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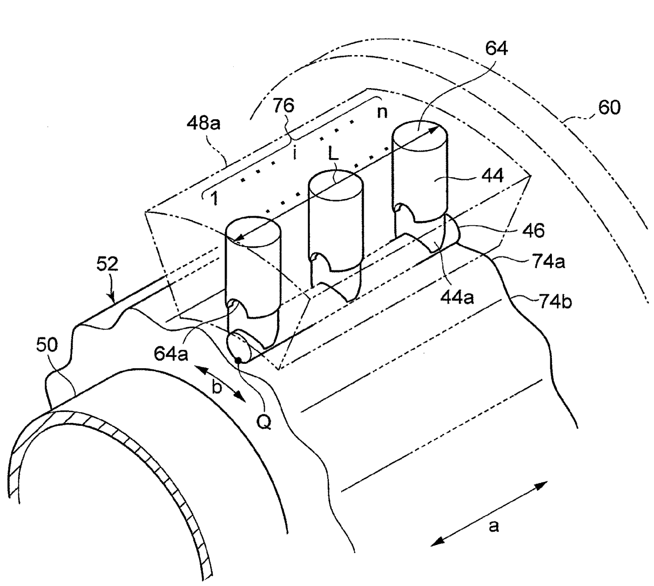
(54) **Radial piston hydraulic machine and wind turbine generator**

(57) It is intended to suppress generation of a skew phenomenon of a roller in a radial piston hydraulic machine. The radial piston hydraulic machine is provided with a plurality of pistons, at least one roller, a cylinder block including a plurality of cylinders configured to guide the plurality of pistons reciprocably along a radial direction, respectively, and a cam configured to contact each of the at least one roller. Each roller is provided for n pistons that are arranged along an axial direction of the hydraulic machine to share, n being an integer not less than two.

FIG. 4



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Description

[Technical Field]

[0001] The present disclosure relates to a radial piston hydraulic machine which is applicable to a hydraulic pump, a hydraulic motor or the like, as well as a wind turbine generator equipped with the radial piston hydraulic machine.

[Background Art]

[0002] From the perspective of preserving the global environment, power generating apparatuses which use renewable energy such as solar power and wind power are becoming popular. For instance, there is a wind turbine generator which converts wind energy into rotational energy of a rotor and further converts the rotational energy into electric power by means of a generator. In a conventional wind turbine generator, a rated rotation speed of the rotor is relatively small compared to a rated rotation speed of the generator and thus, a mechanical speed increaser (gear type) is provided between the rotor and the generator.

[0003] Meanwhile, wind turbine generators are progressively made larger to improve power generation efficiency, and accordingly a speed increaser becomes heavier and more expensive. Thus, it is becoming popular to use a wind turbine generator adopting a hydraulic transmission configured by a hydraulic pump and a hydraulic motor, instead of a mechanical speed increaser. Normally, this type of hydraulic transmission is provided with a hydraulic pump driven by rotation of a rotor, a hydraulic motor coupled to a generator, and a hydraulic pipe for circulating pressurized oil between the hydraulic pump and the hydraulic motor. For instance, disclosed in Patent Document 1 is a wind turbine generator configured to transmit rotational energy of a rotor rotated by wind power to a generator via a hydraulic transmission.

[0004] There is also a radial piston hydraulic machine having a plurality of pistons arranged radially. For instance, a radial piston hydraulic pump used for a power transmission apparatus is disclosed in Patent Document 2. This hydraulic pump is provided with an outer race having a cam face on an inner peripheral surface and an inner race having a plurality of cylinders arranged radially to face the outer race. The plurality of cylinders of the inner race has a plurality of pistons configured to be slidable therein, and to each of the pistons, a ball is attached so as to contact the cam face.

[0005] Patent Document 3 discloses a radial piston hydraulic machine which serves as a drive train for a wind turbine generator. This radial piston hydraulic machine is provided with a piston which is reciprocable in a cylinder, a roller attached to the piston and a cam having a cam face contacting the roller.

[Citation List]

[Patent Literature]

[0006]

[Patent Document 1]
WO 2010/033035
[Patent Document 2]
JP 2010-19192 A
[Patent Document 3]
US 2010/0040470 A

[Summary]

[Technical Problem]

[0007] A radial piston hydraulic machine comprises a rotation shaft, a plurality of cylinders radially arranged around the rotation shaft, a plurality of pistons being reciprocable inside the plurality of cylinders, and a member, such as a cam, for transmitting a motion between the rotation shaft and the piston. The hydraulic pump is configured to discharge high pressure operating oil by rotating the rotation shaft using an external force and converting rotational motion of the rotation shaft into reciprocating motion of the piston. The hydraulic motor is configured to rotate the rotation shaft using the reciprocating motion of the piston which is supplied with the high pressure operating oil.

[0008] During operation of the hydraulic machine, a moment around the shaft is sometimes generated at the piston due to the load transmitted from the cam. This moment may results in generation of a phenomenon called skew in which the piston rotates around the cylinder axis with the roller. Once this phenomenon occurs, the shaft direction of the roller does coincide with the axial direction of the cam and thus, a high stress is generated in part between the roller and the cam. This makes it difficult to smoothly transmit the power between the roller and the cam, which can result in performance decrement of the radial piston hydraulic machine.

[0009] It is an object of at least one embodiment of the present invention to suppress generation of the skew phenomenon of the roller in the radial piston hydraulic machine.

[Solution to Problem]

[0010] To achieve the above object, a radial piston hydraulic machine according to at least one embodiment of the present invention comprises:

a plurality of pistons;
at least one roller;
a cylinder block comprising a plurality of cylinders configured to guide the plurality of pistons reciprocably along a radial direction of the hydraulic machine, respectively;
a cam configured to contact each of the at least one roller,
wherein each of the at least one roller is provided for n pistons of the plurality of pistons, the n pistons being aligned along an axial direction of the hydraulic machine to share said each of the at least one roller, n being an integer not less than two.

[0011] In these embodiments, each of the rollers is supported by the pistons at two or more points that are different in the axial direction of the hydraulic machine. In the conventional single-point supporting method for supporting the roller by the piston at one point, there is a room for rotational movement of the roller around the axis of the piston. However, by supporting the roller at two or more points in the axial direction, the rotational movement of the roller is suppressed. This effectively suppresses generation of the skew phenomenon of the roller. As a result, it is possible to prevent generation of partial stress between the cam and the roller. This enables smooth transmission of the power between the cam and the roller. Further, by supporting the roller at two or more supporting points in the axial direction, it is possible to effectively increase a load carrying capacity of the roller between the supporting points. Thus, even if the length of the roller is increased in the axial direction, it is possible to support the roller reliably.

[0012] The above hydraulic machine is includes a hydraulic pump and a hydraulic motor, and the present invention is applicable to both the hydraulic pump and the hydraulic motor. Further, there are a hydraulic machine which has a rotation part inside the cylinder block and a hydraulic machine which has a rotation part outside the cylinder block. In the former hydraulic machine, the ring cam is an outward ring cam having a cam face facing outward. In the latter hydraulic machine, the ring cam is an inward ring cam having a cam face facing inward. The present invention is applicable to both of these.

[0013] Further, the piston is arranged in the cylinder to reciprocate along the radial direction of the hydraulic machine. The term "along", however, not just refers to a state of being strictly parallel in a geometric sense with respect to a reference direction or object as a reference but also includes a state of being at an angle to a certain extent with respect the radial direction of the hydraulic machine (e.g. 30° or less).

[0014] In some embodiments, the cam is a ring cam having a plurality of lobes disposed along a circumferential direction of the hydraulic machine, the ring cam being arranged to face the plurality of pistons and being configured rotatable so that the lobes move relative to the plurality of pistons in the circumferential direction, the plurality of cylinders includes a cylinder array that is formed by n cylinders of the plurality of cylinders arranged along the axial direction corresponding to the n pistons, and the plurality of lobes extends linearly in the axial direction over an area in the axial direction occupied by the cylinder array.

[0015] In the above radial piston hydraulic machine, the plurality of lobes extends linearly in the axial direction over the area in the axial direction occupied by the cylinder array. This enables smooth relative rotation of the roller relative to the lobes, the roller corresponding to the n cylinders aligned in the axial direction in the same manner as the plurality of lobes. Further, as the plurality of lobes extends linearly in the axial direction over the area in the axial direction occupied by the cylinder array, it simplifies the configuration of the ring cam and also facilitates work for installing the ring cam. Therefore, it is possible to improve productivity of the radial piston hydraulic machine.

[0016] In some embodiments, each of the at least one roller includes a cylindrical part extending along the axial direction over a region where the n pistons are provided, and the cylindrical part is configured to contact the cam over the region in the axial direction. As are result, the contact area of the roller with respect to the cam face can be increased in the axial direction of the roller, it is possible to reduce a contact surface pressure per unit contact area of the roller with respect to the cam face. Therefore, in these embodiments, it is possible to prevent fatigue fracture of the roller, the ring cam, the pistons and the like, in addition to the skew suppressing effect.

[0017] In some embodiments, each of the at least one roller includes at least one contact part configured to contact and engage with the cam and at least one engagement part having a diameter smaller than the at least one contact part and the engagement part being configured to engage with the n pistons. In these embodiments, in addition to the skew suppressing effect, there are following advantages. As the engagement part of the roller with respect to the piston has a small diameter, it is possible to arrange the cylinder near the rotation part. This has the advantage of compact configuration of the cylinder block accommodating the cylinder.

[0018] In some embodiments, each of the at least one roller includes a cylindrical member which is fixed to the n pistons and at least one ring member configured to contact the cam at an outer periphery and to rotate around the cylindrical member, and each of the at least one ring member includes a lubrication part to be supplied with lubricating oil, the lubrication part being provided on an inner periphery of said ring member.

[0019] In this case, the cylindrical member is supported by the ring member via an oil film of the lubricating oil. This allows, to some extent, for a relative movement of the cylindrical member relative to the ring member (e.g. tilting of the cylindrical member relative to the ring member, where the axis of the cylindrical member tilts relative to the axis of the ring member). Thus, even if there is difference in position or dimension among the n pistons and the n cylinders due to manufacture tolerance, this difference in size and dimension can be absorbed by the relative movement between the ring member and the cylindrical member so that the n pistons can be reciprocated smoothly in the n cylinders.

[0020] In each of the aforesaid n pistons and the cylindrical member, a supply line is provided for supplying operating oil of a hydraulic chamber formed by the piston and the cylinder as the lubricating oil to the lubrication part.

[0021] By using as the lubricating oil the operating oil of the hydraulic chamber formed by the piston and the cylinder in the above manner, the supply line for supplying the lubricating oil to the lubrication part can be formed in the piston and in the cylindrical part, instead of outside the cylinder. As a result, it is possible to attain the above effect of smooth reciprocating of the n pistons in the n cylinders, with a simple configuration.

[0022] Each of the aforesaid n pistons has a piston circumferential surface which is crowned so that an outer diameter of an end of the piston in an axial direction of the piston is smaller than an outer diameter of a center of the piston in the axial direction.

[0023] With this configuration of the piston 44, even when the axes of the n pistons sharing the one roller are tilted relative to the axes of the n cylinders, respectively, it is possible to prevent contact (seizure) of an edge part of the piston head belonging to each of the pistons with respect to the inner peripheral surface of the cylinder. Thus, even if there is difference in position or dimension among a plurality of the cylinders and a plurality of the pistons due to manufacture tolerance, assembling thereof can be easy. Further, even if there is difference in position or dimension among a plurality of the cylinders and a plurality of the pistons due to manufacture tolerance, the pistons can be reciprocated smoothly in the cylinders, respectively.

[0024] In some embodiments, an oil supply valve is also provided to collectively change a supply state of operating oil to n hydraulic chambers formed by the n pistons and n cylinders of the plurality of cylinders corresponding to the n pistons, respectively. With this configuration, only one oil supply valve is needed for supplying the operating oil to the n hydraulic chambers and thus, the number of the oil supply valves can be reduced. As a result, it is possible to simply the configuration of the hydraulic machine.

[0025] In some embodiments, the cylinder block comprises: a cylinder cartridge having at least one cylinder of n cylinders of the plurality of cylinders corresponding to the n pistons; a cylinder block body having a cartridge hole into which the cylinder cartridge is inserted, and the hydraulic machine further comprises a cover member attached to the cylinder block body so as to restrict the cylinder cartridge inserted in the cartridge hole, so to prevent it from coming out from the cylinder block body along the radial direction.

[0026] By mounting the cover member on the cylinder block body, it is easy to restrict the cylinder cartridge from coming out from the cylinder block body.

[0027] In some embodiments, the cylinder block comprises: a cylinder cartridge having n cylinders of the plurality of cylinders corresponding to the n pistons; and a cylinder block body having a cartridge hole into which the cylinder cartridge is inserted, and the cylinder cartridge is configured to be removable from and insertable into the cylinder block body in such a state that the n pistons are integrated with the roller corresponding to the n pistons.

[0028] When the roller or the n pistons need to be replaced due to influence of the frictional wear or the like, the roller and the n pistons can be replaced in a unitized state. This reduces workload for replacing the parts and also facilitates maintenance of the hydraulic machine.

[0029] In some embodiments, the cylinder cartridge is configured removable from the cylinder block body to an opposite side of the cam in a radial direction of the hydraulic machine in such a state that the cylinder cartridge is integrated with a valve for controlling a state of communication between a hydraulic chamber formed by the piston and the cylinder and an outside of the hydraulic chamber.

[0030] At the replacement of the valve, the valve is replaced in the state where the cylinder cartridge is integrated with the valve. This reduces workload for replacing the valve and also facilitates maintenance of the hydraulic machine. Further, the cylinder cartridge can be removed without removing the cam from the hydraulic machine and without causing interference between the cylinder cartridge and the cam. This further facilitates the replacement work of the cylinder cartridge.

[0031] In some embodiments, the cylinder block is configured to be separable into a plurality of segments each of which includes n cylinders of the plurality of cylinders corresponding to the n pistons.

[0032] By using the cylinder block which is separable per each of the segments which includes n cylinders associated with one roller that is shared by n pistons as described above, one roller, n pistons and one segment of the cylinder block holding the roller and the n pistons can be integrally removed and attached at the replacement thereof. Therefore, this facilitates assembling and disassembling of the cylinder block including the rollers, the pistons and the cylinders. This also facilitates maintenance and inspection of the roller, the piston and the like.

[0033] In some embodiments, the cylinder block body is formed in a continuous manner over an entire circumference in a circumferential direction of the hydraulic machine.

[0034] For instance, in the case where the hydraulic machine constitutes a hydraulic machine for a drive train of a wind turbine generator, when replacing a part of the segments at the site, the wind load acts on the cylinder block to some extent. Thus, immediately after the segment is removed, the positions of remaining segments are slightly displaced. This makes it difficult to mount a new segment. In view of this, by forming the cylinder block body in a continuous manner over the entire circumference in the circumferential direction of the hydraulic machine, it is possible to solve problems resulting from assembling of the segments.

[0035] In some embodiments, the plurality of cylinders is provided on a moving path of n cylinders of the plurality of cylinders corresponding to the n pistons when the n cylinders are (virtually) moved in a spiral or spiral-like manner around an axis of the hydraulic machine.

[0036] By arranging a plurality of the cylinders in this manner, a contact position of the cam and an edge of each roller supporting the n pistons can be easily distributed in the axial direction of the hydraulic machine. Thus, even if the contact surface pressure between the cam and the roller is locally high near the edge of the roller, as the contact position of the edge of each roller and the cam is distributed in the axial direction, it is possible to effectively suppress generation of scratches and friction wear on the cam surface.

[0037] A wind turbine generator according to some embodiments of the present invention comprises:

at least one blade;
a hub on which the at least one blade is mounted;
a hydraulic pump configured to be driven by rotation of the hub;
a hydraulic motor configured to be driven by pressurized oil generated by the hydraulic pump; and
a generator configured to be driven by the hydraulic motor,
wherein at least one of the hydraulic pump or the hydraulic motor is a radial piston hydraulic machine,
wherein the radial piston hydraulic machine comprises: a plurality of pistons; at least one roller; a cylinder block comprising a plurality of cylinders configured to guide the plurality of pistons reciprocably along a radial direction of the hydraulic machine, respectively; and a cam configured to contact each of the at least one roller, and
wherein each of the at least one roller is provided for n pistons of the plurality of pistons, the n pistons being arranged along an axial direction of the hydraulic machine to share said each of the at least one roller, n being an integer not less than two.

[0038] As a result, by supporting the roller by at least two points that are apart in the axial direction, it is possible to effectively suppress generation of the skew phenomenon at the roller. Therefore, it is possible to suppress generation of partial stress between the cam and the roller. This enables smooth transmission of the power between the cam and the roller. Further, by supporting the roller at two or more supporting points in the axial direction, it is possible to effectively increase a load carrying capacity of the roller between the supporting points. Thus, even if the length of the roller is increased in the axial direction, it is possible to support the roller reliably. Therefore, it is possible to achieve smooth operation of the radial piston hydraulic machine and also to improve power generation efficiency of the wind turbine generator.

[Advantageous Effects]

[0039] According to some embodiments of the present invention, each roller is provided for n pistons that are aligned along an axial direction of the hydraulic machine, n being an integer not less than two and thus, the roller is supported at two or more points that are apart from each other in the axial direction. This effectively suppresses generation of the skew phenomenon at the roller. As a result, it is possible to suppress generation of partial stress between the cam and the roller and also to prevent generation of partial stress between the cam and the roller. This enables smooth transmission of the power between the cam and the roller. Further, by supporting the roller at two or more supporting points that are apart in the axial direction, it is possible to effectively increase a load carrying capacity of the roller between the supporting points. Thus, even if the length of the roller is increased in the axial direction, it is possible to support the roller reliably.

BRIEF DESCRIPTION OF DRAWINGS

[0040]

[FIG.1]
FIG.1 is an illustration of a wind turbine generator to which a radial piston hydraulic machine according to one embodiment is applied.
[FIG.2]
FIG.2 is a cross-sectional view of a hydraulic machine according to one embodiment.
[FIG.3]
FIG.3 is a schematic view of oil paths of the hydraulic machine according to one embodiment.
[FIG.4]
FIG.4 is an oblique view of a part of a cylinder block of the hydraulic machine according to one embodiment.
[FIG.5]
FIG.5 is an oblique view of a modification example of the cylinder block.
[FIG.6]
FIG.6 is an oblique view of a part of the cylinder block according to one embodiment.
[FIG.7]
FIG.7 is a front view of a configuration example of a piston and a roller according one embodiment.
[FIG.8]
FIG.8 is a cross-sectional view of a cylinder block body and a cylinder assembly according to one embodiment.
[FIG.9]
FIG.9 is a cross-sectional view of the cylinder assembly according to one embodiment.
[FIG.10]
FIG.10 is a cross-sectional view of the cylinder assembly according to one embodiment.
[FIG.11]
FIG.11 is a cross-sectional view of a part of the cylinder block according to one embodiment.
[FIG.12]
FIG. 12 is a front view of a configuration example of the piston and the roller according one embodiment.
[FIG.13]
FIG. 13 is an oblique view of the cylinder block according to one embodiment.
[FIG.14]
FIG. 14 is an expansion view of the cylinder block according to one embodiment.
[FIG.15]
FIG.15 is a local sectional view of a configuration example of the piston and the roller according to one embodiment.
[FIG.16]
FIG. 16 is an illustration of a configuration example of the piston and the roller according to one embodiment, showing load distribution at positions in an axial direction of the roller.

DETAILED DESCRIPTION

[0041] Embodiments of the present invention will now be described in detail with reference to the accompanying drawings. It is intended, however, that unless particularly specified, dimensions, materials, shapes, relative positions and the like of components described in the embodiments shall be interpreted as illustrative only and not limitative of the scope of the present invention.

[0042] First, some embodiments are now described in reference to FIG.1 to FIG.4.

[0043] FIG.1 is a schematic illustration of a configuration example of a wind turbine generator to which a radial piston hydraulic machine according to one embodiment is applicable. A wind turbine generator 10 illustrated in FIG.1 comprises a rotor 12 configured by at least one and typically at least two blades 14 and a hub 16 to which the blades 14 are radially connected. The hub 16 may be covered by a hub cover 18. A hydraulic pump 22 is connected to the rotor 12 via a rotation shaft 12. A hydraulic motor 28 is connected to the hydraulic pump 22 via a high pressure oil line 24 and a low pressure oil line 26. More specifically, an outlet of the hydraulic pump 22 is connected to an inlet of the hydraulic motor 28 via the high pressure oil line 24, while an inlet of the hydraulic pump 22 is connected to an outlet of the hydraulic motor 28 via the low pressure oil line 26.

[0044] The hydraulic pump 22 is driven by the rotation shaft 20 to pressurize operating oil, thereby generating high pressure operating oil (pressurized oil). The pressurized oil generated by the hydraulic pump 22 is supplied to the hydraulic motor 28 via the high pressure oil line 24 to drive the hydraulic motor 28. The operating oil having performed work in the hydraulic motor 28 turns into low pressure operating oil. This low pressure operating oil is returned to the hydraulic pump 22 via the low pressure oil line 26.

[0045] Further, a generator 30 is connected to the hydraulic motor 28. The generator 30 is a synchronous generator configured to be driven by the hydraulic motor 28 and is connected to a grid not shown.

[0046] The rotor shaft 20 is at least in part covered by a nacelle 32. The hydraulic pump 22, the hydraulic motor 28 and the generator 30 are installed inside the nacelle 32 installed to an upper end of the tower 34. In this embodiment and other embodiments described below, at least one of the hydraulic pump 22 or the hydraulic motor 28 is the radial piston hydraulic machine which is described hereinafter.

[0047] FIG.2 is a longitudinal section of a hydraulic machine according to one embodiment. A hydraulic machine 40 illustrated in FIG.2 configures the hydraulic pump 22 or the hydraulic motor 28. The hydraulic machine 40 comprises a plurality of cylinders 42 formed along the radial direction of the hydraulic machine 40, a plurality of pistons provided slidably in the plurality of cylinders 42, respectively, and a cylinder block in which the plurality of cylinders 42 is provided. The cylinders 42 are disposed at equal intervals in the circumferential direction and axial direction (arrow a) of the cylinder block 48. Each of the pistons 44 is configured to reciprocate in the cylinder 42 along the radial direction of the hydraulic machine 40. In response to the reciprocating motion of each of the piston 44, volume of a hydraulic chamber r formed by the piston 44 and the cylinder 42 changes cyclically.

[0048] A rotation shaft 50 is centrally arranged inside the cylinder block 48. In the case where the hydraulic machine 40 is the hydraulic pump 22, the rotation shaft 50 is provided integrally with the rotor shaft 20 or configured to rotate in interlink with the rotor shaft 20. A ring cam 52 is mounted to an outer peripheral surface of the rotation shaft 50. The ring cam 52 is configured to rotate with the rotation shaft 50 and has a cam face contacting a roller 46 provided to the piston 44. In this case, to cause a relative rotational motion of the ring cam 52 relative to the roller 46, at least one bearing 54a may be provided between the cylinder block 26 and the ring cam 52.

[0049] The reciprocating motion of the piston 44 which accompanies cyclic volume change of the hydraulic chamber r is convertible into a rotational motion of the ring cam 52, and vice versa. For instance, in the case where the hydraulic machine 40 is the hydraulic pump 22, the rotational motion of the ring cam 52 rotating with the rotation shaft 50 is converted into a reciprocating motion of the piston 44. As a result, the volume of the hydraulic chamber r changes cyclically, thereby generating high pressure operating oil in the hydraulic chamber r. This high pressure oil is used to drive the hydraulic motor 28.

[0050] In the case where the hydraulic machine 40 is the hydraulic motor 28, the reciprocating motion of the piston 44 occurs in response to feeding of this high pressure oil to the hydraulic motor 28 from the hydraulic pump 22. Then, the reciprocating motion of the piston 44 is converted into the rotational motion of the ring cam 52. As a result, the rotation shaft 50 of the hydraulic machine 40 rotates with the ring cam 52. In this manner, by the movement of the ring cam 52, the energy is converted between rotational energy (mechanical energy) of the rotation shaft 50 of the hydraulic machine 40 and fluid energy of the operating oil. Therefore, the hydraulic machine 40 is capable of serving an intended function as the hydraulic pump 22 or the hydraulic motor 28.

[0051] In the cylinder block 48, at least one inner oil path 56 (56a, 56b) communicating with a plurality of the hydraulic chambers r is formed. In one embodiment, a plurality of the inner oil paths 56 (56a, 56b) is provided along the axial direction of the hydraulic machine 40. Further, an end plate 60 is provided at one end face of the cylinder block 48. The end plate 60 is an annular plate member. An annular collecting path 58 (58a, 58b) communicating with the plurality of inner oil paths 56 (56a, 56b) is formed in the endplate 60. In one embodiment, the bearing 54b is provided between the endplate 60 and the ring cam 52, and the endplate 60 can be maintained in a stationary state without being affected by the rotational motion of the ring cam 52.

[0052] The annular collecting paths 58 (58a, 58b) are respectively connected to outer pipes 62 (62a, 62b). In this manner, each of the hydraulic chambers r is configured to communicate with the outer pipes 62 (62a, 62b) via the inner oil paths 56 (56a, 56b) and the annular collecting paths 58 (58a, 58b). In some embodiments, the cylinder block 48 includes a plurality of cylinder sleeves 64 as cylinder cartridges which form cylinders 42, and a cylinder block body 66 having a plurality of sleeve holes 66a into which the plurality of cylinder sleeves 64 is inserted, respectively.

[0053] As some of the functions that the cylinder block 48 is expected to serve, there are the function of forming the cylinder 24 as the slide part for guiding the piston 44 slidably and the function of forming a structure for supporting the cylinder 42. By providing the cylinder sleeve 64 and the cylinder block body 66 separately as described above, the cylinder sleeve 64 and the cylinder block body 66 can share the functions expected in the cylinder block 48 (formation of the cylinder 42 and formation of the structure). This enables designing of the cylinder sleeve 64 and the cylinder block body 66 according to their respective functions, hence achieving reduced weight of the cylinder block 48 as a whole.

[0054] FIG.3 is a schematic view of oil paths for supplying or discharging the operating oil with respect to the hydraulic machine 40. In FIG.3, branch oil paths 70a, 70b are provided to connect each of the inner oil paths 56 (56a, 56b) to the hydraulic chamber r. On-off valves 72a, 72b are provided in the branch oil paths 70a, 70b, respectively. One of the inner oil paths 56a, 56b is an oil supply path for supplying the operating oil to the hydraulic chamber r, and the other one of the inner oil paths 56a, 56b is an oil discharge path for discharging the operating oil from the hydraulic chamber r.

[0055] The on-off valves 72a, 72b are controlled so as to open or close in synchronization with the rotational motion of the ring cam 52 in the circumferential direction. Specifically, in a cycle where the roller 46 contacting the cam face of the ring cam 52 moves from a bottom dead center toward the top dead center, the on-off valve provided in the oil discharge path is opened while the on-off valve provided in the oil supply path is closed. Further, in a cycle where the roller 46 moves from the top dead center toward the bottom dead center, the on-off valve provided in the oil supply path is opened while the on-off valve provided in the oil discharge path is closed. As the on-off valves 72a, 72b, electromagnetic valves or spring-type on-off valves may be used, for instance. The spring-type on-off valve is provided with a spring for energizing a valve element toward a seat surface and is configured to move the valve element between an closed position and an open position by using a hydraulic pressure of the hydraulic chamber r and a balance between an elastic force of the spring and the hydraulic pressure.

[0056] In an exemplary embodiment illustrated in FIG.3, the ring cam 52 has a plurality of crest portions (a plurality of lobes) 74a disposed along a circumferential direction of the hydraulic machine 20 to contact the rollers 46. On the cam face of the ring cam 52, the plurality of crest portions (the plurality of lobes) 74a and a plurality of trough portions 74b are alternately arranged along the circumferential direction. The lobes 74a move in the circumferential direction in response to rotation of the ring cam 52.

[0057] FIG.4 is an oblique view of a part of the cylinder block 48. The cylinder block 48 is configured to be separable into a plurality of segments 48a in the circumferential direction. In one segment 48a, n cylinder sleeves 64 are arranged corresponding to n pistons (n being an integer not less than 2). Specifically, a cylinder array 76 is disposed in one segment 48a, and the cylinder array 76 is formed by n cylinders 42 (see FIG.2) disposed in the axial direction in correspondence to the n pistons. A holding part 44a is formed at an end of the piston 44 provided in each of the n cylinder sleeves 64 so as to surround the roller 46 from both sides. One roller 46 having a cylindrical shape is rotatably held by a plurality of the holding parts 44a belonging, respectively, to the plurality of pistons 44. The outer peripheral surface of the piston 44 has a stepless configuration without step difference. The n cylinder sleeves 64 are aligned in the axial direction of the cylinder sleeve 64 (in the direction of arrow a), and the roller 46 extends along the axial direction. An arc-shaped notch 64a is formed at an end of the cylinder sleeve 64 so that the roller 46 enters the notch 64a when the piston 44 reaches the top dead center.

[0058] The lobe 74a of the ring cam 52 is configured to extend linearly in the axial direction over an axial area L occupied by the cylinder array 76. Further, the roller 46 is disposed along the extending direction of the lobe 74a and contacts the cam face. The roller 46 has a cylindrical shape, and its outer peripheral surface has a stepless configuration to contact the cam face of the ring cam 52 across the entire area in the axial direction.

[0059] As illustrated in FIG.5, in the case where the number of the cylinder sleeves 64 in the axial direction is large, the cylinder block 48 may be formed by segments 48a so that the cylinder block 48 is separable into the segments 48a not only in the circumferential direction but in the axial direction.

[0060] The cylinder block 48 may have the configuration which his not separable into segments in the circumferential direction or the axial direction. Specifically, the cylinder block body 66 may be formed to be continuous across the entire circumference in the circumferential direction (the direction of arrow b of FIG.4) of the hydraulic machine 40. For instance, in the case where the hydraulic machine 40 constitutes a hydraulic machine for a drive train of a wind turbine generator, when the segments 48a needs to be partially replaced at the site, the wind load impinges on the cylinder block 48 to some extent. Thus, immediately after the segment 48a is removed, the positions of remaining segments are slightly displaced. This makes it difficult to mount a new segment. In view of this, by forming the cylinder block body 66 in a continuous manner over the entire circumference in the circumferential direction of the hydraulic machine 40, it is possible to solve problems resulting from assembling of the segments 48a.

[0061] In the embodiment illustrated in FIG.4 and FIG.5, the roller 46 is provided for the n pistons aligned in the axial direction of the hydraulic machine in the axial direction of the roller 46). Specifically, the roller 46 is held at multiple places that are apart from one another in the axial direction of the roller 46, by means of the n pistons 44. Thus, it is possible to prevent the axis of the roller 48 from moving away from a ridge line direction of the lobe 74a. This suppresses generation of the skew phenomenon of the roller 46. Further, by supporting the roller 46 at multiple points, the roller 46 can be supported reliably. As a result, it is possible to suppress generation of partial stress between the ring cam 52 and the roller 46. This enables smooth transmission and conversion of the power and prevents performance decrement of the hydraulic machine 40. Further, as the roller 46 contact the cam face over the entire axial area of the roller 46, the contact area of the roller 46 with respect to the cam face can be increased in the axial direction. Thus, it is possible to reduce the contact surface pressure between the roller 46 and the cam face. Even if the diameter of the roller 46 is relatively small, it is possible to keep the contact surface pressure in an appropriate range and also possible to prevent fatigue fracture of the roller 46, the ring cam 52, the pistons 44 and the like.

[0062] As it is possible to reduce the contact surface pressure of the roller 46 with respect to the cam face, it is no longer necessary to increase a diameter of a roller-side section of the piston 44. Thus, the outer diameter of the piston 44 can be the same on the hydraulic chamber side and on the roller side. This allows the stepless configuration of the outer peripheral surface of the piston 44. Therefore, it is possible to facilitate machining of the piston 44 and the cylinder sleeve 64 and also to achieve reduced cost. Further, the lobe 74a of the ring cam 52 is configured to extend linearly in the axial direction and thus, it is possible to improve the degree of freedom in arranging the roller 46 which is provided for the n pistons 44 aligned in the axial direction of the hydraulic machine 40.

[0063] As the cylinder block 48 is separable by each segment 48a, it is easy to assemble and disassemble the cylinder block 48. This makes it easy to perform maintenance and replace parts that are arranged inside the cylinder block 48. Further, by configuring the cylinder sleeve 64 to be removable from the cylinder block 48, it is easy to attach and remove the cylinder sleeve 64 and also to perform maintenance and inspection of the cylinder sleeve 64.

[0064] Next, another configuration example of the n pistons 44 and the roller 46 is described in reference to FIG.6 and FIG.7. The roller 46 illustrated in FIG.6 and FIG.7 has a section 46a and another section 46b. The section 46a is held by the holding part 44a of the piston 44 and has a diameter different from that of the section 46b. Specifically, the diameter of the section 46a is smaller than the diameter of the section 46b. The small-diameter section 46a and the large-diameter section 46b are concentrically arranged, and a stepped portion is formed between the small-diameter section 46a and the large-diameter section 46b. The small-diameter section 46a (an engagement part) is configured to engage with the piston 44. The large-diameter section 46b is configured so that the outer periphery contacts the cam face4. The rest of the configuration is substantially the same as the embodiment described in reference to FIG.1 to FIG.4.

[0065] With the above configuration, it is possible to arrange the cylinder sleeve 64 and the piston 44 closer to the ring cam 52. Thus, it has the advantage of compact configuration of the cylinder block 48 accommodating the cylinder sleeve 64.

[0066] Next, a configuration example in which the n pistons 44 and the roller 46 are configured as a cartridge is described in reference to FIG.8 and FIG.9. The embodiment illustrated in FIG.8 and FIG.9 is one example in which the hydraulic machine 40 composes the hydraulic pump 22. As illustrated in FIG.8, a plurality of cartridge holes 80 having an oval shape is formed in the cylinder block body 66 in the circumferential direction. A cylinder assembly 82A is installed in each of the cartridge holes 80. The configuration of the cylinder assembly 82A is explained below.

[0067] As illustrated in FIG.8 and FIG.9, the cylinder assembly 82A has an oval base plate 84. The area of the base plate 84 is larger than the area of the cartridge hole 80, and the base plate 84 has an oval shape similar to the shape of the cartridge hole 80. As illustrated in FIG.9, a cylinder cartridge 86 is mounted on the base plate 84. In the cylinder cartridge 86 as a cylinder casing, n hydraulic chambers r (n being an integer not smaller than 2) are formed. The cylinder cartridge 86 is mounted on one surface of the base plate 84 and fastened to the base plate 84 by fastening members 88 (e.g. bolts).

[0068] In the cylinder cartridge 86a, between the chambers r of the cylinder cartridge 86a, a partition wall 86a is formed at a position nearer to the base plate 84 than a position of a pressure receiving face 44b of the piston 44 at the top dead center. Between the partition wall 86a and the base plate 84, an operating oil space s1 is formed to communicate with each of the hydraulic chambers r of the cylinder cartridge 86a. Preferably each of the hydraulic chambers r is at the same distance from the operating oil space s1. The base plate 84 has a communication hole 84a formed therein. The communication hole 84a is preferably arranged in a center region of the base plate 84 and to face the operating oil space s1. The end of each of the pistons 44 clasps one common roller 46 from both sides and has a holding part 44a for rotatably holding the roller 46.

[0069] A retaining arm 90 is integrally provided in the holding part 44a of the piston 44 disposed on each side of the roller 46. A needle-like retaining end 90a projecting from the retaining arm 90 contacts the center of the roller 46 to restrict movement of the roller 46 in the axial direction. As the center of the roller 46 does not rotate, there is no friction between the retaining end 90a and the roller 46. Therefore, there is no frictional wear between these parts. In this manner, the movement of the roller 46 in the axial direction is restricted by the retaining arms 90.

[0070] On the other surface of the base plate 84, a high pressure valve block 92 and a low pressure valve block 104 are mounted. A casing 94 which forms the high pressure valve block 92 is detachably mounted on the base plate 84 by fastening members (e.g. bolts) 102. A high-pressure oil discharge pipe 96 is provided in the casing 94. In a space formed inside the casing 94, a spring-type on-off valve 98 is provided. The spring type on-off valve 98 is configured by a spherical valve element 99 and a coil spring 100. A valve seat 94a is formed on an inner wall of the casing 94. The coil spring 100 is configured to apply a pressing force for pressing the valve element 99 to the valve seat 94a. Between the valve seat 94a and the communication hole 84a, an operating oil space s2 is formed. When the hydraulic pressure acting on the valve element 99 via the operating oil space s2 exceeds the pressing force of the spring 100, the spring type on-off valve is released and hence the operating oil space s2 communicates with the high-pressure oil discharge pipe 96.

[0071] A casing 106 which forms the low pressure valve block 104 is detachably mounted on the base plate 84 by fastening members (e.g. bolts) 115. A low-pressure oil supply pipe 108 is connected to the casing 106. In the casing 106, an electromagnetic valve 110 is provided. A coil 114 is provided around a valve rod 112 of the electromagnetic valve 110. The electric current flowing in the coil 114 generates a force that moves the valve rod 112. A valve seat 106a is formed inside the casing 106, and a coil spring 113 is provided inside the coil 114. When the electric current flows through the coil 114, a force in the direction of approaching the valve seat 106a acts on the valve element 111 of the electromagnetic valve 110 to block communication between the operating oil space s2 and the low-pressure oil supply pipe 108. When the electric current does not flow in the coil 114, the valve element 11 is unseated from the valve seat

106a by the spring force of the coil spring 113, and hence the low-pressure oil supply pipe 108 communicates with the operating oil space s2.

[0072] Holes 84b are formed in the base plate 84 near its outer edge, and the cylinder assembly 82A is inserted in the cartridge hole 80 of the cylinder block 66 and then installed in the cylinder block body 66 by fastening members (e.g. bolts) via the holes 84b. In a plurality of the cylinder assemblies 82A installed in the cylinder block body 66, the reciprocating motion of the piston 44 causes the high pressure oil to be discharged from the hydraulic chamber r to the high-pressure oil discharge pipe 96 and the operating oil to be supplied to the low-pressure oil supply pipe 108 from the hydraulic chamber r.

[0073] In the cylinder assembly 82A, an electromagnetic valve 110 is provided as an oil supply valve to collectively change a supply state of the operating oil to n hydraulic chambers r formed by the n pistons 44 and the n cylinder cartridges 86, respectively. As a result, only one oil supply valve is needed for the n hydraulic chambers r and thus, the number of the oil supply valves can be reduced and the cylinder block 48 can be reduced in size and cost.

[0074] Further, in the cylinder assembly 82A, a spring-type on-off valve is provided as an oil discharge valve to collectively change a discharge state of the operating oil from the n hydraulic chambers r formed by the n pistons 44 and the n cylinder cartridges 86, respectively. As a result, only one oil discharge valve is needed for the n hydraulic chambers r and thus, the number of the oil discharge valves can be reduced and the cylinder block 48 can be reduced in size and cost.

[0075] The n pistons 44 and the roller 46 illustrated in FIG.8 and FIG.9 constitute the cylinder assembly 82A as a cartridge which is detachable integrally with the cylinder casing with respect to the cylinder block body 66. As a result, when the roller 46 or the n pistons 44 need to be replaced due to influence of the frictional wear or the like, the cylinder assembly 82A can be replaced simply by removing the cylinder assembly 82A from the cylinder block body 66 and installing a new cylinder assembly 82A. This facilitates maintenance of the hydraulic machine 40.

[0076] The cylinder assembly 82A is configured removable from the cylinder block body 66 to an opposite side of the cam 52 in the radial direction of the hydraulic machine 40 (the direction of arrow P). As a result, to replace the cylinder assembly 82A, the cylinder assembly 82A alone can be removed without removing the cam 52 from the hydraulic machine 40 and this causes no interference between the cylinder assembly 82A and the cam 52. As a result, this further facilitates the replacement work of the cylinder assembly 82A.

[0077] As for the cylinder assembly 82A, the operating oil spaces s1 and s2 are formed in communication with each of the hydraulic chambers r, an inlet of the high-pressure valve block 92 and an inlet of the low-pressure valve block 104 face the operating oil space s2, and these valve blocks are arranged with the same distance from the communication hole 84a. This makes it possible to supply or discharge the operating oil equally with respect to each of the hydraulic chambers r and these valve blocks. Therefore, the surface pressure can be generated equally over the entire contact area of the axially long roller 46 with respect to the cam face. As a result, the hydraulic machine 40 can operate smoothly, and uneven wear does not occur on the lobe 74a and the cam face of the ring cam 52, which result in enhanced life of these parts.

[0078] Further, as for the cylinder assembly 82A, the casing 94 for the high-pressure valve block 92 and the casing 106 for the low-pressure valve block 104 are configured such that a top cover 103 belonging to the casing 94 and a top cover 116 belonging to the casing 106 are formed separately from the casing body and mounted on the casing body by fastening embers (e.g. bolts) 118. Thus, at the maintenance and inspection, the top covers 103, 116 can be removed to facilitates the maintenance and inspection of the components arranged in the casing.

[0079] Next a cylinder assembly 82B which is a modified example of the cylinder assembly 82A is described in reference to FIG.10. FIG.10 illustrates one example in which the hydraulic machine 40 composes the hydraulic pump 22. As for the cylinder assembly 82B of the embodiment illustrated in FIG.10, the cylinder cartridge 86, the piston 44 and the rollers 46 which have the same configuration as those of the embodiment illustrated using FIG.8 and FIG.9, are mounted on one surface of a base plate 120. Thus, these components are given the same reference numerals as those of the embodiment illustrated using FIG.8 and FIG.9 and are not explained further.

[0080] The common operating oil space s1 is formed to communicate with each of the hydraulic chambers r. The base plate 120 has a communication hole 120a formed in its center region. On the outer edge of the base plate 120, holes 120b are formed. The base plate 120 is mounted on the cylinder block body 66 using fastening members (e.g. bolts) via the holes 120b.

[0081] On the other surface of the base plate 120, a spring-type on-off valve 126 having the same configuration as the spring-type on-off valve 98 illustrated in FIG.9 and an electromagnetic valve 128 having the same configuration as the electromagnetic valve 110 illustrated in FIG.9 are aligned along the radial direction of the hydraulic machine 40 (a direction of arrow c). On the other surface of the base plate 120, a casing 122 and a casing 124 are arranged along the radial direction of the hydraulic machine 40 and are joined together by a fastening member. The on-off valve 126 is provided in the casing 122, and the electromagnetic valve 128 is provided in the casing 124. The operating oil space s2 is formed between the base plate 120 and the spring-type on-off valve 126, and an inlet of the electromagnetic valve 128 communicates with the operating oil space s2 via an oil path 130 formed in the casing 122.

[0082] In the casing 122, a high pressure oil discharge path 132 is formed communicating with the operating oil space s2 via the on-off valve 126. In the casing 124, a low pressure oil supply path 134 is formed communicating with the oil path 130 via the electromagnetic valve 128. A plurality of the pistons 44 connected to one roller 46 move in synchronization. When each of the pistons 44 approaches the top dead center and each of the hydraulic chambers 3 becomes pressurized, the spring-type on-off valve 126 opens to discharge the high pressure oil to the high pressure oil discharge path 132. When each of the pistons 44 approaches the bottom dead center, the electromagnetic valve 128 opens to supply the low pressure oil to each of the hydraulic chambers r from the low pressure oil discharge path 134.

[0083] According to this embodiment, in addition to the effects similar to those obtained in the embodiment illustrated by FIG.8 and FIG.9, it is possible to downsize the casings which incorporate the spring-type on-off valve 126 and the electromagnetic valve 128, as the casings 122 and 124 disposed in the radial direction of the hydraulic machine 40 can accommodate the spring-type on-off valve 126 and the electromagnetic valve 128. Therefore, it is possible to downsize the valve block arranged on the outer side of the cylinder block body 66.

[0084] In the embodiment illustrated in FIG.10, the base plate 120 and the cylinder block body 66 are joined together by fastening members penetrating the holes 120b formed in the base plate 120. Alternatively, as illustrated in FIG.11, a cover member 129 may be provided to cover the whole cylinder assembly 82B, and the cover member 129 and the cylinder block body 66 may be joined together by fastening members penetrating holes 129a formed in the cover member 129. The cover member 129 is configured to restrict the cylinder assembly 82B inserted in the cartridge hole 80 formed in the cylinder block body 66 from coming out from the cylinder block body 66 along the radial direction. By mounting the cover member 129 on the cylinder block body 66, it is possible to easily restrict the cylinder assembly 82B from coming out from the cylinder block body 66. Further, the cover member 129 covers the whole cylinder assembly 82B and thus, it is possible to effectively restrict the cylinder assembly 82B from coming out from the cylinder block body 66.

[0085] Another configuration example of the roller 46 and the piston 44 is described in reference to FIG.12. FIG.12 is an illustration of the configuration example for preventing the roller from moving in the axial direction. In the embodiment illustrated in FIG.12, in the same manner as the foregoing embodiments, one roller 46 is rotatably held by the holding parts 44a of the pistons 44. The roller 46 has a stepped portion 140 in a region between the pistons 44, and this region forms a small diameter section 142. In other region of the roller 46, a large diameter section 144 which is larger in diameter than the small diameter section 142. The large diameter section 144 contacts the cam face. A frame 146 is provided between the pistons 44 and adjacent to the outer periphery of the roller 46. In the frame 146, a projection 148 is formed, which projects toward the roller 46 and is freely fitted to the stepped portion 140.

[0086] In the embodiment illustrated in FIG.12, the projection 148 is inserted in the small diameter section 142 to prevent the axial movement of the roller 46. Thus, it is not necessary to provide the restraining arm 90 illustrated in FIG. 9 in the piston 44. Therefore, it is not necessary to adapt the axial direction dimension of the roller 46 to the restraining arm 90. This enhances the degree of freedom in designing the roller 46.

[0087] In reference to FIG.13 and FIG.14, a disposition example of the cylinders 42 is described. FIG.13 is an oblique view of the cylinder block 48, and FIG.14 is an expansion view of the cylinder block 48 illustrated in FIG.13. In some embodiments, the hydraulic machine 40 can be configured similarly to the configuration described in reference to FIG. 1 to FIG.4, except for the disposition of the cylinders 42 illustrated in FIG.13 and FIG.14.

[0088] As for the cylinder block 48 illustrated in FIG. 13 and FIG. 14, a plurality of the cylinders 42 is provided on a moving path 102 of the cylinder array 76 when the cylinder array 76 is moved in a spiral or spiral-like manner around an axis 101 of the hydraulic machine 40. The cylinder array 76 is formed by n cylinders 42 aligned along the axial direction of the hydraulic machine 40 corresponding to n pistons. By arranging a plurality of the cylinders 42 in this manner, a contact position Q (see FIG.4) between an edge of the roller 46 supporting the n pistons 44 and the cam 52 can be easily distributed in the axial direction of the hydraulic machine 40. Thus, even if the contact surface pressure between the cam 52 and the roller 46 is locally high near the edge of the roller 46, as the contact position Q between the edge of each roller 46 and the cam 56 is distributed in the axial direction, it is possible to effectively suppress generation of scratches and friction wear on the cam surface.

[0089] Next, another configuration example of the roller 46 and the piston 44 is described in reference to FIG.15. The roller 46 illustrated in FIG.15 includes a cylindrical member 150 which is fixed to n pistons 44 and a ring member 152 configured to contact the cam at a peripheral surface and to rotate around the cylindrical member 150. Herein, the cylindrical member 150 is fixed to the pistons 44 so as not to rotate relative to the pistons 44. The ring member 152 includes a lubrication part 154 on an inner periphery of the ring member 152 to be supplied with lubricating oil. In this case, the cylindrical member 150 is supported by the ring member 152 via an oil film of the lubricating oil. This allows, to some extent, for the movement of the cylindrical member 150 relative to the ring member 152 (e.g. tilting of the cylindrical member 150 relative to the ring member 152, where the axis of the cylindrical member 152 tilts relative to the axis of the ring member 152). Thus, even if there is difference in position or dimension among the n pistons 44 sharing the one roller 46 and the n cylinders 42 corresponding to the n pistons 44 due to manufacture tolerance, this difference in size and dimension can be absorbed by the relative movement between the ring member 152 and the cylindrical member 150 so that the n pistons 44 can be reciprocated smoothly in the n cylinders 42.

[0090] Inside each of the n pistons 44 and inside the cylindrical member 150 that are illustrated in FIG.15, a supply line 156 is formed to supply the operating oil as lubricating oil to the lubrication part from the hydraulic chamber r formed by the piston 44 and the cylinder 42.

[0091] By using as the lubricating oil the operating oil of the hydraulic chamber r formed by the piston 44 and the cylinder 42, the supply line 156 for supplying the lubricating oil to the lubrication part 154 can be formed in the piston 44 and in the cylindrical part 150 instead of outside the cylinder 42. As a result, it is possible to achieve smooth rotation of the ring member 152 relative to the cylindrical member 150 with a simple configuration.

[0092] On the peripheral surface of the cylindrical member 150 illustrated in FIG.15, a supply port 158 is provided to supply the lubricating oil from the supply line 156 to the lubrication part 154. The supply port 158 is provided in the peripheral surface of the cylindrical member 150 on a side (the cam 52 side) opposite to the hydraulic chamber r. As a result, the pressure of the oil film acts on the ring member 152 against the force that the ring member 152 receives from the cam 52. Thus, even if the force that the ring member 152 receives from the cam 52 changes due to a pressure change in the hydraulic chamber r, it is possible to maintain the oil film between the ring member 152 and the cylindrical member 150. This action works strongly in the period when the pressure in the hydraulic chamber is relatively high and the oil film is prone to deficiency. Thus, it is possible to favorably maintain the oil film even when the pressure in the hydraulic chamber changes.

[0093] The supply line 156 illustrated in FIG.15 is provided with a seal member 159 in a boundary area between the piston 44 and the cylindrical member 150. As a result, even in the case where the supply line 156 is provided inside the piston 44 and inside the cylindrical member 150, it is possible to supply the lubricating oil from the hydraulic chamber r to the supply port 158 while preventing leaking of the lubricating oil in the boundary area between the piston 44 and the cylindrical member 150 by means of the seal member 159.

[0094] As described above, the roller 46 illustrated in FIG.15 comprises a cylindrical member 150 which is fixed to the piston 44 and does not rotate, and a ring member 152 which is rotatable around the cylindrical member 150. Specifically, the roller 46 is configured such that the entire roller 46 does not rotate but at least a part of the roller 46 rotates.

[0095] Next, an example shape of the piston 44 is described in reference to FIG.16. The piston 44 illustrated in FIG. 16 is formed into a shape of a barrel. In other words, the piston 44 includes a piston peripheral surface 160 which is crowned such that an outer diameter R_2 of an axial direction end of the piston 44 (a piston head) is smaller than an outer diameter R_1 of an axial direction center part of the piston 44.

[0096] With this configuration of the piston 44, even when the axes of the n pistons 44 sharing the one roller 46 are tilted relative to the axes of the n cylinders 42 respectively, it is possible to prevent contact (seizure) of an edge part of the piston head belonging to each of the pistons 44 with respect to the inner peripheral surface of the cylinder 42. Thus, even if there is difference in position or dimension among a plurality of the cylinders 42 and a plurality of the pistons 44 due to manufacture tolerance, assembling thereof can be easy. Further, even if there is difference in position or dimension among a plurality of the cylinders 42 and a plurality of the pistons 44 due to manufacture tolerance, the pistons 44 can be reciprocated smoothly in the cylinders 42, respectively.

[0097] The shape of the piston 44 illustrated in FIG.16 (the outer diameter R_2 of the piston head being smaller than the outer diameter R_1 of the axial direction center part of the piston 44) is also applicable to pistons of any one of the embodiments described in reference to other drawings. The shapes of the pistons 44 may be made different from one another. For instance, in the case where three pistons 44 are provided for one roller 46 and aligned in the axial direction of the roller 46, the pistons 44 may have the following configurations. The piston peripheral surfaces 160 of these three pistons 44 may be configured such that a ratio (R_2/R_1) of the outer diameter R_2 of the piston head to the outer diameter R_1 of the piston axial center part is greater in one piston 44 disposed in the middle than other two pistons. In this case, the force (a side force) along the circumferential direction of the hydraulic machine 40 concentrates on the middle piston 44 among these three pistons 44 and the other two pistons 44 is not subjected to a large force. Therefore, the middle piston 44 bears the side force and the other two pistons 44 stabilize supporting of the roller 46 supported by the three pistons 44.

[0098] Further, a distance between support areas of adjacent two of the n pistons 44 in the axial direction of the roller 46 may be made more than two times as large as a distance between the edge of the roller 46 and an end of the support area of the piston 44 disposed at each end of the roller 46. The support area of the piston 44 indicates the area where the roller 46 is supported by this piston 44.

[0099] In the exemplary embodiment illustrated in FIG.16, the distance between two pistons 44 in the axial direction of the roller 46 is 6x, whereas the distance between a supporting point of the piston 44 and the edge of the roller 46 is x. In other words, the following relationship is satisfied, (the distance between the support areas of the pistons 44 in the axial direction of the roller 46) > (a distance twice as large as the distance between the edge of the roller 46 and the support area of the piston 44). In this case, as illustrated in FIG.16, the pistons 44 are configured so that a load at a position which is 3x apart from the support area of the piston 44 supporting the roller 46 toward the roller center in the axial direction of the roller 46 equals to a load at a position which is x apart from the support area toward the outside in the axial direction.

[0100] As described above, by supporting the roller 46 by at least two places that are apart in the axial direction, it is possible to effectively increase a load capacity of the roller 46 between the support areas. Thus, it is possible to support the roller 46 in a stable manner even in the case where the axial length of the roller 46 is increased for the purpose of reducing the contact surface pressure between the roller 46 and the cam 52, or the like.

[Reference Signs list]

[0101]

10	Wind turbine generator
12	Rotor
14	Blade
16	Hub
18	Hub cover
20	Rotor shaft
22	Hydraulic pump
24	High pressure oil line
26	Low pressure oil line
28	Hydraulic motor
30	Generator
32	Nacelle
34	Tower
40	Hydraulic machine
42	Cylinder
44	Piston
44a	Holding part
46	Roller
46a, 142	Small-diameter section
46b, 144	Large-diameter section
48	Cylinder block
50	Rotation shaft
52	Ring cam
54a, 54b	Bearing
56, 56a, 56b	Inner oil path

58, 58a, 58b	Annular collecting oil path
60	End plate
62, 62a, 62b	Outer pipe
64	Cylinder sleeve
64a	Notch
66	Cylinder block body
66a	Sleeve hole
70a, 70b	Branch oil path
72a, 72b	On-off valve
74a	Crest portion
74b	Trough portion
80	Cartridge hole
82A, 82B	Cylinder assembly
84, 120	Base plate
84a	Communication hole
86	Cylinder casing
86a	Partition wall
88, 102	Fastening member
90	Arm
90a	Retaining end
92	High-pressure valve block
94, 106, 122, 124	Casing
94a	Valve seat
96	High-pressure oil discharge pipe
98, 126	Spring-type on-off valve
99	Valve element
100	Coil spring
103, 116	Top cover
104	Low-pressure valve block

108	Low-pressure oil supply pipe
110, 128	Electromagnetic valve
111	Valve element
112	Valve rod
113	Coil spring
114	Coil
129	Cover member
129a	Hole
130	Oil path
132	High-pressure oil discharge path
134	Low-pressure oil supply path
140	Stepped portion
142	Cylinder array
146	Frame
148	Projection
150	Cylindrical member
152	Ring member
154	Lubrication part
156	Supply line
158	Supply port
160	Piston peripheral surface
164	Seal member
r	Hydraulic chamber
s1, s2	Operating oil space

Claims

1. A radial piston hydraulic machine comprising:

a plurality of pistons;
at least one roller;
a cylinder block comprising a plurality of cylinders configured to guide the plurality of pistons reciprocably along a radial direction of the hydraulic machine, respectively;
a cam configured to contact each of the at least one roller,

wherein each of the at least one roller is provided for n pistons of the plurality of pistons, the n pistons being aligned along an axial direction of the hydraulic machine to share said each of the at least one roller, n being an integer not less than two.

2. The radial piston hydraulic machine according to claim 1,
wherein the cam is a ring cam having a plurality of lobes disposed along a circumferential direction of the hydraulic machine, the ring cam being arranged to face the plurality of pistons and being configured rotatable so that the lobes move relative to the plurality of pistons in the circumferential direction,
wherein the plurality of cylinders includes a cylinder array that is formed by n cylinders of the plurality of cylinders arranged along the axial direction corresponding to the n pistons, and
wherein the plurality of lobes extends linearly in the axial direction over an area in the axial direction occupied by the cylinder array.

3. The radial piston hydraulic machine according to claim 1 or 2,
wherein said each of the at least one roller includes a cylindrical part extending along the axial direction over a region where the n pistons are provided, and
wherein the cylindrical part is configured to contact the cam over the region in the axial direction.

4. The radial piston hydraulic machine according to claim 1 or 2,
wherein each of the at least one roller includes at least one contact part configured to contact and engage with the cam and at least one engagement part having a diameter smaller than the at least one contact part and the engagement part being configured to engage with the n pistons.

5. The radial piston hydraulic machine according to claim 1 or 2,
wherein each of the at least one roller includes a cylindrical member which is fixed to the n pistons and at least one ring member configured to contact the cam at an outer periphery and to rotate around the cylindrical member, and
wherein each of the at least one ring member includes a lubrication part to be supplied with lubricating oil, the lubrication part being provided on an inner periphery of said ring member.

6. The radial piston hydraulic machine according to claim 5,
wherein, in each of the n pistons and the cylindrical member, a supply line is provided for supplying operating oil of a hydraulic chamber formed by the piston and the cylinder as the lubricating oil to the lubrication part.

7. The radial piston hydraulic machine according to any one of claims 1 to 6,
wherein each of the n pistons has a piston circumferential surface which is crowned so that an outer diameter of an end of the piston in an axial direction of the piston is smaller than an outer diameter of a center of the piston in the axial direction.

8. The radial piston hydraulic machine according to any one of claims 1 through 7, further comprising:

an oil supply valve for collectively changing a supply state of operating oil to n hydraulic chambers formed by the n pistons and n cylinders of the plurality of cylinders corresponding to the n pistons, respectively.

9. The radial piston hydraulic machine according to any one of claims 1 through 8,
wherein the cylinder block comprises:

a cylinder cartridge having at least one cylinder of n cylinders of the plurality of cylinders corresponding to the n pistons; and
a cylinder block body having a cartridge hole into which the cylinder cartridge is inserted, and

wherein the hydraulic machine further comprises a cover member attached to the cylinder block body so as to restrict the cylinder cartridge inserted in the cartridge hole, so to prevent it from coming out from the cylinder block body along the radial direction.

10. The radial piston hydraulic machine according to any one of claims 1 through 8,
wherein the cylinder block comprises:

a cylinder cartridge having n cylinders of the plurality of cylinders corresponding to the n pistons; and a cylinder block body having a cartridge hole into which the cylinder cartridge is inserted, and

wherein the cylinder cartridge is configured to be removable from and insertable into the cylinder block body in such a state that the n pistons are integrated with the roller corresponding to the n pistons.

11. The radial piston hydraulic machine according to claim 9 or 10,
wherein the cylinder cartridge is configured removable from the cylinder block body to an opposite side of the cam in a radial direction of the hydraulic machine in such a state that the cylinder cartridge is integrated with a valve for controlling a state of communication between a hydraulic chamber formed by the piston and the cylinder and an outside of the hydraulic chamber.

12. The radial piston hydraulic machine according to any one of claims 1 to 11,
wherein the cylinder block is configured to be separable into a plurality of segments each of which includes n cylinders of the plurality of cylinders corresponding to the n pistons.

13. The radial piston hydraulic machine according to any one of claims 9 to 11,
wherein the cylinder block body is formed in a continuous manner over an entire circumference in a circumferential direction of the hydraulic machine.

14. The radial piston hydraulic machine according to any one of claims 1 to 13,
wherein the plurality of cylinders is provided on a moving path of n cylinders of the plurality of cylinders corresponding to the n pistons when the n cylinders are moved in a spiral or spiral-like manner around an axis of the hydraulic machine.

15. A wind turbine generator comprising:

at least one blade;
a hub on which the at least one blade is mounted;
a hydraulic pump configured to be driven by rotation of the hub;
a hydraulic motor configured to be driven by pressurized oil generated by the hydraulic pump; and
a generator configured to be driven by the hydraulic motor,
wherein at least one of the hydraulic pump or the hydraulic motor is a radial piston hydraulic machine,
wherein the radial piston hydraulic machine comprises:

a plurality of pistons;
at least one roller;
a cylinder block comprising a plurality of cylinders configured to guide the plurality of pistons reciprocably along a radial direction of the hydraulic machine, respectively; and
a cam configured to contact each of the at least one roller, and

wherein each of the at least one roller is provided for n pistons of the plurality of pistons, the n pistons being arranged along an axial direction of the hydraulic machine to share said each of the at least one roller, n being an integer not less than two.

FIG.1

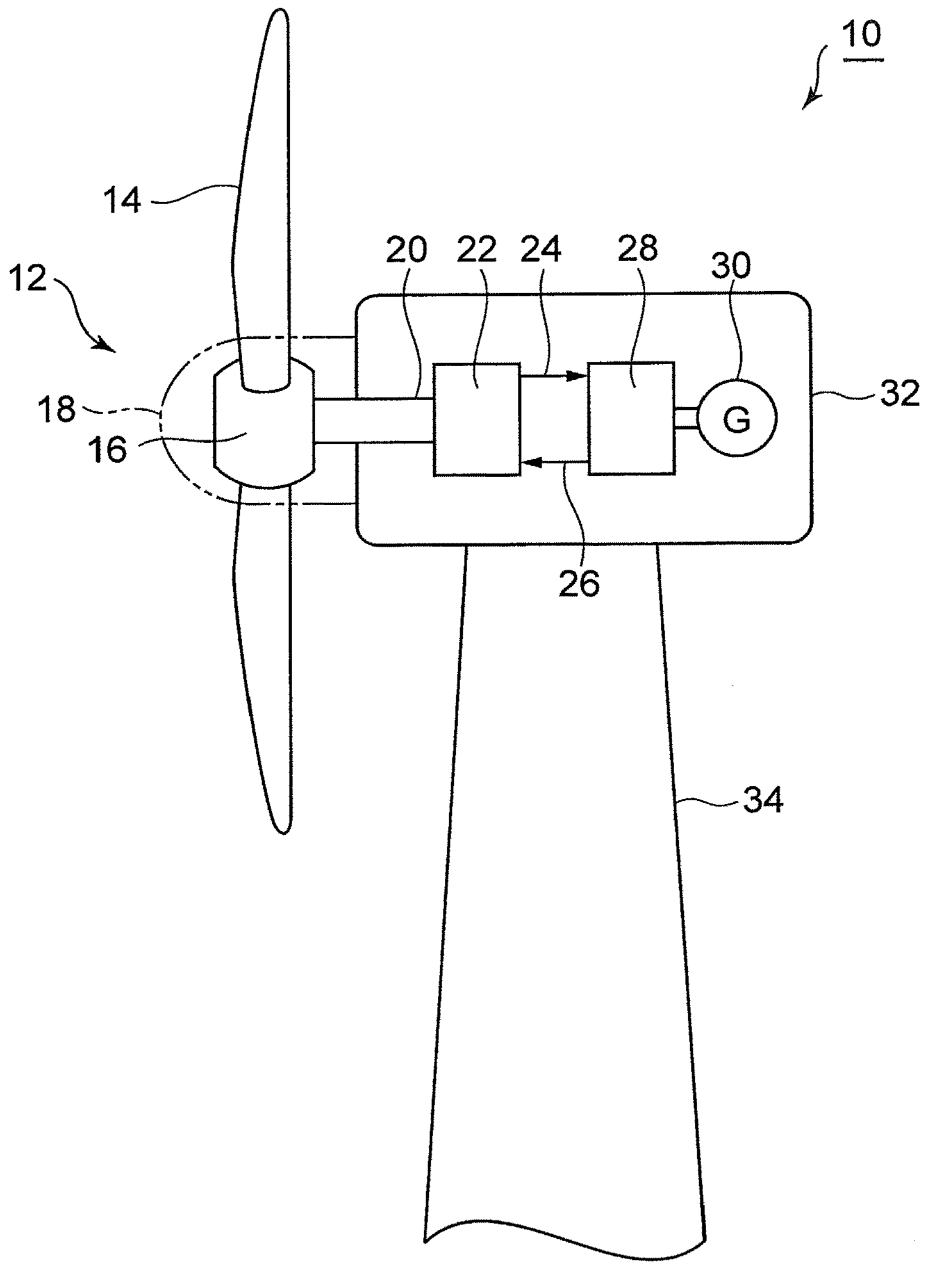


FIG.2

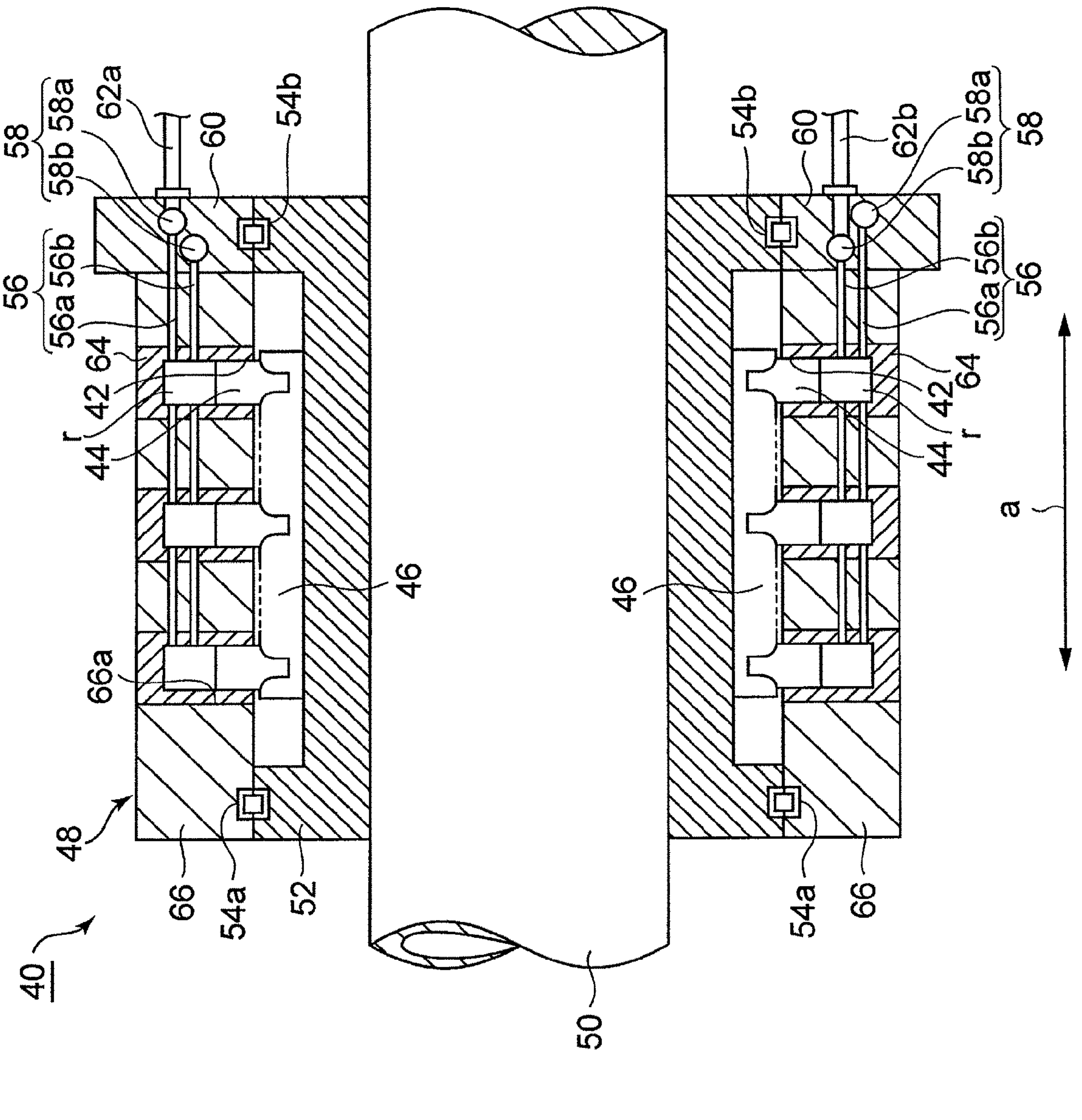

40
48
50
52
54a
54b
56
56a
56b
58
58a
58b
60
62a
62b
64
66
66a
42
44
46
r
a

FIG.3

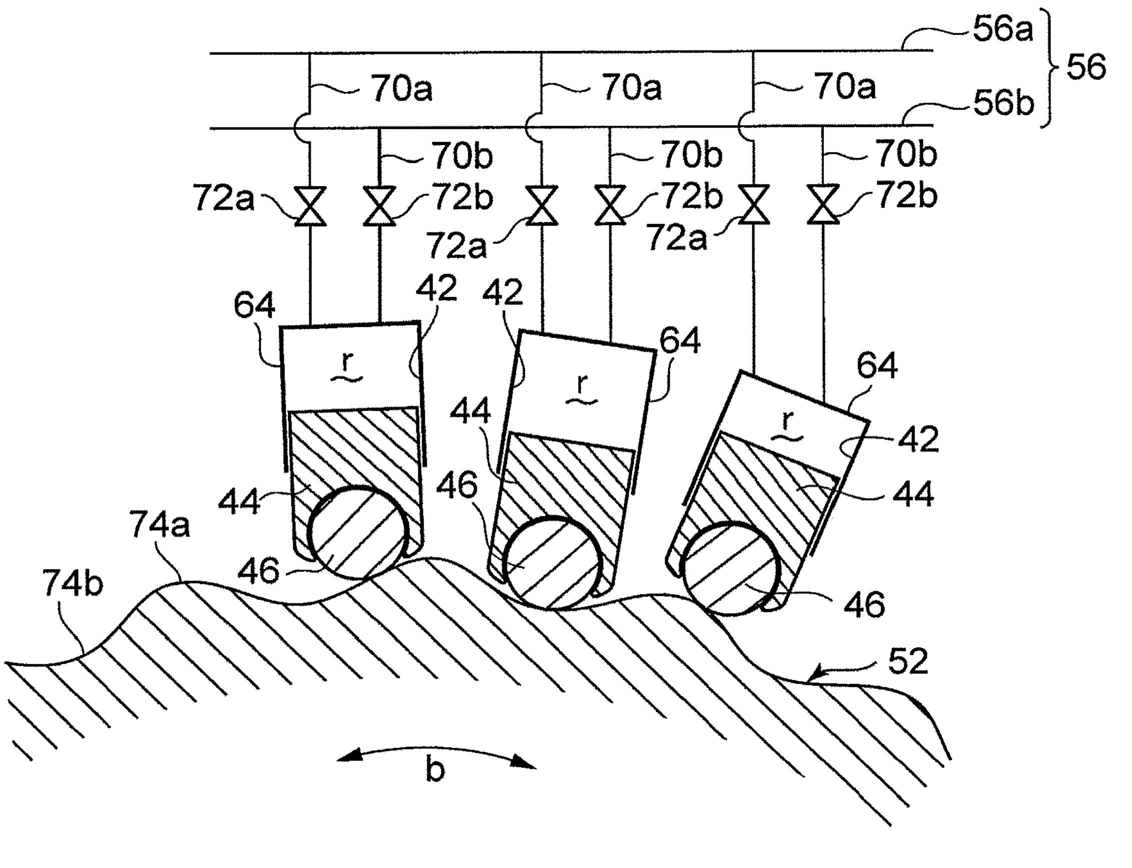

56a
56
70a
70a
70a
56b
70b
70b
70b
72a
72b
72b
72b
72a
72a
64
42
42
64
64
r
r
r
42
44
44
44
46
44
74a
46
46
74b
46
52
b

FIG. 4

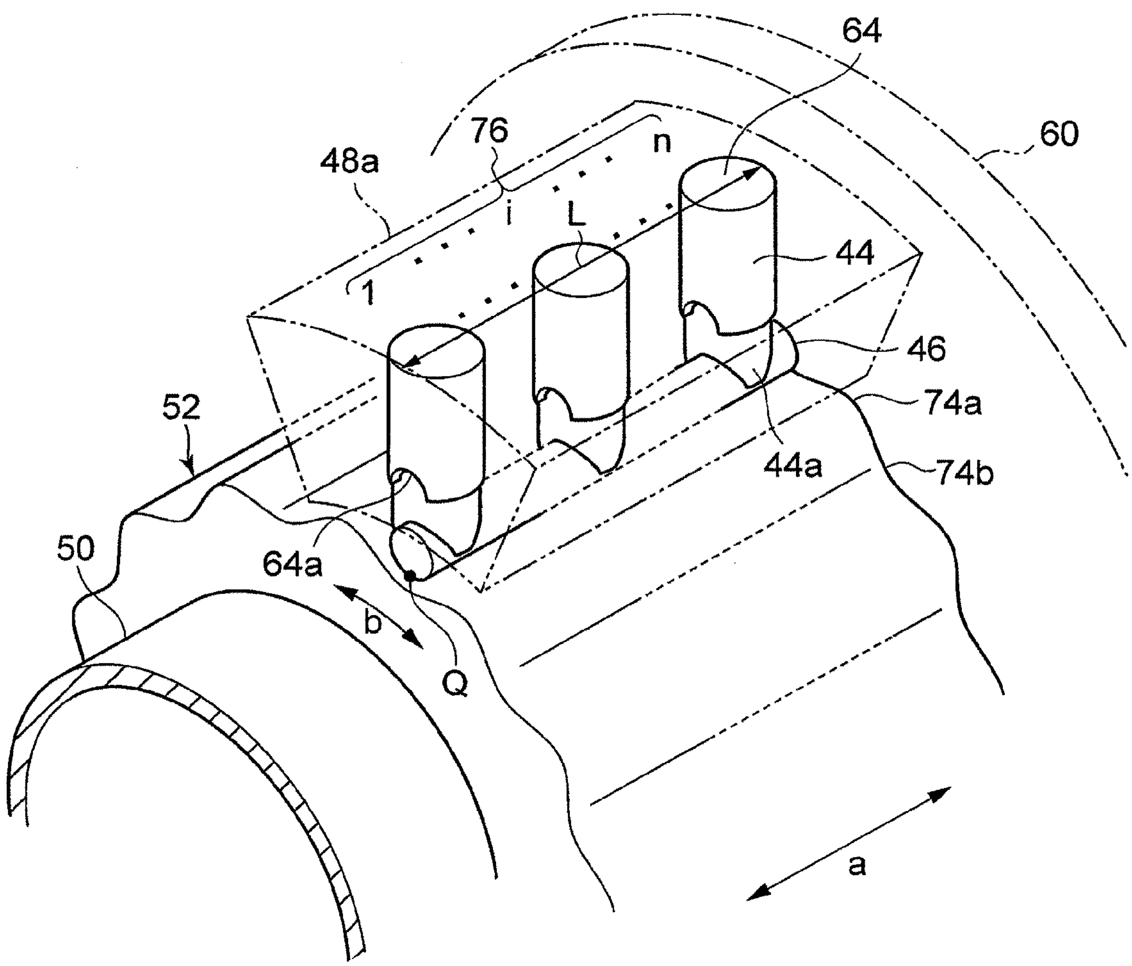


FIG. 5

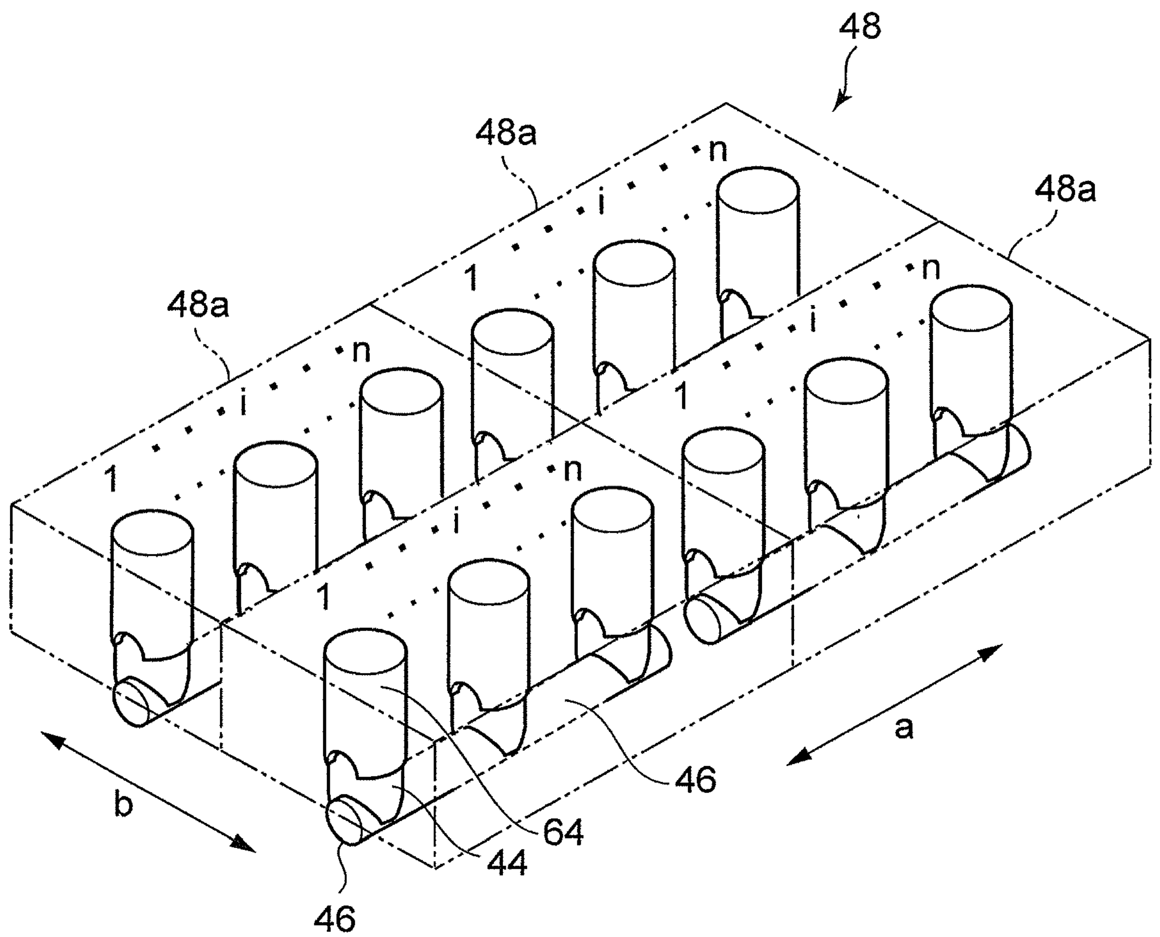


FIG. 6

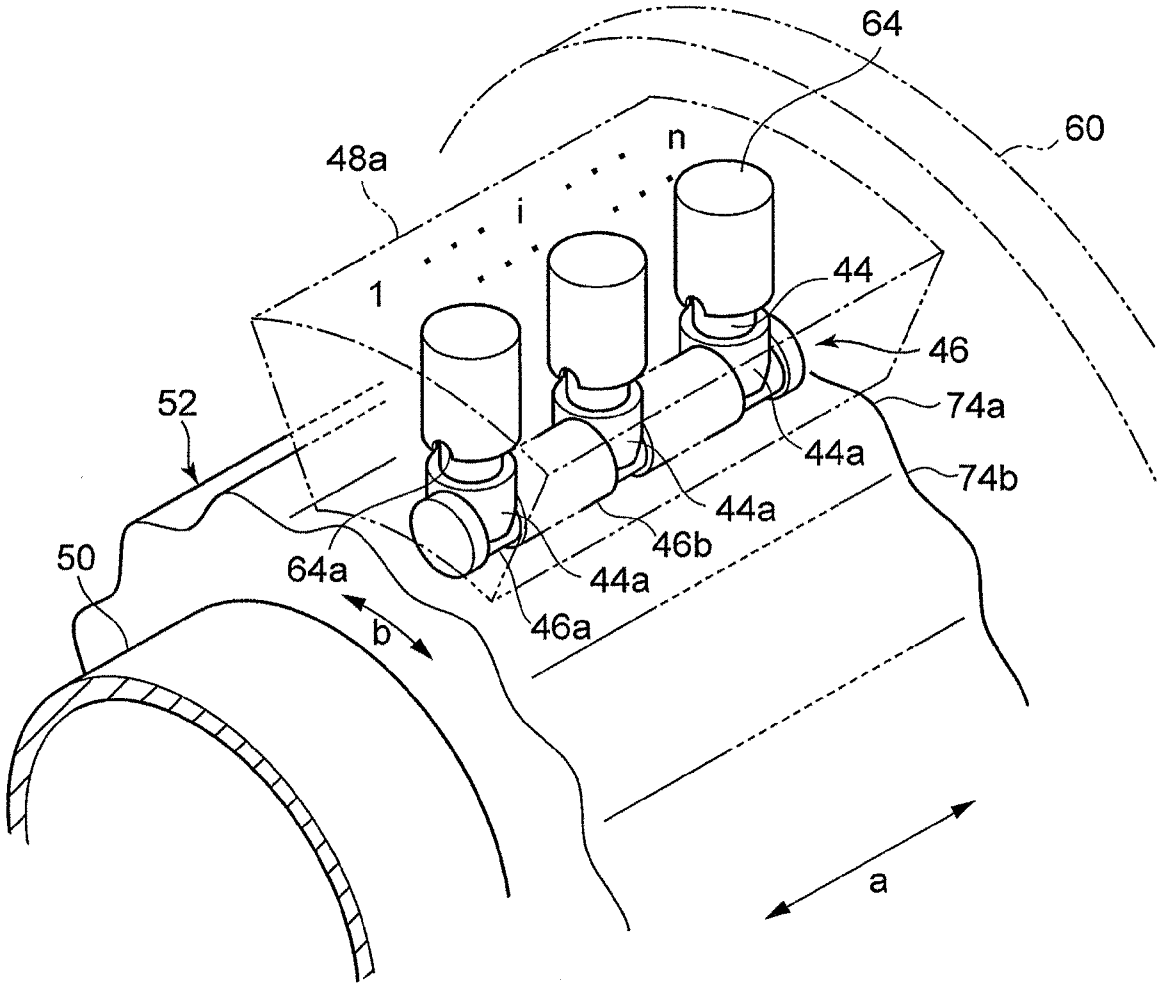


FIG. 7

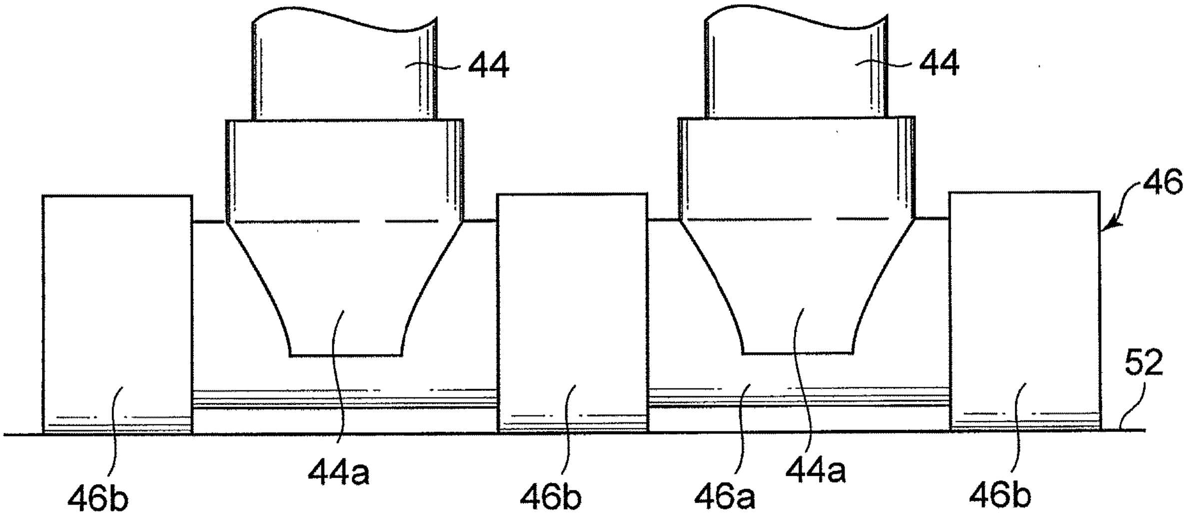


FIG. 8

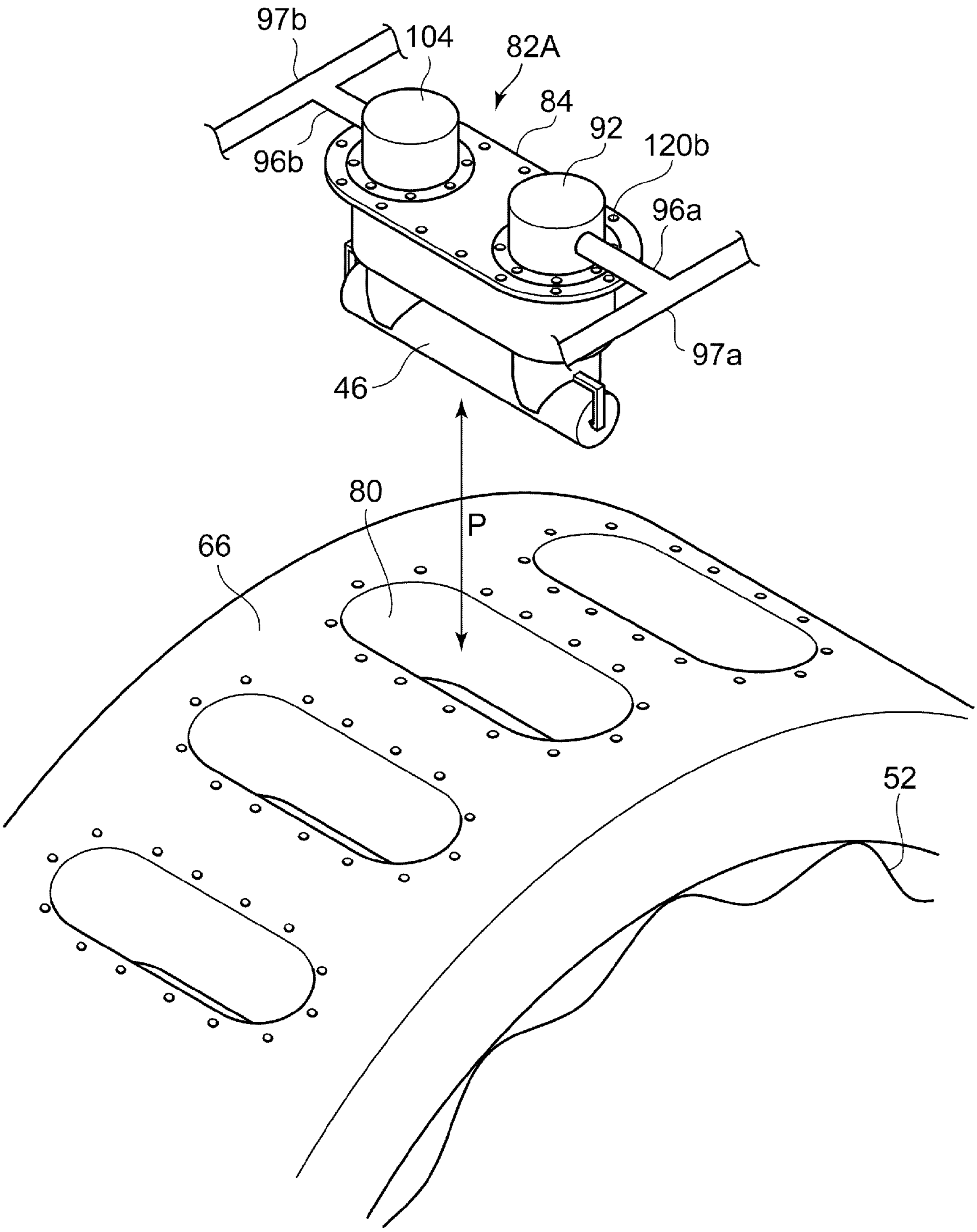


FIG. 9

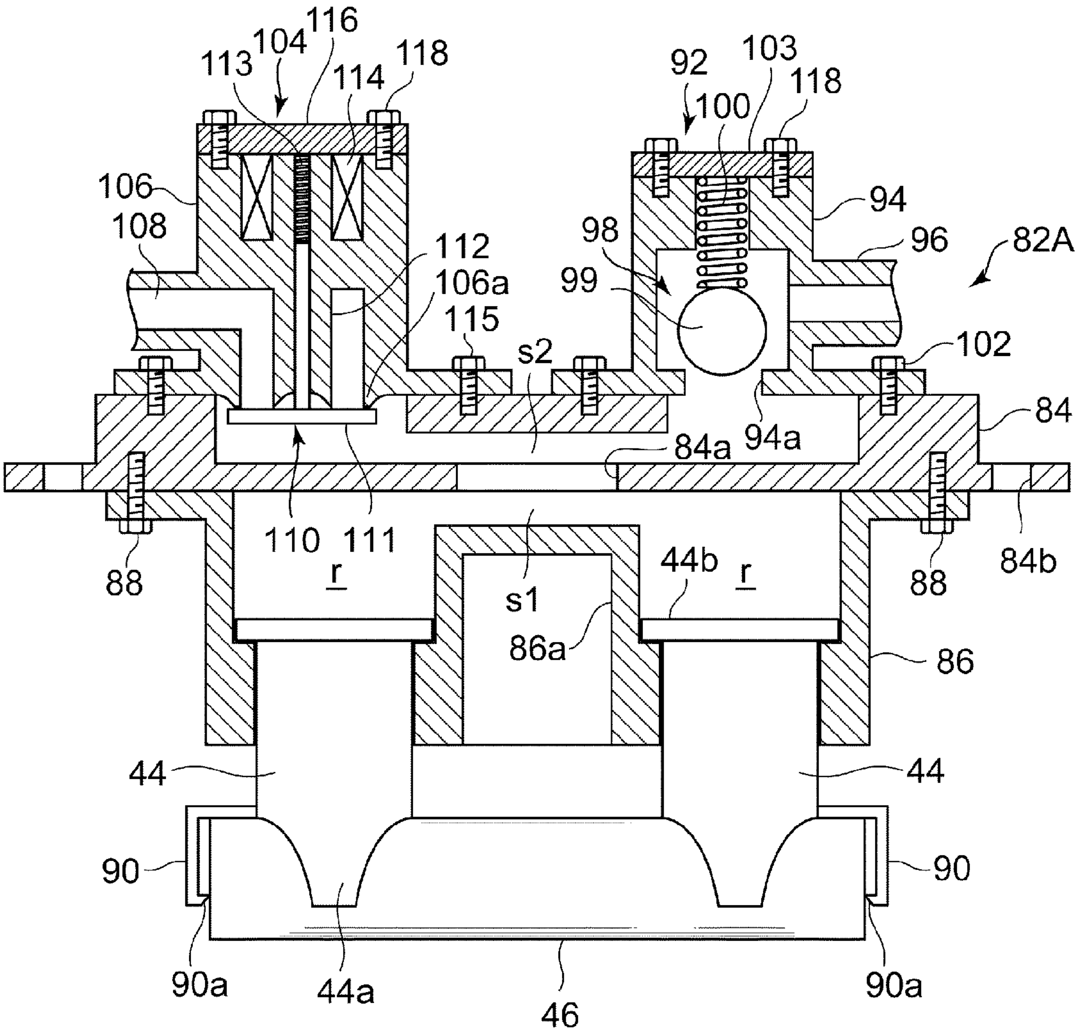

113
104
116
114
118
106
108
112
106a
115
s2
92
103
100
118
94
98
96
82A
99
102
84
94a
84a
110
111
88
84b
r
s1
44b
r
86a
86
44
44
90
90
90a
44a
46
90a

FIG. 10

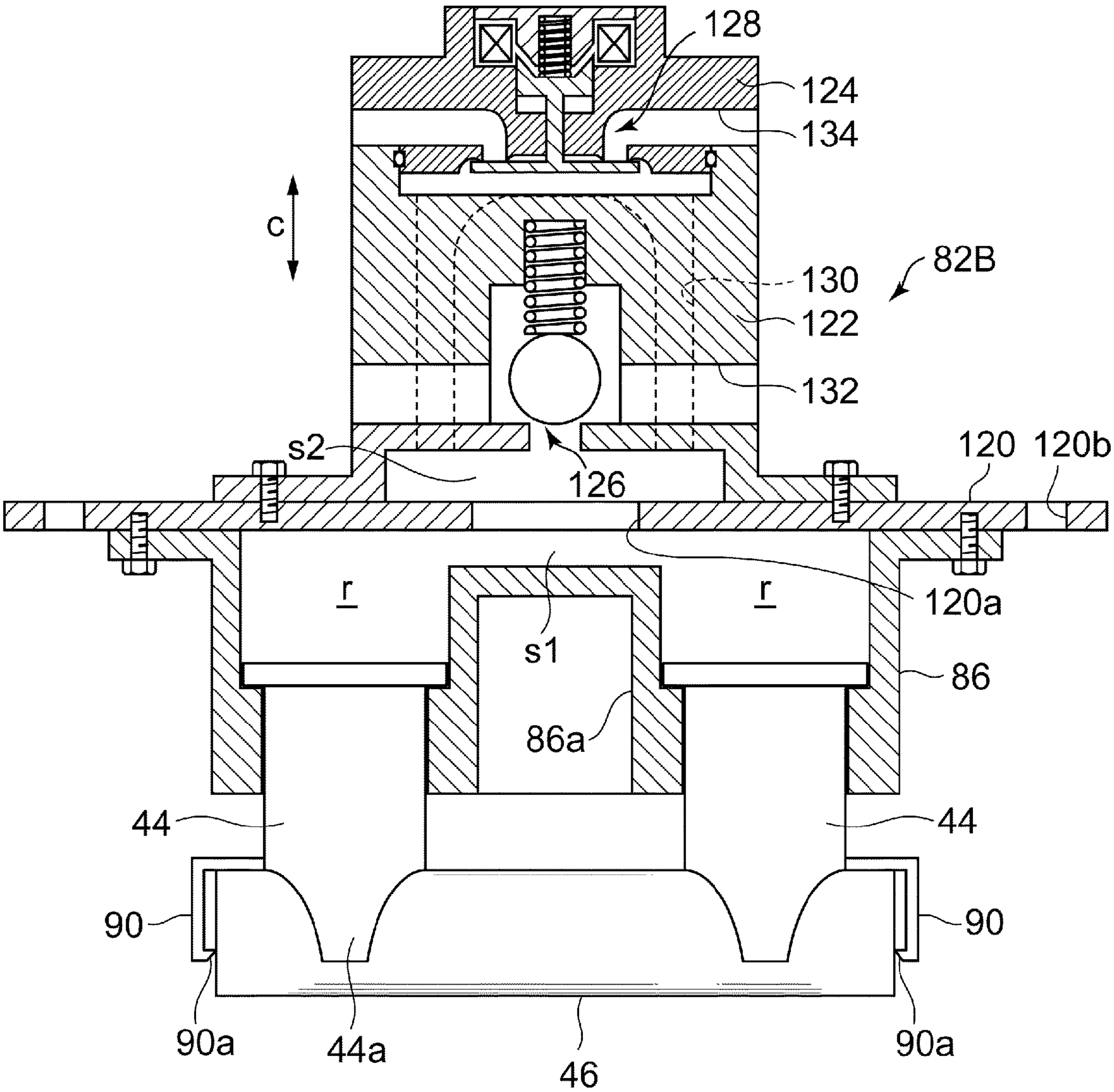
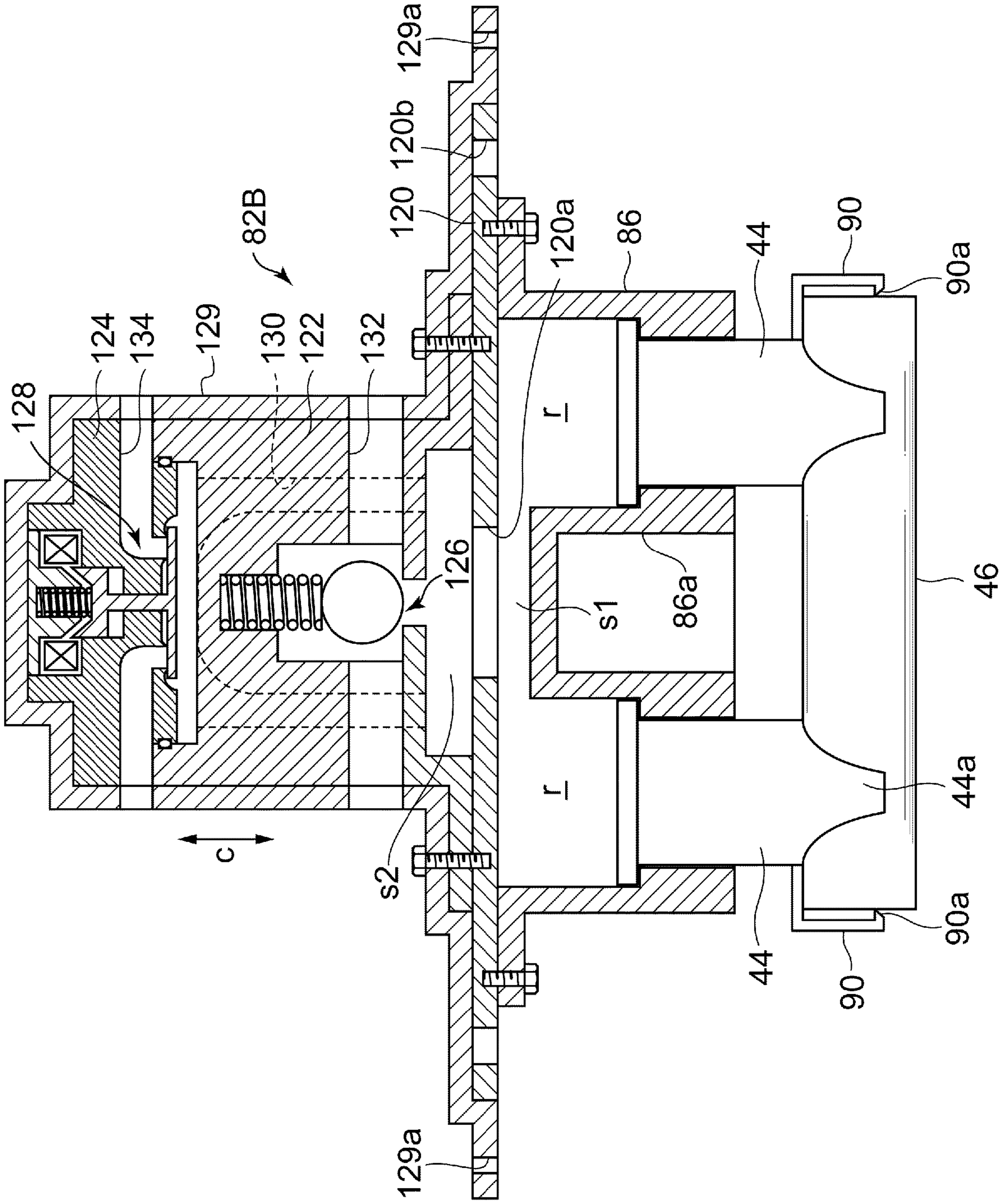

128
124
134
c
82B
130
122
132
s2
126
120
120b
120a
r
s1
r
86
86a
44
44
90
90
90a
44a
46
90a

FIG. 11



82B
128
124
134
129
130
122
132
120
120b
129a
120a
86
44
90
90a
126
s1
86a
46
r
s2
c
44a

FIG. 12

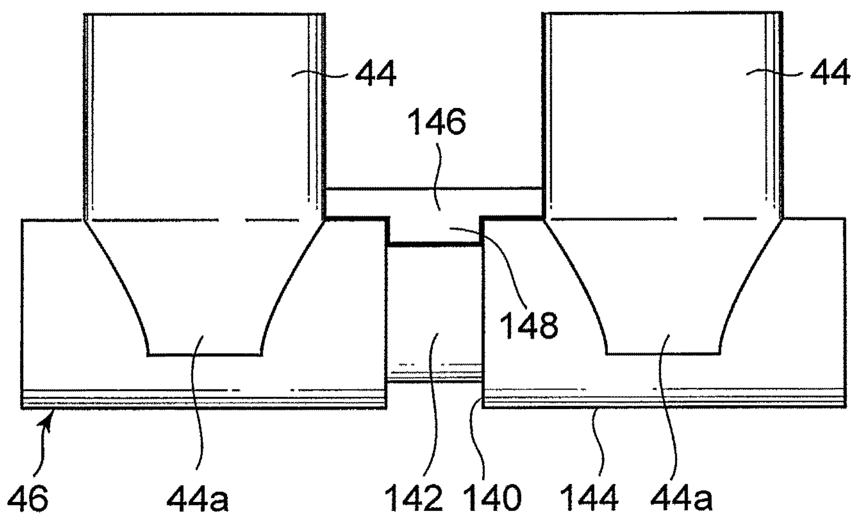


FIG. 13

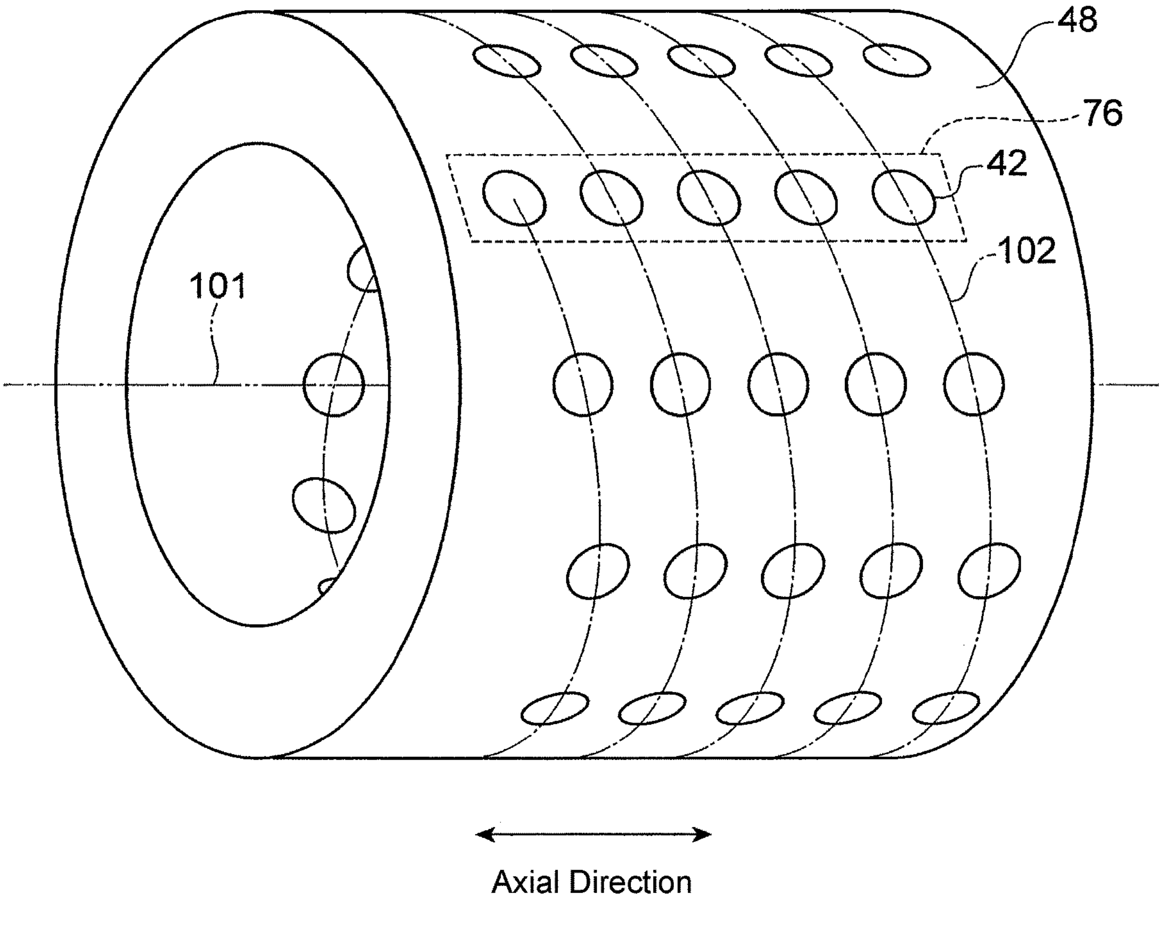


FIG. 14

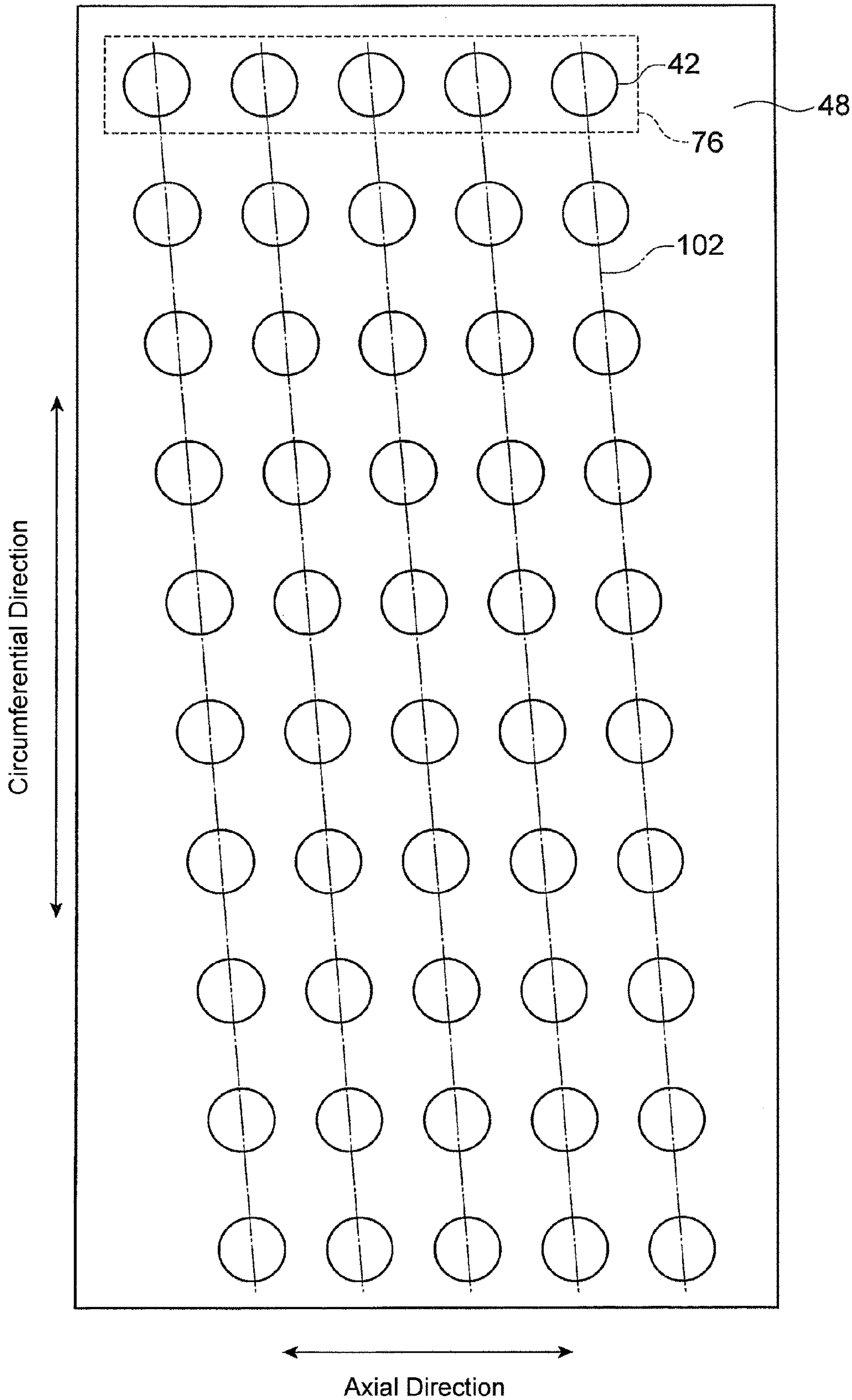


FIG. 15

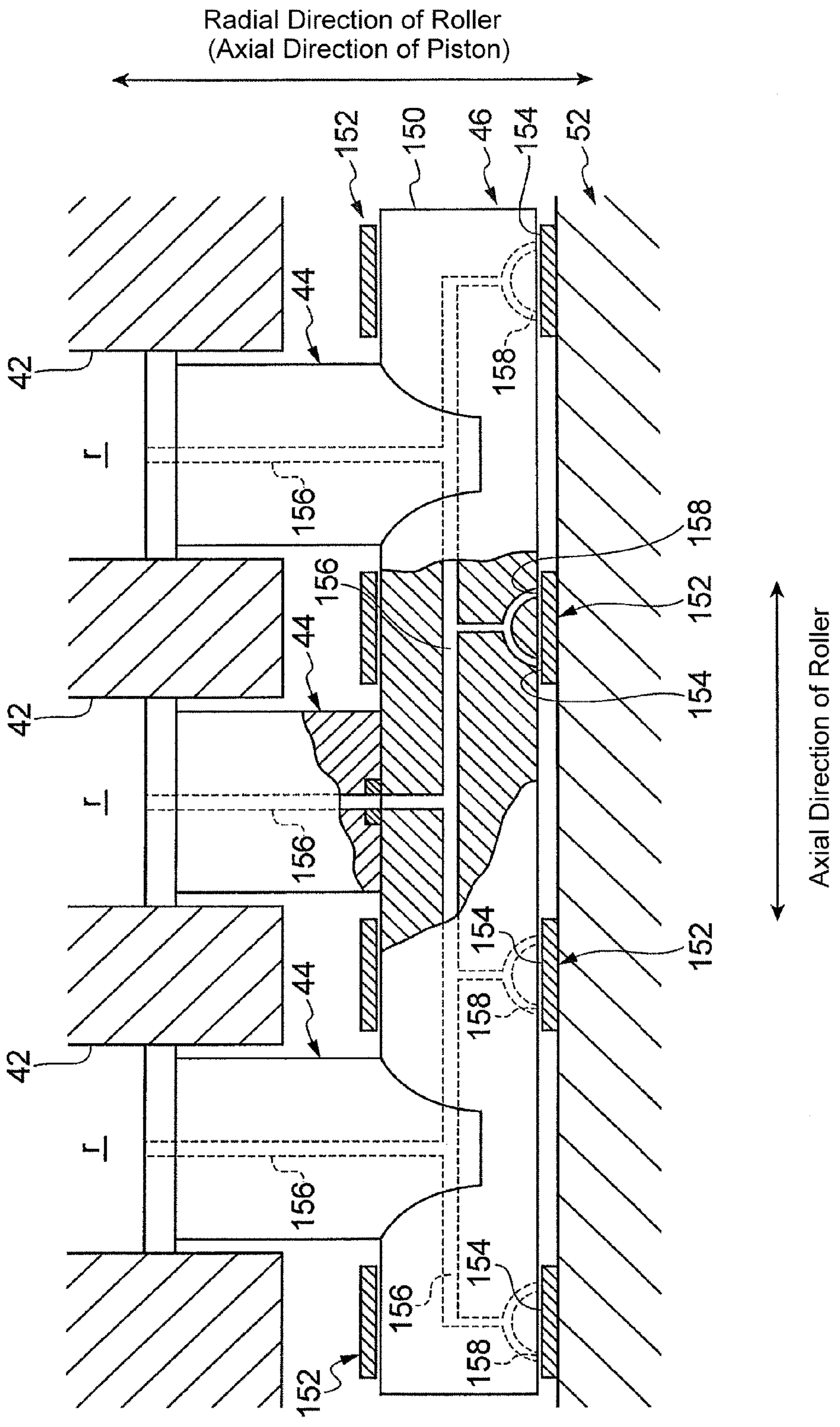
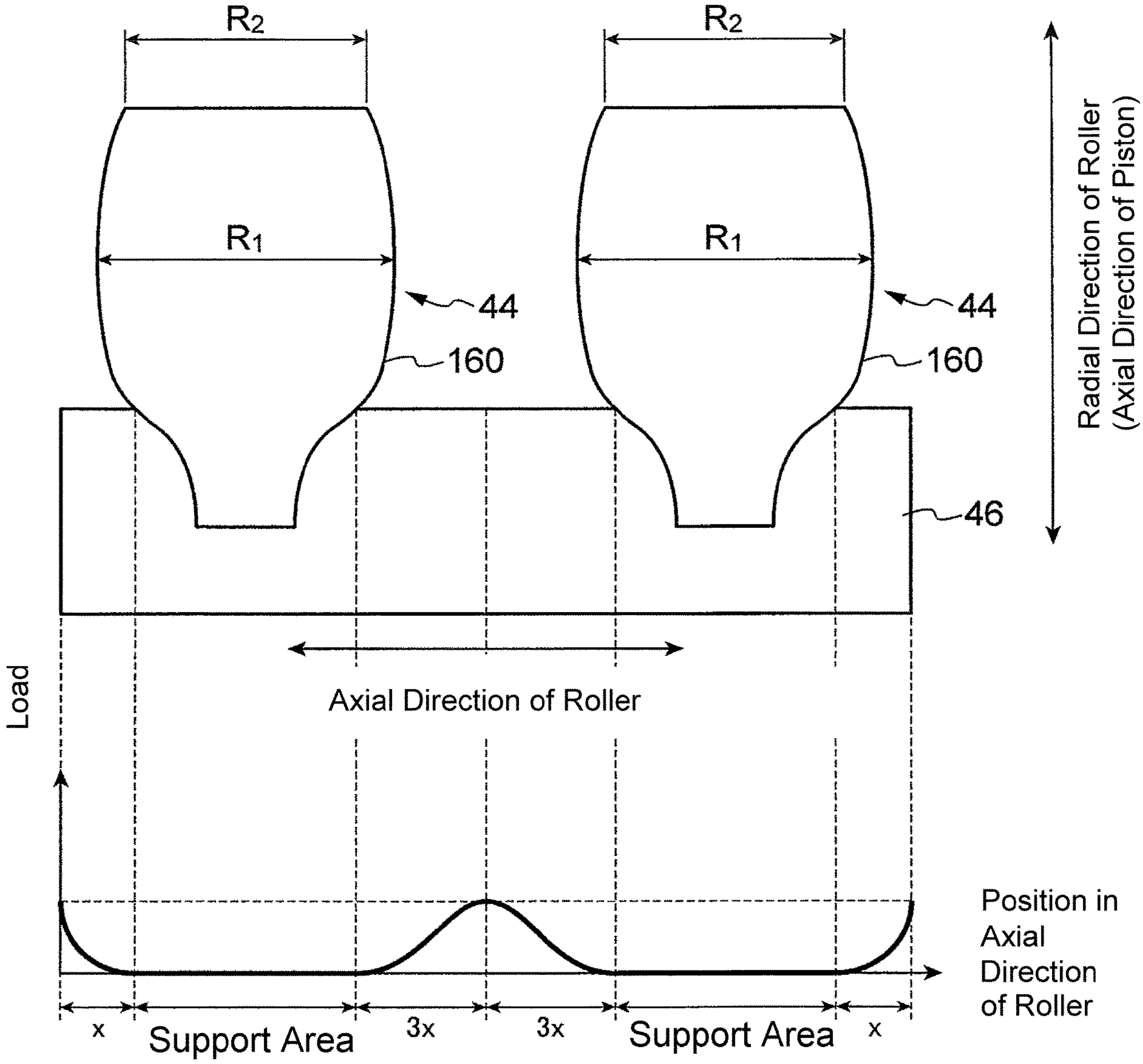

Radial Direction of Roller
(Axial Direction of Piston)
Axial Direction of Roller
152
150
46
154
52
42
44
r
156
158

FIG. 16


R2
R2
R1
R1
44
44
160
160
46
Radial Direction of Roller
(Axial Direction of Piston)
Axial Direction of Roller
Load
Position in
Axial
Direction
of Roller
x
Support Area
3x
3x
Support Area
x

REFERENCES CITED IN THE DESCRIPTION

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- JP 2010019192 A **[0006]**
- US 20100040470 A **[0006]**