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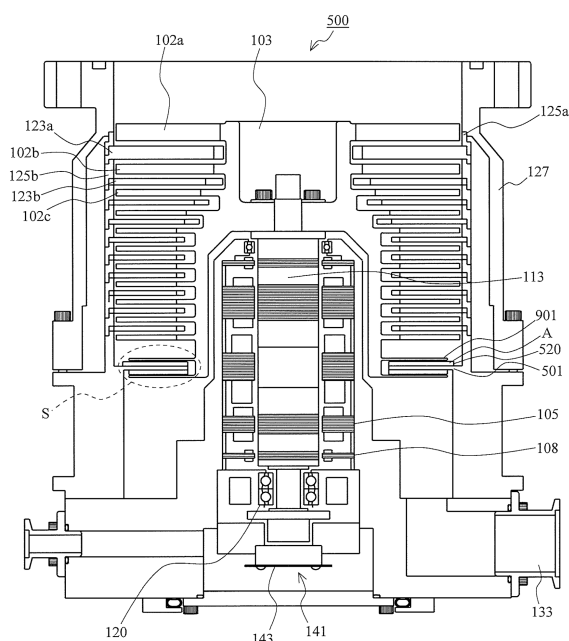
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(54) **VACUUM PUMP, FIXED DISK, AND RETROFITTED COMPONENT**

(57) Provided is a vacuum pump in which an exhaust speed can be improved while maintaining a back pressure dependence performance, as well as a stator disc and a retrofitted component used in the vacuum pump. In a vacuum pump according to an embodiment, an inflow guide portion for guiding inflow of a gas is provided on a gas inflow port of a spiral groove formed in a stator disc that serves as a Siegbahn element, is disposed opposite a rotor disc, and has a spiral groove with a root portion and a ridge portion in an opposed surface thereof. The inflow guide portion is shaped such that the stator disc ridge portion extends outward beyond the outer diameter of the opposing rotor disc.

Fig.9



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Description

[Technical Field]

[0001] The present invention relates to a vacuum pump, and a stator disc and a retrofitted component used in the vacuum pump.

[Background Art]

[0002] A vacuum pump includes a casing forming a housing in which an inlet port and an outlet port are formed, and a structure that causes the vacuum pump to produce an exhaust performance is housed inside the casing. The structure that produces the exhaust performance is constituted of a rotating portion (a rotor portion) held so as to be free to rotate, and a fixed portion (a stator portion) fixed to the casing. By rotating the rotating portion at a high rotation speed using a motor, a gas is sucked through the inlet port by an interaction between a rotor blade (a rotor disc) and a stator blade (a stator disc), whereupon the gas is exhausted to the outlet port.

[0003] A type of pump known as a Siegbahn molecular pump, which has a Siegbahn configuration, is in use as a vacuum pump. The Siegbahn vacuum pump includes a rotor disc and a stator disc arranged so as to leave a gap (a clearance) in an axial direction from the rotor disc, and a spiral groove (a spiral-shaped flow passage) is engraved in a gap-opposed surface of either the rotor disc or the stator disc. By applying momentum in a tangential direction of the rotor disc (in other words, a rotation direction of the rotor disc) from the rotor disc to gas molecules that have entered the spiral groove by diffusion, superior directionality from the inlet port toward the outlet port is applied to the gas molecules by the spiral groove, and as a result, the gas molecules are exhausted.

[0004] Various types of Siegbahn molecular pumps exist, such as a type in which pairs of rotor discs and stator discs are provided in a plurality of stages and a type used in combination with pairs of stator blades and rotor blades (known as turbo stages).

[0005] The document disclosed in PTL 1 describes a Siegbahn vacuum pump in which an inlet port-side outlet of the spiral groove includes a part that overlaps an outlet port-side inlet of the spiral groove in the axial direction, thus generating an effect whereby the superior momentum in the exhaust direction is unlikely to be lost.

[Citation List]

[Patent Literature]

[0006] [PTL 1] Japanese Patent Application Publication No. 2015-102076

[Summary of Invention]

[Technical Problem]

[0007] Back pressure dependence performance and exhaust speed can be cited as elements representing the exhaust performance of a typical vacuum pump.

[0008] Fig. 14 is a graph showing relationships between suction pressure and back pressure in terms of the back pressure dependence performance and the exhaust speed, which are indices indicating the exhaust performance.

[0009] Here, a favorable (high) back pressure dependence performance means that even when the back pressure (the outlet port pressure) increases, the suction pressure (the inlet port pressure) is unlikely to be affected thereby. In other words, the back pressure dependence performance is poor (low) when the suction pressure is immediately affected by an increase in the back pressure.

[0010] The pressure of a vacuum pump varies depending on how a user of the vacuum pump uses the vacuum pump, and therefore demand exists for a vacuum pump in which a constant suction pressure (a favorable back pressure dependence performance) can be maintained with stability.

[0011] Meanwhile, the exhaust speed refers to the ability to form a vacuum state more quickly when exhaust is performed under same conditions, and a higher exhaust speed results in a superior exhaust performance.

[0012] By using the Siegbahn element described above, an improvement in the back pressure dependence performance can be expected. However, when an attempt is made to further improve the back pressure dependence performance, it becomes necessary to take measures such as increasing the number of Siegbahn stages, increasing a length, and reducing depth of the flow passage.

[0013] When such measures are taken, however, the Siegbahn inlet pressure increases while conductance of the gas deteriorates, and as a result, the exhaust speed decreases. In other words, there is a tradeoff between the back pressure dependence performance and the exhaust speed.

[0014] Hence, an object of the present invention is to provide a vacuum pump in which the exhaust speed can be increased while maintaining the back pressure dependence performance, as well as a stator disc and a retrofitted component used in the vacuum pump.

[Solution to Problem]

[0015] An invention disclosed in claim 1 provides a vacuum pump for exhausting a gas by an interaction between a rotor disc and a stator disc, the vacuum pump including a casing, a rotor shaft, which is disposed inside the casing, the rotor disc, which is capable of rotating together with the rotor shaft, and the stator disc, which is disposed so as to oppose the rotor disc in an axial direction of the rotor shaft and has a spiral groove with a root portion and a ridge portion in an opposed surface

thereof, wherein an inflow guide portion for guiding inflow of the gas is provided on a gas inflow port of the spiral groove.

[0016] An invention disclosed in claim 2 provides the vacuum pump described in claim 1, wherein the inflow guide portion is shaped such that the ridge portion extends integrally outward beyond an outer diameter of the opposing rotor disc.

[0017] An invention disclosed in claim 3 provides the vacuum pump described in claim 2, wherein the inflow guide portion is shaped such that the ridge portion also extends integrally in the axial direction toward an inlet port side.

[0018] An invention disclosed in claim 4 provides the vacuum pump described in claim 1, wherein the inflow guide portion is shaped such that the ridge portion extends outward beyond an outer diameter of the opposing rotor disc by attaching a retrofitted component shaped such that the ridge portion extends outward beyond the outer diameter of the opposing rotor disc.

[0019] An invention disclosed in claim 5 provides the vacuum pump described in claim 4, wherein the inflow guide portion is shaped such that the retrofitted component also extends in the axial direction toward an inlet port side.

[0020] An invention disclosed in claim 6 provides the vacuum pump described in any one of claim 1 to claim 5, wherein the rotor disc and the stator disc are arranged in a plurality of stages, and the inflow guide portion is provided on a stage furthest toward an inlet port side, among the plurality of stages of the stator discs.

[0021] An invention disclosed in claim 7 provides the vacuum pump described in any one of claim 1 to claim 5, wherein the inflow guide portion and an opposing stator-side component contact each other so that there is no gap therebetween.

[0022] An invention disclosed in claim 8 provides a stator disc used in a vacuum pump for exhausting a gas by an interaction with a rotor disc, wherein the stator disc is disposed so as to oppose the rotor disc in an axial direction, has a spiral groove with a root portion and a ridge portion in an opposed surface thereof, and includes an inflow guide portion shaped such that the ridge portion extends integrally outward beyond an outer diameter of the opposing rotor disc.

[0023] An invention disclosed in claim 9 provides a retrofitted component attached to a stator disc that is used in a vacuum pump for exhausting a gas by an interaction with a rotor disc, and disposed so as to oppose the rotor disc in an axial direction, and moreover has a spiral groove with a root portion and a ridge portion in an opposed surface thereof, wherein the retrofitted component is shaped such that the ridge portion extends outward beyond an outer diameter of the opposing rotor disc.

[Advantageous Effects of Invention]

[0024] According to the present invention, by using a

Siegbahn exhaust element in a vacuum pump, the exhaust speed can be improved while maintaining the back pressure dependence performance.

5 [Brief Description of Drawings]

[0025]

[Fig. 1]

10 Fig. 1 is a schematic view showing an example configuration of a turbo molecular pump according to an embodiment of the present invention.

[Fig. 2]

15 Fig. 2 is a view showing a circuit diagram of an amplifier circuit used in this embodiment of the present invention.

[Fig. 3]

20 Fig. 3 is a time chart showing control performed when a detection value is larger than a current command value, according to this embodiment of the present invention.

[Fig. 4]

25 Fig. 4 is a time chart showing control performed when the detection value is smaller than the current command value, according to this embodiment of the present invention.

[Fig. 5]

30 Fig. 5 is a schematic view showing an example configuration of a conventional Siegbahn molecular pump.

[Fig. 6]

Fig. 6 is an enlarged view illustrating a conventional stator disc.

[Fig. 7]

35 Fig. 7 is a schematic view showing an example configuration of a conventional combined turbo molecular pump.

[Fig. 8]

40 Fig. 8 is a perspective view illustrating a ridge portion forming a spiral groove provided in a stator disc that serves as a Siegbahn element of the conventional combined turbo molecular pump.

[Fig. 9]

45 Fig. 9 is a schematic view showing an example configuration of a combined turbo molecular pump according to a first embodiment of the present invention.

[Fig. 10]

50 Fig. 10 is a perspective view illustrating a ridge portion forming a spiral groove provided in a stator disc that serves as a Siegbahn element of the combined turbo molecular pump according to the first embodiment of the present invention.

[Fig. 11]

55 Fig. 11 is a schematic view showing an example configuration of a combined turbo molecular pump according to a second embodiment of the present invention.

[Fig. 12]

Fig. 12 is a schematic view showing an example configuration of a combined turbo molecular pump according to a third embodiment of the present invention.

[Fig. 13]

Fig. 13 is a perspective view illustrating a ridge portion forming a spiral groove provided in a stator disc that serves as the Siegbahn element of the combined turbo molecular pump according to the third embodiment of the present invention.

[Fig. 14]

Fig. 14 is a graph showing relationships between suction pressure and back pressure in terms of the back pressure dependence performance and the exhaust speed, which are indices indicating the exhaust performance.

[Description of Embodiments]

(1) Outline of embodiment

[0026] In a vacuum pump according to this embodiment, an inflow guide portion for guiding inflow of a gas is provided in a gas inflow port of a spiral groove formed in a stator disc, the stator disc forming a Siegbahn element, being disposed opposite a rotor disc, and having a spiral groove with a root portion and a ridge portion in an opposed surface thereof.

[0027] The inflow guide portion is shaped such that the stator disc ridge portion extends outward beyond the outer diameter of the opposing rotor disc.

(2) Details of embodiment

[0028] The vacuum pump according to this embodiment may be a combined vacuum pump combining a turbo molecular pump, in which rotor blades and stator blades are provided in a plurality of stages, with a Siegbahn vacuum pump, or a vacuum pump including only a Siegbahn vacuum pump.

[0029] Accordingly, basic configurations of a turbo molecular pump and a Siegbahn vacuum pump will be described with reference to Figs. 1 to 6.

[0030] Fig. 1 is a longitudinal sectional view showing an example of a turbo molecular pump 100. In the turbo molecular pump 100 of Fig. 1, an inlet port 101 is formed in an upper end of a cylindrical outer tube 127. A rotating body 103 in which a plurality of rotor blades 102 (102a, 102b, 102c, ...) are formed on a peripheral portion radially and in multiple stages, the rotor blades 102 serving as turbine blades for sucking and exhausting gas, is installed in the outer tube 127. A rotor shaft 113 is mounted in the center of the rotating body 103, and the rotor shaft 113 is supported and positionally controlled so as to levitate in the air by a 5-axis control magnetic bearing, for example. The rotating body 103 is typically formed from a metal such as aluminum, and aluminum alloy.

[0031] Upper-side radial electromagnets 104 are arranged by disposing four electromagnets in pairs respectively on an X axis and a Y axis. Four upper-side radial sensors 107 are provided in proximity to the upper-side radial electromagnets 104 so as to correspond respectively to the upper-side radial electromagnets 104. The upper-side radial sensors 107 employ inductance sensors, eddy current sensors, or the like having a conductive winding, for example, and detect the position of the rotor shaft 113 on the basis of variation in the inductance of the conductive winding, which varies in accordance with the position of the rotor shaft 113. The upper-side radial sensors 107 are configured to detect radial displacement of the rotor shaft 113, or in other words the rotating body 103 fixed thereto, and transmit the detected displacement to a control device 200.

[0032] In the control device 200, a compensation circuit having a PID adjustment function, for example, generates excitation control command signals for the upper-side radial electromagnets 104 on the basis of position signals detected by the upper-side radial sensors 107, whereupon an amplifier circuit 150 shown in Fig. 2 (to be described below) controls excitation of the upper-side radial electromagnets 104 on the basis of the excitation control command signals, thereby adjusting the upper-side radial position of the rotor shaft 113.

[0033] The rotor shaft 113 is formed from a material (iron, stainless steel, or the like) with high magnetic permeability or the like so as to be attracted by the magnetic force of the upper-side radial electromagnets 104. The aforesaid adjustment is performed independently in each of an X axis direction and a Y axis direction. Furthermore, lower-side radial electromagnets 105 and lower-side radial sensors 108 are arranged similarly to the upper-side radial electromagnets 104 and the upper-side radial sensors 107 so that the lower-side radial position of the rotor shaft 113 is adjusted in a similar manner to the upper-side radial position.

[0034] Furthermore, axial electromagnets 106A, 106B are arranged above and below a disc-shaped metal disc 111 provided in a lower portion of the rotor shaft 113. The metal disc 111 is formed from a material having high magnetic permeability, such as iron. An axial sensor 109 is provided to detect axial displacement of the rotor shaft 113, and an axial position signal therefrom is transmitted to the control device 200.

[0035] In the control device 200, the compensation circuit having a PID adjustment function, for example, generates an excitation control command signal for each of the axial electromagnet 106A and the axial electromagnet 106B on the basis of the axial position signal detected by the axial sensor 109, whereupon the amplifier circuit 150 controls excitation of each of the axial electromagnet 106A and the axial electromagnet 106B on the basis of the excitation control command signals. Accordingly, the axial electromagnet 106A attracts the metal disc 111 upward by magnetic force, the axial electromagnet 106B attracts the metal disc 111 downward by

magnetic force, and as a result, the axial position of the rotor shaft 113 is adjusted.

[0036] Thus, the control device 200 is configured to appropriately adjust the magnetic force exerted on the metal disc 111 by the axial electromagnets 106A, 106B, whereby the rotor shaft 113 is magnetically levitated in an axial direction so as to be held in space without contact. Note that the amplifier circuit 150 that controls excitation of the upper-side radial electromagnets 104, the lower-side radial electromagnets 105, and the axial electromagnets 106A, 106B will be described below.

[0037] Meanwhile, a motor 121 includes a plurality of magnetic poles arranged peripherally so as to surround the rotor shaft 113. Each magnetic pole is controlled by the control device 200 so as to drive the rotor shaft 113 to rotate through electromagnetic force acting between the magnetic poles and the rotor shaft 113. Further, a rotation speed sensor such as a Hall element, a resolver, or an encoder, for example, not shown in the figures, is incorporated into the motor 121, and from a detection signal from the rotation speed sensor, the rotation speed of the rotor shaft 113 is detected.

[0038] Furthermore, for example, a phase sensor, not shown in the figures, is mounted near the lower-side radial sensors 108 in order to detect the phase of the rotation of the rotor shaft 113. In the control device 200, detection signals from the phase sensor and the rotation speed sensor are used together to detect the positions of the magnetic poles.

[0039] A plurality of stator blades 123 (123a, 123b, 123c, ...) are arranged at slight intervals from the rotor blades 102 (102a, 102b, 102c, ...). The rotor blades 102 (102a, 102b, 102c, ...) are formed at an incline of a predetermined angle from a plane perpendicular to the axis of the rotor shaft 113 in order to respectively collide with molecules of exhaust gas and thereby convey the exhaust gas downward. The stator blades 123 (123a, 123b, 123c, ...) are formed from a metal such as aluminum, iron, stainless steel, or copper, or a metal such as an alloy containing these metals as a component, for example.

[0040] Further, the stator blades 123 are likewise formed at an incline of a predetermined angle from a plane perpendicular to the axis of the rotor shaft 113, and are arranged alternately with the stages of the rotor blades 102 so as to face the inside of the outer tube 127. Outer peripheral ends of the stator blades 123 are supported in a state of being inserted with play between a plurality of stacked stator blade spacers 125 (125a, 125b, 125c, ...).

[0041] The stator blade spacers 125 are ring-shaped members formed from a metal such as aluminum, iron, stainless steel, or copper, or a metal such as an alloy containing these metals as a component, for example. The outer tube 127 is fixed to the outer periphery of the stator blade spacers 125 with a slight gap left therebetween. The base portion 129 is disposed on a bottom portion of the outer tube 127. An outlet port 133 is formed

to the base portion 129 and connected to the outside. Exhaust gas that enters the inlet port 101 from the side of a chamber (a vacuum chamber) so as to be conveyed toward the base portion 129 is sent to the outlet port 133.

[0042] Moreover, in accordance with the application of the turbo molecular pump 100, a screw spacer 131 is arranged between a lower portion of the stator blade spacers 125 and the base portion 129. The screw spacer 131 is a cylindrical member formed from a metal such as aluminum, copper, stainless steel, or iron, or an alloy containing these metals as a component, and has a plurality of spiral-shaped thread grooves 131a engraved in an inner peripheral surface thereof. The direction of the spirals of the thread grooves 131a is the direction in which molecules of the exhaust gas are conveyed toward the outlet port 133 when the molecules move in the rotation direction of the rotating body 103. A cylindrical portion 102d is suspended from the lowermost portion of the rotating body 103 after the rotor blades 102 (102a, 102b, 102c, ...). An outer peripheral surface of the cylindrical portion 102d is cylindrical and protrudes toward the inner peripheral surface of the screw spacer 131 so as to approach the inner peripheral surface of the screw spacer 131 with a predetermined gap left therebetween. The exhaust gas that is conveyed to the thread grooves 131a by the rotor blades 102 and stator blades 123 is sent to the base portion 129 while being guided by the thread grooves 131a.

[0043] The base portion 129 is a disc-shaped member forming a bottom portion of the turbo molecular pump 100, and is typically formed from a metal such as iron, aluminum, or stainless steel. The base portion 129 physically holds the turbo molecular pump 100 and also functions as a heat conduction path, and therefore a metal that is rigid and has high thermal conductivity, such as iron, aluminum, or copper, is preferably used.

[0044] In this configuration, when the rotor blades 102 are driven to rotate together with the rotor shaft 113 by the motor 121, exhaust gas is sucked from the chamber through the inlet port 101 by the actions of the rotor blades 102 and stator blades 123. The rotation speed of the rotor blades 102 is normally 20000 to 90000 rpm, and the peripheral velocity on the tip ends of the rotor blades 102 reaches 200 to 400 m/s. The exhaust gas sucked through the inlet port 101 passes between the rotor blades 102 and the stator blades 123 so as to be conveyed to the base portion 129. At this time, the temperature of the rotor blades 102 increases due to friction heat generated when the exhaust gas comes into contact with the rotor blades 102, conduction of the heat generated by the motor 121, and so on, and this heat is transmitted to the stator blade 123 side by radiation or by being conducted by the gas molecules of the exhaust gas.

[0045] The stator blade spacers 125 are joined to each other by outer peripheral portions thereof so that the heat received by the stator blades 123 from the rotor blades 102, the friction heat generated when the exhaust gas comes into contact with the stator blades 123, and so on

are transmitted to the outside.

[0046] Note that in the above description, the screw spacer 131 is disposed on the outer periphery of the cylindrical portion 102d of the rotating body 103, and the thread grooves 131a are engraved in the inner peripheral surface of the screw spacer 131. Conversely, however, the thread grooves may be engraved in the outer peripheral surface of the cylindrical portion 102d, and a spacer having a cylindrical inner peripheral surface may be disposed on the periphery thereof.

[0047] Furthermore, depending on the application of the turbo molecular pump 100, the periphery of electrical parts including the upper-side radial electromagnets 104, the upper-side radial sensors 107, the motor 121, the lower-side radial electromagnets 105, the lower-side radial sensors 108, the axial electromagnets 106A, 106B, the axial sensor 109, and so on may be covered by a stator column 122, and the interior of the stator column 122 may be maintained at a predetermined pressure using a purge gas, thereby ensuring that the gas sucked through the inlet port 101 does not infiltrate the electrical parts.

[0048] In this case, a pipe, not shown in the figures, is disposed in the base portion 129, and the purge gas is introduced through this pipe. The introduced purge gas is sent to the outlet port 133 through gaps between a protective bearing 120 and the rotor shaft 113, between a rotor and a stator of the motor 121, and between the stator column 122 and inner peripheral-side cylindrical portions of the rotor blades 102.

[0049] Here, the turbo molecular pump 100 requires control based on model specification and individually regulated unique parameters (for example, characteristics corresponding to the model). In order to store these control parameters, the turbo molecular pump 100 includes, in a main body thereof, an electronic circuit portion 141. The electronic circuit portion 141 is constituted by a semiconductor memory such as an EEP-ROM, an electronic component such as a semiconductor element for accessing the semiconductor memory, a substrate 143 on which these components are mounted, and so on. The electronic circuit portion 141 is housed in a lower portion of a rotation speed sensor, not shown in the figures, near the center, for example, of the base portion 129 constituting the lower portion of the turbo molecular pump 100, and is closed by an airtight bottom lid 145.

[0050] Incidentally, in a semiconductor manufacturing process, a process gas introduced into a chamber may have a property whereby the process gas becomes a solid when the pressure thereof increases beyond a predetermined value or the temperature thereof decreases below a predetermined value. In the interior of the turbo molecular pump 100, the pressure of the exhaust gas is lowest in the inlet port 101 and highest in the outlet port 133. When the pressure of the process gas increases beyond a predetermined value or the temperature thereof decreases below a predetermined value as the process gas is conveyed from the inlet port 101 to the

outlet port 133, the process gas takes a solid form, and the solid adheres to and is deposited in the interior of the turbo molecular pump 100.

[0051] For example, when SiCl_4 is used as a process gas in an Al etching device, it can be seen from the vapor pressure curve that at low vacuum (760 [torr] to 10-2 [torr]) and low temperature (approximately 20 [°C]), a solid product (AlCl_3 , for example) is precipitated, and the solid product adheres to and is deposited in the interior of the turbo molecular pump 100. When, as a result, the precipitate of the process gas accumulates in the interior of the turbo molecular pump 100, the deposit narrows the pump flow passage, causing a reduction in the performance of the turbo molecular pump 100. Moreover, the aforesaid product is more likely to coagulate in and adhere to high-pressure parts near the outlet port 133 and the screw spacer 131.

[0052] Hence, to solve this problem, conventionally, a heater, not shown in the figures, or an annular water-cooling pipe 149 is wrapped around the outer periphery of the base portion 129 and so on, a temperature sensor (a thermistor, for example), not shown in the figures, is embedded in the base portion 129, for example, and control (referred to hereinafter as a TMS (Temperature Management System)) is performed to heat the heater or provide cooling through the water-cooling pipe 149 on the basis of a signal from the temperature sensor so as to maintain the temperature of the base portion 129 at a constant high temperature (a set temperature).

[0053] Next, the amplifier circuit 150 for controlling excitation of the upper-side radial electromagnets 104, the lower-side radial electromagnets 105, and the axial electromagnets 106A, 106B will be described in relation to the turbo molecular pump 100 configured as described above. Fig. 2 is a circuit diagram of the amplifier circuit 150.

[0054] In Fig. 2, an electromagnet winding 151 constituting the upper-side radial electromagnets 104 and so on is connected at one end to a positive electrode 171a of a power supply 171 via a transistor 161 and connected at the other end to a negative electrode 171b of the power supply 171 via a current detection circuit 181 and a transistor 162. The transistors 161, 162 are so-called power MOSFETs, and are structured such that a diode is connected between the source and the drain thereof.

[0055] At this time, the transistor 161 is configured such that a cathode terminal 161a of the diode thereof is connected to the positive electrode 171a, and an anode terminal 161b is connected to one end of the electromagnet winding 151. Further, the transistor 162 is configured such that a cathode terminal 162a of the diode thereof is connected to the current detection circuit 181, and an anode terminal 162b is connected to the negative electrode 171b.

[0056] Meanwhile, a current regeneration diode 165 is configured such that a cathode terminal 165a thereof is connected to one end of the electromagnet winding 151, and an anode terminal 165b thereof is connected to the

negative electrode 171b. Similarly, a current regeneration diode 166 is configured such that a cathode terminal 166a thereof is connected to the positive electrode 171a, and an anode terminal 166b thereof is connected to the other end of the electromagnet winding 151 via the current detection circuit 181. The current detection circuit 181 is constituted by, for example, a Hall sensor-type current sensor or an electrical resistor element.

[0057] The amplifier circuit 150 configured as described above corresponds to one electromagnet. Accordingly, in a case where the magnetic bearing performs 5-axis control and the electromagnets 104, 105, 106A, 106B total ten in number, a similar amplifier circuit 150 is formed for each electromagnet such that ten amplifier circuits 150 are connected in parallel to the power supply 171.

[0058] Furthermore, an amplifier control circuit 191 is constituted by, for example, a digital signal processor unit (referred to hereinafter as a DSP unit), not shown in the figures, of the control device 200, and the amplifier control circuit 191 switches the transistors 161, 162 ON and OFF.

[0059] The amplifier control circuit 191 compares a current value detected by the current detection circuit 181 (a signal reflecting this current value will be referred to as a current detection signal 191c) with a predetermined current command value. The magnitude (pulse width times T_{p1} , T_{p2}) of a pulse width generated in a control cycle T_s serving as one period of PWM control is then determined on the basis of the comparison result. As a result, gate drive signals 191a, 191b having this pulse width are output from the amplifier control circuit 191 to the gate terminals of the transistors 161, 162.

[0060] Note that when the rotation speed of the rotating body 103 passes through the resonance point during an acceleration operation, when a disturbance occurs during a constant speed operation, and so on, it is necessary to control the position of the rotating body 103 at high speed and with great force. Therefore, a voltage of approximately 50 V, for example, is used as the power supply 171 so that the current flowing through the electromagnet winding 151 can be rapidly increased (or reduced). Further, a capacitor is normally connected between the positive electrode 171a and the negative electrode 171b of the power supply 171 in order to stabilize the power supply 171 (not shown).

[0061] In this configuration, when the transistors 161, 162 are both switched ON, the current (referred to hereinafter as an electromagnet current i_L) flowing through the electromagnet winding 151 increases, and when the transistors 161, 162 are both switched OFF, the electromagnet current i_L decreases.

[0062] Further, when one of the transistors 161, 162 is switched ON and the other is switched OFF, a so-called flywheel current is maintained. By passing a flywheel current through the amplifier circuit 150 in this manner, hysteresis loss in the amplifier circuit 150 can be reduced, making it possible to suppress the power consumption of

the circuit as a whole. Moreover, by controlling the transistors 161, 162 in this manner, high frequency noise such as harmonics generated in the turbo molecular pump 100 can be reduced. Furthermore, by measuring the flywheel current using the current detection circuit 181, the electromagnet current i_L flowing through the electromagnet winding 151 can be detected.

[0063] More specifically, as shown in Fig. 3, when the detected current value is smaller than the current command value, the transistors 161, 162 are both switched ON for a time corresponding to the pulse width time T_{p1} once during the control cycle T_s (100 μ s, for example). Accordingly, the electromagnet current i_L during this period increases from the positive electrode 171a to the negative electrode 171b in the direction of a current value i_{Lmax} (not shown) that can flow through the transistors 161, 162.

[0064] As shown in Fig. 4, meanwhile, when the detected current value is larger than the current command value, the transistors 161, 162 are both switched OFF for a time corresponding to the pulse width time T_{p2} once during the control cycle T_s . Accordingly, the electromagnet current i_L during this period decreases from the negative electrode 171b to the positive electrode 171a in the direction of a current value i_{Lmin} (not shown) that can be regenerated through the diodes 165, 166.

[0065] In both cases, following the elapse of the pulse width times T_{p1} , T_{p2} , one of the transistors 161, 162 is switched ON. Accordingly, during this period, a flywheel current is maintained in the amplifier circuit 150.

[0066] Fig. 5 is a view illustrating a conventional Siegbahn molecular pump 1000 and a schematic view showing an example configuration of the conventional Siegbahn molecular pump 1000. Arrows show a flow of gas molecules.

[0067] Fig. 6 is a view illustrating a stator disc 501 provided in the conventional Siegbahn molecular pump 1000, and a sectional view of the stator disc 501 when seen from the side of an inlet port 101 (Fig. 5) of the conventional Siegbahn molecular pump 1000. Arrows inside the stator disc 501 show a flow of gas molecules, and arrows outside the stator disc 501 show a rotation direction of a rotor disc 901 (Fig. 5).

[0068] A casing 201 that forms a housing of the Siegbahn molecular pump 1000 has a substantially cylindrical shape, and together with a base 700 provided on a lower portion (an outlet port 60 side) of the casing 201 constitutes a housing for the Siegbahn molecular pump 1000. A gas conveyance mechanism, which is a structure that causes the Siegbahn molecular pump 1000 to produce an exhaust performance, is housed inside the housing.

[0069] The gas conveyance mechanism can be broadly divided into a rotating portion that is supported to be free to rotate, and a stator portion that is fixed to the housing.

[0070] An inlet port 401 for introducing gas into the Siegbahn molecular pump 1000 is formed on an end portion of the casing 201. Further, a flange portion 50

that bulges out toward an outer peripheral side is formed on an end surface of the casing 201 on the inlet port 401 side.

[0071] Furthermore, the outlet port 60 for exhausting gas from the Siegbahn molecular pump 1000 is formed in the base 700.

[0072] The rotating portion is constituted by a shaft 701 serving as a rotating shaft, a rotor 801 disposed on the shaft 701, a plurality of rotor discs 901 provided on the rotor 801, a rotating cylinder 110, and so on. Note that the shaft 701 and the rotor 801 together constitute a rotor portion.

[0073] Each rotor disc 901 is formed from a disc member having a disc shape that extends radially perpendicular to the axis of the shaft 701.

[0074] Further, the rotating cylinder 110 is formed from a cylindrical member having a cylindrical shape that is concentric with the rotational axis of the rotor 801.

[0075] A motor portion 202 for rotating the shaft 701 at high speed is provided midway in an axial direction of the shaft 701.

[0076] Furthermore, radial-direction magnetic bearing devices 301, 310 for supporting the shaft 701 in a non-contact manner in a radial direction are provided on the inlet port 401 side and the outlet port 60 side of the shaft 701 relative to the motor portion 202, while an axial-direction magnetic bearing device 400 for supporting the shaft 701 in a non-contact manner in the axial direction is provided on a lower end of the shaft 701.

[0077] A stator portion is formed on an inner peripheral side of the housing. The stator portion is constituted by a plurality of the stator discs 501, which are provided on the inlet port 401 side, and so on, and a spiral groove portion 530, which is a spiral groove formed from a stator disc root portion 510 and a stator disc ridge portion 520, is engraved in the stator disc 501.

[0078] Note that here, a configuration in which the spiral groove (the spiral groove portion 530) is engraved in the stator disc 501 has been described, but the spiral groove may be engraved in the rotor disc 901. In other words, a spiral groove flow passage formed from a spiral groove may be engraved in the gap-opposed surface of at least one of the stator disc 501 and the rotor disc 901.

[0079] Each stator disc 501 is formed from a disc member having a disc shape that extends radially perpendicular to the axis of the shaft 701.

[0080] The stator discs 501 of the respective stages are fixed so as to be spaced from each other by cylindrical spacers 601. The arrows in Fig. 5 show the flow of gas.

[0081] In the Siegbahn molecular pump 1000, the rotor discs 901 and the stator discs 501 are arranged alternately and formed in a plurality of stages in the axial direction, and in order to satisfy the exhaust performance required of the vacuum pump, desired numbers of rotor components and stator components may be provided as required.

[0082] In the Siegbahn molecular pump 1000 having this configuration, vacuum exhaust processing is per-

formed in a vacuum chamber (not shown) disposed in the Siegbahn molecular pump 1000.

[0083] Fig. 7 is a schematic view showing an example configuration of a conventional combined turbo molecular pump (a pump integrating a turbo molecular pump with a Siegbahn element), and Fig. 8 is a perspective view illustrating the stator disc ridge portion 520 forming the spiral groove provided in the stator disc that serves as the Siegbahn element of the conventional combined turbo molecular pump. In Fig. 7, a location denoted by S indicates the Siegbahn element.

[0084] As is evident from Figs. 7 and 8, in a combined turbo molecular pump 500, the outer diameter of the stator disc ridge portion 520 forming the spiral groove engraved in the stator disc 501 of the uppermost stage, which serves as an introduction portion of the Siegbahn exhaust element, is the same size as the outer diameter of the corresponding rotor disc 901. This is in order to correspond to the fact that the stator disc 501 and the rotor disc 901 are the same size. Conventionally, therefore, the stator disc ridge portion 520 forming the spiral groove of the uppermost stage, which serves as the introduction portion of the Siegbahn exhaust element, does not project beyond the outer diameter of the corresponding rotor disc 901.

[0085] Fig. 9 is a schematic view showing an example configuration of a combined turbo molecular pump according to a first embodiment of the present invention, and Fig. 10 is a perspective view illustrating the stator disc ridge portion 520 forming the spiral groove provided in the stator disc that serves as the Siegbahn element of the combined turbo molecular pump according to the first embodiment of the present invention.

[0086] As is evident from these figures, an inflow guide portion A is provided on the stator disc ridge portion 520 forming the spiral groove provided in the stator disc 501 so as to project beyond the outer diameter of the corresponding rotor disc 901. In other words, the stator disc ridge portion 520 is disposed in a form that projects from the outer diameter of the corresponding rotor disc 901.

[0087] By providing the inflow guide portion A, pressure on a downstream side of the stator disc ridge portion 520 (a location on a back surface (an opposite) side of the inflow guide portion A, on which the gas impinges) decreases so that the gas flowing upstream of the stator disc ridge portion 520 is sucked in. More specifically, in the location where the gas collides with the inflow guide portion A, the pressure increases, but since the pressure on the opposite side (the downstream side) decreases, it is assumed that stagnant gas on the upstream side will flow in so as to be sucked in.

[0088] Hence, by providing the inflow guide portion A, it is possible to induce a longitudinal-direction gas flow, which has conventionally been lacking.

[0089] Accordingly, by providing the inflow guide portion A, the exhaust speed can be increased while maintaining the back pressure dependence performance, and as a result, the exhaust performance can be improved.

[0090] The inflow guide portion A may be formed integrally with the stator disc ridge portion 520 or formed by attaching a retrofitted component (a separate component). The material may be the same as or different to the material of the stator disc ridge portion 520. The retrofitted component may be attached by being fixed by screws, welded, or fitted.

[0091] Fig. 11 is a schematic view showing an example configuration of a combined turbo molecular pump according to a second embodiment of the present invention. Likewise in the second embodiment, the inflow guide portion A is provided on the stator disc ridge portion 520 forming the spiral groove provided in the stator disc 501 so as to project beyond the outer diameter of the corresponding rotor disc 901. The inflow guide portion A and an opposing stator-side component contact each other so that there is no gap therebetween. In other words, the inflow guide portion A projects further than in the first embodiment.

[0092] According to the second embodiment, the inflow guide portion A and the opposing stator-side component contact each other so that there is no gap therebetween. Since there is no gap therebetween, inflow to the back surface side of the inflow guide portion A (the opposite side to the surface on which the gas impinges) decreases further, leading to a further reduction in pressure on the back surface side. As a result, suction (introduction) of the gas can be further encouraged.

[0093] Accordingly, stagnant gas can be exhausted more efficiently, which contributes to an increase in the exhaust speed.

[0094] Note that in the second embodiment, similarly to the first embodiment, the inflow guide portion A may be formed integrally with the stator disc ridge portion 520 or formed by attaching a retrofitted component (a separate component).

[0095] Fig. 12 is a schematic view showing an example configuration of a combined turbo molecular pump according to a third embodiment of the present invention, and Fig. 13 is a perspective view illustrating the stator disc ridge portion 520 forming the spiral groove provided in the stator disc that serves as the Siegbahn element of the combined turbo molecular pump according to the third embodiment of the present invention.

[0096] In the third embodiment, the inflow guide portion A is shaped not only to extend in the outer diameter direction thereof but also to extend integrally in the axial direction toward the inlet port side. The extension in the axial direction toward the inlet port side is preferably set so that the gap between the inflow guide portion A and the opposing rotor disc 901 is as narrow as possible. It is preferable to provide a gap of approximately 1.5 mm, for example, so that the inflow guide portion A does not contact the rotor disc 901 during rotation thereof.

[0097] According to the third embodiment, the surface area of the inflow guide portion A (the surface area on which the gas impinges) is greater than in the first embodiment, leading to a further reduction in the flow to the

back surface side (the opposite side to the surface on which the gas impinges). As a result, suction of the gas can be even further encouraged.

[0098] Likewise in the third embodiment, similarly to the first and second embodiments, the inflow guide portion A may be formed integrally with the stator disc ridge portion 520 or formed by attaching a retrofitted component (a separate component).

[0099] Furthermore, similarly to the second embodiment, the inflow guide portion A may contact the opposing stator-side component so that there is no gap therebetween.

[0100] In the first to third embodiments, when a plurality of stages of the Siegbahn element exist, the inflow guide portion A is preferably provided on the uppermost stage (the stage nearest the inlet port) in the axial direction.

[0101] Furthermore, likewise in a Siegbahn vacuum pump in which only the Siegbahn element exists in a plurality of stages, the inflow guide portion A is preferably provided on the uppermost stage (the stage nearest the inlet port) in the axial direction. Note that the inflow guide portion A may also be provided on another stage as well as the uppermost stage.

[0102] The embodiments and modified examples of the present invention may be configured in various combinations as required.

[0103] Moreover, various modifications may be applied to the present invention within a scope that does not depart from the spirit of the present invention. The present invention naturally extends to these modifications.

[Reference Signs List]

[0104]

100	Turbo molecular pump (vacuum pump)
101	Inlet port
102	Rotor blade
102d	Cylindrical portion
103	Rotating body
113	Rotor shaft
122	Stator column
123	Stator blade
125	Stator blade spacer
127	Outer tube
129	Base portion
131	Screw spacer
131a	Thread groove
133	Outlet port
200	Control device
500	Combined turbo molecular pump
501	Stator disc
510	Stator disc root portion
520	Stator disc ridge portion
530	Spiral groove portion
901	Rotor disc
1000	Siegbahn molecular pump

Claims

1. A vacuum pump for exhausting a gas by an interaction between a rotor disc and a stator disc, the vacuum pump comprising:

a casing;

a rotor shaft, which is disposed inside the casing;

the rotor disc, which is capable of rotating together with the rotor shaft; and

the stator disc, which is disposed so as to oppose the rotor disc in an axial direction of the rotor shaft and has a spiral groove with a root portion and a ridge portion in an opposed surface thereof,

wherein an inflow guide portion for guiding inflow of the gas is provided on a gas inflow port of the spiral groove.
2. The vacuum pump according to claim 1, wherein the inflow guide portion is shaped such that the ridge portion extends integrally outward beyond an outer diameter of the opposing rotor disc.
3. The vacuum pump according to claim 2, wherein the inflow guide portion is shaped such that the ridge portion also extends integrally in the axial direction toward an inlet port side.
4. The vacuum pump according to claim 1, wherein the inflow guide portion is shaped such that the ridge portion extends outward beyond an outer diameter of the opposing rotor disc by attaching a retrofitted component shaped such that the ridge portion extends outward beyond the outer diameter of the opposing rotor disc.
5. The vacuum pump according to claim 4, wherein the inflow guide portion is shaped such that the retrofitted component also extends in the axial direction toward an inlet port side.
6. The vacuum pump according to any one of claim 1 to claim 5, wherein the rotor disc and the stator disc are arranged in a plurality of stages, and the inflow guide portion is provided on a stage furthest toward an inlet port side, among the plurality of stages of the stator discs.
7. The vacuum pump according to any one of claim 1 to claim 5, wherein the inflow guide portion and an opposing stator-side component contact each other so that there is no gap therebetween.
8. A stator disc used in a vacuum pump for exhausting a gas by an interaction with a rotor disc, wherein the stator disc is disposed so as to oppose

the rotor disc in an axial direction, has a spiral groove with a root portion and a ridge portion in an opposed surface thereof, and comprises an inflow guide portion shaped such that the ridge portion extends integrally outward beyond an outer diameter of the opposing rotor disc.

9. A retrofitted component attached to a stator disc that is used in a vacuum pump for exhausting a gas by an interaction with a rotor disc, and disposed so as to oppose the rotor disc in an axial direction, and moreover has a spiral groove with a root portion and a ridge portion in an opposed surface thereof, wherein the retrofitted component is shaped such that the ridge portion extends outward beyond an outer diameter of the opposing rotor disc.

Fig.1

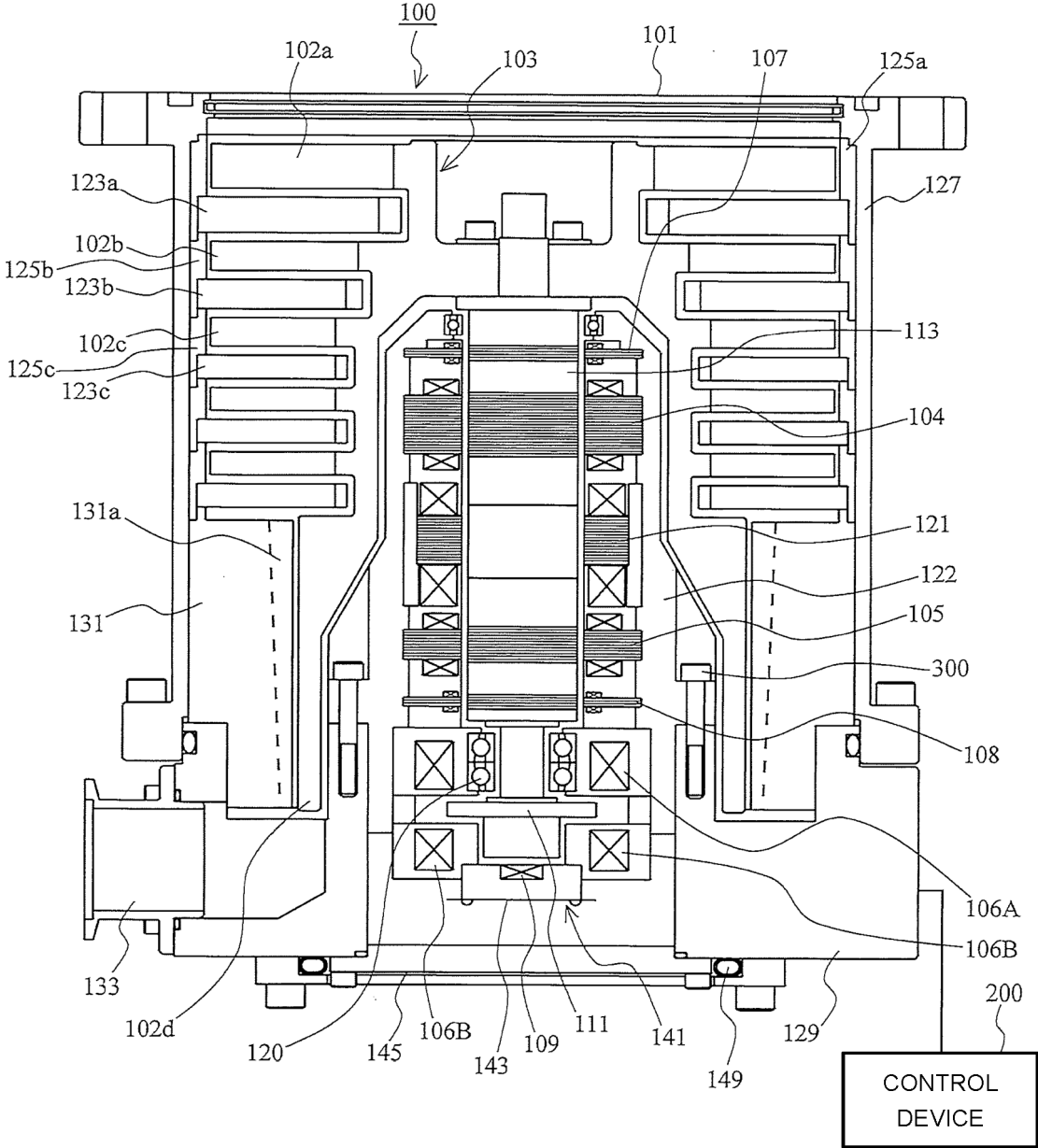


Fig.2

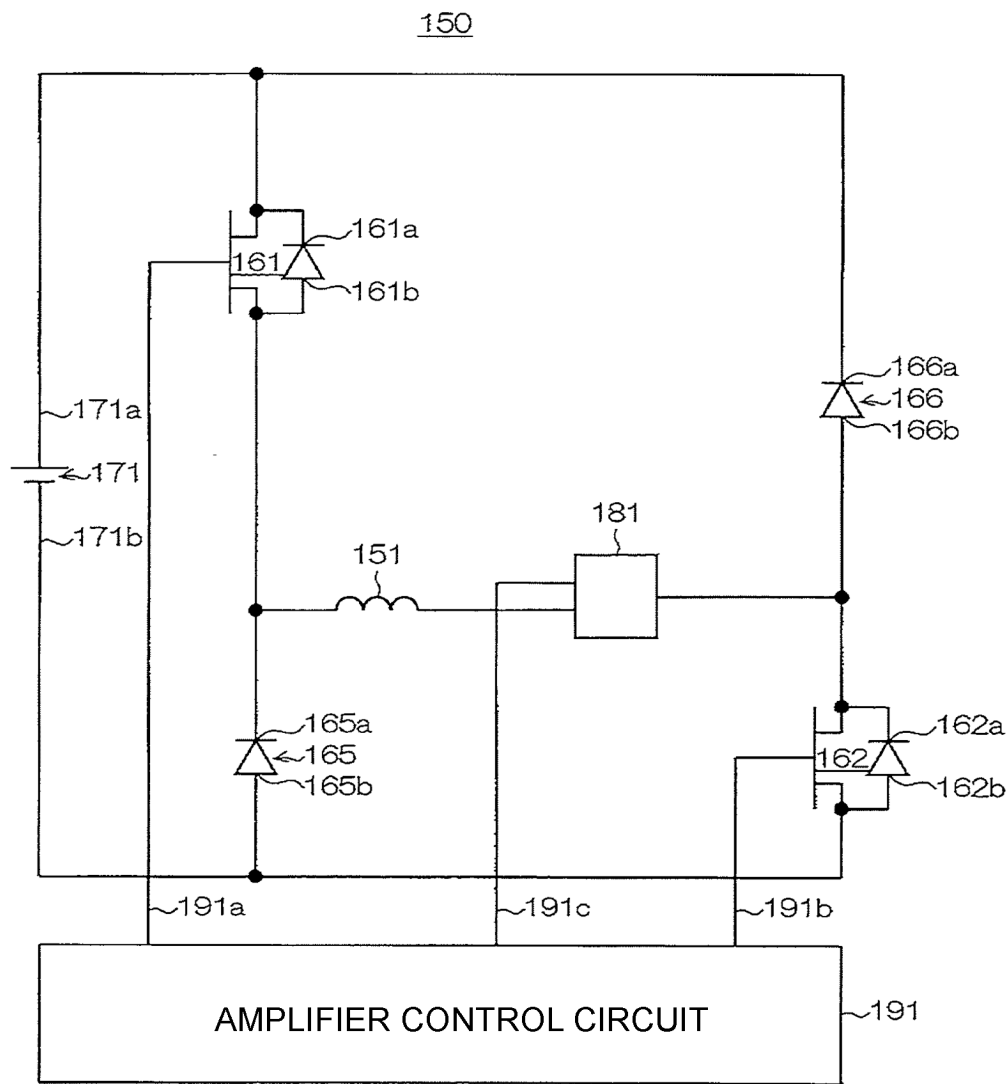


Fig.3

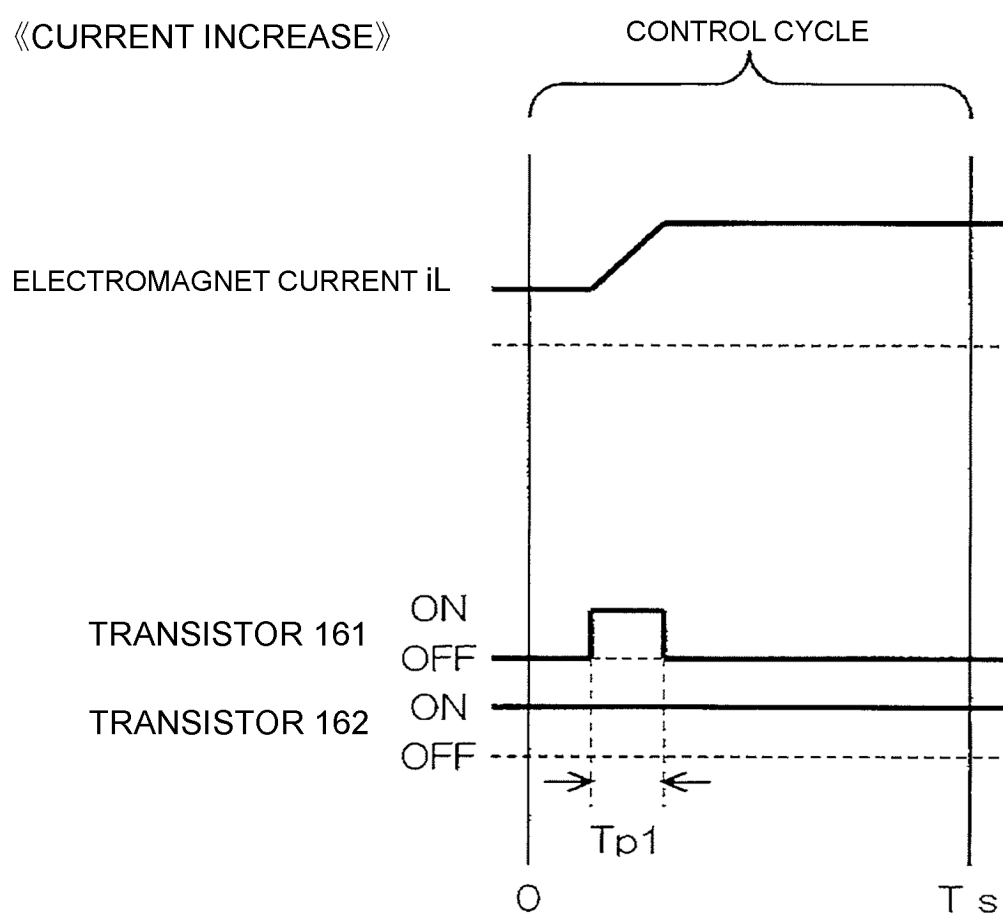


Fig.4

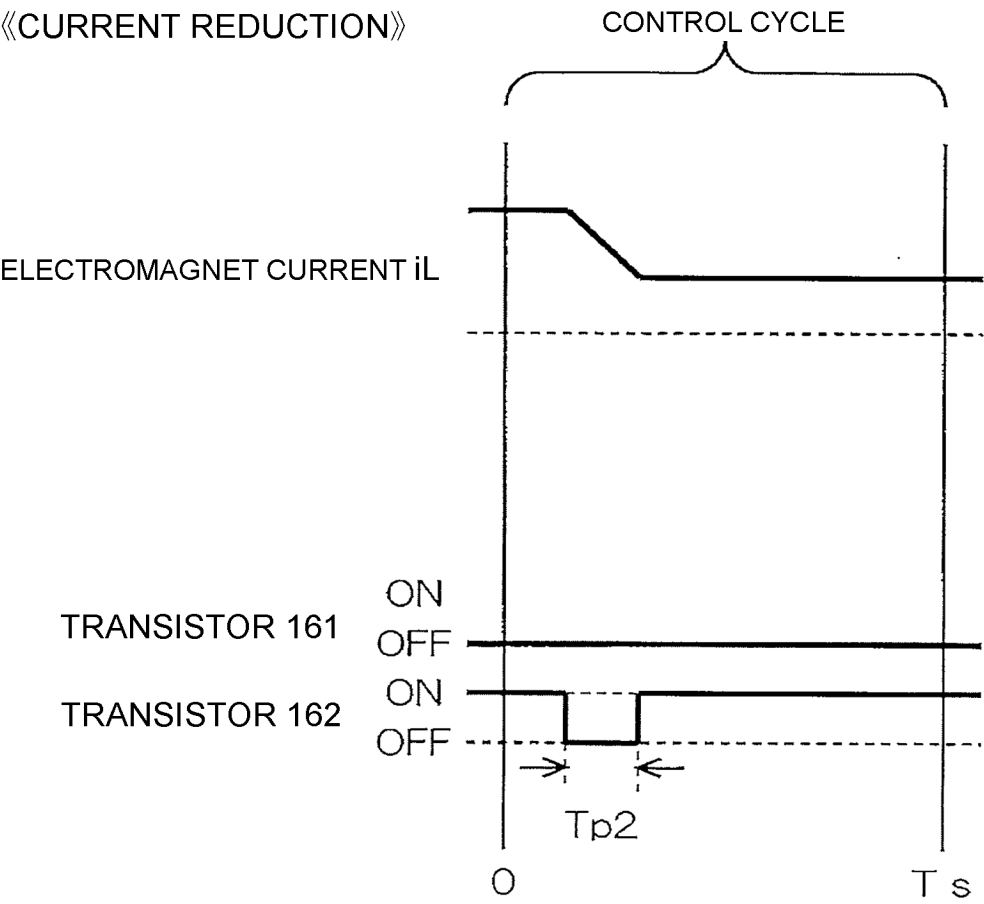


Fig.5

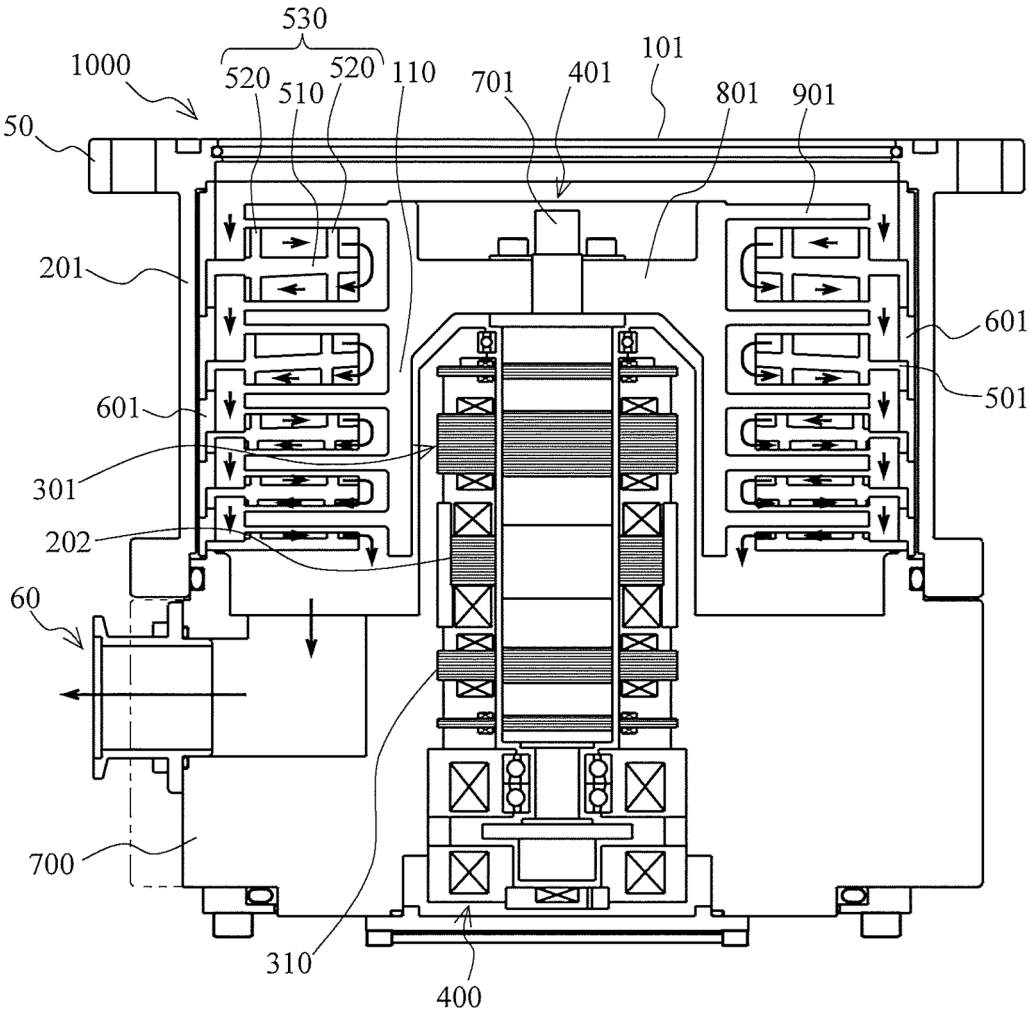


Fig.6

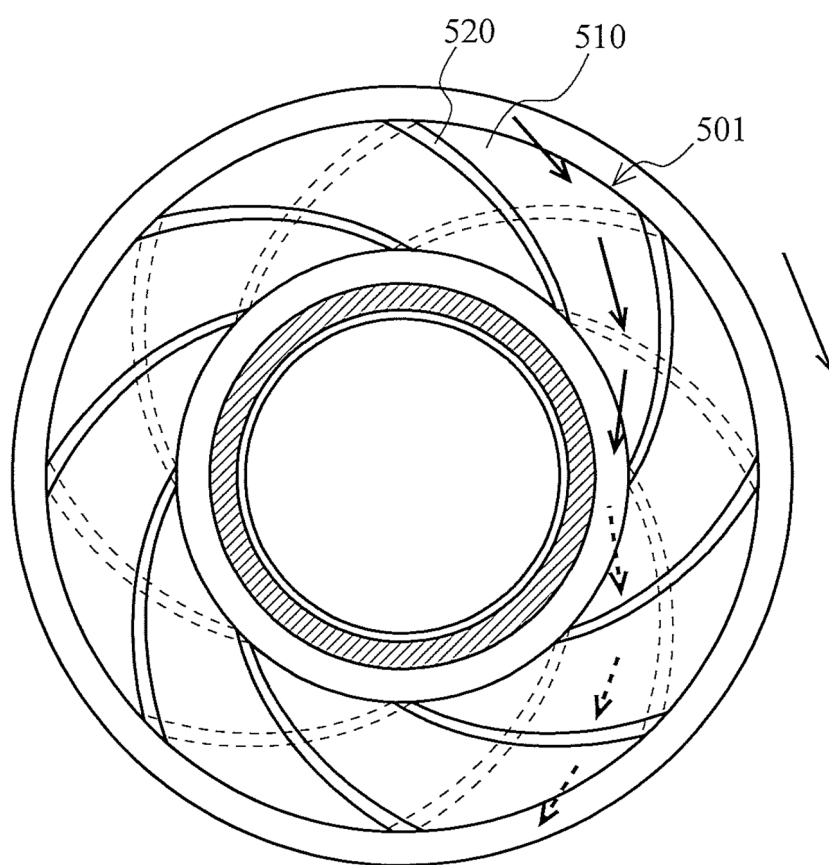


Fig.7

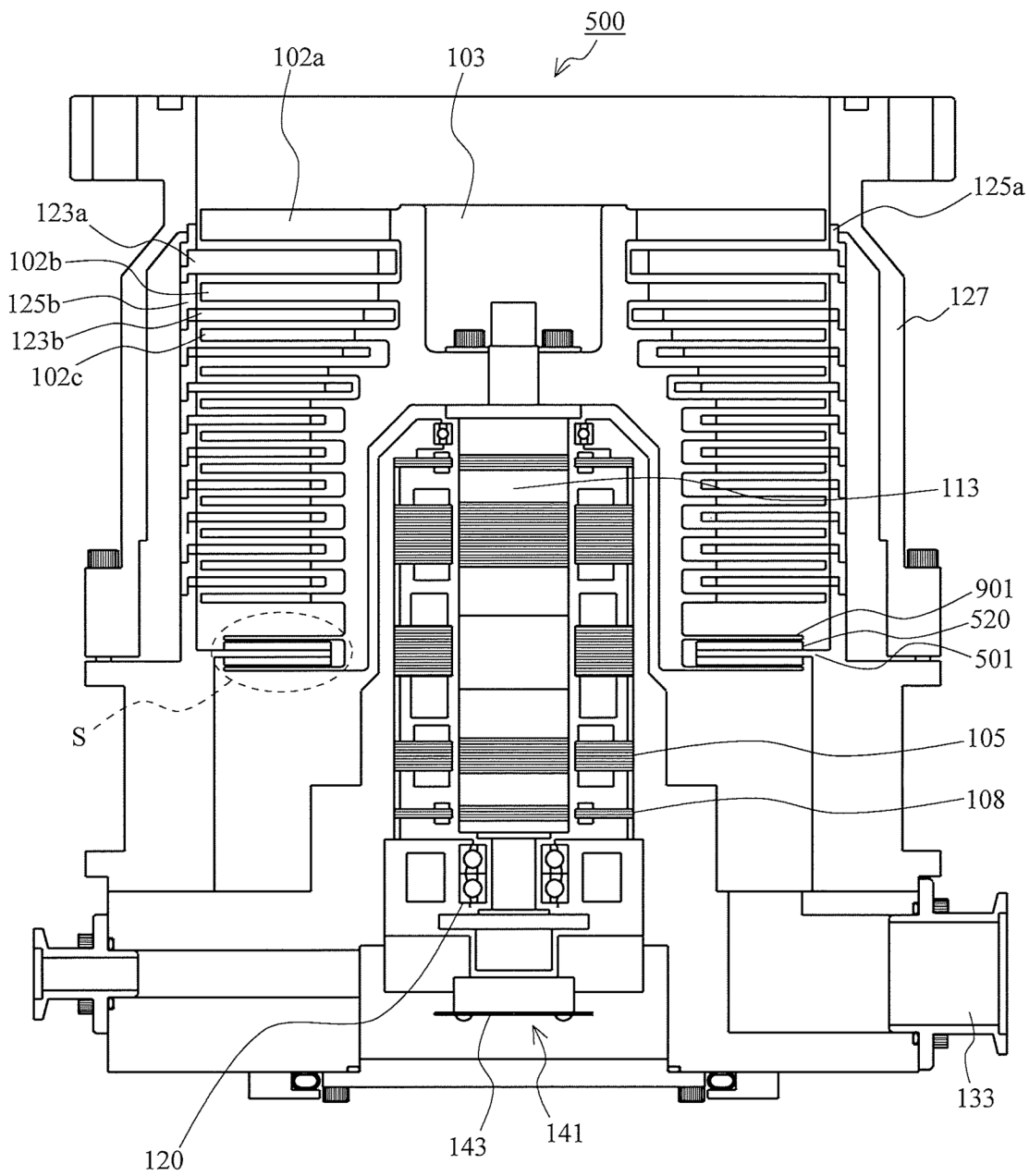


Fig.8

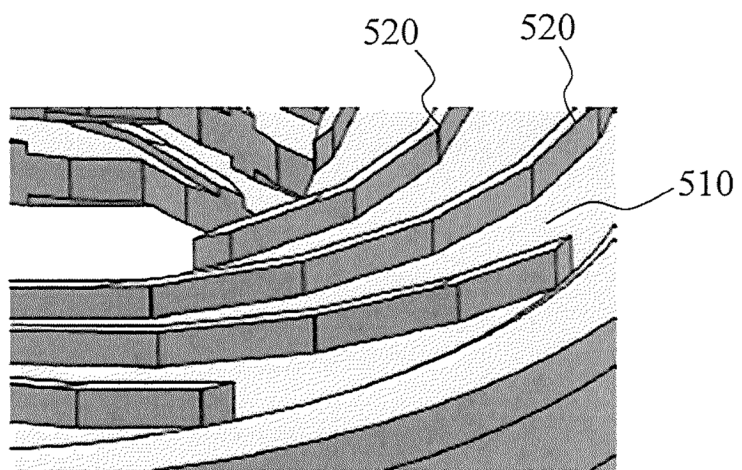


Fig.9

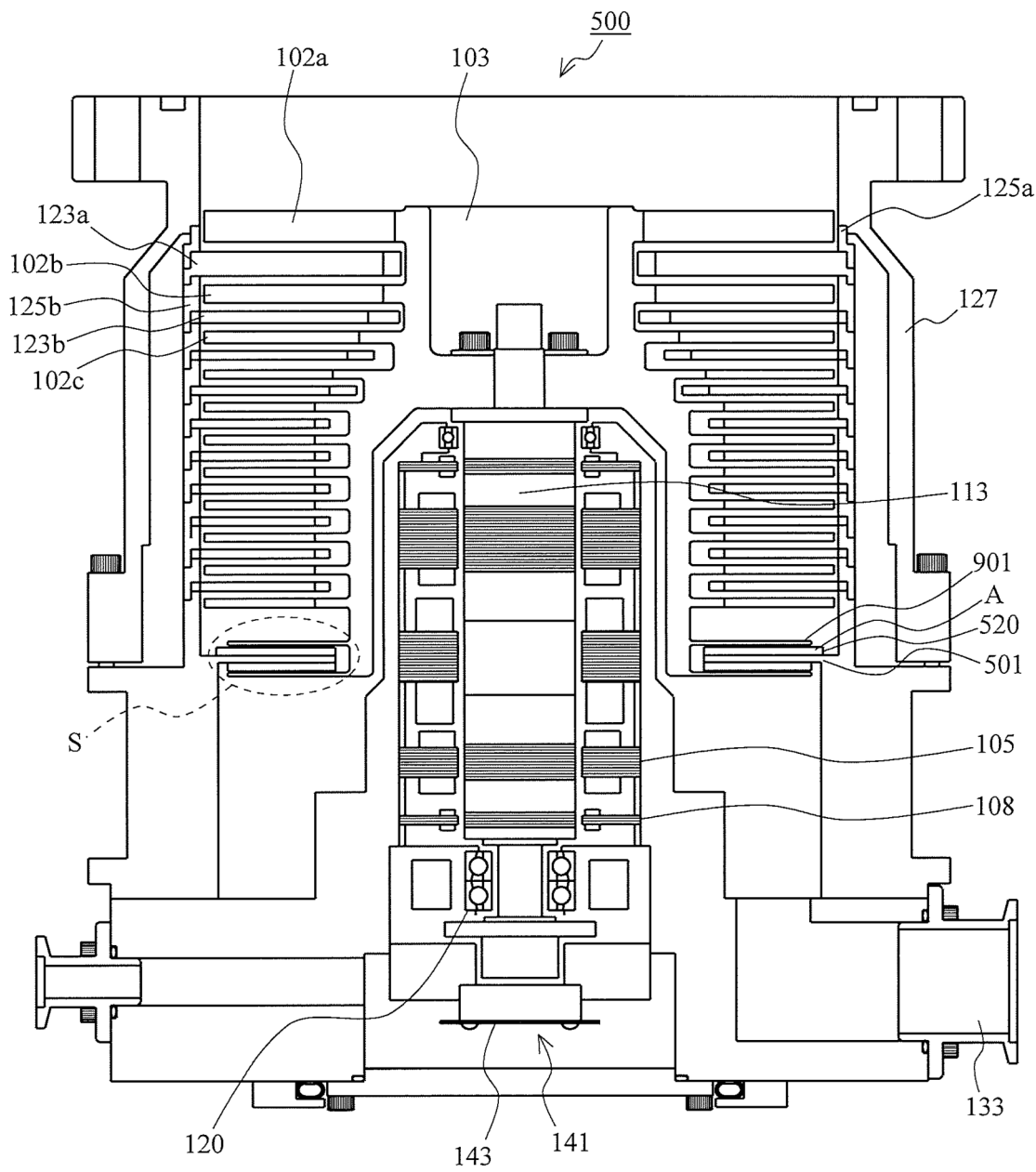


Fig.10

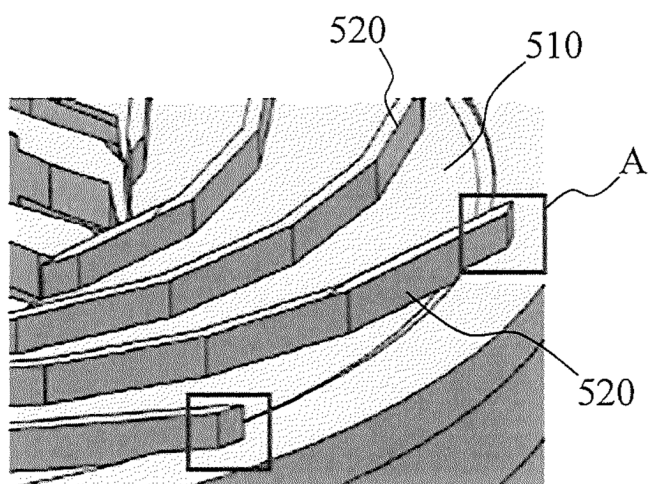


Fig.11

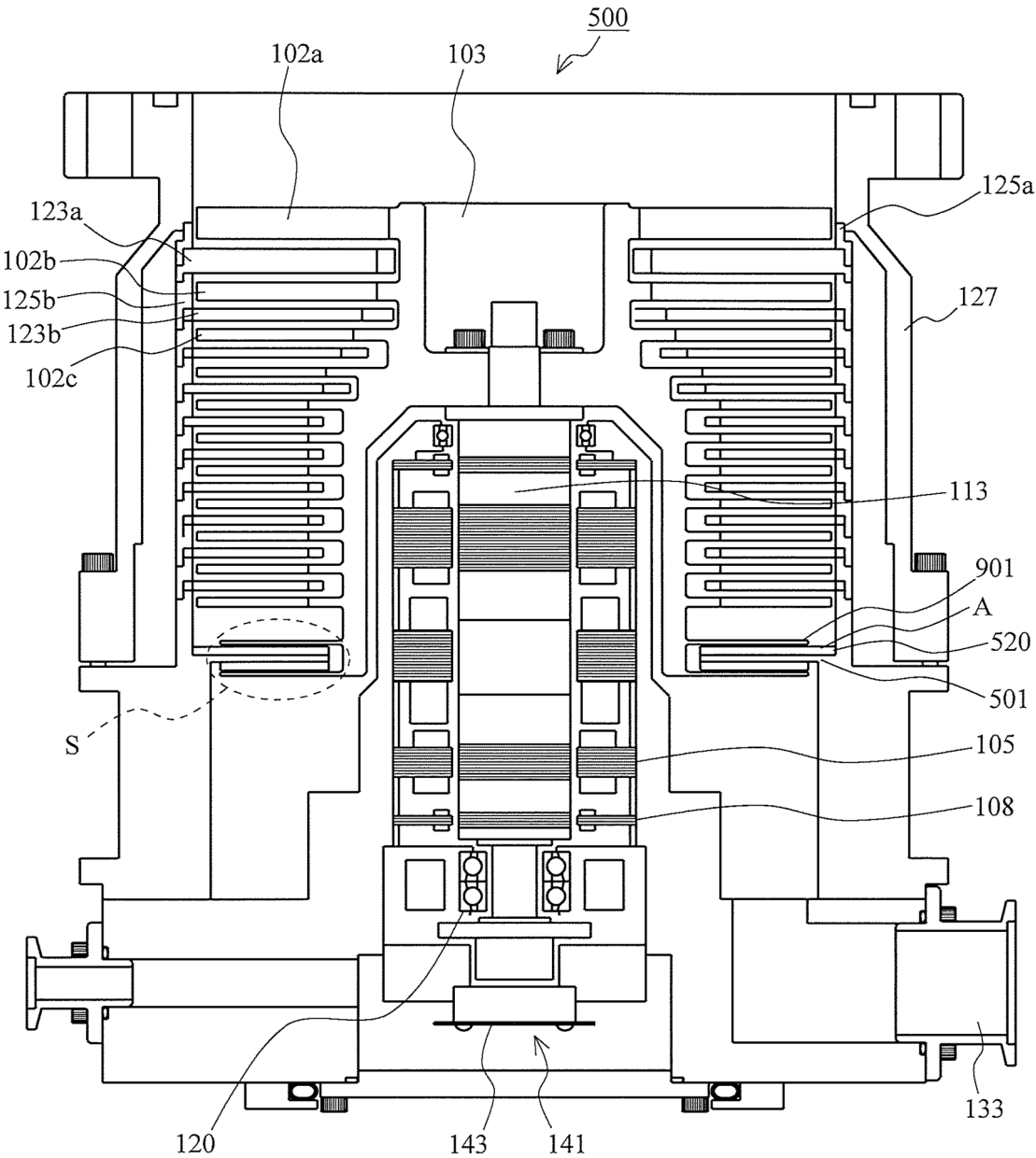


Fig.12

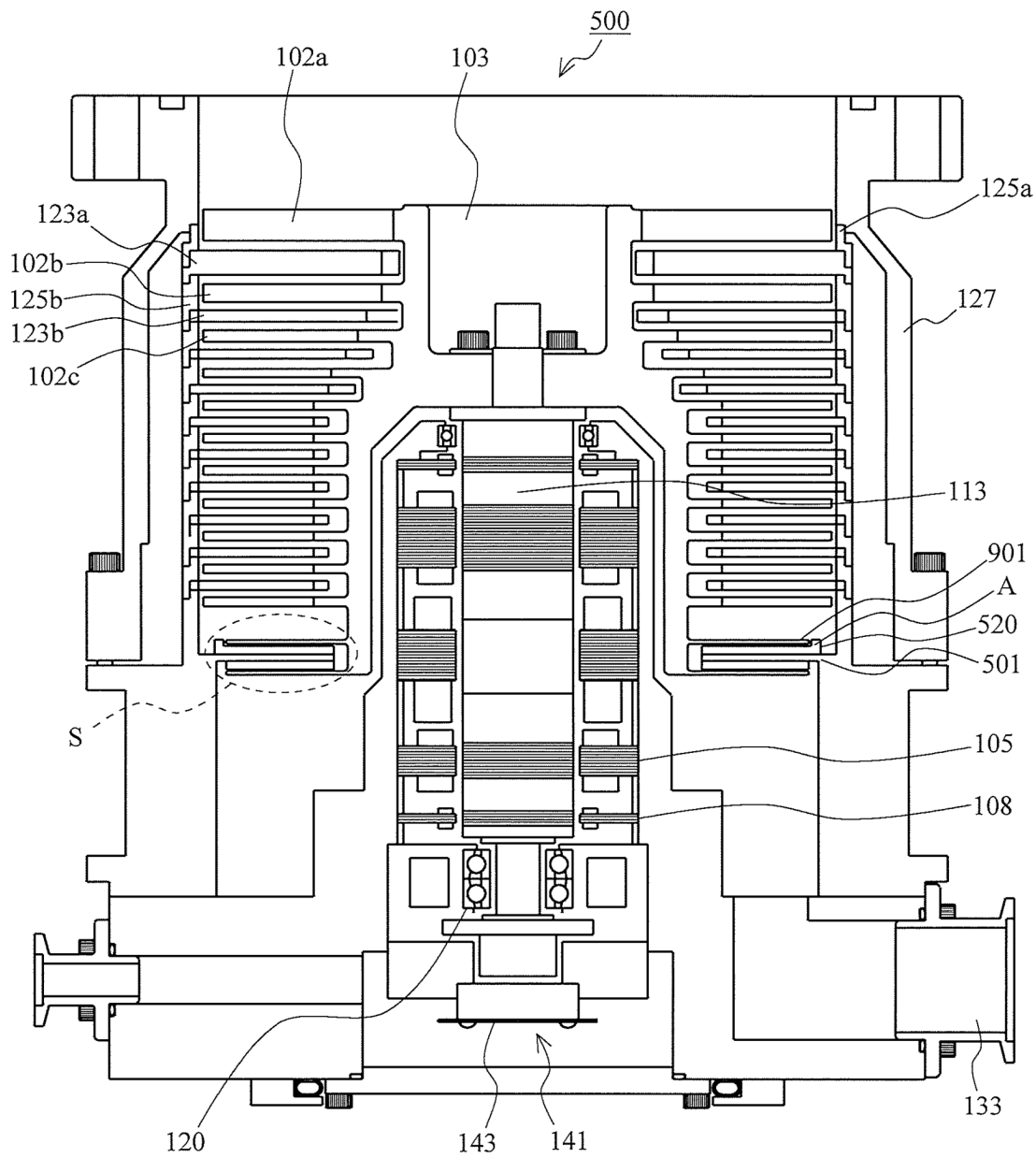


Fig.13

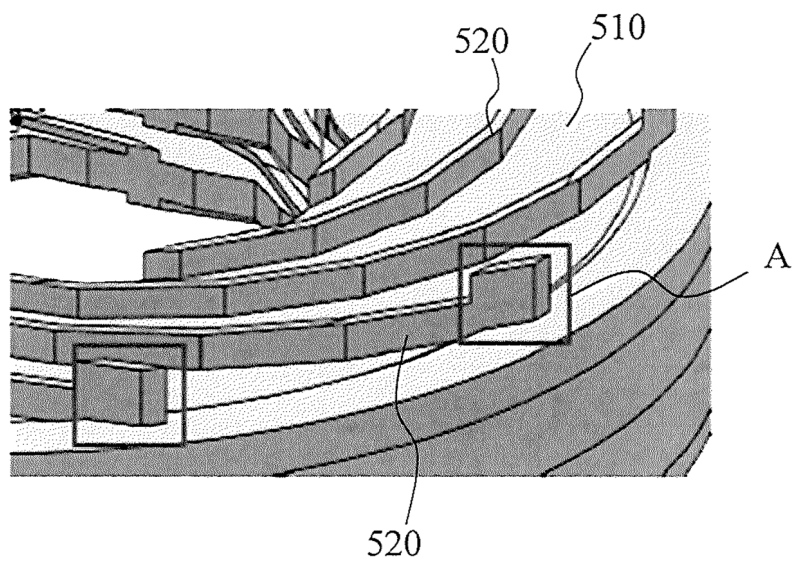
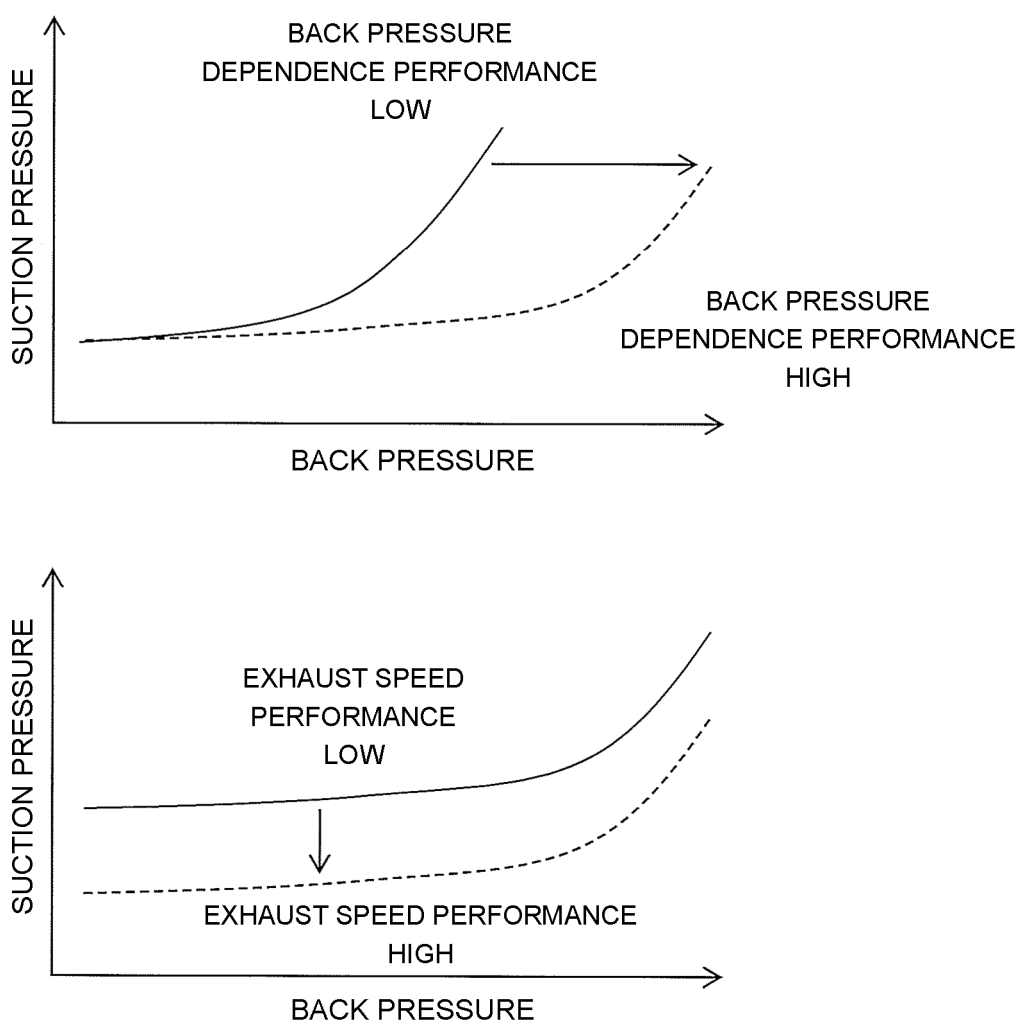


Fig.14



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2024/029684

A. CLASSIFICATION OF SUBJECT MATTER

F04D 19/04(2006.01)i

FI: F04D19/04 D

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)

F04D19/04

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

Published examined utility model applications of Japan 1922-1996

Published unexamined utility model applications of Japan 1971-2024

Registered utility model specifications of Japan 1996-2024

Published registered utility model applications of Japan 1994-2024

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.
X	WO 2021/105656 A1 (EDWARDS LIMITED) 03 June 2021 (2021-06-03) fig. 1, 2	1-2, 6-8
A		3-5, 9
X	JP 2010-504464 A (EDWARDS LIMITED) 12 February 2010 (2010-02-12) fig. 1, 2	1-2, 6-8
A		3-5, 9
X	JP 2015-124656 A (EDWARDS KK) 06 July 2015 (2015-07-06) paragraphs [0026]-[0028], fig. 4-6	1, 6-7
A		2-5, 8-9

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

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Date of the actual completion of the international search

05 November 2024

Date of mailing of the international search report

12 November 2024

Name and mailing address of the ISA/JP

Japan Patent Office (ISA/JP)

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2024/029684

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				paragraphs [0096]-[0107], fig. 4-6			
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				EP	3088744	A1	
				KR	10-2016-0102160	A	
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REFERENCES CITED IN THE DESCRIPTION

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