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(54) COOLING STRUCTURE FOR CYLINDER BLOCK AND SWASH PLATE-TYPE HYDRAULIC DEVICE EQUIPPED WITH SAME

(57) The present invention provides a cooling structure of a cylinder block, the cooling structure being capable of improving a cooling performance of sliding surfaces. A cylinder block 12 includes a plurality of cylinders 20, and pistons 13 are respectively inserted into the cylinders 20 through openings. Each of the pistons 13 performs reciprocating sliding on a sliding surface 12b which defines the cylinder 20. A plurality of cooling depressions 31 are formed on an outer peripheral surface 12a of the cylinder block 12. Each of the cooling depressions 31 extends from a front end surface of the cylinder block 12 on a dividing wall 32 located between the two adjacent cylinders 20 and is formed by reducing the thickness of the dividing wall 32 so as to reduce a thickness t of a portion between the sliding surface 12b and the outer peripheral surface 12a.

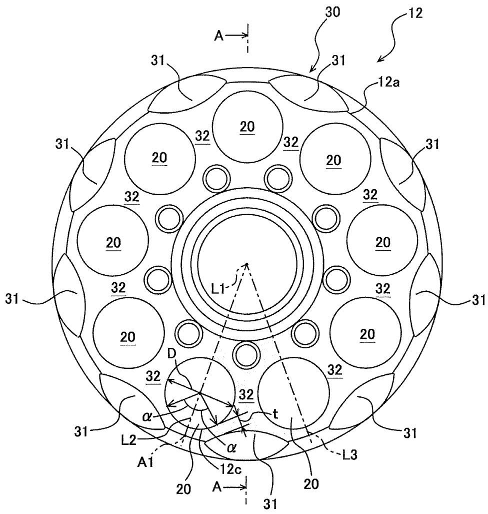

Fig. 2

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Description

Technical Field

[0001] The present invention relates to a cooling structure of a cylinder block, such as a cylinder block of a swash plate type liquid-pressure apparatus, configured such that: a plurality of cylinders are formed on the cylinder block; pistons can be respectively inserted through openings of the cylinders, the openings being formed on a piston insertion end surface of the cylinder block; and the inserted pistons perform reciprocating sliding in the cylinders when the cylinder block is rotated.

Background Art

[0002] Various oil-pressure motors and oil-pressure pumps are used in industrial machinery, such as construction machinery. As one example of the oil-pressure motors and oil-pressure pumps, a swash plate type oil-pressure motor/pump (hereinafter may be referred to as a "swash plate type oil-pressure apparatus") as in PTL 1 is known. The swash plate type oil-pressure apparatus of PTL 1 includes a rotating shaft, and a cylinder block is integrally attached to the rotating shaft. Cylinders are formed on an end surface of the cylinder block so as to be arranged at regular intervals in a circumferential direction, and pistons are respectively inserted into the cylinders. Shoes are respectively attached to end portions of the pistons, the end portions projecting from the cylinders. The shoes are arranged on a supporting surface of a swash plate provided to be inclined.

[0003] In the swash plate type oil-pressure apparatus configured as above, the cylinder block is rotated by the reciprocating movements of the pistons in the cylinders. By supplying high-pressure operating oil to the cylinders, the pistons perform the reciprocating movements, and this rotates the cylinder block. Thus, the rotating shaft formed integrally with the cylinder block is rotated by the rotation of the cylinder block. To be specific, the swash plate type oil-pressure apparatus serves as the oil-pressure motor. In addition, in the swash plate type oil-pressure apparatus, by rotating the cylinder block, the pistons perform the reciprocating movements in the cylinders. By rotating the cylinder block by the rotating shaft, the swash plate type oil-pressure apparatus can suction the low-pressure operating oil and eject the high-pressure operating oil. To be specific, the swash plate type oil-pressure apparatus can also serve as the oil-pressure pump.

Citation List

Patent Literature

[0004] PTL 1: Japanese Laid-Open Patent Application Publication No. 2010-174690

Summary of Invention

Technical Problem

[0005] The swash plate type oil-pressure apparatus configured as in PTL 1 has been mainly used in low-speed rotation and medium-speed rotation. However, it is desired that in order to respond to the increase in the rotation of a driving device of the construction machinery or the industrial machinery, the swash plate type oil-pressure apparatus is configured to be able to be used in high-speed rotation. However, if the cylinder block of the swash plate type oil-pressure apparatus is rotated at high speed, the influence of centrifugal force acting on the pistons and the shoes increases and becomes unignorable, unlike a case where the cylinder block of the swash plate type oil-pressure apparatus is rotated at low speed.

[0006] For example, when the pistons perform the reciprocating movements in the cylinders, heat is generated by the sliding of the pistons on sliding surfaces of the cylinder block. The amount of heat generated on the sliding surfaces depends on the contact pressure between the pistons and the cylinder block. In a conventional low-speed rotation type in which the centrifugal force is extremely small, the contact pressure corresponds to the pressure of the operating oil supplied or ejected. Therefore, the heat generated on the sliding surfaces is comparatively small in amount. On this account, the sliding surfaces can be adequately cooled only by the operating oil leaking from clearances each formed between the sliding surface and the piston for allowing the operating oil to escape.

[0007] However, when the cylinder block is rotated at high speed, the influence of the centrifugal force on the contact pressure becomes larger than the influence of the oil pressure on the contact pressure. As the rotating speed increases, the contact pressure increases, and the amount of heat generated on the sliding surfaces also increases. With this, the temperatures of the sliding surfaces increase, and the cooling by the operating oil leaking from the clearances becomes especially difficult. On this account, the temperature increase in the vicinity of the openings of the cylinders become significant. In addition, since the pistons are pressed outward by the increase in the centrifugal force, the width of each of radially outer clearances of the cylinder block becomes smaller than the width of each of radially inner clearances of the cylinder block. In this case, the flow of the operating oil at the narrow radially outer clearances becomes nonsmooth, and the operating oil is heated at the narrow radially outer clearances. If the operating oil is continuously heated, and the temperature thereof exceeds a transition temperature of the operating oil, a lubrication performance of the operating oil decreases. With this, the amount of heat generated on the sliding surfaces further increases, and the cylinders and the pistons may be burned out. By increasing the widths of the clearances, the decrease in the lubrication performance of the operating oil and the burnout can be prevented. However, if the widths of the clearances are increased, the leakage amount of operating oil significantly increases. Therefore, the performance as the pump or motor deteriorates, and the increase in the pressure of the oil- pressure apparatus is limited.

[0008] Here, an object of the present invention is to provide a cooling structure of a cylinder block capable of improving a cooling performance for sliding surfaces.

Solution to Problem

[0009] A cooling structure of a cylinder block according to the present invention is configured such that: a plurality of cylinders each including an opening on a piston insertion end surface of the cylinder block are formed on the cylinder block; and when the cylinder block is rotated, pistons respectively inserted in the cylinders perform reciprocating sliding, the cooling structure including: a plurality of cooling depressions formed on an outer peripheral surface of the cylinder block, wherein each of the cooling depressions extends from the piston insertion end surface on a dividing wall located between the two adjacent cylinders and is formed by reducing a thickness of the dividing wall so as to reduce a thickness of a portion between the outer peripheral surface of the cylinder block and a sliding surface on which the piston slides.

[0010] According to the present invention, the thickness of the portion between the sliding surface and the outer peripheral surface becomes small. Since the temperature of the sliding surface in the vicinity of the outer periphery which generates heat by the centrifugal force generated by the high-speed rotation is higher than the temperature of drain oil in a case on the periphery of the sliding surface. Therefore, the heat generated on the sliding surfaces can be quickly transferred to the outer peripheral surface and thus can be released from the outer peripheral surface. With this, the cooling performance of the sliding surfaces can be improved, and the temperature increase of the sliding surfaces can be suppressed. In addition, since the cooling depressions extend from the piston insertion end surface on which the openings of the cylinders are located, the increase in the surface temperature of a portion of the sliding surface can be especially suppressed, the portion increasing in temperature most significantly and being located in the vicinity of the piston insertion end surface. Therefore, the occurrence of the burnout of the sliding surface can be suppressed.

[0011] For example, in a case where the present invention is used in a liquid-pressure apparatus, such as an oil-pressure pump or an oil-pressure motor, a clearance is formed between the sliding surface and the outer peripheral surface of the piston, and the operating oil leaking from the clearance is utilized as lubricating oil. By suppressing the temperature increase of the sliding surface, the increase in the temperature of the lubricating oil can be suppressed, and the transition of the lubricating oil can be prevented. With this, since the decrease in the lubrication performance of the lubricating oil can be prevented, smooth movements of the pistons can be maintained, and the amount of heat generated on the sliding surfaces can be reduced.

[0012] In the above invention, it is preferable that: each of the pistons perform the reciprocating sliding between a top dead center and a bottom dead center in the cylinder; and each of the cooling depressions be formed so as to extend from the piston insertion end surface in parallel with the cylinder and be formed such that a tip end of the cooling depression is located on the piston insertion end surface side of a vicinity of an end surface of the piston located at the bottom dead center, the end surface being located in the cylinder.

[0013] According to the above configuration, while maintaining the stiffness of a portion where the pressure becomes high when the piston is located at the bottom dead center, the cooling performance of a region where the surface temperature becomes high can be improved. With this, damages by the burnout of the cylinder and the piston can be prevented without decreasing a service limit pressure of the operating liquid supplied to the cylinder block.

[0014] In the above invention, it is preferable that each of the cooling depressions be formed so as to satisfy $0.02D \leq tmin \leq 0.3D$, where tmin denotes a minimum thickness of the portion between the outer peripheral surface of the cylinder block and the sliding surface, and D denotes an inner diameter of the cylinder.

[0015] According to the above configuration, the stiffness of a region of the sliding surface can be secured while improving the cooling effect, the region being located on the outer peripheral surface side. With this, the burnout of the cylinder block and the damages on the opening side can be prevented.

[0016] A swash plate type liquid-pressure apparatus of the present invention is configured to be connected to a low-pressure passage through which a low-pressure operating liquid flows and a high-pressure passage through which a high-pressure operating oil flows and further configured such that: the cylinder block is rotated by supplying the operating liquid through the high-pressure passage to the cylinders and discharging the operating liquid from the cylinders to the low-pressure passage; or by rotating the cylinder block, the operating liquid is suctioned through the low-pressure passage to the cylinders, and the operating liquid is then compressed and ejected to the high-pressure passage, and the swash plate type liquid-pressure apparatus includes any one of the above cooling structures.

[0017] In the swash plate type liquid-pressure apparatus, the clearance is formed between the sliding surface and the outer peripheral surface of the piston, and the operating oil leaking from the clearance is utilized as the lubricating oil. According to the above configuration, by suppressing the temperature increase of the sliding surface, the increase in the temperature of the lubricating oil leaking from the clearance can be suppressed, and the transition of the lubricating oil can be prevented. With this, the decrease in the lubrication performance of the lubricating oil can be prevented, the smooth movements of the pistons can be maintained, and the amount of heat generated on the sliding surfaces can be reduced.

[0018] In the above invention, it is preferable that the swash plate type liquid-pressure apparatus further include a casing configured to accommodate the cylinder block, wherein the casing is connected to the low-pressure passage through a communication passage, and low-pressure operating oil in the low-pressure passage is introduced to the casing.

[0019] According to the above configuration, since the outer peripheral surface of the cylinder block can be subjected to low-pressure, low-temperature operating liquid introduced to the casing, the outer peripheral surface can be cooled by the operating liquid. With this, a larger amount of heat can be released from the outer peripheral surface, so that the increase in the surface temperature of the sliding surface can be further suppressed.

Advantageous Effects of Invention

[0020] According to the present invention, the cooling performance for the sliding surfaces can be improved.

Brief Description of Drawings

[0021]

[Fig. 1] Fig. 1 is a cross-sectional view showing a swash plate type liquid-pressure apparatus according to an embodiment of the present invention.

[Fig. 2] Fig. 2 is a front view showing a cylinder block included in the swash plate type liquid-pressure apparatus shown in Fig. 1 when viewed from front.

[Fig. 3] Fig. 3 is a cross-sectional view taken along line A-A of Fig. 2 and showing the cylinder block.

[Fig. 4] Fig. 4 is one example of a diagram of an oil-pressure circuit around the swash plate type liquid-pressure apparatus.

[Fig. 5] Fig. 5A is a diagram showing a piston located at a bottom dead center. Fig. 5B is a graph showing surface temperatures at respective positions of a sliding surface of the cylinder block in a state shown in Fig. 5A. Fig. 5C is a graph showing oil pressures of the sliding surface of the cylinder block in the state shown in Fig. 5A.

[Fig. 6] Fig. 6 is a front view showing a cooling structure of the cylinder block of another embodiment.

Description of Embodiments

[0022] Hereinafter, a swash plate type liquid- pressure apparatus 1 according to an embodiment of the present invention will be explained in reference to the above drawings. The swash plate type liquid- pressure apparatus 1 explained below is just one embodiment of the present invention. The present invention is not limited to the embodiment, and additions, eliminations and modifications may be made within the spirit of the present invention.

Swash Plate Type Liquid-pressure Apparatus

[0023] In construction machinery, industrial machinery, and ships, the swash plate type liquid-pressure apparatus 1 is provided to drive respective devices and actuators included therein. Examples of the construction machinery are oil-pressure shovels, cranes, and bulldozers. Examples of the industrial machinery are land devices, such as oil-pressure units, pressing machines, ironmaking machines, and injection molding machines. The swash plate type liquid-pressure apparatus 1 is a so-called swash plate type motor/pump and has the function of a liquid-pressure motor configured to cause a rotated object included in the industrial machinery or ship to rotate or the function of a liquid-pressure pump configured to supply a pressure liquid to an actuator included in the industrial machinery or ship to activate the actuator. In the following explanation, for convenience of explanation, a fluid used is operating oil, and the swash plate type liquid-pressure apparatus 1 will be explained as an oil-pressure motor.

[0024] As shown in Fig. 1, an oil-pressure motor 1 that is the swash plate type liquid-pressure apparatus 1 is a high-speed rotation oil-pressure motor including a rotating shaft 11 and capable of rotating the rotating shaft 11 at high rotation speed. In addition to the rotating shaft 11, the oil-pressure motor 1 further includes a cylinder block 12, a plurality of pistons 13, a plurality of shoes 14, a swash plate 15, and a valve plate 16, and these components are accommodated in a casing 17. The rotating shaft 11 extends in a front-rear direction so as to penetrate the casing 17 and is rotatably supported by bearings 18 and 19 at front and rear end portions of the casing 17. The cylinder block 12 is fitted on the rotating shaft 11 so as to be located on a rear end portion of a middle portion of the rotating shaft 11.

[0025] The cylinder block 12 is formed in a substantially cylindrical shape, and an axis thereof is located so as to coincide with an axis L1 of the rotating shaft 11. The cylinder block 12 is integrally splined to the rotating shaft 11 and is not relatively rotatable with respect to the rotating shaft 11. A front end portion of an outer peripheral surface 12a of the cylinder block 12 is reduced in thickness toward a radially inner side over the entire periphery in the circumferential direction, and a cooling structure 30 is formed on the front end portion of the outer peripheral surface 12a. Details of the configuration of the cooling structure 30 will be described below. A plurality of cylinders 20 are formed on the cylinder block 12. As shown in Fig. 2, the cylinders 20 are arranged at regular intervals in the circumferential direction. As shown in Fig. 3, the cylinders 20 extend in parallel with the axis L1. Each of the cylinders 20 is a hole defined by a sliding surface having a circular cross section and a bottom surface and has an opening on a front end surface (piston insertion end surface) of the cylinder block 12. The pistons 13 are respectively inserted through the openings to fit in the cylinders 20.

[0026] Each of the pistons 13 is formed in a substantially columnar shape and performs the reciprocating sliding in the front-rear direction while sliding on the sliding surface 12b defining the cylinder 20. A cylindrical sleeve (not shown), such as a copper bushing, may fit in the cylinder 20. In this case, the piston 13 slides on an inner peripheral surface of the sleeve, and the sliding surface on which the piston 13 slides denotes the inner peripheral surface of the sleeve. In the following explanation, the sleeve does not fit in the cylinder 20. However, the same is true for a case where the sleeve fits in the cylinder 20.

[0027] An outer diameter of the piston 13 is slightly smaller than an inner diameter of the cylinder 20, and a clearance is formed around the piston 13, that is, the clearance is formed between the piston 13 and the sliding surface 12b. Further, the piston 13 includes a spherical support portion 13a at its front end portion. The spherical support portion 13a projects from the cylinder 20 regardless of the position of the piston 13. An outer surface of the spherical support portion 13a is formed in a substantially spherical shape, and the shoe 14 is attached to the spherical support portion 13a.

[0028] Each of the shoes 14 is formed in a substantially bottomed cylindrical shape, and an inner surface thereof is formed in a partial spherical shape corresponding to the spherical support portion 13a. The spherical support portion 13a of the piston 13 fits in the shoe 14, and the piston 13 is rotatable around a center point that is the center of the spherical support portion 13a. The shoe 14 includes, at its bottom portion, a flange 14a projecting in a radially outward direction and is arranged on the swash plate 15 such that the bottom portion thereof contacts the swash plate 15.

[0029] The swash plate 15 is formed in a substantially circular plate shape. The swash plate 15 is provided in the casing 17 so as to be inclined such that an upper portion thereof is located on a rear side, and the rotating shaft 11 penetrates the vicinity of the center of the swash plate 15. The swash plate 15 is provided on a front side of the cylinder block 12 and includes a supporting plate 21 on the cylinder block 12 side. The supporting plate 21 is formed in an annular shape, and the plurality of shoes 14 are arranged on the supporting plate 21 at regular intervals in the circumferential direction. A retainer plate 22 is provided on the plurality of shoes 14 so as to press the shoes 14 against the supporting plate 21.

[0030] The retainer plate 22 is formed in a substantially annular shape, and the rotating shaft 11 penetrates the center of the retainer plate 22 so as to be relatively rotatable with respect to the retainer plate 22. Attachment holes 22a, the number of which is equal to the number of shoes 14, are formed on the retainer plate 22. The attachment holes 22a are arranged at regular intervals in the circumferential direction. Opening portions of the shoes 14 are respectively inserted in the attachment holes 22a, and the retainer plate 22 contacts the flanges 14a. Thus, the retainer plate 22 and the supporting plate 21 sandwich the flanges 14a. A spherical bushing 23 is inserted in an inner hole of the retainer plate 22. The spherical bushing 23 is formed in a substantially cylindrical shape and is externally attached to the rotating shaft 11 and the cylinder block 12. The spherical bushing 23 is biased toward the supporting plate 21 by a plurality of pressing springs 40 provided at the cylinder block 12, and the retainer plate 22 is pressed against the supporting plate 21 by the spherical bushing 23.

[0031] An upper portion of the swash plate 15 on which the plurality of shoes 14 are arranged as above is coupled to a regulator 24 provided at an upper portion of the casing 17. The regulator 24 includes a plunger 25 configured to be movable in the front-rear direction, and the swash plate 15 is coupled to the plunger 25. Therefore, by causing the plunger 25 to move in the front-rear direction, the inclination angle of the swash plate is changed. Thus, the strokes of the pistons 13 can be adjusted, and the volumes of oil chambers 20a of the cylinders 20 can be changed. Each of the oil chambers 20a is a space in the cylinder 20, the space being located on the rear side of a rear end surface of the piston 13.

[0032] Cylinder ports 26 respectively connected to the oil chambers 20a are formed at the cylinder block 12. One cylinder port 26 is formed for one cylinder 20, that is, the cylinder ports 26 correspond one-to-one to the cylinders 20. The cylinder ports 26 open on a rear end surface of the cylinder block 12, and the valve plate 16 is provided on this rear end surface.

[0033] The valve plate 16 is an annular plate-shaped member and is located between the cylinder block 12 and a rear end portion of the casing 17. The valve plate 16 is fixed to the casing 17 by pin members, not shown, so as not to be relatively rotatable with respect to the casing 17. The rotating shaft 11 is inserted through an inner hole of the valve plate 16, and the rotating shaft 11 and the valve plate 16 are configured to be relatively rotatable with respect to each other. An inlet port 16a and an outlet port 16b are formed on the valve plate 16 located as above.

[0034] Each of the inlet port 16a and the outlet port 16b is formed in a substantially circular-arc shape. The inlet port 16a and the outlet port 16b are located so as to be spaced apart from each other in the circumferential direction. Each of the inlet port 16a and the outlet port 16b penetrates the valve plate 16 in the thickness direction. Regarding each of the inlet port 16a and the outlet port 16b, its opening located on the cylinder block 12 side is connected to some of the cylinder ports 26. By rotating the cylinder block 12, a destination to which the cylinder port 26 is connected is alternately switched between the inlet port 16a and the outlet port 16b. The other opening of the inlet port 16a is connected to a high-pressure passage 27 shown in Fig. 4, and the other opening of the outlet port 16b is connected to a low-pressure passage 28 shown in Fig. 4. To be specific, by rotating the cylinder block 12, each of the cylinders 20 is alternately connected to the high-pressure passage 27 and the low-pressure passage 28. In Fig. 1, for convenience of explanation, the positions of the inlet port 16a and the outlet port 16b are shifted in the circumferential direction from the actual positions of the inlet port 16a and the outlet port 16b. A circuit configuration shown in Fig. 4 is one example for further improving the cooling effect. Even without this configuration, the cooling effect can be obtained by oil in a case.

[0035] A communication passage 29 shown in Fig. 4 is formed at the casing 17. An internal space of the casing 17 and the low-pressure passage 28 are connected to each other through the communication passage 29. With this, a certain amount of operating oil flowing through the low-pressure passage 28 can be introduced through the communication passage 29 to the internal space of the casing 17 to be utilized as a cooling liquid. Thus, the rotating shaft 11, the cylinder block 12, the pistons 13, and the like can be cooled by low-pressure, low-temperature operating oil.

[0036] In the oil-pressure motor 1 configured as above, while the piston 13 moves from a top dead center where the piston retracts most in the cylinder 20 to a bottom dead center where the piston 13 projects most from the cylinder 20, the operating oil flowing through the high-pressure passage 27 is suctioned to the oil chamber 20a through the inlet port 16a. With this, the piston 13 is pressed forward by the operating oil. As a result, the shoe 14 is pressed against the swash plate 15. Since the swash plate 15 is inclined, the pressed shoe 14 slides on the swash plate 15 so as to move downward and revolves around the axis L1 in one direction along the circumferential direction. With this, the rotational force around the axis L1 is applied to the cylinder block 12, and the cylinder block 12 and the rotating shaft 11 rotate around the axis L1.

[0037] When the piston 13 is located between the bottom dead center and the top dead center, the oil chamber 20a is connected to the low-pressure passage 28 via the outlet port 16b. By the rotation of the cylinder block 12, the shoe 14 slides on the swash plate 15 so as to move upward and revolves around the axis L1 in one direction along the circumferential direction. When the shoe 14 moves upward, the piston 13 is pressed backward. With this, the operating oil in the oil chamber 20a is discharged through the outlet port 16b to the low-pressure passage 28. As above, in the oil-pressure motor 1, by suctioning and ejecting the operating oil, the pistons 13 perform the reciprocating sliding in the front-rear direction, and the cylinder block 12 and the rotating shaft 11 are rotated around the axis L1.

[0038] As described above, in the oil-pressure motor 1 configured to repeat the suction and discharge of the operating oil, when suctioning and discharging the operating oil, the pistons 13 slide on the sliding surfaces 12b to perform the reciprocating sliding in the front-rear direction. Therefore, frictional heat is generated on the sliding surfaces 12b when sliding, and the surface temperature of the sliding surface 12b, especially the surface temperature of a region on the opening side, increases. The clearance is formed between the outer surface of the piston 13 and the sliding surface 12b. By utilizing the operating oil leaking from the clearance as lubricating oil, the pistons 13 are lubricated. Thus, the frictional heat generated on the sliding surfaces 12b is reduced, and the sliding surfaces 12b are cooled by the lubricating oil. As above, in the oil-pressure motor 1, by providing the clearances, the increase in the surface temperatures of the sliding surfaces 12b is suppressed. However, to further suppress the increase in the surface temperatures, the oil-pressure motor 1 further includes the cooling structure 30 of the cylinder block 12.

Cooling Structure of Cylinder Block

[0039] The cooling structure 30 of the cylinder block 12 includes cooling depressions 31. As shown in Fig. 2, the cooling depressions 31 are respectively formed at dividing walls 32 each located between two adjacent cylinders 20 and extend from the front end surface of the cylinder block 12 toward the rear end surface thereof in parallel with the axis L1. In the present embodiment, a tip end of the cooling depression 31 is located on the cylinder block 12 front end surface side of the vicinity of the rear end surface of the piston 13 located at the bottom dead center, that is, the tip end of the cooling depression 31 is located on the front side of the vicinity of the rear end surface of the piston 13 located at the bottom dead center (see Fig. 3). Each of the dividing walls 32 denotes an entire wall (region shown by a diamond net pattern in Fig. 2) located between straight lines L2 and L3 respectively extending from the center of the cylinder block 12 through one of the centers of two adjacent cylinders 20 to the outer peripheral surface 12a and from the center of the cylinder block 12 through the other center to the outer peripheral surface 12a.

[0040] Figs. 5B and 5C are graphs respectively showing surface temperatures and oil pressures at respective positions on the sliding surface 12b when the piston 13 is located at the bottom dead center (see Fig. 5A). In Fig. 5B, a vertical axis shows a surface temperature T of the sliding surface 12b, and a horizontal axis shows a distance d from the front end surface of the cylinder block 12. In Fig. 5C, a vertical axis shows an oil pressure P applied to the sliding surface 12b, and a horizontal axis shows the distance d from the front end surface of the cylinder block 12. As is clear from Fig. 5B, regarding the surface temperature of the sliding surface 12b, a portion located on the rear side of the rear end surface of the piston 13 (to be specific, a portion between a distance d1 and a distance d2) is cooled by the operating oil in the oil chamber 20a, so that the potion is maintained at a substantially constant temperature. In contrast, regarding a portion located on the cylinder 20 opening side of the rear end surface of the piston 13 (to be specific, a portion between a distance 0 and the distance d1), the cooling effect by the operating oil in the clearance is small. Therefore, the surface temperature increases toward the opening side, and the surface temperature is the highest in the vicinity of the opening, that is, highest on the front end surface of the cylinder block 12.

[0041] In addition, as is clear from Fig. 5C, regarding the oil pressure applied to the sliding surface 12b, since a region of the sliding surface 12b, the region being located on the rear side of the rear end surface of the piston 13, forms the oil chamber 20a, the oil pressure applied to this region is substantially equal to the pressure of the operating oil suctioned through the inlet port 16a. In contrast, regarding the oil pressure applied to a region of the sliding surface 12b, the region being located on the front side of the rear end surface of the piston 13, since a front portion of the clearance is connected to the casing 17, the oil pressure decreases toward the opening side. The oil pressure on the opening side is decreased up to the pressure in the casing, that is, a drain pressure.

[0042] As above, the surface temperature of the sliding surface 12b and the oil pressure applied to the sliding surface 12b are different between the front side and rear side of the rear end surface of the piston 13 located at the bottom dead center. When the piston 13 is located at the bottom dead center, a high pressure is applied to the sliding surface 12b over a widest range. As in the present embodiment, by arranging the tip end of the cooling depression 31 on the cylinder block 12 front end surface side of the rear end surface of the piston 13, the cooling performance of a region where the surface temperature becomes high can be improved while increasing the stiffness of a region where the oil pressure applied to the sliding surface 12b becomes high. With this, damages by the burnout of the cylinder 12 and the piston 13 can be prevented without decreasing a service limit pressure of the operating oil.

[0043] When viewed from front as in Fig. 2, the cooling depression 31 extending as above is bent so as to project toward a radially inner side. A region of the dividing wall 32 is reduced in thickness, the region being located between the sliding surface 12b and the outer peripheral surface 12a. As above, by reducing the thickness of the dividing wall 32, that is, by reducing a thickness t of a portion between the sliding surface 12b and the outer peripheral surface 12a, the heat generated on the sliding surface 12b can be quickly transferred to the outer peripheral surface 12a subjected to the low-temperature operating oil. Thus, the heat can be released to the low-temperature operating oil, and the temperature increase of the sliding surface 12b can be suppressed. Therefore, even if the cylinder block 12 is increased in speed, the operating oil (lubricating oil) in the clearance between the sliding surface 12b and the piston 13 can be prevented from increasing in temperature and exceeding the transition temperature, and the burnout of the sliding surface 12b by the decrease in the lubrication performance of the operating oil can also be prevented. In addition, the surface temperature of the sliding surface 12b can be reduced without increasing the clearance between the sliding surface 12b and the piston 13 and forming oil grooves on the sliding surface 12b. Therefore, the cooling performance improves without decreasing the performance of the motor.

[0044] Hereinafter, the shape of the cooling depression 31 will be further explained. The cooling depression 31 is formed to satisfy $0.02D \leq tmin \leq 0.3D$, where tmin denotes a minimum thickness of the portion between the sliding surface 12b and the outer peripheral surface 12b, and D denotes the inner diameter of the cylinder 20. More specifically, the cooling depression 31 is formed to satisfy $0.02D \leq t \leq 0.3D$, where t denotes a thickness of a portion between the outer peripheral surface 12a and a region 12c (corresponding to a region located on the outer peripheral surface 12a side in the sliding surface 12b) located on a radially outer side in the sliding surface 12b, and D denotes the inner diameter of the cylinder 20. The region 12c located on the radially outer side is a region spreading from an intersection point A1 toward both directions along the circumferential direction, the intersection point A1 being one of two points where the straight line L2 and the sliding surface 12b intersect with each other and being located on the radially outer side. When the cylinder block 12 is rotated at high speed, the piston 13 pressed by the centrifugal force contacts the region 12c. Thus, the piston 13 slides on the sliding surface 12b in a state where the piston 13 contacts the region 12c by the large centrifugal force. Therefore, high frictional heat is generated on the region 12c. For example, the region 12c is a region spreading from the intersection point A1 as a center toward both directions along the circumferential direction and having a center angle α, and the center angle α satisfies $30° \leq \alpha \leq 180°$. By external factors, such as the rotating speed and rotational direction of the cylinder block 12, and vibrations, the position where the piston 13 contacts may be out of the range defined by the center angle α. Therefore, the cooling depression 31 may be formed such that the thickness t around the sliding surface 12b satisfies $0.02D \leq t \leq 0.3D$ over a wider range than the range defined by the center angle α (for example, see Fig. 6 described below) .

[0045] By setting the thickness t to 0.3D or less, the cooling performance of the sliding surface 12b, especially the region located on the opening side, can be improved, and the increase in the surface temperature of the sliding surface 12b can be suppressed. With this, the temperature increase of the operating oil (lubricating oil) flowing through the clearance between the sliding surface 12b and the piston 13 can be suppressed, and the temperature of the operating oil can be prevented from increasing and exceeding the transition temperature. Therefore, the burnout of the sliding surface 12b by the decrease in the lubrication performance of the operating oil can be prevented.

[0046] Since the surface temperature of the sliding surface 12b can be decreased without increasing the clearance between the sliding surface 12b and the piston 13 and forming oil grooves on the sliding surface 12b, the cooling performance improves without decreasing the performance of the motor. Further, by setting the thickness t to 0.02D or more, the stiffness in the vicinity of the opening side of the region 12c located on the radially outer side in the sliding surface 12b can be secured. Even when the piston 13 performs the reciprocating sliding at high speed in operation, the damages in the vicinity of the opening side can be prevented.

Other Embodiments

[0047] In the above embodiment, a bottom surface of the cooling depression 31 is bent in an arch shape. However, the bottom surface does not have to have the arch shape. For example, as shown in Fig. 6, a cooling depression 31A of a cooling structure 30A may be formed along the sliding surface 12b to have a sharp tip shape, so that the thickness t of an entire semicircle located on the radially outer side in the sliding surface 12b may become uniform. In addition, the shape of the cooling depression 31 does not have to be bent. The bottom surface may be flat, or the bottom surface may be formed like a fin by forming depressions and projections thereon. Further, the vicinity of the tip end of the bottom surface of the cooling depression 31 is bent toward the tip end so as to be located on the radially outer side. However, the vicinity of the tip end of the bottom surface does not have to be bent and may be flat up to the tip end (for example, see reference sign 41 shown by a chain double-dashed line in Fig. 3). Further, in the above embodiment, as shown in Fig. 3, the tip end of the cooling depression 31 is located between the front end surface of the cylinder block 12 and the rear end surface of the piston 13 located at the bottom dead center. However, the tip end of the cooling depression 31 may be located in the vicinity of the rear end surface.

[0048] The above embodiment has explained a case where the swash plate type liquid-pressure apparatus 1 is the oil-pressure motor. However, as described above, the swash plate type liquid-pressure apparatus 1 may be the oil-pressure pump. In this case, the cylinder block 12 is rotated by rotating the rotating shaft 11 by an electric motor or an engine. By the rotation of the cylinder block 12, the pistons 13 perform the reciprocating sliding. In the oil-pressure pump, the outlet port 16b is connected to the high-pressure passage 27, and the inlet port 16a is connected to the low-pressure passage 28. While the piston 13 moves from the top dead center to the bottom dead center, the operating oil is suctioned through the inlet port 16a to the oil chamber 20a. While the piston 13 moves from the bottom dead center to the top dead center, the suctioned operating oil is compressed and ejected through the outlet port 16b to the high-pressure passage 27.

[0049] As above, even in the case of the oil-pressure pump, the pistons perform the reciprocating sliding in the cylinders 20 and slide on the sliding surfaces 12b. Therefore, as with the oil-pressure motor 1, the heat is generated on the sliding surfaces 12b. On this account, even in the case of using the swash plate type liquid-pressure apparatus 1 as the oil-pressure pump, the same operational advantages as the oil-pressure motor 1 can be obtained by the cooling structure 30 of the cylinder block 12.

[0050] Further, the above embodiment has explained the swash plate type liquid- pressure apparatus 1. However, the cooling structure 30 of the cylinder block 12 may be applied to an inclined shaft type liquid- pressure apparatus. However, in the inclined shaft type liquid-pressure apparatus, even if the speed is increased, the surface temperature of the sliding surface 12b does not increase, unlike the swash plate type liquid- pressure apparatus 1. Therefore, higher operational advantages are obtained in the case of the swash plate type liquid- pressure apparatus. Although the oil is used as the operating liquid, other liquids, such as water, may be used as the operating liquid.

Reference Signs List

[0051]

1	oil-pressure motor
12	cylinder block
12a	outer peripheral surface
12b	sliding surface
12c	region
13	piston
17	casing
20	cylinder
27	high-pressure passage
28	low-pressure passage
29	communication passage
30	cooling structure
31	cooling depression
32	dividing wall

Claims

1. A cooling structure of a cylinder block configured such that: a plurality of cylinders each including an opening on a piston insertion end surface of the cylinder block are formed on the cylinder block; and when the cylinder block is rotated, pistons respectively inserted in the cylinders perform reciprocating sliding,
   the cooling structure comprising
   a plurality of cooling depressions formed on an outer peripheral surface of the cylinder block, wherein
   each of the cooling depressions extends from the piston insertion end surface on a dividing wall located

between the two adjacent cylinders and is formed by reducing a thickness of the dividing wall so as to reduce a thickness of a portion between the outer peripheral surface of the cylinder block and a sliding surface on which the piston slides.

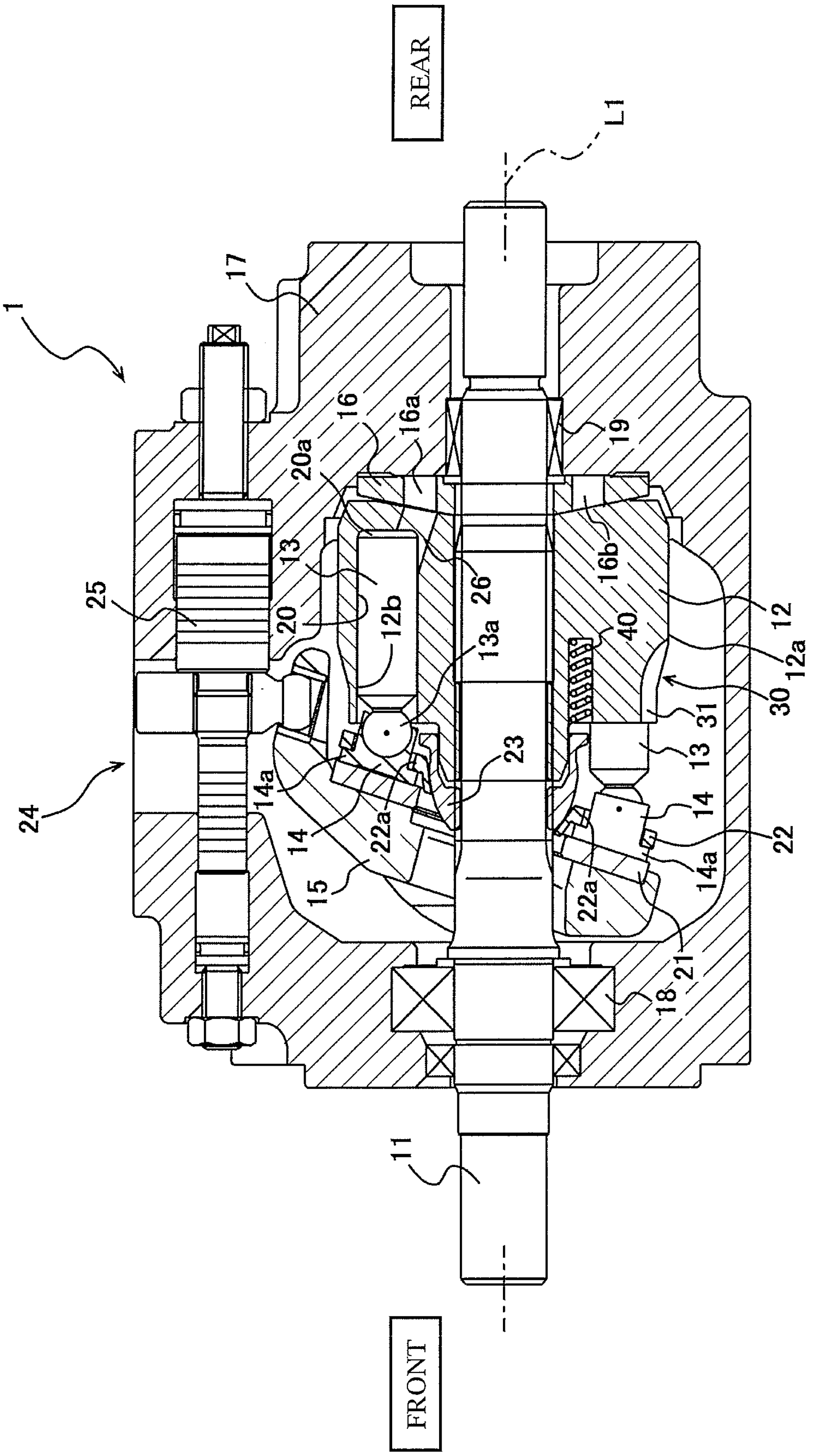
2. The cooling structure, wherein:

each of the pistons performs the reciprocating sliding between a top dead center and a bottom dead center in the cylinder; and
each of the cooling depressions is formed so as to extend from the piston insertion end surface in parallel with the cylinder and is formed such that a tip end of the cooling depression is located on the piston insertion end surface side of a vicinity of an end surface of the piston located at the bottom dead center, the end surface being located in the cylinder.

3. The cooling structure, wherein each of the cooling depressions is formed so as to satisfy $0.02D \leq tmin \leq 0.3D$, where tmin denotes a minimum thickness of the portion between the outer peripheral surface of the cylinder block and the sliding surface, and D denotes an inner diameter of the cylinder.

4. A swash plate type liquid-pressure apparatus configured to be connected to a low-pressure passage through which a low-pressure operating liquid flows and a high-pressure passage through which a high-pressure operating oil flows and further configured such that: the cylinder block is rotated by supplying the operating liquid through the high-pressure passage to the cylinders and discharging the operating liquid from the cylinders to the low-pressure passage; or by rotating the cylinder block, the operating liquid is suctioned through the low-pressure passage to the cylinders, and the operating liquid is then compressed and ejected to the high-pressure passage, the swash plate type liquid-pressure apparatus comprising the cooling structure according to any one of claims 1 to 3.

5. The swash plate type liquid-pressure apparatus according to claim 4, further comprising a casing configured to accommodate the cylinder block, wherein the casing is connected to the low-pressure passage through a communication passage, and low-pressure operating oil in the low-pressure passage is introduced to the casing.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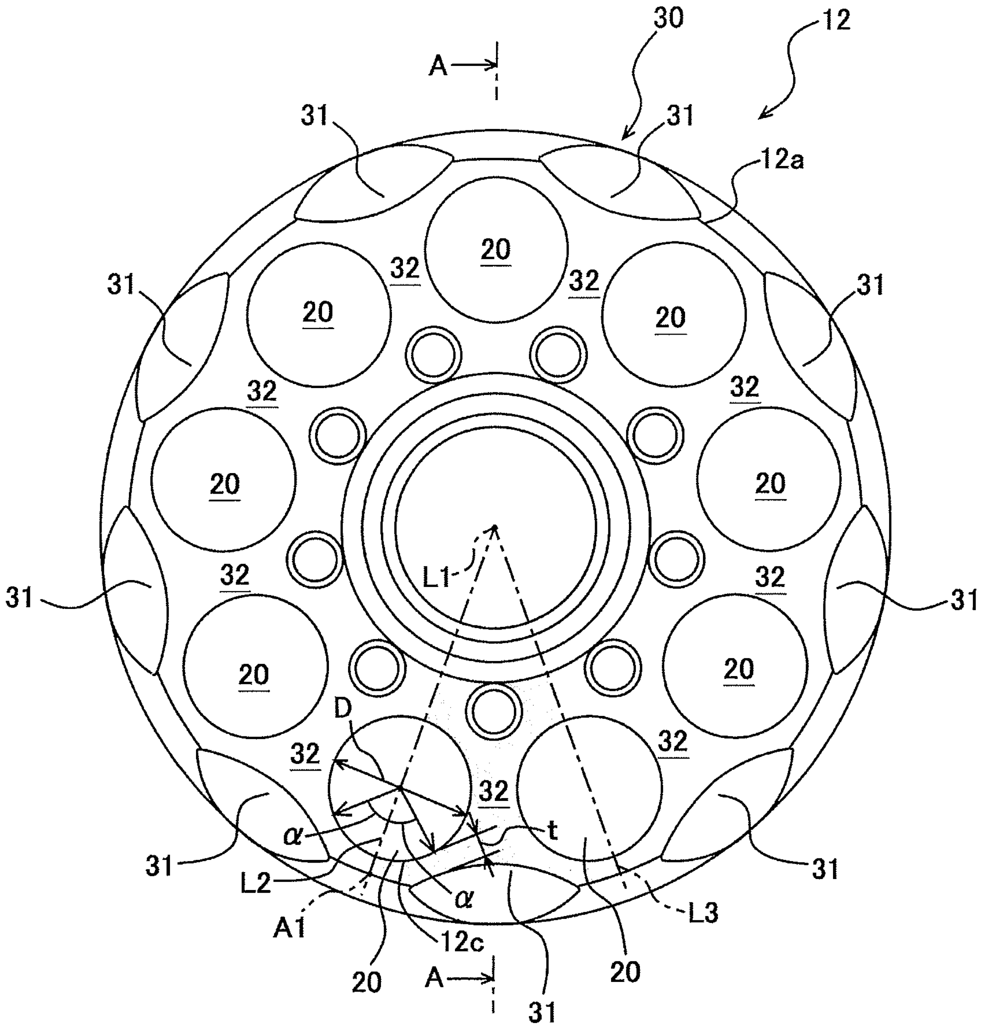
11
FRONT

Fig. 1



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A
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Fig. 2

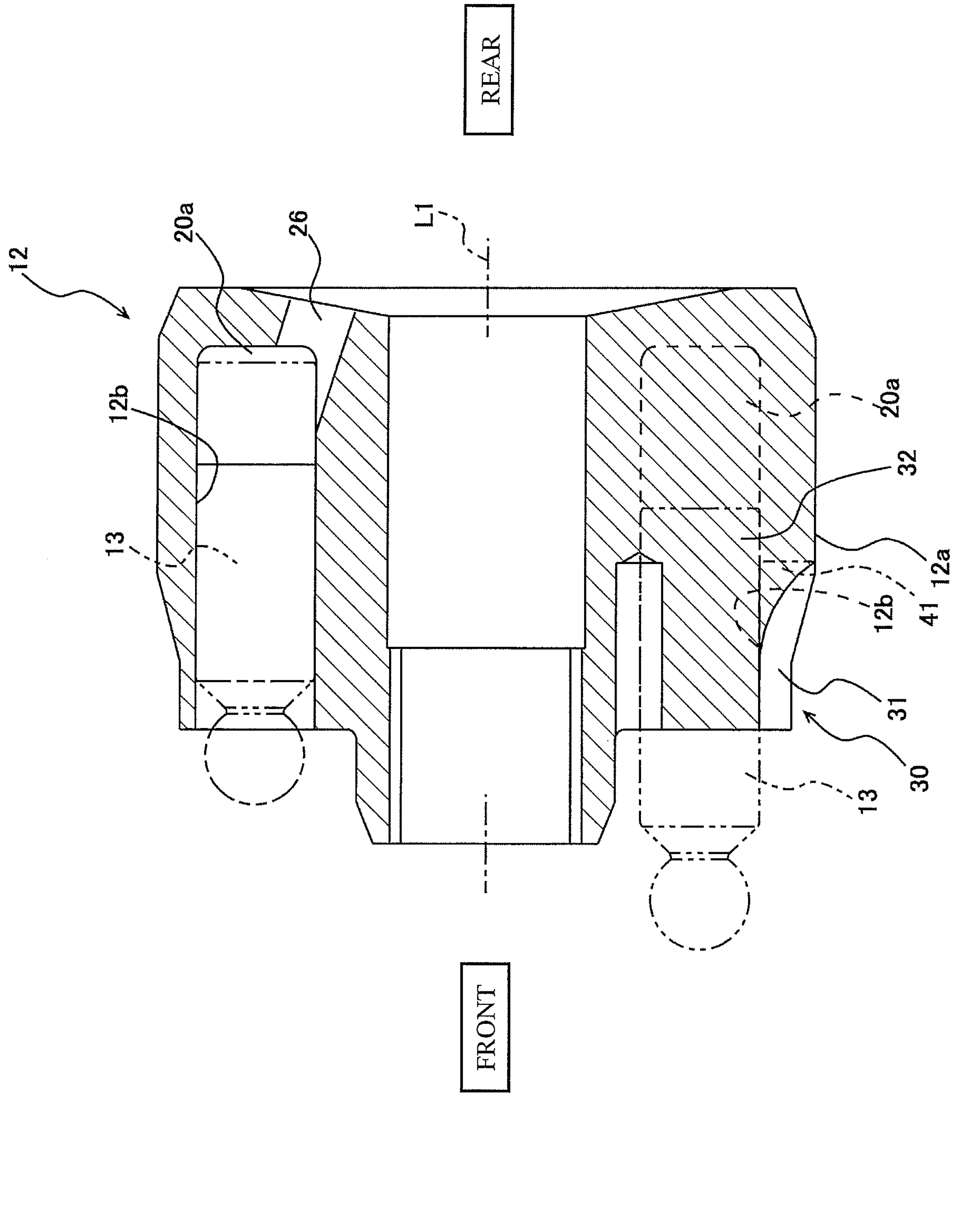


Fig. 3

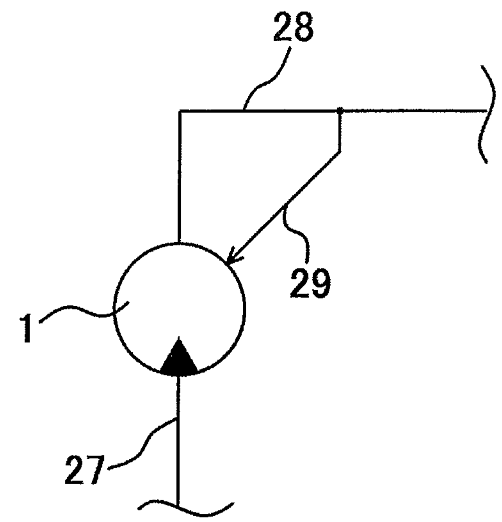


Fig. 4

Fig. 5A

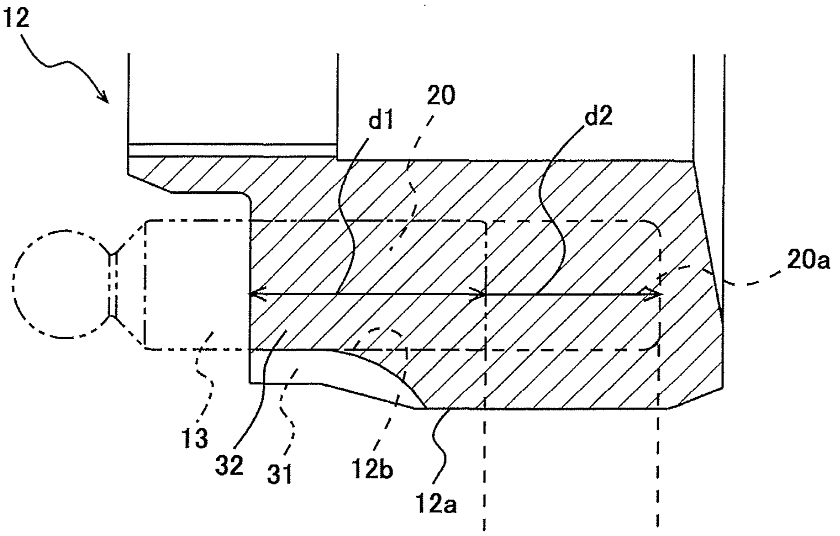


Fig. 5B

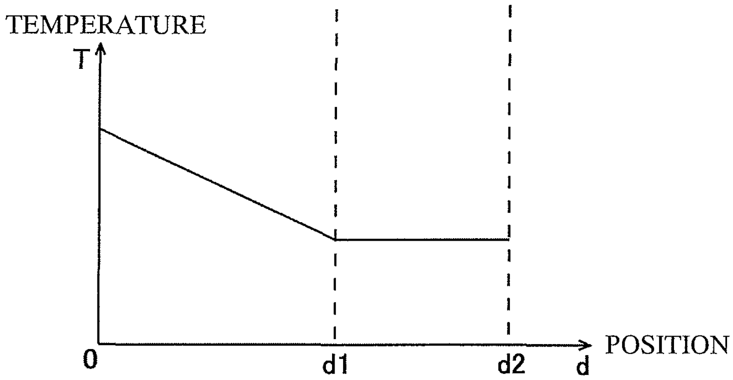
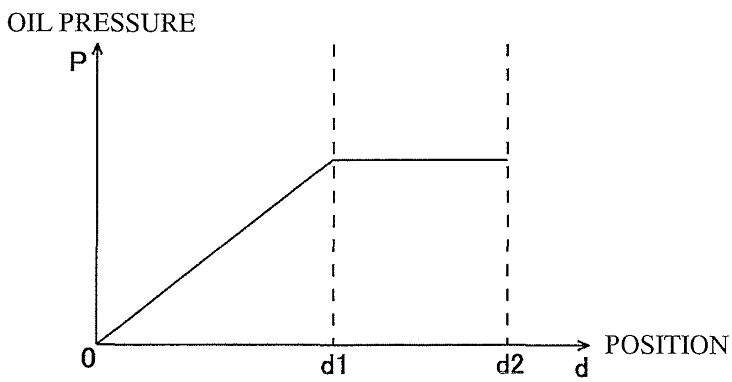


Fig. 5C



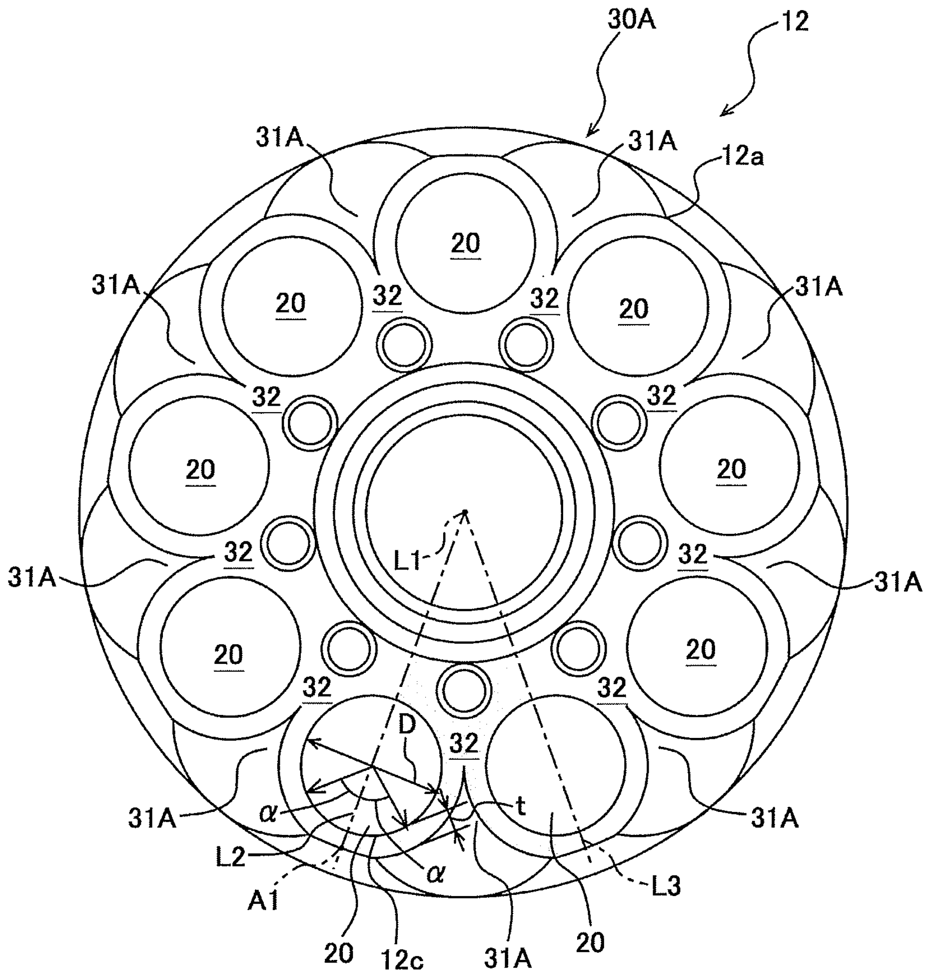

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Fig. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2010/006721

A. CLASSIFICATION OF SUBJECT MATTER
F04B53/08(2006.01)i, *F03C1/253*(2006.01)i, *F04B1/22*(2006.01)i, *F04B53/16* (2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F04B53/08, F03C1/253, F04B1/22, F04B53/16

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2011
Kokai Jitsuyo Shinan Koho	1971-2011	Toroku Jitsuyo Shinan Koho	1994-2011

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 2001-59561 A (Yanmar Diesel Engine Co., Ltd.), 06 March 2001 (06.03.2001), entire text; all drawings (Family: none)	1,3-5 2
Y A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 176184/1977(Laid-open No. 102710/1979) (Sanwa Seiki Ltd.), 19 July 1979 (19.07.1979), fig. 2 (Family: none)	1,3-5 2

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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Date of the actual completion of the international search
04 February, 2011 (04.02.11)

Date of mailing of the international search report
15 February, 2011 (15.02.11)

Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2010/006721

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 2010-180890 A (Mitsubishi Heavy Industries, Ltd.), 19 August 2010 (19.08.2010), fig. 8(a), 8(b) (Family: none)	1,3-5 2
Y A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 29242/1985(Laid-open No. 145882/1986) (Diesel Kiki Co., Ltd.), 09 September 1986 (09.09.1986), fig. 2 (Family: none)	1,3-5 2

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REFERENCES CITED IN THE DESCRIPTION

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