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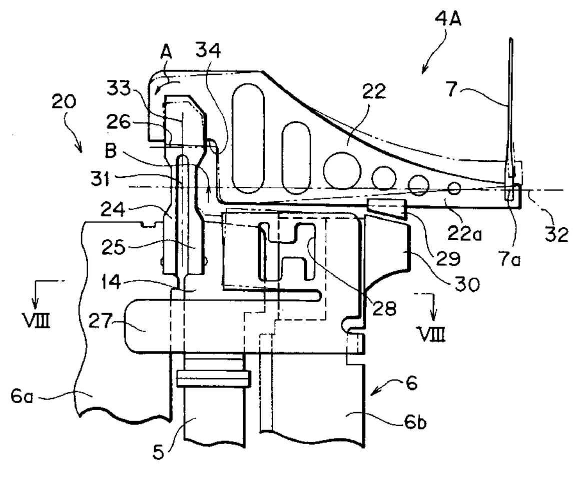
(54) **Dot matrix impact print head device.**

(57) A dot matrix impact print head device having a plurality of print units. In each of the print units, an end of a support leaf spring (24) supported on a print head body and an end of a drive leaf spring(25) whose another end is connected to a piezoelectric element (5) are joined parallel to each other by a rigid joint (26). The joint is fixed to a proximal end of an arm (22).When the support and drive leaf springs are resiliently deformed, the arm is angularly moved about a pivotal center axis (31) defined by these leaf springs. A line (32) interconnecting the axis (31) and the proximal end of the print wire (7a) extends substantially perpendicularly across the direction of back-and-forth movement of the print wire. When a piezo-electric element (5) is displaced in response to the application of a voltage, an arm (32) is angularly moved through the two leaf springs (25, 26) to move a print wire (7) mounted on the distal end of the arm (22) back and forth.

FIG. 1



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The present invention relates to a dot matrix impact print head device having a piezoelectric element which is expanded and contracted in response to the application of a voltage thereto and transmits expanding and contracting movement to a print wire that strikes a print medium such as a sheet of paper.

One example of a conventional print head device is disclosed in a Japanese Patent application Kokai (OPI) No. 63-312852. The device includes a print head having a head body, an arm, a motion transmitting mechanism, and a piezoelectric element. The print head includes a print wire for striking a print medium. The head body includes a nose, and a front end of the print wire can project forwardly from and be retracted back into the nose. The arm has a distal end to which a proximal portion of the print wire is fixed. The motion transmitting mechanism is mounted on the distal end of the arm, and the piezoelectric element is mounted on an end of the motion transmitting mechanism. The piezoelectric element is expansible and contractible in response to the application of a voltage thereto. In accordance with the expansion and contraction of the piezoelectric element, the arm is moved through the motion transmitting mechanism, so that the print wire can be moved toward and away from the print sheet.

The applicant has proposed in a co-pending U. S. Patent Application Serial No.07/760,479 filed September 16, 1991 (corresponding to British Patent Application No. 9120995.7 filed October 3, 1991), an improvement over the above described conventional print unit. The improved device is shown in Figs. 6 through 8 of the accompanying drawings.

The disclosed print head includes a head body 1 substantially in the shape of a disk as viewed in plan, and a cylindrical cover 2 covering a back of the head body 1. The head body 1 has a nose 3 projecting from a central portion thereof. The head body 1 houses a plurality of radially arranged print units 4. Each of the print units 4 includes a piezoelectric element 5, a support frame 6 supporting the piezoelectric element 5, a print wire 7 having a front end that can project forwardly from and be retracted back into the nose 3, an arm 8 to which a proximal end 7a of the print wire 7 is attached, and a motion transmitting mechanism 9 for amplifying the expanding and contracting movement of the piezoelectric element 5 and transmitting the amplified movement through the arm 8 to the print wire 7. In the nose 3, intermediate guide plates 42 are provided for guiding reciprocating movements of the print wires 7.

The motion transmitting mechanism 9 converts the expanding and contracting movement of the piezoelectric element 5 into angular movement of the arm 8 for amplifying projecting and retracting movement of the print wire 7 mounted on the distal end of the arm 8. The motion transmitting mechanism 9 is in the form of an Eden's twin strips spring which has two parallel leaf springs 12, 13. The leaf springs 12, 13 have ends joined to a rigid joint 10, providing a Π shape as viewed in side elevation. The first leaf spring 12 has a proximal end brazed to one side of the support frame 6. The second leaf spring 13 has a proximal end brazed to a movable member 14 mounted on a front end of the piezoelectric element. The first and second leaf springs 12, 13 extend in a direction parallel to the print wire 7. Further, the two leaf springs 12, 13 extend in a direction opposite the extending direction of the print wire 7.

As shown in Fig. 7, when a voltage is applied to expand the piezoelectric element 5 and move the movable member 14 in the direction indicated by an arrow B, the joint 10 interconnecting the ends of the leaf springs 12, 13 is angularly moved in the direction indicated by an arrow A into a two-dot-and-dash line position. The arm 8 is angularly moved about an axis 15 that is located substantially intermediately between the parallel leaf springs 12, 13 and substantially at the center of the leaf springs 12, 13 in the longitudinal direction thereof.

Upon actuation of the piezoelectric element 5, the proximal end 7a of the print wire 7 is caused by the arm 8 to angularly move about the axis 15 along a curve having a radius R of curvature. With this arrangement, the proximal end 7a of the print wire 7 is disposed in a position closer to the nose 3 than a reference line 16 that extends from the axis 15 in a direction substantially parallel to the arm 8 and substantially perpendicular to direction in which the leaf springs 12, 13 extend, as shown in Fig. 7. Specifically, the position of the proximal end 7a is spaced perpendicularly from the reference line 16 toward the nose 3 by a distance Hl .

Therefore, as chematically shown in Figs. 2 and 7, when the print wire 7 is held at its rest position with the piezoelectric element 5 being de-energized, a line 17 interconnecting the axis 15 and the proximal end 7a along the radius R is angularly spaced from the reference line 16 by an angle α.

If the stroke of expansion of the piezoelectric element 5 remains the same, the angle by which the arm 8 angularly moves also remains the same irrespective of the angle α between the line 17 and the reference line 16. For efficient printing, therefore, the angle by which the arm 8 angularly moves should preferably be converted into a maximum back-and-forth movement of the print wire 7. In the case where the line 17 is not perpendicular to the direction in which the print wire 7 moves back and forth, i.e., the direction parallel to a Y-axis, (that is, the line 17 forms an angle $90° - \alpha$ with the direction of back-and-forth movement of the print wire 7), when the arm 8 is angularly moved by $\Delta\alpha$, a force component $\sin(\alpha + \Delta\alpha) - \sin\alpha$ which is effective to produce the back-and-force movement of the print wire 7 is too small to be efficient enough. When the arm 8 is angularly moved by $\Delta\alpha$ to produce a displacement Y1 along the Y-axis which is equal to the back-and-force movement of the print wire 7 that is required for printing operation, a displacement X1 of the proximal end 7a along an-X-axis is greater as the angle α is larger.

The print wire 7 has an intermediate portion guided by the nose 3 so that the print wire 7 is slidably movable in the axial direction and limited against transverse movement. Consequently, if the transverse displacement of the proximal end 7a is large, then undue forces are imposed on the print wire 7, presenting a large resistance to the axial sliding movement of the print wire 7. Accordingly, a desired printing process cannot be carried out unless a large voltage is applied to the piezoelectric element 5. Stated otherwise, the electric power consumption of the disclosed print head is large, resulting in an energy loss in the performance of the print head.

Thus, it is an object of the present invention to solve the aforesaid technical problems attendant to the print head device disclosed in the above described copending U.S. Patent Application. That is, the object of the invention is to provide large stroke of the printing wire in the back-and-forth direction yet providing a minimum displacement of the print wire in a lengthwise direction of the arm.

There is provided in accordance with the present invention a dot matrix impact print head device for providing a dot matrix pattern on a print medium comprising a print head body having a nose portion, a print wire, an arm, a piezoelectric element, and a motion transmitting means. The print wire has a distal end to strike on the print medium and has a proximal end. The distal end is projectable forwardly from and retractable back into the nose portion in a projecting/retracting direction. The arm has a distal end portion to which the proximal end of the print wire is attached and has a proximal end portion. The piezoelectric element is supported on the print head body. The piezoelectric element is expandable and shrinkable in a longitudinal direction thereof. The motion transmitting means has a first resilient portion fixed to the print head body, a second resilient portion coupled to the piezoelectric element and a third portion joining together the first and the second resilient portions. The third portion is coupled to the proximal end portion of the arm. A pivotal center is defined in the motion transmitting means and resilient deformation of the first and second resilient portions provides a pivotal motion of the arm about the pivotal center. A line connecting between the pivotal center and the proximal end of the print wire extends in a direction substantially perpendicular to the projecting/retracting direction.

The invention will now be described by way of example only with reference to the accompanying drawings in which:

Fig. 1 is a fragmentary side elevational view showing a dot matrix impact print head device according to a first embodiment of the present invention;

Fig. 2 is a schematic diagram illustrative of operation of the present invention and for description of difference between the device of the present invention and a device disclosed in the copending U. S. patent application;

Fig. 3 is a fragmentary side elevational view showing a dot matrix impact print head device according to a second embodiment of the present invention;

Fig. 4 is a fragmentary side elevational showing a dot matrix impact print head device according to a third embodiment of the present invention;

Fig. 5 is a fragmentary side elevational view showing a dot matrix impact print head device according to a fourth embodiment of the present invention;

Fig. 6 is a cross-sectional view showing a dot matrix impact print head device disclosed in a co-pending U. S. Patent Application Serial No. 07/760,479;

Fig. 7 is a fragmentary side elevational view showing the device disclosed in the co-pending application; and

Fig. 8 is a cross-sectional view taken along line VIII - VIII of Figs. 1 and 7.

A dot matrix type print head device according to a first embodiment of the present invention will be described with reference to Figs. 1, 2 and 8. The device has a basic structure substantially the same as that of the print head device disclosed in the co-pending U. S. Patent Application Serial No. 07/760,479 such as shown in Fig. 7.

The dot matrix impact print head device according to the first embodiment generally includes a print head body 1 having a nose, and a print unit 4A. The print unit 4A includes a print wire 7, an elongated piezoelectric element 5, a motion transmitting mechanism 20, and a support frame 6. The piezoelectric element 5 is in the form of a stack of bonded piezoelectric ceramic segments. The motion transmitting mechanism 20 is mounted on one end of the piezoelectric element 5 for amplifying and transmitting expanding and contracting movement of the piezoelectric element 5 to the print wire 7.

The support frame 6 extends from one side face of the print head body 1 and supporting the motion transmitting mechanism 20 and the piezoelectric element 5. The support frame 6 is provided with a stop 30. The support frame 6 is of an integral unitary structure having a U-shape cross-section. The support frame 6 is composed of a main column 6a, an auxiliary column 6b, and an end portion (not shown), which jointly surround lengthwise sides and another end of the piezoelectric element 5. There are a plurality of (24 in the embodiment) the print units 4A disposed radially on the back of the head body 1. The print wires 7 of the print units 4A can project forwardly from and be retracted back into the nose on the front surface of the print head body 1.

When a voltage is applied, the piezoelectric element 5 is expanded and contracted along the stack thereof, i.e., in the longitudinal direction thereof. A temperature compensation member (not shown) for correcting the dimensions of the piezoelectric element 5 which is contracted when the temperature increases, is interposed between the rear end of the support frame 6 and the rear end of the piezoelectric element 5.

The print wire 7 has a proximal end 7a brazed to an arm 22 which is of a substantially triangular shape as viewed in side elevation. The motion transmitting mechanism 20 is coupled to a proximal end of the arm 22. Expanding and contracting movement of the piezoelectric element 5 is amplified and converted into back-and-forth movement of the print wire 7 by the motion transmitting mechanism 20 and the arm 22. The arm 22 has one side provided with an abutment block 29 formed of a synthetic resin. The abutment block 29 is abutable on the stop 30 on the support frame 6. The motion transmitting mechanism 20 includes a support leaf spring 24 and a drive leaf spring 25 extending rearwardly in the longitudinal direction of the main column 6a parallel to each other, and a rigid joint 26 interconnecting distal ends of the springs 24, 25. The joint 26 is fitted in and fixed to the proximal end of the arm 22 as by spot-welding. The support leaf spring 24 has a proximal end brazed to a side of the main column 6a. The drive leaf spring 25 has a proximal end brazed to a side of a movable member 14 that is adhesively fixed to a front end of the piezoelectric element 5.

When a voltage is applied, the piezoelectric element 5 is expanded and the movable member 14 is moved in the direction indicated by an arrow B (Fig. 1). Thus, the joint 26 which interconnect the springs 24, 25 is angularly displaced in the direction indicated by an arrow A, and the angular displacement of the joint 26 is amplified by the arm 22 to cause the print wire 7 to project from the nose. When the voltage application is stopped, the arm 22 is angularly moved back under the resiliency of the springs 24, 25 until the abutment block 29 mounted on the arm 22 abuts against and is stopped by the stop 30 mounted on the support frame 6.

Fig. 8 is a cross-sectional view taken along line VIII - VIII of Figs. 1 and 7. A quadric link mechanism 27 is disposed astride of the other side of the movable member 14 and the auxiliary column 6b. The quadric link mechanism 27 is in the form of a resilient member such as a leaf spring, and has a pair of wider side panels 27a each having a recess 28 that is substantially H-shaped as viewed in side elevation. The wider side panels 27a are fixed to front and back sides of the auxiliary column 6b and also front and back sides of the movable member 14 by spot-welding at positions adjacent the drive leaf spring 25a and the stop 30. When the piezoelectric element 5 is expanded and contracted in response to a voltage applied thereto, the wider side panels 27a are elastically deformed into the shape of a parallelogram as viewed in side elevation, moving the movable member 14 in the longitudinal direction of and parallel to the auxiliary column 6b that is fixed in position with respect to the movable member 14.

Since the movable member 14 is movable in the longitudinal direction of and parallel to the auxiliary column 6b, i.e., linearly in the longitudinal direction of the piezoelectric element 5, no bending stresses are applied to the bonded surfaces of the stacked piezoelectric ceramic units, and hence the stacked piezoelectric ceramic units will not be peeled off accidentally along the bonded surfaces.

When the support and drive leaf springs 24, 25 are elastically deformed, the arm 22 or the motion transmitting mechanism 20 is angularly moved about an axis 31. A line 32 which interconnects the axis 31 and the proximal end 7a of the print wire 7 which is joined to the distal end of the arm 22 extends substantially perpendicularly to the direction in which the print wire 7 moves back and forth. In the first embodiment, the direction of back-and-forth movement of the print wire 7 lies parallel to an axis 33 of the motion transmitting mechanism 20, along which the springs 24, 25 extend, the axis 33 passing through the axis 31.

The arm 22 has, on its lower side (Fig. 1), an integral protrusion 22a extending between the proximal end thereof to which the joint 26 is attached and the distal end thereof to which the proximal end 7a of the print wire 7 is fixed. The protrusion 22a projects to the longitudinal intermediate portions of the springs 24, 25. In other words, a recess 34 is formed at the proximal end of the arm 22, and the joint 6 is fixed to the recess 34. The recess defines a depth in a direction toward the dot impacting direction of the printing wire 7, i.e., in the direction toward the back of the head body 1 (Fig. 1).

When the piezoelectric element 21 is expanded to turn the arm 22 by an angle $\Delta\alpha$ to produce a displacement Y2 of the proximal end 7a along the Y-axis, which displacement Y2 is equal to the displacement of the print wire 7 toward the nose necessary to effect a printing process, a displacement X2 of the proximal end 7a along the X-axis is very small. Accordingly, any displacement along the X-axis of the distal end of the print wire 7 in its free state is also very small, so that any resistance presented to the axial sliding movement of the intermediate portion of the print wire 7 in the nose is minimized.

For example, it is assumed that the proximal end 7a of the print wire 7 is spaced from the axis 31 by 50 mm, and that the axis of the print wire 7 extends perpendicularly to the line 32. With such dimensions, when the arm 22 is angularly moved by an angle $\alpha\Delta = 5°$, the proximal end 7a of the print wire 7 is displaced by 4.36 mm along the Y-axis and by 0.19 along the X-axis.

On the other hand, if it is assumed in the conventional arrangement that the line 17 interconnecting the axis 15 and the proximal end 7a has a length of 50 mm and intersects with the reference line 16 at an angle of 50°m then when the arm 8 is angularly moved by an angle $\alpha\Delta = 5°$, the proximal end 7a of the print wire 7 is displaced by 2.66 mm along the Y-axis and by 3.45 mm along the X-axis.

A dot matrix impact print head device according to a second embodiment of the present invention is shown in Fig. 3. In a print units 4B, a drive leaf spring 25 and a support leaf spring 24, which jointly serve as an Eden's twin strips spring, are positioned in an inverted relationship to those shown in Fig. 1. When the piezoelectric element 5 is contracted upon the application of a voltage, the print wire 7 projects from the nose for dot printing.

Fig. 4 shows a dot matrix impact printing device having a print unit 4C according to a third embodiment of the present invention. In this embodiment, a support leaf spring 24 and a drive leaf spring 25 are positioned on opposite sides of a joint 26 and extend respectively opposite directions parallel to each other.

In the above embodiments, the springs 24, 25 extend parallel to the direction of back-and-forth movement of the print wire 7. In these embodiments, it is preferable that when the arm 22 is angularly moved by an angle $\Delta\alpha$, the arm 22 is moved between an angle of - $(\Delta\alpha/2)$ to an angle of $(\Delta\alpha/2)$ with respect to a reference line (i.e., a line extending from the axis 31 perpendicularly to the direction of back-and-forth movement of the print wire 7). With this arrangement, no displacement in X-direction occurs at the position before and after the movement of the print wire 7.

A dot matrix impact print head device having a print units 4D according to a fourth embodiment of this invention is shown in Fig. 5. In this embodiment, an arm 22 has a longitudinal direction thereof extending parallel to the direction in which the support and drive leaf springs 24, 25 extend, and a line 32 interconnecting the axis 31 and the proximal end 7a of the print wire 7 extends substantially perpendicularly to the direction in which the print wire 7 moves back and forth.

According to the present invention, the line 32 interconnecting the pivotal center axis 31 and the proximal end 7a of the print wire 7 is selected in position to be substantially aligned with the reference line 16 in the conventional print head. Stated otherwise, the line which interconnects the axis about which the arm is angularly movable upon elastic deformation of the support and drive leaf spring resulting from the expansion and contraction of the piezoelectric element and the position where the proximal end of the print wire is fixed to the distal end of the arm, is selected in position to extend substantially perpendicularly across the direction in which the print wire 7 extends (i.e. moves back and forth). With such a positional limitation, any transverse displacement of the print wire 7 is greatly reduced while the angular displacement of the arm is selected to cause the print wire 7 to move back and forth over a minimum stroke necessary for dot printing.

With the present invention, the energy applied to energize the piezoelectric element can be reduced for effective back-and-forth movement of the print wire. Accordingly the dot matrix impact print head device according to the present invention can be relatively small in size and can exhibit improved printing performance.

While the invention has been described in detail and with reference to specific embodiment thereof, it would be apparent to those skilled in the art that various changes and modifications may be made therein without departing from the spirit and scope of the invention.

Claims

1. A dot matrix impact print head device for providing a dot matrix pattern on a print medium comprising:

   a print head body having a nose portion;

   a print wire having a distal end to strike on the print medium and having a proximal end, the distal end being projectable forwardly from and retractable back into the nose portion in a projecting/retracting direction;

   an arm having a distal end portion to which the proximal end of the print wire is attached and having a proximal end portion;

   a piezoelectric element supported on the print head body, the piezoelectric element being expandable and shrinkable in a longitudinal direction thereof;

   a motion transmitting means having a first resilient portion fixed to the print head body, a second resilient portion coupled to the piezoelectric element and a third portion joining together the first and the second resilient portions, the third portion being coupled to the proximal end portion of the arm, a pivotal center being defined in the motion transmitting means and resilient deformation of the first and second resilient portions providing a pivotal motion of the arm about the pivotal center, a line connecting between the pivotal center and the proximal end of the print wire extending in a direction substantially perpendicular to the projecting/retracting direction.

2. The dot matrix impact print head device as claimed in claim 1, wherein the arm extends substantially perpendicular to extending direction of the print wire and the piezoelectric element, and the proximal end portion of the arm is formed with a notch to which the third portion is fixed for orienting the line connecting between the pivotal center and the proximal end of the print wire in a direction substantially perpendicular to the projecting/retracting direction

3. The dot matrix impact print head device as claimed in claim 1 or 2, wherein the piezoelectric element extends in a direction substantially parallel with the projecting/retracting direction of the print wire, and wherein the first and second resilient portions extend parallel with the piezoelectric element.

4. The dot matrix impact print head device as claimed in any preceding claim, wherein the first resilient portion comprises a support leaf spring having one end fixed to the print head body and having another end, and the second resilient portion comprises a drive leaf spring having one end fixed to the piezoelectric element and having another end, and the other ends of the support leaf spring and the drive leaf spring being joined together to constitute the third portion.

5. The dot matrix impact print head device as claimed in claim 4, wherein the support leaf spring and the drive leaf spring extend side by side in parallel with each other.

6. The dot matrix impact print head device as claimed in claim 4, wherein the support leaf spring and the drive leaf spring extend in parallel with each other, and the support leaf spring extends in one direction and the drive leaf spring extends in opposite direction with respect to the third portion.

7. The dot matrix impact print head device as claimed in claim 1, wherein the arm extends linearly with respect to an extending direction of the first and second resilient portions for orienting the line connecting between the pivotal center and the proximal end of the print wire in a direction substantially perpendicular to the projecting/ retracting direction.

8. The dot matrix impact print head device as claimed in claim 1 or 7 , wherein the piezoelectric element extends in a direction substantially perpendicular to the projecting/retracting direction of the print wire, and wherein the first and second resilient portions extend parallel with the piezoelectric element.

9. The dot matrix impact print head device as claimed in claim 8, wherein the first resilient portion comprises a support leaf spring having one end fixed to the print head body and having another end, and the second resilient portion comprises a drive leaf spring having one end fixed to the piezoelectric element and having another end, and the other ends of the support leaf spring and the drive leaf spring being joined together to constitute the third portion.

10. The dot matrix impact print head device as claimed in claim 8 or 9, wherein the support leaf spring and the drive leaf spring extend side by side in parallel with each other.

FIG. 1

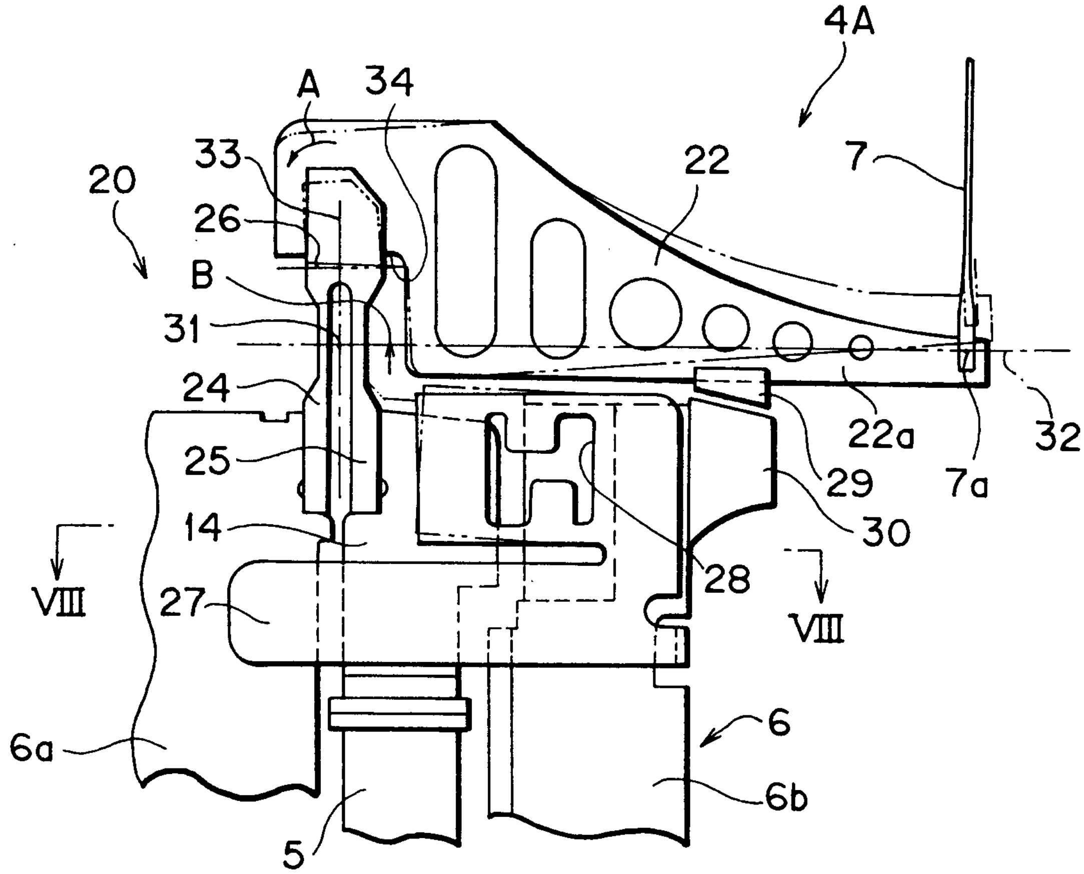
4A
A
34
33
20
26
22
7
B
31
24
25
22a
32
29
7a
30
14
28
VIII
27
VIII
6
6a
6b
5

FIG. 2

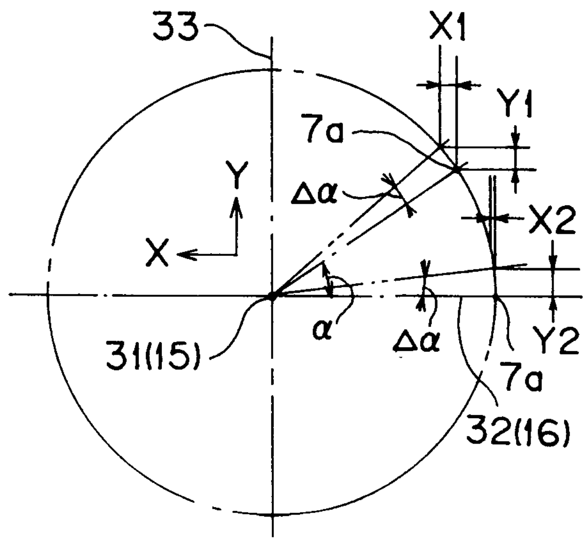
33
X1
Y1
7a
Y
Δα
X2
X
α
Δα
Y2
31(15)
7a
32(16)

FIG. 3

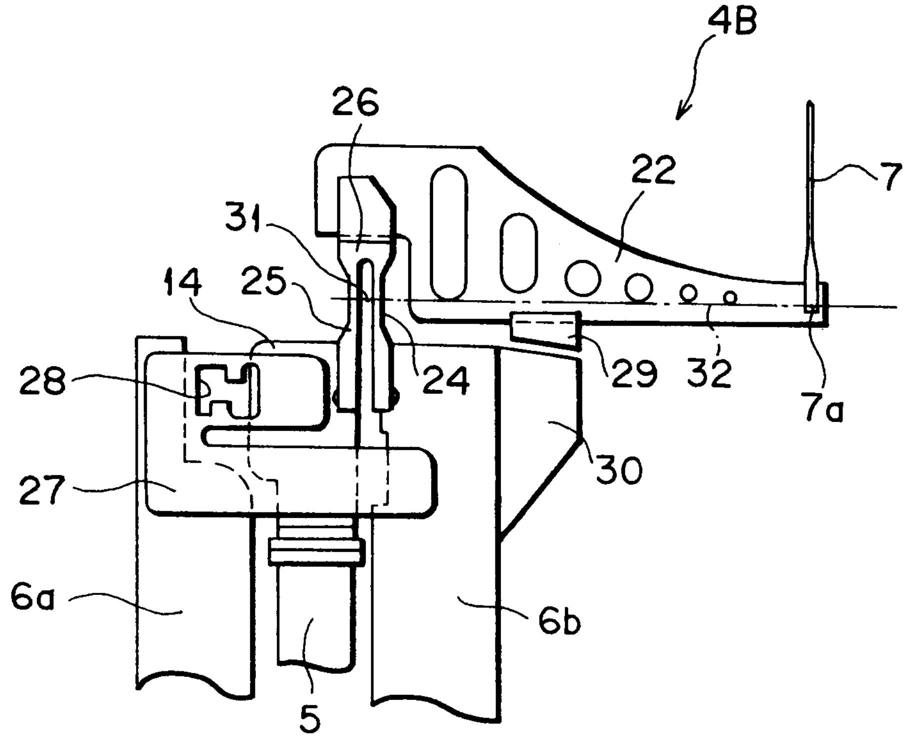
4B
26
22
7
31
25
14
24
29
32
28
7a
30
27
6a
6b
5

FIG. 4

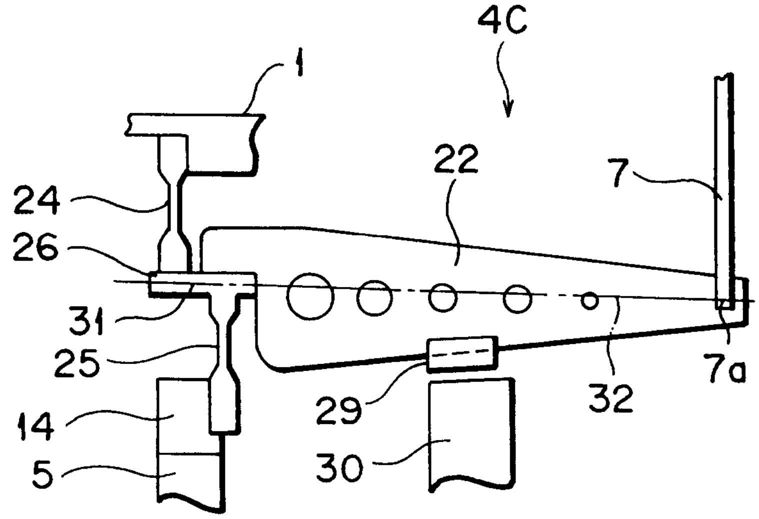
4C
1
22
7
24
26
31
25
29
32
7a
14
30
5

FIG. 5

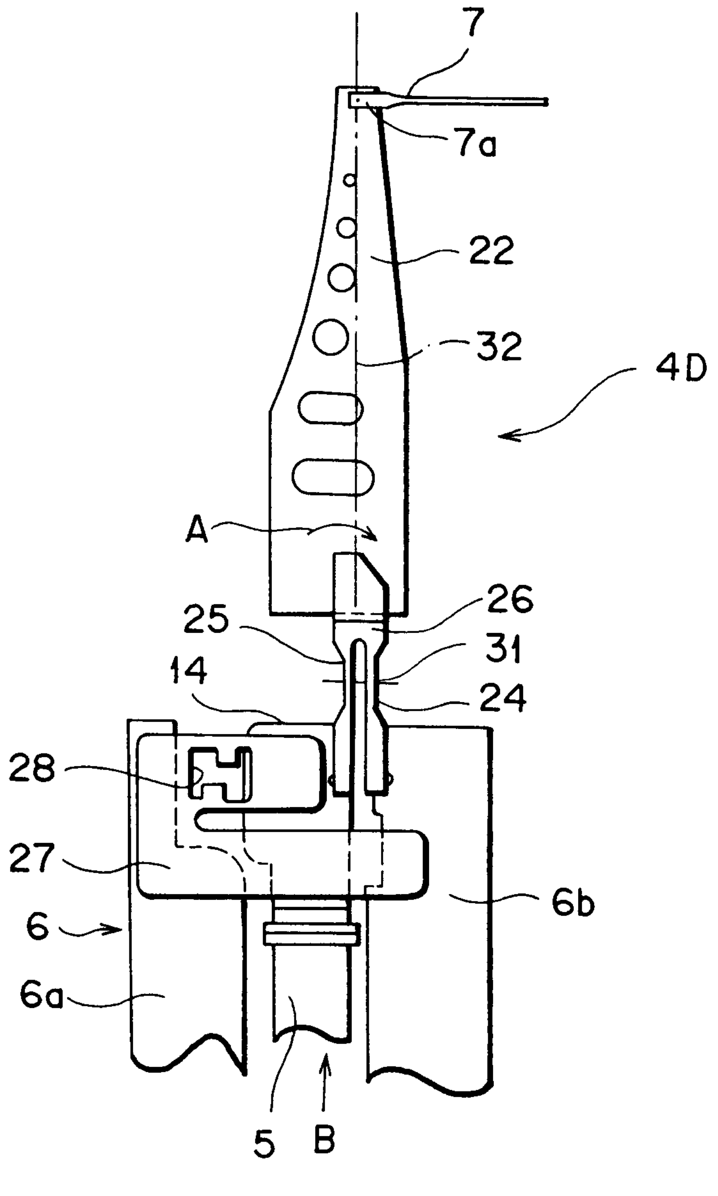

FIG. 6

RELATED ART

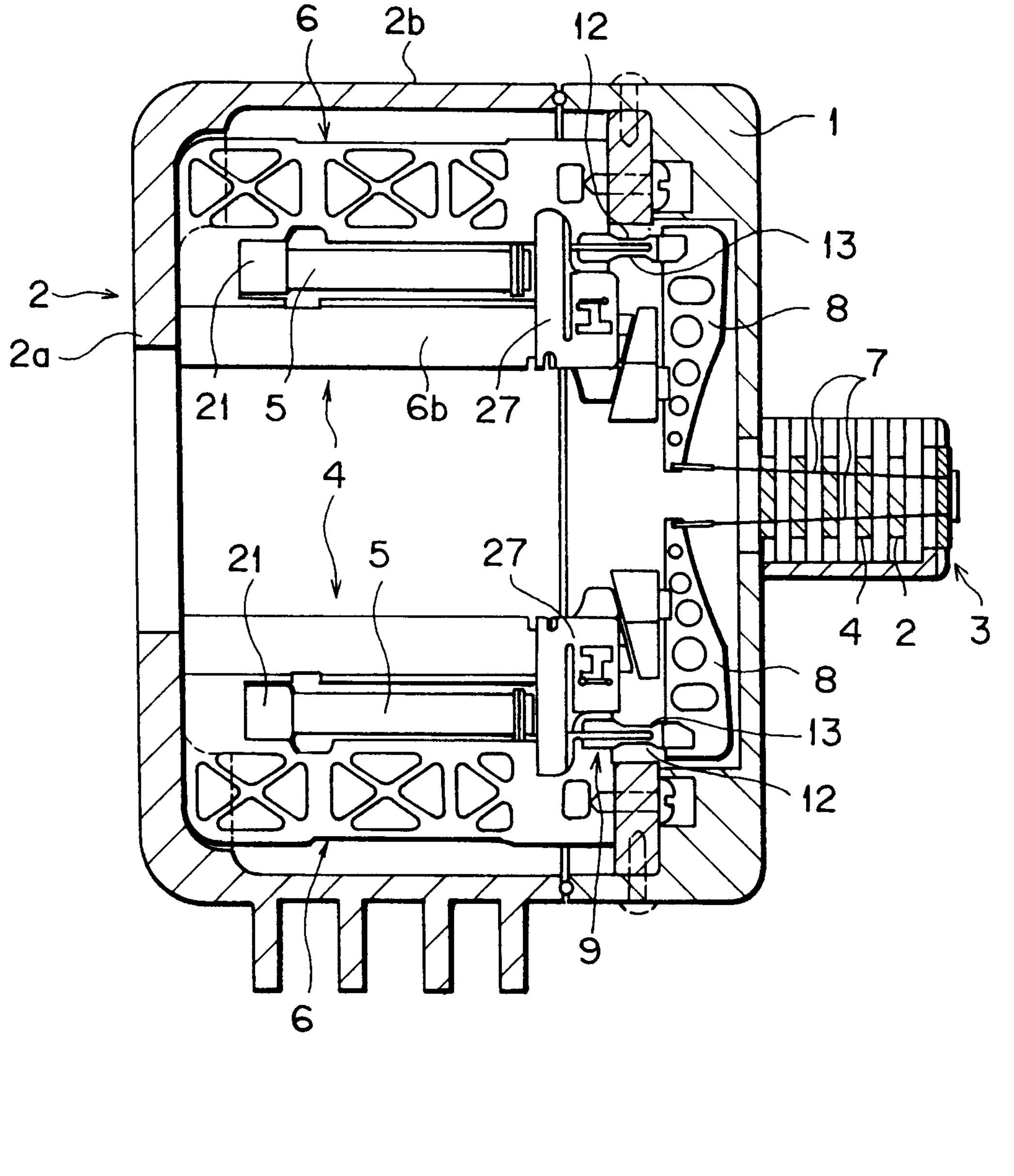

FIG. 7
RELATED ART

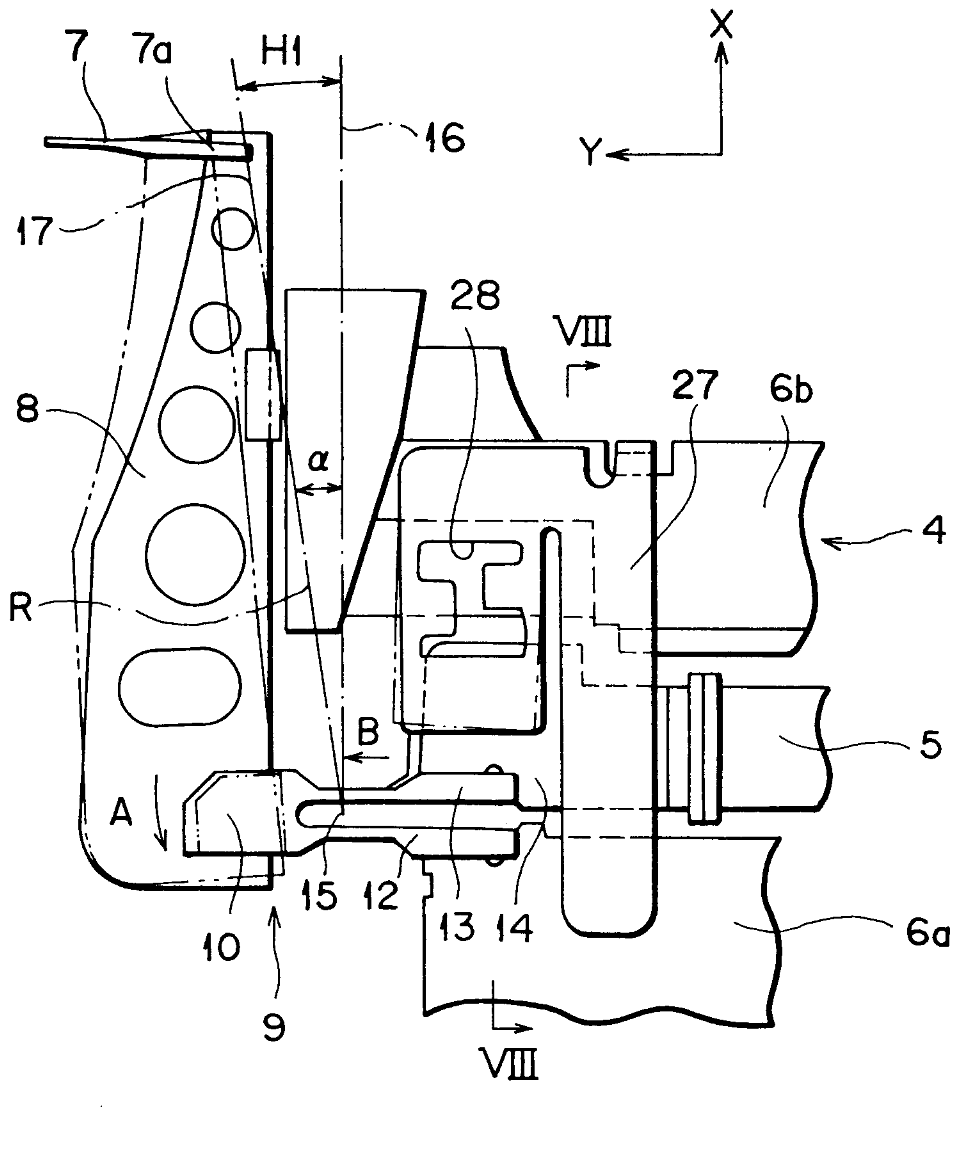

FIG. 8