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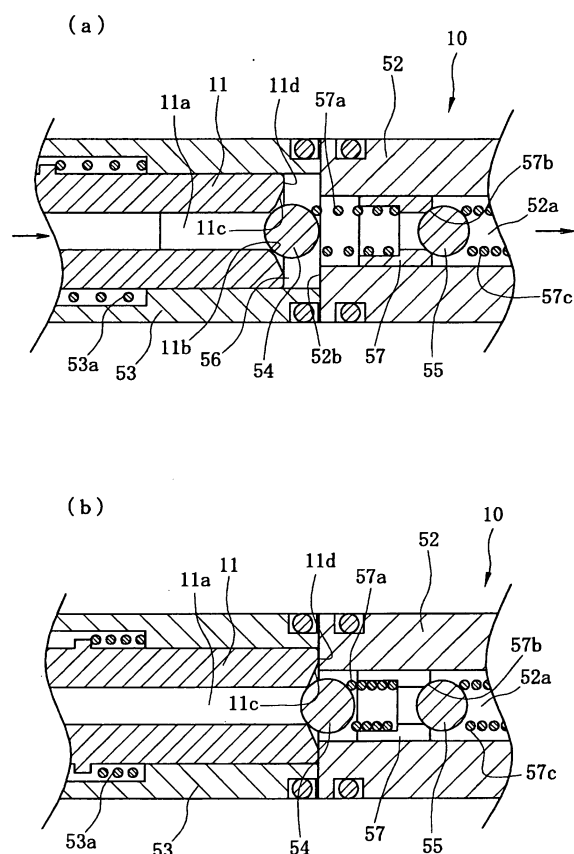
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(54) **Electromagnetic pump**

(57) The present invention provides an electromagnetic pump which discharge amount can be increased by increasing drive frequency, even when it is used for high viscosity fluid, such as oil at low temperature.

The electromagnetic pump comprises an inner yoke 52 and a plunger 11 which form a magnetic circuit, wherein the plunger 11 reciprocates in a cylinder 53 in which a magnetic gap between the inner yoke 52 and the plunger 11 is narrowed by electromagnetic force, and enlarged by an elastic member 53a, and wherein a contact face area where a top end face 11d of the plunger 11 overlaps with a top end face 52b of the inner yoke 52 is set between 50 and 5% of the outer diameter circle area of the plunger 11. With this structure, the plunger 11 can be detached reliably from the inner yoke 52 and returned to an initial position by the elastic member 53a at the time of demagnetization. Hence, pumping by the plunger 11 is ensured, and the discharge amount can be increased by increasing the drive frequency.

FIG.1



Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to an electromagnetic pump, more particularly relates to a technology to increase discharge amount by increasing drive frequency even in the case that high-viscosity liquid is managed.

2. Description of the Related Art

[0002] Oil-mixed gasoline is used as fuel for a two stroke gasoline engine. Here, an electromagnetic pump is used to mix oil with gasoline.

[0003] Fig. 6 is a sectional view of an electromagnetic pump 50 which is disclosed in Fig 1 of Japanese patent laid-open 2000-145623. Fig. 6(a) shows an initial state (non-powered state), and (b) shows a discharge completed state (powered state).

[0004] A hollow thick-walled cylindrical plunger 51 made of ferromagnetic material, which hollow portion forms a flow path 51a, is fitted in a cylinder 53 made of non-ferromagnetic material slidably in a side-to-side direction in the figure. At a top end face 51b of the flow path 51a, an inlet valve seat 51c is formed by being chamfered as a taper-shape. A coil spring 53a is disposed between a step portion formed at the cylinder 53 and a convex portion formed at the plunger 51 so as to continuously urge the plunger 51 to a direction apart from an inner yoke 52. Consequently, the coil spring 53a is an elastic member for returning the plunger 51.

[0005] The inner yoke 52 is fixed so as to maintain clearance to form a space 56 with the plunger 51. The gap between the top end face 51b of the plunger 51 and a top end face 52b of the inner yoke 52 is the magnetic gap. The inner yoke 52 also forms a hollow thick-walled cylindrical shape having a flow path 52a. The outer diameter is almost the same as that of the cylinder 53, and the inner diameter is slightly larger than the diameter of an inlet valve body 54 so that the spherical inlet valve body 54 which moves to contact with or separate from the inlet valve seat 51c can go into the inner yoke 52.

[0006] A valve seat 57 which has a stepped hole is press-fitted and fixed in the flow path 52a of the inner yoke 52. An outlet valve seat 57b is formed at the outlet side of the smaller diameter hole of the valve seat 57, and a coil spring 57a which presses the inlet valve body 54 to the inlet valve seat 51c is disposed at the larger diameter hole.

[0007] A spherical outlet valve body 55 is disposed being free to contact with or separate from the outlet valve seat 57b. A coil spring 57c as an outlet side elastic member presses the outlet body 55 toward the outlet valve seat 57b.

[0008] A coil which is not shown in figures is disposed outside the cylinder 53 and the inner yoke 52. When power is supplied to the coil, the plunger 51 and the inner yoke 52 form a magnetic circuit, and the plunger 51 moves within the cylinder 53 so as to contact the inner yoke 52 as shown in Fig. 6 (b). When the power supply is discontinued, the plunger 51 separates from the inner yoke 52 by the returning force of the coil spring 53a, and returns to the state as shown in Fig. 6 (a).

[0009] With the electromagnetic pump 50 of the abovementioned structure, oil in the space 56 is pressed when the plunger 51 moves from the state of Fig. 6 (a) to that of Fig. 6 (b) by supplying power to the coil, and the oil is discharged through the flow path 52a while pressing the outlet valve body 55 to open. When the plunger 51 returns from the state of Fig. 6 (b) to that of Fig. 6 (a), oil in the flow path 51a presses the inlet valve body 54 to open and flows into the space 56. By repeating these operations, the oil intermittently flows in the direction of the arrow. Since the discharged amount of the oil is constant with one to-and-fro operation of the plunger 51, the discharged oil amount can be controlled by controlling the frequency of the pulse electric current supplied to the coil.

[0010] Fig. 7 is a diagram showing relations between drive frequency and the oil discharge amount of the electromagnetic pump of Fig. 6. The vertical axis is for the oil discharge amount Q, and the horizontal axis is for the drive frequency f Hz. A dotted line 61 shows theoretical discharge amount which is calculated by the diameter and the stroke amount of the plunger 51. As shown by the dotted line 61, the oil discharge amount increases in proportion to the increase of the drive frequency.

[0011] A line 62 shows the case that the electromagnetic pump 50 is operated at normal temperature. As shown, the discharge amount is almost the same as the theoretical value at normal temperature.

[0012] However, as shown by a curved line 63, when the electromagnetic pump 50 is operated at low temperature of below -10 degrees Celsius, the discharge amount sharply decreases than the theoretical value when the drive frequency exceeds 8 Hz, while it is almost the same as the theoretical value shown by the line 61 when the drive frequency is below 8 Hz. Then to the contrary, when the drive frequency exceeds 10 Hz, the discharge amount decreases.

[0013] When the conventional electromagnetic pump 50 is used for a motorcycle with a 50 cc engine, there is no problem because it can be operated at 6 or 7 Hz to obtain the required oil amount. However, to use the electromagnetic pump 50 for a motorcycle with a 125 cc engine, it has to be operated at 10 Hz or higher. Here, there arises a problem that the required oil discharge amount can not be obtained at low temperature circumstances.

[0014] Fig. 8 shows relations between pulse current supplied to a coil and moving state of the plunger 51. Fig. 8 (a) shows pulse current supplied to the coil. Fig.

8 (b) shows to-and-fro moving state of the plunger 51 at normal temperature. Fig. 8 (c) shows the state at low temperature.

[0015] In Fig. 8 (a) through (c), the horizontal axes are for time, and the scales are the same. The vertical axis of (a) is for voltage. The vertical axes of (b) and (c) are for the position of the plunger 51. A discharge completed position is shown in Fig. 6 (b), where the plunger 51 is adsorbed to the inner yoke 52. An initial position is shown in Fig. 6 (a), where the plunger 51 is most separated from the inner yoke 52 being pushed and returned by the coil spring 53a when power is not supplied.

[0016] 12 V voltage is supplied and discontinued to the coil at established intervals, and rectangular waves appear at established intervals as shown in Fig. 8 (a). At a rising phase of the rectangular wave, the plunger 51 starts to be attracted toward the inner yoke 52. At a falling phase of the rectangular wave, the plunger 51 starts to return toward the initial position by the coil spring 53a.

[0017] As shown in Fig. 8 (b), at normal temperature, the plunger 51 moves from the initial position to the discharge completed position almost in synchronization with the rectangular wave of (a). In this manner, at normal temperature, the plunger 51 discharges almost the same amount as the theoretical value even when the drive frequency increases.

[0018] As shown in Fig. 8 (c), at low temperature of below -10 degrees Celsius, the plunger 51 starts to move at the rising phase of the first rectangular wave with a slight relay, and reaches the discharge completed position. However, at the falling phase of the rectangular wave, the plunger 51 starts to return toward the initial position with a large delay. Here, since the next rectangular wave rises before reaching the initial position, the plunger 51 reverses at some midpoint and moves toward the discharge completed position. Therefore, the plunger 51 moves as triangular waves, not as rectangular waves, and the stroke amount is decreased. In this situation, when the drive frequency increases, the height of the triangular waves becomes low and the stroke amount decreases and the discharge amount decreases.

[0019] The poor motion of the plunger 51 at low temperature circumstance is considered to be caused by the viscosity increase of the oil. The viscosity increase of the oil causes sticking of the top end face 51b of the plunger 51 with the end of the inner yoke 52.

[0020] To obtain the required discharge amount at 6 or 7 Hz by upsizing the electromagnetic pump 50 can be a solution, but it increases the manufacturing cost of the electromagnetic pump. Further, it can be considered to strengthen the coil spring 53a to overcome the oil viscosity so that the plunger 51 can return quickly to the initial position. However, in this case, the attracting force between the plunger 51 and the inner yoke 52 must be increased to be attracted. To do so, the electric current being supplied to the coil has to be increased. Generally,

a motorcycle with an engine of around 125 cc is capable to flow the electric current about 0.5 through 1.0 A to the electromagnetic pump 50. With this current, the electromagnetic attracting force to overcome the oil viscosity cannot be obtained.

[0021] The present invention was devised in the light of the abovementioned facts. The object is to provide an electromagnetic pump which discharge amount can be increased by increasing drive frequency, even when it is used with high viscosity fluid, such as oil at low temperature.

SUMMARY OF THE INVENTION

[0022] To achieve the abovementioned object, an electromagnetic pump of the present invention comprises an inner yoke and a plunger which form a magnetic circuit, wherein the plunger reciprocates in a cylinder in which a magnetic gap between the inner yoke and the plunger is narrowed by electromagnetic force, and enlarged by an elastic member, and wherein a contact face area where a top end face of the plunger overlaps with a top end face of the inner yoke is set at or below 50 % of the outer diameter circle area of the plunger. Here, it is desirable to set the contact face area between 15 and 7 % of the outer diameter circle area of the plunger.

[0023] In the present invention, by setting the contact face area where the top end face of the plunger overlaps with the top end face of the inner yoke between 50 and 5% of the outer diameter circle area of the plunger, the plunger can easily be detached from the inner yoke by elastic force of the elastic member at the time of demagnetization. Therefore, discharge amount is increased by increasing drive frequency even when it is used for high viscosity fluid.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024]

Fig. 1 is a sectional view showing an embodiment of an electromagnetic pump of the present invention. Fig.1 (a) shows the initial state, and (b) shows the discharge completed state.

Fig. 2 is a perspective view of the top end portion of a plunger. Fig.2 (a) shows the plunger of the present invention, and (b) shows the plunger which is shown in the related art.

Fig. 3 is a diagram showing relations between the area ratio of a contact face and oil discharge amount of the electromagnetic pump.

Fig. 4 is a sectional view showing another embodiment of a top end shape of the plunger of the present invention.

Fig. 5 is a sectional view showing another embodiment of the present invention.

Fig. 6 is a sectional view of an electromagnetic pump of a related art. Fig. 6 (a) shows the initial state (non-powered state), and (b) shows the discharge completed state (powered state).

Fig. 7 is a diagram showing relations between drive frequency and oil discharge amount of the electromagnetic pump of Fig. 6.

Fig. 8 shows relations between pulse current supplied to a coil and moving state of the plunger.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0025] The embodiments of the present invention are explained in the following with reference to the drawings.

[0026] Fig. 1 is a sectional view showing an embodiment of an electromagnetic pump of the present invention. Fig. 1 (a) shows the initial state, and (b) shows the discharge completed state.

[0027] Since the basic structure of an electromagnetic pump 10 is the same as explained with the related art, the same numeral notes are given to the same arrangements, and the structure that is arranged differently is mainly explained. A hollow thick-walled cylindrical plunger 11 made of ferromagnetic material has the same structure as the related art, but the arrangement at the top end portion is different. Namely, an inlet valve seat 11b is disposed at the top end of a hollow flow path 11a, and a taper face 11c is formed outside. Then, a top end face 11d which contacts to the top end face 52b of the inner yoke 52 is formed at the outside of the taper face 11c.

[0028] Fig. 2 is a perspective view of the top end portion of the plunger. Fig. 2 (a) shows the plunger 11 of the present invention, and (b) shows the plunger 51 which is shown in the related art. The outer diameters of the plungers 11, 51 are both D, and the inner diameters are both d. Here, with the plunger 51 of the related art, the contact face which contacts to the top end face 52b of the inner yoke 52 when power is supplied is hatched in the drawing. The contact face is a doughnut-shaped portion which outer diameter is the same as that of the top end face 51b, and which inner diameter is the same as that of the flow path 52a of the inner yoke 52. The area of the contact face is slightly smaller than the whole area of the top end face 51b. On the contrary, with the plunger 11 of the present invention, the top end face 11d, which is hatched in the drawing, is formed as a narrow ring shape so that the area becomes small, by forming the taper face 11c between the top end face 11d and the inlet valve seat 11b.

[0029] Fig. 1 (b) shows a state that the plunger 11 is absorbed to the inner yoke 52 after power is supplied to

the electromagnetic pump 10 in Fig. 1 (a). As mentioned above, only the top end face 11d, which area is smaller than that of the related art, is the contact face between the plunger 11 and the inner yoke 52. When power supply is discontinued, the magnetic circuit disappears and the plunger 11 is returned to the initial position by the coil spring 53a. Because the contact face area is small, the plunger 11 can be detached from the inner yoke 52 with light force. Therefore, in the case that the drive frequency is increased even when the viscosity increases at low temperature, the stroke amount of the plunger 11 can be maintained close to the full-stroke amount between the initial position and the discharge completed position. Hence, pumping by the plunger 11 is ensured, and the discharge amount is increased in accordance with the frequency.

[0030] Fig. 3 is a diagram showing relations between the area ratio of the contact face and the oil discharge amount of the electromagnetic pump. Numeral notes added to legends □, •, Δ, ○, * in the figure stand for the area ratio of the contact face, which shows the percentage of the contact face to the area of the outer diameter circle of the plunger 11. The area S of the outer diameter circle of the plunger 11 is calculated by the equation; $S = \pi D^2/4$. Here, D stands for the outer diameter of the plunger 11. When the contact face is ring-shaped, the area s of the contact face is calculated by the equation; $s = (\text{the area of the outer diameter circle}) - (\text{the area of the inner diameter circle})$. Here, the outer diameter circle is the outer diameter circle of the top end face 11d. The inner diameter circle is the larger one of either the diameter of the flow path 52a of the inner yoke 52 or the inner diameter circle of the top end face 11d. In this manner, the contact face area s and the area ratio of s to S can be calculated.

[0031] With the plunger 51 of the related art, since the diameter of the flow path 52a is slightly larger than the inner diameter of the top end face 51b, the area of the contact face is calculated to be slightly smaller than the area of the top end face 51b by the equation; $(\text{the area of the outer diameter circle of the top end face 51b}) - (\text{the area of the flow path 52a})$. As a result of calculating the area of the contact face, the percentage of the area s of the top end face 51b to the area S of the outer diameter circle of the plunger was 62.2 %.

[0032] With the plunger 11 shown in Fig. 1 of the present invention, since the inner diameter of the top end face 11d was larger than the diameter of the flow path 52a, the calculation was performed as $(\text{the area of the contact face}) = (\text{the area of the top end face 11d})$. Then, four kinds of plunger 11 which area ratios of the top end face 11d were 46.4 %, 30.7 %, 14.9 % and 7.6 % were made. The discharge amounts were measured with each plunger while changing the drive frequency. Here, the oil temperature during the measurement was maintained at -15 degrees Celsius at which influence of the viscosity exists.

[0033] In Fig. 3, a line 20 shows theoretical value that

the discharge amount is perfectly in proportion to the drive frequency. A line 22 connecting □ shows the case with the plunger of the related art which area ratio of the contact face is 62.2 %. The discharge amount was the maximum at 9 Hz, and the discharge amount decreased to the contrary when the drive frequency increased afterwards.

[0034] A line 23 connecting • shows the case that the area ratio is 46.4 %. A line 24 connecting △ shows the case that the area ratio is 30.7 %. A line 25 connecting ○ shows the case that the area ratio is 14.9 %. A line 26 connecting * shows the case that the area ratio is 7.6 %. In all of these cases, although some efficiency drops occurred at 8 through 10 Hz, the discharge amounts increased in accordance with the increase of the drive frequency.

[0035] The diagram of Fig. 3 explains that the discharge amount continues to increase in accordance with the increase of the drive frequency if the area ratio is equal to or less than 50 %. In particular, it is desirable to set the area ratio of the contact face between 15 and 7 %, because the increase of the discharge amount becomes even closer to the theoretical value.

[0036] The discharge amount becomes close to the theoretical value in accordance with the decrease of the area ratio while increasing the drive frequency within the area ratio range between 50 and 15 %. However, it almost remains same when the area ratio is at or below 15 %.

[0037] As mentioned above, when the contact face area where the top end face 11d of the plunger 11 overlaps with the top end face 52b of the inner yoke 52 is between 50 and 5 % of the area of the outer diameter circle of the plunger 11, the discharge amount can be increased even when the drive frequency is increased to 10 Hz or more. When the area ratio is less than 5 %, additional advantage of decreasing the contact face area can not be obtained. On the contrary, in this case, it is considered that disadvantage, such as deformation or wear of the contact face, may occur.

[0038] Fig. 4 is a sectional view showing another embodiment of a top end shape of the plunger of the present invention. A plunger 21 in Fig. 4 (a) has an inlet valve seat 21b which is formed at the outlet of a hollow portion 21a, a stepped face 21c which is formed outside the inlet valve seat 21b instead of the taper face, and a top end face 21d which is formed outside the stepped face 21c.

[0039] A plunger 31 in Fig. 4 (b) has a spherical inlet valve seat 31b which is formed outside the outlet of a hollow portion 31a. The inlet valve seat 31b is extended outside, and a top end face 31c is formed outside the inlet valve seat 31b. In this manner, various embodiments can be adopted to make the area of the top end face small.

[0040] Fig. 5 is a sectional view showing another embodiment of the present invention. The same numeral notes are given to the same arrangements of the related

art. In this embodiment, a taper face 42a is formed at the end face of an inner yoke 42, so as to make the top end face 42b area of the inner yoke 42 small. Consequently, the contact face becomes small.

[0041] Decreasing the area of the contact face of the plunger and the inner yoke of the present invention can be performed by decreasing the area of either the plunger or the inner yoke. It is also possible to decrease the area of the contact face by changing both shapes of the top end faces and being overlapped each other.

Claims

1. An electromagnetic pump comprising an inner yoke and a plunger which form a magnetic circuit:

wherein said plunger reciprocates in a cylinder in which a magnetic gap between said inner yoke and said plunger is narrowed by electromagnetic force, and enlarged by an elastic member; and

wherein a contact face area where a top end face of said plunger overlaps with a top end face of said inner yoke is set at or below 50 % of the outer diameter circle area of said plunger.

2. The electromagnetic pump according to claim 1, wherein said contact face area is set between 15 and 7 % of the outer diameter circle area of said plunger.

FIG. 1

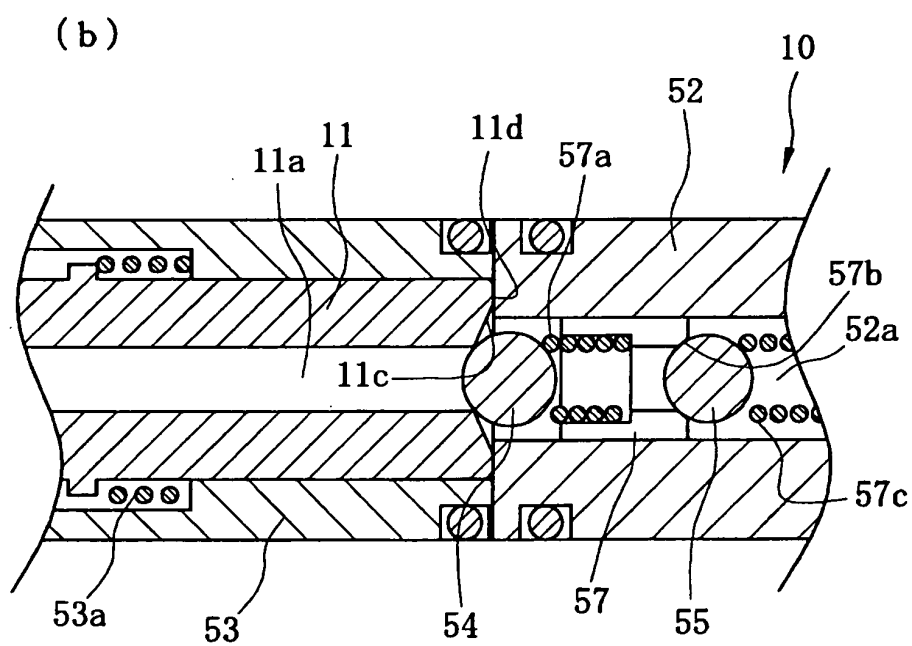
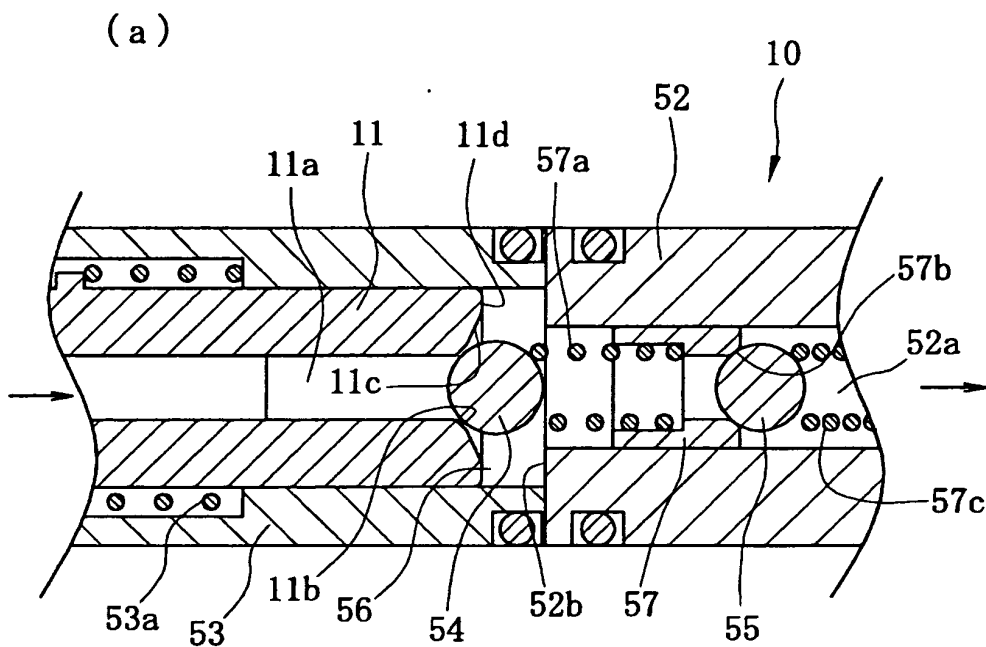
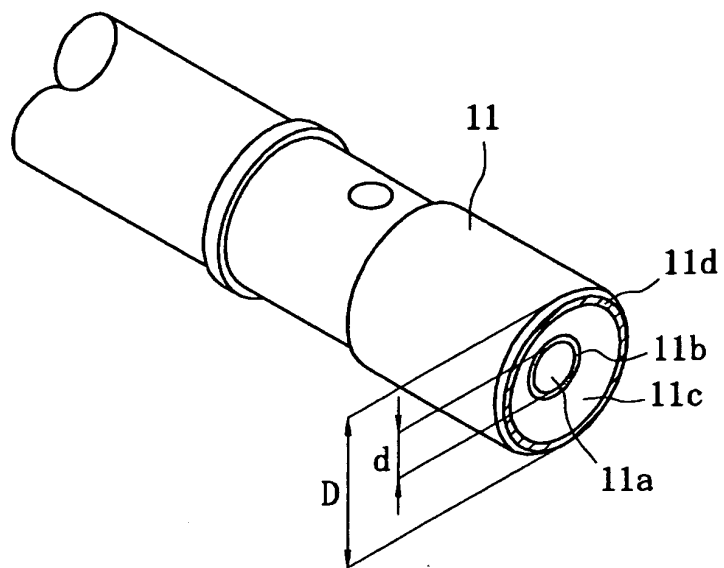


FIG.2

(a)



(b)

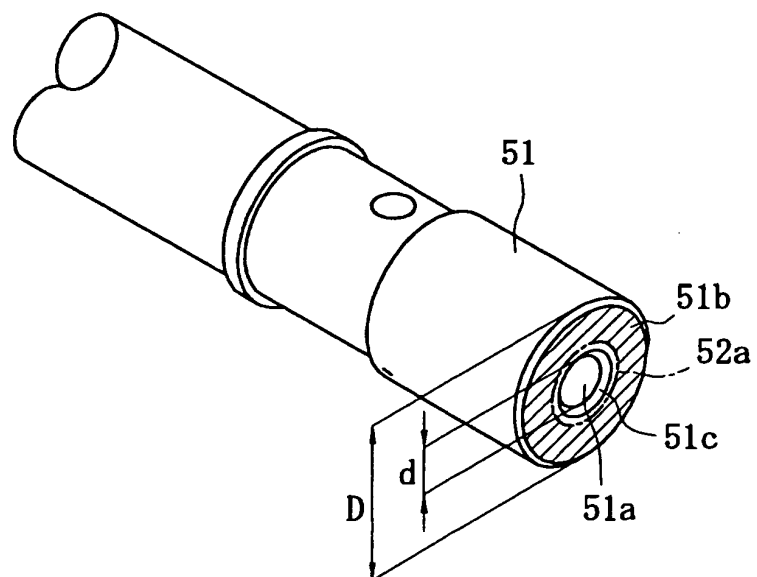


FIG.3

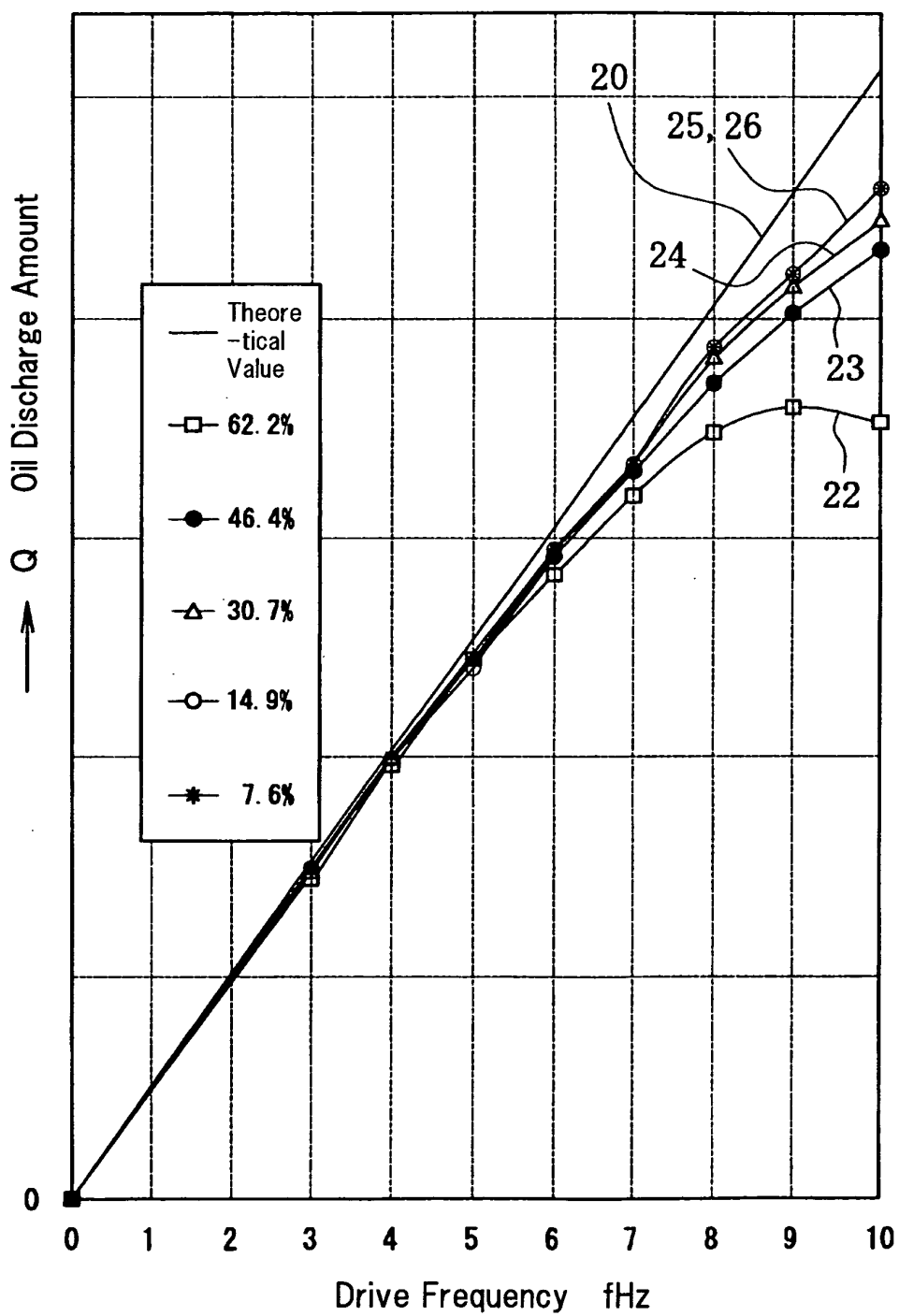
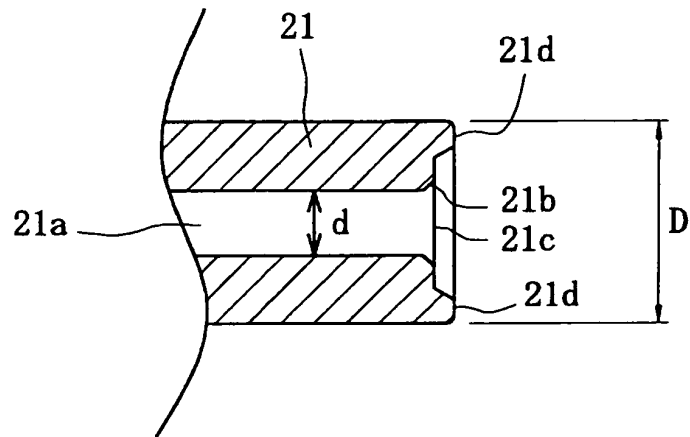


FIG.4

(a)



(b)

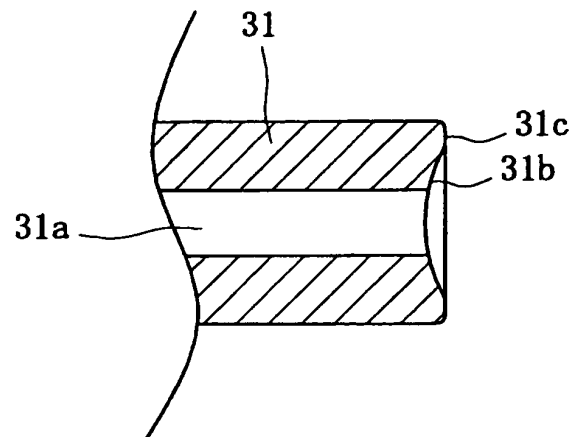


FIG.5

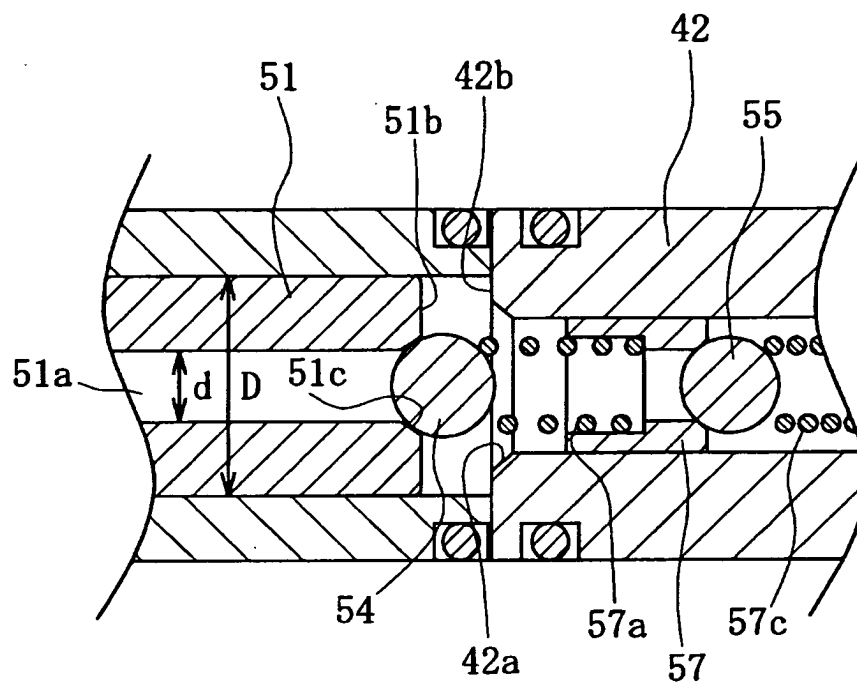


FIG. 6

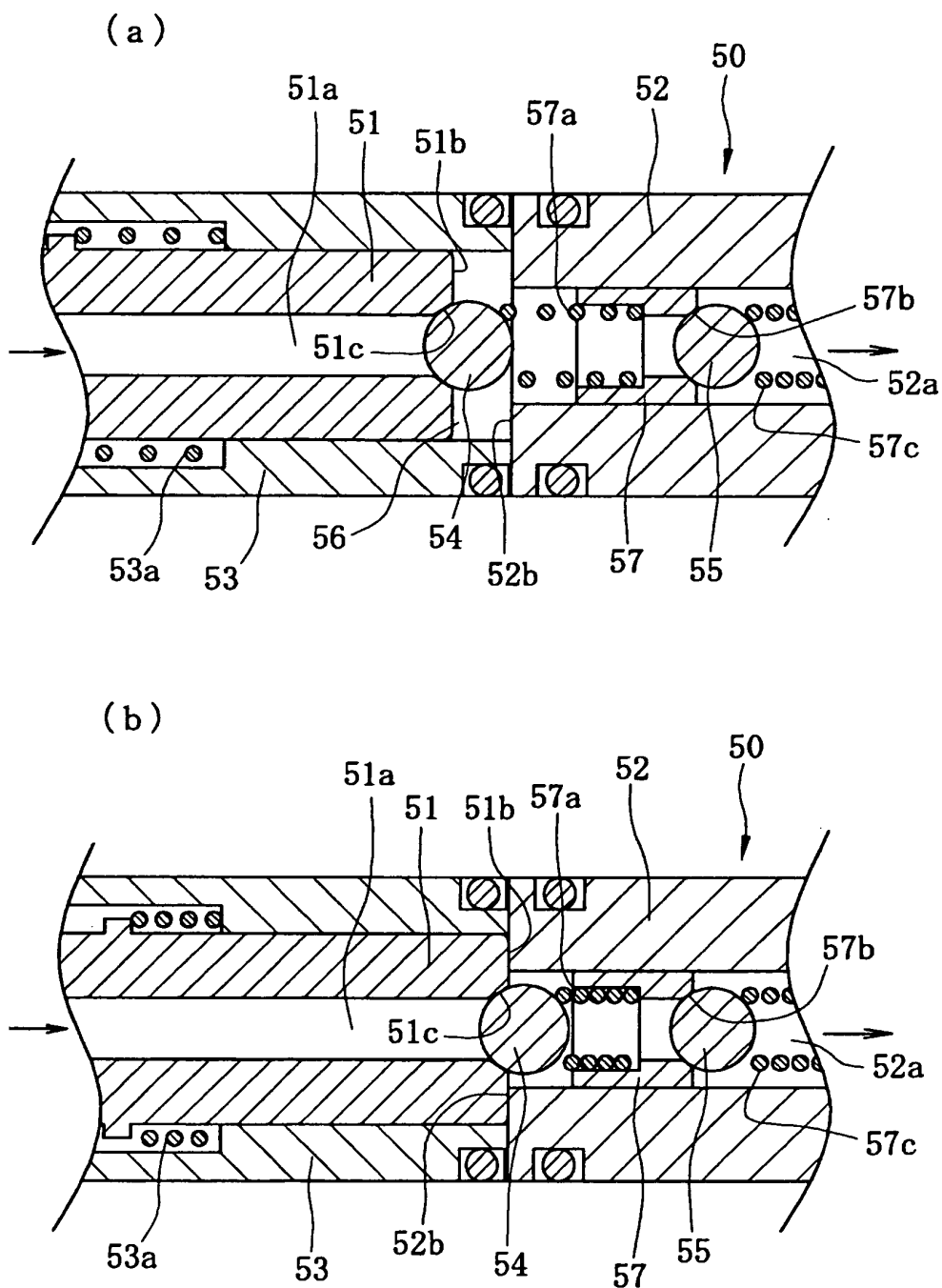


FIG. 7

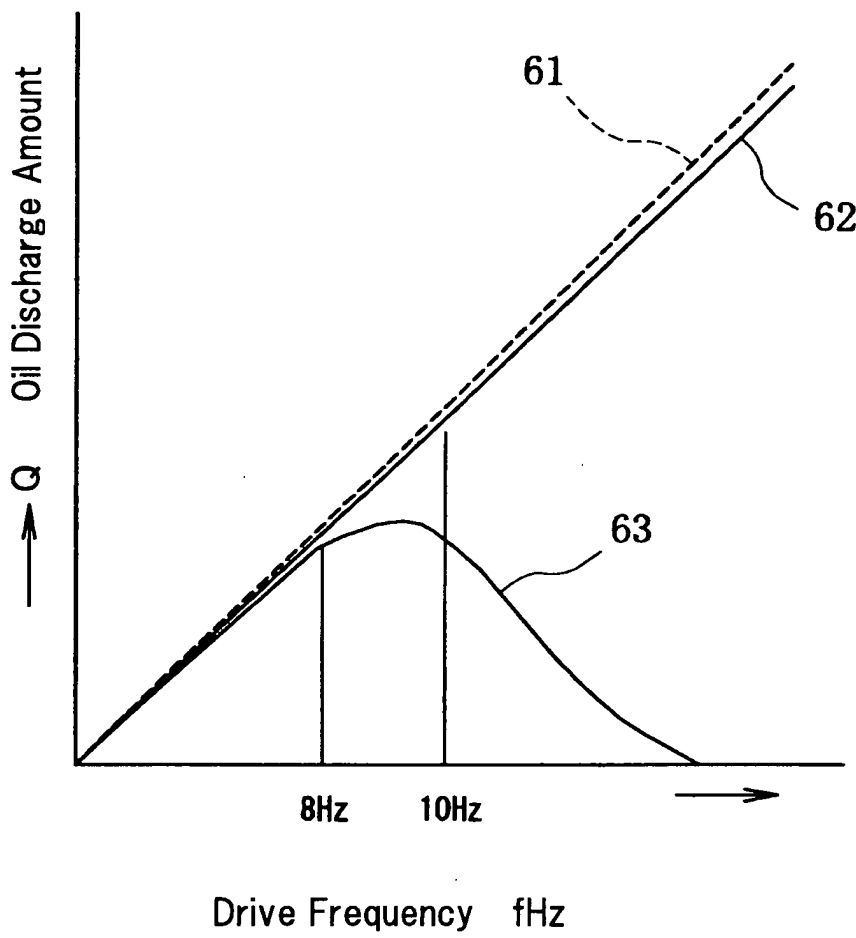
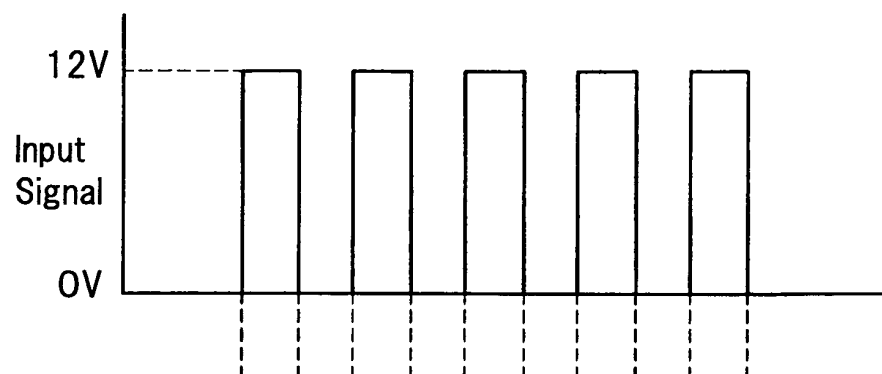
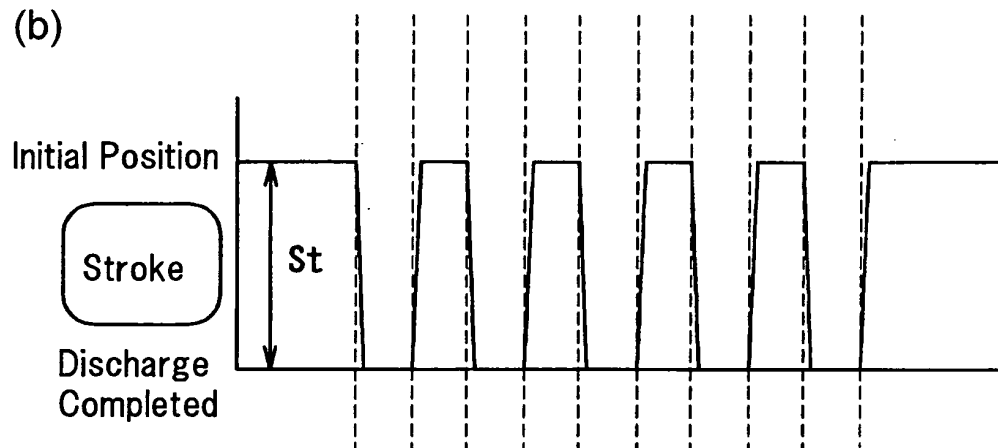


FIG.8

(a)



(b)



(c)

