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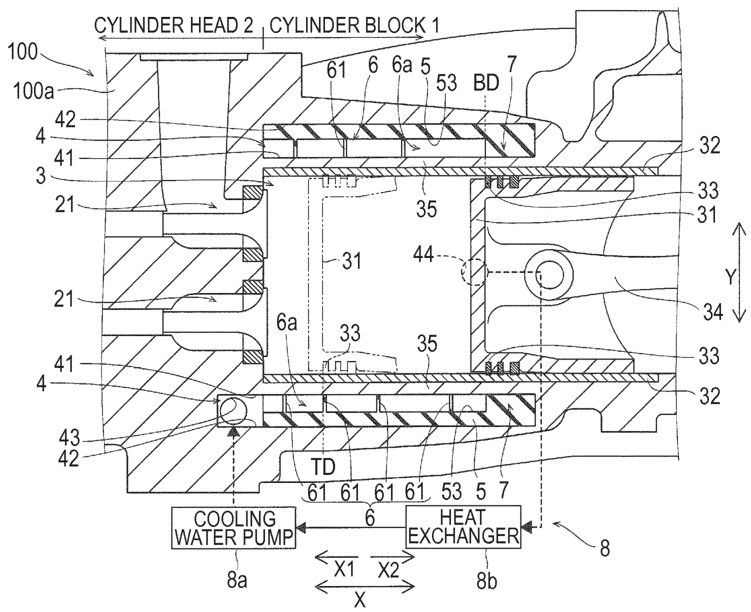
(54) INTERNAL COMBUSTION ENGINE

(57) An internal combustion engine (100, 200) includes: a cylinder (3, 103, 303); a water jacket (4, 104) that is formed so as to surround an outer periphery of the cylinder; and a cooling water guide section (6, 106, 206, 306) that is disposed on an inside of the water jacket and guides cooling water such that the cooling water flows equal to or more than one lap along the outer periphery of the cylinder.

FIG.1

(FIRST EMBODIMENT)



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Description

TECHNICAL FIELD

[0001] This disclosure relates to an internal combustion engine and, particularly, an internal combustion engine including a cylinder and a water jacket.

BACKGROUND DISCUSSION

[0002] In the related art, an internal combustion engine including a cylinder and a water jacket has been known (see for example, JP 2012-202290A (Reference 1)).

[0003] The internal combustion engine having three cylinders arranged in series and the water jacket formed along an outer periphery of the three cylinders is disclosed in Reference 1. The water jacket is formed so as to surround the periphery of the three cylinders which are continuously formed. Cooling water is supplied to an inside of the water jacket, from a supply port on one end side to a discharge port on the other end side in an arrangement direction of the three cylinders. The internal combustion engine described in Reference 1 is provided with a filling member filling a middle lower portion which is formed from an intermediate position to a bottom portion of the water jacket. The cooling water supplied to the water jacket circulates through an upper portion of which a temperature is relatively high and does not circulate through the middle lower portion of which a temperature is relatively low in the cylinder. Thus, uniform temperature distribution of the upper portion and the lower portion of the cylinder is achieved in Reference 1.

[0004] However, in the internal combustion engine described in Reference 1, the uniform temperature distribution of the upper portion and the lower portion of the cylinder can be achieved, whereas temperature distribution of each cylinder in a circumferential direction is not taken into consideration. Thus, there is a problem that temperature unevenness of each cylinder in the circumferential direction cannot be reduced. If the temperature unevenness of the cylinder in the circumferential direction occurs, a difference in thermal expansion in the circumferential direction occurs and thus roundness of the cylinder is deteriorated. As a result, following capability of a piston ring is reduced and oil consumption is likely to increase.

SUMMARY

[0005] Thus, a need exists for an internal combustion engine capable of suppressing temperature unevenness of a cylinder in a circumferential direction.

[0006] An internal combustion engine according to an aspect of this disclosure including: a cylinder; a water jacket that is formed so as to surround an outer periphery of the cylinder; and a cooling water guide section that is disposed on an inside of the water jacket and guides cooling water such that the cooling water flows equal to or more than one lap along the outer periphery of the cylinder.

[0007] The internal combustion engine according to the aspect of this disclosure is provided with the water jacket that is formed so as to surround the outer periphery of the cylinder; and the cooling water guide section that is disposed on the inside of the water jacket and guides the cooling water such that the cooling water flows equal to or more than one lap along the outer periphery of the cylinder. Thus, the cooling water supplied on the inside of the water jacket can circulate equal to or more than one lap in the circumferential direction of the cylinder. Thus, it is possible to perform cooling of the cylinder uniformly over the entire periphery of the cylinder. Therefore, it is possible to suppress temperature unevenness of the cylinder in the circumferential direction by making cooling of the cylinder uniform in the circumferential direction. As a result, since thermal expansion of the cylinder in the circumferential direction is uniform and deterioration in roundness is unlikely to occur, it is possible to achieve suppression of oil consumption.

[0008] In the internal combustion engine according to the aspect described above, it is preferable that the cooling water guide section includes a cooling water guide fin that extends equal to or more than one lap along the outer periphery of the cylinder, and the cooling water guide fin is formed so as to extend along the outer periphery of the cylinder while inclined between a top dead center side and a bottom dead center side of the cylinder. In such a configuration, the cooling water can be circulated between the top dead center and the bottom dead center along the outer periphery of the cylinder in a spiral shape in addition to the circulation of the cooling water over the entire periphery of the cylinder in the circumferential direction. As a result, the temperature unevenness of the cylinder in the circumferential direction is suppressed and it is possible to suppress (temperature distribution is uniform) temperature unevenness of the cylinder in an axial direction.

[0009] In this case, it is preferable that the cooling water guide fin is configured such that the distance between threads of the cooling water guide fin in the axial direction of the cylinder is gradually increased from the top dead center side to the bottom dead center side. In such a configuration, if a flow rate of the cooling water is constant, it is possible to relatively increase a flow velocity and to gradually decrease the flow velocity toward the bottom dead center side by narrowing the distance between the threads of the fin on the top dead center side. That is, it is possible to relatively increase heat transfer on the top dead center side of the cylinder of which the temperature is relatively high and to gradually decrease the heat transfer toward the bottom dead center side of which the temperature is gradually lowered. As a result, it is possible to make the temperature distribution further uniform in the axial direction of the cylinder.

[0010] In the configuration in which the guide fin is formed so as to circulate along the outer periphery of the cylinder while being inclined between the top dead center side and the bottom dead center side of the cylinder, preferably the water jacket has a supply port of the cooling water provided on the top dead center side of the cylinder and a discharge port provided on the bottom dead center side of the cylinder, and the cooling water guide fin is configured so as to guide the cooling water to the discharge port while allowing the cooling water that is supplied from the supply port to flow equal to or more than one lap along the outer periphery of the cylinder. In such a configuration, the top dead center side of which the temperature is relatively high is cooled in advance by the cooling water having a low temperature and the cooling water of which the temperature is increased by flowing through the top dead center side can be circulated on the bottom dead center side of which the temperature is relatively low. Thus, it is possible to make the temperature distribution further uniform in the axial direction of the cylinder. In addition, since the cooling water can be guided by the cooling water guide fin while circulating from the supply port to the discharge port, it is possible to uniformly cool the cylinder in the circumferential direction by only disposing respectively the supply port and the discharge port on the top dead center side and the bottom dead center side. As a result, it is possible to freely set the positions of the supply port and the discharge port in the circumferential direction and thereby it is possible to improve a degree of freedom in design and to simplify a structure of a cooling system (layout).

[0011] In the internal combustion engine according to the aspect described above, it is preferable that the water jacket is provided so as to surround the outer periphery of the single cylinder over the entire periphery. In such a configuration, since the water jacket itself surrounds the outer periphery of the single cylinder, it is possible to easily circulate the cooling water equal to or more than one lap around the periphery of the cylinder by only providing the cooling water guide section on the inside of the water jacket. Furthermore, it is also possible to cool each cylinder individually even in a multi-cylinder internal combustion engine unlike a case where the water jacket is provided to surround a plurality of cylinders together. As a result, it is possible to perform further uniform cooling for each cylinder.

[0012] In this application, the following other configurations are conceivable in addition to the internal combustion engine according to the aspect described above.

Supplementary Articles

[0013] In the internal combustion engine according to another configuration of the present application, the cooling water guide section is integrally formed in a water jacket spacer disposed on the inside of the water jacket. Furthermore, in the internal combustion engine having another configuration, a cooling water shield section is further provided which is disposed in a predetermined portion of the cylinder on the bottom dead center side and is provided so as to fill a space between the outer peripheral surface of the cylinder and the water jacket spacer. In addition, in the internal combustion engine having another configuration, the cooling water guide section is provided separately from the cylinder and is provided so as to come into close contact with the outer peripheral surface of the cylinder. In addition, in the internal combustion engine having another configuration, the cooling water guide section is integrally provided with the cylinder so as to protrude from the outer peripheral surface of the cylinder. In addition, in the internal combustion engine having another configuration, a cylinder block and a cylinder head including the cylinder and the cooling water guide section are integrally formed.

[0014] As described above, in the configuration according to the aspect of this disclosure, it is possible to suppress temperature unevenness of the cylinder in the circumferential direction.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] The foregoing and additional features and characteristics of this disclosure will become more apparent from the following detailed description considered with the reference to the accompanying drawings, wherein:

Fig. 1 is a view illustrating a longitudinal sectional structure around a cylinder block in an engine according to a first embodiment disclosed here;

Fig. 2 is a schematic perspective view for describing a structure of a spacer according to the first embodiment disclosed here;

Fig. 3 is a schematic perspective view for describing the flow of cooling water in a water jacket;

Fig. 4 is a schematic view illustrating a cross sectional structure of a cylinder block in an engine according to a second embodiment disclosed here;

Fig. 5 is a schematic sectional view that is taken along line V-V of Fig. 4;

Fig. 6 is a schematic view illustrating a first modification example of an engine according to the first embodiment disclosed here; and

Fig. 7 is a schematic view illustrating a second modification example of an engine according to the first embodiment disclosed here.

DETAILED DESCRIPTION

[0016] Hereinafter, an embodiment disclosed here will be described with reference to the drawings.

First Embodiment

[0017] A configuration of an engine 100 according to a first embodiment disclosed here will be described with reference to Figs. 1 to 3. Moreover, the engine 100 is an example of the "internal combustion engine" according to this disclosure.

[0018] In the first embodiment, an example in which the embodiment disclosed here is applied to a single-cylinder gas engine used in a cogeneration system is described. In the cogeneration system, an output shaft of the engine 100 is connected to a generator (not illustrated) and power of the engine 100 is used for power generation. Moreover, exhaust heat due to an operation of the engine 100 is recovered and the recovered exhaust heat is supplied to a heat utilization device such as a facility for heating.

[0019] As illustrated in Fig. 1, the engine 100 integrally includes a cylinder block 1 and a cylinder head 2 provided in an upper portion of the cylinder block 1. That is, the engine 100 has a single block structure in which the cylinder block 1 and the cylinder head 2 are integrally formed. A structure 100a configured of the cylinder block 1 and the cylinder head 2 is a cast product made of aluminum alloy that is a light metal.

[0020] The cylinder block 1 is provided with a cylinder 3 in which a piston 31 reciprocates on an inside thereof and a water jacket 4 that is a cooling water passage. A water jacket spacer (hereinafter, referred to as "spacer") 5 is provided in the water jacket 4. In the first embodiment, a cooling water guide section 6 and a cooling water shield section 7 are integrally formed in the spacer 5 disposed on an inside of the water jacket 4. Hereinafter, for the sake of convenience, in an X direction of extension of the cylinder 3, an X1 direction is referred to as an upper side in an axial direction and an X2 direction is referred to as a lower side in the axial direction. Furthermore, a rotation direction of a center axis of the cylinder 3 in the X direction is referred to as "circumferential direction".

[0021] The cylinder head 2 is disposed on an upper side (X1 side) with respect to the cylinder block 1 in the axial direction. Each of ports 21 for intake air and exhaust air, and a part (upper end portion in the axial direction) of the water jacket 4 are provided in the cylinder head 2.

[0022] One cylinder 3 is formed in the cylinder block 1. That is, the engine 100 according to the first embodiment is a single-cylinder engine. The cylinder 3 is formed in a substantially cylindrical shape within the cylinder block 1. The cylinder 3 is disposed such that the axial direction extends transversely in a horizontal direction (X direction). Furthermore, the piston 31 and a cylinder liner 32 that is formed in a cylindrical shape are disposed on an inside of the cylinder 3. The cylinder liner 32 is a dry-type liner adjacent to the water jacket 4 across a bore wall 35.

[0023] A plurality of piston rings 33 are mounted on an outer peripheral surface of the piston 31. The piston 31 is configured so as to reciprocate between a top dead center and a bottom dead center in the X direction within the cylinder 3. Furthermore, a crankshaft (not illustrated) is configured to be continuously rotated through a connecting rod 34 by the reciprocation of the piston 31. The piston 31 reciprocates in the X direction while sliding the piston rings 33 against an inner peripheral surface of the cylinder liner 32. The piston rings 33 maintains airtightness of a combustion chamber and forms an appropriate oil film by scraping excess oil on the inner peripheral surface of the cylinder liner 32. Furthermore, the piston rings 33 also function as contact portions for transmitting heat of the piston 31 to the water jacket 4 through the cylinder liner 32 and the bore wall 35.

[0024] The water jacket 4 is integrally formed with the cylinder block 1 so as to surround the outer periphery of the cylinder 3. The water jacket 4 is provided so as to surround the outer periphery of the single cylinder 3 over the entire periphery. Thus, the water jacket 4 is formed in a substantially cylindrical shape so as to surround the periphery of the cylindrical cylinder 3. The water jacket 4 has a function of maintaining the cylinder block 1 including the cylinder 3 at a constant temperature by circulating the cooling water (coolant) on the inside thereof. The water jacket 4 includes an inner peripheral surface 41 that is the outer peripheral surface of the cylinder 3 and an outer peripheral surface (inner surface of an outer peripheral wall) 42. In the X direction, the water jacket 4 is provided so as to extend further than a position BD of the piston rings 33 in the bottom dead center of the piston 31 on the X2 side and extend further than a position TD of the piston rings 33 in the top dead center of the piston 31 on the X1 side.

[0025] Furthermore, the water jacket 4 has a supply port 43 of the cooling water provided on the top dead center side (X1 side) of the cylinder 3 and a discharge port 44 provided on the bottom dead center side (X2 side) of the cylinder 3. The supply port 43 is disposed further on the X1 side than an upper end portion (end portion on the X1 side) of the cylinder 3 in the axial direction. Furthermore, the discharge port 44 is disposed in a position adjacent to the bottom dead center of the piston 31. Moreover, positions of the supply port 43 and the discharge port 44 in the circumferential direction are arbitrary. The supply port 43 is connected to a cooling water pump 8a and the cooling water is supplied from the supply port 43 to the inside of the water jacket 4. For example, the discharge port 44 is connected to a heat exchanger 8b (condenser, radiator, and the like) and the cooling water within the water jacket 4 is flown to the heat exchanger 8b. The cooling water which is subjected to thermal radiation in the heat exchanger 8b is flown to the cooling water pump 8a through a circulation flow passage. Thus, the water jacket 4 configures a part of a fluid circuit 8 circulating the cooling water.

[0026] The spacer 5 is provided so as to come into close contact with the inner peripheral surface 41 and the outer peripheral surface 42 of the water jacket 4 respectively in the inside of water jacket 4. The spacer 5 is a substantially cylindrical member formed of rubber, resin, and the like, and as illustrated in Fig. 2, is configured of a first member 51 and a second member 52 by being divided into two parts in a vertical direction. The spacer 5 is provided so as to surround the outer periphery of the cylinder 3 over the entire periphery. Moreover, Fig. 2 is a view illustrating a schematic shape (cylindrical shape) of the spacer 5. In practice, each of the ports 21 for intake air and exhaust air or various structures for a spark plug (not illustrated) and the like is provided particularly in the vicinity of an upper end portion of the cylinder 3 in the axial direction, and the spacer 5 is formed into a shape conforming to the structure portions.

[0027] As illustrated in Fig. 1, the cooling water guide section 6 has a function for guiding the flow of the cooling water within the water jacket 4 from the supply port 43 to the discharge port 44. The cooling water guide section 6 is integrally formed on the inner peripheral surface side of the spacer 5. Here, in the first embodiment, the cooling water guide section 6 is configured so as to guide the cooling water flowing equal to or more than one lap along the outer periphery of the cylinder 3. In the first embodiment, as illustrated in Fig. 3, the cooling water guide section 6 is configured such that the cooling water flows a plurality of laps around the outer periphery of the cylinder 3. Moreover, for the sake of convenience, an end surface portion of the spacer 5 is indicated by being hatched in Fig. 3.

[0028] The cooling water guide section 6 includes a guide fin 61 (see Fig. 2) extending along the outer periphery of the cylinder 3. The guide fin 61 extends along the outer periphery (that is, the inner periphery of the spacer 5) of the cylinder 3 over a plurality of laps. As an example, in a schematic view illustrated in Fig. 2, the guide fin 61 is formed so as to circulate around the periphery of the cylinder 3 for approximately four laps. The guide fin 61 is formed so as to be continuous without interruption. Moreover, since the spacer 5 is divided as described above, the guide fin 61 is also divided and is formed in the first member 51 and the second member 52 respectively. Moreover, the guide fin 61 is an example of a "cooling water guide fin" according to the embodiment disclosed here and the cooling water guide fin may also be a shape such that the fin is interrupted in the vicinity of the bottom dead center or a distance between the fin and the outer periphery of the cylinder is gradually increased, and thereby the cooling water is stagnated.

[0029] The guide fin 61 is configured so as to guide the cooling water to the discharge port 44 while allowing the cooling water supplied from the supply port 43 to flow a plurality of laps along the outer periphery of the cylinder 3. That is, the guide fin 61 is formed so as to extend along the outer periphery of the cylinder 3 while being inclined between the top dead center side (supply port 43 side) and the bottom dead center side (discharge port 44 side) of the cylinder 3. Thus, as illustrated in Fig. 3, the guide fin 61 is configured so as to allow the cooling water to flow substantially in a spiral shape along the outer periphery of the cylinder 3. Moreover, "spiral shape" in the present specification is used in a sense widely including a curve that moves in a direction perpendicular to the rotation direction while rotating.

[0030] It is preferable that the guide fin 61 circulates around the outer periphery of the cylinder 3 equal to or more than one lap on the top dead center side of the cylinder 3 and circulates around the outer periphery of the cylinder 3 equal to or more than one lap on the bottom dead center side. Furthermore, as illustrated in Fig. 1, it is preferable that the guide fin 61 circulates around the outer periphery of the cylinder 3 equal to or more than one lap in the position TD of the piston rings 33 in the top dead center of the piston 31 and further on an upper side (X1 side) than the position TD in the axial direction. Thus, particularly, since the cooling water can flow through the vicinity of the top dead center equal to or more than one lap, it is possible to suppress temperature unevenness of the cylinder 3 in the circumferential direction in the vicinity of the top dead center of which the temperature is high.

[0031] Furthermore, the guide fin 61 has a planar shape protruding inward (cylinder 3 side) from an inner surface 53 of the spacer 5 in a radial direction. Then, the guide fin 61 is configured such that a tip end portion (inner end surface) comes into close contact with the inner peripheral surface 41 of the water jacket 4. Thus, in the cooling water guide section 6, the inside of the water jacket 4 is partitioned by the threads of the guide fin 61 adjacent (for example, adjacent between a first lap and a second lap) to each other in the X direction, the inner surface 53 of the spacer 5, and the inner peripheral surface 41 (outer peripheral surface of the cylinder 3) of the water jacket 4, and configures a flow passage 6a for guiding the cooling water. Moreover, as illustrated in Fig. 3, a protrusion amount (that is, a distance Da between the inner surface 53 of the spacer 5 and the outer peripheral surface of the cylinder 3) of the guide fin 61 is constant from an upper end (end portion on the X1 side) in the axial direction to a lower end (end portion on the X2 side) in the axial direction.

[0032] Furthermore, the guide fin 61 is formed such that a distance (fin distance) Db between the threads of the guide fin 61 is greater on the bottom dead center side (X2 side) than that on the top dead center side (X1 side). Particularly, in the first embodiment, the guide fin 61 is configured such that the distance Db between the threads of the guide fin 61 in the axial direction X is gradually and continuously increased from the top dead center side to the bottom dead center side. Specifically, positions of the threads of the guide fin for each half lap from the supply port 43 are positions P0 to P7 on the basis of the end surface position (hatched portion) of the threads of the guide fin 61 in Fig. 3. Then, the fin distance Db of each of the threads of the guide fin 61 adjacent in the X direction is distances D1 to D6 in order from the supply port 43 side (the top dead center side). The threads of the guide fin 61 are formed such that the distances become $D0<D1<D2<D3<D4<D5<D6$. As a result, a flow passage sectional area of the flow passage 6a configured by the cooling water guide section 6 is gradually increased from the top dead center side to the bottom dead center side. As a result, a flow velocity of the cooling water supplied from the supply port 43 is great on the top dead center side and is gradually decreased

on the bottom dead center side.

[0033] The flow passage sectional area of the flow passage 6a is a product (DaxDb) of the distance Da between the inner surface 53 of the spacer 5 and the outer periphery of the cylinder 3 (inner peripheral surface 41 of the water jacket 4) and the fin distance Db (D1 to D6) between the threads of the guide fin 61. Thus, the protrusion amount (distance Da) of the guide fin 61 and the fin distance Db (D1 to D6) in each position are determined depending on the flow passage sectional area required for realizing a desired flow velocity of the cooling water. However, the flow passage sectional area is set so as to be equal to or more than the minimum flow passage sectional area in the entirety of the fluid circuit 8 (see Fig. 1) of the cooling water. Furthermore, a thickness t (see Fig. 2) of the guide fin 61 is at least less than the minimum distance (D1) between the threads of the guide fin 61. The threads of the guide fin 61 are formed such that the thickness t becomes as small as possible while securing mechanical strength.

[0034] As illustrated in Fig. 1, the cooling water shield section 7 is disposed in a predetermined portion of the cylinder 3 on the bottom dead center side and is provided to fill a space between the outer peripheral surface of the cylinder 3 and the spacer 5. Specifically, the cooling water shield section 7 is provided in the position BD of the piston rings 33 in the bottom dead center of the piston 31 in the axial direction (X direction). The cooling water shield section 7 is formed as a thick portion of the spacer 5 and is provided so as to fill the position BD and the space on the X2 side further than the position BD inside the water jacket 4. As a result, the circulation of the cooling water within the water jacket 4 is suppressed by the cooling water shield section 7 in a region equal to or lower than the position BD (position BD and the X2 side further than the position BD). Moreover, since the circulation of the cooling water is prevented in the cooling water shield section 7, the discharge port 44 of the cooling water is disposed above (X1 side) the cooling water shield section 7 in the axial direction.

[0035] Next, a cooling operation of the engine 100 according to the first embodiment will be described with reference to Figs. 1 and 3. Moreover, in Fig. 3, the flow of the cooling water is indicated by arrow CW. In Fig. 3, a size (thickness) of the arrow CW indicates a magnitude of the flow velocity of the cooling water.

[0036] As illustrated in Fig. 1, cooling water CW from the cooling water pump 8a is supplied from the supply port 43 to the inside of the water jacket 4 with the operation of the engine 100. As illustrated in Fig. 3, the cooling water CW introduced from the supply port 43 flows on a lower side (X2 side) on which the spacer 5 is disposed in the axial direction while circulating along the outer peripheral surface 42 of the water jacket 4. Moreover, in this case, some of the cooling water CW also goes around and into an upper end surface (combustion chamber) of the cylinder 3 in the axial direction and fills a portion of the water jacket 4 on the X1 side.

[0037] If the cooling water CW reaches the upper end portion (end portion on the X1 side) of the spacer 5 in the axial direction, the cooling water CW flows into the cooling water guide section 6. Thereafter, the cooling water CW flows through the inside of the flow passage 6a partitioned by the threads of the guide fin 61 adjacent to each other in the X direction and the inner surface 53 of the spacer 5, thereby circulating around the outer periphery of the cylinder 3 in the portion on the top dead center side. The portion of the cylinder 3 on the top dead center side is uniformly cooled in the circumferential direction and temperature distribution in the circumferential direction is made uniform by the circulating cooling water CW. Furthermore, in this case, since the fin distance Db of the guide fin 61 is relatively small on the top dead center side, the flow velocity of the cooling water CW is relatively increased and cooling of a portion of the cylinder 3 of which the temperature is high on the top dead center side is effectively performed.

[0038] The distance of the threads of the guide fin 61 is gradually increased as the cooling water CW flowing in the spiral shape advances on the lower side in the axial direction. As a result, the flow velocity of the cooling water CW is also gradually decreased. Furthermore, the temperature of the cooling water CW is increased as the cooling water CW advances on the lower side in the axial direction. As a result, the bottom dead center side of the cylinder 3 of which the temperature is relatively low is suppressed from being cooled more than necessary and the temperature distribution of the cylinder 3 is made uniform in the axial direction. Moreover, since the cooling water CW also circulates around the outer periphery of the cylinder 3 on the bottom dead center side of the cylinder 3, the temperature distribution is made uniform in the circumferential direction similar to the top dead center side.

[0039] Thereafter, if the cooling water CW reaches the cooling water shield section 7 of a lower end portion of the spacer 5 in the axial direction, the flow on the side in the X2 direction is prevented by the cooling water shield section 7. Then, the cooling water CW is promptly discharged from the discharge port 44. As a result, the temperature distribution is made uniform in the circumferential direction over the entire periphery of the cylinder 3 (temperature unevenness is suppressed). In addition, the cooling water CW is flown in the spiral shape from the supply port 43 to the discharge port 44 and thereby the temperature distribution of the cylinder 3 in the axial direction is also uniform. In the first embodiment, the cooling operation of the engine 100 is performed as described above.

[0040] In the first embodiment, it is possible to obtain the following effects.

[0041] In the first embodiment, as described above, the water jacket 4 that is formed so as to surround the outer periphery of the cylinder 3 and the cooling water guide section 6 that is disposed on the inside of the water jacket 4 and guides the cooling water such that the cooling water flows equal to or more than one lap along the outer periphery of the cylinder 3 are provided. Thus, the cooling water can circulate equal to or more than one lap in the circumferential direction of the cylinder 3. Thus, it is possible to perform cooling of the cylinder 3 uniformly over the entire periphery of the cylinder 3. Therefore, it is possible to suppress temperature unevenness of the cylinder 3 in the circumferential direction by making cooling of the cylinder 3 uniform in the circumferential direction. As a result, since thermal expansion of the cylinder 3 in the circumferential direction is uniform and deterioration in roundness is unlikely to occur, it is possible to achieve suppression of oil consumption.

[0042] Furthermore, in the first embodiment, as described above, the guide fin 61 extending equal to or more than one lap along the outer periphery of the cylinder 3 is provided. Then, the guide fin 61 is formed so as to extend along the outer periphery of the cylinder 3 while being inclined between the top dead center side and the bottom dead center side of the cylinder 3. Thus, the cooling water can circulate in the spiral shape between the top dead center side and the bottom dead center side along the outer periphery of the cylinder 3. As a result, temperature unevenness of the cylinder 3 in the circumferential direction is suppressed and it is possible to suppress temperature unevenness of the cylinder 3 in the axial direction.

[0043] Furthermore, in the first embodiment, as described above, the guide fin 61 is configured such that the distance Db between the threads of the guide fin 61 in the axial direction of the cylinder 3 is gradually increased from the top dead center side to the bottom dead center side. Thus, if a flow rate of the cooling water is constant, it is possible to relatively increase the flow velocity as the fin distance is narrowed on the top dead center side and to gradually decrease the flow velocity toward the bottom dead center side. As a result, it is possible to make the temperature further uniform in the axial direction of the cylinder 3.

[0044] Furthermore, in the first embodiment, as described above, the supply port 43 is provided on the top dead center side of the cylinder 3 and the discharge port 44 is provided on the bottom dead center side of the cylinder 3. Then, the guide fin 61 is configured so as to guide the cooling water supplied from the supply port 43 to the discharge port 44 while allowing the cooling water to flow equal to or more than one lap along the outer periphery of the cylinder 3. Thus, the top dead center side of which the temperature is relatively high is cooled in advance by the cooling water having a low temperature and the cooling water of which the temperature is increased by flowing through the top dead center side can be circulated on the bottom dead center side of which the temperature is relatively low. As a result, it is possible to make the temperature further uniform in the axial direction of the cylinder 3. In addition, since the cooling water can be guided by the guide fin 61 while circulating from the supply port 43 to the discharge port 44, it is possible to uniformly cool the cylinder 3 in the circumferential direction by only disposing respectively the supply port 43 and the discharge port 44 on the top dead center side and the bottom dead center side. As a result, it is possible to freely set the positions of the supply port 43 and the discharge port 44 in the circumferential direction and thereby it is possible to improve the degree of freedom in design and to simplify the structure of the cooling system (layout).

[0045] Furthermore, in the first embodiment, as described above, the water jacket 4 is provided to surround the outer periphery of the single cylinder 3 over the entire periphery. Thus, since the water jacket 4 itself surrounds the cylinder 3, it is possible to easily circulate the cooling water equal to or more than one lap in the periphery of the cylinder 3 by only providing the cooling water guide section 6 on the inside of the water jacket 4.

Second Embodiment

[0046] Next, a second embodiment will be described with reference to Figs. 4 and 5. In the second embodiment, an example in which the embodiment disclosed here is applied to a multi-cylinder engine 200, for example, for an automobile is described different from the first embodiment described above in which the embodiment disclosed here is applied to the single-cylinder engine 100 that is used for the cogeneration system. Moreover, the engine 200 is an example of "internal combustion engine" according to this disclosure here.

[0047] As illustrated in Fig. 4, the engine 200 according to the second embodiment is a series four-cylinder gasoline engine. Four cylinders 103 are linearly arranged in a cylinder block 101 of the engine 200 in a direction (Y direction) of extension of a crankshaft.

[0048] A water jacket 104 in the second embodiment is integrally formed in the cylinder block 101 so as to surround the outer peripheries of the four cylinders 103 respectively. That is, the water jacket 104 is provided so as to surround the outer periphery of the single cylinder 103 over an entire periphery. Thus, a passage section 132 (see Fig. 5) passing through a wall section 131 of the cylinder 103 in the circumferential direction is formed in the wall section 131 between each of the cylinders 103. Furthermore, the water jacket 104 has a supply port 143 and a discharge port 144 respectively for each of the four cylinders 103.

[0049] Furthermore, similar to the first embodiment, a cooling water guide section 106 is integrally formed in a spacer 105. As illustrated in Fig. 5, the spacer 105 is also disposed on an inside of the passage section 132 and a plurality (four) of spacers 105 are provided so as to surround an outer periphery of each of the cylinders 103 over an entire periphery. Thus, as illustrated in Fig. 4, for example, the spacer 105 is divided into three and is configured of a first member 151 and a second member 152 surrounding the outer periphery of the cylinder 103, except for the passage section 132, and a third member

153 inserted into the passage section 132. In this case, the third member 153 inserted into the passage section 132 is common between adjacent cylinders 103, the first member 151 and the second member 152 are provided for each cylinder 103.

[0050] As illustrated in Fig. 5, the cooling water guide section 106 includes a guide fin 161 and guides the cooling water so as to allow the cooling water to flow equal to or more than one lap along the outer periphery of the cylinder 103. Moreover, the guide fin 161 is an example of "cooling water guide fin" according to the embodiment disclosed here.

[0051] The threads of the guide fin 161 are formed on both sides of the third member 153 in a portion in which the threads of the guide fin 161 are disposed within the passage section 132 in the cooling water guide sections 106. That is, the third member 153 of the spacer 105 is disposed at a center within the passage section 132 in the radial direction (Y direction) and the threads of the guide fin 161 are formed in the third member 153 so as to extrude toward both outside (toward each of adjacent cylinders 103) in the radial direction. A fin portion 161 a of the guide fin 161 formed in the third member 153 on a Y1 side configures a part of the cooling water guide section 106 provided in the cylinder 103 on the Y1 side. A fin portion 161 b on a Y2 side configures a part of the cooling water guide section 106 provided in the cylinder 103 (adjacent cylinder) on the Y2 side. Moreover, the shape of the guide fin 161 is similar to that of the first embodiment described above. Thus, also in the second embodiment, similar to the first embodiment described above, the guide fin 161 is configured such that a fin distance Db between the threads of the guide fin 161 in the axial direction is gradually increased from the top dead center side (X1 side) to the bottom dead center side (X2 side).

[0052] According to such a configuration, in the engine 200 of the second embodiment, the water jacket 104 surrounding the outer periphery of the cylinder 103 over the entire periphery with respect to the four cylinders 103 and the cooling water guide section 106 are provided. Then, the cooling water is supplied from four supply ports 143 to the inside of each water jacket 104 and is guided so as to flow equal to or more than one lap along the outer periphery of each cylinder 103 by the cooling water guide section 106. Moreover, as illustrated in Fig. 4, if the water jacket 104 is formed so as to surround the entire periphery of the cylinder 103, the water jackets 104 themselves may be connected to each other or may be individually provided for each cylinder 103. If the water jackets 104 are connected to each other, a flow passage 6a may be partitioned for each cylinder 103 by the spacer 105 (the cooling water guide section 106) disposed on the inside of the water jacket 104.

[0053] Furthermore, the flow passage 6a configured of the cooling water guide section 106 may be partially connected to the adjacent flow passage 6a within the water jacket 104. In the cooling water guide section 106, the flow may be formed equal to or more than one lap along the outer periphery of each cylinder 103 or may be partially coupled with the flow of the cooling water of the adjacent cylinder 103.

[0054] Moreover, other configurations of the engine 200 according to the second embodiment are similar to those of the first embodiment described above.

[0055] Even if a plurality of cylinders 103 are provided as the second embodiment, it is possible to obtain the same effects as those of the first embodiment described above. That is, in the second embodiment, the cooling water supplied to the inside of the water jacket 104 can be circulated at least one lap of each cylinder 103 in the circumferential direction. Thus, it is possible to perform uniform cooling over the entire periphery of each cylinder 103. Therefore, it is possible to suppress temperature unevenness of each cylinder 103 by uniform cooling of the cylinder 103 in the circumferential direction. As a result, for each of the plurality of cylinders 103, since thermal expansion in the circumferential direction is uniform and deterioration in roundness is unlikely to occur, it is possible to achieve suppression of oil consumption.

[0056] Furthermore, in the second embodiment, the water jacket 104 is provided so as to surround the outer periphery of the single cylinder 103 over the entire periphery. Thus, it is also possible to cool each cylinder 103 individually even in the multi-cylinder engine 200 unlike a case where the water jacket is provided to surround a plurality of cylinders together. As a result, it is possible to perform further uniform cooling for each cylinder 103.

[0057] Other effects of the second embodiment are the same as those of the first embodiment described above.

[0058] Moreover, it has to be considered that the embodiments disclosed here are examples and not intended to be limited in all respects. The scope of this disclosure is indicated by the appended claims rather than the description of the embodiments described above and includes all modifications (modification examples) within the meaning and the scope equivalent to the appended claims.

[0059] For example, in the first embodiment described above, the single-cylinder engine 100 having one cylinder 3 is illustrated and in the second embodiment described above, the multi-cylinder (four cylinders) engine 200 having four cylinders 103 is illustrated, but this disclosure is not limited to the embodiments. In this disclosure, the engine may be an engine having two, three, or five or more cylinders in addition to the single-cylinder and the four cylinders.

[0060] In addition, in the first embodiment described above, an example in which the cylinder block 1 and the cylinder head 2 are integrally formed in the structure 100a is illustrated, but this disclosure is not limited to the embodiment. In this disclosure, the cylinder block 1 and the cylinder head 2 may be separately provided. In this case, the water jacket may be an open deck structure in which the water jacket is open to the upper end surface (coupling surface with the cylinder head) of the cylinder block in the axial direction or may be a closed deck structure in which the water jacket is not open. However, if the cylinder block and the cylinder head are provided separately, it is necessary to firmly coupling the cylinder block and the cylinder head by interposing a gasket (sealing member) in the coupling surface. Thus, normally, since thick flange sections are provided on the periphery of the coupling surface of the cylinder block and the cylinder head and it is necessary to firmly couple the flange sections each other, cooling performance in the vicinity of the coupling surface is reduced. If the cylinder block and the cylinder head are integrally formed, since the gasket or the flange section is not required to be provided, it is possible to improve the cooling performance in the vicinity of a boundary between the cylinder block and the cylinder head.

[0061] Furthermore, in the first embodiment and the second embodiment described above, examples in which the dry-type cylinder liner 32 adjacent to the water jacket 4 across the bore wall 35 is provided are illustrated, but this disclosure is not limited to the embodiments. In this disclosure, a wet-type cylinder liner may be provided.

[0062] Furthermore, in the first embodiment and the second embodiment described above, examples in which the cooling water guide section 6 guides the cooling water so as to allow the cooling water to flow a plurality of laps along the outer periphery of the cylinder 3 are illustrated, but this disclosure is not limited to the embodiments. In this disclosure, the cooling water guide section may guide the cooling water so as to allow the cooling water to flow equal to or more than one lap along the outer periphery of the cylinder. That is, the number of laps of the cooling water may be any laps equal to or more than one lap. Furthermore, the number of laps of the cooling water may be one lap and a half.

[0063] Furthermore, in the first embodiment and the second embodiment described above, examples in which the planar guide fin 61 is provided in the cooling water guide section 6 are illustrated, but this disclosure is not limited to the embodiments. For example, as the cooling water guide section, a concave portion recessed in a semicircular shape to the inside in the radial direction is formed in the water jacket spacer, a flow passage partitioned by the concave portion and the outer peripheral surface (inner peripheral surface of the water jacket) of the cylinder may be formed.

[0064] Furthermore, in the first embodiment described above, an example in which the fin distance Db is continuously changed such that the fin distance Db is gradually increased from the top dead center side to the bottom dead center side is illustrated, but this disclosure is not limited to the embodiment. In this disclosure, the fin distance Db may be discontinuously changed stepwise.

[0065] Furthermore, in the first embodiment and the second embodiment described above, examples in which the distance Da between the inner surface 53 of the spacer 5 and the outer peripheral surface of the cylinder 3 is constant are illustrated, but this disclosure is not limited to the embodiments. In this disclosure, the distance Da between the inner surface 53 of the spacer 5 and the outer peripheral surface of the cylinder 3 may be changed depending on the position in the axial direction.

[0066] For example, as a first modification example illustrated in Fig. 6, a distance Da between an inner surface 53 of a spacer 205 and an outer peripheral surface of a cylinder 3 may be configured so as to gradually increase from the top dead center side (X1 side) to the bottom dead center side (X2 side). In a cooling water guide section 206 of the first modification example, the distance Da is configured so as to gradually increase from the top dead center side to the bottom dead center side by gradually decreasing a thickness of the spacer 205 toward the bottom dead center side in the radial direction. As a result, it is possible to obtain the same effects as those in the first embodiment and the second embodiment described above in which the fin distance Db between the threads of the guide fin 61 is gradually increased from the top dead center side to the bottom dead center side. That is, since a flow passage sectional area (Da×Db) of a flow passage 6a is gradually increased toward the bottom dead center side, it is possible to gradually decrease the flow velocity of the cooling water toward the bottom dead center side.

[0067] Moreover, both a configuration in which the distance Da is charged depending on the position in the axial direction as the first modification example and a configuration in which the fin distance Db is changed depending on the position in the axial direction as the first embodiment and the second embodiment described above may be applied to the cooling water guide section. That is, the distance Da between the inner surface 53 of the spacer 5 and the outer peripheral surface of the cylinder 3 is gradually increased toward the bottom dead center side (X2 side) and the fin distance Db between the threads of the guide fin 61 may be gradually increased toward the bottom dead center side. According to such a configuration, it is possible to further greatly change the flow velocity of the cooling water between the top dead center side and the bottom dead center side. As a result, it is possible to increase the degree of freedom in design in order to optimize the flow velocity of the cooling water depending on the position of the cylinder in the axial direction.

[0068] Furthermore, in the first embodiment and the second embodiment described above, examples in which the cooling water guide section 6 is integrally formed in the spacer 5 are illustrated, but this disclosure is not limited to the embodiments. In this disclosure, as a second modification example illustrated in Fig. 7, a cooling water guide section 306 may be integrally formed with a cylinder 303. In the second modification example, a guide fin 361 of the cooling water guide section 306 is integrally provided with the cylinder 303 so as to protrude from an outer peripheral surface (bore wall 35) of the cylinder 303. On the other hand, in a spacer 305, the guide fin is not provided. The guide fin 361 is configured such that a tip end portion comes into close contact with an inner surface 53 of the spacer 305. Thus, a flow passage 6a that is partitioned by upper and lower parts of the guide fin 361 in the axial direction, the inner surface 53 of the spacer 305 and an inner peripheral surface 41 of a water jacket 4 is configured in the cooling water guide section 306. Moreover, the guide fin 361 is an example of "cooling water guide fin" of this disclosure. Even in such a configuration, it is possible to obtain the same effects as those of the first embodiment and the second embodiment described above. In addition, in this disclosure, the cooling water guide section may be formed separately from the water jacket spacer.

[0069] The principles, preferred embodiment and mode of operation of the present invention have been described in the foregoing specification. However, the invention which is intended to be protected is not to be construed as limited to the particular embodiments disclosed. Further, the embodiments described herein are to be regarded as illustrative rather than restrictive. Variations and changes may be made by others, and equivalents employed, without departing from the spirit of the present invention. Accordingly, it is expressly intended that all such variations, changes and equivalents which fall within the spirit and scope of the present invention as defined in the claims, be embraced thereby.

Claims

1. An internal combustion engine (100, 200) comprising:

a cylinder (3, 103, 303);
a water jacket (4, 104) that is formed so as to surround an outer periphery of the cylinder; and
a cooling water guide section (6, 106, 206, 306) that is disposed on an inside of the water jacket and guides cooling water such that the cooling water flows equal to or more than one lap along the outer periphery of the cylinder.

2. The internal combustion engine according to claim 1, wherein the cooling water guide section includes a cooling water guide fin (61, 161, 361) that extends equal to or more than one lap along the outer periphery of the cylinder, and
wherein the cooling water guide fin is formed so as to extend along the outer periphery of the cylinder while inclined between a top dead center side and a bottom dead center side of the cylinder.

3. The internal combustion engine according to claim 2, wherein the cooling water guide fin is configured such that a distance between threads of the cooling water guide fin in an axial direction of the cylinder is gradually increased from the top dead center side to the bottom dead center side.

4. The internal combustion engine according to claim 2 or 3,
wherein the water jacket has a supply port (43, 143) of the cooling water provided on the top dead center side of the cylinder and a discharge port (44, 144) provided on the bottom dead center side of the cylinder, and
wherein the cooling water guide fin is configured so as to guide the cooling water to the discharge port while allowing the cooling water that is supplied from the supply port to flow equal to or more than one lap along the outer periphery of the cylinder.

5. The internal combustion engine according to any one of claims 1 to 4,
wherein the water jacket is provided so as to surround the outer periphery of the single cylinder over the entire periphery.

FIG.1

(FIRST EMBODIMENT)

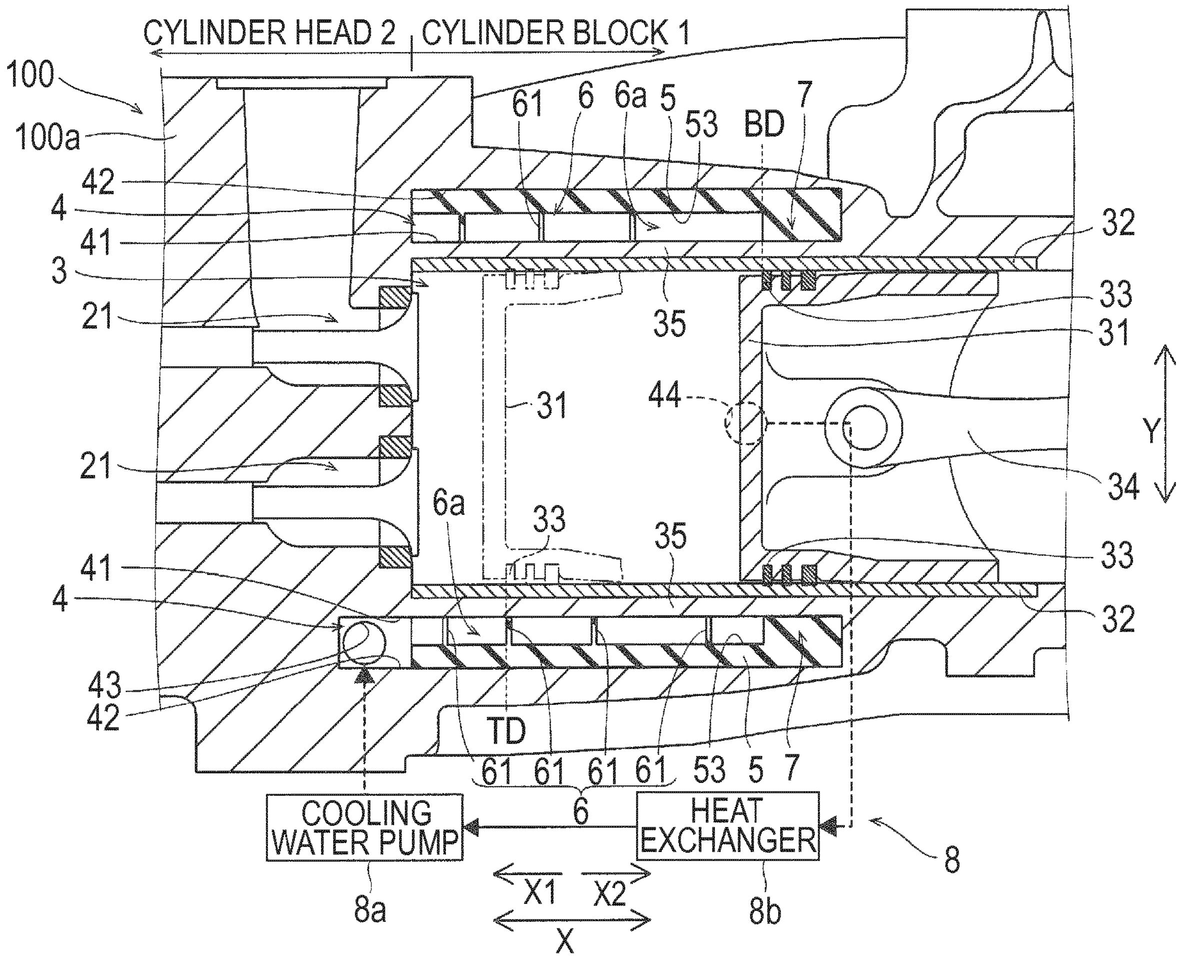


FIG.2

(FIRST EMBODIMENT)

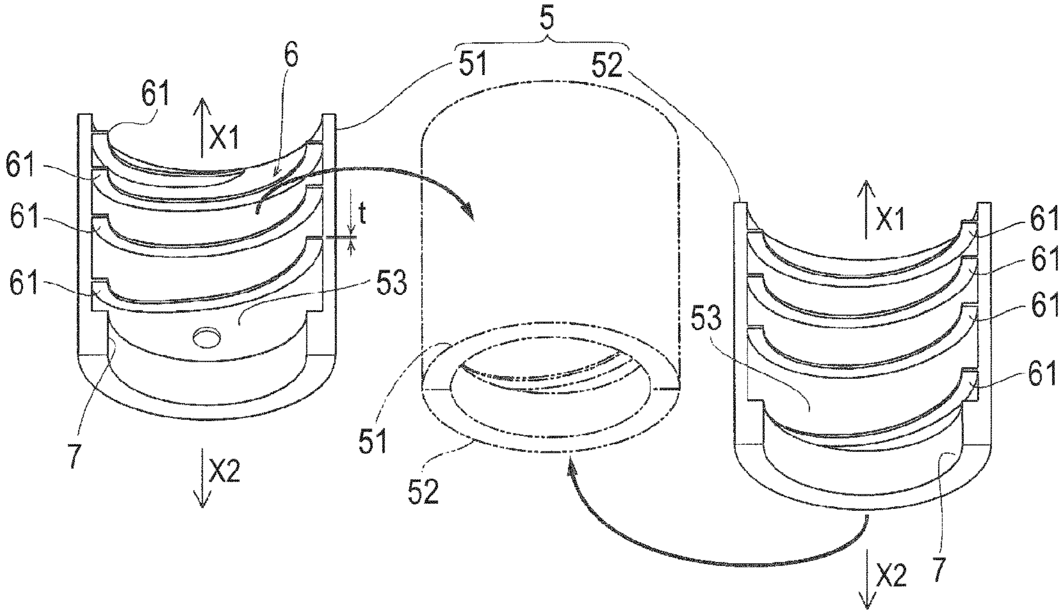


FIG.3

(FIRST EMBODIMENT)

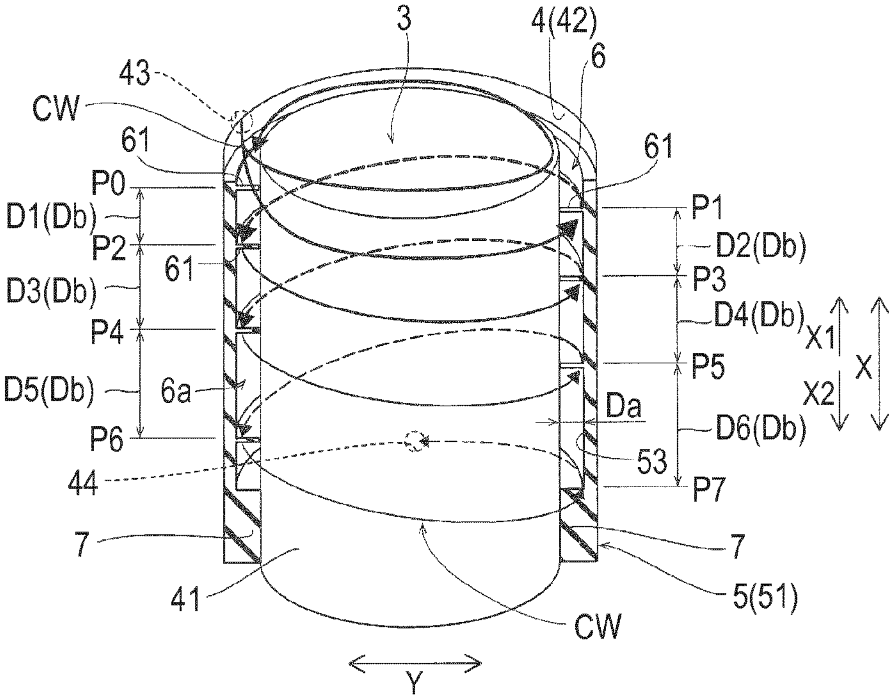


FIG.4

(SECOND EMBODIMENT)

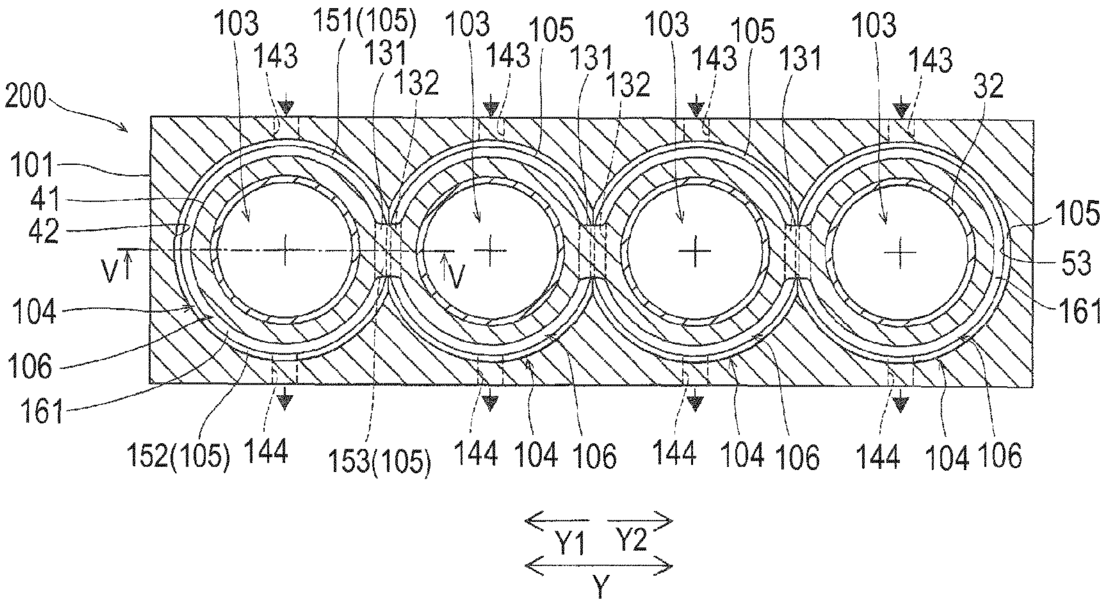


FIG.5

(SECOND EMBODIMENT)

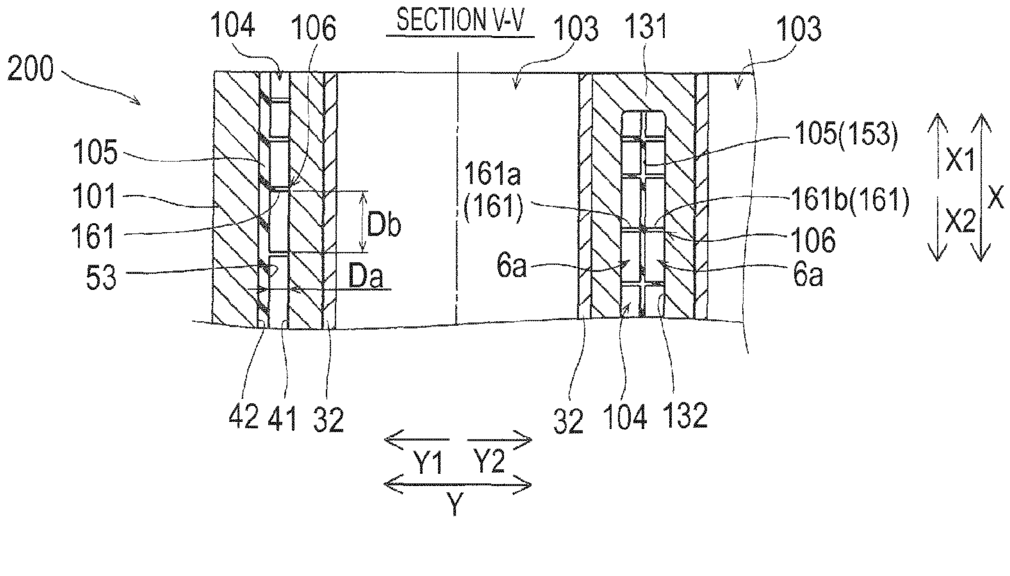


FIG.6

(FIRST MODIFICATION EXAMPLE)

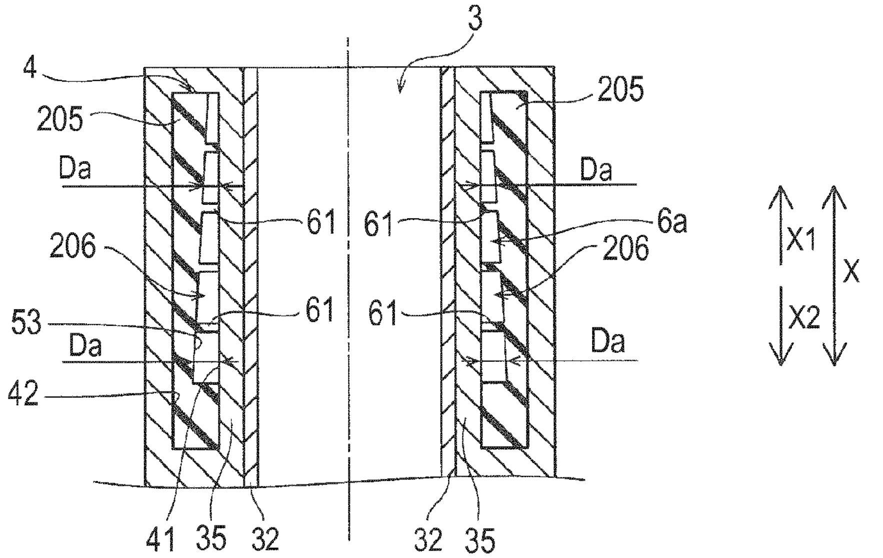
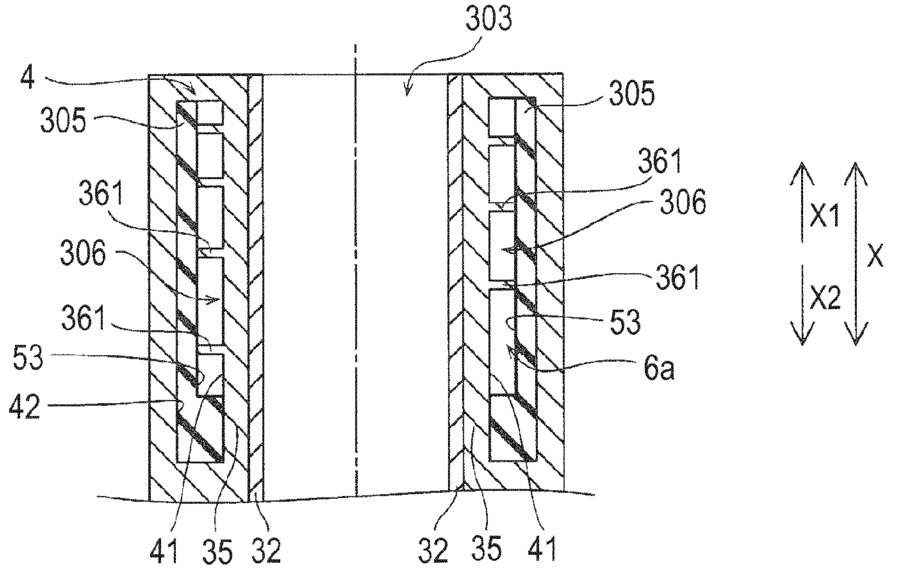


FIG.7

(SECOND MODIFICATION EXAMPLE)



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EUROPEAN SEARCH REPORT

Application Number
EP 15 17 3376

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	21 October 2015	Schwaller, Vincent

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