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(54) **INTERNAL COMBUSTION ENGINE**

(57) [Object]

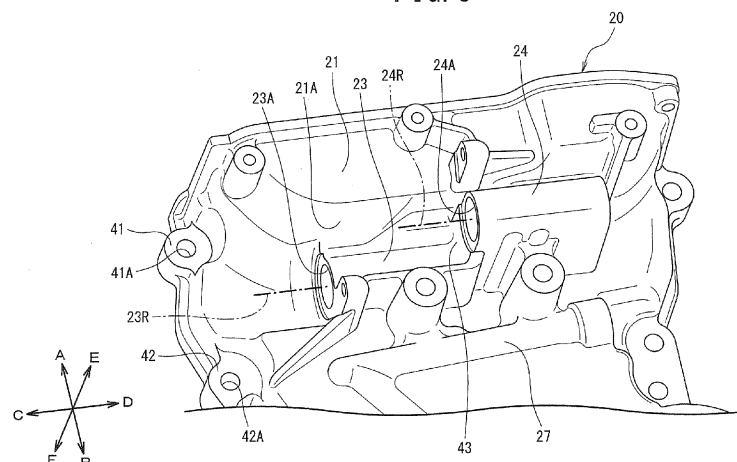
To provide an internal combustion engine capable of improving rigidity of a portion in the vicinity of a first solenoid valve attachment portion and a second solenoid valve attachment portion provided between adjacent cylinder head fastening portions of an oil pump accommodation portion of a chain casing and suppressing a load caused by a vibration of the oil pump accommodation portion from acting on a first solenoid valve and a second solenoid valve.

[Solution]

An axis 23R of an accommodation hole 23A of a first solenoid valve attachment portion 23 and an axis 24R of

an accommodation hole 24A of a second solenoid valve attachment portion 24 are arranged at different positions in an EF direction. At least a part of the first solenoid valve attachment portion 23 and the second solenoid valve attachment portion 24 overlaps in an AB direction. Fastening holes 41A and 42A of cylinder head fastening portions 41 and 42 are formed outside a projection area obtained by projecting the accommodation hole 23A of the first solenoid valve attachment portion 23 toward the fastening holes 41A and 42A and outside a projection area obtained by projecting the accommodation hole 24A of the second solenoid valve attachment portion 24 toward the fastening holes 41A and 42A.

FIG. 3



Description

[Technical Field]

[0001] This invention relates to an internal combustion engine.

[Background of the Invention]

[0002] A solenoid valve unit of an internal combustion engine described in JP 4613760 B2 includes a first solenoid valve which is provided in a cover disposed at an end portion of the internal combustion engine and controls the amount of hydraulic oil supplied from a hydraulic source to a first hydraulic mechanism, a second solenoid valve which is provided in the cover to be adjacent to the first solenoid valve and controls the amount of hydraulic oil supplied from the hydraulic source to a second hydraulic mechanism, and an oil filter which is provided between the first solenoid valve and the second solenoid valve in the cover, is connected to each solenoid valve, and filters hydraulic oil supplied to each solenoid valve.

[Prior Art]

[Patent Literature]

[0003] [Patent Literature 1] JP 4613760 B2

[Summary of the Invention]

[Problem to be solved by the Invention]

[0004] However, in the technique described in Patent Literature 1, when two solenoid valve attachment portions respectively accommodating the solenoid valves are integrally formed with a chain casing, it is necessary to increase a gap between fastening portions in order to avoid the interference between a casting pin forming bolt holes of a plurality of fastening portions of the chain casing to be fastened to a cylinder head and a casting pin forming an accommodation hole of the solenoid valve attachment portion accommodating the solenoid valve in a casting direction. As a result, since the rigidity of a portion in the vicinity of the solenoid valve attachment portion disposed between the adjacent fastening portions of the chain casing decreases, a problem arises in that a load of a vibration caused by a decrease in rigidity acts on the solenoid valve.

[0005] This invention has been made in view of the above-described circumstances and an object of this invention is to provide an internal combustion engine capable of improving rigidity of a portion in the vicinity of a first solenoid valve attachment portion and a second solenoid valve attachment portion provided between adjacent cylinder head fastening portions of an oil pump accommodation portion of a chain casing and suppressing a load caused by a vibration of the oil pump accommo-

ation portion from acting on a first solenoid valve and a second solenoid valve.

[Means to solve the problem]

[0006] According to aspects of this invention, there is provided an internal combustion engine including: a variable valve timing mechanism configured by winding a timing chain thereon; a solenoid valve controlling hydraulic oil supplied to the variable valve timing mechanism; a chain casing fixed to a cylinder head to cover the timing chain and the variable valve timing mechanism; a cylinder head cover connected to the cylinder head; an oil pan provided on the side opposite to the cylinder head with respect to the chain casing and connected to the cylinder head through a cylinder block; an intake port provided in the cylinder head and taking air; and an exhaust port provided on the side opposite to the intake port with respect to the chain casing and discharging an exhaust gas, wherein a bulging portion covering the variable valve timing mechanism is formed in the chain casing, wherein the solenoid valve is disposed closer to the oil pan than the bulging portion in the chain casing, wherein when a direction of the cylinder head cover with respect to the chain casing and a direction of the oil pan are defined as an AB direction, a direction of the intake port with respect to the chain casing and a direction of the exhaust port are defined as a CD direction, and an outward direction and an inward direction of the chain casing with respect to the chain casing are defined as an EF direction, the solenoid valve includes a large diameter portion and a small diameter portion, includes a first solenoid valve, a large diameter portion, and a small diameter portion arranged on the side of the intake port in the CD direction, and includes a second solenoid valve disposed on the side of the exhaust port in the CD direction, wherein the chain casing includes an oil pump accommodation portion accommodating an oil pump, a first solenoid valve attachment portion including an accommodation hole accommodating at least the small diameter portion of the first solenoid valve and integrally formed with the oil pump accommodation portion, a second solenoid valve attachment portion including an accommodation hole accommodating at least the small diameter portion of the second solenoid valve and integrally formed with the oil pump accommodation portion, and a plurality of cylinder head fastening portions including a fastening hole for fastening the oil pump accommodation portion to the cylinder head, wherein the accommodation hole of the first solenoid valve attachment portion and the accommodation hole of the second solenoid valve attachment portion are arranged on either the side of the intake port or the side of the exhaust port in the CD direction and open to either the side of the intake port or the side of the exhaust port, wherein an axis of the accommodation hole of the first solenoid valve attachment portion and an axis of the accommodation hole of the second solenoid valve attachment portion are arranged

at different positions in the EF direction, wherein at least a part of the first solenoid valve attachment portion and the second solenoid valve attachment portion overlaps in the AB direction, and wherein the fastening holes of the adjacent cylinder head fastening portions are formed outside a projection area obtained by projecting the accommodation hole of the first solenoid valve attachment portion toward the fastening hole and outside a projection area obtained by projecting the accommodation hole of the second solenoid valve attachment portion toward the fastening hole.

[Effect of the Invention]

[0007] In this way, according to this invention, it is possible to provide an internal combustion engine capable of improving rigidity of a portion in the vicinity of a first solenoid valve attachment portion and a second solenoid valve attachment portion provided between adjacent cylinder head fastening portions of an oil pump accommodation portion of a chain casing and suppressing a load caused by a vibration of the oil pump accommodation portion from acting on a first solenoid valve and a second solenoid valve.

[Brief description of figures]

[0008]

[Fig. 1] Fig. 1 is a front view of an internal combustion engine according to an embodiment of this invention.

[Fig. 2] Fig. 2 is a side view of the internal combustion engine according to an embodiment of this invention.

[Fig. 3] Fig. 3 is a perspective view of a chain casing of the internal combustion engine according to an embodiment of this invention.

[Fig. 4] Fig. 4 is a front view of the chain casing of the internal combustion engine according to an embodiment of this invention.

[Fig. 5] Fig. 5 is a side view of the chain casing of the internal combustion engine according to an embodiment of this invention.

[Fig. 6] Fig. 6 is a cross-sectional view when viewed from a direction VI-VI of Fig. 4.

[Embodiment(s) of the Invention]

[0009] An internal combustion engine according to embodiments of this invention is an internal combustion engine including: a variable valve timing mechanism configured by winding a timing chain thereon; a solenoid valve controlling hydraulic oil supplied to the variable valve timing mechanism; a chain casing fixed to a cylinder head to cover the timing chain and the variable valve timing mechanism; a cylinder head cover connected to the cylinder head; an oil pan provided on the side opposite to the cylinder head with respect to the chain casing and connected to the cylinder head through a cylinder

block; an intake port provided in the cylinder head and taking air; and an exhaust port provided on the side opposite to the intake port with respect to the chain casing and discharging an exhaust gas, wherein a bulging portion covering the variable valve timing mechanism is formed in the chain casing, wherein the solenoid valve is disposed closer to the oil pan than the bulging portion in the chain casing, wherein when a direction of the cylinder head cover with respect to the chain casing and a direction of the oil pan are defined as an AB direction, a direction of the intake port with respect to the chain casing and a direction of the exhaust port are defined as a CD direction, and an outward direction and an inward direction of the chain casing with respect to the chain casing are defined as an EF direction, the solenoid valve includes a large diameter portion and a small diameter portion, includes a first solenoid valve, a large diameter portion, and a small diameter portion arranged on the side of the intake port in the CD direction, and includes a second solenoid valve disposed on the side of the exhaust port in the CD direction, wherein the chain casing includes an oil pump accommodation portion accommodating an oil pump, a first solenoid valve attachment portion including an accommodation hole accommodating at least the small diameter portion of the first solenoid valve and integrally formed with the oil pump accommodation portion, a second solenoid valve attachment portion including an accommodation hole accommodating at least the small diameter portion of the second solenoid valve and integrally formed with the oil pump accommodation portion, and a plurality of cylinder head fastening portions including a fastening hole for fastening the oil pump accommodation portion to the cylinder head, wherein the accommodation hole of the first solenoid valve attachment portion and the accommodation hole of the second solenoid valve attachment portion are arranged on either the side of the intake port or the side of the exhaust port in the CD direction and open to either the side of the intake port or the side of the exhaust port, wherein an axis of the accommodation hole of the first solenoid valve attachment portion and an axis of the accommodation hole of the second solenoid valve attachment portion are arranged at different positions in the EF direction, wherein at least a part of the first solenoid valve attachment portion and the second solenoid valve attachment portion overlaps in the AB direction, and wherein the fastening holes of the adjacent cylinder head fastening portions are formed outside a projection area obtained by projecting the accommodation hole of the first solenoid valve attachment portion toward the fastening hole and outside a projection area obtained by projecting the accommodation hole of the second solenoid valve attachment portion toward the fastening hole.

[0010] Accordingly, the internal combustion engine according to embodiments of this invention can improve the rigidity of the portion in the vicinity of the first solenoid valve attachment portion and the second solenoid valve attachment portion provided between the adjacent cylinder

der head fastening portions of the oil pump accommodation portion of the chain casing and suppress the load caused by the vibration of the oil pump accommodation portion from acting on the first solenoid valve and the second solenoid valve.

[Embodiments]

[0011] Hereinafter, an internal combustion engine according to an embodiment of this invention will be described with reference to the drawings. Figs. 1 to 6 are diagrams showing the internal combustion engine according to an embodiment of this invention.

[0012] In Figs. 1 to 6, the AB direction, the CD direction, and the EF direction are the directions orthogonal to each other and based on the state in which the internal combustion engine separated from the vehicle is upright so that the cylinder head is directly above the crank shaft. Further, in this embodiment, the EF direction coincides with the front to rear direction of the vehicle equipped with the internal combustion engine.

[0013] First, a configuration will be described. In Figs. 1 and 2, an internal combustion engine 1 mounted on the vehicle includes a cylinder block 2. The cylinder block 2 is provided with a crank shaft 2A and the crank shaft 2A extends in the EF direction.

[0014] The cylinder block 2 is provided with three cylinders (not shown) arranged in the EF direction and the cylinders extend in the AB direction. The internal combustion engine 1 of this embodiment is an FR (front engine-rear drive) type vertical engine. Additionally, the internal combustion engine 1 is not limited to an in-line engine and may be, for example, a V-type engine. Then, the number of cylinders is not limited to three.

[0015] A cylinder head 3 is provided on the upper side of the cylinder block 2. The cylinder head 3 includes an intake port 3A (see Fig. 2) which takes air, an exhaust port 3B (see Fig. 1) which discharges an exhaust gas, an intake valve, and an exhaust valve or the like (not shown). The intake port 3A opens to the right wall of the cylinder head 3 and the exhaust port 3B opens to the left wall of the cylinder head 3.

[0016] A cylinder head cover 4 is provided on the upper side of the cylinder head 3. An oil pan 5 is provided below the cylinder block 2 and the oil pan 5 stores oil for lubricating the internal combustion engine 1.

[0017] The internal combustion engine 1 is installed below a floor panel of the vehicle (not shown). The cylinder block 2 is installed so that the center lines of the plurality of cylinders are inclined with respect to the vertical direction of the vehicle. Specifically, the cylinder block 2 is installed so that the center line is inclined in the left to right direction of the vehicle with respect to the vertical direction.

[0018] An undercover 1A is provided below the internal combustion engine 1. The undercover 1A extends in the horizontal direction and covers the internal combustion engine 1 from below. A bottom surface 5A of the oil pan

5 is located at the bottom portion of the internal combustion engine 1 in a vehicle mounted state. This bottom surface 5A is inclined with respect to the left to right direction of the internal combustion engine 1 itself to extend in parallel to the undercover 1A in the vehicle mounted state.

[0019] In this way, the internal combustion engine 1 is mounted on the front portion of the vehicle while being largely inclined. Therefore, in the vehicle mounted state, the right side surface (intake side) of the internal combustion engine 1 faces the upper side of the vehicle and the left side surface (exhaust side) of the internal combustion engine 1 faces the lower side of the vehicle.

[0020] The internal combustion engine 1 includes a variable valve timing mechanism 11 on which a timing chain 10 is wound, a cylindrical first solenoid valve 15 and a second solenoid valve 16 which are hydraulic control valves controlling hydraulic oil supplied to the variable valve timing mechanism 11, and a cylinder head cover 4 which is connected to the cylinder head 3. Further, the internal combustion engine 1 includes a chain casing 20 which is fixed to the cylinder head 3 to cover the timing chain 10 and the variable valve timing mechanism 11. The variable valve timing mechanism 11 includes an intake side variable valve timing mechanism 12 which is disposed on the side of the intake port 3A and an exhaust side variable valve timing mechanism 13 which is disposed on the side of the exhaust port 3B.

[0021] The internal combustion engine 1 includes an oil pan which is provided on the side opposite to the cylinder head 3 with respect to the chain casing and is connected to the cylinder head 3 through the cylinder block 2, an intake port 3A which is provided in the cylinder head 3 and takes air, and an exhaust port 3B which is provided on the side opposite to the intake port 3A with respect to the chain casing and discharges an exhaust gas.

[0022] The chain casing 20 is provided with a bulging portion 21 which covers the variable valve timing mechanism 11. The bulging portion 21 bulges toward the outside (front side) of the chain casing 20. The bulging portion 21 is formed at the end portion (upper end portion) on the side of the cylinder head cover 4 in the chain casing 20. The first solenoid valve 15 and the second solenoid valve 16 are arranged closer to the oil pan 5 than the bulging portion 21 in the chain casing 20.

[0023] Further, the internal combustion engine 1 includes an oil pump 6 which is provided around the crank shaft 2A to pressure-feed oil stored in the oil pan 5 to a lubrication required portion and the variable valve timing mechanism 11.

[0024] Here, in this embodiment, the direction of the cylinder head cover with respect to the chain casing 20 and the direction of the oil pan are defined as the AB direction, the direction of the intake port 3A with respect to the chain casing 20 and the direction of the exhaust port 3B are defined as the CD direction, and the outward direction and the inward direction of the chain casing 20 are defined as the EF direction.

[0025] The first solenoid valve 15 is disposed on the side of the intake port 3A in the CD direction. The first solenoid valve 15 includes a large diameter portion 15A and a small diameter portion 15B. The second solenoid valve 16 is disposed on the side of the exhaust port 3B in the CD direction. The second solenoid valve 16 includes a large diameter portion 16A and a small diameter portion 16B. A connector (not shown) for electrically controlling the first solenoid valve 15 and the second solenoid valve 16 is connected to the side of the intake port 3A in the CD direction of the large diameter portions 15A and 16A. A connection port of each connector faces the outside (front side) of the chain casing 20 in the EF direction.

[0026] Here, since the internal combustion engine 1 of this embodiment is mounted on the vehicle in a largely inclined posture, the uppermost portions of the first solenoid valve 15 and the second solenoid valve 16 in the up to down direction of the vehicle in the vehicle mounted state are arranged on the lower side of the uppermost portion of the cylinder head cover 4 in the up to down direction of the vehicle. Further, a connector (not shown) of the end portion on the side of the intake port 3A of the second solenoid valve 16 in the CD direction is disposed at a position on the lower side in the up to down direction of the vehicle and on the side of the cylinder head cover 4 with respect to a connector (not shown) of the end portion on the side of the intake port 3A of the first solenoid valve 15 in the CD direction.

[0027] Accordingly, since the connector of the second solenoid valve 16 is disposed between the connector of the first solenoid valve 15 and the cylinder head cover 4 and on the lower side of the uppermost portions of both the first solenoid valve 15 and the cylinder head cover 4 in the up to down direction of the vehicle, it is possible to suppress dust collection to the connector of the second solenoid valve 16 without disposing the second solenoid valve 16 inside the cylinder head cover 4.

[0028] The chain casing 20 includes an oil pump accommodation portion 29 which accommodates the oil pump 6, a first solenoid valve attachment portion 23 which includes an accommodation hole 23A (see Fig. 3) accommodating at least the small diameter portion 15B of the first solenoid valve 15, and a second solenoid valve attachment portion 24 which includes an accommodation hole 24A (see Fig. 3) accommodating at least the small diameter portion 16B of the second solenoid valve 16. The first solenoid valve attachment portion 23 and the second solenoid valve attachment portion 24 are integrally formed with the oil pump accommodation portion 29.

[0029] Here, the oil pump accommodation portion 29 is a flat portion which does not bulge in the direction of the crank shaft 2A in the chain casing 20. The oil pump accommodation portion 29 is disposed below the bulging portion 21 and is continuous to the lower portion of the bulging portion 21. Since the oil pump accommodation portion 29 has a flat shape rather than a bulging shape like the bulging portion 21, the rigidity thereof is inferior

to that of the bulging portion 21 as it is. Here, in this embodiment, the rigidity of the portion of the oil pump accommodation portion 29 provided with the first solenoid valve attachment portion 23 and the second solenoid valve attachment portion 24 is improved. Further, since it is preferable to compactly arrange the first solenoid valve attachment portion 23 and the second solenoid valve attachment portion 24 in the AB direction, the first solenoid valve attachment portion 23 and the second solenoid valve attachment portion 24 are arranged in a staggered manner in the CD direction and the EF direction.

[0030] The chain casing 20 includes a plurality of cylinder head fastening portions 41 and 42 and the cylinder head fastening portions 41 and 42 respectively include fastening holes 41A and 42A for fastening the oil pump accommodation portion 29 to the cylinder head 3. The cylinder head fastening portions 41 and 42 are adjacent to each other in the AB direction.

[0031] In Figs. 3 and 4, the accommodation hole 23A of the first solenoid valve attachment portion 23 and the accommodation hole 24A of the second solenoid valve attachment portion 24 are arranged on either the side of the intake port 3A or the side of the exhaust port 3B in the CD direction and open to either the side of the intake port 3A or the side of the exhaust port 3B. That is, the accommodation hole 23A of the first solenoid valve attachment portion 23 and the accommodation hole 24A of the second solenoid valve attachment portion 24 are arranged in the same direction in the CD direction and open in the same direction. In this embodiment, the accommodation hole 23A of the first solenoid valve attachment portion 23 and the accommodation hole 24A of the second solenoid valve attachment portion 24 are arranged on the side of the intake port 3A and open toward the intake port 3A.

[0032] In Figs. 3 and 5, an axis 23R of the accommodation hole 23A of the first solenoid valve attachment portion 23 and an axis 24R of the accommodation hole 24A of the second solenoid valve attachment portion 24 are arranged at different positions in the EF direction. Specifically, the axis 23R is disposed on the inside of the chain casing 20 in the EF direction in relation to the axis 24R. Additionally, the axis 23R and the axis 24R may be parallel to each other. In this case, since the casting pins forming the accommodation holes 23A and 24A can be extracted in the same direction, it is possible to manufacture the chain casing 20 by a simple mold structure and to further shorten the distance between the first solenoid valve attachment portion 23 and the second solenoid valve attachment portion 24 in the CD direction (the direction of the axes 23R and 24R).

[0033] In Fig. 5, at least a part of the first solenoid valve attachment portion 23 and the second solenoid valve attachment portion 24 overlaps in the AB direction. Specifically, a lower end portion 24L of the second solenoid valve attachment portion 24 is disposed between an upper end portion 23U and a lower end portion 23L of the

first solenoid valve attachment portion 23 in the AB direction and the upper end portion 23U of the first solenoid valve attachment portion 23 is disposed between an upper end portion 24U and a lower end portion 24L of the second solenoid valve attachment portion 24.

[0034] In Fig. 4, the fastening holes 41A and 42A of the adjacent cylinder head fastening portions 41 and 42 are formed outside the projection area in which the accommodation hole 23A of the first solenoid valve attachment portion 23 is projected toward the fastening holes 41A and 42A and outside the projection area in which the accommodation hole 24A of the second solenoid valve attachment portion 24 is projected toward the fastening holes 41A and 42A. Specifically, the fastening holes 41A and 42A of the cylinder head fastening portions 41 and 42 are formed outside the area between an upper end portion 23A1 and a lower end portion 23A2 of the projection area in which the accommodation hole 23A of the first solenoid valve attachment portion 23 is projected toward the fastening holes 41A and 42A.

[0035] Further, the fastening holes 41A and 42A of the cylinder head fastening portions 41 and 42 are formed outside the area between an upper end portion 24A1 and a lower end portion 24A2 of the projection area in which the accommodation hole 24A of the second solenoid valve attachment portion 24 is projected toward the fastening holes 41A and 42A. In this embodiment, in Fig. 4, the cylinder head fastening portion 41 is disposed above the upper end portion 24A1 of the projection area of the accommodation hole 24A of the second solenoid valve attachment portion 24 and the cylinder head fastening portion 42 is disposed below the lower end portion 23A2 of the projection area of the accommodation hole 23A of the first solenoid valve attachment portion 23.

[0036] As shown in Fig. 5, in the EF direction, an inner end portion 24F of the chain casing 20 of the accommodation hole 24A of the second solenoid valve attachment portion 24 is disposed on the outside of the chain casing 20 (the right side of Fig. 5) in relation to an outer end portion 23E of the chain casing 20 of the accommodation hole 23A of the first solenoid valve attachment portion 23.

[0037] As shown in Fig. 4, in the CD direction, an end portion 24C on the side of the intake port 3A of the accommodation hole 24A of the second solenoid valve attachment portion 24 is disposed on the side of the exhaust port 3B in relation to an end portion 23D on the side of the exhaust port 3B of the accommodation hole 23A of the first solenoid valve attachment portion 23.

[0038] In Figs. 3 and 6, the chain casing 20 includes a connection portion 43. The connection portion 43 extends in the EF direction and connects the end portion on the side of the exhaust port 3B in the CD direction of the first solenoid valve attachment portion 23 and an end portion on the side of the intake port 3A in the CD direction of the second solenoid valve attachment portion 24. Additionally, the connection portion 43 also extends in the AB direction. Thus, the connection portion 43 connects the first solenoid valve attachment portion 23 and the

second solenoid valve attachment portion 24 in the EF direction and the AB direction.

[0039] In Fig. 6, the chain casing 20 includes an oil gallery portion 27 which extends in the CD direction and includes an oil passage 27A through which oil flows and a wall portion 21A which is provided at the end portion on the side of the oil pan 5 (the lower end portion of Fig. 6) in the AB direction of the bulging portion 21, extends in the EF direction, and is continuous to the oil pump accommodation portion 29. The first solenoid valve attachment portion 23 and the second solenoid valve attachment portion 24 are arranged between the oil gallery portion 27 and the wall portion 21A in the AB direction.

[0040] Additionally, in order to suppress the vibration of an intake manifold (not shown) connected to the intake port 3A of the cylinder head 3 from being transmitted to the chain casing 20, it is preferable to improve the rigidity of the portion in the vicinity of the intake manifold in the chain casing 20. Here, as shown in Fig. 3, the intake port 3A and the intake manifold connected to the intake port 3A are arranged between the cylinder head fastening portion 41 and the cylinder head fastening portion 42 in the AB direction. Further, any one of the projection area in which the accommodation hole 23A of the first solenoid valve attachment portion 23 is projected toward the fastening holes 41A and 42A and the projection area in which the accommodation hole 24A of the second solenoid valve attachment portion 24 is projected toward the fastening holes 41A and 42A is disposed between the cylinder head fastening portion 41 and the cylinder head fastening portion 42 in the AB direction. With such a configuration, since it is possible to set the distance between the cylinder head fastening portion 41 and the cylinder head fastening portion 42 to a minimum distance, it is possible to improve the rigidity of the portion in the vicinity of the cylinder head fastening portions 41 and 42 in the chain casing 20. Further, it is possible to suppress the vibration of the portion in the vicinity of the cylinder head fastening portions 41 and 42 in the chain casing 20.

[0041] As described above, in this embodiment, the internal combustion engine 1 includes the first solenoid valve 15 which includes the large diameter portion 15A and the small diameter portion 15B and are arranged on the side of the intake port 3A in the CD direction and the second solenoid valve 16 which includes the large diameter portion 16A and the small diameter portion 16B and are arranged on the side of the exhaust port 3B in the CD direction.

[0042] Further, the chain casing 20 includes the oil pump accommodation portion 29 which accommodates the oil pump 6, the first solenoid valve attachment portion 23 which includes the accommodation hole 23A accommodating at least the small diameter portion 15B of the first solenoid valve 15 and is integrally formed with the oil pump accommodation portion 29, the second solenoid valve attachment portion 24 which includes the accommodation hole 24A accommodating at least the small diameter portion 16B of the second solenoid valve 16 and

is integrally formed with the oil pump accommodation portion 29, and the plurality of cylinder head fastening portions 41 and 42 which include the fastening holes 41A and 42A fastening the oil pump accommodation portion 29 to the cylinder head 3.

[0043] Further, the accommodation hole 23A of the first solenoid valve attachment portion 23 and the accommodation hole 24A of the second solenoid valve attachment portion 24 are arranged on either the side of the intake port 3A or the side of the exhaust port 3B in the CD direction and open to either the side of the intake port 3A or the side of the exhaust port 3B.

[0044] Further, the axis 23R of the accommodation hole 23A of the first solenoid valve attachment portion 23 and the axis 24R of the accommodation hole 24A of the second solenoid valve attachment portion 24 are arranged at different positions in the EF direction. At least a part of the first solenoid valve attachment portion 23 and the second solenoid valve attachment portion 24 overlaps in the AB direction. The fastening holes 41A and 42A of the adjacent cylinder head fastening portions 41 and 42 are formed outside the projection area in which the accommodation hole 23A of the first solenoid valve attachment portion 23 is projected toward the fastening holes 41A and 42A and outside the projection area in which the accommodation hole 24A of the second solenoid valve attachment portion 24 is projected toward the fastening holes 41A and 42A.

[0045] Accordingly, since it is possible to compactly arrange the first solenoid valve attachment portion 23 and the second solenoid valve attachment portion 24 in the AB direction, it is possible to prevent the interference between the casting pins forming the fastening holes 41A and 42A of the cylinder head fastening portions 41 and 42 of the oil pump accommodation portion 29 and the casting pins forming the accommodation holes 23A and 24A of the first solenoid valve attachment portion 23 and the second solenoid valve attachment portion 24 during casting in the manufacturing process of manufacturing the chain casing 20 by casting. Further, it is possible to reduce the gap between the cylinder head fastening portions 41 and 42.

[0046] Thus, it is possible to improve the rigidity of the portion in the vicinity of the first solenoid valve attachment portion 23 and the second solenoid valve attachment portion 24 between the cylinder head fastening portions 41 and 42 in the oil pump accommodation portion 29. Therefore, it is possible to suppress the load caused by the vibration from the oil pump accommodation portion 29 to the first solenoid valve 15 and the second solenoid valve 16.

[0047] As a result, it is possible to improve the rigidity of the portion in the vicinity of the first solenoid valve attachment portion 23 and the second solenoid valve attachment portion 24 provided between the adjacent cylinder head fastening portions 41 and 42 of the oil pump accommodation portion 29 of the chain casing 20 and to suppress the load caused by the vibration of the oil pump

accommodation portion 29 from acting on the first solenoid valve 15 and the second solenoid valve 16.

[0048] Further, in this embodiment, in the EF direction, the inner end portion 24F of the chain casing 20 of the accommodation hole 24A of the second solenoid valve attachment portion 24 is disposed on the outside of the chain casing 20 in relation to the outer end portion 23E of the chain casing 20 of the accommodation hole 23A of the first solenoid valve attachment portion 23. Further, in the CD direction, the end portion 24C on the side of the intake port 3A of the accommodation hole 24A of the second solenoid valve attachment portion 24 is disposed on the side of the exhaust port 3B in relation to the end portion 23D on the side of the exhaust port 3B of the accommodation hole 23A of the first solenoid valve attachment portion 23.

[0049] Accordingly, it is possible to reduce the distance between the first solenoid valve attachment portion 23 and the second solenoid valve attachment portion 24 in the AB direction and to separate the accommodation hole 23A of the first solenoid valve attachment portion 23 and the accommodation hole 24A of the second solenoid valve attachment portion 24 in the CD direction and the EF direction. Therefore, it is possible to suppress the occurrence of casting defects such as cavities between the outer peripheral portion of the first solenoid valve attachment portion 23 and the outer peripheral portion of the second solenoid valve attachment portion 24.

[0050] Thus, it is possible to eliminate the adverse effect on the precise control of the variable valve timing mechanism and to reduce the gap between the first solenoid valve 15 and the second solenoid valve 16 in the AB direction.

[0051] Thus, it is possible to further improve the rigidity of the portion in the vicinity of the first solenoid valve attachment portion 23 and the second solenoid valve attachment portion 24 between the cylinder head fastening portions 41 and 42 in the oil pump accommodation portion 29 and to further suppress the load caused by the vibration from the oil pump accommodation portion 29 to the first solenoid valve 15 and the second solenoid valve 16.

[0052] Further, in this embodiment, the chain casing 20 includes the connection portion 43 which connects the end portion on the side of the exhaust port 3B in the CD direction of the first solenoid valve attachment portion 23 and the end portion on the side of the intake port 3A in the CD direction of the second solenoid valve attachment portion 24 and the connection portion 43 extends in the EF direction.

[0053] Accordingly, since the connection portion 43 is connected to the end portion on the side of the exhaust port 3B of the first solenoid valve attachment portion 23 and the end portion on the side of the intake port 3A of the second solenoid valve attachment portion 24, it is possible to attenuate the vibration particularly in the AB direction between the first solenoid valve attachment portion 23 and the second solenoid valve attachment portion

24 by the connection portion 43. Thus, it is possible to suppress the vibration of one of the first solenoid valve 15 and the second solenoid valve 16 from acting on the other thereof particularly in the AB direction. Therefore, it is possible to protect the first solenoid valve 15 and the second solenoid valve 16 from the adverse effects caused by the transmission of the vibration.

[0054] Further, in this embodiment, the chain casing 20 includes an oil gallery portion 27 which extends in the CD direction and through which oil flows and a wall portion 21A which is provided at the end portion on the side of the oil pan 5 in the AB direction of the bulging portion 21, extends in the EF direction, and is continuous to the oil pump accommodation portion 29. Then, the first solenoid valve attachment portion 23 and the second solenoid valve attachment portion 24 are arranged between the oil gallery portion 27 and the wall portion 21A in the AB direction.

[0055] Accordingly, it is possible to minimize the distance between the first solenoid valve attachment portion 23 and the second solenoid valve attachment portion 24 and to minimize the distance between the variable valve timing mechanism 11 and the oil gallery portion 27 in the AB direction. Accordingly, it is possible to improve the responsiveness and the control accuracy of the variable valve timing mechanism 11. Further, since it is possible to minimize the length of the oil path from the oil gallery portion 27 to the variable valve timing mechanism 11, it is possible to reduce the amount of oil required to flow to the first solenoid valve attachment portion 23 and the second solenoid valve attachment portion 24 and to reduce the weight of the internal combustion engine 1 and the vehicle.

[0056] While embodiments of this invention have been described, it is apparent that some artisan could have made changes without departing from the scope of this invention. It is intended that any and all such modifications and equivalents are involved in the appended claims.

(DESCRIPTION OF REFERENCE NUMERALS)

[0057] 1 ... Internal combustion engine, 2 ... Cylinder block, 3 ... Cylinder head, 3A ... Intake port, 3B ... Exhaust port, 4 ... Cylinder head cover, 5 ... Oil pan, 10 ... Timing chain, 11 ... Variable valve timing mechanism, 15 ... First solenoid valve, 15A ... Large diameter portion, 15B ... Small diameter portion, 16 ... Second solenoid valve, 16A ... Large diameter portion, 16B ... Small diameter portion, 20 ... Chain casing, 21 ... Bulging portion, 21A ... Wall portion, 23 ... First solenoid valve attachment portion, 23A ... Accommodation hole, 23R ... Axis, 24 ... Second solenoid valve attachment portion, 24A ... Accommodation hole, 24R ... Axis, 27 ... Oil gallery portion, 29 ... Oil pump accommodation portion, 41, 42 ... Cylinder head fastening portion, 41A, 42A ... Fastening hole, 43 ... Connection portion

Claims

1. An internal combustion engine comprising:

a variable valve timing mechanism configured by winding a timing chain thereon;
a solenoid valve controlling hydraulic oil supplied to the variable valve timing mechanism;
a chain casing fixed to a cylinder head to cover the timing chain and the variable valve timing mechanism;
a cylinder head cover connected to the cylinder head;
an oil pan provided on the side opposite to the cylinder head with respect to the chain casing and connected to the cylinder head through a cylinder block;
an intake port provided in the cylinder head and taking air; and
an exhaust port provided on the side opposite to the intake port with respect to the chain casing and discharging an exhaust gas,
wherein a bulging portion covering the variable valve timing mechanism is formed in the chain casing,
wherein the solenoid valve is disposed closer to the oil pan than the bulging portion in the chain casing,
wherein when a direction of the cylinder head cover with respect to the chain casing and a direction of the oil pan are defined as an AB direction, a direction of the intake port with respect to the chain casing and a direction of the exhaust port are defined as a CD direction, and an outward direction and an inward direction of the chain casing with respect to the chain casing are defined as an EF direction, the solenoid valve includes a large diameter portion and a small diameter portion, includes a first solenoid valve, a large diameter portion, and a small diameter portion arranged on the side of the intake port in the CD direction, and includes a second solenoid valve disposed on the side of the exhaust port in the CD direction,
wherein the chain casing includes an oil pump accommodation portion accommodating an oil pump, a first solenoid valve attachment portion including an accommodation hole accommodating at least the small diameter portion of the first solenoid valve and integrally formed with the oil pump accommodation portion, a second solenoid valve attachment portion including an accommodation hole accommodating at least the small diameter portion of the second solenoid valve and integrally formed with the oil pump accommodation portion, and a plurality of cylinder head fastening portions including a fastening hole for fastening the oil pump accommoda-

tion portion to the cylinder head,
 wherein the accommodation hole of the first solenoid valve attachment portion and the accommodation hole of the second solenoid valve attachment portion are arranged on either the side of the intake port or the side of the exhaust port in the CD direction and open to either the side of the intake port or the side of the exhaust port, wherein an axis of the accommodation hole of the first solenoid valve attachment portion and an axis of the accommodation hole of the second solenoid valve attachment portion are arranged at different positions in the EF direction, wherein at least a part of the first solenoid valve attachment portion and the second solenoid valve attachment portion overlaps in the AB direction, and wherein the fastening holes of the adjacent cylinder head fastening portions are formed outside a projection area obtained by projecting the accommodation hole of the first solenoid valve attachment portion toward the fastening hole and outside a projection area obtained by projecting the accommodation hole of the second solenoid valve attachment portion toward the fastening hole.

2. The internal combustion engine according to claim 1,

wherein in the EF direction, an inner end portion of the chain casing of the accommodation hole of the second solenoid valve attachment portion is disposed on the outside of the chain casing in relation to an outer end portion of the chain casing of the accommodation hole of the first solenoid valve attachment portion, and wherein in the CD direction, an end portion on the side of the intake port of the accommodation hole of the second solenoid valve attachment portion is disposed on the side of the exhaust port in relation to an end portion on the side of the exhaust port of the accommodation hole of the first solenoid valve attachment portion.

3. The internal combustion engine according to claim 1 or 2,

wherein the chain casing includes a connection portion connecting an end portion on the side of the exhaust port in the CD direction of the first solenoid valve attachment portion and an end portion on the side of the intake port in the CD direction of the second solenoid valve attachment portion, and wherein the connection portion extends in the EF direction.

4. The internal combustion engine according to any one

of claims 1 to 3,

wherein the chain casing includes an oil gallery portion extending in the CD direction and allowing oil to flow therethrough and a wall portion provided at an end portion on the side of the oil pan in the AB direction of the bulging portion, extending in the EF direction, and continuous to the oil pump accommodation portion, and wherein the first solenoid valve attachment portion and the second solenoid valve attachment portion are arranged between the oil gallery portion and the wall portion in the AB direction.

FIG. 1

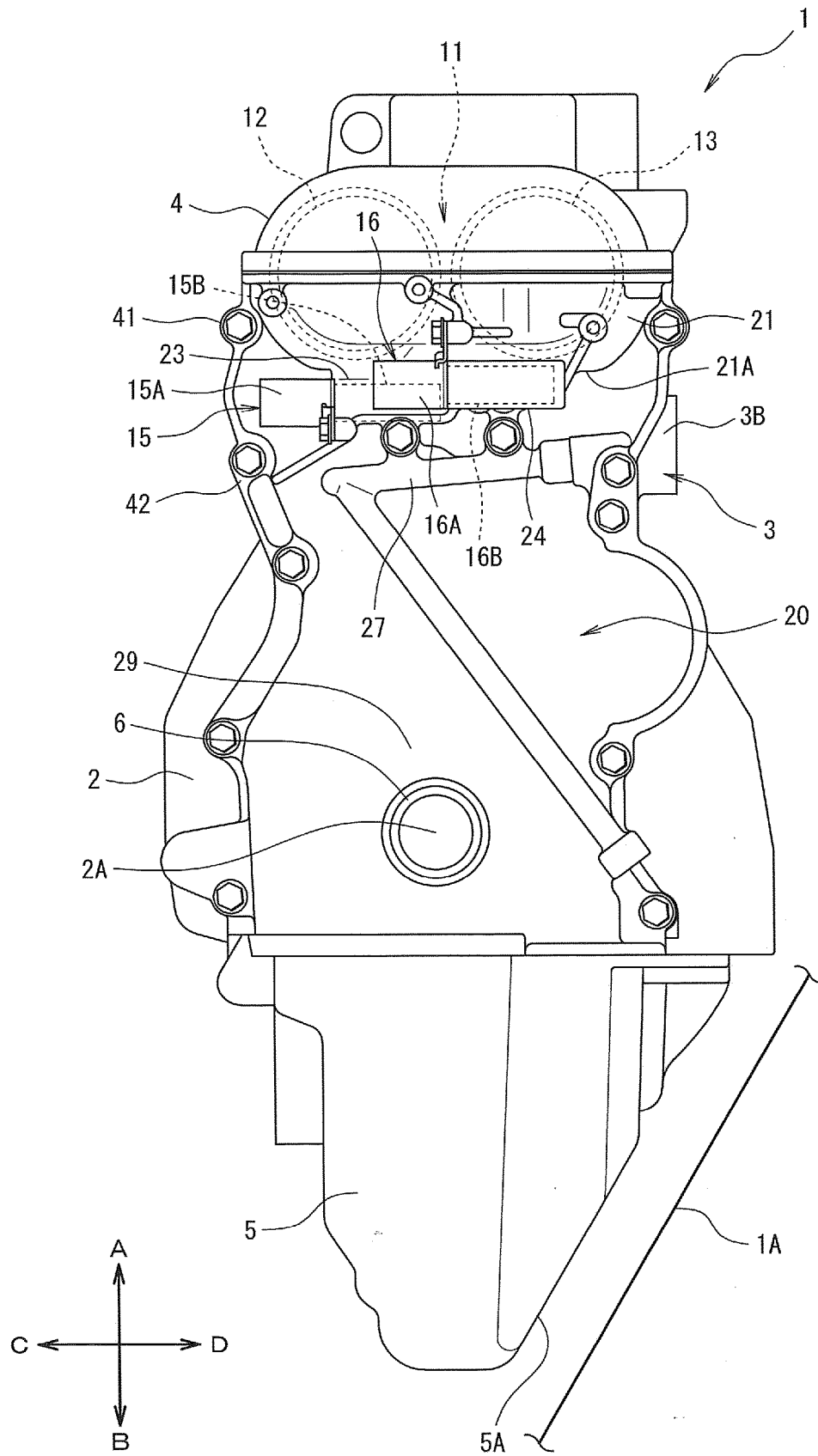


FIG. 2

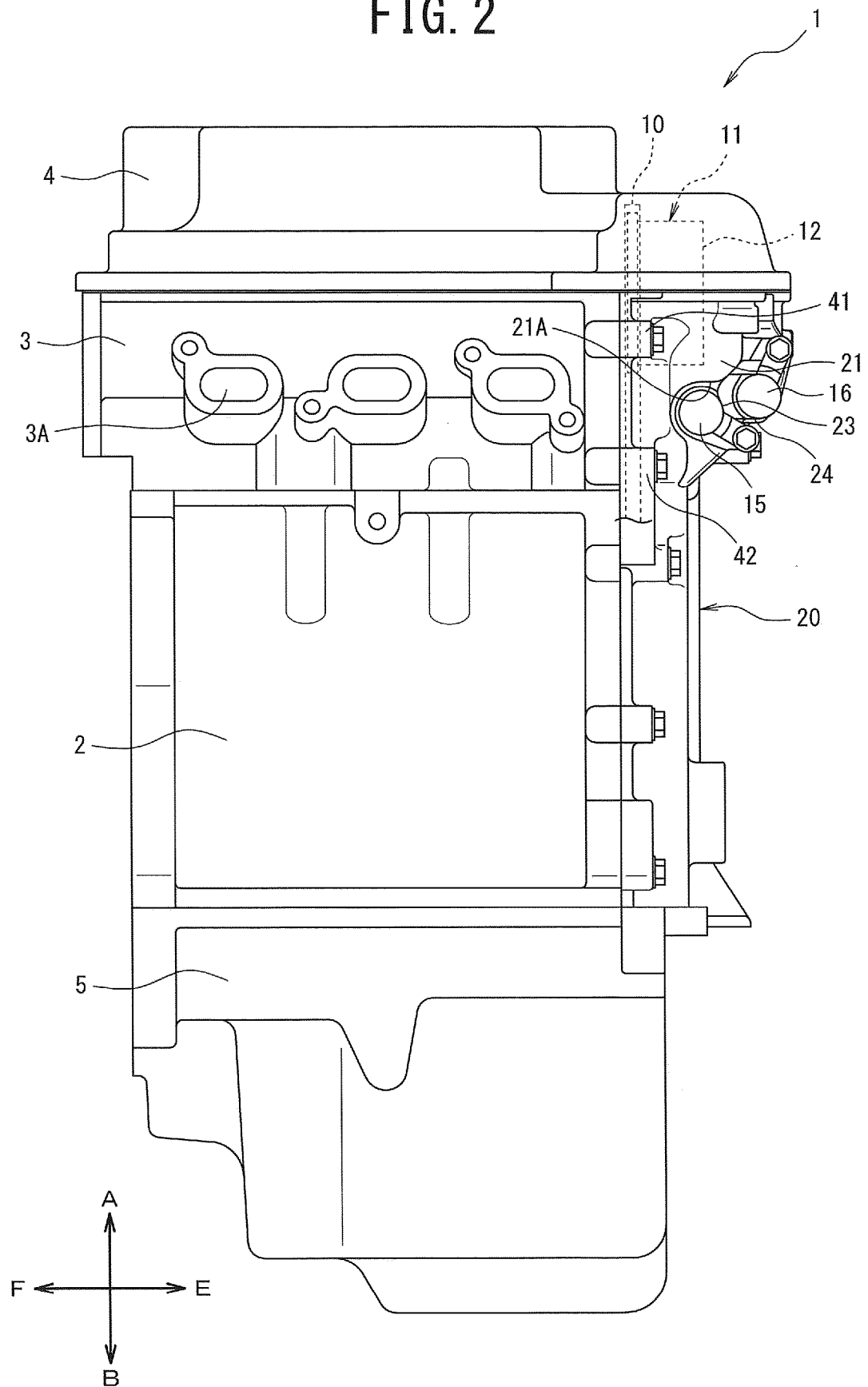


FIG. 3

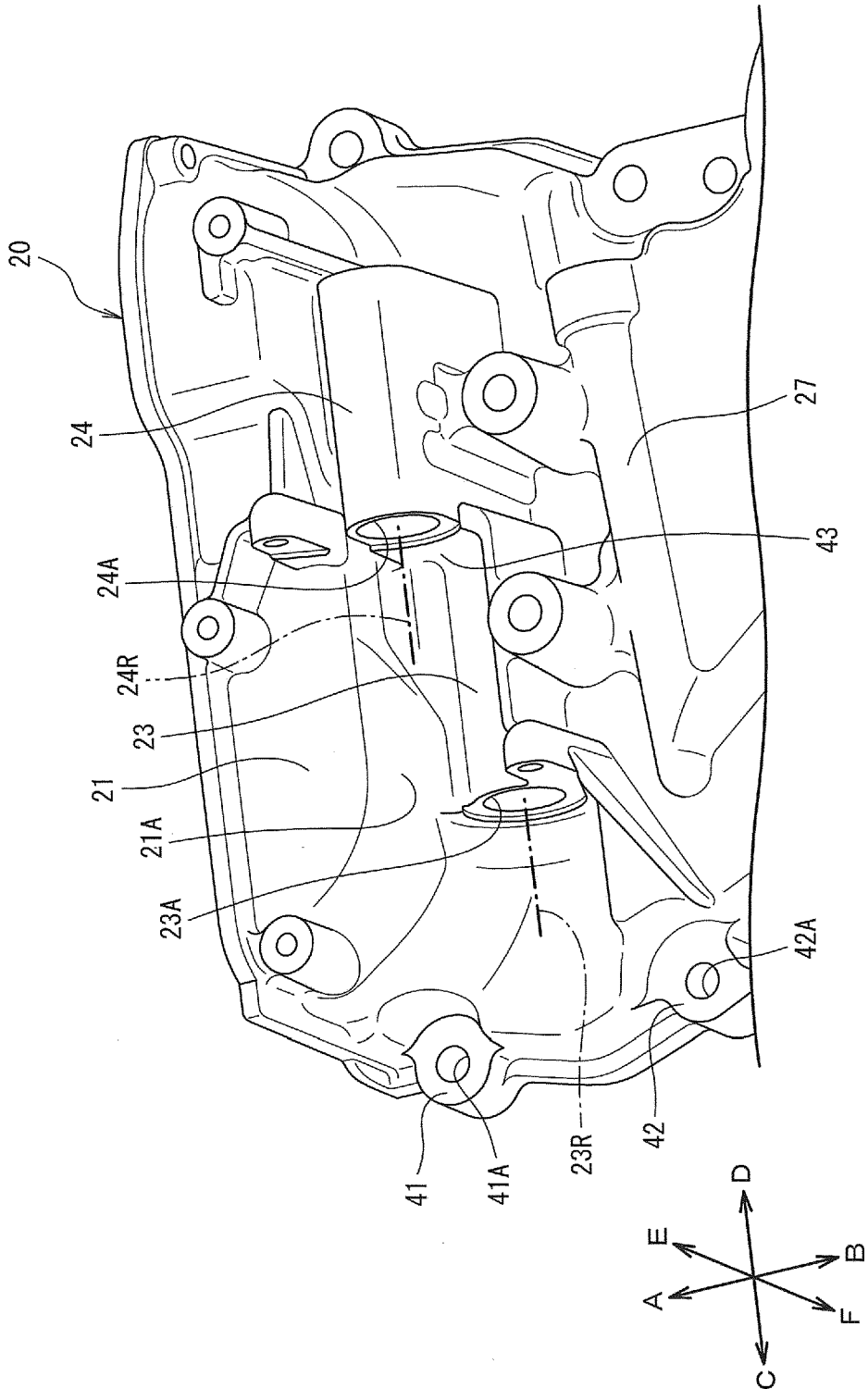


FIG. 4

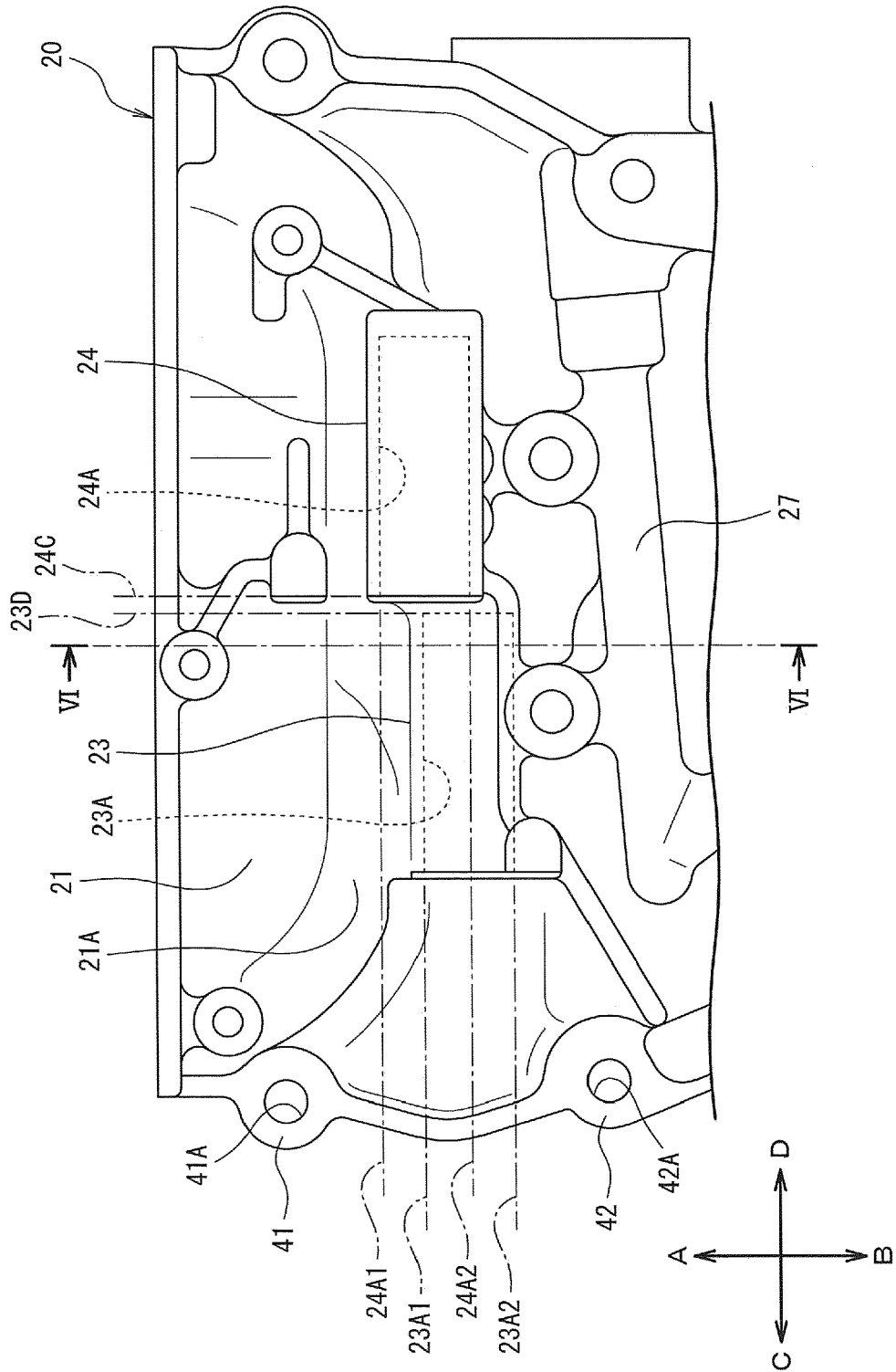


FIG. 5

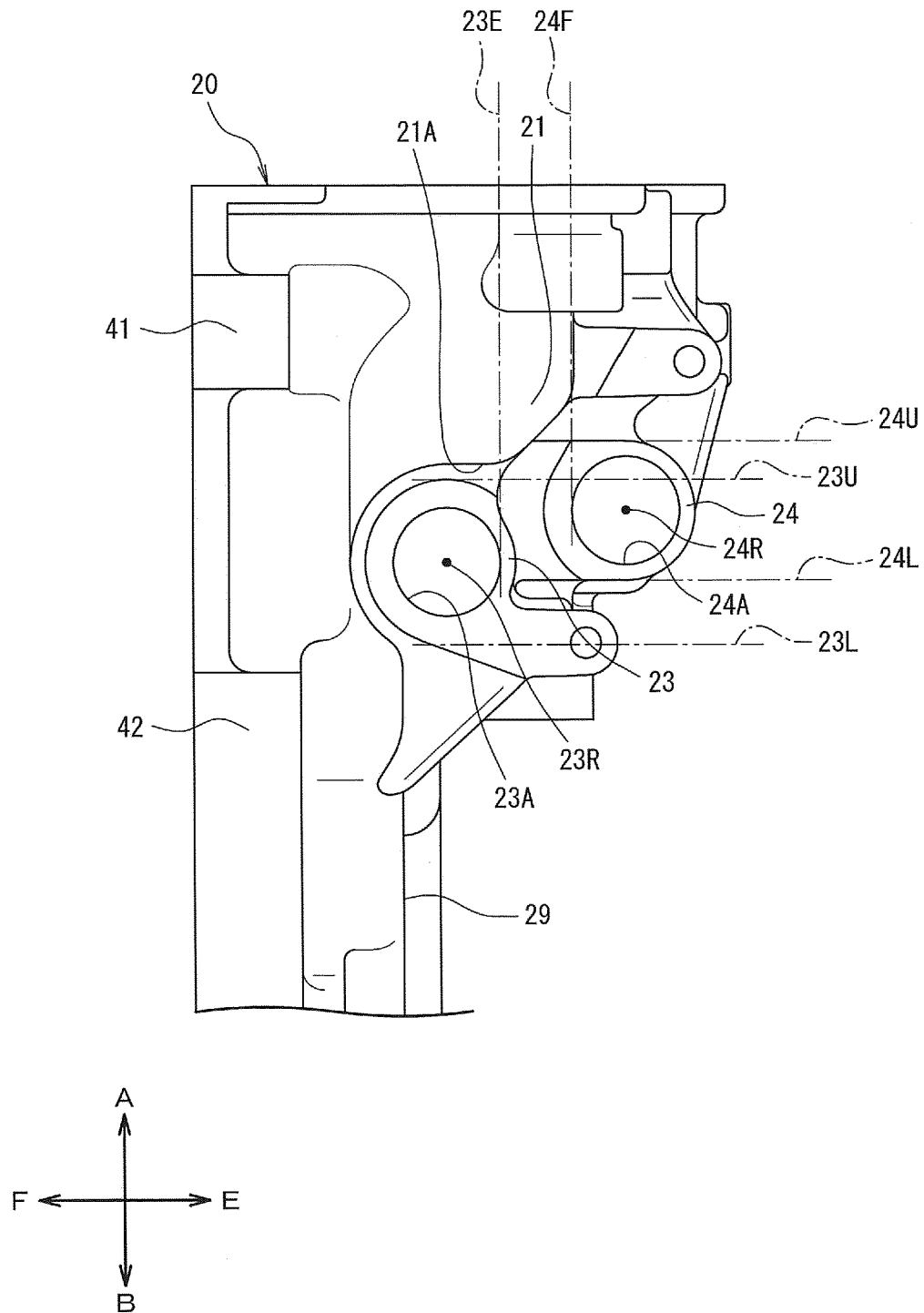
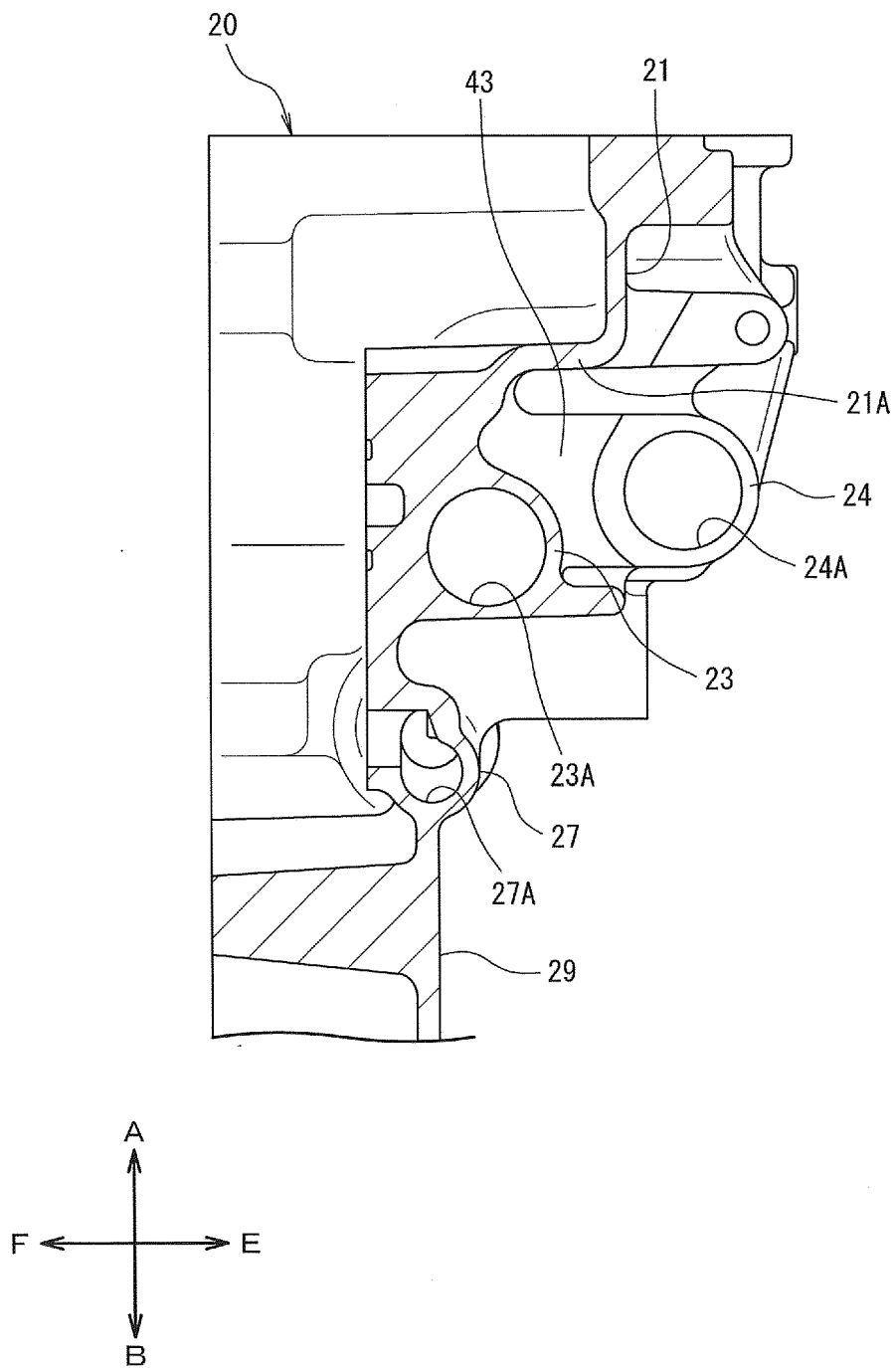


FIG. 6





EUROPEAN SEARCH REPORT

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Place of search The Hague		Date of completion of the search 30 March 2023	Examiner Van der Staay, Frank
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