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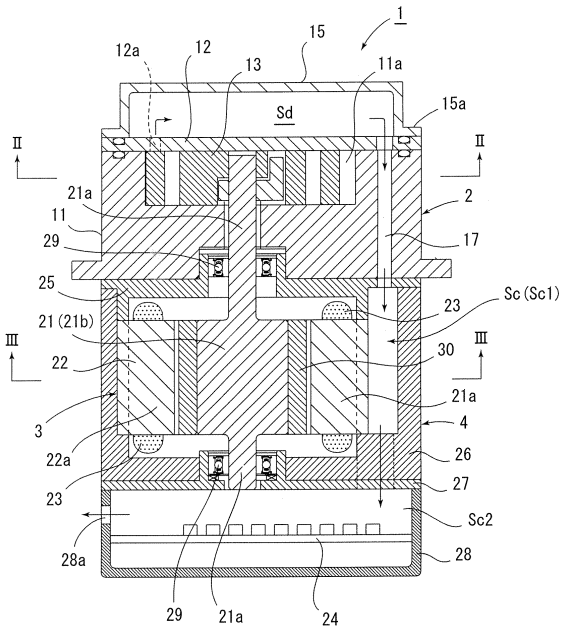
(54) VACUUM PUMP

(57) A vacuum pump 1 includes a pump means 2 for compressing gas inhaled from an intake port 11b and discharging the compressed gas from an exhaust port 12b and a motor 3 for driving the pump means.

A housing 4 which houses a stator core 22 and serves as a motor casing of the motor is provided to form a cooling passage Sc between the outer surface of the stator core and the inner surface of the housing and the gas discharged from the exhaust port of the pump means is circulated into the cooling passage to cool the motor.

Cooling the motor allows maintaining not only the performance of the motor but also the suction performance of the pump means.

Fig. 1



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Description

Technical Field

[0001] The present invention relates to a vacuum pump and more specifically to a vacuum pump including a pump means for compressing gas inhaled from an intake port and discharging the compressed gas from an exhaust port and a motor for driving the pump means.

Background Art

[0002] Up to now, a vacuum pump has been used for supplying a negative pressure to a brake booster for an automobile, for example. A vacuum pump including a pump means for compressing gas inhaled from an intake port and discharging the compressed gas from an exhaust port and a motor for driving the pump means has been known as such a vacuum pump (refer to Patent Literature 1).

[0003] In the vacuum pump, the motor drives the pump means, thereby inhaling gas from the intake port and supply the negative pressure to the booster while discharging the inhaled gas from the exhaust port.

Prior Art Documents

Patent Literature

[0004] Patent Literature 1: Japanese Patent Laid-Open No. 4-187891

Summary of Invention

Problems to be Solved by the Invention

[0005] The vacuum pump used for the brake is attached into an engine room of an automobile, so that the vacuum pump is exposed to a high temperature environment with temperature in the engine room and temperature generated by the motor itself.

[0006] Change in a motor characteristic due to increase in temperature also changes a suction performance of the pump means, which become not able to supply a stable negative pressure any longer and affects durability.

[0007] For this reason, the conventional vacuum pump has a problem in that it is needed to use a motor operable even in a high temperature environment, as a vacuum pump.

[0008] In view of such a problem, the present invention provides a vacuum pump capable of maintaining not only the performance of a motor but also the suction performance of the pump means by cooling the motor.

Means for Solving the Problems

[0009] A vacuum pump according to claim 1 of the present invention includes a pump means for compressing gas inhaled from an intake port and discharging the compressed gas from an exhaust port and a motor for driving the pump means, in which a housing for housing a motor casing of the motor is provided to form a cooling passage between the outer surface of the motor casing and the inner surface of the housing and the gas discharged from the exhaust port of the pump means is circulated into the cooling passage to cool the motor.

Advantageous Effects of Invention

[0010] According to the present invention, the gas discharged from the exhaust port is caused to circulate through a cooling passage formed between a motor casing and a housing of the motor to cool the motor, which enables maintaining not only the performance of the motor but also the suction performance of the pump means.

Brief Description of Drawings

[0011]

[Figure 1] Figure 1 is a cross section of a vacuum pump according to the present embodiment.
[Figure 2] Figure 2 is a cross section along the line II - II in Figure 1.
[Figure 3] Figure 3 is a cross section along the line III - III in Figure 1.

Mode for Carrying out the Invention

[0012] The embodiment shown in the figure is described below. Figure 1 shows a vacuum pump 1 for supplying a negative pressure to a brake booster provided in an engine room of an automobile.

[0013] The vacuum pump 1 includes a pump means 2 for compressing inhaled gas and discharging the compressed gas, a motor 3 for driving the pump means 2, and a housing 4 for holding the motor 3. As the pump means 2, a so-called vane pump is used, and as the motor 3, a brushless motor is used.

[0014] As shown in Figure 2, the pump means 2 includes: a pump casing 11, on the upper surface of which a substantially circular pump chamber 11a is formed and to the lower surface of which the motor 3 is fixed; a cover 12 which is provided on the upper surface of the pump casing 11 and closes the pump chamber 11a; a rotor 13 which rotates inside the pump chamber 11a by the motor 3; a plurality of vanes 14 sectioning the pump chamber 11a into a plurality of spaces according to the rotation of the rotor 13; and a silencer 15 for covering the upper surface of the cover 12.

[0015] The pump casing 11 is formed of a substantially rectangular parallelepiped member. An intake port 11b for sucking gas is formed in the pump chamber 11a formed on the upper surface of the pump casing 11, and an exhaust port 12a for discharging the compressed gas is formed on the cover 12 for closing the pump chamber 11a.

[0016] As shown in Figure 2, the intake port 11b communicates with an inhalation port 16 provided on the side face of the pump casing 11 and connected with a booster via a pipe (not shown).

[0017] As shown in Figure 1, the exhaust port 12a is formed by drilling the cover 12 and configured to exhaust the compressed gas upward from the top portion of the pump casing 11 and the cover 12. As shown in Figure 2, the exhaust port 12a is formed on the substantially opposite side of the intake port 11b with the rotor 13 being therebetween.

[0018] The center of the rotor 13 is provided at a position eccentric to the center of the pump chamber 11a. As shown in Figure 1, the rotor 13 is connected with a drive shaft 21 of the motor 3 via a connection member and configured to rotate counterclockwise, as shown in Figure 2.

[0019] Four slits 13a are formed in the rotor 13 at equally spaced intervals and at an angle tilted to a diameter direction thereof and the vanes 14 are retractably provided in the respective slits 13a.

[0020] The leading edge of the vane 14 keeps in contact with the inner peripheral surface of the pump chamber 11a while the vane 14 projects from and retracts into the slit 13a, thereby to section the pump chamber 11a into a plurality of spaces.

[0021] The silencer 15 is a box-shaped member which is bottomed and whose lower end portion is opened. The silencer 15 is equipped with a flange 15a around the opening. The flange 15a is in close contact with a seal member provided on the upper surface of the cover 12 of the pump casing 11 so that the silencer 15 defines a damper space Sd sectioned off from the outside between it and the cover 12.

[0022] As shown in Figure 2, bolt holes 11c are drilled at four corners of the pump casing 11. Bolts are inserted into bolt holes which are formed by drilling at the same position of the cover 12 and the silencer 15 so as to penetrate the bolt holes, thereby to fix the silencer 15 to the pump casing 11 along with the cover 12.

[0023] In the pump casing 11 and the cover 12 is formed a through hole 17 penetrating through from the upper surface to the lower surface thereof. The upper end of the through hole 17 is opened to the damper space Sd defined by the silencer 15.

[0024] Thus, the exhaust port 12a and the through hole 17 formed in the cover 12 are communicated with each other via the damper space Sd and the gas exhausted from the exhaust port 12a passes through the damper space Sd and the through hole 17 and is discharged from the lower surface side of the pump casing 11.

[0025] The motor 3 is a so-called 4-pole and 6-slot brushless motor and includes the drive shaft 21 connected to the rotor 13 of the pump means 2, a cylindrical stator core 22 serving as a motor casing, six pairs of coils 23 provided inside the stator cores 22 and arranged so as to surround the drive shaft 21, and a board 24 which is provided outside the stator cores 22 and controls the coils 23.

[0026] In the present embodiment, the housing 4 forms a part of the motor 3 and includes a first member 25 which is in close contact with the pump casing 11 to pivotally support the front end side of the drive shaft 21, a second member 26 which is provided at the lower portion of the first member 25 to hold the stator core 22, a third member 27 which is provided at the lower portion of the second member 26 to pivotally support the back end side of the drive shaft 21, and a fourth member 28 which is provided at the lower surface of the third member 27 to house the board 24.

[0027] The combination of the first to third members 25 to 27 forms a space therebetween. The fourth member 28 is a box-shaped member which is bottomed and whose upper surface is opened, and a space is formed between the fourth member 28 and the third member 27.

[0028] Bolt holes are formed at four corners of the first to fourth members 25 to 28 at the same position as the bolt holes 11c formed in the pump casing 11. The first to fourth members 25 to 28 are fixed to the lower surface of the pump means 2 by bolts along with the motor 3.

[0029] The drive shaft 21 is formed of a small diameter portion 21a protruding upward and downward and a large diameter portion 21b formed adjacent to the position of the coil 23 shown in Figure 1. A bearing 29 for pivotally supporting

the small diameter portion 21a is provided on the first and third members 25 and 27 of the housing 4. Four permanent magnets 30 arranged to make their magnetic poles different from one another are fixed to the outer peripheral surfaces of the large diameter portion 21b.

[0030] The stator core 22 is cylindrical and held between the first member 25 and the third members 27 of the housing 4 at the upper and lower ends thereof as shown in Figure 1. Thus, the inside of the stator core 22, i.e., the space where the drive shaft 21 is provided, is sectioned off from the outside.

[0031] There are provided six protrusions 22a serving as a stator inside the stator core 22 and a slight space is formed between the outer peripheral surface of the drive shaft 21 and the inner peripheral surface of the protrusions 22a.

[0032] The coils 23 are wound around the respective protrusions 22a. The coils 23 are connected to the board 24 by wires (not shown). The coils 23 generate a magnetic field by the control of the board 24.

[0033] In the present embodiment, as shown in Figures 1 and 3, the center of the stator core 22 slightly deviates from the housing 4 to the left shown in the Figures. Only the outer peripheral surface on the right side in the figure of the stator core 22 is exposed inside the housing 4, but the other portions are in close contact with the second member 26 to be held so that the stator core 22 does not move.

[0034] The space formed between the outer surface of the stator core 22 and the inner surface of the housing 4 forms a first cooling passage Sc1, which constitutes a cooling passage Sc. The first cooling passage Sc1 communicates with the through hole 17 formed in the pump casing 11 of the pump means 2 as shown in Figures 1 and 3.

[0035] A communication port 31 shown in a broken line is formed in the bottom surface of the second member 26 and the third member 27 of the housing 4 and communicates with a second cooling passage Sc2, which constitutes the cooling passage Sc and formed by the third member 27 and the fourth members 28.

[0036] The communication port 31 is formed at the lower side shown in the figure while there is a communication position of the through hole 17 shown on the upper side in the figure. Since the communication port 31 is provided on the side substantially opposite to the through hole 17 in the first cooling passage Sc1, the gas circulating inside the first cooling passage Sc1 circulates along the outer surface of the stator core 22.

[0037] As shown in Figure 1, an exhaust port 28a is provided at the side face of the fourth member 28 and exhausts the gas circulating through the second cooling passage Sc2 from the exhaust port 28a.

[0038] In the vacuum pump 1 according to the present embodiment, the diameter of the exhaust port 12a formed in the pump means 2 is smaller than other diameters, or those of the through hole 17, the communication port 31, and the exhaust port 28a formed in the housing 4.

[0039] The operation of the thus configured vacuum pump 1 is described below. Applying current to the coil 23 via the board 24 forming the motor 3 generates a magnetic field in the coil 23 to make the permanent magnet 30 provided on the drive shaft 21 to approach or separate from the coil, thereby rotating the drive shaft 21.

[0040] In the pump means 2, the rotor 13 connected to the drive shaft 21 rotates counterclockwise in the pump chamber 11a formed in the pump casing 11 as shown in Figure 1 to move the vane 14 with the pump chamber 11a sectioned to a plurality of spaces.

[0041] When the space sectioned by the vane 14 passes the intake port 11b formed in the pump chamber 11a while the rotor 13 rotates, the space gradually then increases in volume according to the rotation of the rotor 13, so that gas is taken in via the intake port 11b and a negative pressure is provided to the booster through the inhalation port 16.

[0042] Thereafter, since the space sectioned by the vane 14 further decreases in volume toward the exhaust port 12a, when the space is brought into communication with the exhaust port 12a the compressed gas is exhausted from the exhaust port 28a.

[0043] The gas exhausted from the exhaust port 28a flows into the damper space Sd defined by the silencer 15 to decrease noise generated by the vacuum pump 1.

[0044] The gas circulated through the damper space Sd circulates through the through hole 17 formed by the pump casing 11 and the cover 17, thereafter, flows into the first cooling passage Sc1 of the cooling passage Sc formed in the housing 4.

[0045] At this point, since the exhaust port 12a is smaller in diameter than the through hole 17, an exhaust resistance occurring when the gas in the damper space Sd flows into the through hole 17 is smaller than the exhaust resistance at the exhaust port 12a, so that the intake performance of the pump means 2 is prevented from being decreased.

[0046] The coil 23 of the motor 3 generates heat with current always applied. The transfer of heat increases the temperature of the stator core 22 around which the coil 23 is wound and on which the protrusion 22a is formed.

[0047] The gas flowing into the first cooling passage Sc1 from the through hole 17 circulates toward the communication port 31 formed in the third member 27 and, at this point, the gas circulates along the surface of the stator core 22, so that the coil 23 held by the stator core 22 and the inside of stator core 22 is cooled.

[0048] The gas circulated through the first cooling passage Sc1 is exhausted to the second cooling passage Sc2 through the communication port 31. Also at this point, since the exhaust port 12a is smaller in diameter than the communication port 31, an exhaust resistance occurring when the gas in the first cooling passage Sc1 flows into the communication port 31 is smaller than the exhaust resistance at the exhaust port 12a.

[0049] In the second cooling passage Sc2, the board 24 is arranged in front of the communication port 31, so that the gas flowing through the communication port 31 is injected onto the board 24 to effectively cool the board 24.

[0050] After that, the gas is discharged from the exhaust port 28a which is formed in the fourth member 28 and in a position remote from the communication port 31. At this point also, since the exhaust port 12a is smaller in diameter than the exhaust port 28a, an exhaust resistance occurring when the gas in the first cooling passage Sc1 is discharged from the exhaust port 28a is smaller than the exhaust resistance at the exhaust port 12a.

[0051] According to the vacuum pump 1 of the present embodiment, the circulation of the gas discharged from the exhaust port 12a of the pump means 2 through the cooling passage Sc formed between the outer surface of the stator core 22 of the motor and the inner surface of the housing 5 allows the gas to cool the motor 3.

[0052] This allows the vacuum pump 1 to be operated without losing stability even if the motor 3 lower in heat resistance than a conventional one is used and to be obtained at an inexpensive cost.

[0053] In the present embodiment, the motor 3 uses a brushless motor 3 which is equipped with the coil 23 generating heat at a position close to the inner peripheral surface of the stator core 22, which allows the heat-generating coil 23 to be effectively cooled.

[0054] At this point, the gas does not flow into the space on the side of the drive shaft 21 in the stator core 22 to preclude a foreign matter from entering a rotation portion of the drive shaft 21 inside the stator core 22, preventing the motor 22 from malfunctioning due to the foreign matter.

[0055] The board 24 is required for the brushless motor 3. The board 24 is also provided in the cooling passage Sc and cooled by the gas, which enables resolving the problem of heat resistance of the board 24 that is a drawback of the brushless motor 3.

[0056] In the present embodiment, the cooling passage Sc includes the first cooling passage Sc1 for cooling the stator core 22 and the second cooling passage Sc2 for cooling the board 24 to allow the board 24 to be separately cooled in the second cooling passage Sc2.

[0057] Providing the silencer 15 forming the damper space Sd in the pump means 2 allows reducing noise accompanied by the exhaust of the gas. Forming the through hole 17 in the pump casing 11 enables gas to be supplied to the cooling passage Sc without a new piping being provided outside.

[0058] At this point, since the exhaust port 28a is smaller in diameter than the through hole 17, an exhaust resistance occurring when the gas flows into the through hole 17 is smaller than the exhaust resistance occurring when the gas is exhausted from the exhaust port 28a, so that the efficiency of the pump means 2 is not decreased due to the circulation of the gas in the through hole 17.

[0059] In the above embodiment, as shown in Figure 3, although only a portion of the stator core 22 is exposed to the cooling passage Sc, the shape of the housing 5 can be modified to form the cooling passage surrounding the whole circumference of the stator core 22.

[0060] In Figure 1 of the above embodiment, a groove may be formed in communication with the cooling passage Sc in the circumferential direction in a portion where the second member 26 is in contact with the stator core 22 to allow the gas to be circulated into the groove as the cooling passage Sc.

[0061] Furthermore, the fourth member 28 constituting the housing 4 may be provided between the first member 25 and the pump casing 11 and the board 24 may be housed inside the fourth member 28 as is the case with the above embodiment.

[0062] In this case, the gas flows into the second cooling passage Sc2 formed in the fourth member 28, and then the gas flows into the first cooling passage Sc1 via the communication port 31 formed between the first member 25 and the fourth member 28, for example, to allow the stator core 22 to be cooled.

[0063] In the above embodiment, although the gas is caused to flow into the fourth member 28 of the housing 5 to cool the board, the communication port 31 may be eliminated and an exhaust port may be formed in the second member 26 to allow only the stator core 22 to be cooled but the board 24 not to be cooled.

[0064] The motor 3 in the embodiment may be a so-called brushless motor, since the brushless motor as the motor 3 can also be cooled entirely by cooling the motor casing exposed inside the housing.

Reference Signs List

[0065]

1	Vacuum pump	2	Pump means
3	Motor	4	Housing
11	Pump casing	11a	Pump chamber
11b	Intake port	12	Cover
12a	Exhaust port	15	Silencer

(continued)

21	Drive shaft	22	Stator core (motor casing)
Sd	Damper space	Sc	Cooling passage
Sc1	First cooling passage	Sc2	Second cooling passage

Claims

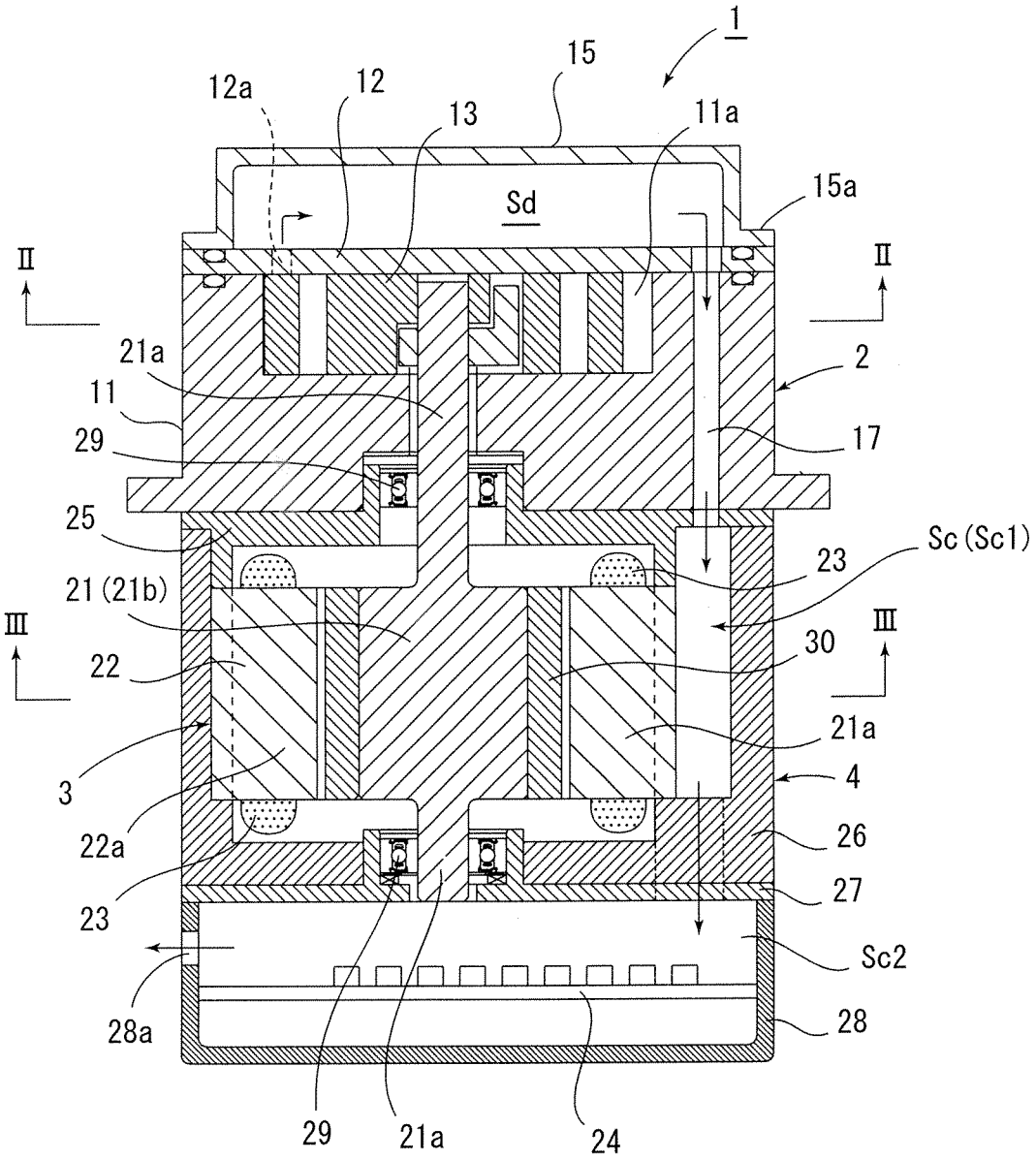
1. A vacuum pump comprising a pump means for compressing gas inhaled from an intake port and discharging the compressed gas from an exhaust port and a motor for driving the pump means,
wherein a housing for housing a motor casing of the motor is provided to form a cooling passage between the outer surface of the motor casing and the inner surface of the housing, and the gas discharged from the exhaust port of the pump means is circulated into the cooling passage to cool the motor.

2. The vacuum pump according to claim 1, wherein the motor is a brushless motor and includes a drive shaft which has a permanent magnet and is connected to the pump means, a plurality of pairs of coils provided inside a stator core serving as the motor casing in such a way as to surround the drive shaft, and a board which is provided outside the stator core and controls the coil, and
the board is arranged inside the cooling passage.

3. The vacuum pump according to claim 2, wherein the cooling passage includes a first cooling passage formed between the inner surface of the housing and the outer surface of the stator core, a second cooling passage which is sectioned from the first cooling passage and houses the board, and a communication port for causing the first cooling passage to communicate with the second cooling passage, and
the exhaust port of the pump means is made smaller in diameter than the communication port.

4. The vacuum pump according to any of claims 1 to 3, wherein the pump means includes: a pump casing, at one end face of which a substantially circular pump chamber is formed and to the other end face of which the motor is fixed; a cover which is formed at the one end face of the pump casing and closes the pump chamber and in which the exhaust port is formed; a rotor which is rotated by the motor inside the pump chamber; and a vane for sectioning the pump chamber into a plurality of spaces while the rotor is rotated, and
wherein a through hole penetrating through from the one end face to the other end face of the pump casing is formed therein such that the through hole is caused to communicate with the cooling passage formed in the housing and a silencer in which a damper space for causing the exhaust port to communicate with the through hole is formed is provided on the one end face of the pump casing,
whereby the air discharged from the exhaust port is circulated into the cooling passage via the damper space and the through hole.

Fig. 1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15
12a
12
13
11a
Sd
15a
II
II
21a
2
11
29
17
25
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23
21 (21b)
III
III
30
22
21a
3
4
22a
26
23
27
Sc2
28a
28
29
21a
24

Fig. 2

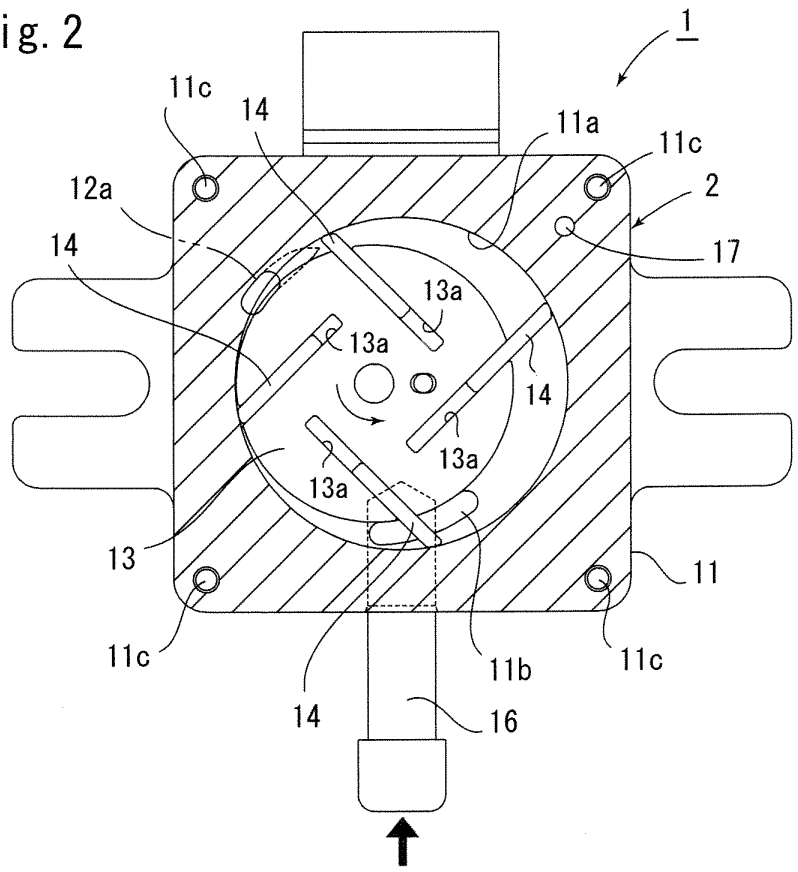
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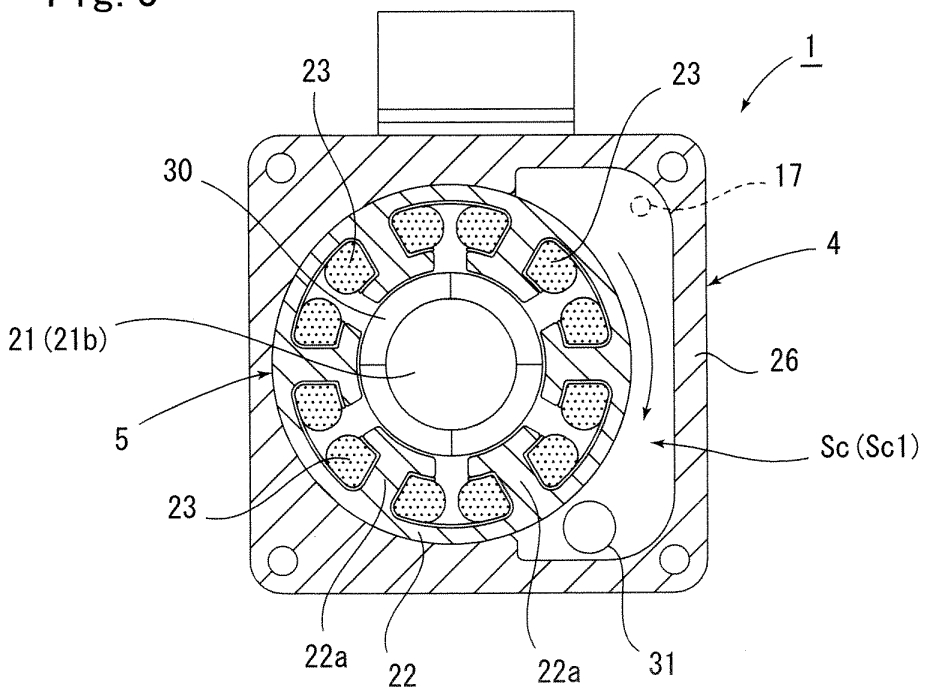
Fig. 3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26
5
Sc (Sc1)
23
22a
22
22a
31

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2013/063629

A. CLASSIFICATION OF SUBJECT MATTER
F04C29/04(2006.01)i, *F04C25/02*(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F04C29/04, F04C25/02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2013
Kokai Jitsuyo Shinan Koho 1971-2013 Toroku Jitsuyo Shinan Koho 1994-2013

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.
A	JP 2007-23958 A (Matsushita Electric Industrial Co., Ltd.), 01 February 2007 (01.02.2007), entire text; all drawings (Family: none)	1-4
A	JP 4519490 B2 (Hitachi Appliances, Inc.), 04 August 2010 (04.08.2010), entire text; all drawings (Family: none)	1-4
A	JP 62-93496 A (Hitachi, Ltd.), 28 April 1987 (28.04.1987), entire text; all drawings (Family: none)	1-4

☐ 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	Date of mailing of the international search report
06 August, 2013 (06.08.13)	13 August, 2013 (13.08.13)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 4187891 A **[0004]**