

FIG. 1

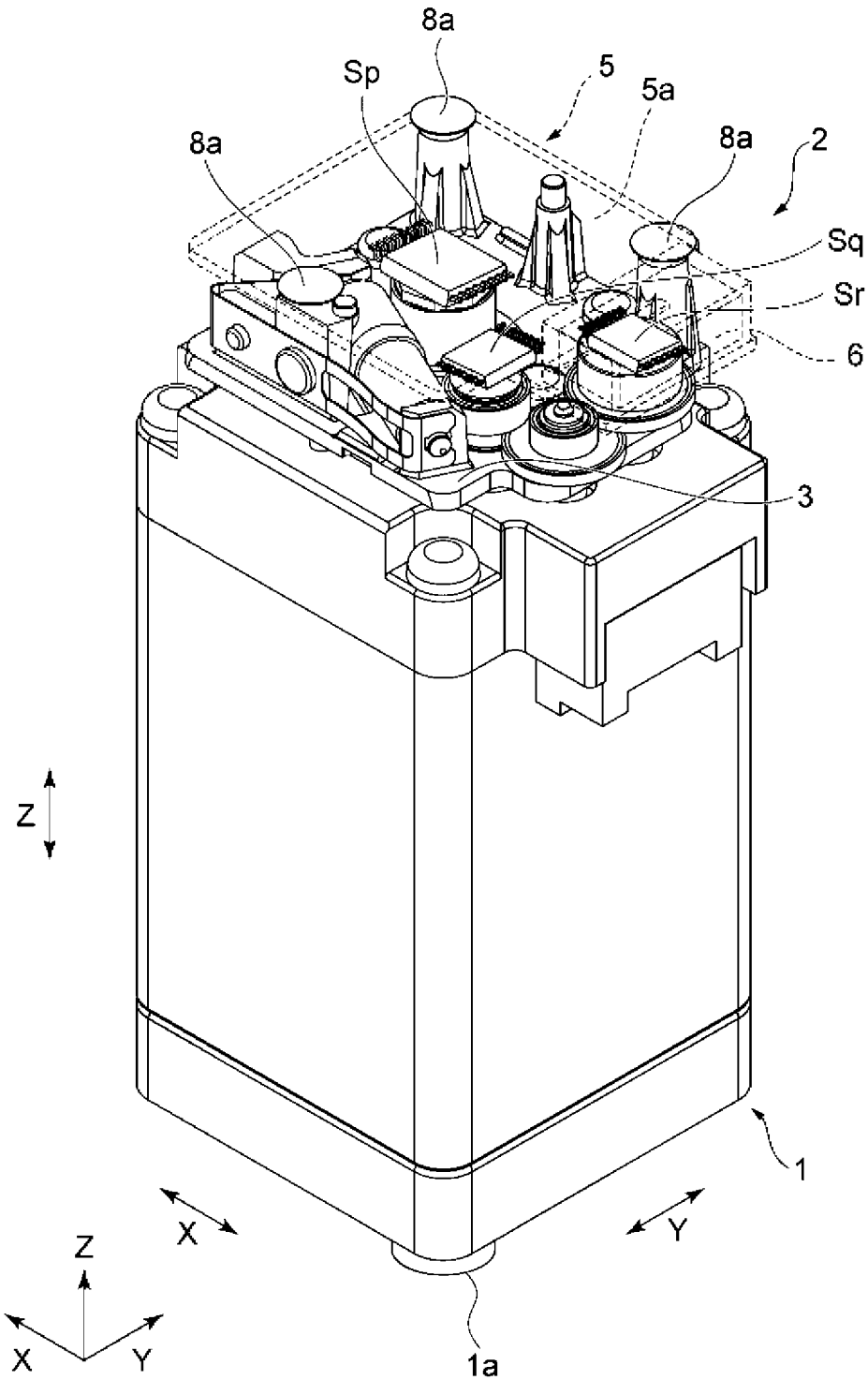


FIG. 2

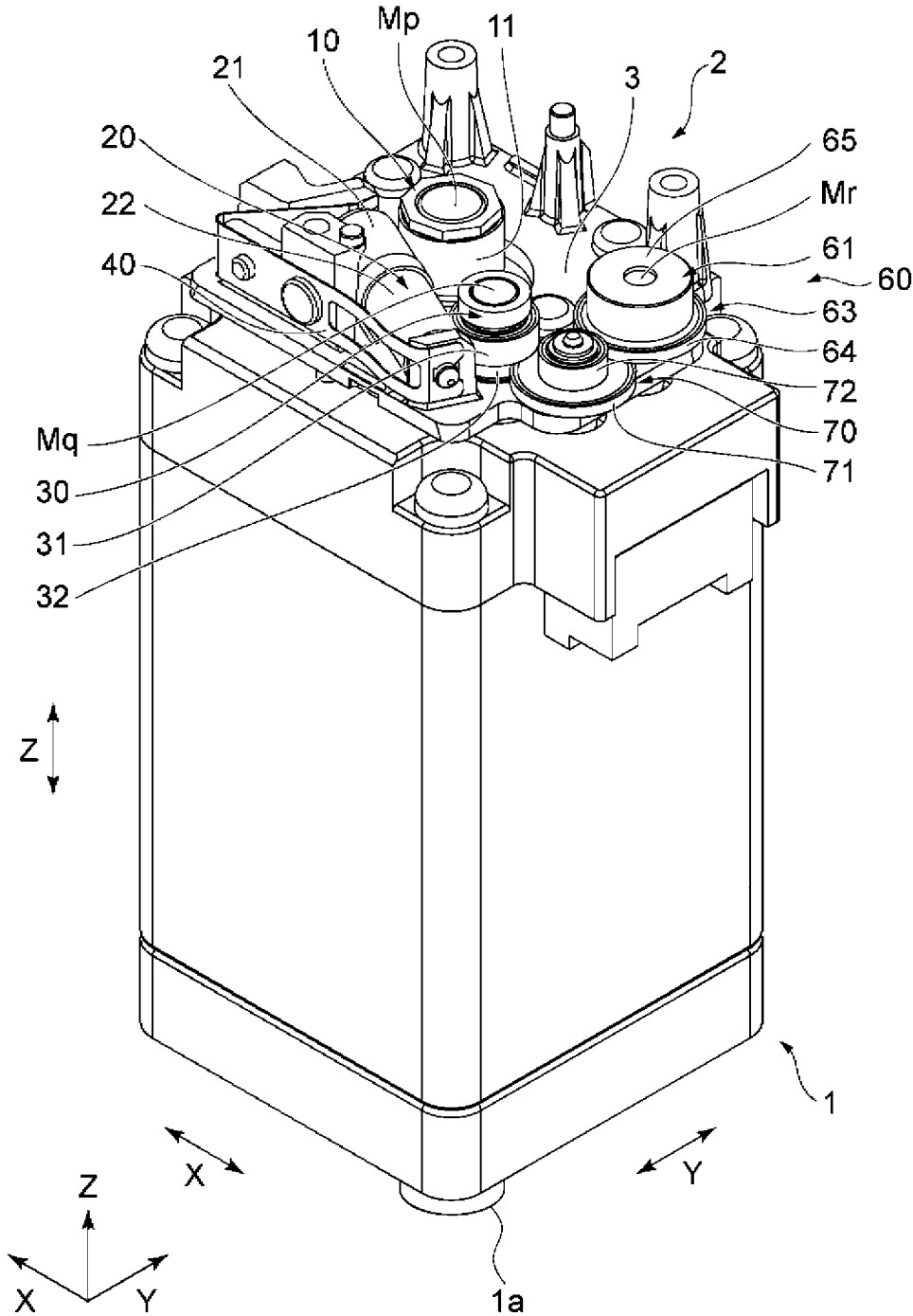


FIG. 3

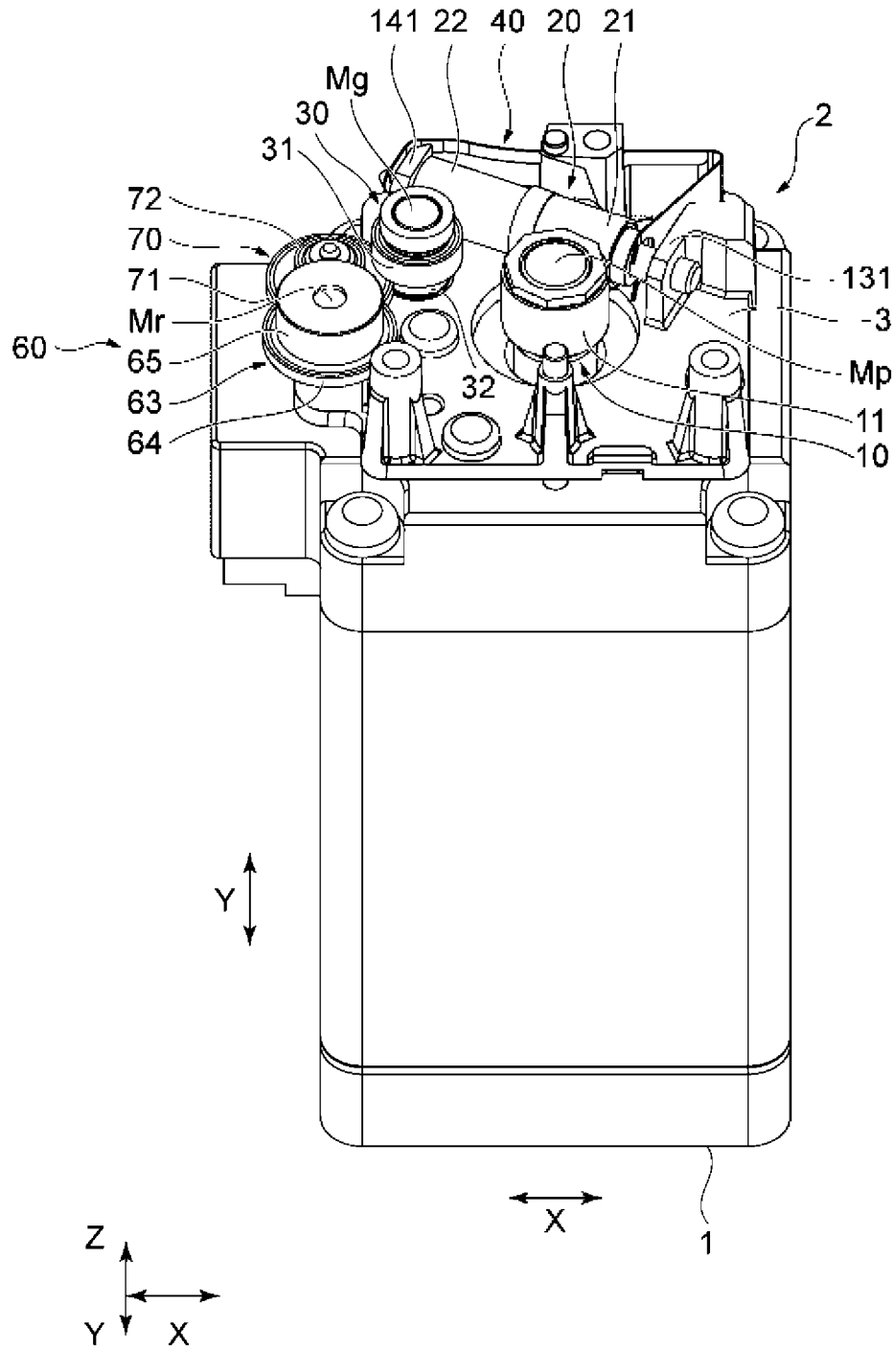


FIG. 4

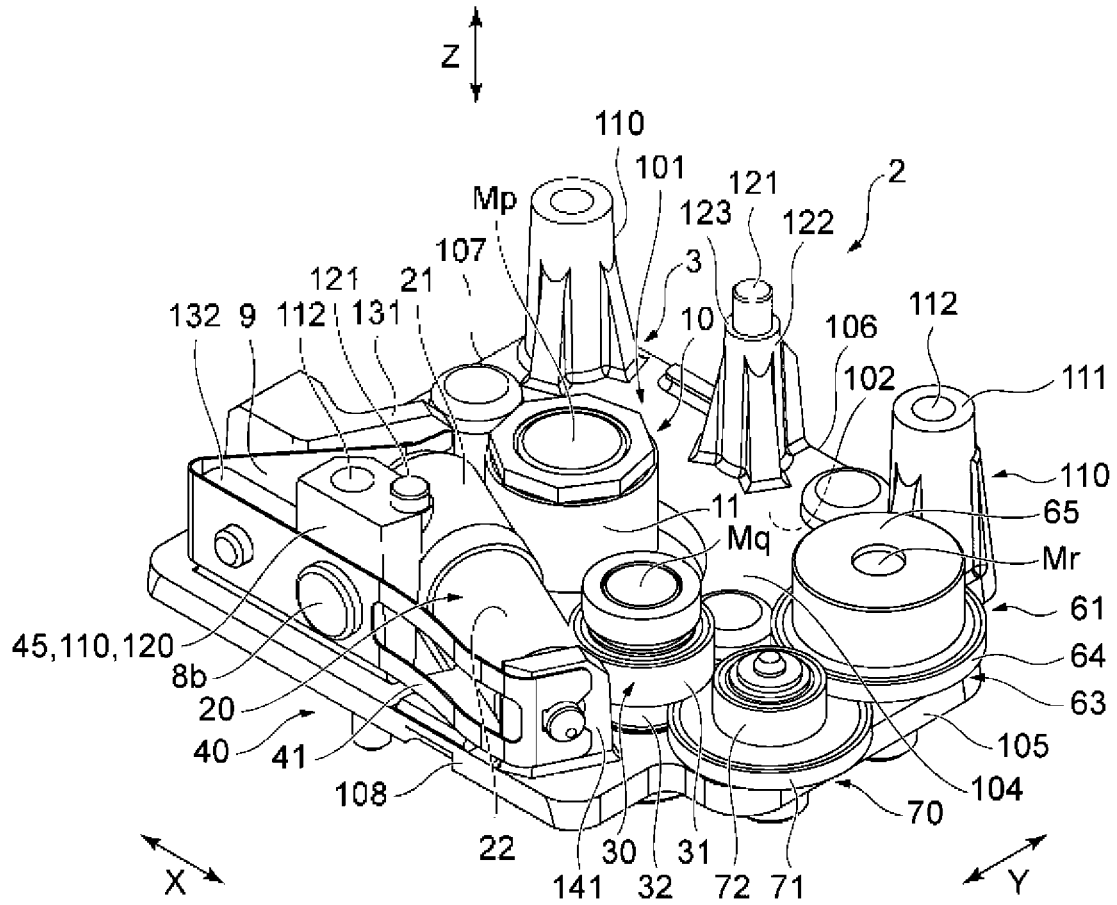


FIG. 5

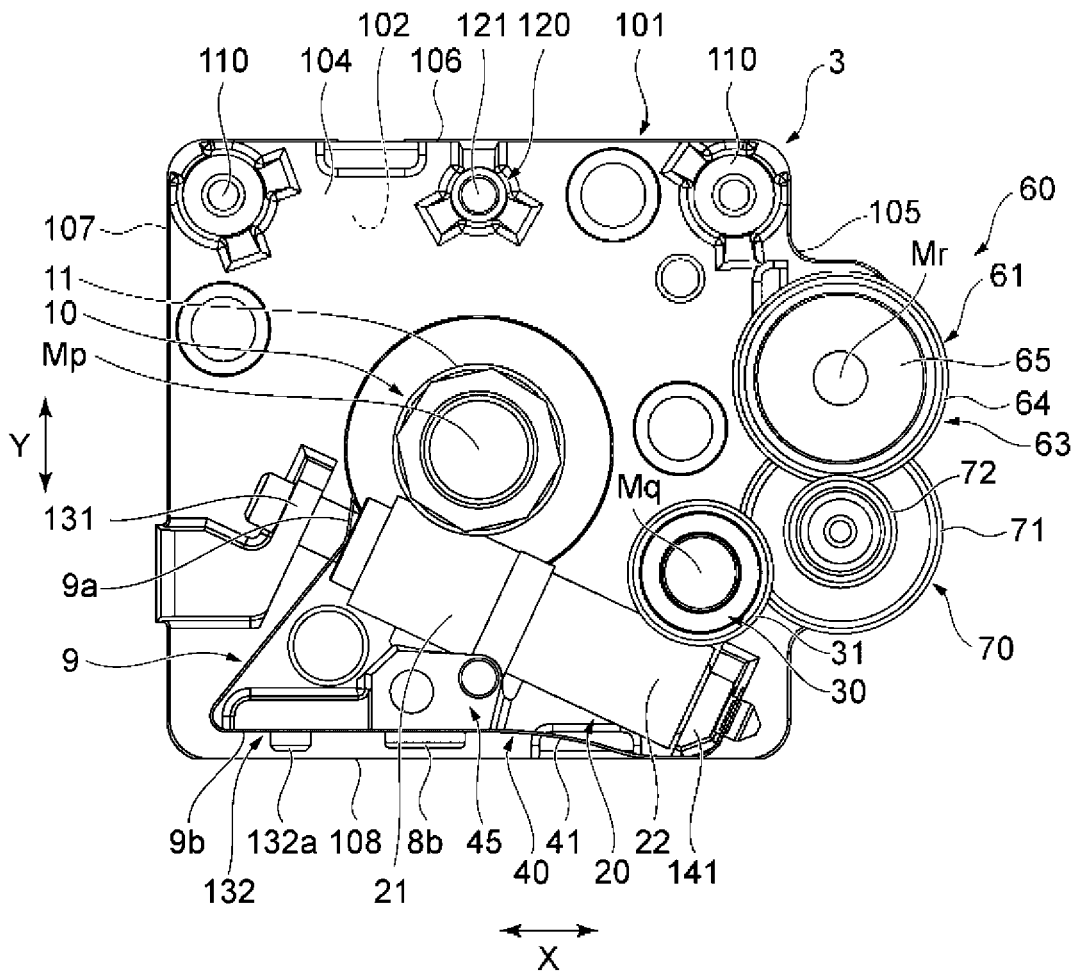


FIG. 6

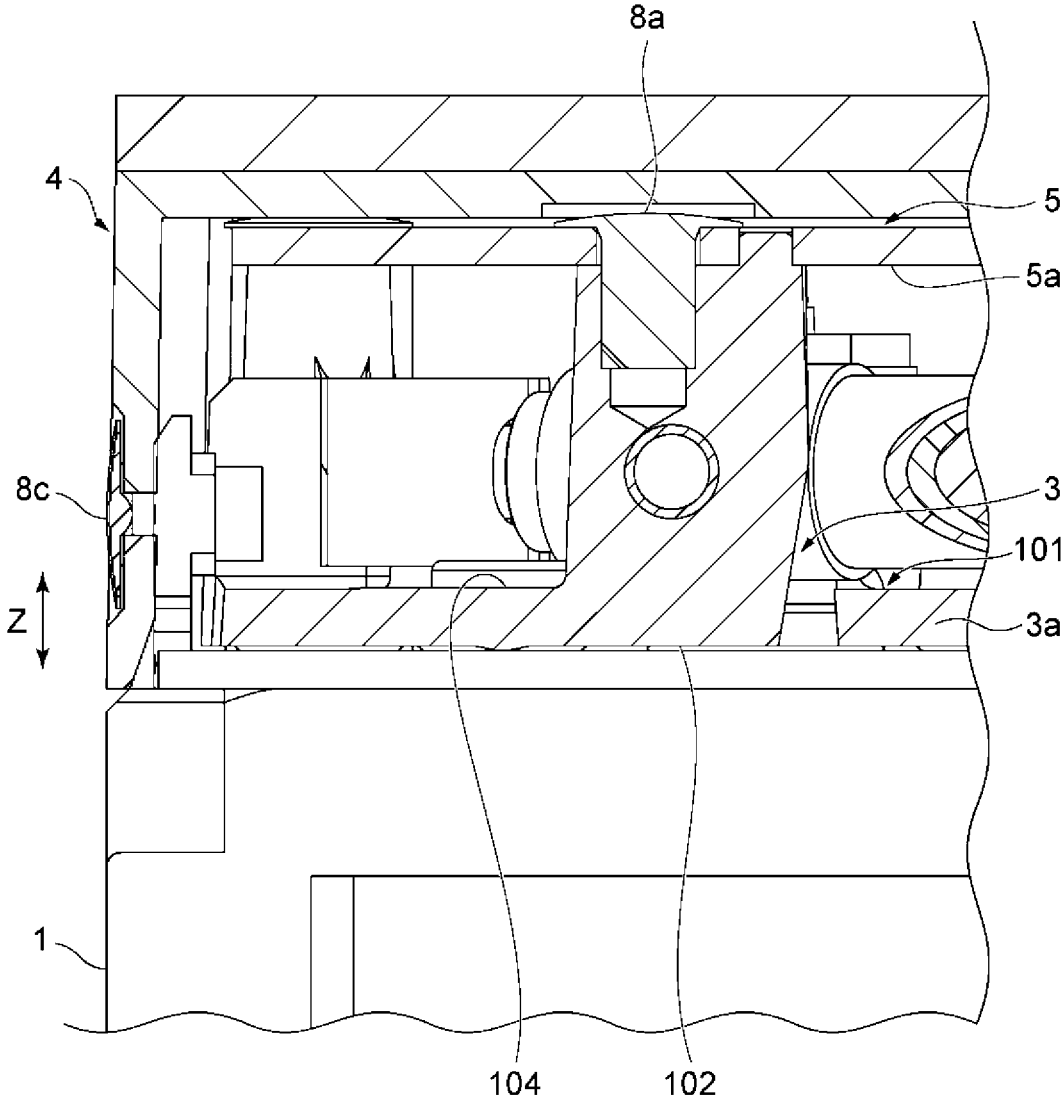


FIG. 7

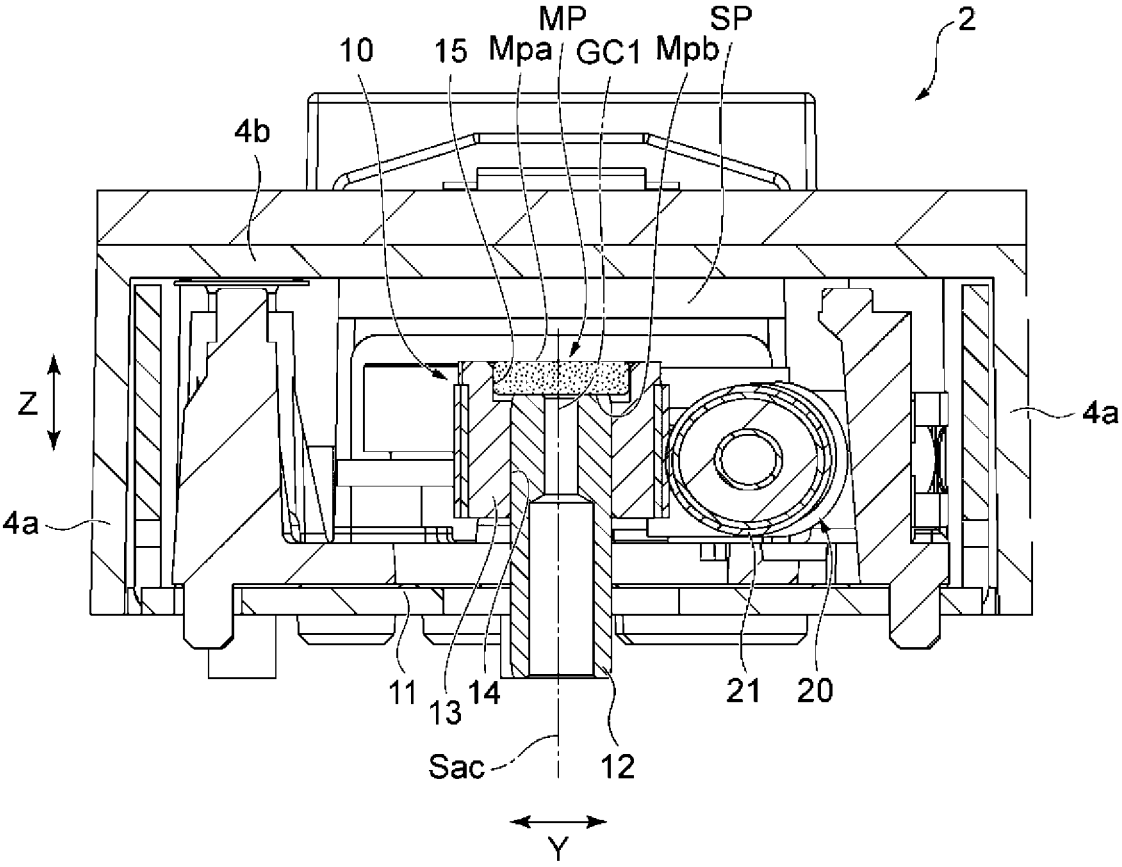


FIG. 8

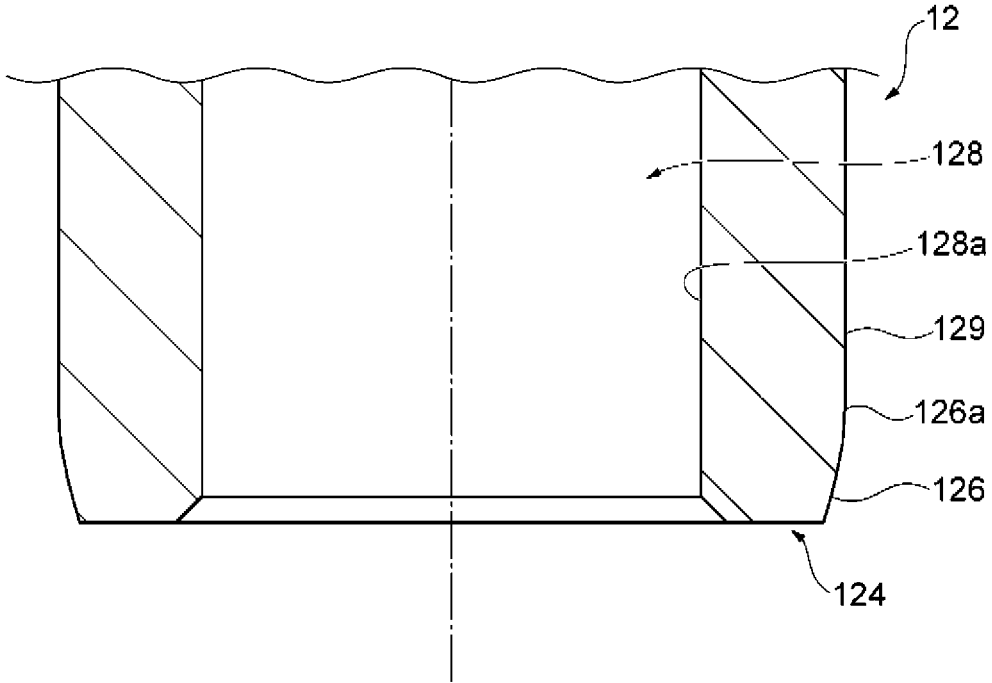


FIG. 10

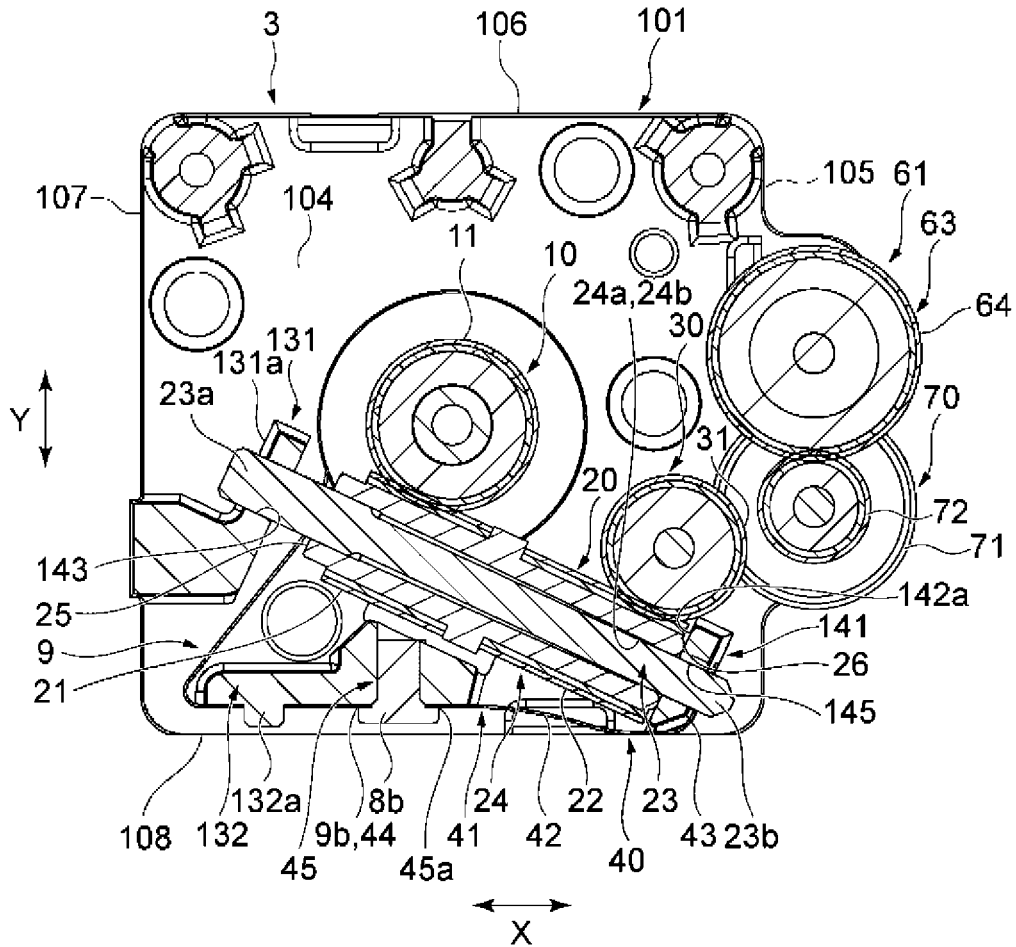


FIG. 11

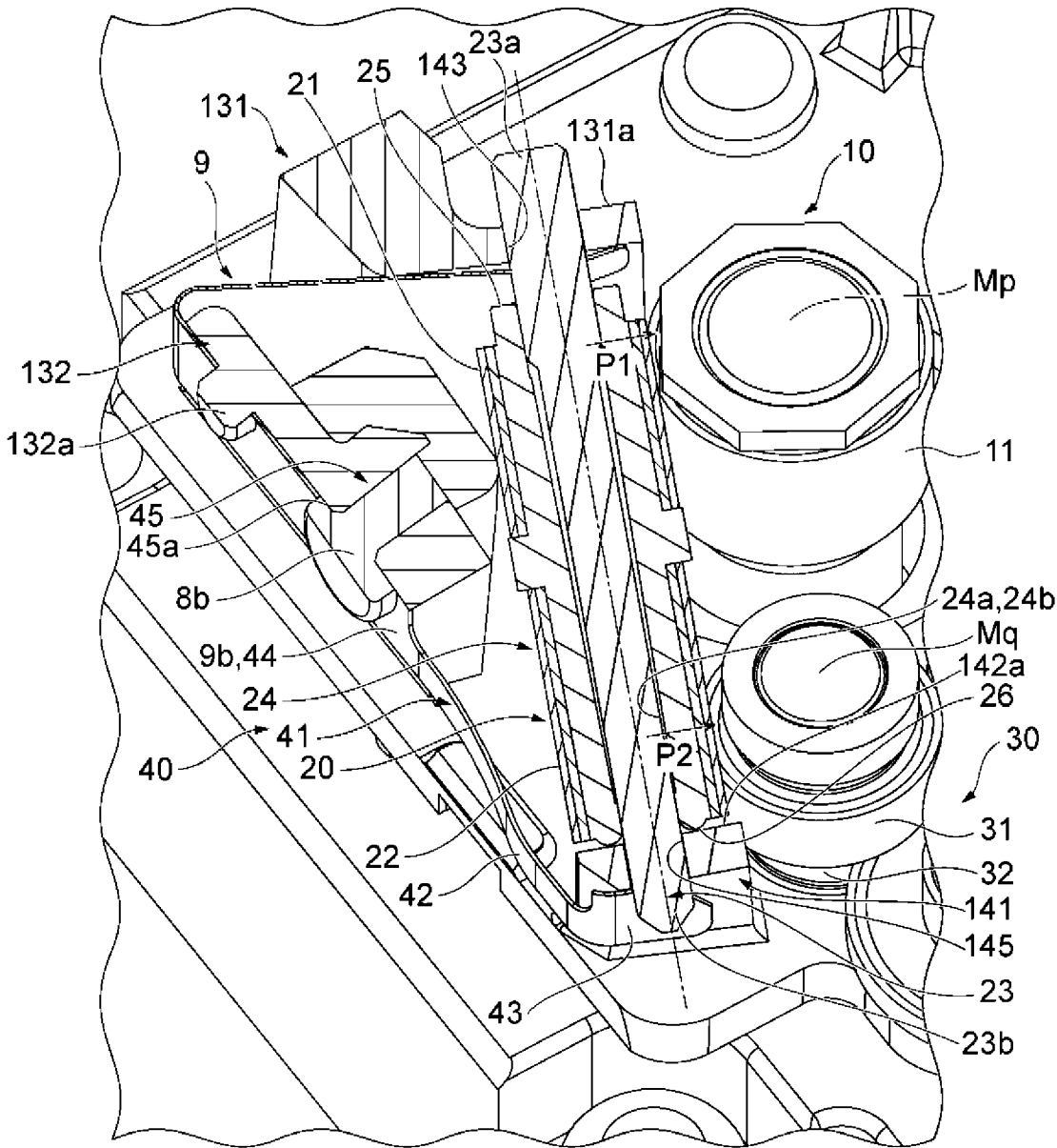


FIG. 12

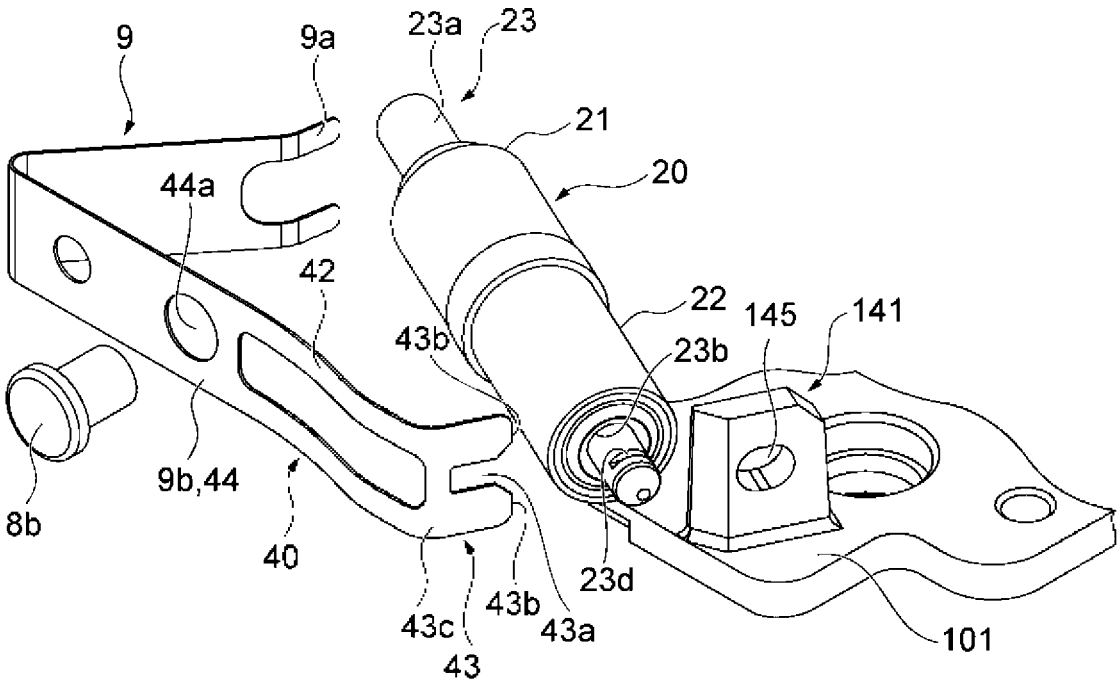


FIG. 14

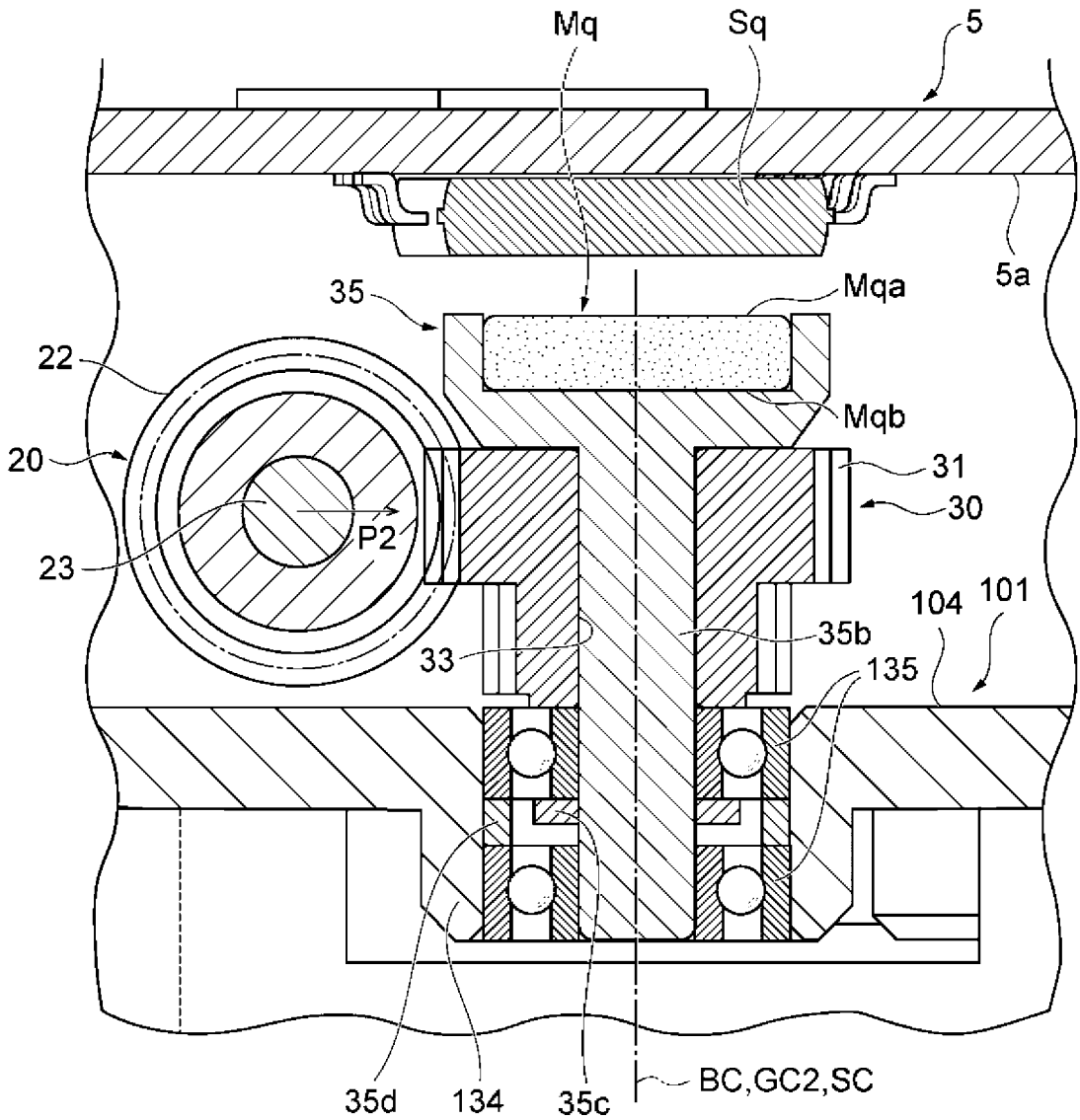


FIG. 15

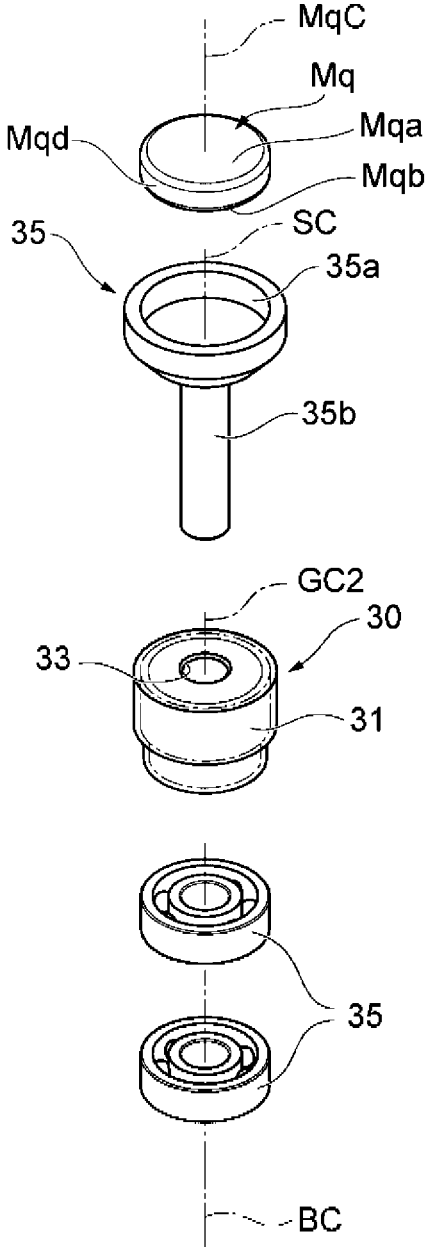


FIG. 16

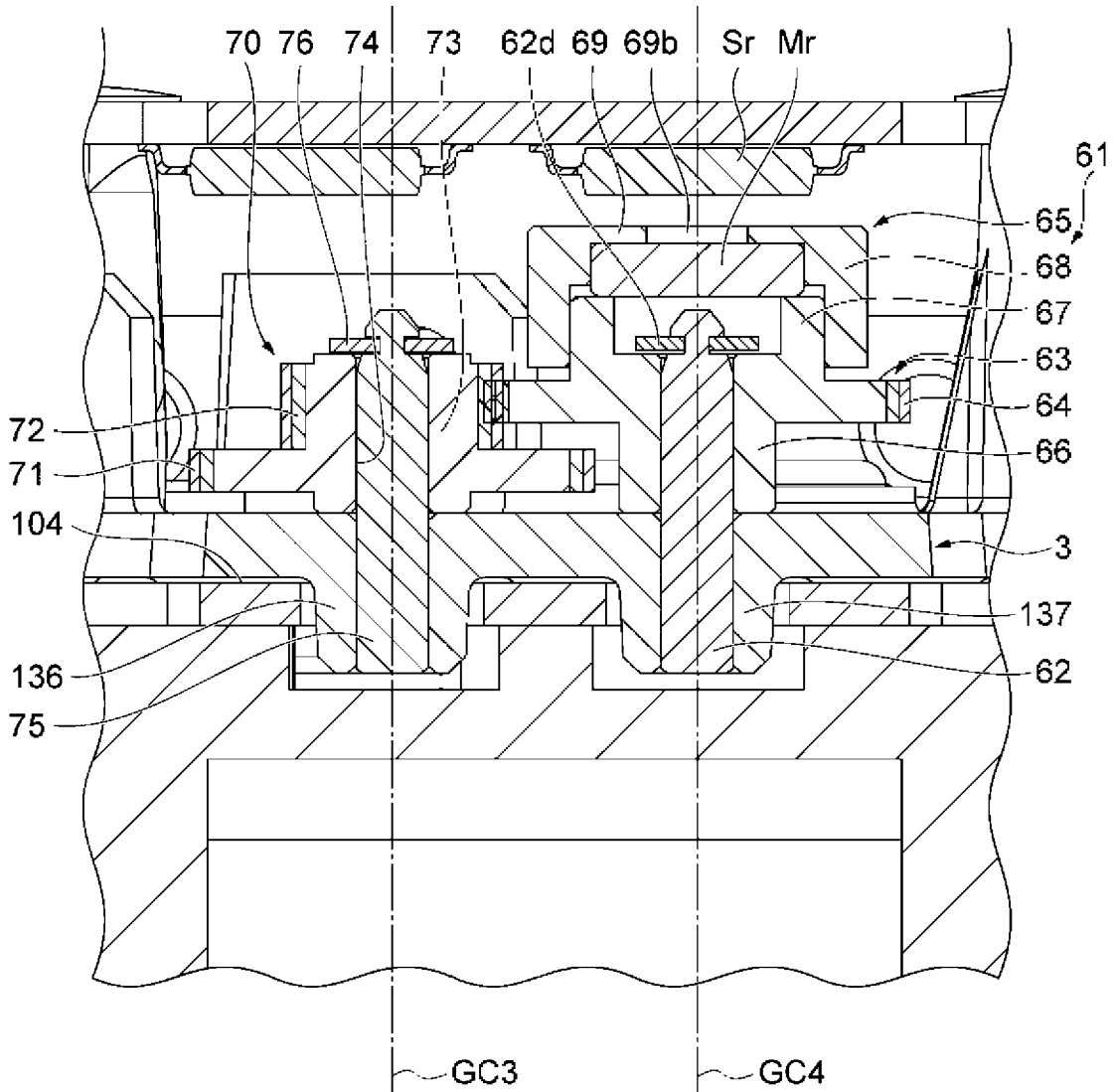


FIG. 17

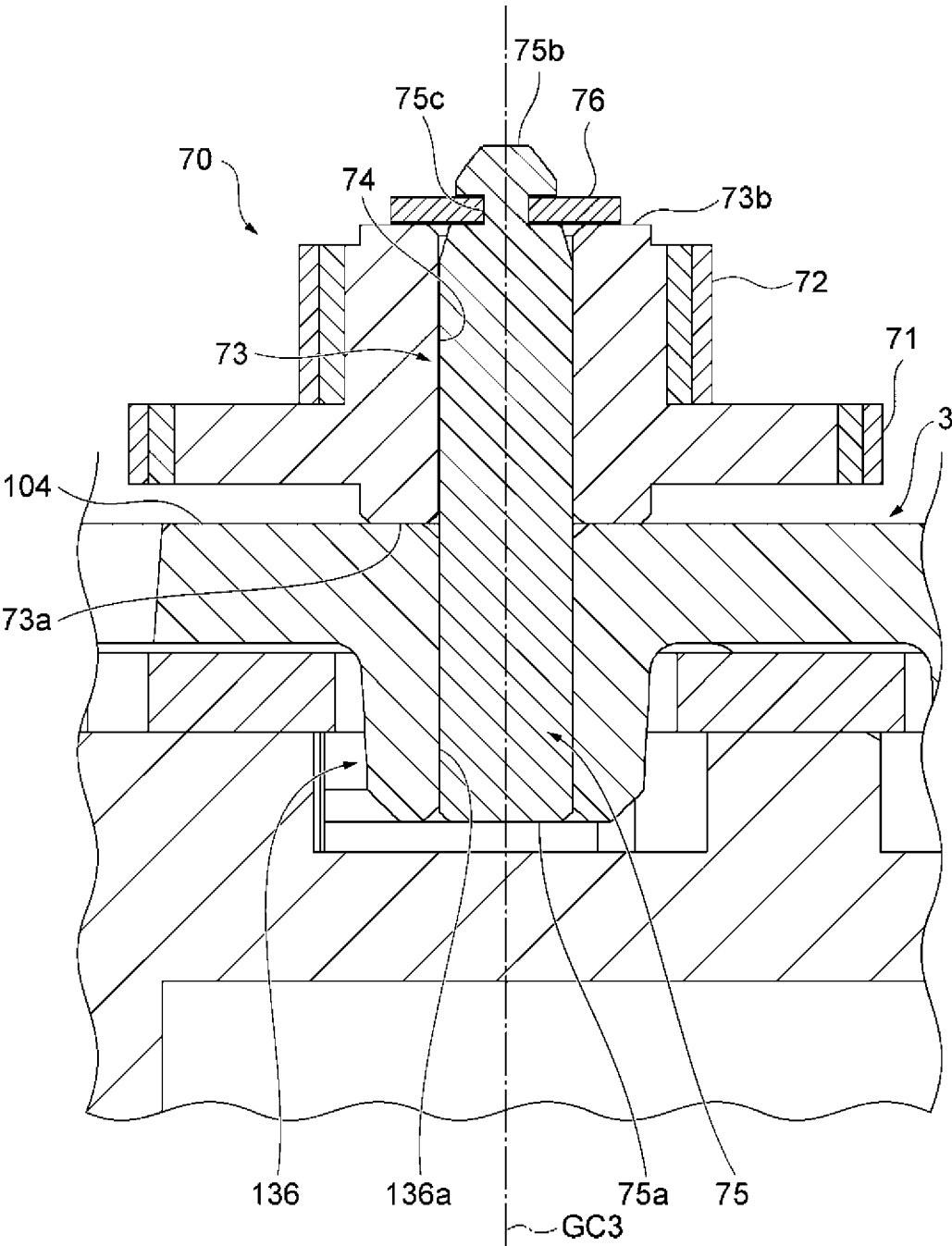


FIG. 18

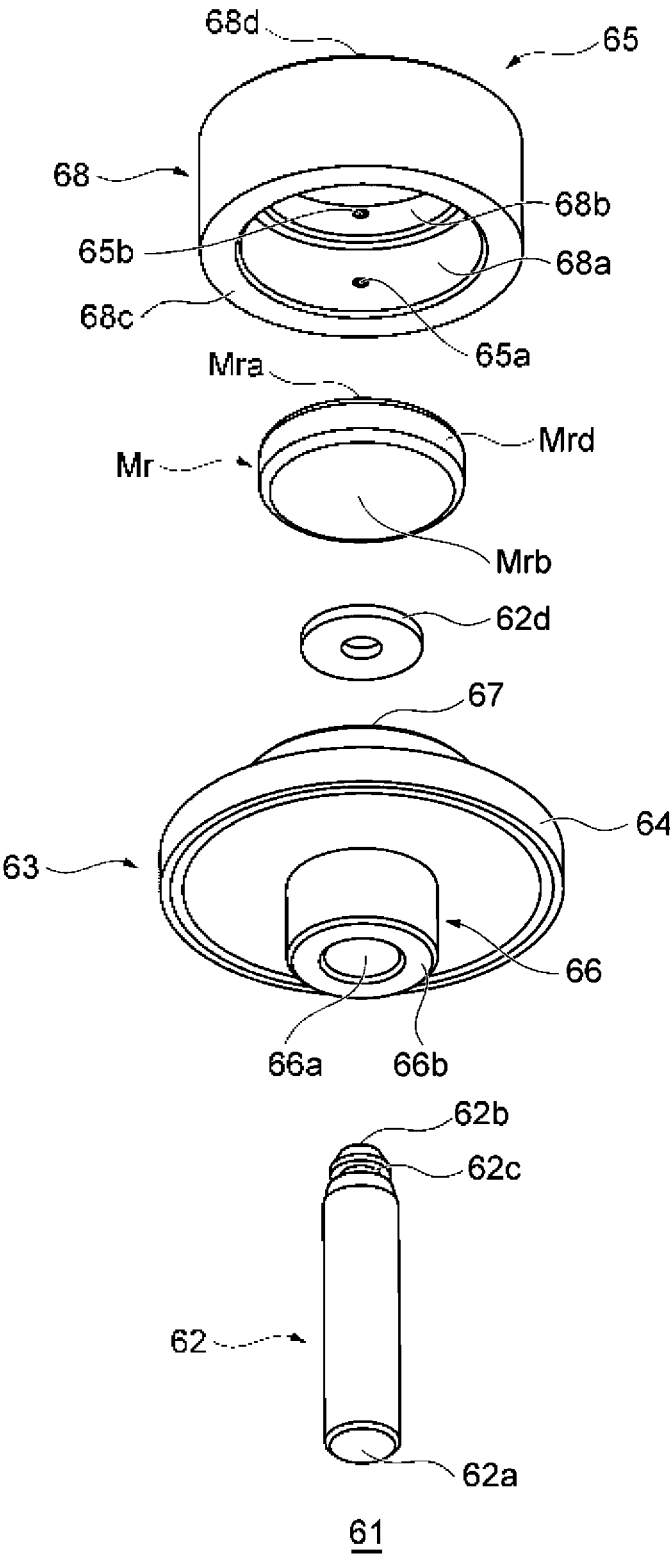


FIG. 20

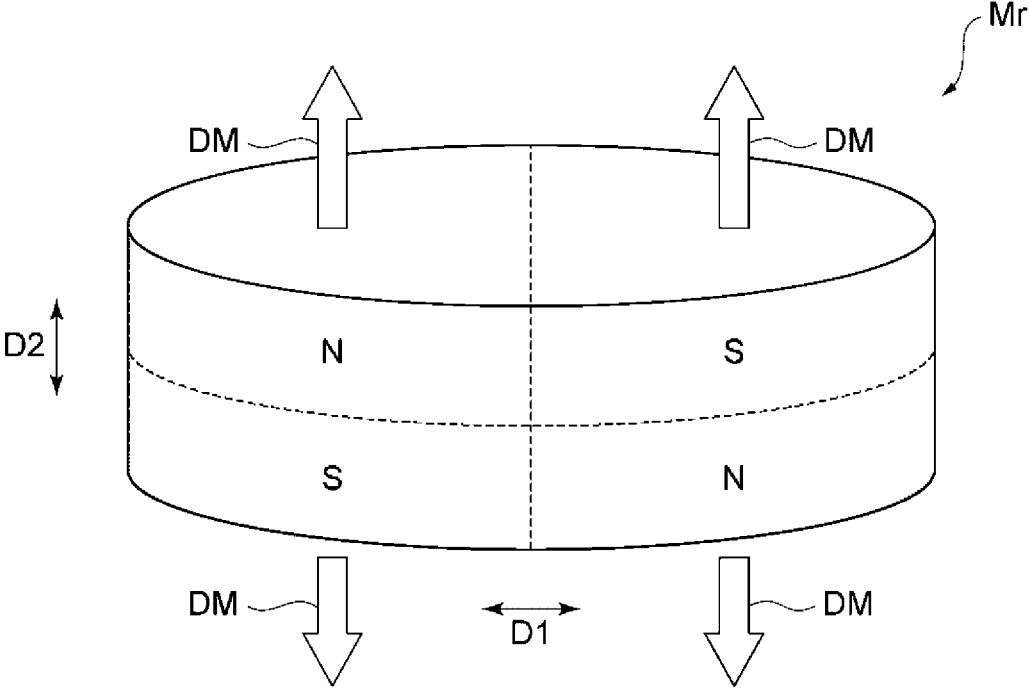


FIG. 21

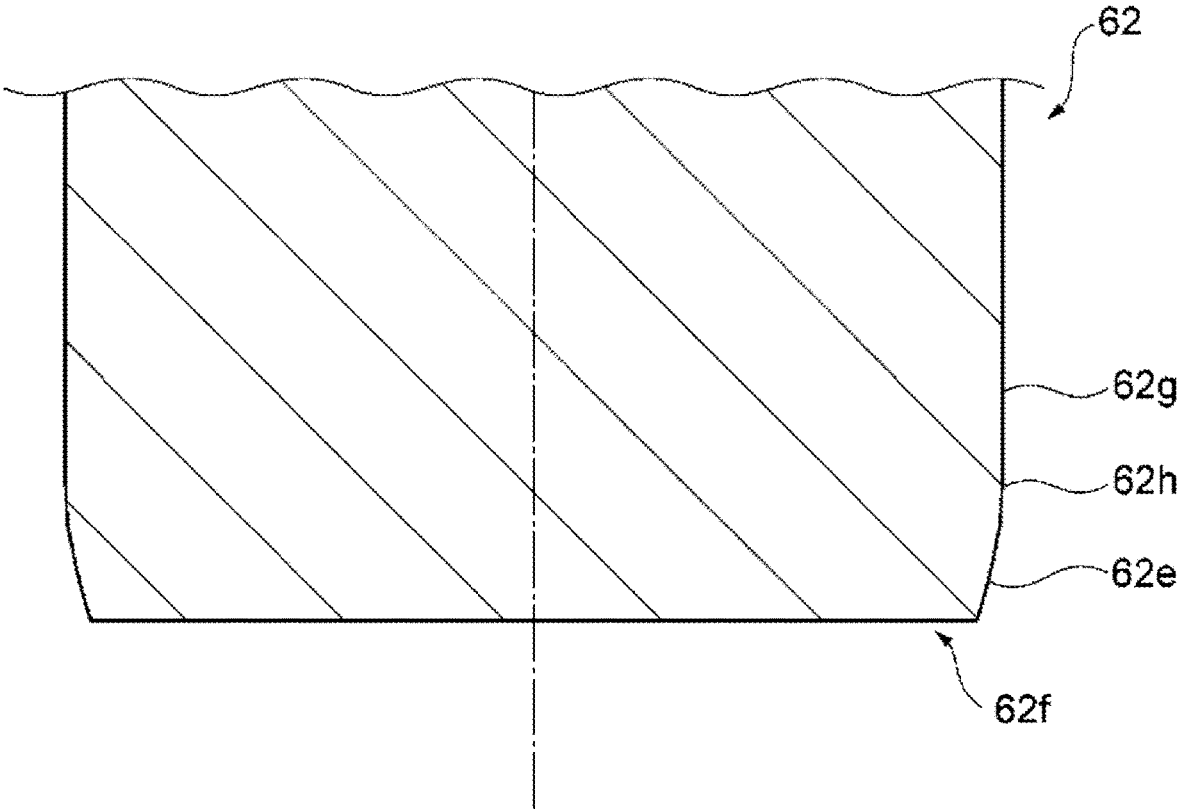


FIG. 22

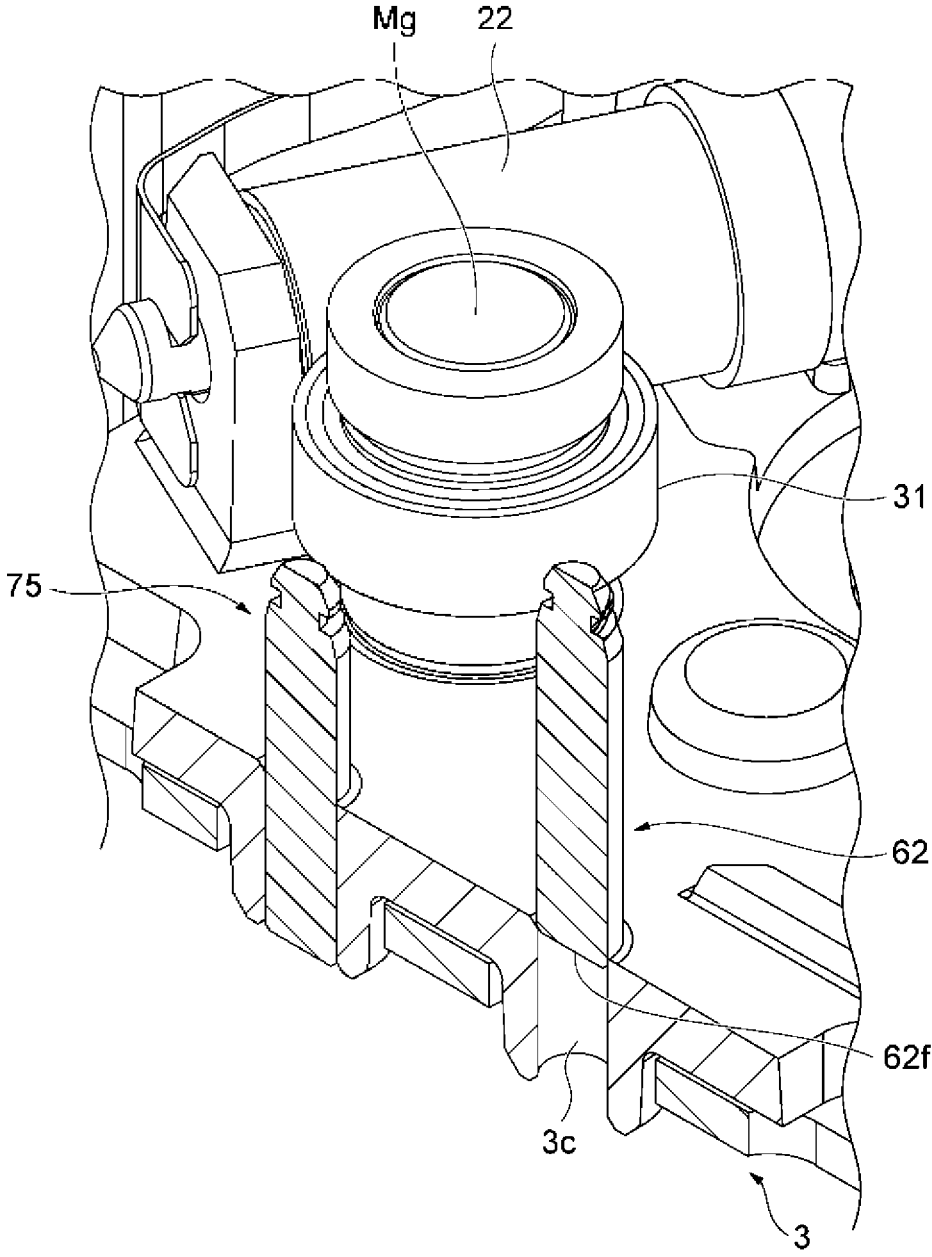


FIG. 23

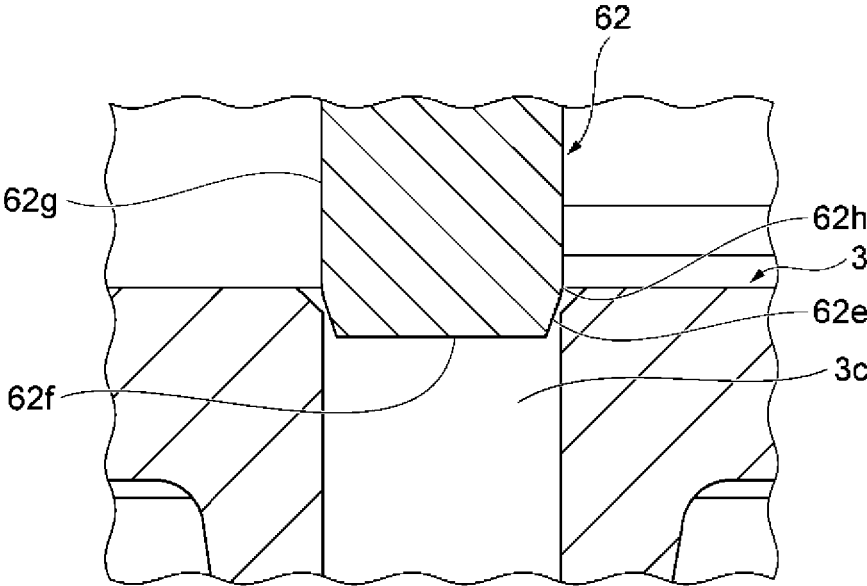


FIG. 24

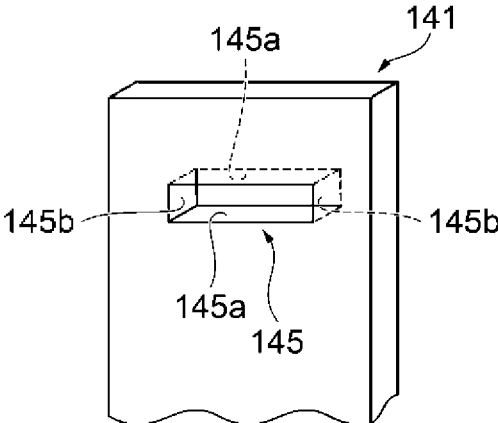


FIG. 25

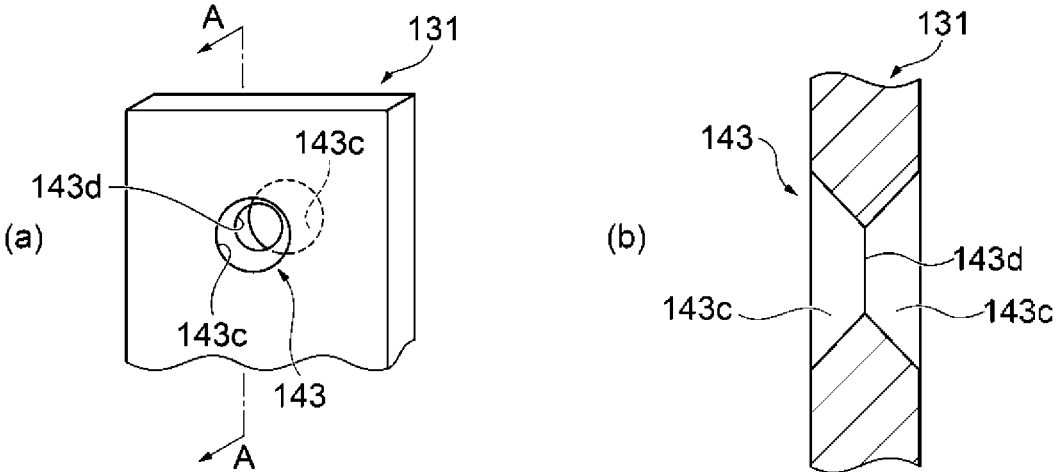


FIG. 26

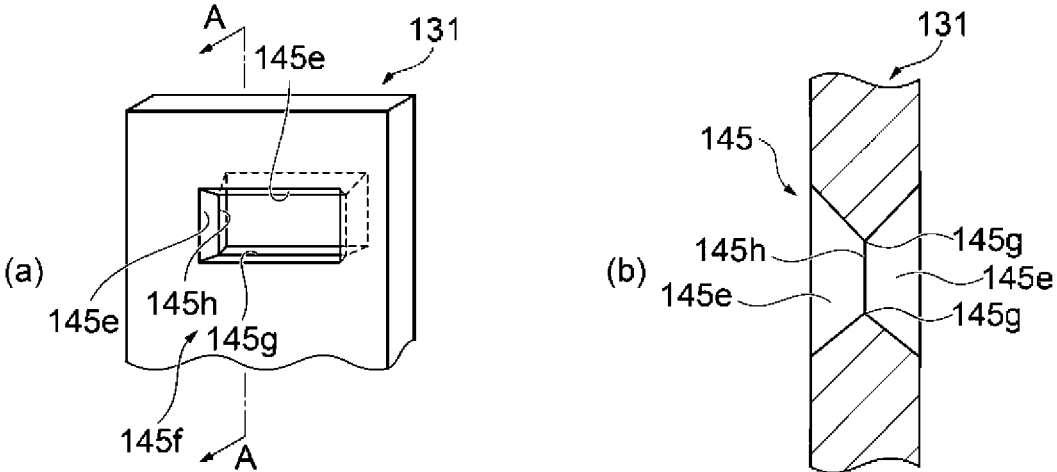


FIG. 27

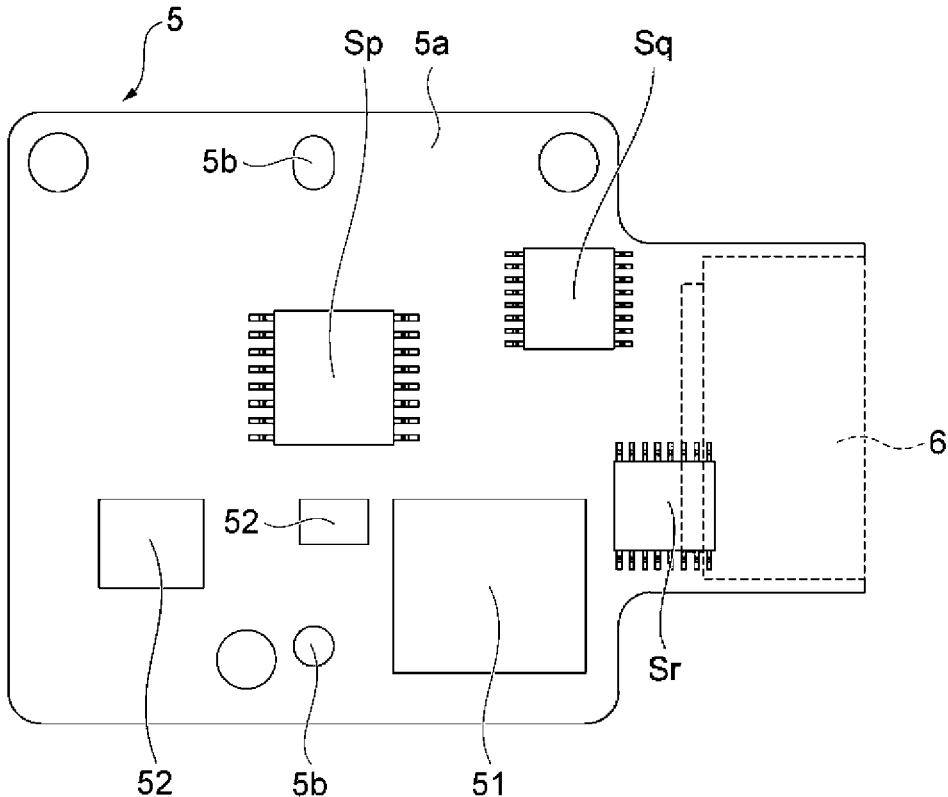


FIG. 28

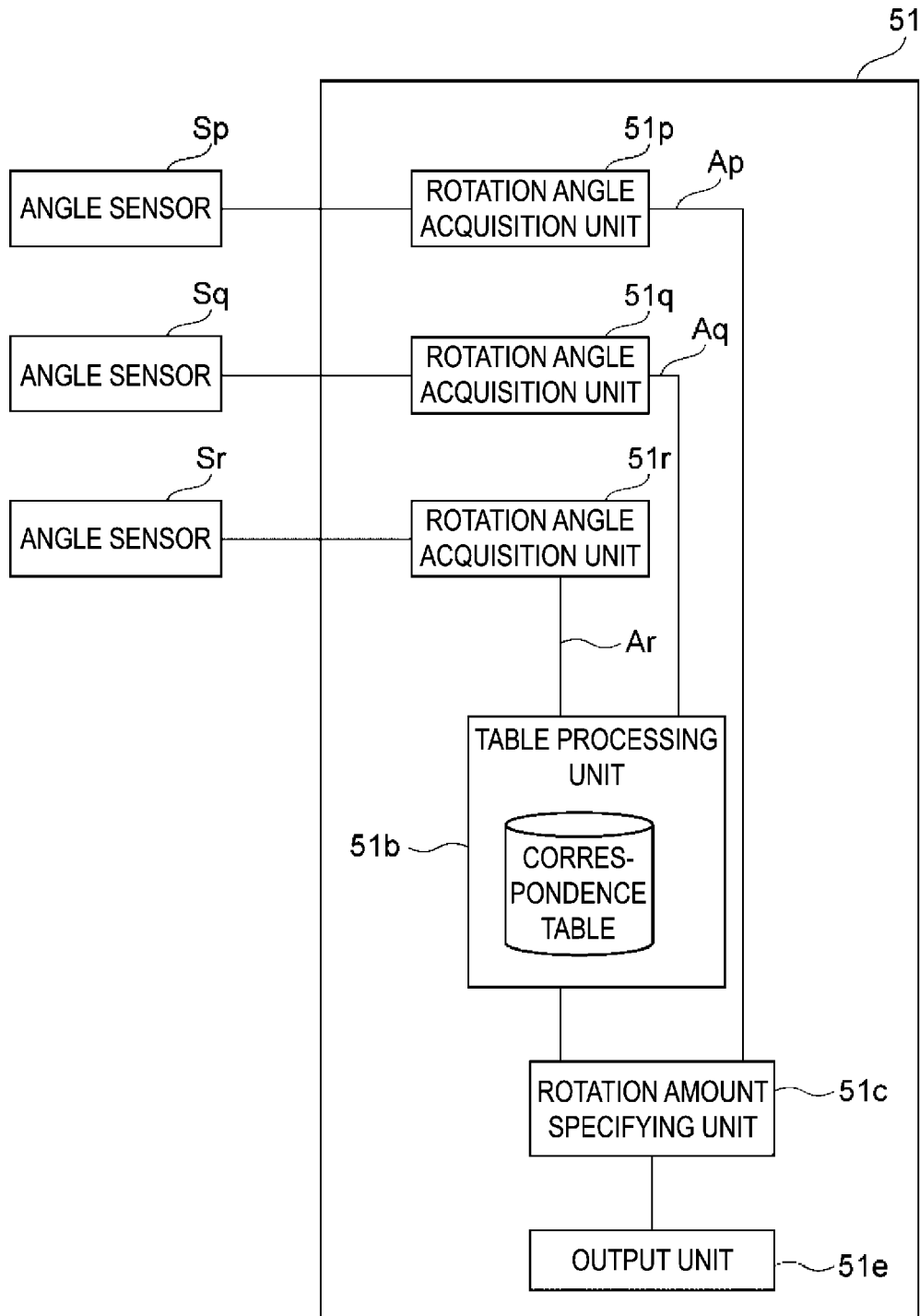


FIG. 29

**SHAFT SUPPORT STRUCTURE,
MAGNETISM DETECTION DEVICE, AND
ABSOLUTE ENCODER**

TECHNICAL FIELD

[0001] The present invention relates to a shaft support structure, a magnetism detection device, and an absolute encoder.

BACKGROUND ART

[0002] Magnetism detection devices configured to detect a magnetic flux from a magnet by using a magnetic sensor have been used for various technologies. In various types of control mechanical devices, the magnetism detection devices are also sometimes used for a rotary encoder used to detect a position and angle of a movable element. The rotary encoder includes an incremental-type encoder configured to detect a relative position or angle and an absolute-type absolute encoder configured to detect an absolute position or angle. Such an absolute encoder sometimes includes a magnetism detection device, and the known absolute encoder including the magnetism detection device includes a magnetic encoder device including a magnetized magnet attached to a rotation shaft (main shaft) to be measured and configured to detect the rotation angle of the magnet by using a magnetic sensor to detect the amount of rotation of the main shaft to be measured. In addition, a known method specifies the amount of rotation of the main shaft during multiple rotations by acquiring the rotation angle of a rotating body rotating while decelerating due to the rotation of the main shaft.

[0003] To broaden the range of the specifiable amount of rotation of the main shaft while maintaining the resolution of the specifiable amount of rotation of the main shaft, such an absolute encoder has a proposed structure for detecting the amounts of rotation of a plurality of magnets by using magnetic sensors as angle sensors corresponding to the magnets. For example, proposed has been a structure for connecting the main shaft and a layshaft or a subsequent shaft by using a reduction mechanism and detecting the amount of rotation of a magnet attached to each shaft by a magnetic sensor corresponding to the magnet to specify the amount of rotation of the main shaft (see, for example, Patent Document 1).

[0004] The absolute encoder uses a structure for attaching a shaft to a supporting member by press-fitting. Examples of a shaft support structure by press-fitting in the absolute encoder include a structure for attaching, to the main shaft, a main shaft adapter for attaching a gear to a main shaft or a structure for press-fitting a shaft of a layshaft gear into a substrate. Known examples of the support structure for attaching a shaft to a supporting member by press-fitting include a structure for providing a circumferential groove in the shaft at a press-fitting margin portion (see, for example, Patent Document 2).

CITATION LIST

Patent Literature

- [0005]** Patent Document 1: JP 2019-15536 A
[0006] Patent Document 2: JP 06-249218 A

SUMMARY OF INVENTION

Technical Problem

[0007] In the absolute encoder having the shaft support structure as described above, a tapered surface is formed at the tip end of the shaft to be press-fitted into a hole of the supporting member.

[0008] Unfortunately, when only linear chamfering is performed on the tapered surface of the shaft, an edge of the hole comes into contact with the tapered surface in press-fitting the tip end of the shaft into the hole, thus generating shavings from both the shaft and the hole. The known shaft support structure by press-fitting may cause the shaft to be press-fitted while being fallen (tilted) due to scraping of the member. Moreover, the known shaft support structure by press-fitting may set a press-fitting margin (dimension necessary for press-fitting) to be long in consideration of inclination of the shaft. Accordingly, improving the accuracy of the shaft support structure by press-fitting has been awaited.

[0009] The present invention has been made in view of the above-described problems, and an object of the present invention is to provide a shaft support structure capable of improving mounting accuracy of a shaft to be press-fitted, a magnetism detection device, and an absolute encoder.

Solution to Problem

[0010] To achieve the above object, a shaft support structure according to the present invention includes: a shaft; and a supporting member having a hole for press-fitting the shaft from one end. The shaft includes a tapered surface portion having a diameter of the one end smaller than a diameter of a peripheral surface. The tapered surface portion is subjected to curved surface processing at a connecting portion with the peripheral surface.

[0011] In the shaft support structure according to an aspect of the present invention, the shaft has a through hole passing through from the one end to the other end, and the through hole has a hole diameter in a region having a predetermined length in an axial direction from a side of the one end larger than a hole diameter at a side of the other end.

[0012] To achieve the above object, a magnetism detection device according to the present invention includes: a magnet magnetized; a magnetic sensor configured to detect a magnetic flux from the magnet; a magnet holder holding the magnet; a shaft rotatably supporting the magnet; and a supporting member having a hole for press-fitting the shaft from one end. The shaft includes: a press-fitting portion as a region having a predetermined length in an axial direction from one end of a peripheral surface to be press-fitted into the hole; and a tapered surface portion having a diameter of the one end smaller than a diameter of a peripheral surface. The tapered surface portion is subjected to curved surface processing at a connecting portion with the peripheral surface.

[0013] In the magnetism detection device according to an aspect of the present invention, the shaft has a through hole passing through from the one end to the other end, and the through hole has a hole diameter in a region having a predetermined length in an axial direction from a side of the one end larger than a hole diameter at a side of the other end.

[0014] In the magnetism detection device according to an aspect of the present invention, the case includes a boss

portion protruding upward from the upper surface portion, and the shielding member includes a boss hole configured to accommodate the boss portion.

[0015] The magnetism detection device according to an aspect of the present invention includes: a magnet supporting portion supporting the magnet at a tip end side of the shaft; and a magnet holding portion configured to cover the magnet and the magnet supporting portion from the tip end side of the shaft and hold the magnet at the tip end side of the shaft. The magnet holding portion is made of a material having a higher breaking elongation characteristic than the magnet supporting portion and includes: a magnet joining portion in contact with a surface at the tip end side of the shaft and an outer peripheral portion of the magnet; and a fitting portion fitted into an outer peripheral portion of the magnet supporting portion.

[0016] To achieve the above object, an absolute encoder according to the present invention includes a magnetism detection device according to the present invention.

Advantageous Effects of Invention

[0017] A shaft support structure, a magnetism detection device, and an absolute encoder according to the present invention can improve mounting accuracy of a shaft to be press-fitted.

BRIEF DESCRIPTION OF DRAWINGS

[0018] FIG. 1 is a perspective view schematically illustrating a configuration of an absolute encoder according to an embodiment of the present invention.

[0019] FIG. 2 is a perspective view schematically illustrating the configuration of the absolute encoder in FIG. 1 with a case and a shield removed.

[0020] FIG. 3 is a perspective view schematically illustrating the configuration of the absolute encoder in FIG. 2 with a substrate, a connector, and a supporting plate removed.

[0021] FIG. 4 is a perspective view schematically illustrating the configuration of the absolute encoder in FIG. 3 when viewed from another angle.

[0022] FIG. 5 is a perspective view schematically illustrating the configuration of the absolute encoder in FIG. 3 with a motor removed.

[0023] FIG. 6 is a plan view schematically illustrating the configuration of the absolute encoder in FIG. 5.

[0024] FIG. 7 is a cross-sectional view of the absolute encoder in FIG. 1 cut along a plane parallel to a central axis of a main shaft.

[0025] FIG. 8 is a cross-sectional view schematically illustrating the configuration of the absolute encoder in FIG. 1 cut along a plane through a central axis of a main shaft gear and orthogonal to a central axis of a first intermediate gear with the motor removed.

[0026] FIG. 9 is an exploded longitudinal cross-sectional view schematically illustrating configurations of a magnet, the main shaft gear, a main shaft adapter, and a main shaft of the motor in the configuration of the absolute encoder in FIG. 8.

[0027] FIG. 10 is an enlarged cross-sectional view illustrating one end portion of the main shaft adapter illustrated in FIG. 8.

[0028] FIG. 11 is a cross-sectional view schematically illustrating the configuration of the absolute encoder in FIG.

6 cut along a plane through the central axis of the first intermediate gear and parallel to an XY plane.

[0029] FIG. 12 is an enlarged perspective view of the cross-sectional view in FIG. 11 when viewed from another angle.

[0030] FIG. 13 is a partial cross-sectional view schematically illustrating the configuration of the absolute encoder in FIG. 6 cut along a plane through the central axis of the first intermediate gear and orthogonal to the XY plane.

[0031] FIG. 14 is an exploded perspective view schematically illustrating a base, the first intermediate gear, a first intermediate gear shaft, a plate spring, and a screw disassembled in the configuration of the absolute encoder in FIG. 12.

[0032] FIG. 15 is a partial cross-sectional view schematically illustrating the configuration of the absolute encoder in FIG. 2 cut along a plane through a central axis of a first layshaft gear and orthogonal to the central axis of the first intermediate gear.

[0033] FIG. 16 is an exploded perspective view schematically illustrating the magnet, a magnet holder, the first layshaft gear, and a bearing disassembled in the configuration of the absolute encoder in FIG. 15.

[0034] FIG. 17 is a partial cross-sectional view schematically illustrating the configuration of the absolute encoder in FIG. 2 cut along a plane through central axes of a second intermediate gear and a second layshaft gear.

[0035] FIG. 18 is an enlarged cross-sectional view illustrating the second intermediate gear illustrated in FIG. 17.

[0036] FIG. 19 is an enlarged cross-sectional view illustrating the magnet holder including the second layshaft gear illustrated in FIG. 17.

[0037] FIG. 20 is an exploded perspective view schematically illustrating the magnet holder illustrated in FIG. 19 exploded.

[0038] FIG. 21 is a schematic perspective view illustrating a cylindrical magnet applicable to a magnet of the magnet holder illustrated in FIG. 19.

[0039] FIG. 22 is an enlarged cross-sectional view illustrating one end portion at the lower end side of the second layshaft gear shaft illustrated in FIG. 18.

[0040] FIG. 23 is a schematic view illustrating a state of the second layshaft gear shaft being press-fitted into a shaft supporting portion of a base portion of a base.

[0041] FIG. 24 is a schematic view illustrating a state of the second layshaft gear shaft being press-fitted into the shaft supporting portion of the base portion of the base.

[0042] FIG. 25 is a diagram schematically illustrating a modified example of a supporting projection supporting a main shaft-side end portion of the first intermediate gear shaft in the absolute encoder.

[0043] FIG. 26 is a diagram schematically illustrating a modified example of the supporting projection supporting the main shaft-side end portion of the first intermediate gear shaft in the absolute encoder.

[0044] FIG. 27 is a diagram schematically illustrating a modified example of the supporting projection supporting the main shaft-side end portion of the first intermediate gear shaft in the absolute encoder.

[0045] FIG. 28 is a view of the substrate in FIG. 2 when viewed from a lower surface side.

[0046] FIG. 29 is a block diagram schematically illustrating a functional configuration of the absolute encoder in FIG. 1.

DESCRIPTION OF EMBODIMENTS

[0047] Embodiments of the present invention are described below with reference to the drawings. The dimensions of members in each drawing are appropriately enlarged or reduced in order to facilitate understanding. In each drawing, some members not important in describing an embodiment of the present invention are omitted. Each drawing illustrates gears with a shape of a tooth portion omitted. Terms including ordinal numbers such as “first” and “second” are used to describe various components, but these terms are used only for distinguishing one component from other components and do not limit the components. The present invention is not limited by the present embodiment.

[0048] A magnetism detection device **60** according to an embodiment of the present invention includes a magnetized magnet **Mr**, an angle sensor **Sr** as a magnetic sensor for detecting a magnetic flux from the magnet **Mr**, a magnet holder **61** for holding the magnet **Mr**, and a second layshaft gear shaft **62** as a shaft. The magnet holder **61** is rotatably supported on the second layshaft gear shaft **62**. The second layshaft gear shaft **62** is made of a magnetic material, and an attractive force due to a magnetic force is generated between the magnet **Mr** and the second layshaft gear shaft **62** in the rotation axis direction of the magnet holder **61**. An absolute encoder **2** according to an embodiment of the present invention includes the magnetism detection device **60** according to the embodiment of the present invention described above. The structures of the absolute encoder **2** and the magnetism detection device **60** are described below in detail.

[0049] FIG. 1 is a perspective view schematically illustrating a configuration of the absolute encoder **2** according to an embodiment of the present invention. FIG. 2 is a perspective view illustrating the configuration of the absolute encoder **2** in FIG. 1 with a case **4** and a shield removed. FIG. 1 transparently illustrates the shield, the case **4**, and a substrate **5** of the absolute encoder **2**, and FIG. 2 transparently illustrates the substrate **5** of the absolute encoder **2**.

[0050] In the present description, for the purpose of convenience, the absolute encoder **2** is described with reference to an XYZ orthogonal coordinate system. The X-axis direction corresponds to a horizontal left-right direction, the Y-axis direction corresponds to a horizontal front-rear direction, and the Z-axis direction corresponds to a vertical up-down direction. The Y-axis direction and the Z-axis direction are orthogonal to the X-axis direction. In the present description, the X-axis direction is also referred to as the left side or the right side, the Y-axis direction is also referred to as the front side or the rear side, and the Z-axis direction is also referred to as the upper side or the lower side. The absolute encoder **2** illustrated in FIGS. 1 and 2 is orientated (upright orientated) such that the left side in the X-axis direction is the left side and the right side in the X-axis direction is the right side. The absolute encoder **2** illustrated in FIGS. 1 and 2 is orientated such that the rear side in the Y-axis direction is the front side and the back side in the Y-axis direction is the rear side. The absolute encoder **2** illustrated in FIGS. 1 and 2 is orientated such that the upper side in the Z-axis direction is the upper side and the lower side in the Z-axis direction is the lower side. A state viewed from the upper side in the Z-axis direction is referred to as a plan view, a state viewed from the front side in the Y-axis direction is referred to as a front view, and a state viewed from the X-axis direction is referred to as a side

view. The notation for such directions is not intended to limit the use orientation of the absolute encoder **2**, and the absolute encoder **2** may be used in any orientation.

[0051] As described above, the absolute encoder **2** is an absolute-type encoder specifying and outputting the amount of rotation of a main shaft **1a** of a motor **1** over multiple rotations. In an embodiment of the present invention, the absolute encoder **2** is provided at an end portion at the upper side in the Z-axis direction of the motor **1**. In an embodiment of the present invention, the absolute encoder **2** has a substantially rectangular shape in plan view and has a rectangular shape being thin and long in the up-down direction being the extension direction of the main shaft **1a** in front view and side view. That is, the absolute encoder **2** has a flat rectangular parallelepiped shape being longer in the horizontal direction than in the up-down direction.

[0052] The absolute encoder **2** includes the case **4** configured to accommodate an internal structure. The case **4** includes a plurality of (for example, four) outer wall portions **4a** surrounding at least part of the main shaft **1a** of the motor **1**, a main shaft gear **10**, a first intermediate gear **20**, a first layshaft gear **30**, a second intermediate gear **70**, and the magnet holder **61**. The case **4** further includes a lid portion **4b** configured to close an upper opening of the four outer wall portions **4a**. The lid portion **4b** is covered with a shield.

[0053] The motor **1** may be a stepper motor or a brushless DC motor, for example. As an example, the motor **1** may be a motor employed as a drive source for driving an industrial robot via a reduction mechanism such as strain wave gearing. The main shaft **1a** of the motor **1** projects from the case of the motor at both sides in the up-down direction. The absolute encoder **2** outputs the amount of rotation of the main shaft **1a** of the motor **1** as a digital signal.

[0054] The motor **1** has a substantially rectangular shape in plan view and also has a substantially rectangular shape in the up-down direction. That is, the motor **1** has a substantially cuboid shape. In plan view, the four outer wall portions constituting the outer shape of the motor **1** each have a length of 25 mm, for example. In other words, the external shape of the motor **1** is a 25 mm square in plan view. The absolute encoder **2** provided in the motor **1** is, for example, a 25 mm square in plan view to match the external shape of the motor **1**.

[0055] In FIGS. 1 and 2, the substrate **5** is provided to cover the inside of the absolute encoder **2** together with the case **4**. The substrate **5** has a substantially rectangular shape in plan view and is a plate-like printed wiring substrate being thin in the up-down direction. A connector **6** is connected to the substrate **5** and is used for connecting the absolute encoder **2** to an external device (not illustrated).

[0056] FIG. 3 is a perspective view schematically illustrating the configuration of the absolute encoder **2** in FIG. 2 with the substrate **5** and the connector **6** removed. FIG. 4 is a perspective view schematically illustrating the configuration of the absolute encoder **2** in FIG. 3 when viewed from another angle. FIG. 5 is a perspective view schematically illustrating the configuration of the absolute encoder **2** in FIG. 3 with the motor **1** removed. FIG. 6 is a plan view schematically illustrating the configuration of the absolute encoder **2** in FIG. 5.

[0057] The absolute encoder **2** includes the main shaft gear **10** having a first worm gear portion **11** (first drive gear), the first intermediate gear **20** having a first worm wheel portion **21** (first driven gear) and a second worm gear portion

22 (second drive gear), the first layshaft gear 30 having a second worm wheel portion 31 (second driven gear) and a gear portion 32 (third drive gear), the second intermediate gear 70, the magnet holder 61 having a second layshaft gear 63, a magnet Mp, an angle sensor Sp corresponding to the magnet Mp, a magnet Mq, an angle sensor Sq corresponding to the magnet Mq, the magnet Mr, an angle sensor Sr corresponding to the magnet Mr, and a microcomputer 51.

[0058] The main shaft 1a of the motor 1 is an output shaft of the motor 1 and is an input shaft transmitting rotational force to the absolute encoder 2. The main shaft gear 10 is fixed to the main shaft 1a of the motor 1 and is rotatably supported by a bearing member of the motor 1 integrally with the main shaft 1a. The first worm gear portion 11 is provided at an outer periphery of the main shaft gear 10 to rotate with the rotation of the main shaft 1a of the motor 1. In the main shaft gear 10, the first worm gear portion 11 is provided so that the central axis of the first worm gear portion 11 coincides with or substantially coincides with the central axis of the main shaft 1a. The first worm wheel portion 21 is provided at an outer periphery of the first intermediate gear 20 and is provided to mesh with the first worm gear portion 11 and rotate with the rotation of the first worm gear portion 11. The axial angle between the first worm wheel portion 21 and the first worm gear portion 11 is set to 90° or approximately 90°.

[0059] Although the outer diameter of the first worm wheel portion 21 is not particularly limited, in the illustrated example, the outer diameter of the first worm wheel portion 21 is set to be smaller than the outer diameter of the first worm gear portion 11 (see FIG. 8), and the outer diameter of the first worm wheel portion 21 is reduced. This reduces the dimension in the up-down direction of the absolute encoder 2.

[0060] The second worm gear portion 22 is provided at the outer periphery of the first intermediate gear 20 and rotates with the rotation of the first worm wheel portion 21. In the first intermediate gear 20, the second worm gear portion 22 is provided so that a central axis of the second worm gear portion 22 coincides with or substantially coincides with a central axis of the first worm wheel portion 21. The second worm wheel portion 31 is provided at an outer periphery of the first layshaft gear 30 and is provided to mesh with the second worm gear portion 22 and rotate with the rotation of the second worm gear portion 22. The axial angle between the second worm wheel portion 31 and the second worm gear portion 22 is set to 90° or approximately 90°. A rotation axis of the second worm wheel portion 31 is parallel or substantially parallel to a rotation axis of the first worm gear portion 11. The gear portion 32 is provided at the outer periphery of the first layshaft gear 30 and rotates with the rotation of the second worm wheel portion 31. In the first layshaft gear 30, the gear portion 32 is provided so that a central axis of the gear portion 32 coincides with or substantially coincides with a central axis of the second worm wheel portion 31.

[0061] Here, the first worm wheel portion 21 moves toward the first worm gear portion 11 to mesh with the first worm gear portion 11 in a direction. This direction is defined as a first meshing direction (direction indicated by an arrow P1 in FIG. 12). Similarly, the second worm gear portion 22 moves toward the second worm wheel portion 31 to mesh with the second worm wheel portion 31 in a direction. This direction is defined as a second meshing direction (direction

indicated by an arrow P2 in FIG. 12). In the present embodiment, the first meshing direction P1 and the second meshing direction P2 are both a direction along a horizontal plane (XY plane).

[0062] The second intermediate gear 70 includes a gear portion 71 (third driven gear) and a gear portion 72 (fourth drive gear). The gear portion 71 is provided at an outer periphery of the second intermediate gear 70, meshes with the gear portion 32 of the first layshaft gear 30, and rotates with the rotation of the gear portion 32. The gear portion 72 is provided at the outer periphery of the second intermediate gear 70 and rotates with the rotation of the gear portion 71. In the second intermediate gear 70, the gear portion 72 is provided so that a central axis of the gear portion 72 coincides with or substantially coincides with a central axis of the gear portion 71. Rotation axes of the gear portions 71 and 72 are provided in parallel to or substantially parallel to a rotation axis of the gear portion 32 of the first layshaft gear 30.

[0063] The magnet holder 61 includes the second layshaft gear 63 and includes a gear portion 64 (fourth driven gear) provided at the second layshaft gear 63, as described below. The gear portion 64 is provided at an outer periphery of the second layshaft gear 63, meshes with the gear portion 72 of the second intermediate gear 70, and rotates with the rotation of the gear portion 72. A rotation axis of the gear portion 64 is provided in parallel to or substantially parallel to the rotation axis of the gear portion 72 of the second intermediate gear 70.

[0064] The angle sensor Sq detects a rotation angle of the second worm wheel portion 31, that is, a rotation angle of the first layshaft gear 30. The magnet Mq is fixed to an upper surface of the first layshaft gear 30 so that the central axes of the magnet Mq and the first layshaft gear 30 coincide with or substantially coincide with each other. The magnet Mq has 2-pole magnetic poles arranged in a direction perpendicular or substantially perpendicular to the rotation axis of the first layshaft gear 30. In order to detect the rotation angle of the first layshaft gear 30, the angle sensor Sq is provided so that a lower surface of the angle sensor Sq faces an upper surface of the magnet Mq across a gap in the up-down direction.

[0065] As an example, the angle sensor Sq is fixed to the substrate 5 supported by substrate pillars 110 disposed at a base 3 (to be described below) of the absolute encoder 2. The angle sensor Sq detects the magnetic flux of the magnet Mq and outputs detection information to the microcomputer 51. The microcomputer 51 specifies the rotation angle of the magnet Mq, that is, the rotation angle of the first layshaft gear 30, on the basis of the input detection information on the magnetic flux.

[0066] The angle sensor Sr detects a rotation angle of the magnet holder 61, that is, a rotation angle of the second layshaft gear 63. The magnet Mr is fixed to an upper surface of the second layshaft gear 63 so that the central axes of the magnet Mr and the second layshaft gear 63 coincide with or substantially coincide with each other. The magnet Mr has 2-pole magnetic poles arranged in a direction perpendicular to a rotation axis of the second layshaft gear 63. In order to detect the rotation angle of the second layshaft gear 63, the angle sensor Sr is provided so that a lower surface of the angle sensor Sr faces an upper surface of the magnet Mr across a gap in the up-down direction.

[0067] As an example, the angle sensor Sr is fixed to the substrate 5 at the same surface as the surface where the angle sensor Sq is fixed, the angle sensor Sq being fixed to the substrate 5. The angle sensor Sr detects the magnetic flux of the magnet Mr and outputs detection information to the microcomputer 51. The microcomputer 51 specifies a rotation angle of the magnet Mr, that is, the rotation angle of the second layshaft gear 63, on the basis of the received detection information on the magnetic flux.

[0068] The magnet Mp is fixed to an upper surface of the main shaft gear 10 so that the central axes of the magnet Mp and the main shaft gear 10 coincide or substantially coincide with each other. The magnet Mp has 2-pole magnetic poles arranged in a direction perpendicular to a rotation axis of the main shaft gear 10. In order to detect the rotation angle of the main shaft gear 10, the angle sensor Sp is provided so that a lower surface of the angle sensor Sp faces an upper surface of the magnet Mp across a gap in the up-down direction.

[0069] As an example, the angle sensor Sp is fixed to the substrate 5, and the angle sensor Sp is fixed to the substrate 5 at the same surface as the surface where the angle sensor Sq is fixed, the angle sensor Sq being fixed to the substrate 5. The angle sensor Sp detects the magnetic flux of the magnet Mp and outputs detection information to the microcomputer 51. The microcomputer 51 specifies the rotation angle of the main shaft gear 10, that is, the rotation angle of the main shaft 1a by specifying the rotation angle of the magnet Mp on the basis of the input detection information on the magnetic flux. The resolution of the rotation angle of the main shaft 1a corresponds to the resolution of the angle sensor Sp. As described below, the microcomputer 51 specifies the amount of rotation of the main shaft 1a on the basis of the specified rotation angle of the first layshaft gear 30, the rotation angle of the second layshaft gear 63, and the specified rotation angle of the main shaft 1a and outputs the specified amount of rotation. As an example, the microcomputer 51 may output the amount of rotation of the main shaft 1a of the motor 1 as a digital signal.

[0070] The absolute encoder 2 configured in this way can specify the rotation number of the main shaft 1a according to the rotation angle of the first layshaft gear 30 specified on the basis of the detection information of the angle sensor Sq and the rotation angle of the second layshaft gear 63 specified on the basis of the detection information of the angle sensor Sr and specify the rotation angle of the main shaft 1a on the basis of the detection information of the angle sensor Sp. Then, the microcomputer 51 specifies the amount of rotation of the main shaft 1a over multiple rotations based on the specified rotation number of the main shaft 1a and the rotation angle of the main shaft 1a.

[0071] The number of threads of the first worm gear portion 11 of the main shaft gear 10 provided at the main shaft 1a is, for example, five, and the number of teeth of the first worm wheel portion 21 is, for example, 20. That is, the first worm gear portion 11 and the first worm wheel portion 21 constitute a first transmission mechanism R1 having a reduction ratio of $20/5=4$ (see FIG. 6). When the first worm gear portion 11 rotates four times, the first worm wheel portion 21 rotates one time. Since the first worm wheel portion 21 and the second worm gear portion 22 are coaxially provided to constitute the first intermediate gear 20 and rotate integrally with each other, when the first worm gear portion 11 rotates four times, that is, when the main shaft 1a

and the main shaft gear 10 rotate four times, the first intermediate gear 20 rotates one time and the second worm gear portion 22 rotates one time.

[0072] The number of threads of the second worm gear portion 22 is, for example, two, and the number of teeth of the second worm wheel portion 31 of the first layshaft gear 30 is, for example, 25. That is, the second worm gear portion 22 and the second worm wheel portion 31 constitute a second transmission mechanism R2 having a reduction ratio of $25/2=12.5$ (see FIG. 6). When the second worm gear portion 22 rotates 12.5 times, the second worm wheel portion 31 rotates one time. Since the first lay shaft gear 30 formed with the second worm wheel portion 31 is configured to rotate integrally with a magnet holder 35 and the magnet Mq as described below, when the second worm gear portion 22 constituting the first intermediate gear 20 rotates 12.5 times, the magnet Mq rotates one time.

[0073] The number of teeth of the gear portion 32 of the first layshaft gear 30 is, for example, 18, and the number of teeth of the gear portion 71 of the second intermediate gear 70 is, for example, 36. That is, the gear portion 32 and the gear portion 71 constitute a third transmission mechanism R3 having a reduction ratio of $40/20=2$ (see FIG. 5). When the gear portion 32 of the first layshaft gear 30 rotates twice, the gear portion 71 of the second intermediate gear 70 rotates one time. The number of teeth of the gear portion 72 of the second intermediate gear 70 is, for example, 19, and the number of teeth of the gear portion 64 of the second layshaft gear 63 is, for example, 38. That is, the gear portion 64 and the gear portion 72 constitute a fourth transmission mechanism R4 having a reduction ratio of $38/19=2$ (see FIG. 5). When the gear portion 72 of the second intermediate gear 70 rotates twice, the gear portion 64 of the second layshaft gear 63 rotates one time.

[0074] Since the gear portion 71 and the gear portion 72 are coaxially provided to constitute the second intermediate gear 70 and rotate integrally with each other, when the gear portion 71 rotates one time, the gear portion 72 rotates one time. Accordingly, the second intermediate gear 70 as a whole has a reduction ratio of 4. That is, when the gear portion 32 of the first layshaft gear 30 rotates four times, the second intermediate gear 70 rotates twice and the gear portion 64 of the second layshaft gear 63 rotates one time. The second layshaft gear 63 formed with the gear portion 64 constitutes the magnet holder 61 as described below and rotates integrally with the magnet Mr. Therefore, when the gear portion 32 constituting the first layshaft gear 30 rotates four times, the magnet Mr rotates one time.

[0075] From the above, when the main shaft 1a rotates 200 times, the first intermediate gear 20 rotates 50 times, the first layshaft gear 30 and the magnet Mq rotate four times, the second intermediate gear 70 rotates twice, and the second layshaft gear 63 and the magnet Mr rotate once. That is, the rotation number for 50 rotations of the main shaft 1a can be specified by the detection information of the angle sensor Sq regarding the rotation angle of the first layshaft gear 30, and the rotation number for 200 rotations of the main shaft 1a can be specified by the detection information of the angle sensor Sr regarding the rotation angle of the second layshaft gear 63. The first layshaft gear 30 has a smaller reduction ratio with respect to the main shaft gear 10 than the second layshaft gear 63, and the resolution of the amount of rotation of the main shaft 1a based on the detection information of the magnetic sensor Sq corresponding to the magnet Mq

rotating together with the first layshaft gear **30** is higher than the resolution of the amount of rotation of the main shaft **1a** based on the detection information of the magnetic sensor **Sr** corresponding to the magnet **Mr** rotating together with the second layshaft gear **63**. Therefore, in the absolute encoder **2**, the range of the specifiable amount of rotation of the main shaft **1a** can be expanded without lowering the resolution of the specifiable amount of rotation of the main shaft **1a**.

[0076] The configuration of the absolute encoder **2** is described below in more detail.

[0077] As described above (see FIGS. **1** to **6**), the absolute encoder **2** includes the base **3**, the case **4**, the substrate **5**, and the connector **6**. The absolute encoder **2** further includes the main shaft gear **10**, the first intermediate gear **20**, the first layshaft gear **30**, the second intermediate gear **70**, the magnet holder **61** having the second layshaft gear **63**, and a biasing mechanism **40**. The absolute encoder **2** includes the magnets **Mp**, **Mq**, and **Mr** and the angle centers **Sp**, **Sq**, and **Sr** and includes the microcomputer **51** for controlling a drive unit, a detection unit, and the like of the absolute encoder **2**.

[0078] The base **3** is a base rotatably holding rotating bodies such as the main shaft gear **10**, the first intermediate gear **20**, the first layshaft gear **30**, the second intermediate gear **70**, and the magnet holder **61** (second layshaft gear **63**) and fixing members such as the substrate **5** and the biasing mechanism **40**. As illustrated in FIGS. **3** to **6**, FIGS. **11** to **14**, and others, the base **3** includes a base portion **101** and various supporting portions (to be described below) for supporting each member of the absolute encoder **2** provided at the base portion **101**. As illustrated in FIG. **7**, the case **4** is fixed to the base **3** via a supporting plate **3a**. The supporting plate **3a** is interposed between the base **3** and the motor **1**, and the case **4** is fixed to the supporting plate **3a**, for example, at one position by a screw **8c**. The substrate **5** is configured to be fixed to the base **3**, for example, at three positions by screws **8a**. The base portion **101** is a plate-like portion having a pair of surfaces facing the up-down direction of the absolute encoder **2** and extends in the horizontal direction (X-axis direction and Y-axis direction).

[0079] The substrate pillars **110** and substrate positioning pins **120** being portions for supporting the substrate **5** are provided at an upper surface **104** being a surface at the upper side of the base portion **101**. The base **3** includes, for example, three substrate pillars **110** and two substrate positioning pins **120**.

[0080] As illustrated in FIG. **5** and others, the substrate pillars **110** are portions protruding upward from the upper surface **104** of the base portion **101** and are, for example, columnar or substantially columnar portions. A screw hole **112** extending downward is formed at an end surface on an upper side (upper end surface **111**) of each of the substrate pillars **110**. The upper end surface **111** of each of the substrate pillars **110** is formed extending on the same horizontal plane or extending along the same horizontal plane. In the absolute encoder **2**, a lower surface **5a** of the substrate **5** is in contact with the upper end surfaces **111** of the substrate pillars **110**, and the substrate **5** is fixed to the substrate pillars **110** by the screws **8a** screwed into the screw holes **112**. As described below, one of the substrate pillars **110** is integrated with a supporting projection **45** constituting the one substrate positioning pin **120** and the biasing mechanism **40** described below. The substrate pillars **110** may have ribs for reinforcement.

[0081] As illustrated in FIG. **5** and others, the substrate positioning pin **120** is a portion protruding upward from the upper surface **104** of the base portion **101** and is, for example, a columnar or a substantially columnar portion. An upper end portion (a tip end portion **121**) of the substrate positioning pin **120** is narrower than a portion (a base portion **122**) being lower than the tip end portion **121**, and a stepped surface **123** is formed between the tip end portion **121** and the base portion **122**. The tip end portions **121** of the substrate positioning pins **120** are insertable into positioning holes **5b** formed in the substrate **5** as illustrated in FIG. **28** described below, and the substrate **5** is positioned relative to the base **3** by inserting the tip end portions **121** of the substrate positioning pins **120** into the positioning holes **5b** of the substrate **5**.

[0082] As illustrated in FIG. **5** and others, the base **3** includes supporting projections **131**, **132**, and **141** provided at the upper surface **104** of the base portion **101** and being portions protruding upward (see FIGS. **3** to **6** and others). The supporting projection **132** is a portion supporting a plate spring **9** configured to push the first intermediate gear **20** in the central axial direction of the first intermediate gear **20**, as described below. The supporting projections **131** and **141** are portions for rotatably supporting the first intermediate gear **20**, as described below. The base **3** further includes a bearing holder portion **134** supporting a bearing **135** configured to rotatably hold the first layshaft gear **30**, as described below (see FIG. **15**). As described below, the base **3** further includes a shaft supporting portion **136** that supports the second layshaft gear shaft **62** that rotatably supports the magnet holder **61** formed with the second layshaft gear **63**, and a shaft supporting portion **137** supporting a shaft **75** configured to rotatably support the second intermediate gear **70** (see FIGS. **17** to **19**). Additionally, the supporting projection **45** is formed at the upper surface **104** of the base portion **101** of the base **3**. As described below, the supporting projection **45** is a portion constituting the biasing mechanism **40** biasing the second worm gear portion **22** in the direction of the second worm wheel portion **31** and is a portion supporting a biasing spring **41**.

[0083] Subsequently, each component of the absolute encoder **2** supported by the base **3** is described in detail.

[0084] Main Shaft Gear

[0085] FIG. **8** is a cross-sectional view schematically illustrating the configuration of the absolute encoder **2** in FIG. **1** cut along a plane through the central axis of the main shaft gear **10** and orthogonal to the central axis of the first intermediate gear **20** with the motor **1** removed. FIG. **9** is an exploded longitudinal cross-sectional view schematically illustrating configurations of the magnet **Mp**, the main shaft gear **10**, a main shaft adapter **12**, and the main shaft **1a** of the motor **1** in the configuration of the absolute encoder **2** in FIG. **8**.

[0086] As illustrated in FIGS. **8** and **9**, the main shaft gear **10** is a tubular member provided coaxially or substantially coaxially with the main shaft **1a** of the motor **1** and the main shaft adapter **12**. The main shaft gear **10** includes a tubular portion **13** having a tubular shape and the first worm gear portion **11** provided at the outer side in the radial direction of the tubular portion **13**. The first worm gear portion **11** is a gear portion of the main shaft gear **10**. As illustrated in FIG. **9**, a press-fitting portion **1b** in the form of a cylindrical surface and forming a space at an inner peripheral side is formed at the upper end of the main shaft **1a** of the motor **1**,

and the press-fitting portion **1b** has a shape allowing the main shaft adapter **12** to be press-fitted and fixed. The tubular portion **13** of the main shaft gear **10** is formed with a press-fitting portion **14** in the form of a cylindrical surface and forming a space at an inner side, and the press-fitting portion **14** has a shape allowing the main shaft adapter **12** to be press-fitted and fixed.

[0087] As illustrated in FIGS. **8** and **9**, a magnet holding portion **15** for holding the magnet **Mp** is formed in the tubular portion **13** of the main shaft gear **10**. The magnet holding portion **15** is a portion forming a recess part corresponding to the shape of the magnet **Mp** and being recessed downward from an upper end surface **13a** of the tubular portion **13**. The magnet holding portion **15** can accommodate the magnet **Mp**. The magnet holding portion **15** has an inner peripheral surface **15a** in the form of a cylindrical surface communicating with the press-fitting portion **14** and having a larger diameter than the press-fitting portion **14**, and an annular bottom surface **15b** connecting the inner peripheral surface **15a** and the press-fitting portion **14**.

[0088] The inner peripheral surface **15a** of the magnet holding portion **15** is formed in contact with an outer peripheral surface **Mpd** of the magnet **Mp** accommodated in the magnet holding portion **15**. In the absolute encoder **2**, an upper end surface **12a** of the main shaft adapter **12** is positioned above the bottom surface **15b** of the magnet holding portion **15**. In the absolute encoder **2**, a bottom surface **Mpb** of the magnet **Mp** is in contact with the upper end surface **12a** of the main shaft adapter **12** but is not in contact with the bottom surface **15b** of the magnet holding portion **15** of the main shaft gear **10**. Thus, the magnet **Mp** is positioned in the up-down direction by the upper end surface **12a** of the main shaft adapter **12** and positioned in the horizontal direction by the inner peripheral surface **15a** of the magnet holding portion **15**. The lower surface **Mpb** of the magnet **Mp** positioned in this manner is bonded and fixed to the upper end surface **12a** of the main shaft adapter **12**.

[0089] As described above, the magnet **Mp** is fixed to the main shaft adapter **12**, and the magnet **Mp**, the main shaft gear **10**, and the main shaft adapter **12** rotate integrally with the main shaft **1a** of the motor **1**. The magnet **Mp**, the main shaft gear **10**, and the main shaft adapter **12** are configured to rotate about the same axis line as the main shaft **1a** of the motor **1**.

[0090] The first worm gear portion **11** is constituted by a tooth portion formed into a helical shape and is formed meshing with the first worm wheel portion **21** of the first intermediate gear **20**. The first worm gear portion **11** is made of, for example, polyacetal resin. The first worm gear portion **11** is an example of a first drive gear.

[0091] As illustrated in FIG. **9**, the magnet **Mp** is a disk-shaped or substantially disk-shaped permanent magnet inserted into the magnet holding portion **15** of the main shaft gear **10** and has an upper surface **Mpa** and the lower surface **Mpb** opposing each other. In the absolute encoder **2**, the position (position in the up-down direction) of the magnet **Mp** in a direction of a central axis **GC1** of the main shaft gear **10** is defined by the upper end surface **12a** of the main shaft adapter **12** as described above so that the upper surface **Mpa** of the magnet **Mp** opposes the surface of the angle sensor **Sp** across a certain distance in the up-down direction.

[0092] A central axis **MpC** of the magnet **Mp** (axis representing the center of the magnet **Mp** or axis passing through the center of a magnetic pole boundary) coincides or

substantially coincides with the central axis **GC1** of the main shaft gear **10**, a central axis **SaC** of the main shaft adapter **12**, and a central axis **MoC** of the main shaft **1a** of the motor **1**. When these central axes are made to coincide or substantially coincide with each other, the angle sensor **Sp** can detect the rotation angle or the amount of rotation of the magnet **Mp** with higher accuracy.

[0093] In an embodiment of the present invention, the two magnetic poles (N/S) of the magnet **Mp** are preferably formed adjacent in a horizontal plane (XY plane) perpendicular to the central axis **MpC** of the magnet **Mp**. This can further improve the detection accuracy of the rotation angle or amount of rotation of the angle sensor **Sp**. The magnet **Mp** is formed from a magnetic material such as a terrific material, an Nd (neodymium) —Fe (iron) —B (boron) material. The magnet **Mp** may be, for example, a rubber magnet or a bond magnet including a resin binder.

[0094] Main Shaft Adapter

[0095] FIG. **10** is an enlarged cross-sectional view illustrating one end portion **124** of the main shaft adapter **12**.

[0096] The main shaft adapter **12** according to an embodiment of the shaft support structure of the present invention is a shaft to be press-fitted into the press-fitting portion **1b** and the press-fitting portion **14** by using the main shaft **1a** of the motor **1** and the tubular portion **13** of the main shaft gear **10** as supporting members. As illustrated in FIGS. **8**, **9** and **10**, the main shaft adapter **12** includes tapered surface portions **126** and **127** and a through hole **128**.

[0097] The through hole **128** passes through the one end portion **124** to the other end portion **125** of the main shaft adapter **12**. The through hole **128** has a first hole portion **128a** occupying a region having a predetermined length in the axial direction from the one end portion **124** side, and a second hole portion **128c** communicating with the first hole portion **128a** and occupying a region up to the other end portion **125**. In the through hole **128**, the diameter of the hole of the first hole portion **128a** in the region having the predetermined length in the axial direction from the one end portion **124** side is larger than the diameter of the hole of the second hole portion **128c** provided at the other end portion **125** side. An end portion **128b** between the first hole portion **128a** and the second hole portion **128c** is a portion formed when the first hole portion **128a** is machined by a drill having an angle at the tip of a cutting edge. The first hole portion **128b** does not exist when machined by an endmill.

[0098] To support the main shaft **1a** having various diameters, the absolute encoder **2** has a structure of attaching the main shaft gear **10** to the main shaft **1a** of the motor **1**. In the structure, the main shaft gear **10** is not directly attached to the main shaft **1a** but is fixed to the main shaft **1a** via the main shaft adapter **12**. The main shaft **1a** is a rotation shaft of the motor and requires rigidity. Since the magnet **Mg** needs to be fixed to the main shaft adapter **12** with an adhesive as described above, the main shaft **1a** and the main shaft adapter **12** are preferably made of a metal. Thus, a high press-fitting force is required when the main shaft adapter **12** is press-fitted into the press-fitting portion **1b** of the main shaft **1a**. In this case, the press-fitting force may cause breakage such as buckling deformation of the main shaft **1a** or scraping of the press-fitting portion (inner or outer diameter portion) between the main shaft **1a** and the main shaft adapter **12**.

[0099] In the absolute encoder **2**, by making the diameter of the first hole portion **128a** of the through hole **128** of the

main shaft adapter **12** larger than the diameter of the second hole portion **128c** and making the wall thickness thinner, the main shaft adapter **12** can be easily bent, the press-fitting force to the main shaft **1a** can be reduced, and the load to the main shaft **1a** can be reduced. On the other hand, since the magnet **Mp** is fixed to the upper portion (tip end side) of the main shaft adapter **12** with an adhesive, a contact area with the magnet **Mp** (thickness between the outer diameter and the inner diameter of the main shaft adapter **12**) is required. Therefore, in the main shaft adapter **12**, the diameter of the through hole **128** is made different at a predetermined position in the axial direction, for example, with a region corresponding to a press-fitting margin (dimension necessary for press-fitting) at the one end portion **124** side as a boundary.

[0100] That is, making the diameter of the first hole portion **128a** of the main shaft adapter **12** at the one end portion **124** side (lower side in FIG. 9) from the press-fitting margin larger than the diameter of the second hole portion **128c** allows a peripheral surface **129** of the main shaft adapter **12** to be easily deformed and easily press-fitted into the press-fitting portion **1b**. By making the diameter of the second hole portion **128c** at the other end portion **125** side (upper side in FIG. 9) with respect to the press-fitting margin smaller than the diameter of the first hole portion **128a**, an adhesive area with the magnet **Mp** can be secured and reduction of the press-fitting force can be achieved without impairing an adhesive holding force.

[0101] The tapered surface portions **126** and **127** are inclined outer peripheral surfaces such that the diameters of the one end portion **124** and the other end portion **125** are smaller than the diameter of the peripheral surface **129**. In the tapered surface portion **126**, a connecting portion **126a** of an outer peripheral surface between the tapered surface portion **126** and the peripheral surface **129** of the main shaft adapter **12** is connected by a curved surface. Also in the tapered surface portion **127** at the other end portion **125** side, a connecting portion **127a** of an outer peripheral surface between the tapered surface portion **127** and the peripheral surface **129** is connected by a curved surface. That is, curved surface processing is performed on the connecting portions **126a** and **127a** of the outer peripheral surfaces between the tapered surface portions **126** and **127** and the peripheral surface **129**.

[0102] As illustrated in FIG. 9, a region of the main shaft adapter **12** having a predetermined length in the axial direction from the one end portion **124** is press-fitted into the press-fitting portion **1b** formed at the upper end of the main shaft **1a** of the motor **1**. A region of the main shaft adapter **12** having a predetermined length in the axial direction from the other end portion **125** is press-fitted into the press-fitting portion **14** formed in the tubular portion **13** of the main shaft gear **10**.

[0103] In a case where only linear chamfering is performed on the tapered surface portion **126**, when the one end portion **124** of the main shaft adapter **12** is press-fitted into the press-fitting portion **1b**, if the edge of the hole of the press-fitting portion **1b** and the tapered surface portion **126** come into contact with each other, shavings are generated from both the main shaft adapter **12** and the press-fitting portion **1b**. Similarly, in a case where only linear chamfering is performed on the tapered surface portion **127**, when the other end portion **125** of the main shaft adapter **12** is press-fitted into the press-fitting portion **14**, the edge of the

hole of the press-fitting portion **14** and the tapered surface portion **127** come into contact with each other, causing the generation of shavings from both the main shaft adapter **12** and the press-fitting portion **14**.

[0104] On the other hand, when the main shaft adapter **12** is press-fitted into the press-fitting portion **1b** and the press-fitting portion **14**, after the tapered surface portions **126** and **127** are inserted into the press-fitting portions **1b** and **14**, the connecting portions **126a** and **127a** of the outer peripheral surfaces between the tapered surface portions **126** and **127** and the peripheral surface **129** come into contact with the press-fitting portions **1b** and **14**. The connecting portions **126a** and **127a** of the outer peripheral surfaces between the tapered surface portions **126** and **127** and the peripheral surface **129** of the main shaft adapter **12** are subjected to curved surface processing, and thus the main shaft adapter **12** is smoothly press-fitted into the press-fitting portions **1b** and **14**. This can prevent both the main shaft adapter **12** and the press-fitting portions **1b** and **14** from being scraped. Therefore, the main shaft adapter **12** can reduce scattering of the shavings and the like. In addition, the main shaft adapter **12** can reduce the main shaft adapter **12** being press-fitted while falling (inclining) due to the member being scraped. Further, the main shaft adapter **12** suppresses the inclination of the main shaft adapter **12** and can reduce a press-fitting margin (dimension necessary for press-fitting) to be reduced.

[0105] The curved surface processing on the connecting portions **126a** and **127a** preferably has, for example, a radius **R** of about 1 [mm]. The main shaft adapter **12** can prevent, by making surface roughness of the surfaces of the peripheral surface **129** and the tapered surface portions **126** and **127** including the connecting portions **126a** and **127a** smoother, materials of the surfaces of both the main shaft adapter **12** and the press-fitting portion **14** from being scraped. Surface roughness **Rmax** (maximum roughness) of the surface of the main shaft adapter **12** may be, for example, 1.6 [μm] or less. The curved surface processing on the connecting portions **126a** and **127a** may be performed on either the one end portion **124** or the other end portion **125**.

[0106] First Intermediate Gear

[0107] FIG. 11 is a cross-sectional view schematically illustrating the configuration of the absolute encoder **2** in FIG. 6 cut along a plane through the central axis of the first intermediate gear **20** and parallel to the horizontal plane (**XY** plane). FIG. 12 is an enlarged perspective view of the absolute encoder **2** sectioned as illustrated in FIG. 11, when viewed from above at a layshaft-side end portion **23b** side of a first intermediate gear shaft **23**. FIG. 13 is a partial cross-sectional view schematically illustrating the configuration of the absolute encoder **2** in FIG. 6 cut along a plane through the central axis of the first intermediate gear **20** and orthogonal to the horizontal plane (**XY** plane).

[0108] As illustrated in FIGS. 4 to 6 and FIGS. 11 to 13, the first intermediate gear **20** is rotatably supported by the first intermediate gear shaft **23** at the upper side of the base portion **101** of the base **3**. The first intermediate gear shaft **23** extends in parallel to the horizontal plane. The first intermediate gear shaft **23** is not parallel to each of the left-right direction (**X**-axis direction) and the front-rear direction (**Y**-axis direction) in plan view. That is, the first intermediate gear shaft **23** is inclined with respect to each of the left-right direction and the front-rear direction. The first intermediate gear shaft **23** being inclined with respect to

each of the left-right direction and the front-rear direction means that the first intermediate gear shaft 23 extends obliquely with respect to outer peripheral surfaces 105 to 108 of the base portion 101 of the base 3 (see FIG. 11). In the absolute encoder 2, the first intermediate gear shaft 23 is supported on the base portion 101 of the base 3 by the supporting projection 131 located at the main shaft gear 10 side and the supporting projection 141 located at the first layshaft gear 30 side.

[0109] As illustrated in FIG. 11, the outer peripheral surfaces of the base 3 are constituted by a right-side outer peripheral surface 105, a left-side outer peripheral surface 107 parallel to a YZ plane, and a rear-side outer peripheral surface 106 and a front-side outer peripheral surface 108 parallel to the XZ plane and extending between the right-side outer peripheral surface 105 and the left-side outer peripheral surface 107. The right-side outer peripheral surface 105 is a side surface provided at the right side (right side in the X-axis direction) of the base 3. The left-side outer peripheral surface 107 is a side surface provided at the left side (left side in the X-axis direction) of the base 3. The rear-side outer peripheral surface 106 is a side surface provided at the rear side (rear side in the Y-axis direction) of the base 3. The front-side outer peripheral surface 108 is a side surface provided at the front side (front side in the Y-axis direction) of the base 3.

[0110] As illustrated in FIGS. 3 to 6, the dimensions of the absolute encoder 2 in plan view are aligned with the dimensions of the motor 1 being 25 mm square as an example. Thus, the first intermediate gear 20 disposed in parallel to the upper surface 104 of the base 3 is provided extending obliquely with respect to the outer peripheral surfaces 105 to 108 of the base 3, allowing the dimensions of the absolute encoder 2 in the horizontal direction to be reduced. The horizontal direction is a direction equal to a direction orthogonal to the central axis of the main shaft 1a of the motor 1 and is a direction equal to the direction parallel to the XY plane.

[0111] As illustrated in FIGS. 5 and 6 and FIGS. 11 to 14, the first intermediate gear 20 is a tubular member formed rotatably around the first intermediate gear shaft 23 and includes the first worm wheel portion 21, the second worm gear portion 22, a tubular portion 24, a main shaft-side sliding portion 25, and a layshaft-side sliding portion 26. The tubular portion 24 is a member extending in a tubular shape and has an inner peripheral surface 24b forming a through hole 24a. The first intermediate gear shaft 23 can be inserted into the through hole 24a. The through hole 24a is a space surrounded by an inner peripheral surface 24b of the tubular portion 24. The inner peripheral surface 24b is formed slidably at an outer peripheral surface of the first intermediate gear shaft 23 inserted into the through hole 24a, and the first intermediate gear 20 is supported on the first intermediate gear shaft 23 rotatably around the first intermediate gear shaft 23. The first intermediate gear 20 is a member integrally formed of metal, resin, or the like and is formed of polyacetal resin as an example.

[0112] As illustrated in FIGS. 5 to 8, the first worm wheel portion 21 is a gear meshing with the first worm gear portion 11 of the main shaft gear 10. The first worm wheel portion 21 is an example of a first driven gear. The first worm wheel portion 21 is provided at one end portion side of the tubular portion 24 of the first intermediate gear 20 and is composed of, for example, a plurality of teeth provided at a cylindrical

surface formed at one end portion side of the tubular portion 24 of the first intermediate gear 20. In the absolute encoder 2, the first intermediate gear 20 is provided so that the first worm wheel portion 21 is located near the center of the base portion 101 of the base 3. Accordingly, the one end portion of the tubular portion 24 provided in the vicinity of the first worm wheel portion 21 is an end portion of the first intermediate gear 20 at the main shaft gear 10 side.

[0113] As illustrated in FIG. 8, the outer diameter of the first worm wheel portion 21 is smaller than the outer diameter of the first worm gear portion 11. The central axis of the first worm wheel portion 21 is coaxial or substantially coaxial with the central axis of the inner peripheral surface 24b of the tubular portion 24. In the absolute encoder 2, the central axis of the first worm wheel portion 21 is parallel or substantially parallel to the upper surface 104 of the base portion 101 of the base 3, allowing the outer diameter of the first worm wheel portion 21 to be decreased and thus the absolute encoder 2 in the up-down direction (height direction) to be reduced in size.

[0114] As illustrated in FIGS. 5, 6, 11 to 15, and others, the second worm gear portion 22 is composed of a tooth portion formed in a helical shape and is disposed coaxially or substantially coaxially with the first worm wheel portion 21. The second worm gear portion 22 is an example of a second drive gear. Specifically, the second worm gear portion 22 is provided at the other end portion side of the tubular portion 24 and is composed of, for example, the tooth portion formed in a helical shape and provided at a cylindrical surface formed at the other end portion side of the tubular portion 24. The other end portion side of the tubular portion 24 is a side of the end portion of the first intermediate gear 20 at the first layshaft gear 30 side. The central axis of the second worm gear portion 22 is coaxial or substantially coaxial with the central axis of the inner peripheral surface 24b of the tubular portion 24. When the second worm gear portion 22 meshes with the second worm wheel portion 31 provided at the first layshaft gear 30, the rotational force of the first intermediate gear 20 is transmitted to the first layshaft gear 30.

[0115] As described above, the axial angle between the first worm gear portion 11 and the first worm wheel portion 21 is 90° or substantially 90°, and the central axis of the first worm gear portion 11 and the central axis of the first worm wheel portion 21 are orthogonal or substantially orthogonal to each other when viewed from a direction perpendicular to the central axis of the first worm gear portion 11 and perpendicular to the central axis of the first worm wheel portion 21. Similarly, the axial angle between the second worm gear portion 22 and the second worm wheel portion 31 is 90° or substantially 90°, and the central axis of the second worm gear portion 22 and the central axis of the second worm wheel portion 31 are orthogonal or substantially orthogonal to each other when viewed from a direction perpendicular to the central axis of the second worm gear portion 22 and perpendicular to the central axis of the second worm wheel portion 31.

[0116] As illustrated in FIG. 15, the outer diameter of the second worm gear portion 22 is set as small as possible in order to achieve miniaturization of the absolute encoder 2 in the up-down direction (height direction).

[0117] As illustrated in FIGS. 6 and 11 to 13, the main shaft-side sliding portion 25 of the first intermediate gear 20 is provided at an end of the first intermediate gear 20, that

is, at an end of the first intermediate gear 20 at the main shaft gear 10 side. Specifically, the main shaft-side sliding portion 25 is an end surface of one end of the tubular portion 24 and is an annular surface facing the central axial direction of the first intermediate gear 20 formed at one end of the tubular portion 24. In the absolute encoder 2, the main shaft-side sliding portion 25 of the first intermediate gear 20 is in contact with one end 9a of the plate spring 9 described below.

[0118] The plate spring 9 is an example of an elastic member and is made of metal, for example. The plate spring 9 is a member for pushing the first intermediate gear 20 in the central axial direction of the first intermediate gear shaft 23 in the absolute encoder 2. As illustrated in FIGS. 4 to 6 and 13, the other end 9b of the plate spring 9 is supported on a projection 132a of the supporting projection 132 of the base 3 and is fixed to the supporting projection 45 of the base 3 by a screw 8b to be supported on the base 3. The one end 9a of the plate spring 9 is formed in contact with the main shaft-side sliding portion 25 of the first intermediate gear 20. Specifically, as illustrated in FIGS. 4 and 13, the one end 9a of the plate spring 9 is constituted by two branched portions divided into two prongs. A gap greater than the diameter of the first intermediate gear shaft 23 is formed between the two branched portions constituting the one end 9a of the plate spring 9. This causes, in the absolute encoder 2, the two branched portions of the one end 9a of the plate spring 9 to be in contact with the main shaft-side sliding portion 25 of the first intermediate gear 20 with the first intermediate gear shaft 23 passing through between the two branched portions.

[0119] As illustrated in FIGS. 4, 6, 11, and 13, in the absolute encoder 2, the plate spring 9 is supported on the supporting projection 132 of the base 3 and is fixed to the supporting projection 45 of the base 3 at the other end 9b such that the one end 9a is in contact with the main shaft-side sliding portion 25 of the first intermediate gear 20 in a state of the plate spring 9 being bent. Therefore, an elastic force is generated in the plate spring 9, and the main shaft-side sliding portion 25 of the first intermediate gear 20 is pressed by the one end 9a of the plate spring 9. The pressing force of the plate spring 9 biases the first intermediate gear 20 in a direction from the supporting projection 131 at the main shaft gear 10 side toward the supporting projection 141 at the first layshaft gear 30 side along the first intermediate gear shaft 23. When the first intermediate gear 20 rotates in this state, the main shaft-side sliding portion 25 of the first intermediate gear 20 rotates while being in contact with the one end 9a of the plate spring 9.

[0120] As illustrated in FIGS. 4, 6, and 11 to 14, the layshaft-side sliding portion 26 of the first intermediate gear 20 is provided at the other end of the first intermediate gear 20, that is, at an end of the first intermediate gear 20 at the first layshaft gear 30 side. Specifically, the layshaft-side sliding portion 26 is an end surface of the other end of the tubular portion 24, is an annular surface facing the central axial direction of the first intermediate gear 20 formed at the other end of the tubular portion 24 and opposes the main shaft-side sliding portion 25 in the central axial direction of the first intermediate gear 20.

[0121] In the absolute encoder 2, the layshaft-side sliding portion 26 of the first intermediate gear 20 is in contact with the supporting projection 141, and the supporting projection 141 defines the position of the first intermediate gear 20 in the central axial direction of the first intermediate gear shaft

23. As described above, since the first intermediate gear 20 is pressed by the plate spring 9 in a direction from the supporting projection 131 at the main shaft gear 10 side toward the supporting projection 141 at the first layshaft gear 30 side, the layshaft-side sliding portion 26 of the first intermediate gear 20 is also pressed in the same direction to be in contact with the supporting projection 141. In this way, the pressing force of the plate spring 9 is transmitted from the first layshaft gear 30 to the supporting projection 141, and the first intermediate gear 20 is stably supported in the direction from the supporting projection 131 toward the supporting projection 141. When the first intermediate gear 20 rotates, the layshaft-side sliding portion 26 of the first intermediate gear 20 rotates while being in contact with the supporting projection 141.

[0122] The supporting projection 131 and the supporting projection 141 described above are respectively examples of a first shaft supporting portion and a second shaft supporting portion rotatably holding the first intermediate gear 20 via the first intermediate gear shaft 23. As illustrated in FIGS. 5, 6, and 11 to 13, the supporting projection 131 and the supporting projection 141 are paired with each other and are, for example, substantially rectangular parallelepiped portions protruding upward from the base portion 101 of the base 3 or portions having substantially rectangular parallelepiped portions. The supporting projection 131 is provided near the main shaft gear 10 and is provided near the left side of the base 3 and near the center of the base 3 in the front-rear direction in plan view (see FIGS. 6 and 11). The supporting projection 141 is provided in the vicinity of the first layshaft gear 30, and is provided at the right side and the front side of the base 3 in plan view.

[0123] As illustrated in FIGS. 6 and 11 to 13, the supporting projection 131 and the supporting projection 141 serve as supporting members slidably supporting the first intermediate gear shaft 23 along the horizontal plane, that is, serve as supporting members slidably supporting the first intermediate gear 20 along the horizontal plane. The first intermediate gear shaft 23 is a columnar rod-like member, and includes a main shaft-side end portion 23a as one end portion and a layshaft-side end portion 23b as the other end portion. The main shaft-side end portion 23a is an end portion of the first intermediate gear shaft 23 located at the main shaft gear 10 side in the absolute encoder 2, and the layshaft-side end portion 23b is an end portion of the first intermediate gear shaft 23 located at the first layshaft gear 30 side in the absolute encoder 2.

[0124] By the biasing mechanism 40 described below, the first worm wheel portion 21 provided at the main shaft-side end portion 23a side of the first intermediate gear shaft 23 is movable in a first meshing direction (direction indicated by an arrow P1 in FIG. 12), and is not movable in the extension direction of the first intermediate gear shaft 23 (central axial direction of the first intermediate gear shaft 23) and a direction (up-down direction) orthogonal to the first meshing direction P1. As described above, the first worm wheel portion 21 moves toward the first worm gear portion 11 to mesh with the first worm gear portion 11 in a direction. This direction is the first meshing direction.

[0125] As illustrated in FIGS. 11 to 14, the supporting projection 131 is formed with a through hole 143. The main shaft-side end portion 23a of the first intermediate gear shaft 23 is inserted into the through hole 143. A shape of a cross section orthogonal to the extension direction of the through

hole **143** is a circular hole shape. The circular hole shape is a shape having a perfect circle or a substantially perfect circle profile.

[0126] The absolute encoder **2** may further include a snap ring (not illustrated) as a fixed portion formed to be engageable with the main shaft-side end portion **23a** of the first intermediate gear shaft **23**. The snap ring is a member forming a portion in the main shaft-side end portion **23a** of the first intermediate gear shaft **23**, the portion not passing through the through hole **143** of the supporting projection **131**, and is a member partially increasing an outer diameter of the main shaft-side end portion **23a** of the first intermediate gear shaft **23**. The snap ring is an annular member such as an e-ring engaging with a groove (not illustrated) formed in the first intermediate gear shaft **23**, for example. In the absolute encoder **2**, the snap ring is provided at the main shaft-side end portion **23a** of the first intermediate gear shaft **23** to be located on a side opposite to the layshaft-side end portion **23b** side with respect to the supporting projection **131**. That is, the snap ring is provided in contact with an outer surface **131a** of the supporting projection **131**. The outer surface **131a** is a surface of the supporting projection **131** facing a side opposite to the supporting projection **141** side. This restricts the movement of the first intermediate gear shaft **23** in a direction from the main shaft-side end portion **23a** toward the layshaft-side end portion **23b** due to contact between the snap ring and the outer surface **131a** of the supporting projection **131**.

[0127] By the biasing mechanism **40** described below, the second worm gear portion **22** provided at the layshaft-side end portion **23b** side of the first intermediate gear shaft **23** is movable in a second meshing direction (direction indicated by an arrow P2 in FIG. 12), and is not movable in the extension direction of the first intermediate gear shaft **23** (central axial direction of the first intermediate gear shaft **23**) and a direction (Z-axis direction) orthogonal to the second meshing direction P2. As described above, the second worm gear portion **22** moves toward the second worm wheel portion **31** to mesh with the second worm wheel portion **31** in a direction. This direction is the second meshing direction.

[0128] The supporting projection **141** is formed with a through hole **145**. The layshaft-side end portion **23b** of the first intermediate gear shaft **23** is inserted into the through hole **145**. A shape of a cross section orthogonal to the extension direction of the through hole **145** is an elongate hole shape. The elongate hole shape of the through hole **145** has a major axis and a minor axis orthogonal to the major axis. The major axis-side width is greater than the minor axis-side width. The major axis-side width of the elongate hole shape of the through hole **145** in the supporting projection **141** at the first layshaft gear **30** side is greater than the diameter of the outer peripheral surface of the first intermediate gear shaft **23**. The minor axis-side width of the through hole **145** is identical or substantially identical to the diameter of the outer peripheral surface of the first intermediate gear shaft **23**. In the absolute encoder **2**, the major axis direction of the through hole **145** in the supporting projection **141** is parallel or substantially parallel to the horizontal plane. The first intermediate gear shaft **23** with the layshaft-side end portion **23b** inserted into the through hole **145** of the supporting projection **141** is engaged with the biasing spring **41** as described below. The biasing spring **41** biases the layshaft-side end portion **23b** of the first intermediate gear shaft **23** in the second meshing direction P2.

[0129] In this way, by the biasing mechanism **40** described below, the supporting projection **131**, and the supporting projection **141**, the first intermediate gear shaft **23** is configured such that the layshaft-side end portion **23b** can move in parallel or substantially parallel to the horizontal direction with the main shaft-side end portion **23a** as a fulcrum (center of oscillation), and the second worm gear portion **22** at the layshaft-side end portion **23b** can move in parallel or substantially parallel to the horizontal direction over a larger width than the first worm wheel portion **21** at the main shaft-side end portion **23a** side. This allows the first intermediate gear shaft **23**, that is, the first intermediate gear **20** biased by the biasing mechanism **40** and supported on the supporting projection **131** and the supporting projection **141** to oscillate along the horizontal plane (XY plane).

[0130] In such a configuration, the amount of movement (amount of oscillation) of the first intermediate gear shaft **23** is determined by the depth of the through hole **143** formed in the supporting projection **131**, that is, the thickness of the supporting projection **131** in the central axial direction of the first intermediate gear shaft **23**, the clearance between the through hole **143** and the first intermediate gear shaft **23**, and the major axis-side width of the through hole **145**. However, when the clearance between the through hole **143** and the first intermediate gear shaft **23** is large, since the first intermediate gear shaft **23** is subject to more backlash and becomes misaligned, this clearance is preferably kept small. Therefore, by forming the supporting projection **131** with a thin plate or the like to reduce the thickness of the supporting projection **131**, that is, making the through hole **143** shallower, making it possible to ensure the amount of movement of the first intermediate gear shaft **23** while reducing the clearance between the through hole **143** and the first intermediate gear shaft **23**. The amount of movement of the first intermediate gear shaft **23** can be defined by the major axis-side width of the through hole **145** by setting the amount of movement of the first intermediate gear shaft **23** based on the thickness of the supporting projection **131** larger than the amount of movement of the first intermediate gear shaft **23** based on the major axis-side width of the through hole **145**.

[0131] First Layshaft Gear

[0132] FIG. 15 is a partial cross-sectional view schematically illustrating the configuration of the absolute encoder **2** in FIG. 2 cut along a plane through the central axis of the first layshaft gear **30** and orthogonal to the central axis of the first intermediate gear **20**. FIG. 16 is an exploded perspective view schematically illustrating the magnet Mq, the magnet holder **35**, the first layshaft gear **30**, and the bearing **135** disassembled in the configuration of the absolute encoder **2** in FIG. 15.

[0133] As illustrated in FIGS. 15 and 16, the first layshaft gear **30** is a cylindrical member, and in the first layshaft gear **30**, a shaft portion **35b** of the magnet holder **35** is press-fitted and fixed to the magnet holder **35**. The first layshaft gear **30** includes the second worm wheel portion **31**, the gear portion **32**, and a through hole **33**. The first layshaft gear **30** is an integrally formed member made of metal or resin, and in this embodiment, the first layshaft gear **30** is made of polyacetal resin as an example.

[0134] The second worm wheel portion **31** is a gear meshed with the second worm gear portion **22** of the first intermediate gear **20**. The second worm wheel portion **31** is an example of a second driven gear. The second worm wheel

portion 31 is composed of, for example, a plurality of teeth provided at the outer peripheral portion of an upper-side cylindrical portion of the first layshaft gear 30. When the first intermediate gear 20 rotates, the rotational force of the first intermediate gear 20 is transmitted to the first layshaft gear 30 via the second worm gear portion 22 of the first intermediate gear 20 and the second worm wheel portion 31.

[0135] The gear portion 32 is a gear meshing with the gear portion 71 of the second intermediate gear 70. The gear portion 32 is an example of a third drive gear. The gear portion 32 is composed of, for example, a plurality of teeth provided at the outer peripheral portion of a lower-side cylindrical portion of the first layshaft gear 30. As illustrated in FIG. 15, the gear portion 32 is formed below the second worm wheel portion 31, and the addendum circle diameter of the gear portion 32 is smaller than the addendum circle diameter of the second worm wheel portion 31. As the first layshaft gear 30 rotates, the rotational force of the first layshaft gear 30 is transmitted to the second intermediate gear 70 via the gear portion 32 of the first layshaft gear 30 and the gear portion 71 of the second intermediate gear 70.

[0136] As illustrated in FIGS. 15 and 16, the through hole 33 is a hole passing through the layshaft gear 30 having a cylindrical shape along the central axis of the cylindrical layshaft gear 30. The shaft portion 35b of the magnet holder 35 is press-fitted into the through hole 33, and the first layshaft gear 30 is configured to rotate integrally with the magnet holder 35.

[0137] The magnet holder 35 includes a magnet holding portion 35a and the shaft portion 35b. The magnet holder 35 is an integrally formed member made of metal or resin, and in this embodiment, the magnet holder 35 is made of non-magnetic stainless steel as an example. The outer rings of two of the bearings 135 are press-fitted into the inner peripheral surface of the tubular bearing holder portion 134 formed in the base 3. The shaft portion 35b of the magnet holder 35 is a columnar member. The shaft portion 35b is press-fitted into the through hole 33 of the first layshaft gear 30, and the lower portion of the shaft portion 35b is fixed by being inserted into inner rings of the two bearings 135. Accordingly, the magnet holder 35 is supported on the base 3 by the two bearings 135, and rotates integrally with the first layshaft gear 30. The magnet holder 35 is held by the bearing holder portion 134 via the bearing 135 to be rotatable around a rotation axis parallel or substantially parallel to the Z-axis. A bearing stopper 35c is press-fitted into the shaft portion 35b of the magnet holder 35. In assembling the first layshaft gear 30, the outer ring of the bearing 135 installed at the upper surface 104 side of the base 3 is first press-fitted into the bearing holder portion 134, and then the shaft portion 35b of the magnet holder 35 is inserted into the inner ring of the bearing 135. Subsequently, the bearing stopper 35c is press-fitted into the shaft portion 35b of the magnet holder 35 until the bearing stopper 35c contacts the lower side of the inner ring of the bearing 135. Subsequently, while the shaft portion 35b of the magnet holder 35 is inserted into the inner ring of the bearing 135 installed at the lower surface 102 side of the base 3, and the outer ring is fixed by being press-fitted into the bearing holder portion 134. Thus, the bearing stopper 35c can prevent the magnet holder 35 inserted into the bearing 135 from being removed from the bearing 135, and the bearing 135 and the magnet holder 35 can be fixed with no gap, allowing backlash of the magnet Mg in the up-down direction to be minimized as

much as possible. Although the press-fitting positions of the two bearings 135 are determined by contacting bearing positioning members 35d provided at the base 3, the two bearings 135 may be positioned to make the surfaces of the upper surface 104 and the lower surface 102 of the base 3 and the surfaces of the bearings 135 to have the same height without the bearing positioning members 35d.

[0138] The magnet holding portion 35a is provided at the upper end of the magnet holder 35. The magnet holding portion 35a is a bottomed cylindrical member. The magnet holding portion 35a has a depression recessed from the upper end surface of the magnet holder 35 toward the lower side. The inner peripheral surface of the depression in the magnet holding portion 35a is formed in contact with an outer peripheral surface Mqd of the magnet Mq. This causes, in the absolute encoder 2, the magnet Mq to be accommodated in the depression of the magnet holding portion 35a to be fixed to the magnet holding portion 35a.

[0139] Since the shaft portion 35b of the magnet holder 35 is supported by the two bearings 135 disposed in the bearing holder portion 134 formed in the base 3, the magnet holder 35 can be prevented from tilting. Further, disposing the two bearings 135 at the furthest possible distance away from each other in the up-down direction of the shaft portion 35b increases the effect of preventing the magnet holder 35 from tilting.

[0140] As illustrated in FIG. 16, the magnet Mq is a disk-shaped or substantially disk-shaped permanent magnet to be press-fitted into the magnet holding portion 35a of the magnet holder 35, and has an upper surface Mqa and a lower surface Mqb. In the absolute encoder 2, the upper surface Mqa of the magnet Mq faces the lower surface of the angle sensor Sp with a certain distance in between. A central axis MqC of the magnet Mq (axis representing the center of the magnet Mq or axis passing through the center of a magnetic pole boundary) coincides with a central axis SC of the magnet holder 35, a central axis GC2 of the first layshaft gear 30, and a central axis BC of the bearing 135. When these central axes are made to coincide with each other, the rotation angle or the amount of rotation can be detected with higher accuracy.

[0141] In an embodiment of the present invention, the two magnetic poles (N/S) of the magnet Mq are preferably formed adjacent to each other in the horizontal plane (XY plane) perpendicular to the central axis MqC of the magnet Mq. This can further improve the detection accuracy of the rotation angle or the amount of rotation by the angle sensor Sq. The magnet Mq is formed from a magnetic material such as a ferritic material, an Nd (neodymium)—Fe (iron)—B (boron) material. The magnet Mq may be, for example, a rubber magnet or a bond magnet including a resin binder.

[0142] Second Intermediate Gear

[0143] FIG. 17 is a partial cross-sectional view schematically illustrating the configuration of the absolute encoder 2 in FIG. 2 cut along a plane through the central axes of the second intermediate gear 70 and the second layshaft gear 63. FIG. 18 is an enlarged cross-sectional view illustrating the second intermediate gear 70 illustrated in FIG. 17.

[0144] As illustrated in FIGS. 17 and 18, the second intermediate gear 70 is a member rotatably supported on the shaft 75 fixed to the shaft supporting portion 136 of the base 3, and includes the gear portion 71, the gear portion 72, and a main body portion 73. The second intermediate gear 70 is, for example, a member integrally formed from a resin

material having low sliding resistance, and an example of the resin material of the second intermediate gear 70 is polyacetal resin. The shaft 75 is fixed to the shaft supporting portion 136 of the base 3 so that a central axis GC3 of the second intermediate gear 70 is parallel or substantially parallel to the central axis GC2 of the first layshaft gear 30, and for example, a portion at the lower end (lower end surface 75a) side of the shaft 75 is fixed by being press-fitted into a through hole 136a of the shaft supporting portion 136 of the base 3.

[0145] The main body portion 73 is a cylindrical or substantially cylindrical portion and has a through hole 74 inside. The through hole 74 is formed so that the shaft 75 is slidably inserted into the through hole 74. The gear portion 71 is a gear meshed with the gear portion 32 of the first layshaft gear 30. The gear portion 71 is an example of a third driven gear. The gear portion 71 is composed of, for example, a plurality of teeth provided at a lower-side outer peripheral portion of the main body portion 73. As the first layshaft gear 30 rotates, the rotational force of the first layshaft gear 30 is transmitted to the gear portion 71 of the second intermediate gear 70 via the gear portion 32 of the first layshaft gear 30. As a result, the second intermediate gear 70 rotates.

[0146] The gear portion 72 is a gear meshing with the gear portion 64 of the second layshaft gear 63. The gear portion 72 is an example of a fourth drive gear. The gear portion 72 is composed of, for example, a plurality of teeth provided at an upper-side outer peripheral portion of the main body portion 73, and is provided above the gear portion 71. As the second intermediate gear 70 rotates, the rotational force of the second intermediate gear 70 is transmitted to the gear portion 64 of the second layshaft gear 63 via the gear portion 72. As a result, the second layshaft gear 63 rotates.

[0147] As illustrated in FIGS. 17 and 18, in the second intermediate gear 70, the through hole 74 is a hole extending through the main body portion 73 so that the central axis of the through hole 74 coincides or substantially coincides with the central axis of each of the gear portion 71 and the gear portion 72. The through hole 74 is formed so that the central axis GC3 of the second intermediate gear 70 coincides or substantially coincides with the central axis of the shaft 75.

[0148] An end surface on a lower side (lower end surface 73a) of the main body portion 73 is formed in contact with the upper surface 104 of the base 3 and slidably with respect to the upper surface 104. The lower end surface 73a of the main body portion 73 is, for example, a plane or a substantially plane orthogonal or substantially orthogonal to the central axis GC3 of the second intermediate gear 70. An end surface on an upper side (upper end surface 73b) of the main body portion 73 is formed in contact with a member facing the upper end surface 73b and slidably with respect to the member. The upper end surface 73b of the main body portion 73 is, for example, a plane or a substantially plane orthogonal or substantially orthogonal to the central axis GC3 of the second intermediate gear 70.

[0149] An annular groove 75c is formed around the axial line of the shaft 75 in a portion at an upper end (upper end surface 75b) side of the shaft 75, and a snap ring 76 is formed to be engageable with the groove 75c. The snap ring 76 is a member for holding a state of the second intermediate gear 70 being rotatably supported on the shaft 75 and is a member for partially increasing an outer diameter of a portion of the shaft 75 at the upper end surface 75b side. As

illustrated in FIG. 18, the snap ring 76 is, for example, an annular member such as a c-ring or an e-ring. In the absolute encoder 2, the groove 75c is provided in the shaft 75 so that the snap ring 76 faces the upper end surface 73b of the main body portion 73 of the second intermediate gear 70. In the absolute encoder 2, the snap ring 76 attached to the groove 75c may be in contact with the upper end surface 73b of the second intermediate gear 70, or may face the upper end surface 73b of the second intermediate gear 70 with a gap. Movement of the second intermediate gear 70 in the axial direction of the shaft 75 is restricted by the snap ring 76.

[0150] The second intermediate gear 70 is configured as described above, the shaft 75 is inserted into the through hole 74 of the second intermediate gear 70 and the snap ring 76 is attached to the groove 75c of the shaft 75 in the absolute encoder 2, and the second intermediate gear 70 is attached in the absolute encoder 2. In the absolute encoder 2, the second intermediate gear 70 is rotatable about a rotation axis parallel or substantially parallel to the central axis GC2 of the first layshaft gear 30 with the shaft 75 as a rotation axis. The second intermediate gear 70 is slidably on the upper surface 104 of the base 3 and the snap ring 76 attached to the shaft 75, restricting movement of the second intermediate gear 70 in the axial direction of the shaft 75.

[0151] Second Lay shaft Gear

[0152] FIG. 19 is an enlarged cross-sectional view illustrating the magnet holder 61 including the second layshaft gear 63 illustrated in FIG. 17, and FIG. 20 is an exploded perspective view schematically illustrating an exploded state of the magnet holder 61 illustrated in FIG. 19.

[0153] As illustrated in FIGS. 17, 19, and 20, the magnet holder 61 is a member rotatably supported on the second layshaft gear shaft 62 fixed to the shaft supporting portion 137 of the base 3, and includes the second layshaft gear 63, a magnet holder portion 65, and the magnet Mr. The magnet holder portion 65 is a member for fixing the magnet Mr in the magnet holder 61 by interposing the magnet Mr in the magnet holder 61 by interposing between the magnet holder portion 65 and the second layshaft gear 63. The second layshaft gear shaft 62 is fixed to the shaft supporting portion 137 of the base 3 so that an axial line (central axis GC4) of second layshaft gear shaft 62 is parallel or substantially parallel to the central axis GC3 of the second intermediate gear 70, and for example, a portion of the second layshaft gear shaft 62 at a lower end (lower end surface 62a) side is fixed by being press-fitted into the through hole 137a of the shaft supporting portion 137 of the base 3. In the absolute encoder 2, the second layshaft gear shaft 62 is fixed to the base 3 so that the magnet Mr of the magnet holder 61 faces the angle sensor Sr attached to the substrate 5, in the direction of the central axis GC3.

[0154] The second layshaft gear 63 includes the gear portion 64, a main body portion 66, and a magnet supporting portion 67. The second layshaft gear 63 is a member integrally formed from a resin material having low sliding resistance. That is, the gear portion 64, the main body portion 66, and the magnet supporting portion 67 are integrally formed from the same material and each form part of the second layshaft gear 63. Polyacetal resin is an example of the resin material of the second layshaft gear 63. The main body portion 66 is a cylindrical or substantially cylindrical portion and has a through hole 66a inside. The through hole 66a is formed so that the second layshaft gear shaft 62 is slidably inserted into the through hole 66a. The gear portion

64 is a gear meshed with the gear portion **72** of the second intermediate gear **70**. The gear portion **64** is an example of a fourth driven gear. The gear portion **64** is composed of, for example, a plurality of teeth provided at the outer peripheral portion of the main body portion **66**. In the illustrated example, the gear portion **64** forms a disc-shaped portion protruding from the outer peripheral surface of the main body portion **66** in the outer peripheral direction, and a plurality of teeth are provided at the outer peripheral surface of the disc-shaped portion. As the second intermediate gear **70** rotates, the rotational force of the second intermediate gear **70** is transmitted to the gear portion **64** of the second layshaft gear **63** via the gear portion **72** of the second intermediate gear **70**. As a result, the second layshaft gear **63** rotates.

[0155] As illustrated in FIGS. 17 and 19, in the second layshaft gear **63**, the through hole **66a** is a hole extending through the main body portion **66** so that the central axis of the through hole **66a** coincides or substantially coincides with the central axis of the gear portion **64**. The through hole **66a** is formed so that the central axis GC4 of the second layshaft gear **63** coincides or substantially coincides with the central axis of the second layshaft gear shaft **62**.

[0156] An end surface on a lower side (lower end surface **66b**) of the main body portion **66** is formed in contact with the upper surface **104** of the base **3** and slidably with respect to the upper surface **104**. The lower end surface **66b** of the main body portion **66** is, for example, a plane or a substantially plane orthogonal or substantially orthogonal to the central axis GC4 of the second layshaft gear **63**. An end surface on an upper side (upper end surface **66c**) of the main body portion **66** is formed in contact with a member faced by the upper end surface **66c** and slidably with respect to the member. The upper end surface **66c** of the main body portion **66** is, for example, a plane or a substantially plane orthogonal or substantially orthogonal to the central axis GC4 of the second layshaft gear **63**.

[0157] The magnet supporting portion **67** is a portion extending upward from a portion of the main body portion **66** above the gear portion **64**, and is a tubular portion extending along the central axis GC4 of the second layshaft gear **63**. The magnet supporting portion **67** extends upward beyond the upper end surface **66c** of the main body portion **66**, and a cylindrical space is formed inside the magnet supporting portion **67** by the upper end surface **66c** of the main body portion **66** and a surface (inner peripheral surface **67a**) facing the inner peripheral side of the magnet supporting portion **67**. The outer peripheral surface **67b** of the magnet supporting portion **67** is located at the inner peripheral side from a distal end of the gear portion **64**. The magnet supporting portion **67** is, for example, a cylindrical or substantially cylindrical member centered or substantially centered on the central axis GC4 of the second layshaft gear **63**. As illustrated in FIG. 19, the upper end surface **66c** of the main body portion **66** is connected to the inner peripheral surface **67a** of the magnet supporting portion **67**, and the main body portion **66** may be larger at the outer peripheral side than the portion below the gear portion **64** at the portion connected to the magnet supporting portion **67**, or may not be larger at the outer peripheral side than the portion below the gear portion **64** at the portion connected to the magnet supporting portion **67**. The shape of the magnet supporting portion **67** is not limited to a cylindrical shape or a substantially cylindrical shape, and may be another shape. For

example, the shape of the magnet supporting portion **67** may be a rectangular tube shape or the like.

[0158] An end surface on an upper side (upper end surface **67c**) of the magnet supporting portion **67** is a plane or a substantially plane orthogonal or approximately orthogonal to the central axis GC4 of the second layshaft gear **63**. In the absolute encoder **2**, the inner peripheral surface **67a** of the magnet supporting portion **67** is located at the inner peripheral side from the surface (outer peripheral surface Mrd) facing the outer peripheral side of the magnet Mr so that the magnet Mr can contact the entire circumference of the upper end surface **67a**. In the absolute encoder **2**, the magnet supporting portion **67** is formed so that the upper end surface **67c** is located above an end surface on an upper side (upper end surface **62b**) of the second layshaft gear shaft **62**. The upper end surface **67c** of the magnet supporting portion **67** is parallel or substantially parallel to the upper surface **104** of the base **3**, and when the second layshaft gear **63** rotates, the upper end surface **67c** rotates without surface wobbling with respect to the upper surface **104** of the base **3**.

[0159] The magnet holder portion **65** is made of a bottomed cylindrical resin material. The resin material of the magnet holder portion **65** is, for example, a resin material. An adhesive adheres to the resin material. Specifically, the magnet holder portion **65** has a tubular portion **68** extending in a tubular shape and a bottom portion **69** extending from an end at one end side of the tubular portion **68** to an inner peripheral side. The tubular portion **68** forms a fitting portion **65a** configured to accommodate the magnet supporting portion **67** of the second layshaft gear **63** inside and allows the magnet holder portion **65** to be fitted into the magnet supporting portion **67**. The tubular portion **68** and the bottom portion **69** form a magnet accommodating portion **65b** configured to accommodate and hold the magnet Mr inside.

[0160] In the absolute encoder **2**, the tubular portion **68** of the magnet holder portion **65** has an inner peripheral surface **68a** having a cylindrical surface shape or a substantially cylindrical surface shape extending along a central axis coinciding or substantially coinciding with the central axis MC4 of the second layshaft gear **63**. The inner peripheral surface **68a** is a surface facing the inner peripheral side, is a surface extending toward the bottom portion **69** from an end (opening end **68c**) of the tubular portion **68** on a side opposite to an end at the bottom portion **69** side, and forms an opening at the opening end **68c** of the tubular portion **68**. A space formed inside by the inner peripheral surface **68a** is the fitting portion **65a**. The inner peripheral surface **68a** is formed in contact with the outer peripheral surface **67b** of the magnet supporting portion **67** so that the magnet supporting portion **67** is tightly fitted into the magnet holder portion **65** when the magnet supporting portion **67** of the second layshaft gear **63** is accommodated in the fitting portion **65a**. The shape of the inner peripheral surface **68a** of the tubular portion **68** is not limited to a cylindrical shape or a substantially cylindrical shape, and may be another shape. The shape of the inner peripheral surface **68a** of the tubular portion **68** corresponds to the shape of the magnet supporting portion **67** to be accommodated.

[0161] In the absolute encoder **2**, the tubular portion **68** of the magnet holder portion **65** has an inner peripheral surface **68b** having a cylindrical surface shape or a substantially cylindrical surface shape extending along a central axis coinciding or substantially coinciding with the central axis

MC4 of the second layshaft gear 63 and extending along a central axis coinciding or substantially coinciding with the central axis MrC of the magnet Mr. The inner peripheral surface 68b is a surface facing the inner peripheral side, and is a surface extending between the inner peripheral surface 68a and a bottom surface 69a of the bottom portion 69. A space formed inside by the inner peripheral surface 68b and the bottom surface 69a of the bottom portion 69 is the magnet accommodating portion 65b. The inner peripheral surface 68b is formed facing the outer peripheral surface Mrd of the magnet Mr in the radial direction when the magnet Mr is accommodated in the magnet accommodating portion 65b. The inner peripheral surface 68b is located at an inner peripheral side from the inner peripheral surface 68a, and a step is formed between the inner peripheral surface 68a and the inner peripheral surface 68b. The width of the inner peripheral surface 68b in the central axial direction is smaller than the width of the magnet Mr in the direction of the central axis MrC. The inner peripheral surface 68b may be formed facing the outer peripheral surface Mrd of the magnet Mr with a space between the inner peripheral surface 68b and the magnet Mr in the radial direction or may be formed facing the outer peripheral surface Mrd of the magnet Mr without a space between the inner peripheral surface 68b and the magnet Mr in the radial direction when the magnet Mr is accommodated in the magnet accommodating portion 65b.

[0162] The bottom portion 69 of the magnet holder portion 65 is a disk-shaped portion extending toward the inner peripheral side from an end (closed end 68d) of the tubular portion 68 on a side opposite to the opening end 68c, and has the bottom surface 69a described above. The bottom surface 69a is a surface facing the magnet accommodating portion 65b, and is a surface along a plane or a substantially plane orthogonal or substantially orthogonal to the central axis of the tubular portion 68. The bottom portion 69 is formed with an opening 69b, a through hole passing through the bottom portion 69 in the central axial direction of the tubular portion 68. The bottom surface 69a of the bottom portion 69 is formed in contact with an upper surface Mra of the magnet Mr in an orientation of the magnet Mr having the central axis MrC of the magnet Mr parallel or substantially parallel to the central axis of the tubular portion 68 when the magnet Mr is accommodated in the magnet accommodating portion 65b. The opening portion 69b of the bottom portion 69 is formed so that the magnetic flux of the magnet Mr passes through the opening portion 69b when the magnet Mr is accommodated in the magnet accommodating portion 65b.

[0163] As described above, the second layshaft gear shaft 62 is made of a magnetic material, and an attractive force due to a magnetic force is generated between the magnet Mr and the second layshaft gear shaft 62 in the rotation axis direction of the magnet holder 61. Specifically, the second layshaft gear shaft 62 generates a magnetic force urging the magnet Mr in the direction of the second layshaft gear shaft 62.

[0164] An annular groove 62c is formed around the axial line of the second layshaft gear shaft 62 in a portion at the upper end (upper end surface 62b) side of the second layshaft gear shaft 62, and a snap ring 62d is formed to be engageable with the groove 62c. The snap ring 62d is a member for restricting the movement of the magnet holder 61 in the axial direction of the second layshaft gear shaft 62, and is a member for partially increasing the outer diameter

of a portion of the second layshaft gear shaft 62 at the upper end surface 62b side. As illustrated in FIG. 19, the snap ring 62d is, for example, an annular member such as a c-ring or an e-ring. In the absolute encoder 2, the groove 62c is provided in the second layshaft gear shaft 62 so that the snap ring 62d faces the upper end surface 66c of the main body portion 66 of the second layshaft gear 63 with a space between the snap ring 62d and the upper end surface 66c.

[0165] As illustrated in FIGS. 19 and 20, the magnet Mr is a disk-shaped or substantially disk-shaped permanent magnet to be accommodated in the magnet accommodating portion 65b of the magnet holder portion 65, and has the upper surface Mra, a lower surface Mrb, and the outer peripheral surface Mrd. In an embodiment of the present invention, the two magnetic poles (N/S) of the magnet Mr are preferably formed adjacent in the horizontal plane (XY plane) perpendicular to the central axis MrC of the magnet Mr. This can further improve the detection accuracy of the rotation angle or the amount of rotation by the angle sensor Sr. The magnet Mr is formed from a magnetic material such as a ferritic material, an Nd (neodymium) —Fe (iron) —B (boron) material. The magnet Mr may be, for example, a rubber magnet or a bond magnet including a resin binder. FIG. 21 is a schematic perspective view illustrating the cylindrical magnet Mr applicable to an embodiment of the present invention. In the magnet Mr of the illustrated example, a first magnetic pole portion N and a second magnetic pole portion S are provided adjacent to each other side by side in a radial direction D1 with the center or substantially the center of the magnet Mr in the radial direction D1 as a boundary. In the magnet Mr of the illustrated example, the first magnetic pole portion N and the second magnetic pole portion S are provided adjacent to each other side by side in an axial direction D2 with the center or substantially the center in the axial (central axis MrC) direction D2 as a boundary. An arrow DM illustrated in FIG. 21 indicates a magnetization direction. Such a magnetization direction is generally called in-plane magnetization, and a magnet magnetized in the in-plane direction is used as the magnet Mr.

[0166] The magnet holder 61 is configured as described above, the second layshaft gear shaft 62 is inserted into the through hole 66a of the main body portion 66 of the second layshaft gear 63 and the snap ring 62d is attached to the groove 62c of the second layshaft gear shaft 62 in the absolute encoder 2, and the second layshaft gear 63 is attached in the absolute encoder 2. In the absolute encoder 2, the magnet holder 61 is rotatable around the rotation axis. The rotation axis of the magnet holder 61 coincides or substantially coincides with the central axis GC4 of the second layshaft gear shaft 62. The snap ring 62d and a portion of the second layshaft gear shaft 62 at the upper end surface 62b side are accommodated in a space formed at the inner peripheral side by the magnet supporting portion 67 of the second layshaft gear 63.

[0167] In the absolute encoder 2, the magnet Mr is accommodated in the magnet accommodating portion 65b of the magnet holder portion 65 and is fixed to the magnet holder portion 65. The magnet Mr is fixed to the magnet holder portion 65 by bonding with an adhesive. For example, the inner peripheral surface 68b forming the magnet accommodating portion 65b of the magnet holder portion 65 and the outer peripheral surface Mrd of the magnet Mr are bonded to each other with an adhesive. Fixing the magnet Mr to the

magnet holder portion **65** with the lower surface Mrb of the magnet Mr in contact with the bottom surface **69a** forming the magnet accommodating portion **65b** of the magnet holder portion **65** allows the central axis MrC of the magnet Mr to coincide with the central axis of the second layshaft gear shaft **62**, the central axis MrC of the magnet Mr to coincide with the rotation axis of the second layshaft gear shaft **62**, and the angle sensor Sr to detect the amount of rotation or the rotation angle of the magnet Mr with higher accuracy. The fixing of the magnet Mr to the magnet accommodating portion **65b** is not limited to the fixing by an adhesive, and may be achieved by another fixing method such as press-fitting of the magnet Mr to the magnet accommodating portion **65b** as in the first layshaft gear **30**.

[0168] In the absolute encoder **2**, the magnet holder portion **65** with the magnet Mr fixed as described above is fitted into the magnet supporting portion **67** of the second layshaft gear **63**, the magnet holder portion **65** is fixed to the second layshaft gear **63**, and the magnet holder **61** is assembled. Specifically, the magnet supporting portion **67** is press-fitted into the fitting portion **65a** of the magnet holder portion **65**, the inner peripheral surface **65a** forming the fitting portion **65a** of the magnet holder portion **65** presses the outer peripheral surface **67b** of the magnet supporting portion **67** to the inner peripheral side. The outer peripheral surface **67b** of the magnet supporting portion **67** presses the inner peripheral surface **68a** of the magnet holder portion **65** to the outer peripheral side, and the magnet holder portion **65** is fixed to the second layshaft gear **63**. The magnet holder portion **65** may be fixed to the second layshaft gear **63** not only by fitting but also by another fixing method.

[0169] In the magnet holder **61** assembled by fixing the magnet holder portion **65** to the second layshaft gear **63**, the magnet Mr is interposed and fixed between the second layshaft gear **63** and the magnet holder portion **65**. Specifically, the upper end surface **67c** of the magnet supporting portion **67** comes into contact with the lower surface Mrb of the magnet Mr, the magnet Mr is interposed between the upper end surface **67c** of the magnet supporting portion **67** and the bottom surface **69a** of the bottom portion **69** of the magnet holder portion **65**, and the magnet Mr is fixed in the direction of the central axis MrC. On the other hand, fixing of the magnet Mr in the radial direction orthogonal to the central axis MrC is achieved by adhesion between the outer peripheral surface Mrd of the magnet Mr and the inner peripheral surface **68b** of the magnet holder portion **65**.

[0170] In the absolute encoder **2**, the upper surface Mra of the magnet Mr faces the angle sensor Sr in the central axial MrC direction of the magnet Mr via the opening **69b** formed in the bottom portion **69** of the magnet holder portion **65**. This allows the angle sensor Sr to detect a magnetic flux from the magnet Mr.

[0171] As described above, the magnet holder **61** attached to the absolute encoder **2** is rotatable about the rotation axis parallel or substantially parallel to the central axis GC3 of the second intermediate gear **70** with the second layshaft gear shaft **62** as a rotation shaft.

[0172] The second layshaft gear shaft **62** is made of a magnetic material and generates a magnetic force urging the magnet Mr toward the second layshaft gear shaft **62**. Therefore, in the absolute encoder **2**, the magnetic force from the second layshaft gear shaft **62** acts on the magnet Mr and attracts the magnet Mr toward the second layshaft gear shaft **62**. When the absolute encoder **2** is in the illustrated orien-

tion (upright state), the lower end surface **66b** of the main body portion **66** of the second layshaft gear **63** is slidably in contact with the upper surface **104** of the base **3**, and an axial force from the second layshaft gear shaft **62** biases the magnet holder **61** in a direction of the lower end surface **66b** of the second layshaft gear **63** contacting the upper surface **104** of the base **3**. A magnet magnetized in the plane direction has a characteristic that the magnetic flux density is concentrated at the center of the magnet as compared with a magnet magnetized in the radial direction. As described above, the magnet Mr is a magnet magnetized in the plane direction, and the second layshaft gear shaft **62** is made of a magnetic material. Thus, the magnetic flux density of the magnet Mr is more concentrated near the center of the magnet Mr due to the magnetic material of the second layshaft gear shaft **62**, thus allowing the angle sensor Sr to accurately detect a magnetic flux in the absolute encoder **2**.

[0173] On the other hand, when the absolute encoder **2** is inverted in the up-down direction (inverted state) from the illustrated upright state, the magnet holder **61** can move relative to the second layshaft gear shaft **62** in the direction of the central axis MC4 of the second layshaft gear **63** due to the gap between the snap ring **62d** and the upper end surface **66c** of the main body portion **66** of the second layshaft gear **63**. That is, the magnet Mr moves to the angle sensor Sr side, and an interval between the magnet Mr and the angle center Sr can be changed. However, in the absolute encoder **2**, the second layshaft gear shaft **62** is made of a magnetic material, and the second layshaft gear shaft **62** attracts the magnet Mr toward the second layshaft gear shaft **62** by the magnetic force of the magnetic material. Accordingly, even when the absolute encoder **2** is in the inverted state, the magnet holder **61** is held with the lower end surface **66b** of the second layshaft gear **63** in contact with the upper surface **104** of the base **3**, maintaining the position of the magnet holder **61** in the central axis MC4 direction in the upright state and preventing the magnet Mr from moving to the angle sensor Sr side. Therefore, even in the inverted state, the interval between the magnet Mr and the angle center Sr is maintained at the interval in the upright state.

[0174] As described above, in the absolute encoder **2**, the interval between the magnet Mr and the angle center Sr is not changed depending on the use orientation of the absolute encoder **2**, and the influence of the use orientation of the absolute encoder **2** on the detection accuracy can be reduced.

[0175] The movement of the second layshaft gear **63** in the axial direction of the second layshaft gear shaft **62** is restricted by the snap ring **62d** attached to the second layshaft gear shaft **62**. That is, the movement of the magnet holder **61** in the axial direction of the second layshaft gear shaft **62** is restricted. Therefore, even when a large impact is applied to the absolute encoder **2** and a force is applied to move the magnet holder **61** upward in the axial direction of the second layshaft gear shaft **62** against the magnetic force of the second lay shaft gear shaft **62**, the movement of the magnet holder **61** is restricted by the snap ring **62d**. Therefore, the occurrence of problems such as coming-off of the magnet holder **61** from the second layshaft gear shaft **62** can be prevented.

[0176] As described above, the magnet supporting portion **67** in the second layshaft gear **63** has the upper end surface **67c**, an end surface on the upper side, also serving as a magnet supporting portion supporting the magnet Mr on the upper side of the second layshaft gear **63**. The magnet holder

portion 65 serves as a magnet holding portion configured to cover the magnet Mr and the second layshaft gear 63 from above and hold the magnet Mr on the upper end surface 67c of the magnet supporting portion 67.

[0177] The magnet holder portion 65 is made of a resin material having a higher breaking elongation characteristic than the second layshaft gear 63. The magnet holder portion 65 has the bottom surface 69a of the bottom portion 69 serving as a magnet joining portion, and the inner peripheral surface 68a serving as the fitting portion 65a.

[0178] The assembly structure by press-fitting is one of construction methods relatively easily performed without requiring special equipment in terms of ensuring the concentricity of members to be assembled. In the press-fit structure between resins such as the magnet holder portion 65 and the second layshaft gear 63, the securing of the holding and centering of assembled components and the securing of the holding strength between press-fit members need to be considered using part of the shape of the member, specifically, the outer peripheral surface 67b of the magnet supporting portion 67 as a guide. Therefore, for the resin material of the magnet holder portion 65 and the second layshaft gear 63, a material having a tendency of a low linear expansion coefficient and a high elastic modulus needs to be selected using a filler-added reinforcing material. However, such a resin material having a low linear expansion coefficient and a high elastic modulus is likely to be cracked at the time of press-fitting in terms of strength, and obtaining durability for maintaining the press-fitted state is difficult.

[0179] The magnet holder portion 65 having the fitting portion 65a has an escape place for deformation after press-fitting in the outer peripheral direction, and is likely to receive tensile stress. On the other hand, since the second layshaft gear 63 at the shaft side to be press-fitted has no place to escape deformation after the magnet holder portion 65 is press-fitted, the risk of breakage due to stress is low compared to the magnet holder portion 65. Thus, focusing on the breaking elongation characteristic of a material in the absolute encoder 2 and adopting the magnet holder portion 65 having a characteristic of the breaking elongation larger than the second layshaft gear 63 without changing the reinforcing filler content rate can prevent breakage at the time of press-fitting. The breaking elongation characteristic (elongation at break) is an elongation at break of a test piece in a tensile test, or an elongation immediately before break between predetermined gauge points.

[0180] Second Layshaft Gear Shaft

[0181] A specific shape of the second layshaft gear shaft 62 described above is described below. FIG. 22 is an enlarged cross-sectional view illustrating one end portion 62f of the second layshaft gear shaft 62 at the lower end surface 62a side.

[0182] As described above, the second layshaft gear shaft 62 of the second layshaft gear 63 is a shaft press-fitted into and fixed to the through hole 137a of the shaft supporting portion 137 of the base portion 101 of the base 3. As illustrated in FIG. 22, the second layshaft gear shaft 62 has a tapered surface portion 62e. The tapered surface portion 62e is an inclined outer peripheral surface such that the diameter of the one end portion 62f is smaller than the diameter of a peripheral surface 62g. The tapered surface portion 62e is connected by a curved surface to a connecting portion 62h on the outer peripheral surface between the tapered surface portion 62e and the peripheral surface 62g of

the second layshaft gear shaft 62. That is, the tapered surface portion 62e is subjected to curved surface processing at the connecting portion 62h on the outer peripheral surface between the tapered surface portion 62e and the peripheral surface 62g.

[0183] FIGS. 23 and 24 are schematic views illustrating a state of the second layshaft gear shaft 62 being press-fitted into the through hole 137a of the base portion 101 of the base 3.

[0184] As illustrated in FIGS. 23 and 24, when the second layshaft gear shaft 62 according to another embodiment of the shaft support structure of the present invention is press-fitted into the through hole 137a of the base 3, the tapered surface portion 62e is inserted into the through hole 137a, and then the connecting portion 62h at the outer peripheral surface between the tapered surface portion 62e and the peripheral surface 62g comes into contact with the through hole 137a. Similar to the connecting portions 126a and 127a of the tapered surface portions 126 and 127 of the main shaft adapter 12, the connecting portion 62h is also subjected to the curved surface processing, and thus the second layshaft gear shaft 62 is smoothly press-fitted into the through hole 137a. This can prevent both the second layshaft gear shaft 62 and the through hole 137a from being scraped. The surface roughness Rmax (maximum roughness) of the surface of the main shaft adapter 12 may be, for example, 1.6 [μm] or less. Therefore, the second layshaft gear shaft 62 can suppress scattering of shavings and the like similar to the main shaft adapter 12. According to the second layshaft gear shaft 62, the second layshaft gear shaft 62 can be suppressed from falling (inclining) and being press-fitted due to the member being cut. Further, the second layshaft gear shaft 62 suppresses the inclination of the second layshaft gear shaft 62 and can reduce a press-fitting margin (dimension necessary for press-fitting).

[0185] In the shaft support structure of the absolute encoder 2, an example of the connecting portion subjected to curved surface processing at the outer peripheral surface between the tapered surface portion and the peripheral surface in the shaft press-fitted into the supporting member is not limited to the main shaft adapter 12 or the second layshaft gear shaft 62 described above. In the absolute encoder 2, for example, the curved surface processing may be performed on a connecting portion at the outer peripheral surface between the tapered surface portion and the peripheral surface in the supporting shaft of the first layshaft gear 30.

[0186] In the absolute encoder 2, the main shaft gear 10, the first intermediate gear 20, the first layshaft gear 30, the second intermediate gear 70, and the second layshaft gear 63 are provided as described above, the rotation axes of the main shaft gear 10 and the first layshaft gear 30 are parallel to each other, and the rotation axis of the first intermediate gear 20 is located at a twisted position with respect to the rotation axes of the main shaft gear 10 and the first layshaft gear 30. The rotation axes of the first layshaft gear 30, the second intermediate gear 70, and the second layshaft gear 63 are parallel to one another. By arranging each gear in this manner, the amount of rotation of the main shaft gear 10 over multiple rotations can be specified according to the detection results of the angle sensors Sq and Sr. Since the rotation axis of the first intermediate gear 20 is located at a twisted position with respect to the rotation axes of the main shaft gear 10 and the first layshaft gear 30 and is orthogonal

to the rotation axes in front view, the absolute encoder 2 can include a bent transmission path and be made thinner.

[0187] Backlash Reduction Mechanism

[0188] As described above, the absolute encoder 2 includes the biasing mechanism 40 biasing the second worm gear portion 22 in the direction of the second worm wheel portion 31, and the biasing mechanism 40 is a backlash reduction mechanism configured to reduce backlash between the second worm gear portion 22 and the second worm wheel portion 31. As illustrated in FIGS. 5, 6, 11, 14, and others, the biasing mechanism 40 includes the biasing spring 41, the supporting projection 45, and the screw 8b for fixing the biasing spring 41 to the supporting projection 45. The through hole 143 of the supporting projection 131 and the through hole 145 of the supporting projection 141 of the base 3 also constitute the biasing mechanism 40.

[0189] The biasing spring 41 is a member for generating a pressing force pressing the second worm gear portion 22 in the direction of the second worm wheel portion 31, and is an elastic member. The biasing spring 41 is, for example, a plate spring, and is made of a metal plate. As illustrated in FIGS. 12 and 14, specifically, the biasing spring 41 includes a spring portion 42 being a portion elastically deforming to generate a pressing force, and an engaging portion 43 and a fixed portion 44 being opposing portions interposing the spring portion 42 between the engaging portion 43 and the fixed portion 44. The engaging portion 43 and the fixed portion 44 are portions forming a pair of end portions of the biasing spring 41.

[0190] The fixed portion 44 is formed to be fixable to the supporting projection 45 protruding from the upper surface 104 of the base portion 101 of the base 3 by using the screw 8b. The screw 8b is an example of a fixing member, and the fixed portion 44 is formed with a hole 44a. The screw 8b is inserted into the hole 44a. The fixed portion 44 extends in a planar shape and is configured to be fixed to the supporting projection 45 by the screw 8b while in contact with a planar supporting surface 45a of the supporting projection 45.

[0191] The engaging portion 43 has a shape capable of engaging with the layshaft-side end portion 23b of the first intermediate gear shaft 23. As illustrated in FIGS. 13 and 14, the engaging portion 43 includes, for example, an engaging groove 43a forming a gap extending along an extension direction from the spring portion 42 of the engaging portion 43. The engaging groove 43a is a groove open to a side of a tip end edge 43b being an end edge opposing a connecting portion 43c of the engaging portion 43 with the spring portion 42, and is formed by a branched portion divided into two prongs, similar to the one end 9a of the plate spring 9 described above. The engaging portion 43 extends in a planar shape. The layshaft-side end portion 23b of the first intermediate gear shaft 23 is formed with an engaged groove 23d being an annular groove extending in a direction orthogonal or substantially orthogonal to the central axis of the first intermediate gear shaft 23, and the engaging groove 43a of the engaging portion 43 can engage with the engaged groove 23d. When one side of the engaging groove 43a parallel to the up-down direction presses the first intermediate gear shaft 23 in the engaged groove 23d, the first intermediate gear 20 is biased in the direction of the second worm gear portion 22 moving toward the second worm wheel portion 31. Two sides of the engaging groove 43a parallel to the left-right direction are in contact with the first intermediate gear shaft 23 in the engaged groove 23d, and

movement of the biasing spring 41 in the up-down direction is restricted by the first intermediate gear shaft 23.

[0192] The spring portion 42 has a shape being likely to elastically deform in the engaging direction of the engaging portion 43 with the first intermediate gear shaft 23, and specifically, as illustrated in FIG. 14, the spring portion 42 has a shape likely to deflect in the extension direction of the engaging groove 43a. For example, the spring portion 42 is curved protruding in a direction opposite to the direction of biasing the first intermediate gear 20.

[0193] The biasing spring 41 is fixed to the supporting projection 45 by the screw 8b at the fixed portion 44 in an orientation of the spring portion 42 being raised from the fixed portion 44 on the side opposite to the supporting projection 45. The dimensions of the spring portion 42 and the engaging portion 43, the angle of the extension direction of the engaging portion 43 with respect to the extension direction of the spring portion 42, and the like are set so that the engaging groove 43a of the engaging portion 43 engages with the engaged groove 23d of the first intermediate gear shaft 23 in this fixed state and that the spring portion 42 generates a pressing force for pressing the engaging portion 43 against the first intermediate gear shaft 23 in this engaged state. In the fixed and engaged state of the biasing spring 41, when the snap ring (not illustrated) described above is attached to the first intermediate gear shaft 23, a snap ring 144 is in contact with the outer surface of the supporting projection 141. To achieve a backlash reduction function described below, the engaging groove 43a of the engaging portion 43 is preferably formed extending in a direction orthogonal or substantially orthogonal to the central axis of the first intermediate gear shaft 23 in the fixed state of the biasing spring 41. The snap ring may be omitted as described above because the biasing spring 41 can restrict the movement of the first intermediate gear shaft 23 in the central axial direction.

[0194] As illustrated in FIGS. 5, 6, 11, 14, and others, the plate spring 9 and the biasing spring 41 are integrally formed as one member. Specifically, the other end 9b of the plate spring 9 and the fixed portion 44 of the biasing spring 41 are integrally formed and made of the same member. That is, the plate spring 9 and the biasing spring 41 are formed by a continuous elastic member and are each part of the continuous elastic member, and the other end 9b of the plate spring 9 and the fixed portion 44 of the biasing spring 41 are formed in the same part of the continuous elastic member.

[0195] The action of the biasing mechanism 40 of the absolute encoder 2 is described below.

[0196] In the absolute encoder 2, the first intermediate gear shaft 23 is supported at the base 3 by the main shaft-side end portion 23a being inserted into the through hole 143 formed in the supporting projection 131 of the base 3 and the layshaft-side end portion 23b being inserted into the through hole 145 formed in the supporting projection 141 of the base 3. In this way, the first intermediate gear shaft 23 is supported on the supporting projections 131 and 141.

[0197] The first intermediate gear 20 is rotatably supported on the first intermediate gear shaft 23 in this way. Due to the action of the plate spring 9, the first intermediate gear 20 is biased toward the supporting projection 141, and the layshaft-side sliding portion 26 of the first intermediate gear 20 is in contact with an inner surface 141a of the supporting projection 141 (see FIG. 13).

[0198] As described above, the through hole 145 has an elongate hole shape with the major axis longer than the minor axis and supports the layshaft-side end portion 23b of the first intermediate gear shaft 23, the layshaft-side end portion 23b is supported to be movable along the major axis of the through hole 145, that is, within the range of the width of the major axis of the through hole 145 along with the horizontal plane. On the other hand, the through hole 143 supporting the main shaft-side end portion 23a of the first intermediate gear shaft 23 has a circular hole shape, and thus, in the absolute encoder 2, the first intermediate gear shaft 23 can oscillate along the horizontal plane by the through holes 143 and 145 of the supporting projections 141 and 142 and the biasing mechanism 40, with the supported portion of the main shaft-side end portion 23a as a center or a substantial center.

[0199] In the first intermediate gear shaft 23 supported in this manner, the engaging portion 43 of the biasing spring 41 is engaged with the engaged groove 23d of the layshaft-side end portion 23b, and the biasing spring 41 applies a biasing force to the layshaft-side end portion 23b of the first intermediate gear shaft 23 to press the second worm gear portion 22 of the first intermediate gear 20 toward the direction (second meshing direction P2) of the second worm wheel portion 31 of the first layshaft gear 30. This causes the second worm gear portion 22 of the first intermediate gear 20 to be pressed against the second worm wheel portion 31 of the first layshaft gear 30 and causes a so-called “bottoming-out” phenomenon between the second worm gear portion 22 and the second worm wheel portion 31, resulting in the backlash between gears of zero.

[0200] Since the layshaft-side end portion 23b at the moving side of the first intermediate gear shaft 23, supported in an oscillating manner, is biased by the biasing spring 41, the first intermediate gear shaft 23 is constantly biased in the direction of the second worm gear portion 22 moving toward the second worm wheel portion 31 during oscillation. Therefore, the backlash between the second worm gear portion 22 and the second worm wheel portion 31 can always be made zero without causing rotation malfunction between gears due to oscillation of the first intermediate gear shaft 23.

[0201] For example, when the ambient temperature around the absolute encoder 2 is high, the first layshaft gear 30 expands according to the linear expansion coefficient of the material, and the pitch circles of the gears of the second worm wheel portion 31 expand. At this time, when the through hole 145 formed in the supporting projection 141 of the base 3 is not an elongate hole as in the present embodiment but a circular hole, the layshaft-side end portion 23b of the first intermediate gear shaft 23 is fixed by the through hole 145, and the first intermediate gear shaft 23 cannot oscillate as in the present embodiment. Therefore, the second worm wheel portion 31 of the first layshaft gear 30, having expanded gear pitch circles due to the increase in temperature, may come into forceful contact with the second worm gear portion 22 of the first intermediate gear 20 and the gear may not rotate.

[0202] Additionally, when the ambient temperature around the absolute encoder 2 is low, the first layshaft gear 30 contracts according to the linear expansion coefficient of the material, and the pitch circles of the gears of the second worm wheel portion 31 are reduced. At this time, when the through hole 145 formed in the supporting projection 141 of the base 3 is not an elongate hole as in the present embodi-

ment but a circular hole, the layshaft-side end portion 23b of the first intermediate gear shaft 23 is fixed by the through hole 145, and the first intermediate gear shaft 23 cannot oscillate as in the present embodiment. In this case, the backlash between the second worm gear portion 22 of the first intermediate gear 22 and the second worm wheel portion 31 of the first lay shaft gear 30 increases, and the rotation of the first intermediate gear 22 is not accurately transferred to the first layshaft gear 30.

[0203] In contrast, in the absolute encoder 2 according to the present embodiment, as described above, the first intermediate gear shaft 23 is supported in a manner allowing the first intermediate gear shaft 23 to oscillate along the horizontal plane with the supported portion of the main shaft-side end portion 23a as a center or a substantial center, and the first intermediate gear 20 is constantly biased by the biasing mechanism 40 from the second worm gear portion 22 side to the second worm wheel portion 31 side. Additionally, the first intermediate gear 20 supported on the first intermediate gear shaft 23 is biased toward the supporting projection 141 by the plate spring 9. Therefore, even when a change in the ambient temperature occurs and the pitch circles of the gears of the second worm wheel portion 31 of the first layshaft gear 30 are changed as described above, the backlash becomes zero while the tooth surfaces between the second worm gear portion 22 and the second worm wheel portion 31 are kept in contact by an appropriate pressing force. Therefore, non-rotation of the gear due to a change in temperature and deterioration of the accuracy of the rotation transmitted from the first intermediate gear 20 to the first layshaft gear 30 can be avoided.

[0204] Therefore, in the absolute encoder 2, the influence of backlash in the reduction mechanism on detection accuracy can be reduced. This can broaden the range of the specifiable amount of rotation of the main shaft 1a while maintaining the specifiable resolution of the amount of rotation of the main shaft 1a.

[0205] Regardless of the position of the layshaft-side end portion 23b of the first intermediate gear shaft 23 due to oscillation, the biasing mechanism 40 is preferably set so that a constant or substantially constant pressing force is generated from the biasing spring 41.

[0206] As described above, the through hole 143 of the supporting projection 131 supporting the main shaft-side end portion 23a of the first intermediate gear shaft 23 has a circular hole shape, the through hole 145 of the supporting projection 141 supporting the layshaft-side end portion 23b has an elongate hole shape with the major axis-side width larger than the minor axis-side width, and the first intermediate gear shaft 23 can oscillate in parallel or substantially parallel to the horizontal direction with the through hole 143 of the supporting projection 141 as a fulcrum. Therefore, during oscillation of the first intermediate gear shaft 23, the amount of movement of the second worm gear portion 22 relative to the second worm wheel portion 31 is greater than the amount of movement of the first worm wheel portion 21 relative to the first worm gear portion 11, and the first worm gear portion 11 and the first worm wheel portion 21 do not bottom out even when the second worm gear portion 22 and the second worm wheel portion 31 bottom out.

[0207] As illustrated in FIGS. 10 to 13, the through hole 145 supporting the first intermediate gear shaft 23 at the layshaft-side end portion 23b forms a tubular surface or a substantially cylindrical surface, but the through hole 145 is

not limited to having such a shape. For example, as illustrated in FIG. 25, the cross-sectional shape of the through hole 145 may be a rectangle or a substantial rectangle instead of an elongate hole. That is, the through hole 145 may be a through hole extending in a quadrangular pillar shape and forming a pair of surfaces 145a opposing each other and a pair of surfaces 145b opposing each other. The pair of surfaces 145a and the pair of surfaces 145b forming the through hole 145 may be flat surfaces or curved surfaces. In the absolute encoder 2, the pair of surfaces 145a extend in the horizontal direction, and the pair of surfaces 145b extend in the up-down direction. The width in the horizontal direction of the surface 145a is greater than the width in the up-down direction of the surface 145b. The first intermediate gear shaft 23 can oscillate also in the through hole 145 illustrated in FIG. 25 similar to the through hole 145 described above.

[0208] Similarly, the through hole 143 is not limited to having the shape described above. For example, the through hole 143 may have a so-called knife edge structure. Specifically, the through hole 143 may be in contact with the first intermediate gear shaft 23 by line contact or point contact. For example, as illustrated in (a) and (b) of FIG. 26, the through hole 143 may be formed by a pair of conical or substantially conical inclined surfaces 143c having a smaller diameter further inward along the extension direction of the through hole 143. In this case, the through hole 143 is in contact with and supports the first intermediate gear shaft 23 along an annular line (connecting line 143d) depicting a circular hole of the connecting portions of the pair of inclined surfaces 143c. The circular hole shape of the connecting line 143d has a similar shape in plan view to the circular hole shape of the through hole 143 described above. Since the through hole 143 supports the first intermediate gear shaft 23 by line contact or point contact, the first intermediate gear shaft 23 can oscillate even though the diameter of the circular hole of the through hole 143 is made closer to the diameter of the first intermediate gear shaft 23. Therefore, the cross-sectional shape of the through hole 143 can be made closer to a shape having no gap between the through hole 143 and the first intermediate gear shaft 23. This can suppress movement of the portion of the first intermediate gear shaft 23 in contact with the through hole 143 during oscillation of the first intermediate gear shaft 23, and the oscillation of the first intermediate gear shaft 23 can suppress variation in the distance between the first worm gear portion 11 and the first worm wheel portion 21. The through hole 145 of the supporting projection 141 may also have the so-called knife edge structure like the through hole 143 of the supporting projection 131 described above, or may be formed by a pair of conical or substantially conical inclined surfaces forming an annular line depicting an elongate hole.

[0209] As illustrated in (a) and (b) of FIG. 27, the through hole 145 may be formed by a pair of quadrangular pyramid-shaped or substantially quadrangular pyramid-shaped inclined surfaces 145e tapering toward the inner side in the extension direction of the through hole 145. In this case, the through hole 145 is in contact with and supports the first intermediate gear shaft 23 along an annular line (connecting line 145f) depicting a rectangular shape or substantially rectangular shape of connecting portions of the pair of inclined surfaces 145e. The connecting line 145f has line portions 145g being a pair of portions opposing each other,

and line portions 145h being a pair of portions opposing each other. The pair of line portions 145g and the pair of line portions 145h may be straight lines or curved lines. In the absolute encoder 2, the pair of line portions 145g extend horizontally, and the pair of line portions 145h extend in the up-down direction. The length of the line portion 145g is greater than the length of the line portion 145h in the up-down direction. The through hole 143 of the supporting projection 131 may also be formed by a pair of quadrangular pyramid-shaped or substantially quadrangular pyramid-shaped inclined surfaces forming an annular line depicting a rectangular shape or a substantially rectangular shape, similar to the through hole 145 of the supporting projection 142 described above. In this case, the annular line is a square or a substantial square. In this case as well, similar to the case in FIG. 26 described above, since the through hole 143 supports the first intermediate gear shaft 23 by line contact or point contact, the first intermediate gear shaft 23 can oscillate even though the length of the line portion extending in the up-down direction (corresponding to the line portion 145h in FIG. 27) and the length of the line portion extending in the horizontal direction (corresponding to the line portion 145g in FIG. 27) are made closer to the diameter of the first intermediate gear shaft 23. Therefore, the shape of the through hole 143 can be made closer to a shape having no gap in the up-down direction and the horizontal direction between the through hole 143 and the first intermediate gear shaft 23. This can suppress movement of the portion of the first intermediate gear shaft 23 in contact with the through hole 143 during oscillation of the first intermediate gear shaft 23, and the oscillation of the first intermediate gear shaft 23 can suppress variation in the distance between the first worm gear portion 11 and the first worm wheel portion 21.

[0210] Control Unit

[0211] A control unit of the absolute encoder 2 is described below. FIG. 28 is a view of the substrate 5 in FIG. 2 when viewed from the lower surface 5a side. The microcomputer 51, a line driver 52, a bidirectional driver 53, and the connector 6 are mounted on the substrate 5. The microcomputer 51, the line driver 52, the bidirectional driver 53, and the connector 6 are electrically connected by pattern wiring on the substrate 5.

[0212] The bidirectional driver 53 performs bidirectional communication with an external device connected to the connector 6. The bidirectional driver 53 converts data such as operation signals into differential signals to communicate with the external device. The line driver 52 converts data representing the amount of rotation into a differential signal, and outputs the differential signal in real time to the external device connected to the connector 6. The connector 6 is connected to a connector of the external device.

[0213] FIG. 29 is a block diagram schematically illustrating a functional configuration of the absolute encoder 2 in FIG. 1. Each block of the microcomputer 51 illustrated in FIG. 29 represents a function implemented by executing a program by using a central processing unit (CPU) serving as the microcomputer 51.

[0214] The microcomputer 51 includes a rotation angle acquisition unit 51p, a rotation angle acquisition unit 51q, a rotation angle acquisition unit 51r, a table processing unit 51b, a rotation amount specifying unit 51c, and an output unit 51e. The rotation angle acquisition unit 51p acquires a rotation angle θ_p of the main shaft gear 10 based on a signal

output from the angle sensor Sp. The rotation angle Ap is angle information indicating the rotation angle of the main shaft gear 10. The rotation angle acquisition unit 51q acquires a rotation angle Aq of the first layshaft gear 30 based on a signal output from the magnetic sensor Sq. The rotation angle Aq is angle information indicating the rotation angle of the first layshaft gear 30. The rotation angle acquisition unit 51r acquires a rotation angle Ar of the magnet holder 61, that is, the second layshaft gear 63, based on a signal output from the magnetic sensor Sr. The rotation angle Ar is angle information indicating the rotation angle of the second layshaft gear 63.

[0215] The table processing unit 51b refers to a first correspondence table storing the rotation number of the main shaft gear 10 corresponding to the rotation angle Aq of the first layshaft gear 30 and the rotation angle Ar of the second layshaft gear 63, and specifies the rotation number of the main shaft gear 10 corresponding to the acquired rotation angles Aq and Ar. The rotation amount specifying unit 51c specifies the amount of rotation of the main shaft gear 10 over multiple rotations according to the rotation number of the main shaft gear 10 (main shaft 1a) specified by the table processing unit 51b and the acquired rotation angle Ap of the main shaft gear 10. The output unit 51e converts the amount of rotation of the main shaft gear 10 over the multiple rotations into information indicating the amount of rotation, and outputs the information, the amount of rotation being specified by the rotation amount specifying unit 51c.

[0216] An embodiment of the present invention has been described above, but the present invention is not limited to the absolute encoder 2 according to the embodiment of the present invention described above and includes any aspects included in the gist of the present invention and the scope of the claims. Further, configurations may be combined with each other or combined with known technology as appropriate to at least partially address the problem described above and achieve the effects described above. For example, a shape, a material, an arrangement, a size, and the like of each of the components in the embodiment described above may be changed as appropriate according to a specific usage aspect of the present invention.

REFERENCE SIGNS LIST

[0217] 1 Motor, 1a Main shaft, 1b Press-fitting portion, 2 Absolute encoder, 3 Base, 3a Supporting plate, 4 Case, 4a Outer wall portion, 4b Lid portion, 4c Claw portion, 5 Substrate, 5a Lower surface, 5b Positioning hole, 6 Connector, 8a Screw, 8b Screw, 8c Screw, 9 Plate spring, 9a One end, 9b Other end, 10 Main shaft gear, 11 First worm gear portion, 12 Main shaft adapter, 12a Upper end surface, 13 Tubular portion, 13a Upper end surface, 14 Press-fitting portion, 15 Magnet holding portion, 15a Inner peripheral surface, 15b Bottom surface, 20 First intermediate gear, 21 First worm wheel portion, 22 Second worm gear portion, 23 First intermediate gear shaft, 23a Main shaft-side end portion, 23b Layshaft-side end portion, 23c Groove, 23d Engaged groove, 24 Tubular portion, 24a Through hole, 24b Inner peripheral surface, 25 Main shaft-side sliding portion, 26 Layshaft-side sliding portion, 30 First layshaft gear, 31 Second worm wheel portion, 32 Gear portion, 33 Through hole, 35 Magnet holder, 35a Magnet holding portion, 35b Shaft portion, 35c Bearing stopper, 35d Bearing positioning

member, 40 Biasing mechanism, 41 Biasing spring, 42 Spring portion, 43 Engaging portion, 43a Engaging groove, 43b Tip end edge, 43c Connecting portion, 44 Fixed portion, 44a Hole, 45 Supporting projection, 45a Supporting surface, 51 Microcomputer, 51b Table processing unit, 51c Rotation amount specifying unit, 51e Output unit, 51p Rotation angle acquisition unit, 51q Rotation angle acquisition unit, 51r Rotation angle acquisition unit, 52 Line driver, 53 Bidirectional driver, 60 Magnetism detection device, 61 Magnet holder, 62 Second layshaft gear shaft, 62a Lower end surface, 62b Upper end surface, 62c Groove, 62d Snap ring, 62e Tapered surface portion, 62f One end portion, 62g Peripheral surface, 62h Connecting portion, 63 Second layshaft gear, 64 Gear portion, 65 Magnet holder portion, 65a Fitting portion, 65b Magnet accommodating portion, 66 Main body portion, 66a Through hole, 66b Lower end surface, 66c Upper end surface, 67 Magnet supporting portion, 67a Inner peripheral surface, 67b Outer peripheral surface, 67c Upper end surface, 68 Tubular portion, 68a Inner peripheral surface, 68b Inner peripheral surface, 68c Opening end, 68d Closed end, 68e Outer peripheral surface, 69 Bottom portion, 69a Bottom surface, 69b Opening portion, 70 Second intermediate gear, 71 Gear portion, 72 Gear portion, 73 Main body portion, 73a Lower end surface, 73b Upper end surface, 74 Through hole, 75 Shaft, 75a Lower end surface, 75b Upper end surface, 75c Groove, 76 Snap ring, 78 Screw, 100 Shielding member, 101 Base portion, 102 Lower surface, 103 Recessed portion, 104 Upper surface, 105 Outer peripheral surface, Right-side outer peripheral surface, 106 Rear-side outer peripheral surface, 106 Outer peripheral surface, 107 Left-side outer peripheral surface, 107 Outer peripheral surface, 108 Outer peripheral surface, 108 Front-side outer peripheral surface, 110 Substrate pillar, 111 Upper end surface, 112 Screw hole, 120 Substrate positioning pin, 121 Tip end portion, 122 Base portion, 123 Stepped surface, 124 One end portion, 125 Other end portion, 126 Tapered surface portion, 126a Connecting portion, 127 Tapered surface portion, 127a Connecting portion, 128 Through hole, 128a First hole portion, 128b End portion, 128c Second hole portion, 129 Peripheral surface, 131 Supporting projection, 131a Outer surface, 132 Supporting projection, 132a Projection, 134 Bearing holder portion, 135 Bearing, 136 Shaft supporting portion, 136a Through hole, 137 Shaft supporting portion, 137a Through hole, 141 Supporting projection, 141a Inner surface, 142 Supporting projection, 143 Through hole, 143c Inclined surface, 143d Connecting line, 144 Snap ring, 145 Through hole, 145a Surface, 145b Surface, 145e Inclined surface, 145f Connecting line, 145g Line portion, 145h Line portion, Ap Angle information, Aq Angle information, BC Center of bearing, GC1 Central axis of main shaft gear, GC2 Central axis of second layshaft gear, GC3 Central axis, GC4 Central axis, MoC Central axis of main shaft of motor, Mp Magnet, Mpa Upper surface, Mpb Lower surface, MpC Central axis of magnet, Mpd Outer peripheral surface, Mq Magnet, Mpa Upper surface, Mqb Lower surface, MqC Central axis of magnet, Mqd Outer peripheral surface, Mr Magnet, Mra Upper surface, Mrb Lower surface, MrC Central axis of

magnet, Mrd Outer peripheral surface, P Biasing direction, P1 First meshing direction, P2 Second meshing direction, R1 First transmission mechanism, R2 Second transmission mechanism, SaC Central axis of main shaft adapter, SC Central axis of magnet holder, Sp Angle sensor, Sq Angle sensor, Sr Angle sensor, XYZ Orthogonal coordinate system

1. A shaft support structure, comprising:
 - a shaft; and
 - a supporting member having a hole for press-fitting the shaft from one end,
 wherein the shaft includes a tapered surface portion having a diameter of the one end smaller than a diameter of a peripheral surface, and the tapered surface portion is subjected to curved surface processing at a connecting portion with the peripheral surface.
2. The shaft support structure according to claim 1, wherein the shaft has a through hole passing through from the one end to the other end, and the through hole has a hole diameter in a region having a predetermined length in an axial direction from a side of the one end larger than a hole diameter at a side of the other end.
3. A magnetism detection device, comprising:
 - a magnet magnetized;
 - a magnetic sensor configured to detect a magnetic flux from the magnet;
 - a magnet holder holding the magnet;
 - a shaft rotatably supporting the magnet; and
 - a supporting member having a hole for press-fitting the shaft from one end,

- wherein the shaft comprises:
- a press-fitting portion as a region having a predetermined length in an axial direction from one end of a peripheral surface to be press-fitted into the hole; and
 - a tapered surface portion having a diameter of the one end smaller than a diameter of a peripheral surface, and the tapered surface portion is subjected to curved surface processing at a connecting portion with the peripheral surface.
4. The magnetism detection device according to claim 3, wherein the shaft has a through hole passing through from the one end to the other end, and the through hole has a hole diameter in a region having a predetermined length in an axial direction from a side of the one end larger than a hole diameter at a side of the other end.
 5. The magnetism detection device according to claim 3, comprising:
 - a magnet supporting portion supporting the magnet at a tip end side of the shaft; and
 - a magnet holding portion configured to cover the magnet and the magnet supporting portion from the tip end side of the shaft and hold the magnet at the tip end side of the shaft,
 wherein the magnet holding portion is made of a material having a higher breaking elongation characteristic than the magnet supporting portion and comprises:
 - a magnet joining portion in contact with a surface at the tip end side of the shaft and an outer peripheral portion of the magnet; and
 - a fitting portion fitted into an outer peripheral portion of the magnet supporting portion.
 6. An absolute encoder comprising a magnetism detection device according to claim 3.

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