a large number of cooling fins, thereby improving the cooling efficiency.

[0030] Preferably, the thickness t of the cooling fins at the leading edges satisfies the relationship $1 \leqq t$. As the thickness of the cooling fins decreases, more cooling fins can be provided; however, if the thickness of the cooling fins is too small, it will be difficult to take heat away from the cylinder block and the cylinder head. This problem does not occur when the thickness t of the cooling fins at the leading edges is 1 mm or more (i.e., $1 \leqq t$).

[0031] Preferably the interspace c between the leading edges of any two adjacent cooling fins satisfies the relationship $3 \leqq c$. When the interspace c between the leading edges of any two adjacent cooling fins is 3 mm or more (i.e., $3 \leqq c$), it is easy to supply cooling air to the feet of the cooling fins, whereby the cooling efficiency is improved.

[0032] Preferably, the cooling fins have a draft of 2.0° or less. By ensuring that the draft is as small as 2.0° or less, it becomes possible to increase the interspace at the feet of the cooling fins, thereby further improving coolability. However, from the standpoint of facilitating release, it is preferable that the draft of the cooling fins is 1.0° or more.

[0033] According to the present invention, there is provided a forced air-cooling type internal combustion engine which excels in both castability and cooling efficiency of a cylinder head and/or a cylinder block.

[0034] 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

[0035] FIG. **1** is a right side view schematically showing a motorcycle (saddled vehicle) **1** according to an embodiment of the present invention.

[0036] FIG. **2** is a cross-sectional view along line **2A-2A**' in FIG. **1.**

[0037] FIG. **3** is a diagram showing enlarged the vicinity of an engine (internal combustion engine) **101** which is shown in FIG. **2.**

[0038] FIG. **4** is a right side view of a portion of the engine **101**.

[0039] FIG. **5** is a cross-sectional left side view of the engine **101**.

[0040] FIG. **6** is an upper plan view schematically showing a cylinder head **100** which is included in the engine **101** according to an embodiment of the present invention.

[0041] FIG. **7** is a bottom view schematically showing a cylinder head **100** which is included in the engine **101** according to an embodiment of the present invention.

[0042] FIG. **8** is a front view schematically showing a cylinder head **100** which is included in the engine **101** according to an embodiment of the present invention.

[0043] FIG. **9** is a rear view schematically showing a cylinder head **100** which is included in the engine **101** according to an embodiment of the present invention.

[0044] FIG. **10** is a left side view schematically showing a cylinder head **100** which is included in the engine **101** according to an embodiment of the present invention.

[0045] FIG. **11** is a right side view schematically showing a cylinder head **100** which is included in the engine **101** according to an embodiment of the present invention.

[0046] FIG. **12** is a cross-sectional view schematically showing a cylinder head **100** which is included in the engine **101** according to an embodiment of the present invention, along line **12A-12A'** in FIG. **10.**

[0047] FIG. **13A** is a cross-sectional view schematically showing cooling fins **10** of the cylinder head **100;** and FIG. **13B** is a cross-sectional view schematically showing a cross fin **20** of the cylinder head **100.**

DETAILED DESCRIPTION

[0048] 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.

[0049] 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).

[0050] 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.

[0051] 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.

[0052] 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**.

[0053] 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.

[0054] 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 **100** which is connected in front of the cylinder block **103;** and a cylinder head cover **105** connected in front of the cylinder head **100.**

[0055] The cylinder block **103** is molded by casting (e.g., gravity casting). The material of the cylinder block **103** is an aluminum alloy or a cast iron, for example. A cylinder **106** is formed in the interior of the cylinder block **103.**

[0056] 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.**

[0057] The cylinder head **100** is overlaid on the cylinder block **103** so as to cover the cylinder **106.** The cylinder head **100** is molded by casting (e.g., gravity casting). The material of the cylinder head **100** is an aluminum alloy or a cast iron, for example. The cylinder head **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 **100** that defines the combustion chamber **110** is referred to as a combustion chamber wall.

[0058] 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.**

[0059] In the present embodiment, the crankcase **102,** the cylinder block **103,** the cylinder head **100,** 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 **100** may be made integral. Moreover, the cylinder head **100** and the cylinder head cover **105** may be made integral.

[0060] 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.**

[0061] An electric generator **120** is provided on the right-hand portion of the crankshaft **112**. A cooling fan (hereinafter simply referred to as a "fan") **121** is fixed at the right end of the crankshaft **112**. The fan **121** rotates together with the crankshaft **112**. The fan **121** is formed so as to suck air toward the left as it rotates. The electric generator **120** and the fan **121** are accommodated within a shroud **130.** The shroud **130** is provided so as to cover at least a portion of the cylinder block **103** and at least a portion of the cylinder head **100.**

[0062] As shown in FIG. **4**, the engine **101** is an engine of a type such that the cylinder block **103** and the cylinder head **100** 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.**

[0063] An intake pipe **141** is connected to an upper portion of the cylinder head **100.** An exhaust pipe **142** is connected to a lower portion of the cylinder head **100.** An intake duct **40** and an exhaust duct **50** are formed in the interior of the cylinder head **100.** 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.

[0064] The engine **101** according to the present embodiment is an air-cooled engine, or more specifically a forced air-cooling type engine, which is cooled with air. As shown in FIG. **2** to FIG. **4,** the cylinder block **103** includes a plurality of cooling fins **114** which are formed at least in a portion that is covered by the shroud **130.** The cooling fins **114** extend in a direction which is substantially orthogonal to the cylinder axis **L1**. As will be described later, the cylinder head **100** also includes a plurality of cooling fins **10** which are formed at least in a portion that is covered by the shroud **130** (see FIG. **8** to FIG. **10).**

[0065] 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.

[0066] 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 fan **121**

(see FIG. **3).** Reference numeral **F** in FIG. **4** indicates the outer periphery of the fan **121,** whereas reference numeral **B** indicates the direction of rotation of the fan **121.**

[0067] The shroud **130** is attached to the crankcase **102,** the cylinder block **103,** and the cylinder head **100,** and extends frontward so as to fit along the cylinder block **103** and the cylinder head **100.** The shroud **130** covers the right-hand portion of the crankcase **102,** the cylinder block **103,** and the cylinder head **100.** Portions of the shroud **130** also partly cover an upper portion and a lower portion of the cylinder block **103** and the cylinder head **100.**

[0068] When the fan **121** rotates with the rotation of the crankshaft **112,** the air which is external to the shroud **130** is introduced into the shroud **130** through the air inlet **132a.** The air having been introduced into the shroud **130** is blown onto the cylinder block **103** and the cylinder head **100.** The cylinder block **103** and the cylinder head **100** are cooled by this air.

[0069] Next, with reference to FIG. **6** to FIG. **12,** the construction of the cylinder head **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 **100.** FIG. **8** and FIG. **9** are a front view and a rear view schematically showing the cylinder head **100.** FIG. **10** and FIG. **11** are a left side view and a right side view schematically showing the cylinder head **100.** FIG. **12** is a cross-sectional view along line **12A-12A'** in FIG. **10.** 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 **100** at which the intake pipe **141** is connected will be regarded as the front side of the cylinder head **100.**

[0070] As shown in FIG. **6** to FIG. **12,** the cylinder head **100** includes the plurality of cooling fins **10,** a combustion chamber wall **30,** an intake duct **40,** an exhaust duct **50,** and a cooling air duct **60.**

[0071] 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 **100,** and formed so as to protrude out of the cylinder head **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.

[0072] The combustion chamber wall **30** (shown in FIG. **7** and FIG. **10**) defines the combustion chamber **110**. The combustion chamber **110** is a space created by the combustion chamber wall **30** of the cylinder head **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**.

[0073] 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, 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 **100),** the intake pipe **141** is connected.

[0074] 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, 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.

[0075] 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**).

[0076] The cooling air duct **60** (shown in FIG. **10)** is a passage for allowing cooling air to pass through. 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 **100**, whereas an outlet **60b** of the cooling air duct **60** is located on the right side face of the cylinder head **100.** The cooling air **CA** which has been introduced by the fan **121** into the shroud **130** is introduced through the inlet **60a** into the cooling air duct **60,** cools down the cylinder head **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 **100.**

[0077] Moreover, as shown in FIG. **6,** FIG. **7**, and FIG. **12,** the cylinder head **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 **100** to be coupled to the cylinder block **103.** Bosses **80** having the bolt holes **80a** to **80d** may be referred to as bosses for head bolts or bosses for stud bolts.

[0078] The cylinder head **100** further includes cross fins **20** provided so as to cross the cooling fins **10,** the cross fins **20** being connected to the cooling fins **10.** In the present embodiment, two cross fins **20** are provided. One of the two cross fins **20** (the one that is located relatively closer to the exhaust duct **50** side in FIG. **10)** is connected to the cooling fins **10** extending from the exhaust duct wall. The other cross fin **20** (the one that is located relatively closer to the intake duct **40** in FIG. **10)** is connected to the cooling fins **10** extending from the intake duct wall.

[0079] As shown in FIG. **10,** a thickness **t'** of each cross fin **20** at its leading edge is greater than a thickness **t** of each cooling fin **10** at its leading edge. Note that the cooling fins **10** actually are rounded at their leading edges, as shown in FIG. **13A**. In other words, each cooling fin **10** includes a curved portion **10c** having a curved face and a linear portion **10d** having a flat plane. In the present specification, the thickness **t** of each cooling fin **10** at its leading edge refers to the thickness of the outermost portion of the linear portion **10d**, that is, the thickness at the boundary between the curved portion **10c** and the linear portion **10d**. Moreover, the cross fins **20** too are actually rounded at their leading edges, as shown in FIG. **13B.** In other words, each cross fin **20** includes a curved portion **20c** having a curved face and a linear portion **20d** having a flat plane. In the present specification, the thickness **t'** of each cross fin **20** at its leading edge refers to the thickness of the outermost portion of the linear portion **20d,** that is, the thickness at the boundary between the curved portion **20c** and the linear portion **20d.** Note that the drafts of the cooling fins **10** and the cross fins **20** are exaggerated in FIGS. **13A** and **13B.**

[0080] The engine (internal combustion engine) **101** of the present embodiment is a forced air-cooling type engine including the shroud **130** and the fan **121,** as described above. Therefore, even when the thickness and pitch of the cooling fins **10** are reduced (i.e., the thin cooling fins **10** are placed at narrow interspaces) in order to allow as many cooling fins **10** as possible to be provided for an improved cooling efficiency, it is still possible to send sufficient cooling air **CA** through the gaps between adjacent cooling fins **10.**

[0081] Moreover, in the forced air-cooling type engine **101** of the present embodiment, the cylinder head **100** includes the cross fins **20** which are provided so as to cross the cooling fins **10.** The cross fins **20** are connected to the cooling fins **10.** The thickness **t'** of each cross fin **20** at its leading edge is greater than the thickness **t** of each cooling fin **10** at its leading edge. With such cross fins **20** being provided, even if thin cooling fins **10** are provided at narrow interspaces for an improved cooling efficiency, deterioration in melt permeability at casting can be prevented, thereby preventing casting insufficiencies.

[0082] Thus, the forced air-cooling type engine **101** of the present embodiment excels in both castability and cooling efficiency of the cylinder head **100.**

[0083] From the standpoint of preventing deterioration in melt permeability with greater certainty, it is preferable that the thickness **t'** of each cross fin **20** at its leading edge is 1.5 or more times as large as the thickness **t** of each cooling fin **10** at its leading edge. From the standpoint of ensuring sufficiently coolability, it is preferable that the thickness **t'** of each cross fin **20** at its leading edge is equal to or less than 10 times the thickness **t** of each cooling fin **10** at its leading edge.

[0084] The present embodiment illustrates a construction where the cylinder head **100** includes the cross fins **20;** however, in addition to the cylinder head **100** (or in the place of the cylinder head **100),** the cylinder block **103** may also include cross fins which are provided so as to cross the cooling fins **114** and which are connected to the cooling fins **114**. Since at least one of the cylinder block **103** and the cylinder head **100** includes cross fins in addition to the cooling fins, an engine **101** which excels in both castability and cooling efficiency of the cylinder head **100** and/or the cylinder block **103** is obtained.

[0085] However, between the cylinder block **103** and the cylinder head **100,** it is preferably at least the cylinder head **100** that includes the cross fins **20,** as is exemplified by the present embodiment. The reason is as follows. Generally, a cylinder head is likely to have a more complicated shape than a cylinder block; therefore, if thin cooling fins are placed at narrow interspaces, melt permeability around the cooling fins is likely to be deteriorated. By providing the cross fins **20** at least on the cylinder head **100** as in the present embodiment, casting insufficiencies can be effectively prevented.

[0086] As shown in FIG. **12,** it is preferable that the cross fins **20** are at an angle of 45° or less with respect to an axis of rotation of the fan **121** (which corresponds to a center line **L2** (shown for reference in FIG. **12)** of the crankshaft **112)** when viewed in the cylinder axis direction **D1,** as is the case with the present embodiment. When the cross fins **20** are provided at an angle of 45° or less with respect to the axis of rotation of the fan **121** as viewed in the cylinder axis direction **D1** (i.e., extending more in the right-left direction than in the upper-lower direction in the case of a transverse type as in the present embodiment), the cross fins **20** are unlikely to present resistance against the cooling air **CA** which is sent from the fan **121.** Thus, deterioration in cooling efficiency due to the provision of the cross fins **20** can be prevented.

[0087] Moreover, it is preferable that the cross fins **20** overlap with the combustion chamber **110** when viewed in the cylinder axis direction, as shown in FIG. **12.** In other words, it is preferable that the cross fins **20** are connected to the combustion chamber wall **30** defining the combustion chamber **110.** When the cross fins **20** are provided in this manner, the heat generated in the combustion chamber **110** can be transmitted to the cooling fins **10** via the cross fins **20,** thereby improving the cooling efficiency.

[0088] The plurality of head bolts of the engine **101** of the present embodiment include two head bolts that are located on the fan **121** side of the cylinder axis **L1** (corresponding to the bolt holes **80c** and **80d**), such that the cross fins **20** are located in part between these two head bolts (i.e., between the bolt holes **80c** and **80d**), as shown in FIG. **10** and FIG. **12.** Thus placed, the cross fins **20** are close to the center of the combustion chamber **110,** allowing more heat to be transmitted to the cooling fins **10** via the cross fins **20;** as a result, a further enhancement in cooling efficiency is achieved.

[0089] The width **w** of each cross fin **20** along the cylinder axis direction **D1** (see FIG. **10)** is smaller at the leading edge **20a** of the cross fin **20** (see FIG. **12)** than at the foot **20b** of the cross fin **20** (see FIG. **12).** The width **w** of the cross fins **20** thus being set allows a large number of cooling fins **10** to be provided at the leading edge **20a** side, while allowing at the foot **20b** side the cam chamber to be placed near the combustion chamber **110,** thus downsizing the cylinder head **100.** In other words, both coolability and downsizing are reconciled.

[0090] Although FIG. **12** illustrates each cross fin **20** as having a constant thickness from the leading edge **20a** to the foot **20b,** it is preferable that the thickness of each cross fin **20** increases from the leading edge **20a** toward the foot **20b.** The thickness of the cross fins **20** thus being set allows more heat to be transmitted to the cooling fins **10** from the combustion chamber **110.**

[0091] Although FIG. **10** illustrates the cross fins **20** as having a constant thickness along the cylinder axis direction **D1**, it is preferable that the thickness of each cross fin **20** increases toward the cylinder block **103** (i.e., as going in the lower direction in FIG. **10**). The thickness of the cross fins **20** thus being set allows more heat to be transmitted to the cooling fins **10** from the combustion chamber **110**.

[0092] Moreover, it is preferable that a parting line (i.e., the position at which the mold is parted in casting) **P** of the cylinder head **100** and/or the cylinder block **103** is somewhere between the center and the leading edge of each cooling fin **10** (or cooling fin **114)** as shown in FIG. **12,** and more specifically, within 10 mm from the leading edge of each cooling fin **10** (or cooling fin **114).** When the parting line **P** is at such a position, burrs at the parting line **P** are easy to remove. On the other hand, if the parting line **P** is somewhere between the center and the foot of each cooling fin **10** (or cooling fin **114**), the deburring work will become difficult.

[0093] Preferably, the relationships $t \leqq 3$ and $t \leqq c \leqq 3t$ are satisfied by the thickness **t** (mm) of each of the plurality of cooling fins **10** at the leading edge and the interspace **c** (mm) between the leading edges of any two adjacent cooling fins **10** among the plurality of cooling fins **10** (see FIG. **10**). In other words, the thickness **t** is preferably 3 mm or less, and the interspace **c** is preferably between 1 to 3 times as much as the thickness **t.** By placing the thin cooling fins **10** at narrow interspaces while satisfying these relationships, it becomes possible to provide a large number of cooling fins **10**, thereby improving the cooling efficiency. Note that the plurality of cooling fins **114** provided on the cylinder block **103** preferably also satisfy a similar relationship in terms of thickness at leading edges and interspace between leading edges (i.e., it is preferable that the thickness at their leading edges is 3 mm or less, and that the interspace between leading edges is between 1 to 3 times as much as the thickness at the leading edges).

[0094] Preferably, the thickness **t** of the cooling fins **10** at the leading edges satisfies the relationship $1 \leqq t$. In other words, the thickness **t** of the cooling fins **10** at the leading edges is 1 mm or more. As the thickness of the cooling fins **10** decreases, more cooling fins **10** can be provided; however, if the thickness of the cooling fins **10** is too small, it will be difficult to take heat away from the cylinder head **100.** This problem does not occur when the thickness **t** of the cooling fins **10** at the leading edges is 1 mm or more (i.e., $1 \leqq t$). Similarly, the cooling fins **114** on the cylinder block **103** preferably also have a thickness of 1 mm or more at the leading edges.

[0095] Moreover, it is preferable that the interspace **c** between the leading edges of any two adjacent cooling fins **10** satisfies the relationship $3 \leqq c$. In other words, the interspace **c** between the leading edges of any two adjacent cooling fins **10** is preferably 3 mm or more. When the interspace **c** is 3 mm or more ($3 \leqq c$), it is easy to supply cooling air **CA** to the feet of the cooling fins **10,** whereby the cooling efficiency is improved. Similarly with respect to the cooling fins **114** on the cylinder block **103,** it is preferable that the interspace the leading edges of any two adjacent cooling fins **114** is 3 mm or more.

[0096] Preferably, the cooling fins **10** on the cylinder head **100** and/or the cooling fins **114** on the cylinder block **103** have a draft of 2.0° or less. By ensuring that the draft is as small as 2.0° or less, it becomes possible to increase the interspace at the feet of the cooling fins **10** on the cylinder head **100** and/or the cooling fins **114** on the cylinder block **103,** thereby further improving coolability. However, from the standpoint of facilitating release, it is preferable that the draft of the cooling fins **10** on the cylinder head **100** and/or the cooling fins **114** on the cylinder block **103** is 1.0° or more.

[0097] Preferably, the plurality of cooling fins **10** of the cylinder head **100** 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 **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**).

[0098] 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.

[0099] According to the present invention, there is provided a forced air-cooling type internal combustion engine which excels in both castability and cooling efficiency of a cylinder head and/or a cylinder block. A forced air-cooling type internal combustion engine according to the present invention provides excellent cooling efficiency, and is suitably used for various saddled vehicles such as motorcycles.

[0100] 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. A forced air-cooling type internal combustion engine comprising:

    a cylinder block molded by casting;
    a cylinder head molded by casting and overlaid on the cylinder block;
    a shroud covering at least a portion of the cylinder block and at least a portion of the cylinder head; and
    a fan for rotating to introduce air to an inside of the shroud, wherein,
    at least one of the cylinder block and the cylinder head includes a cooling fin formed at least in a portion covered by the shroud and a cross fin provided so as to cross the cooling fin, the cross fin being connected to the cooling fin; and
    a thickness of the cross fin at a leading edge thereof is greater than a thickness of the cooling fin at a leading edge thereof.

2. The forced air-cooling type internal combustion engine of claim 1, wherein, between the cylinder block and the cylinder head, at least the cylinder head includes the cross fin.

3. The forced air-cooling type internal combustion engine of claim 1 or 2, wherein the cross fin is at an angle of 45° or less with respect to an axis of rotation of the fan when viewed in a cylinder axis direction.

4. The forced air-cooling type internal combustion engine of any of claims 1 to 3, wherein the cross fin overlaps with the combustion chamber when viewed in a cylinder axis direction.

5. The forced air-cooling type internal combustion engine of claim 4, further comprising a plurality of head bolts for coupling the cylinder block and the cylinder head, wherein,
    the plurality of head bolts include two head bolts that are located on the fan side of a cylinder axis; and
    the cross fin is located in part between the two head bolts.

6. The forced air-cooling type internal combustion engine of any of claims 1 to 5, wherein the width of the cross fin along a cylinder axis direction is smaller at the leading edge of the cross fin than at a foot of the cross fin.

7. The forced air-cooling type internal combustion engine of any of claims 1 to 6, wherein the thickness of the cross fin increases from the leading edge toward the foot of the cross fin.

8. The forced air-cooling type internal combustion engine of any of claims 1 to 7, wherein the thickness of the cross fin increases toward the cylinder block.

9. The forced air-cooling type internal combustion engine of any of claims 1 to 8, wherein a parting line of at least one of the cylinder block and the cylinder head is located between a center of the cooling fin and the leading edge of the cooling fin.

10. The forced air-cooling type internal combustion engine of any of claims 1 to 9, wherein,
    at least one of the cylinder block and the cylinder head includes a plurality of cooling fins; and,
    given a thickness t (mm) of each of the plurality of cooling fins at the leading edge and an interspace c (mm) between the leading edges of any two adjacent cooling fins among the plurality of cooling fins,
    the thickness t and the interspace c satisfy the relationships $t \leqq 3$ and $t \leqq c \leqq 3t$.

11. The forced air-cooling type internal combustion engine of claim 10, wherein the thickness t further satisfies the relationship $1 \leqq t$.

12. The forced air-cooling type internal combustion engine of claim 10 or 11, wherein the interspace c further satisfies the relationship $3 \leqq c$.

13. The forced air-cooling type internal combustion engine of any of claims 1 to 12, wherein the cooling fin has a draft of not more than 1.0° and not less than 2.0°.

14. A saddled vehicle comprising the forced air-cooling type internal combustion engine of any of claims 1 to 13.

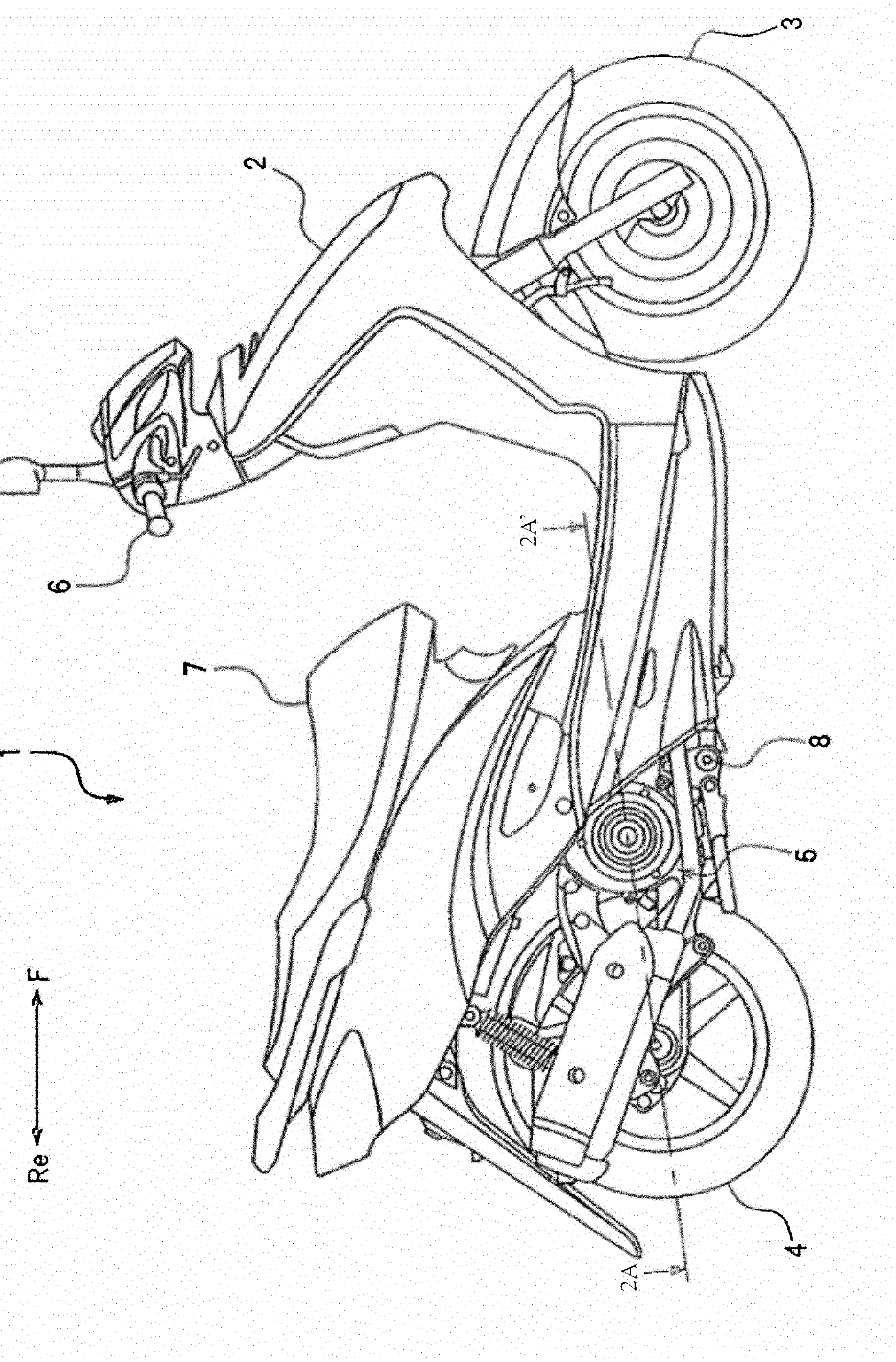
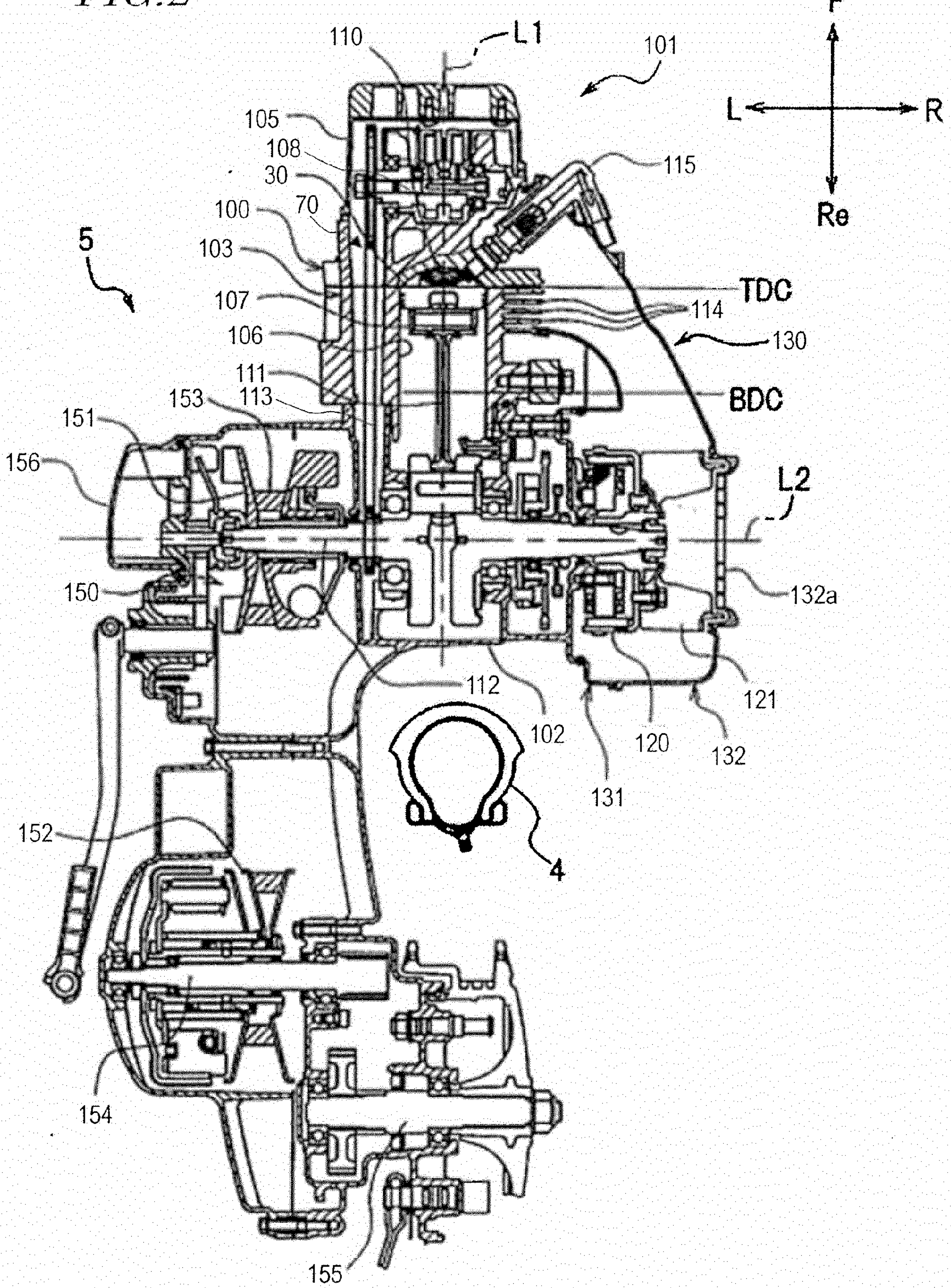


FIG.1

FIG.2



F
L
R
Re
110
L1
101
105
108
30
115
100
70
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103
TDC
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114
130
106
111
BDC
113
153
151
156
L2
132a
150
112
121
102
120
132
131
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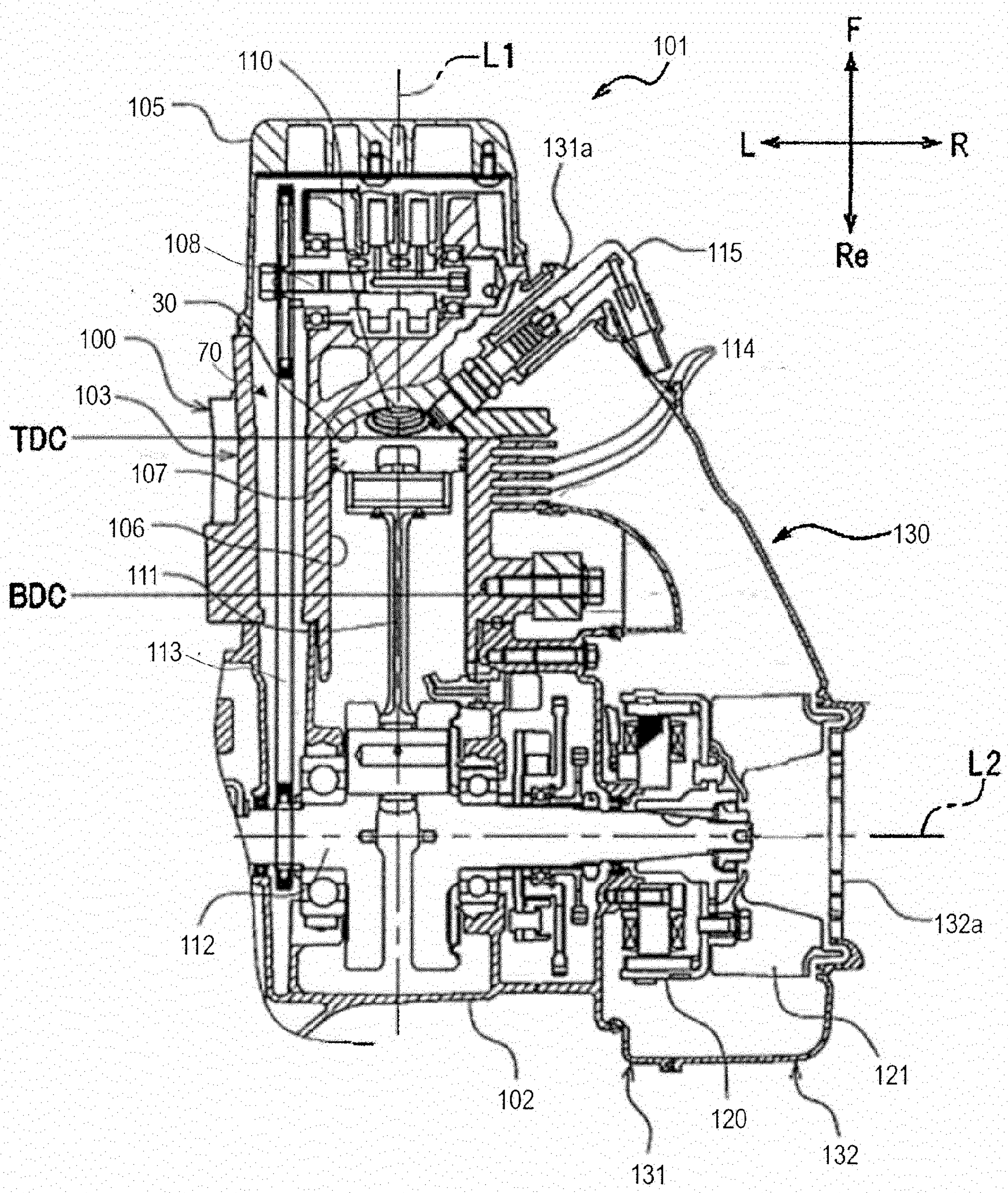
4
154
155

FIG.3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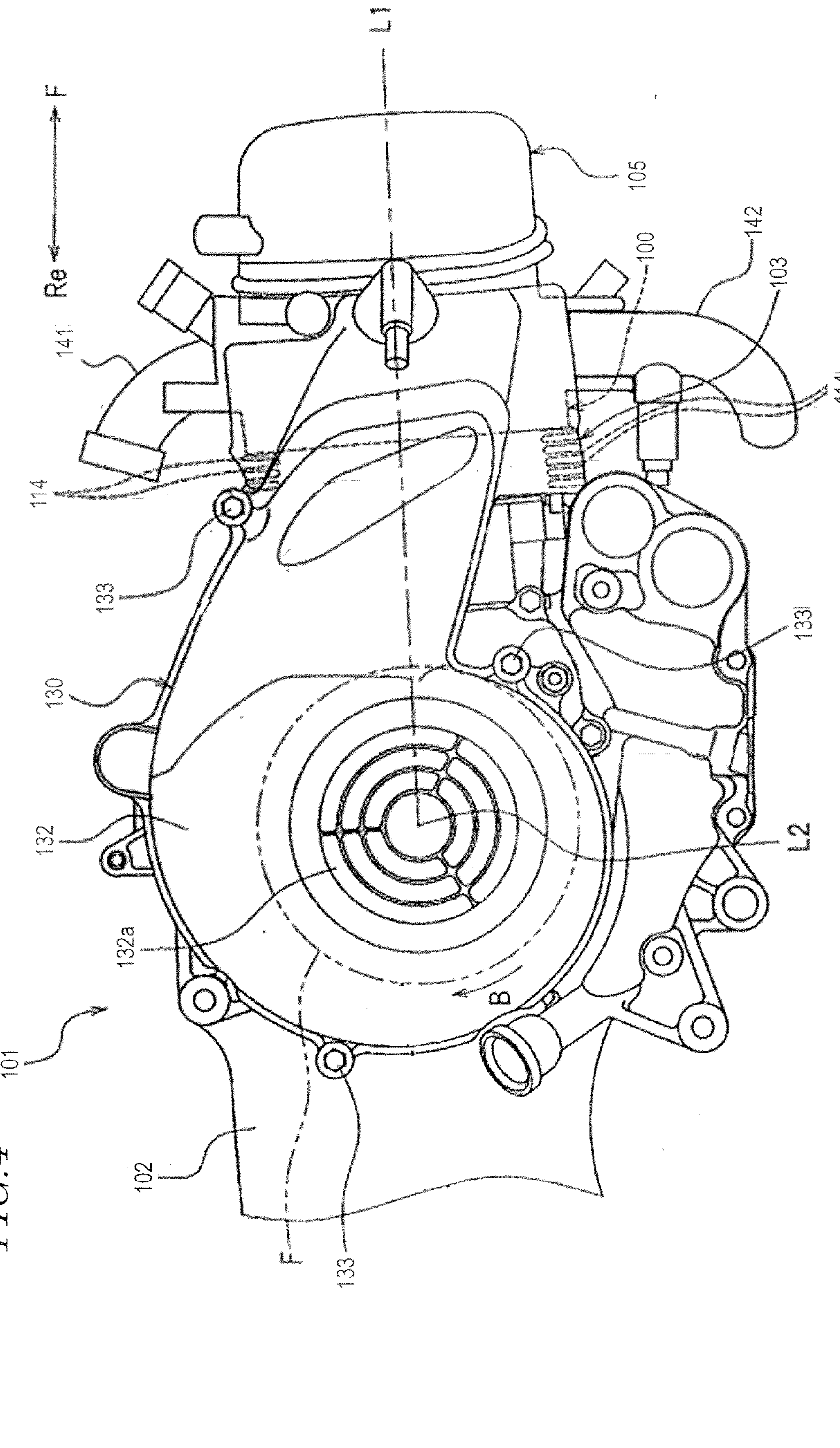
131
132

FIG.4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L2
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102
F
133

FIG.5

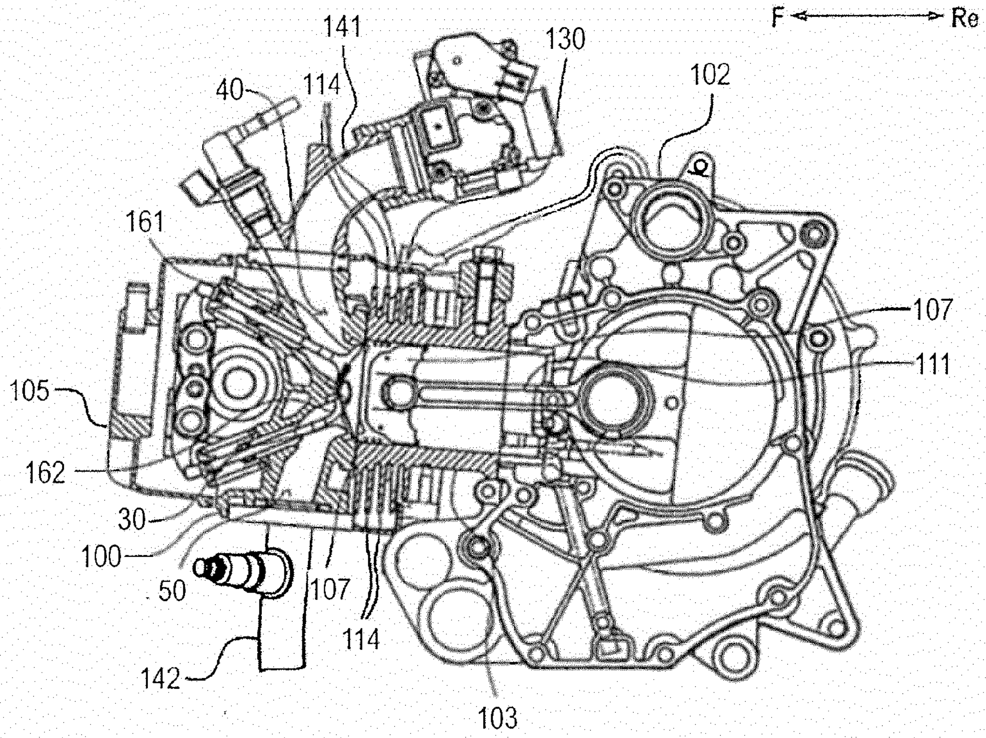
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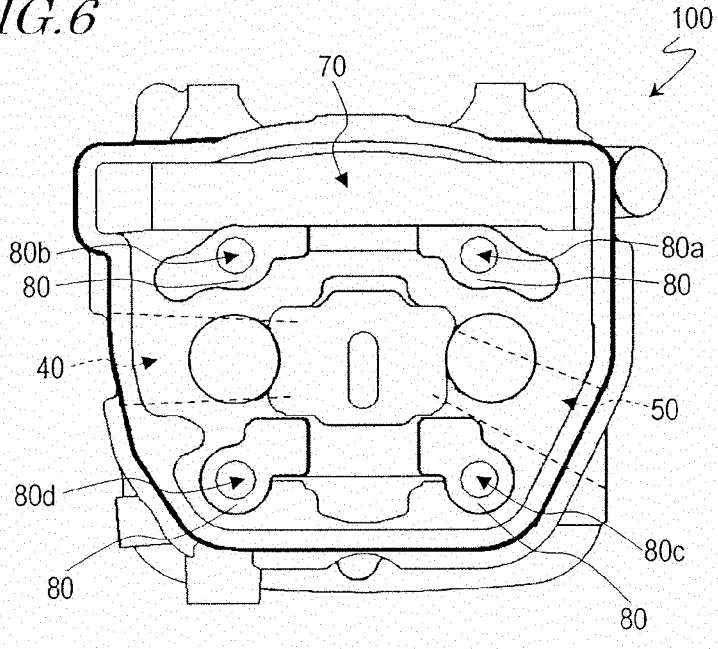
FIG.6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80c
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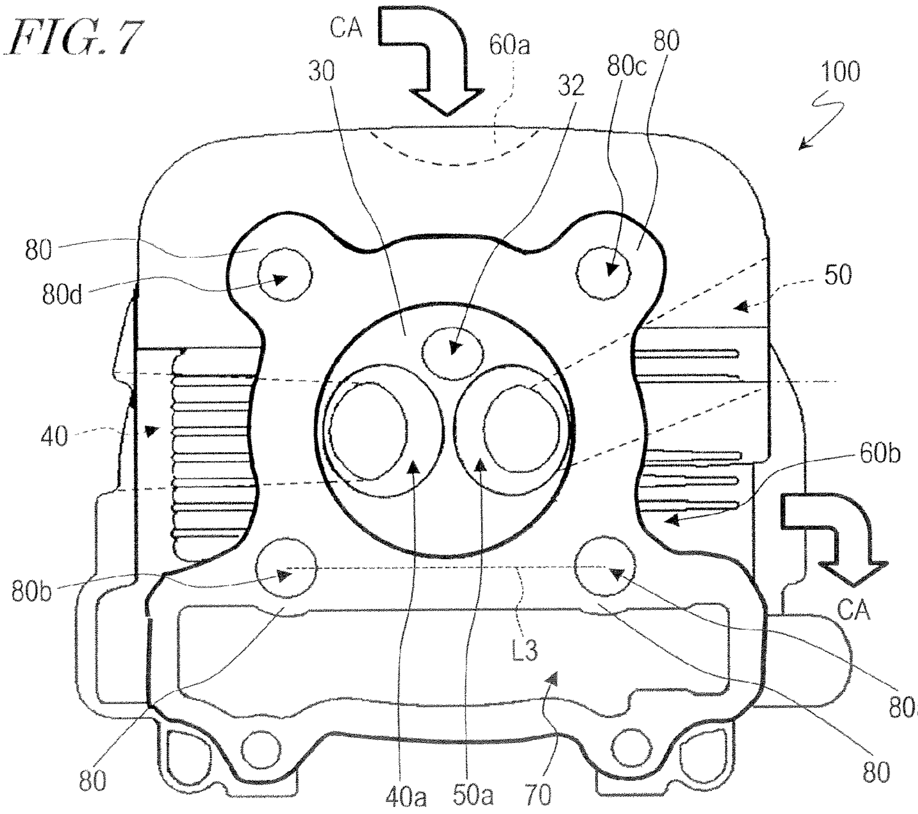
80

FIG.7


CA
60a
80
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32
80c
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40
60b
80b
CA
L3
80a
80
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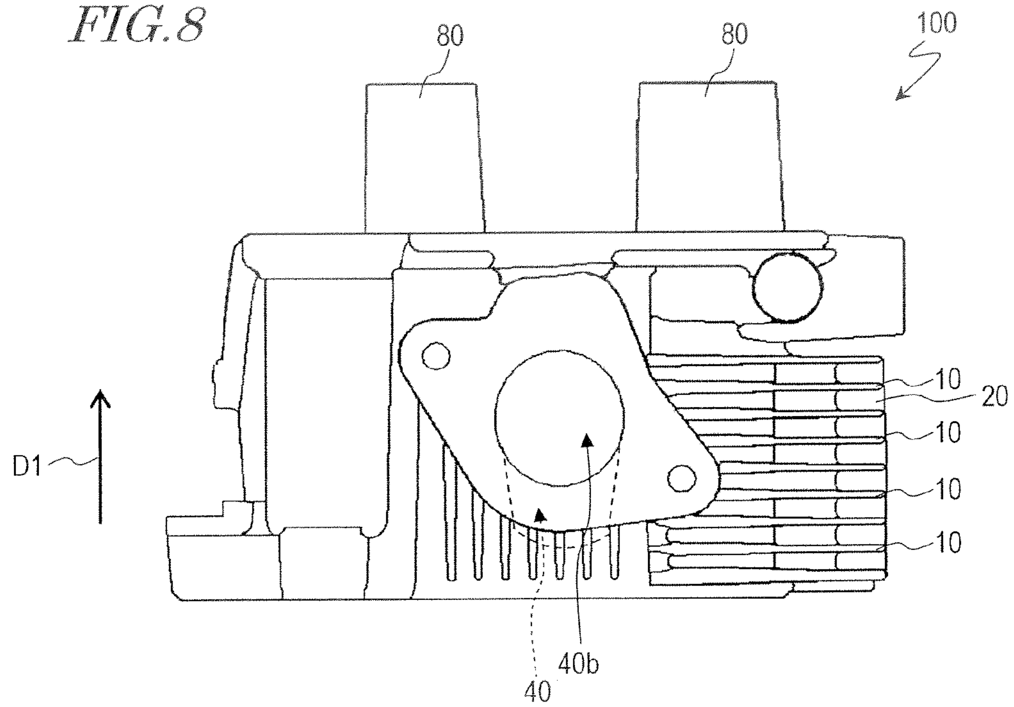
40a
50a
70

FIG.8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D1
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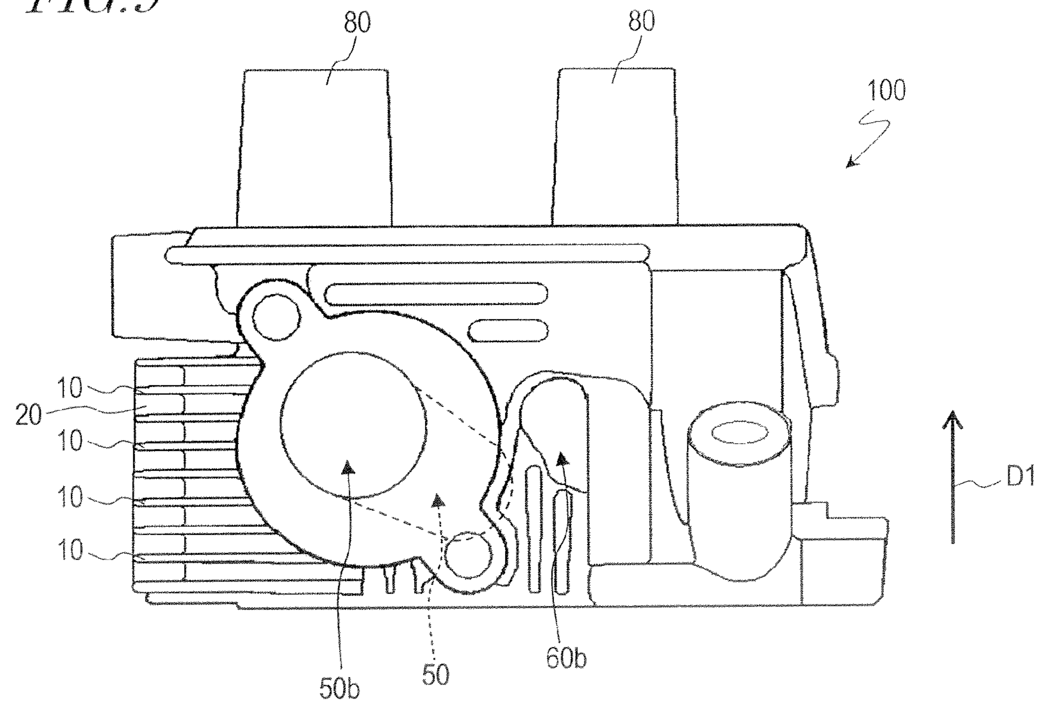
40b
40

FIG.9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50b
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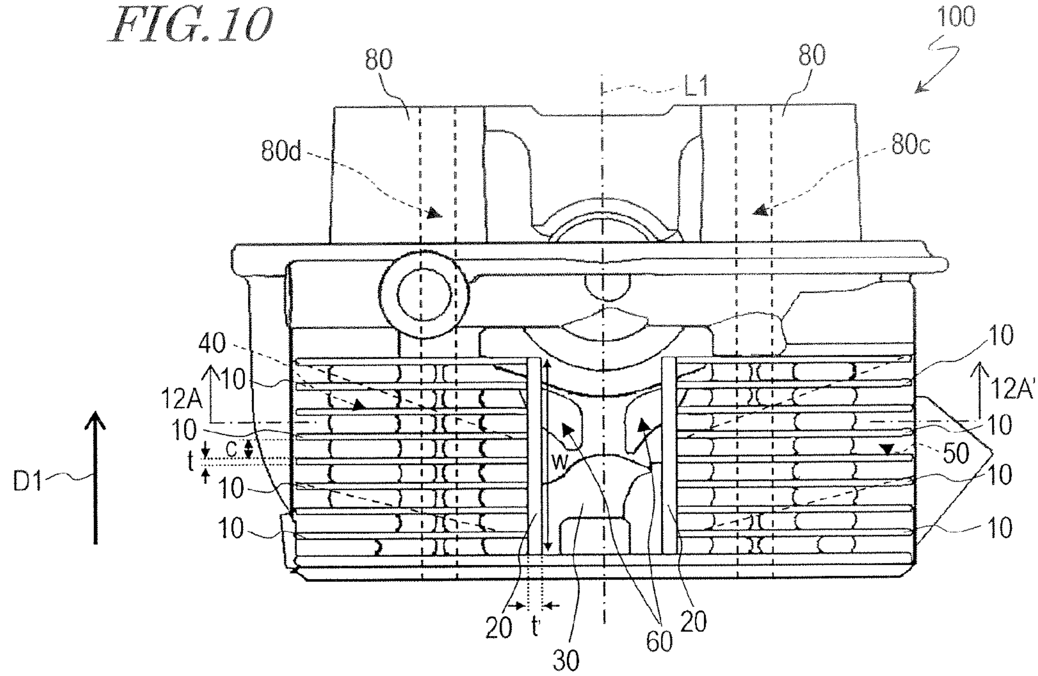
60b

FIG.10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L1
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80d
80c
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10
10
12A
12A'
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10
c
t
w
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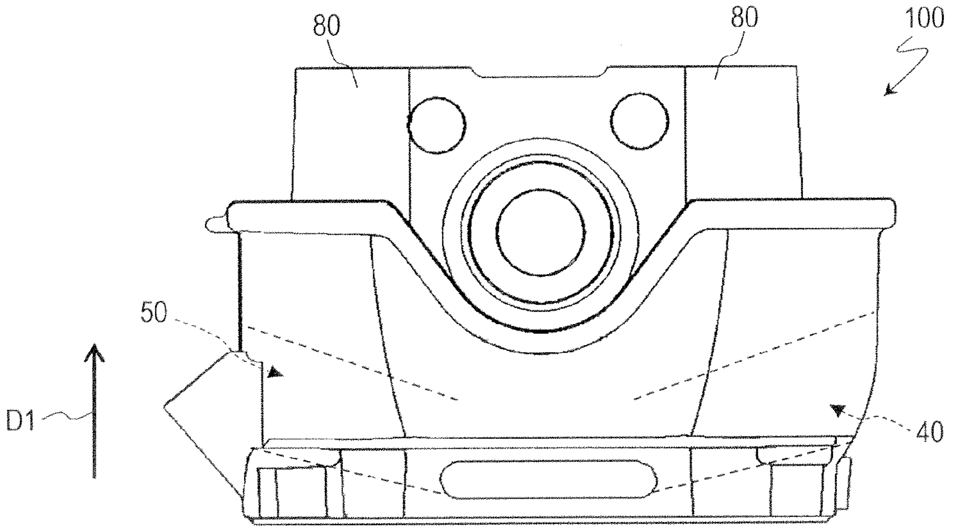
10
10
10
10
D1
20
t'
30
60
20

FIG. 11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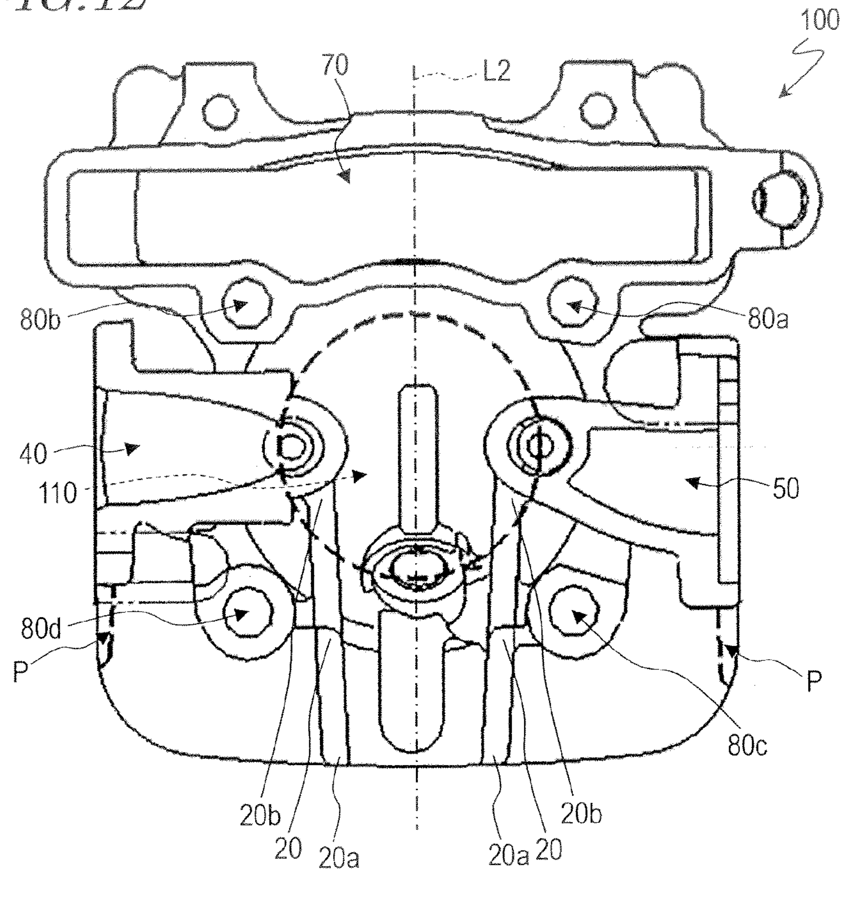
D1
40

FIG. 12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P
P
80c
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20a
20a
20
20b

FIG.13A

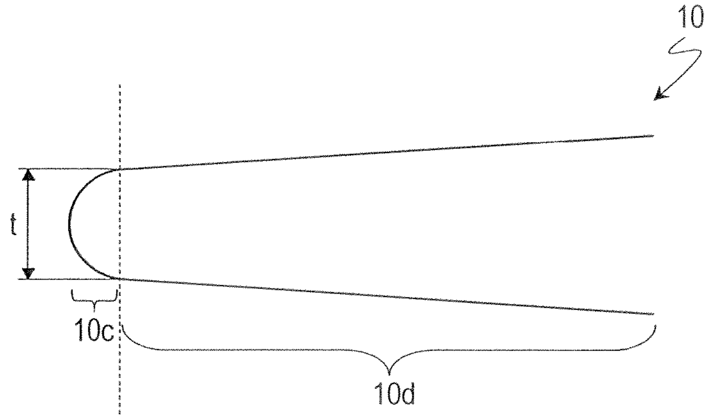
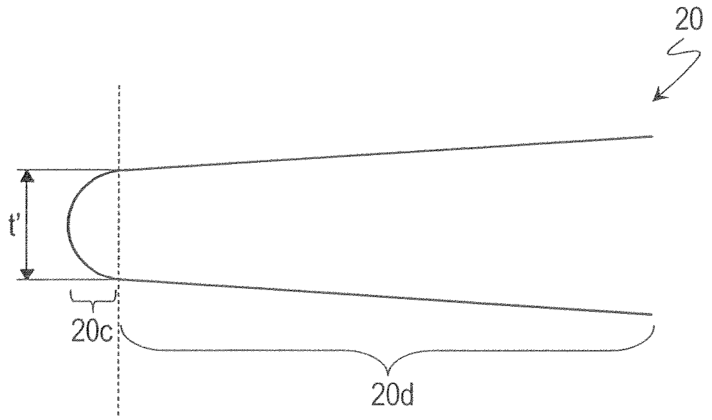


FIG.13B



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EUROPEAN SEARCH REPORT

Application Number
EP 13 18 8290

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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	14 February 2014	Mouton, Jean

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