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(54) ULTRASOUND PROBE

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(57) ABSTRACT

An ultrasound probe includes: an ultrasound transducer provided on a distal end side of an outer tube; an actuator including a movable portion configured to perform a reciprocating motion; and a conversion mechanism. The conversion mechanism is arranged in the longitudinal direction of the outer tube in series with the actuator in the longitudinal direction, arranged in parallel to the ultrasound transducer in the longitudinal direction, and configured to convert the reciprocating motion of the movable portion to a swing motion of the ultrasound transducer. A working point in the mechanism is positioned off a center axis of the outer tube and a center axis of driving force of the reciprocating motion in the movable portion, and the center axis of the driving force of the reciprocating motion in the movable portion is displaced to the working point side by a predetermined distance relative to the center axis.

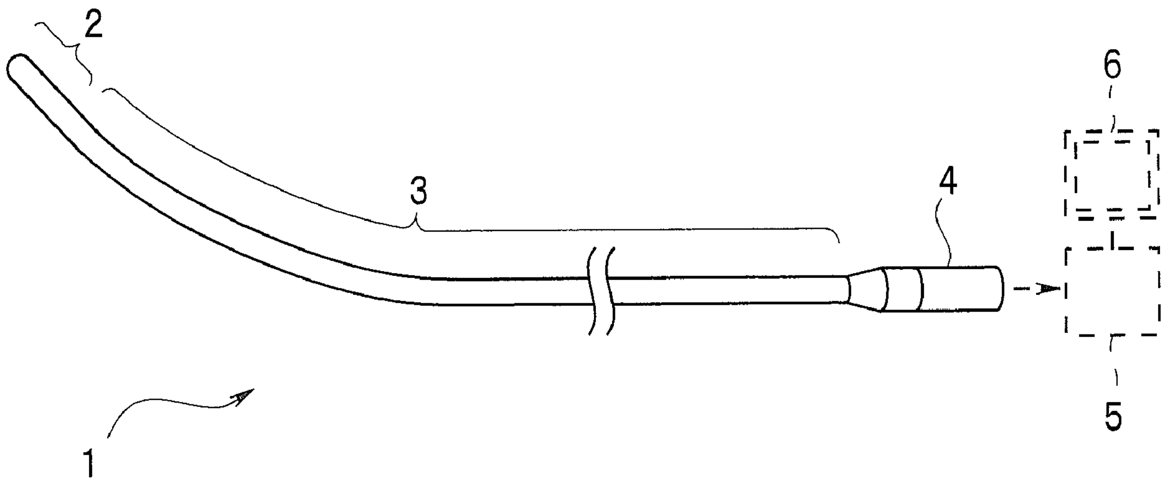


FIG. 1

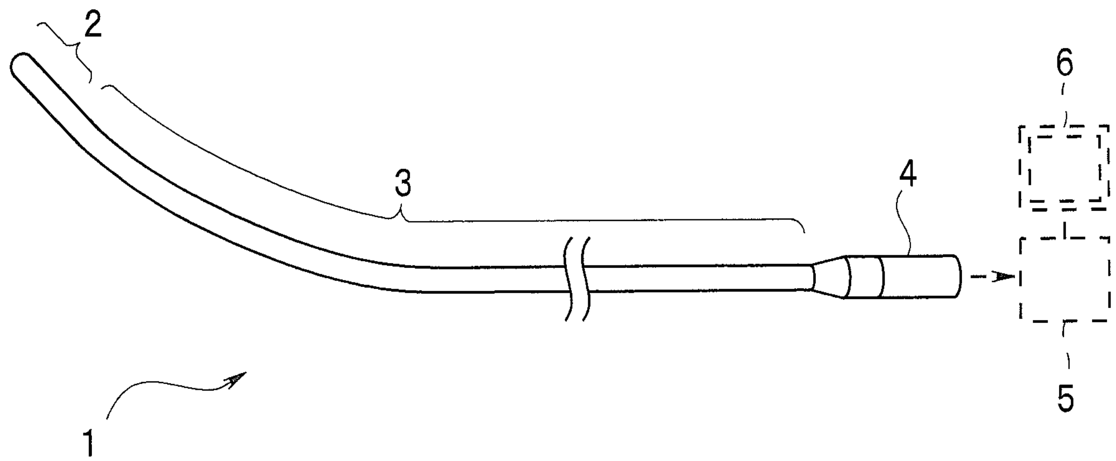


FIG. 2

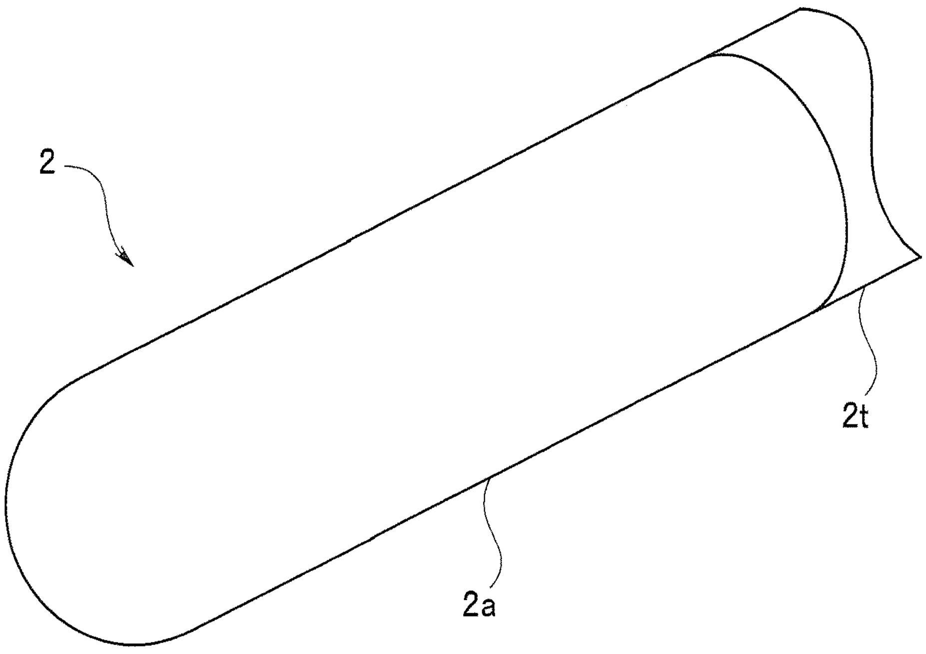

2
2t
2a

FIG. 3

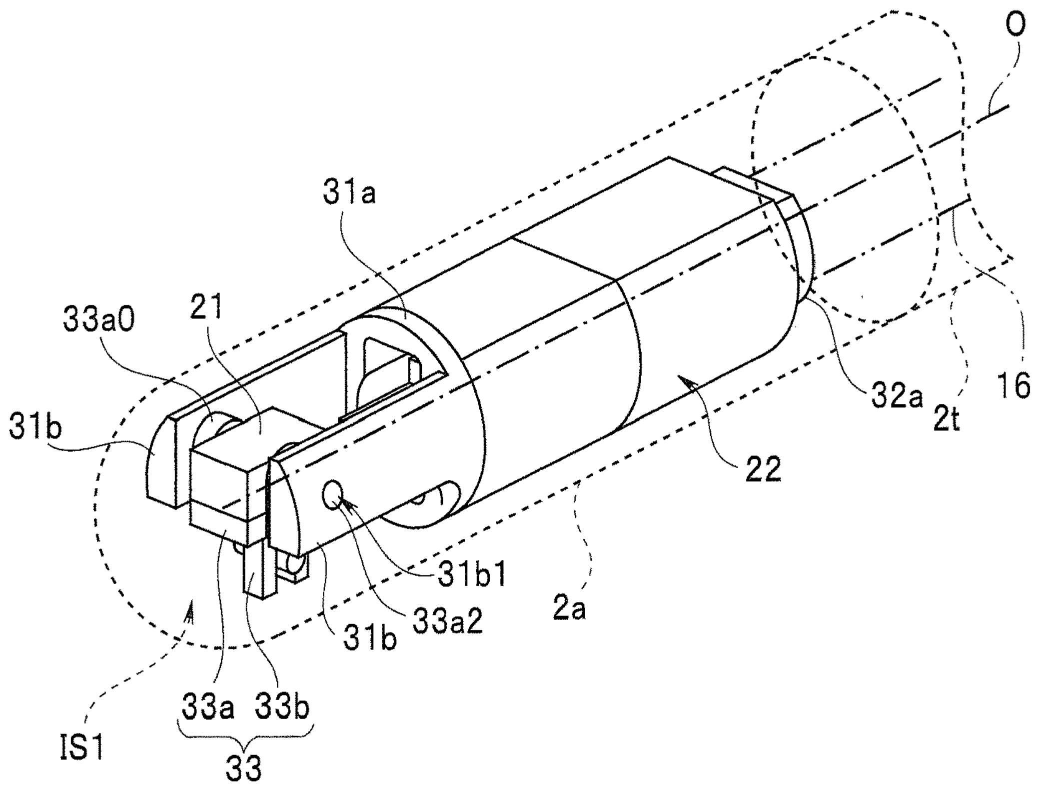

O
31a
33a0
21
31b
32a
2t
16
22
31b1
31b
33a2
2a
IS1
33a
33b
33

FIG. 4

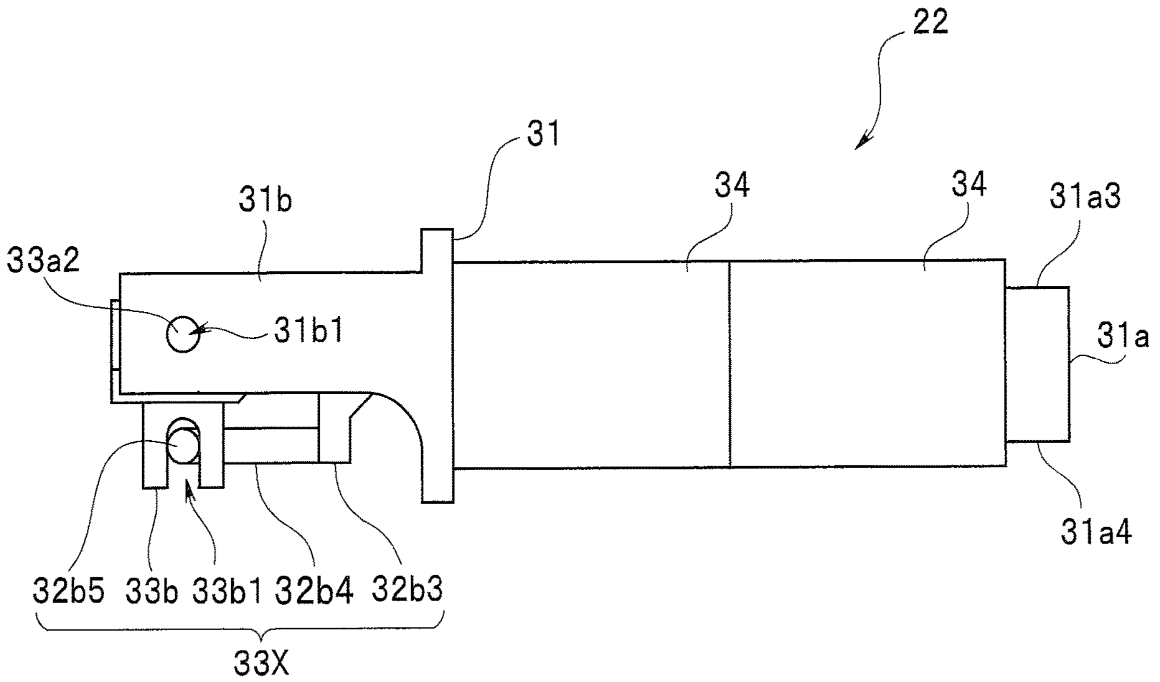

22
31
31b
34
34
31a3
33a2
31b1
31a
32b5
33b
33b1
32b4
32b3
31a4
33X

FIG. 5

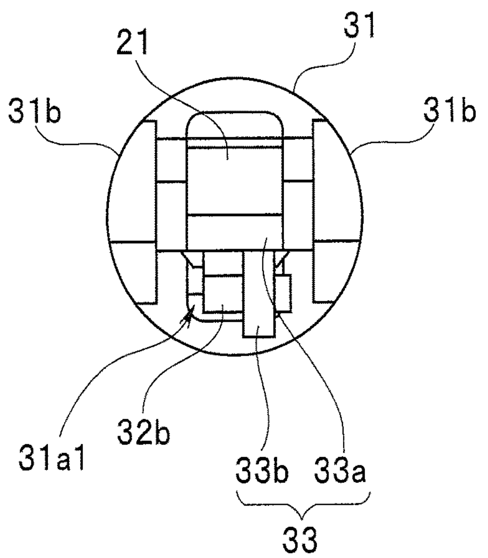

21
31
31b
31b
31a1
32b
33b
33a
33

FIG. 6

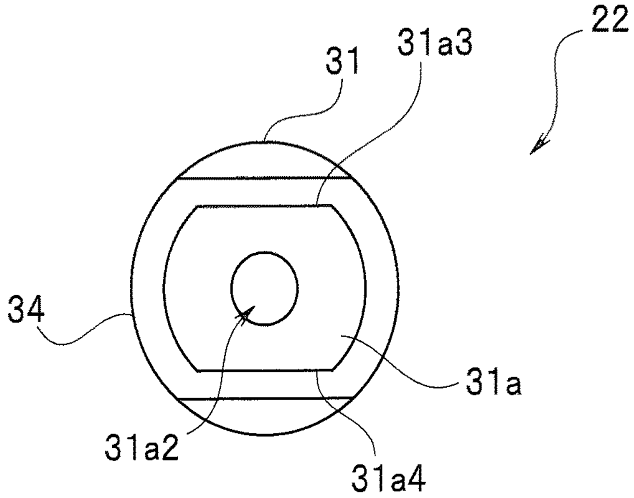

22
31
31a3
34
31a
31a2
31a4

FIG. 7

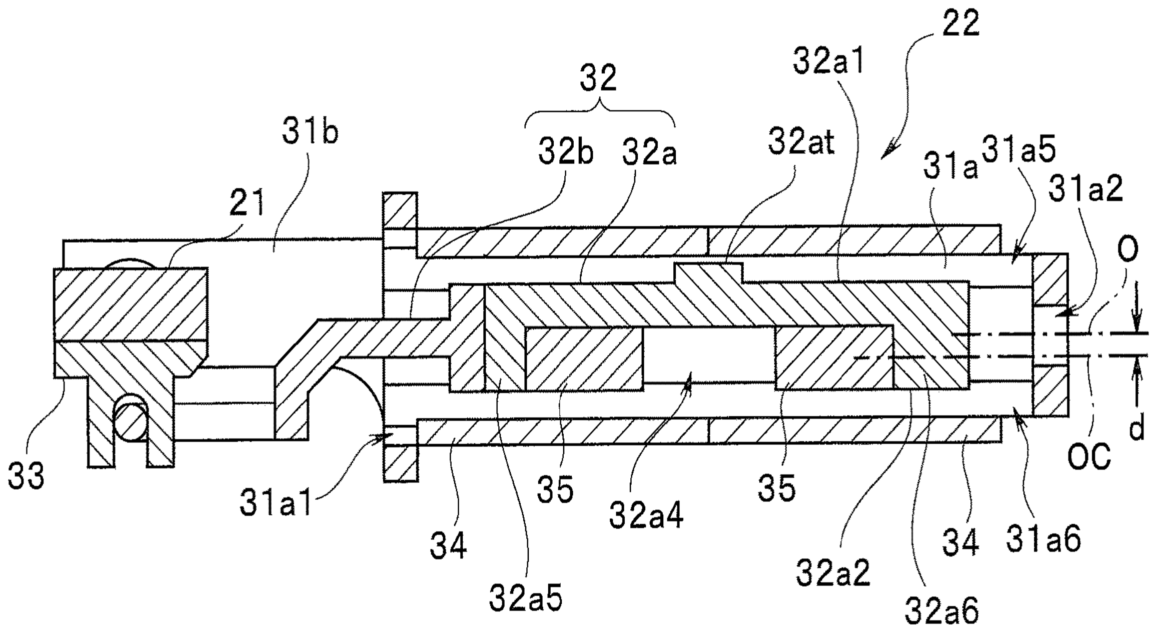

22
32
32a1
31b
32b
32a
32at
31a
31a5
21
31a2
O
d
OC
33
31a1
35
32a4
35
34
31a6
34
32a5
32a2
32a6

FIG. 8

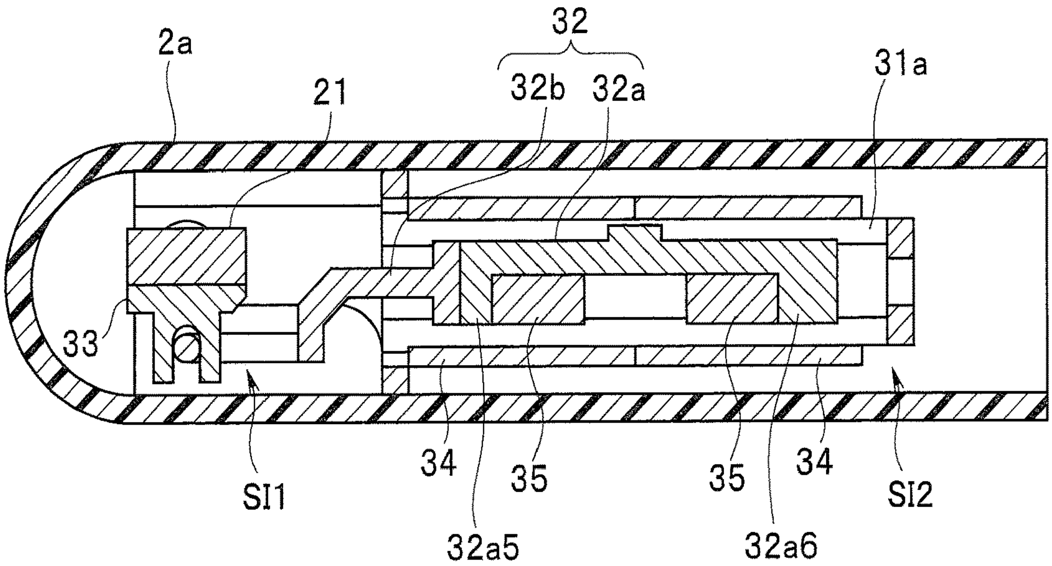

32
2a
21
32b
32a
31a
33
SI1
34
35
35
34
SI2
32a5
32a6

FIG. 9

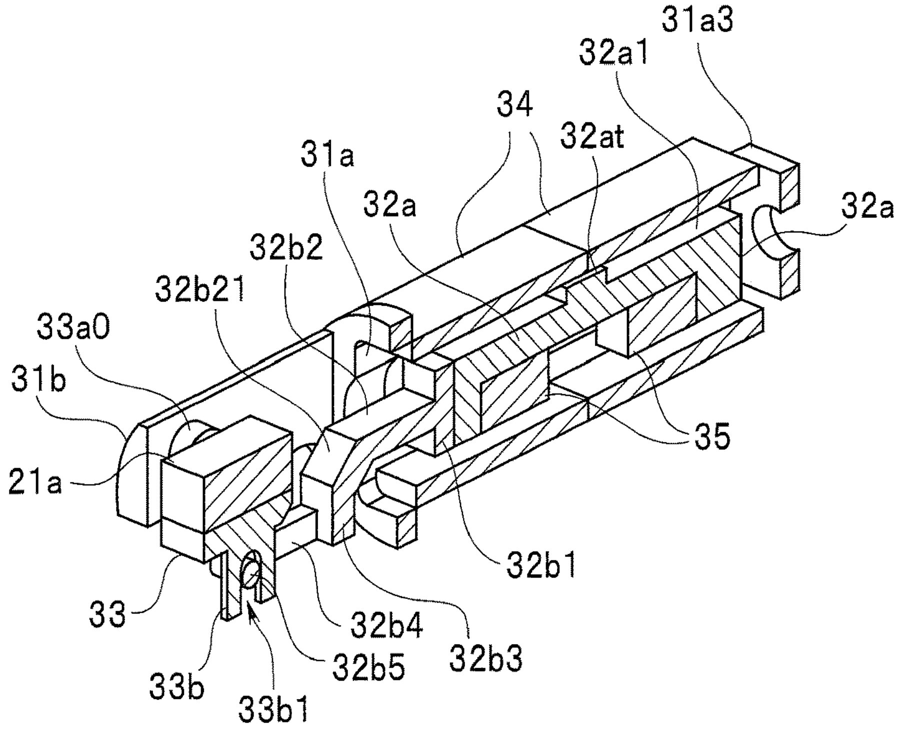

31a3
32a1
34
32at
31a
32a
32a
32b2
32b21
33a0
31b
21a
35
32b1
33
32b4
32b3
32b5
33b
33b1

FIG. 10

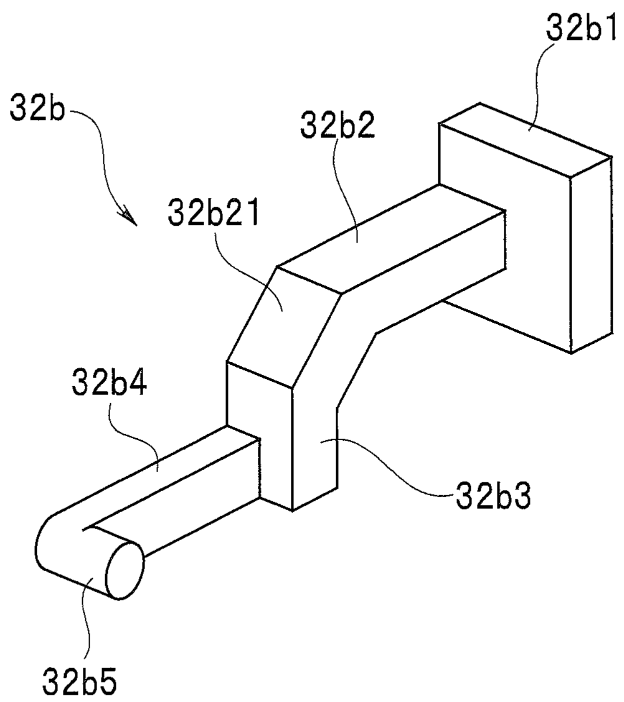

32b
32b1
32b2
32b21
32b4
32b3
32b5

FIG. 11

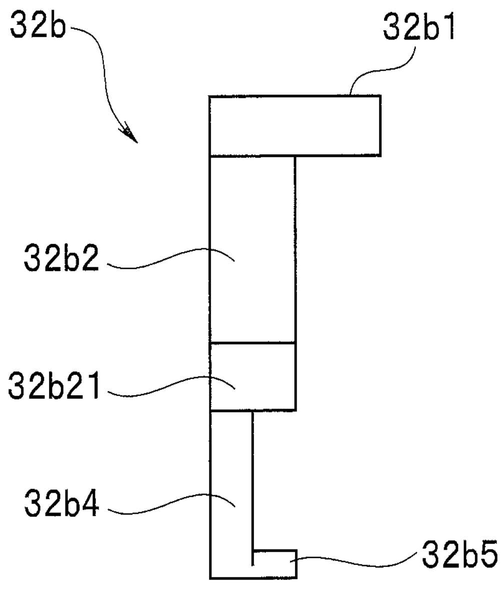

32b
32b1
32b2
32b21
32b4
32b5

FIG. 12

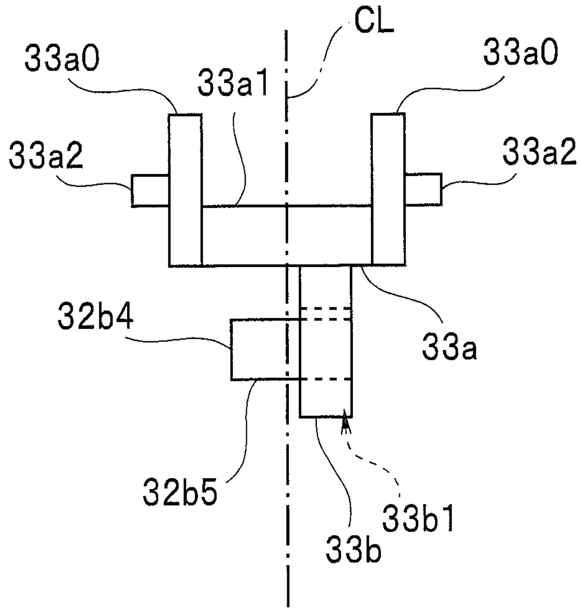


FIG. 13

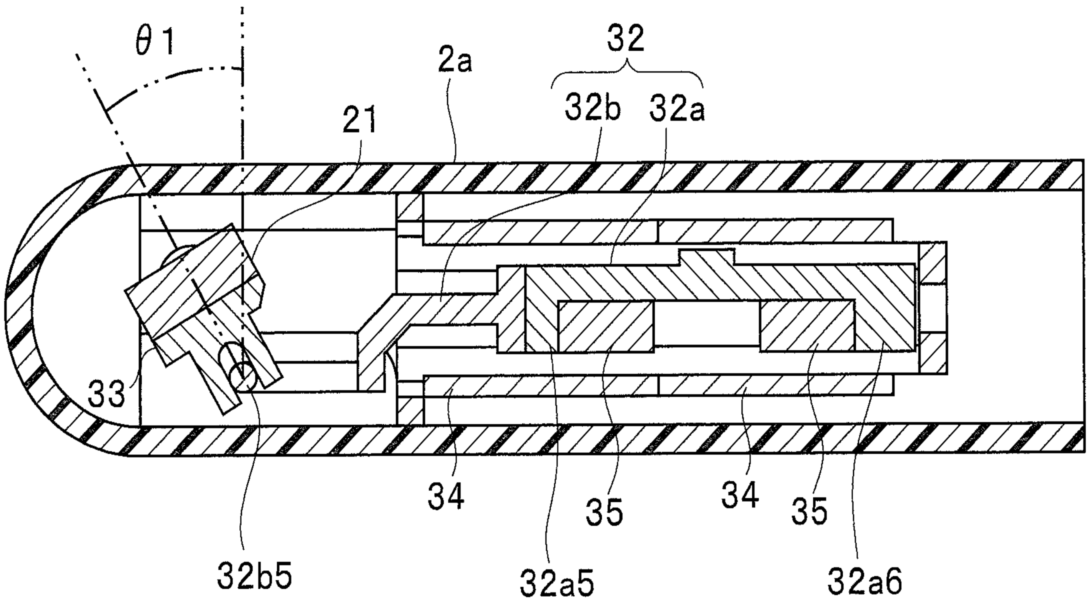

θ1
2a
32
32b
32a
21
33
34
35
34
35
32b5
32a5
32a6

FIG. 14

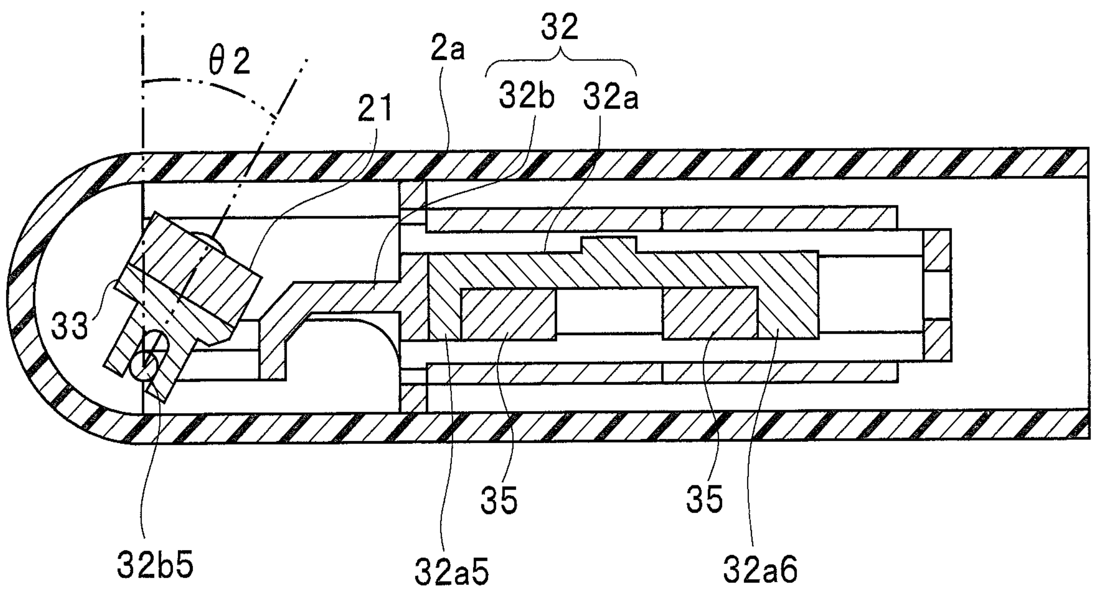

θ2
2a
32
32b
32a
21
33
35
35
32b5
32a5
32a6

FIG. 15

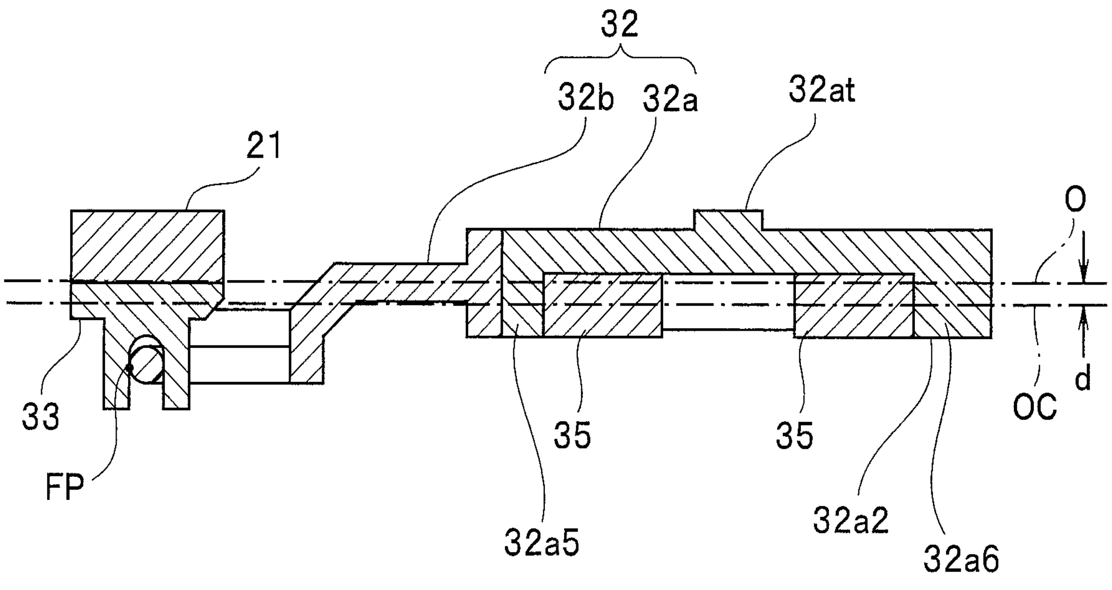
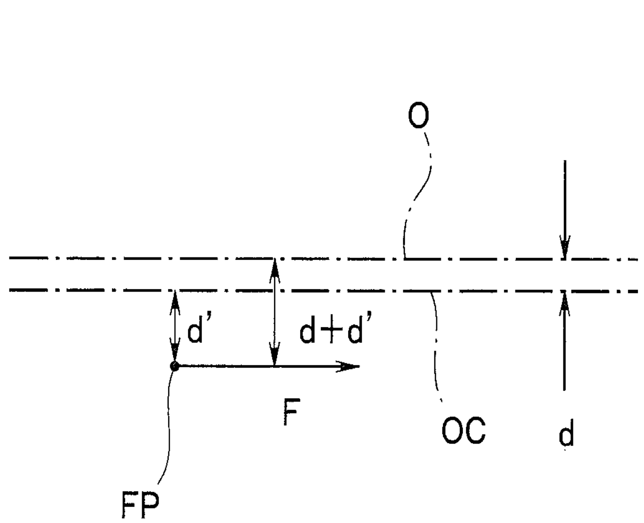


FIG. 16



ULTRASOUND PROBE

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application is a continuation application of PCT/JP2017/019666 filed on May 26, 2017, the entire contents of which are incorporated herein by this reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0002] The present invention relates to an ultrasound probe, and in particular relates to an ultrasound probe of a mechanical scanning system.

2. Description of the Related Art

[0003] Conventionally, an ultrasound imaging device has been widely used in a medical field or the like, and an ultrasound probe that is inserted into a body cavity or into a blood vessel to observe internal organs has been developed.

[0004] An ultrasound transducer is provided on a distal end of a probe, and for a scanning system of the ultrasound transducer, either an electronic scanning system or a mechanical scanning system is used. When it is taken into consideration that the probe itself is to be inserted into a body cavity or the like, it is preferable that a diameter of the probe is small.

[0005] For example, Japanese Patent Application Laid-Open Publication No. 63-145640 discloses an ultrasound probe that achieves the mechanical scanning system by swinging an ultrasound transducer around a predetermined axis.

[0006] A turning member mounted with the ultrasound transducer is arranged inside a distal end portion of the ultrasound probe. In order to make the turning member turn around a turning axis, a rigid operation wire moves back and forth in an axial direction of the ultrasound probe. A distal end portion of the operation wire is fixed to one end of the turning member.

[0007] A point of the turning member to which the distal end portion of the operation wire is fixed becomes a working point when the turning member is driven to swing, and the turning member swings around the turning axis. By the turning member swinging around the turning axis, the ultrasound transducer swings around the turning axis, and mechanical scanning is performed. The working point is positioned on an opposite side of an ultrasound transducer mounting portion of the turning member relative to the turning axis.

[0008] In order to efficiently supply force by back-and-forth movements of the operation wire to the working point, it is preferable that the working point is positioned on a center axis of the operation wire which is a driving member.

SUMMARY OF THE INVENTION

[0009] An ultrasound probe of one aspect of the present invention includes: an outer tube to be inserted into a body; an ultrasound transducer provided on a distal end side of the outer tube and supported swingably within a plane in a longitudinal direction of the outer tube; an actuator including a movable portion configured to perform a reciprocating motion in the longitudinal direction of the outer tube; and a conversion mechanism arranged in the longitudinal direction of the outer tube in series with the actuator in the longitudinal direction, arranged in parallel to the ultrasound transducer in the longitudinal direction, and configured to convert the reciprocating motion of the movable portion to a swing motion of the ultrasound transducer, in which a working point in the conversion mechanism of force by the reciprocating motion of the actuator is positioned off a center axis of the outer tube and a center axis of driving force of the reciprocating motion in the movable portion, and the center axis of the driving force of the reciprocating motion in the movable portion is displaced to the working point side by a predetermined distance relative to the center axis of the outer tube.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. **1** is an external view of an ultrasound probe according to an embodiment of the present invention;

[0011] FIG. **2** is a perspective view of a distal end portion **2** of an ultrasound probe **1** according to the embodiment of the present invention;

[0012] FIG. **3** is a perspective view of an actuator of an ultrasound transducer disposed inside the distal end portion **2**, according to the embodiment of the present invention;

[0013] FIG. **4** is a front view of an actuator **22** according to the embodiment of the present invention;

[0014] FIG. **5** is a left side view of the actuator **22** according to the embodiment of the present invention;

[0015] FIG. **6** is a right side view of the actuator **22** according to the embodiment of the present invention;

[0016] FIG. **7** is a sectional view of the actuator **22** according to the embodiment of the present invention;

[0017] FIG. **8** is a sectional view of the distal end portion **2** of the ultrasound probe **1** when an ultrasound transducer **21** is at an intermediate position when the ultrasound transducer **21** is not swinging, according to the embodiment of the present invention;

[0018] FIG. **9** is a sectional perspective view of the distal end portion **2** when the ultrasound transducer **21** is at the intermediate position when the ultrasound transducer **21** is not swinging, according to the embodiment of the present invention;

[0019] FIG. **10** is a perspective view of a linking member **32*b*** according to the embodiment of the present invention;

[0020] FIG. **11** is a plan view of the linking member **32*b*** according to the embodiment of the present invention;

[0021] FIG. **12** is a diagram for explaining an arrangement state of a transducer mounting portion **33** and the linking member **32*b***, according to the embodiment of the present invention;

[0022] FIG. **13** is a sectional view of the distal end portion **2** when an ultrasound transmission/reception surface **21*a*** of the ultrasound transducer **21** is inclined to a distal end side of the distal end portion **2**, according to the embodiment of the present invention;

[0023] FIG. **14** is a sectional view of the distal end portion **2** when the ultrasound transmission/reception surface **21*a*** of the ultrasound transducer **21** is inclined to a proximal end side of the distal end portion **2**, according to the embodiment of the present invention;

[0024] FIG. **15** is a diagram for explaining a direction of driving force given to an extension portion **33*b*** by the linking member **32*b***, according to the embodiment of the present invention; and

[0025] FIG. **16** is a diagram for explaining a difference in reaction force due to a moment applied to the actuator **22** between a case where a center axis of the driving force is located on a center axis O of an outer tube **22***t* and a case where the center axis of the driving force is displaced by a predetermined distance d.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0026] Hereinafter, the embodiment of the present invention will be described using drawings.

[0027] (Overall Structure)

[0028] FIG. **1** is an external view of an ultrasound probe. An ultrasound probe **1** has an elongated shape, and includes a distal end portion **2**, a flexible tube portion **3** and a connection portion **4** from a distal end.

[0029] The ultrasound probe **1** is a probe of a mechanical scanning system having the elongated shape that can be inserted into a narrow lumen such as a blood vessel, pulmonary peripheral site, and a pancreas and biliary system. The ultrasound probe **1** includes an elongated and flexible resin outer tube **2***t*, and a distal end portion **2** fixed to a distal end of the outer tube **2***t*. A diameter of the ultrasound probe **1** is, for example, 2 to 5 mm. The distal end portion **2** incorporates an ultrasound transducer of the mechanical scanning system, as described later.

[0030] The flexible tube portion **3** is formed of a flexible tube member, and a signal line or the like is inserted inside.

[0031] The connection portion **4** is connected to an ultrasound observation device **5**, as illustrated by a dotted line. To the ultrasound observation device **5**, a monitor **6** is connected. The ultrasound observation device **5** includes an image processing portion configured to process an output signal of the ultrasound probe **1**, generate an ultrasound image and output the ultrasound image to the monitor **6**.

[0032] The ultrasound observation device **5** includes a drive circuit device configured to electronically drive the ultrasound transducer inside the distal end portion **2**, and an image generation portion configured to generate the ultrasound image inside a subject based on a signal from the ultrasound transducer. The ultrasound observation device **5** outputs an image signal of the generated ultrasound image to the monitor **6** which is a display device, and the ultrasound image is displayed on the monitor **6**.

[0033] A user can insert the ultrasound probe **1** into a treatment instrument insertion channel of an endoscope (not illustrated) in endoscopy for example, and view the ultrasound image of the subject displayed on the monitor **6** to perform an examination.

[0034] (Configuration of Distal End Portion of Ultrasound Probe)

[0035] FIG. **2** is a perspective view of the distal end portion **2** of the ultrasound probe **1**. FIG. **3** is a perspective view of an actuator of the ultrasound transducer disposed inside the distal end portion **2**.

[0036] As illustrated in FIG. **2**, the distal end portion **2** of the ultrasound probe **1** includes a resin housing **2***a*. The outer tube **2***t* to be inserted into a body and the housing **2***a* provided on a distal end side of the outer tube **2***t* are configured to be inserted into the body of the subject.

[0037] The housing **2***a* has a cylindrical shape, and a distal end side part of the housing **2***a* is formed into a semispherical shape. A center axis of the housing **2***a* having the cylindrical shape coincides with a center axis O of the ultrasound probe **1**.

[0038] On an inner side of the housing **2***a*, as illustrated in FIG. **3**, an internal space IS**1** configured to house an ultrasound transducer **21** is provided, and the ultrasound transducer **21** is made swingable within a predetermined angle range around a predetermined axis inside the internal space IS**1** by an actuator **22** disposed inside the distal end portion **2**. The ultrasound transducer **21** is provided on the distal end side of the outer tube **2***t*, and is supported swingably within a plane in a longitudinal direction of the outer tube **2***t*. The ultrasound transducer **21** is an element formed of a single plate of a roughly rectangular outer shape.

[0039] The housing **2***a* includes the internal space IS**1** configured to house the ultrasound transducer **21** and a conversion mechanism **33**X (to be described later) on the distal end side, and an internal space IS**2** configured to house the actuator **22** on a proximal end side (see FIG. **8**). The actuator **22** has a shape elongated in a direction of the axis O of the ultrasound probe **1**. A center axis of the actuator **22** coincides with the center axis of the housing **2***a*.

[0040] As illustrated by two-dot chain lines in FIG. **3**, a plurality of signal lines **16** for the ultrasound transducer **21** and the actuator **22** extend from the proximal end side of the actuator **22**, and are inserted into the outer tube **2***t* and the flexible tube portion **3**.

[0041] (Configuration of Actuator)

[0042] FIG. **4** is a front view of the actuator **22**. FIG. **4** is a diagram of a view orthogonal to the axis of the distal end portion **2**. FIG. **5** is a left side view of the actuator **22**. FIG. **6** is a right side view of the actuator **22**. FIG. **5** illustrates a side face when viewing the actuator **22** disposed inside the distal end portion **2** from the distal end side, and FIG. **6** illustrates a side face when viewing the actuator **22** disposed inside the distal end portion **2** from the proximal end side. FIG. **7** is a sectional view of the actuator **22**. FIG. **8** is a sectional view of the distal end portion **2** of the ultrasound probe **1** when the ultrasound transducer **21** is at an intermediate position when the ultrasound transducer **21** is not swinging. FIG. **9** is a sectional perspective view of the distal end portion **2** when the ultrasound transducer **21** is at the intermediate position when the ultrasound transducer **21** is not swinging.

[0043] As described above, the actuator **22** is disposed inside the internal space IS**2** of the distal end portion **2** of the ultrasound probe **1** (see FIG. **8**), and is a drive unit configured to make the ultrasound transducer **21** swing within the predetermined angle range around the predetermined axis. Here, the actuator **22** is an electromagnetic drive unit using a moving magnet type voice coil motor which is an electromagnetic actuator. The voice coil motor includes a coil and a magnet.

[0044] Note that in the present embodiment, the moving magnet type voice coil motor in which a movable portion includes the magnet is used for the actuator **22**, but a moving coil type voice coil motor may be used as the actuator **22**.

[0045] The actuator **22** which is the electromagnetic actuator includes a frame member **31**, a movable portion **32** disposed inside the frame member **31**, and a transducer mounting portion **33** disposed on the distal end side of the movable portion **32** and mounted with the ultrasound transducer **21**. The movable portion **32** performs a reciprocating motion in a longitudinal direction of the outer tube **2***t*.

[0046] As illustrated in FIG. **3** and FIG. **7**, the actuator **22** is disposed inside the ultrasound probe **1** such that a longitudinal axis of the actuator **22** coincides with the center axis O of the ultrasound probe **1** and the longitudinal axis of the actuator **22** becomes parallel to the center axis O.

[0047] As illustrated in FIG. **4** to FIG. **6**, the frame member **31** includes a cylindrical portion **31***a* and two arms **31***b*. As illustrated in FIG. **3** and FIG. **4**, the two arms **31***b* are provided so as to extend in a distal end direction from the distal end of the cylindrical portion **31***a* in parallel to each other. On each arm **31***b*, a hole **31***b***1** through which a shaft portion **33***a***2** to be described later is to be inserted is formed.

[0048] As illustrated in FIG. **5** and FIG. **7**, a hole **31***a***1** is formed on the distal end side of the cylindrical portion **31***a*. As illustrated in FIG. **6** and FIG. **7**, a hole **31***a***2** is also formed on the proximal end side of the cylindrical portion **31***a*. In other words, the actuator **22** includes the frame member **31** configured to house the movable portion **32** inside, and the hole **31***a***2** is formed on an opposite side of the conversion mechanism **33**X to be described later of the frame member **31**. The hole **31***a***2** is a hole for injecting liquid, oil in this case, into the housing **2***a* of the distal end portion **2** for impedance matching when manufacturing the ultrasound probe **1**. The oil injected from the hole **31***a***2** passes through the hole **31***a***1** and enters the internal space IS1.

[0049] As illustrated in FIG. **6**, an upper side face **31***a***3** and a lower side face **31***a***4** of the cylindrical portion **31***a* have a flat surface. As illustrated in FIG. **7**, a through groove **31***a***5** extending in an axial direction of the cylindrical portion **31***a* is formed on the upper side face **31***a***3** of the cylindrical portion **31***a*, and a through groove **31***a***6** extending along the axis of the cylindrical portion **31***a* is also formed on the lower side face **31***a***4** of the cylindrical portion **31***a*.

[0050] On an outer peripheral surface of the cylindrical portion **31***a*, two coil portions **34** formed by winding a coil wire are provided.

[0051] Then, the movable portion **32** includes a column member **32***a* and a linking member **32***b* which extends in the axial direction of the distal end portion **2** from the distal end side of the column member **32***a*.

[0052] On an upper surface and a lower surface of the column member **32***a*, two plane portions **32***a***1** and **32***a***2** formed by being cut along the axis of the cylindrical portion **31***a* are provided respectively. The plane portion **32***a***1** is in parallel to the upper side face **31***a***3** of the cylindrical portion **31***a*, and the plane portion **32***a***2** is in parallel to the lower side face **31***a***4** of the cylindrical portion **31***a*.

[0053] On the plane portion **32***a***1**, a protruding portion **32***at* is formed. The protruding portion **32***at* has such a height that a part of the protruding portion **32***at* enters the through groove **31***a***5**, and restricts rotation around the axis of the movable portion **32**.

[0054] As described later, the column member **32***a* is movable along the axis of the distal end portion **2** inside the cylindrical portion **31***a* in a state where the protruding portion **32***at* enters the through groove **31***a***5**.

[0055] Further, the column member **32***a* includes an elongated recessed portion **32***a***4** formed along the axis of the column member **32***a*. The recessed portion **32***a***4** is, as illustrated in FIG. **7**, formed on a lower side of the column member **32***a*. Inside the recessed portion **32***a***4**, two permanent magnets **35** are arranged along the axis of the column member **32***a*. Each permanent magnet **35** has a rectangular parallelepiped shape, and is arranged inside the recessed portion **32***a***4** with an N pole and an S pole in a predetermined direction so that a magnetizing direction is a direction orthogonal to the axis of the cylindrical portion **31***a*.

[0056] As illustrated in FIG. **7**, the respective coil portions **34** and the respective permanent magnets **35** have such a shape that a dimension in a direction of the reciprocating motion is longer than a dimension in an orthogonal direction of the reciprocating motion of the movable portion **32**. Thus, space efficiency of the distal end portion **2** is excellent.

[0057] In addition, as illustrated in FIG. **7**, since the two coil portions **34** formed by the coil wire are arranged in series along the center axis O of the distal end portion **2** and the two permanent magnets **35** are also arranged in series along the center axis O of the distal end portion **2**, the space efficiency of the distal end portion **2** is excellent.

[0058] As described later, while the column member **32***a* moves back and forth along the center axis O of the distal end portion **2**, as illustrated in FIG. **7**, a longitudinal axis OC of the two permanent magnets **35** is displaced from the center axis O of the distal end portion **2** by a distance d and positioned.

[0059] Note that the column member **32***a* is formed of a ferromagnetic body. Here, for the movable portion **32**, by using a member of the ferromagnetic body as a material of the column member **32***a* that holds the two permanent magnets **35**, magnetic resistance is reduced, output efficiency of a magnetic circuit is improved, and force to move the movable portion **32** is increased.

[0060] Further, drive of the actuator is affected by disturbance acceleration accompanying disturbance (back and forth movement or bending of the probe by an operation of an operator for example) and variation among individuals. Therefore, a swing motion of the ultrasound transducer is not smoothly performed and there are more than a few risks of image degradation such as blurring of an ultrasound image. For such a problem, it is desirable to execute feedback control to the actuator; however, since a sensor needs to be separately provided in that case, a diameter of the device is increased.

[0061] In the present embodiment, by using the ferromagnetic body for the movable portion **32**, change of inductance of the coil to position change of the movable portion **32** is enlarged so that a speed or a position of the movable portion **32** can be estimated without using a sensor and so-called sensorless control can be applied.

[0062] In the coil portions **34**, induced electromotive force is generated by movement of the movable portion **32**. In addition, by a current flowing to the coil portions **34**, self-induced electromotive force is also generated. By detecting the self-induced electromotive force, the above-described sensorless control can be performed. The part of the ferromagnetic body of the movable portion **32** is arranged on the inner side of the two coil portions **34** so that the change of magnitude of the current flowing to the coil portions **34** generated based on the induced electromotive force can detect an end moving position of the movable portion **32**. For accurate position control of the movable portion **32**, it is preferable that a length in the axial direction of the column member **32***a* of the ferromagnetic body is formed to be longer than the length of the two coil portions **34** in the direction of the center axis O of the distal end portion **2**.

[0063] As a result, based on the magnitude of the current flowing to the coil portions **34**, the position of the movable portion **32** in the actuator **22** can be detected.

[0064] Also, as illustrated in FIG. **7**, since the two permanent magnets **35** are disposed inside the recessed portion **32***a***4** of the column member **32***a*, in the case where the column member **32***a* is formed of the ferromagnetic body, the two permanent magnets **35** are disposed between a distal end portion **32***a***5** and a proximal end portion **32***a***6** of the column member **32***a*. In other words, the member of the ferromagnetic body is provided on both sides that are the distal end side and the proximal end side of the two permanent magnets **35**. Thus, influence of a magnetic field from outside in the direction of the center axis O of the distal end portion **2** can be shielded, and even when the magnetic body is present at front and back in the axial direction of the distal end portion **2**, magnetic force drawn by the magnetic body is reduced, and the output efficiency of the actuator **22** is excellent.

[0065] Since the coil wire is wound on an outer side of the cylindrical portion **31***a* of the frame member **31**, an outer shape of the coil portions **34** includes two plane portions **34***a* and **34***b* along the upper side face **31***a***3** and the lower side face **31***a***4** of the cylindrical portion **31***a*. In other words, a part of the outer shape of the two coil portions **34** includes the plane portions.

[0066] The respective coil portions **34** and the respective permanent magnets **35** are disposed so that the two plane portions of the rectangular parallelepiped permanent magnets **35** become parallel to the two plane portions **34***a* and **34***b*.

[0067] The two coil portions **34** and the two permanent magnets **35** of the movable portion **32** form the moving magnet type voice coil motor.

[0068] FIG. **10** is a perspective view of the linking member **32***b*. FIG. **11** is a plan view of the linking member **32***b*.

[0069] As illustrated in FIG. **10**, the linking member **32***b* includes a connection portion **32***b***1**, a first extension portion **32***b***2** extending from the connection portion **32***b***1** to the distal end side in parallel to the center axis O, a bending portion **32***b***3** bent in a direction orthogonal to the center axis O at the distal end portion of the first extension portion **32***b***2**, a second extension portion **32***b***4** extending from one end of the bending portion **32***b***3** to the distal end side in parallel to the center axis O, and a pin portion **32***b***5** protruding in the direction orthogonal to the center axis O at the second extension portion **32***b***4**.

[0070] In other words, the movable portion **32** includes the linking member **32***b* extending toward the distal end side. The pin portion **32***b***5** of the linking member **32***b* engages with a through slit **33***b***1** of an extension portion **33***b* of a fixation portion **33***a* described later.

[0071] The connection portion **32***b***1** is fixed and connected with an adhesive material to the distal end portion **32***a***5** of the column member **32***a* moving back and forth in the direction of the center axis O.

[0072] An inclined portion **32***b***21** is provided on the distal end portion of the first extension portion **32***b***2**, and the bending portion **32***b***3** is connected with the distal end portion of the first extension portion **32***b***2** via the inclined portion **32***b***21**. The inclined portion **32***b***21** is provided for not allowing the linking member **32***b* to restrict a swing range of the ultrasound transducer **21** which is made to swing inside the internal space **IS1** and making it difficult for the linking member **32***b* to be in contact with other members inside the internal space **IS1** or **IS2** when the linking member **32***b* moves to the proximal end side.

[0073] As illustrated in FIG. **3**, the transducer mounting portion **33** includes the fixation portion **33***a* where the ultrasound transducer **21** of the roughly rectangular outer shape is mounted and fixed, and the extension portion **33***b* extending from the fixation portion **33***a*. In other words, the fixation portion **33***a* is a mounting portion configured to mount the ultrasound transducer **21**. The extension portion **33***b* extends to the opposite side of the fixation portion **33***a* relative to a swing axis of the swing motion of the ultrasound transducer **21**. The fixation portion **33***a* includes two sidewall portions **33***a***0**. The respective sidewall portions **33***a***0** include the two shaft portions **33***a***2**. The two shaft portions **33***a***2** are coaxially formed so as to protrude from the two sidewall portions **33***a***0** in directions opposite to each other.

[0074] FIG. **12** is a diagram for explaining an arrangement state of the transducer mounting portion **33** and the linking member **32***b*. FIG. **12** is a diagram viewing the linking member **32***b* and the transducer mounting portion **33** from the distal end side of the distal end portion **2**. As illustrated in FIG. **12**, the fixation portion **33***a* includes a plane portion **33***a***1** for fixing the ultrasound transducer **21** of the single plate by fixing means such as the adhesive material. The ultrasound transducer **21** is disposed between the two sidewall portions **33***a***0**.

[0075] The two shaft portions **33***a***2** protruding in the directions opposite to each other are inserted to the two holes **31***b***1** of the two arms **31***b* such that the fixation portion **33***a* can be turned around the shaft portions **33***a***2**.

[0076] The extension portion **33***b* extends in the direction orthogonal to the plane portion **33***a***1** from the surface on the opposite side of the plane portion **33***a***1**. As illustrated in FIG. **4**, the extension portion **33***b* includes the through slit **33***b***1**. The pin portion **32***b***5** of the linking member **32***b* enters the through slit **33***b***1**.

[0077] More specifically, the through slit **33***b***1** is formed such that the fixation portion **33***a* is supported by the two arms **31***b* turnably around the axis of the two shaft portions **33***a***2**, and the pin portion **32***b***5** can move inside the through slit **33***b***1** when the fixation portion **33***a* is turned around the axis of the two shaft portions **33***a***2**.

[0078] In addition, as illustrated in FIG. **10** to FIG. **12**, the first extension portion **32***b***2** and the second extension portion **32***b***4** of the linking member **32***b* are displaced from a plane CL in parallel to a vertical direction passing through the center axis O of the distal end portion **2** and extend in the distal end direction. Simultaneously, the extension portion **33***b* of the transducer mounting portion **33** also extends from a position displaced from the plane CL in parallel to the vertical direction passing through the center axis O of the distal end portion **2**. Thus, since a thickness in the direction orthogonal to the plane CL of the linking member **32***b* and the extension portion **33***b* can be reduced, the linking member **32***b* and the extension portion **33***b* are not easily brought into contact with an inner wall of the housing **2***a* of the distal end portion **2**.

[0079] In other words, the extension portion **33***b* of the transducer mounting portion **33** and the linking member **32***b* are arranged so as to hold the plane CL that passes through the center axis O of the outer tube **2***t* and is orthogonal to the axis of the swing motion of the ultrasound transducer **21** between the extension portion **33***b* and the linking member

32*b*. The axis of the swing motion of the ultrasound transducer **21** is the axis of the two shaft portions **33***a***2**.

[0080] When the linking member **32***b* moves back and forth within a predetermined range along the axis of the distal end portion **2**, the pin portion **32***b***5** also moves in back and forth directions along the axis of the distal end portion **2**. The reciprocating motion of the pin portion **32***b***5** moves the extension portion **33***b* that engages with the pin portion **32***b***5**, and generates the swing motion that makes the fixation portion **33***a* swing around the axis of the two shaft portions **33***a***2**.

[0081] Note that the linking member **32***b* extending from the column member **32***a* is formed of a non-magnetic body or a weak magnetic body. In other words, the part on the side of the conversion mechanism **33**X described later of the movable portion **32** is the non-magnetic body or the weak magnetic body. When the linking member **32***b* is the ferromagnetic body, since inductance change becomes asymmetrical when performing the above-described sensorless control, there is a risk that the position of the movable portion **32** cannot be accurately detected. Therefore, the linking member **32***b* is formed of the non-magnetic body or the weak magnetic body to prevent deterioration of accuracy of position detection.

[0082] As above, inside the two coil portions **34** formed of the coil wire wound around the axis of the distal end portion **2** of the ultrasound probe **1**, the two permanent magnets **35** are disposed such that N pole and the S pole are in the predetermined direction along the axis of the distal end portion **2**.

[0083] (Action)

[0084] Next, operations of the ultrasound transducer **21** and the actuator **22** inside the distal end portion **2** of the ultrasound probe **1** will be described.

[0085] By the two coil portions **34** and the two permanent magnets **35**, the moving magnet type voice coil motor is formed. By changing the direction of the current made to flow to the respective coil wires of the two coil portions **34**, a moving direction of the two permanent magnets **35** along the axis of the distal end portion **2** can be controlled.

[0086] FIG. **13** is a sectional view of the distal end portion **2** when an ultrasound transmission/reception surface **21***a* of the ultrasound transducer **21** is inclined to the distal end side of the distal end portion **2**. FIG. **14** is a sectional view of the distal end portion **2** when the ultrasound transmission/reception surface **21***a* of the ultrasound transducer **21** is inclined to the proximal end side of the distal end portion **2**.

[0087] The conversion mechanism **33**X generates the swing motion of the ultrasound transducer **21** by the linking member **32***b* moving the extension portion **33***b* of the transducer mounting portion **33** back and forth in the longitudinal direction. More specifically, when the current in a first direction is made to flow to the respective coil wires of the two coil portions **34**, by a principle of the moving magnet type voice coil motor, the movable portion **32** moves to the proximal end side and comes into contact with the inner wall on the proximal end side of the cylindrical portion **31***a*, as illustrated in FIG. **13**. At the time, the ultrasound transmission/reception surface **21***a* of the ultrasound transducer **21** turns to the distal end side. As illustrated in FIG. **13**, a normal direction of the ultrasound transmission/reception surface **21***a* is inclined to the distal end side by θ1 relative to the direction orthogonal to the axis of the distal end portion **2**.

[0088] When the current in a second direction opposite to the first direction is made to flow to the respective coil wires of the two coil portions **34**, by the principle of the moving magnet type voice coil motor, the movable portion **32** moves to the distal end side and comes into contact with the inner wall on the distal end side of the cylindrical portion **31***a*, as illustrated in FIG. **14**. At the time, the ultrasound transmission/reception surface **21***a* of the ultrasound transducer **21** turns to the proximal end side. As illustrated in FIG. **14**, the normal direction of the ultrasound transmission/reception surface **21***a* is inclined to the proximal end side by θ2 relative to the axis orthogonal to the axis of the distal end portion **2**.

[0089] Thus, by alternately changing the direction of making the current flow, the ultrasound transducer **21** is made to swing in the range of an angle (θ1+θ2) around the shaft portion **33***a***2**.

[0090] Thus, the movable portion **32** including the pin portion **32***b***5** and the extension portion **33***b* including the through slit **33***b***1** that engages with the pin portion **32***b***5** configure the conversion mechanism **33**X that converts the reciprocating motion of the movable portion **32** to the swing motion of the ultrasound transducer **21**. The conversion mechanism **33**X is arranged in the longitudinal direction of the outer tube **2***t* in series with the actuator **22** in the longitudinal direction, arranged in parallel to the ultrasound transducer **21** in the longitudinal direction, and configured to convert the reciprocating motion of the movable portion **32** to the swing motion of the ultrasound transducer **21**.

[0091] FIG. **15** is a diagram for explaining a direction of the driving force given to the extension portion **33***b* by the linking member **32***b*.

[0092] As shown in FIG. **15**, a working point FP at which force is applied to the extension portion **33***b* when the linking member **32***b* moves back and forth is positioned off the center axis O of the outer tube **2***t* and a center axis OC of the driving force of the reciprocating motion in the movable portion **32**.

[0093] However, the longitudinal axis OC of the two permanent magnets **35**, which generate driving force in the actuator **22**, is displaced to the working point FP side with respect to the center axis O of the outer tube **2***t*. Specifically, the working point FP in the conversion mechanism **33**X of force by the reciprocating motion of the actuator **22** is positioned off the center axis O of the outer tube **2***t*, and the longitudinal axis OC of the permanent magnets **35**, which is the center axis of the driving force of the reciprocating motion in the movable portion **32**, is displaced to the working point FP side with respect to the center axis O by a predetermined distance d.

[0094] Therefore, reaction force, which is generated at the working point FP due to a moment applied to the actuator **22**, becomes smaller than reaction force in the case where the center axis of the driving force F**1** of the actuator **22** is located on the center axis O.

[0095] FIG. **16** is a diagram for explaining a difference in the reaction force due to the moment applied to the actuator **22** between the case where the center axis of the driving force F**1** is located on the center axis O of the outer tube **2***t* and the case where the center axis of the driving force F**1** is displaced by a predetermined distance d. When the center axis of the driving force F**1** is located on the center axis O of the outer tube **2***t*, the reaction force due to the moment applied to the actuator **22** is represented by F×(d+d'). On the other hand, when the center axis of the driving force F1 is located on OC displaced from the center axis O by the predetermined distance d, the reaction force due to the moment applied to the actuator **22** is represented by F×d', and the reaction force becomes smaller than the above-described value.

[0096] If the reaction force, which is generated at the working point FP due to the moment applied to the actuator **22**, is small, effective conversion of the driving force F**1** to the swing motion is possible. If the reaction force, which is generated at the working portion FP due to the moment applied to the actuator **22**, is large, strong contact occurs between the inner wall of the cylindrical portion **31***a* of the frame member **31** and the column member **32***a* of the movable portion **32**. Such strong contact causes large frictional force between the inner wall and the column member. The inner wall of the cylindrical portion **31***a* is shaved off by the friction, and the shavings created by the inner wall of the cylindrical portion **31***a* being shaved off float in the liquid in the internal space IS**1**, which may lead a possibility that a clear ultrasound image cannot be obtained. That is, as described above, the reaction force, which is generated at the working point FP due to the moment applied to the actuator **22**, is made small, to thereby enable the durability of the conversion mechanism **33**X to be increased.

[0097] In the above described embodiment, the center axis of the actuator **22** coincides with the center axis O of the ultrasound probe **1**. Such a configuration does not create what is called a dead space in the distal end portion **2**. As a result, the outer diameter of the actuator **22** can be increased, which enables the driving force of the actuator **22** to be also increased.

[0098] Furthermore, since the point GP where the driving force F**1** of the actuator **22** is generated is displaced to the working point FP side with respect to the center axis O, the reaction force, which is generated at the working point FP due to the moment applied to the actuator **22**, becomes small, which enables effective transmission of the driving force F**1**.

[0099] As above, according to the above-described embodiment, the ultrasound probe that suppresses increase of the diameter of the probe including a swing mechanism which swings the ultrasound transducer and suppresses decline of force conversion efficiency when converting a back and forth motion of a driving member to the swing motion around a turning axis of a turning member can be provided.

[0100] The present invention is not limited to the above-described embodiment, and can be variously changed and modified or the like without departing from the gist of the present invention.

What is claimed is:

1. An ultrasound probe comprising:

an outer tube to be inserted into a body;

an ultrasound transducer provided on a distal end side of the outer tube and supported swingably within a plane in a longitudinal direction of the outer tube;

an actuator including a movable portion configured to perform a reciprocating motion in the longitudinal direction of the outer tube; and

a conversion mechanism arranged in the longitudinal direction of the outer tube in series with the actuator in the longitudinal direction, arranged in parallel to the ultrasound transducer in the longitudinal direction, and configured to convert the reciprocating motion of the movable portion to a swing motion of the ultrasound transducer, in which a working point in the conversion mechanism of force by the reciprocating motion of the actuator is positioned off a center axis of the outer tube and a center axis of driving force of the reciprocating motion in the movable portion, and the center axis of the driving force of the reciprocating motion in the movable portion is displaced to the working point side by a predetermined distance relative to the center axis of the outer tube.

2. The ultrasound probe according to claim **1**, wherein the actuator is an electromagnetic actuator.

3. The ultrasound probe according to claim **2**, wherein the electromagnetic actuator is a voice coil motor including a coil and a magnet.

4. The ultrasound probe according to claim **3**, wherein the coil or the magnet is in such a shape that a dimension in a direction of the reciprocating motion is longer than a dimension in an orthogonal direction of the reciprocating motion.

5. The ultrasound probe according to claim **4**, wherein the voice coil motor is of a moving magnet type in which the movable portion includes the magnet.

6. The ultrasound probe according to claim **5**, wherein the movable portion includes a ferromagnetic body member.

7. The ultrasound probe according to claim **6**, wherein the ferromagnetic body member is provided on both sides that are a distal end side and a proximal end side of the magnet.

8. The ultrasound probe according to claim **7**, wherein a part on the conversion mechanism side of the movable portion is a non-magnetic body or a weak magnetic body.

9. The ultrasound probe according to claim **1**, wherein the actuator includes a frame member configured to house the movable portion inside and a hole is formed on a side opposite to the conversion mechanism of the frame member.

10. The ultrasound probe according to claim **1**, comprising

an ultrasound transducer mounting portion including a mounting portion configured to mount the ultrasound transducer and a first extension portion extending toward an opposite side of the mounting portion relative to a swing axis of the swing motion,

wherein the movable portion includes a second extension portion extending toward the distal end side and engaged with the first extension portion,

the conversion mechanism generates the swing motion of the ultrasound transducer by the second extension portion causing the first extension portion to move back and forth in the longitudinal direction, and

the first extension portion and the second extension portion are arranged so as to hold a plane that passes through the center axis of the outer tube and is orthogonal to an axis of the swing motion of the ultrasound transducer between the first extension portion and the second extension portion.

11. The ultrasound probe according to claim **1**, comprising

a housing provided on the distal end side of the outer tube and including a first internal space configured to house the ultrasound transducer and the conversion mechanism and a second internal space configured to house the actuator.

* * * * *

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摘要(译)

超声波探头包括：超声波换能器，其设置在外管的前端侧；以及超声波换能器。 致动器，其包括被配置为执行往复运动的可移动部分； 和转换机制。 转换机构在外管的长度方向上与致动器在长度方向上串联布置，并在长度方向上与超声换能器平行布置，并且构造成将可移动部分的往复运动转换成摆动运动。 超声换能器的 机构中的工作点位于外管的中心轴线和可移动部分中的往复运动的驱动力的中心轴线的位置，而可移动部分中的往复运动的驱动力的中心轴线的位移 相对于中心轴以预定距离相对于工作点侧。