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(71) Applicant: ENPLAS CORPORATION [JP/JP]; 2-30-1 Namiki, Kawaguchi-shi, Saitama, 3320034 (JP).

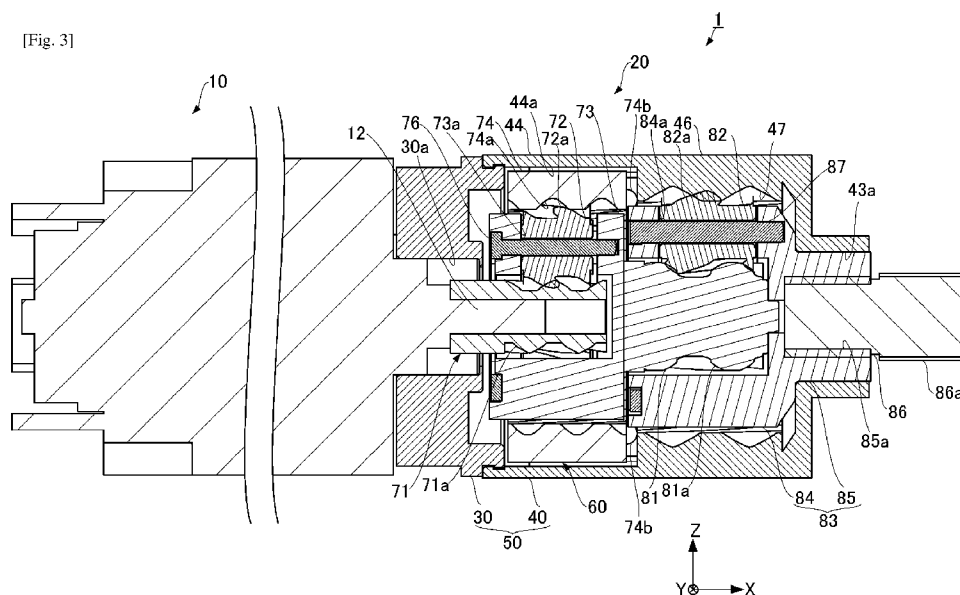
(72) Inventors: KAWADA, Toshiki; c/o ENPLAS CORPORATION, 2-30-1 Namiki, Kawaguchi-shi, Saitama, 3320034 (JP). ISHIDA, Shohei; c/o ENPLAS CORPORATION, 2-30-1 Namiki, Kawaguchi-shi, Saitama, 3320034 (JP). KANEKO, Takuya; c/o ENPLAS CORPORATION, 2-30-1 Namiki, Kawaguchi-shi, Saitama, 3320034 (JP).

(74) Agent: INABA, Yoshiyuki et al.; TMI ASSOCIATES, 23rd Floor, Roppongi Hills Mori Tower, 6-10-1, Roppongi, Minato-ku, Tokyo, 1066123 (JP).

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(54) Title: A GEAR HOUSING FOR A PLANETARY GEAR DEVICE THAT STRUCTURALLY ISOLATES AN INNER GEAR

[Fig. 3]



(57) Abstract: [Technical Problem] To provide separate structural units for an inner gear and a housing, that suppress transmission of vibration from a planetary gear mechanism and suppress noise produced by a planetary gear device. [Solution to Problem] Separate structural units for an inner gear and a housing comprise: an inner gear where first raised portions that extends from one side to the other side in the axial direction is formed on the outer peripheral surface; and a housing where a second raised portion that extends from one side to the other side in the axial direction is formed on the inner peripheral surface, and which contains an inner gear in a state wherein there is a gap from the inner peripheral surface. The movement of the inner gear within the interior of the housing is limited through linear contact of the first raised portion and the second raised portion.

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Description

Title of Invention: A GEAR HOUSING FOR A PLANETARY GEAR DEVICE THAT STRUCTURALLY ISOLATES AN INNER GEAR

Technical Field

[0001] The present invention relates to separate structural units for an inner gear and a housing, a planetary gear device comprising said separate structural units, and an actuator comprising said planetary gear device.

Background Art

[0002] Planetary gear devices are used in a variety of technologies, such as automobiles, robots, and the like. Because planetary gear devices are structured through a combination of a plurality of gears, noise and vibration is produced during operation. Technologies have been proposed to suppress the production of noise and vibration when the planetary gear device is operating.

[0003] As one of such technologies that has been proposed, Patent Document 1 discloses a planetary gear device with a structure that separates the inner gear and the housing, with a gap between the two. Using a structure wherein the inner gear and the housing are separate makes transmission of vibrations from the inner gear to the housing more difficult, reducing the noise that is produced from the vibrations.

Citation List

Patent Literature

[0004] [Patent Document 1] Japanese Unexamined Patent Application Publication H06-074835

Summary of Invention

Technical Problem

[0005] In the planetary gear device of Patent Document 1, the outer peripheral surface of the inner gear and the inner peripheral surface of the housing are formed with shapes that fit together. Because of this, when the inner gear moves during operation of the planetary gear device, there is contact between the outer peripheral surface of the inner gear and the inner peripheral surface of the housing, in a range that has some degree of width. Through this, in the state wherein there is contact between the inner gear and the housing, the vibration of the planetary gear mechanism that propagates to the inner gear is readily transmitted to the housing, so there is a problem in that there is a tendency for the planetary gear device to also produce noise.

[0006] The present invention is to solve problem areas such as described above, and the

object is to provide separate structural units for the inner gear and the housing, able to suppress transmission of the vibrations from the planetary gear mechanism and noise that is produced by the planetary gear device, and to provide a planetary gear device equipped with the separate structural units, and an actuator equipped with the planetary gear device.

Solution to Problem

- [0007] Separate structural units for an inner gear and a housing according to the present invention comprise: an inner gear having a first raised portion, extending in the axial direction from one side to the other side, is formed on the outer peripheral surface; and a housing wherein a second raised portion extending in the axial direction from one side to the other side is formed on the inner peripheral surface, and that contains the inner gear in a state wherein there is a gap from the inner peripheral surface, wherein: the movement of the inner gear within the interior of the housing is limited through linear contact between the first raised portion and the second raised portion.
- [0008] Of the first raised portion and the second raised portion, one raised portion may be formed in a pair with a space therebetween, and the other raised portion may be disposed so as to be inserted between the one raised portion that is formed in a pair; and of the location of contact of the one raised portion and the location of contact of the other raised portion, which linearly contact each other, at least one may be a curved surface.
- [0009] The one raised portion may be the second raised portion and the other raised portion may be the first raised portion; and the first raised portion may have a cross-section that is triangular when sectioned by a plane that is perpendicular to the axial direction, and may linearly contact the second raised portion at an inclined surface that is formed in a plane.
- [0010] Of the location of contact of the first raised portion and the location of contact of the second raised portion, which linearly contact each other, one may be a convex curved surface and the other may be a plane.
- [0011] The location of contact of the first raised portion and the location of contact of the second raised portion, which linearly contact each other, may be convex curved surfaces.
- [0012] Of the location of contact of the first raised portion and the location of contact of the second raised portion, which linearly contact each other, one may be a convex curved surface and the other may be a concave curved surface.
- [0013] The first raised portion and the second raised portion may make linear contact along the axial direction, where the range of linear contact of the first raised portion and the second raised portion may be shorter than the axial direction width of the inner gear.

- [0014] The length with which the first raised portion extends on the inner gear may be shorter than the axial direction width of the inner gear.
- [0015] The first raised portion may extend from only one end of the inner gear.
- [0016] The first raised portion may extend from both ends of the inner gear, and the lengths of the first raised portions that extend from both ends may be shorter than the axial direction width of the inner gear.
- [0017] A plurality of first raised portions may be provided on the inner gear along the axial direction, at intervals from each other.
- [0018] The movement of the inner gear within the interior of the housing may be limited through linear contact between the first raised portion and the second raised portion in a direction that is perpendicular to the axial direction.
- [0019] Of the first raised portions and the second raised portions, one may have a cross-section that is a triangle, when sectioned by a plane that is perpendicular to the axial direction, where the cross-sectional size of the triangle may vary depending on the position in the axial direction, and contact with the other is at a position that has the maximal cross-sectional size.
- [0020] Separate structural units for an inner gear and a housing according to another aspect of the present invention comprise: an inner gear having a first raised portion formed on the outer peripheral surface; a housing wherein a second raised portion is formed on the inner peripheral surface thereof, for containing the inner gear in a state wherein a gap is provided from the inner peripheral surface, wherein: the movement of the inner gear within the interior of the housing is limited through point contact between the first raised portion and the second raised portion.
- [0021] The first raised portion may be formed on the outer peripheral surface of the inner gear so as to extend from one side to the other side in the axial direction, and the second raised portion may be formed on the inner peripheral surface of the housing so as to extend from one side to the other side in the axial direction.
- [0022] A protrusion may be formed on the first raised portion or the second raised portion at the location of contact between the first raised portion and the second raised portion, and the first raised portion and the second raised portion may make point contact through the protrusion.
- [0023] A plurality of the protrusions may be formed along the axial direction.
- [0024] The first raised portion may have a cross-section that is triangular when sectioned by a plane that is perpendicular to the axial direction, and the protrusion may be formed on an inclined surface that forms a plane.
- [0025] The inner gear and the housing may be made from a synthetic resin; and the inner gear may be formed from a synthetic resin of a hardness that is less than that of the synthetic resin for forming the housing.

- [0026] A planetary gear device according to the present invention comprises: separate structural units for an inner gear and a housing as set forth above; one or more planetary gears that mesh with the inner gear; a sun gear that meshes with the one or more planetary gears, positioned at the center of the one or more planetary gears; and a carrier that supports the one or more planetary gears rotatably.
- [0027] The structure may further comprise a second sun gear that rotates similarly to the rotation of the carrier accompanying rotation of the carrier; one or more second planetary gears that are disposed on the periphery of the second sun gear, and that mesh with the second sun gear; a second carrier that supports one or more second planetary gears rotatably; and a second housing whereon is formed, on the inner peripheral surface thereof, inner teeth that mesh with the one or more second planetary gears, wherein: the housing and the second housing may be formed integrally.
- [0028] In another aspect of the present invention, a planetary gear device comprises at least two stages of planetary gear mechanisms that each comprises: a sun gear; one or more planetary gears, arranged on the periphery of the sun gear, for meshing with the sun gear; and a carrier that supports the one or more planetary gears rotatably, wherein: of the at least two stages of planetary gear mechanisms, the planetary gear mechanism that operates at the highest speed comprises separate structural units for an inner gear and a housing as set forth above, where the one or more planetary gears of the planetary gear mechanism and the inner gear mesh; and of the at least two stages of the planetary gear mechanism, the planetary gear mechanism that operates at the lowest speed comprises a housing wherein inner teeth that mesh with the one or more planetary gears of the planetary gear mechanism are formed on the inner peripheral surface.
- [0029] An actuator according the present invention comprises: a planetary gear device as set forth above; and a motor, connected to the planetary gear device, for driving the planetary gear device.

Advantageous Effects of Invention

- [0030] In the present invention, the range of contact between the inner gear and the housing is narrower than in the prior art, thus reducing the transmission, to the housing, of vibrations caused by the planetary gear mechanism. This can suppress the transmission of vibrations from the planetary gear mechanism, and can suppress the noise that is produced from the planetary gear device accompanying vibration of the planetary gear mechanism.

Brief Description of Drawings

- [0031] [fig.1]FIG. 1 is a perspective diagram of an actuator according to a first embodiment according to the present invention.

[fig.2]FIG. 2 is a front view of an actuator viewed from the arrow AII in FIG. 1.

[fig.3]FIG. 3 is a cross-sectional diagram of an actuator, sectioned on the section line III-III in FIG. 2.

[fig.4]FIG. 4 is an assembly perspective diagram of an actuator according to a first embodiment according to the present invention.

[fig.5]FIG. 5 is a cross-sectional diagram of a second housing according to a first embodiment according to the present invention.

[fig.6]FIG. 6 is a perspective diagram of a second housing according to a first embodiment according to the present invention.

[fig.7]FIG. 7 is a perspective diagram of a first planetary gear mechanism according to a first embodiment according to the present invention.

[fig.8]FIG. 8 is a perspective diagram of a second planetary gear mechanism according to a first embodiment according to the present invention.

[fig.9]FIG. 9 is a diagram for explaining the relationship between the second housing and the internal gear according to a first embodiment according to the present invention.

[fig.10]FIG. 10 is an explanatory diagram focusing on a stopper that is formed in the second housing depicted in FIG. 9.

[fig.11]FIG. 11 is an explanatory diagram focusing on a movement limiting raised portion that is formed on the inner gear depicted in FIG. 9.

[fig.12]FIG. 12 is a diagram for explaining the state of contact with the second housing through rotation of the inner gear, depicted in FIG. 9, around the axis.

[fig.13]FIG. 13 is a diagram for explaining the state of contact with the second housing through movement of the inner gear, depicted in FIG. 9, in the direction that is perpendicular to the axis.

[fig.14]FIG. 14 is a diagram for explaining the state of contact between the second housing and the inner gear, when viewed from the arrow XIV in FIG. 12.

[fig.15]FIG. 15 is a schematic diagram comparing the movement limiting raised portion, depicted in FIG. 11, with another example of a movement limiting raised portion.

[fig.16]FIG. 16 is a diagram depicting an inner gear according to a second embodiment according to the present invention.

[fig.17]FIG. 17 is a cross-sectional diagram of a second housing according to a second embodiment according to the present invention.

[fig.18]FIG. 18 is a diagram depicting an inner gear according to a third embodiment according to the present invention.

[fig.19]FIG. 19 is a cross-sectional diagram of a second housing according to a third embodiment according to the present invention.

[fig.20]FIG. 20 is a diagram depicting an inner gear according to a fourth embodiment according to the present invention.

[fig.21]FIG. 21 is a cross-sectional diagram of a second housing according to a fourth embodiment according to the present invention.

[fig.22]FIG. 22 is a perspective diagram of an inner gear according to a fifth embodiment according to the present invention.

[fig.23]FIG. 23 is an explanatory diagram showing the state wherein the inner gear and the second housing according to the fifth embodiment according to the present invention are separated.

[fig.24]FIG. 24 is an explanatory diagram showing the state wherein the inner gear and the second housing according to the fifth embodiment according to the present invention are in contact.

[fig.25]FIG. 25 is a perspective diagram of an inner gear according to a sixth embodiment according to the present invention.

[fig.26]FIG. 26 is an explanatory diagram showing the state wherein the inner gear and the second housing according to the sixth embodiment according to the present invention are separated.

[fig.27]FIG. 27 is an explanatory diagram showing the state wherein the inner gear and the second housing according to the sixth embodiment according to the present invention are in contact.

[fig.28]FIG. 28 is a perspective diagram of an inner gear according to a seventh embodiment according to the present invention.

[fig.29]FIG. 29 is an explanatory diagram showing the state wherein the inner gear and the second housing according to the seventh embodiment according to the present invention are separated.

[fig.30]FIG. 30 is an explanatory diagram showing the state wherein the inner gear and the second housing according to the seventh embodiment according to the present invention are in contact.

[fig.31]FIG. 31 is an explanatory diagram focusing on the location of contact between the inner gear and the second housing according to the another embodiment according to the present invention.

Description of Embodiments

[0032] Separate structural units for an inner gear and a housing, a planetary gear device, and an actuator according to an ideal embodiment according to the present invention will be explained below in reference to the drawings. Note that for ease in understanding the drawings, in each of the drawings an orthogonal coordinate system is depicted with an X axis that is parallel to the axial direction of the actuator 1 according

to the embodiment according to the present invention, and a Y axis and a Z axis that are perpendicular to the X axis.

Example 1

[0033] (Structure of the Actuator 1)

As illustrated in FIG. 1 and FIG. 2, the actuator 1 comprises, for example, a motor 10, and a planetary gear device 20 that is connected to the motor 10.

[0034] The motor 10 has, for example, a motor main unit 11 and a rotary shaft 12, as illustrated in FIG. 3 and FIG. 4. The motor 10 rotates the rotary shaft 12, under the control of a controlling portion, not shown, to drive the planetary gear device 20.

[0035] The planetary gear device 20 reduces, by a prescribed reduction ratio, the rotation that is inputted from the motor 10, directed in FIG. 1, and outputs it to an output gear 86a. The planetary gear device 20 comprises, for example, a housing 50, which has a first housing 30 and a second housing 40, and a planetary gear mechanism 60 that is contained within the housing 50, as depicted in FIG. 3 and FIG. 4.

[0036] The first housing 30 is a member for, for example, attaching the motor 10 to the planetary gear device 20. Moreover, the first housing 30 is assembled together with the second housing 40 to form a containing space S, depicted in FIG. 5, for containing the planetary gear mechanism 60. As illustrated in FIG. 4, an opening 30a is formed in the center of the first housing 30, and the rotary shaft 12 of the motor 10 passes therethrough. The rotary shaft 12 that passes through the opening 30a is secured (connected) to a sun gear 71, described below, of the planetary gear mechanism 60. The first housing 30 is formed through injection molding, made from, for example, a synthetic resin.

[0037] The second housing 40 is open on the side (the "one side") that is connected to the first housing 30, as illustrated in FIG. 5 and FIG. 6, for example, and the planetary gear mechanism 60, depicted in FIG. 4, can be contained therein from this open part. The planetary gear mechanism 60, as depicted in FIG. 4, for example, has a first planetary gear mechanism 70, a second planetary gear mechanism 80, and an output gear 86a, arranged along the axial direction. The planetary gear mechanism 60 reduces, in two stages, the (inputted) rotation produced by the motor 10, and outputs it from the output gear 86a. The second housing 40, as illustrated in FIG. 5, for example, has a first position 41 wherein the first planetary gear mechanism 70 is contained, a second position 42 wherein the second planetary gear mechanism 80 is contained, and a third position 43 wherein the output gear 86a of the second planetary gear mechanism 80 protrudes to the outside.

[0038] The first position 41 of the second housing 40, as depicted in FIG. 5 and FIG. 6, for example, has a round cylinder 44 and a stopper (second raised portion) 45 that extends

along the axial direction (from one side in the axial direction toward the other side). The stopper 45 has a cross-section of a chevron shape when sectioned with a cross-section that is perpendicular to the axial direction, where the shape and size thereof are constant in the axial direction. The stopper 45 is formed in the range of a portion of the first position 41, in the axial direction, but may instead be formed across the entire range thereof. The stopper 45, as illustrated in FIG. 9, for example, is disposed so as to form a pair, in the circumferential direction of the inner wall 44a of the round cylinder 44. Pairs of stoppers 45 are provided in six locations, with equal spacing, on the inner wall 44a of the round cylinder 44, for example. The cross-sectional shape of each stopper 45, as illustrated in FIG. 10, for example, has a standing portion 45a that forms an arc that gradually rises from the inner wall 44a of the round cylinder 44, a rounded apex 45c, and a connecting portion 45b, for connecting the standing portion 45a and the apex 45c while bulging. Note that the shape and size of the cross-section of the stopper 45 are constant in the axial direction. Because of this, as can be appreciated from FIG. 6, for example, the standing portion 45a, the connecting portion 45b, and the apex 45c are curved surfaces that have no curve in the direction that is parallel to the axis. A movement limiting raised portion 75 of the inner gear 74, depicted in FIG. 9 and described below, is inserted between the pair of stoppers 45, to limit the movement of the inner gear 74 within the second housing 40.

- [0039] The second position 42 of the second housing 40, as illustrated in FIG. 5 and FIG. 6, for example, has a round cylinder 46 and an inner tooth portion 47 that is formed on the inner wall of the round cylinder 46. The inner tooth portion 47 is at an incline, with an angle in respect to the axial direction, for example. That is, the second position 42 where the inner tooth portion 47 exists is structured as, for example, a helical gear.
- [0040] The third position 43 of the second housing 40 forms, for example, a cylinder, and has an opening 43a through which passes the output gear 86a of the planetary gear mechanism 60, depicted in FIG. 4. The torque outputted from the output gear 86a can be transmitted to an external mechanism thereby. The second housing 40 is formed through injection molding, made from, for example, a synthetic resin.
- [0041] Additionally, for convenience in the present specification, in FIG. 4 through FIG. 6 the side of the second housing 40 that is open so as to attach to the first housing 30 is termed the "one side" (the -X direction side), and the side of the second housing 40 that has the opening 43a of the third position 43, which is the opposite side, is termed the "other side" (the +X direction side). However, the present invention is not limited thereto, and the side of the second housing 40 that has the opening 43a of the third position 43 may be read and interpreted as the one side, and the side of the second housing 40 that is open for attaching the first housing 30 may be read and interpreted as the other side.

- [0042] The planetary gear mechanism 60, as illustrated in FIG. 4, for example, is contained within the housing 50, and reduces the rotation transmitted from the motor 10 and outputs it from the output gear 86a. The planetary gear mechanism 60 has, for example, a first planetary gear mechanism 70 and a second planetary gear mechanism 80, disposed along the axial direction.
- [0043] The first planetary gear mechanism 70, as illustrated in FIG. 7, for example, comprises: a sun gear 71; three (a plurality of) planetary gears 72 that are disposed around the periphery centered on the sun gear 71; a carrier 73 for supporting rotatably the three (plurality of) planetary gears 72; and an inner gear 74. Note that while, for convenience in the perspective diagram in FIG. 7, only two planetary gears 72 are illustrated, another planetary gear 72 is provided at a position that is on the back side, hidden by the carrier 73.
- [0044] The sun gear 71 is an outer gear having sun tooth portions 71a formed on the outer peripheral surface thereof, and a rotary shaft 12 of the motor 10, depicted in FIG. 4, is secured (connected) thereto. Through this, the sun gear 71 is rotated by the operation of the motor 10. The sun tooth portions 71a have, for example, helical teeth that are cut at an angle in respect to the axis of the sun gear 71. That is, the sun gear 71 is, for example, a helical gear.
- [0045] The planetary gear 72 is, for example, an outer gear wherein planetary tooth portions 72a are formed on the outer peripheral surface thereof. The planetary tooth portions 72a have, for example, helical teeth that are cut at an angle in respect to the axis of the planetary gear 72. That is, the planetary gear 72 is, for example, a helical gear. Three planetary gears 72 are disposed at equal spacing on the same circle centered on the axis of the first planetary gear mechanism 70. The sun gear 71 is positioned between the three planetary gears 72, where the sun tooth portions 71a mesh with the respective planetary tooth portions 72a of the three planetary gears 72.
- [0046] The carrier 73 is formed in, for example, a cylindrical shape, where three containing openings 73a, for containing the planetary gears 72, are formed in the outer peripheral surface thereof. Each of the individual planetary gears 72 is supported rotatably, by a pin 76 that faces in the axial direction, within the respective containing opening 73a, as illustrated in FIG. 3. The planetary gears 72 are attached in a state wherein, for example, a portion of the planetary tooth portion 72a protrudes from the outer peripheral surface of the carrier 73. Through this, the planetary tooth portion 72a can mesh with the inner tooth portion 74a of the inner gear 74, described below.
- [0047] Inner tooth portions 74a are formed on the inner peripheral surface of the inner gear 74, as illustrated in, for example, FIG. 3 and FIG. 7. The inner tooth portion 74a is, for example, a helical gear having helical teeth that are cut at an angle in respect to the axis of the inner gear 74. The tooth tip rounding diameter for the inner gear 74 is

greater than the diameter of the cylindrical carrier 73. Because of this, the carrier 73 that holds the planetary gear 72 is contained in the interior of the inner gear 74. The planetary tooth portions 72a that protrude from the outer peripheral surface of the carrier 73 are meshed with the inner tooth portions 74a of the inner gear 74.

[0048] Moreover, movement limiting raised portions (first raised portions) 75, which enter into the gap between the pairs of stoppers 45 that are formed on the inner wall 44a of the second housing 40, for example, are formed on the outer peripheral surface of the inner gear 74, as illustrated in FIG. 9. The movement limiting raised portions 75 are provided corresponding to, for example, the pairs of stoppers 45, formed in six locations, similar to the pairs of stoppers 45. The movement limiting raised portions 75 have cross-sections that are essentially triangular when sectioned with a plane that is perpendicular to the axial direction. The movement limiting raised portions 75, as depicted in FIG. 11, have, for example, slanted edge portions 75a that are straight, rising from the outer peripheral surface 74b of the inner gear 74, and rounded apices 75b, positioned at locations wherein the slanted edge portions 75a, which arise from both sides, intersect. Note that, as illustrated in FIG. 7, the cross-sectional shape and size of the movement limiting raised portion 75 is constant in the axial direction (with a constant extension from one side to the other side in the axial direction), and thus the slanted edge portion 75a of the movement limiting raised portion 75 structures a plane region. Note that while the movement limiting raised portions 75 are formed across the entire width of the inner gear 74, they may instead be formed in only a portion of the range thereof. Moreover, a hemispherical protrusion 74b, as illustrated in FIG. 7, is formed on an end face, on the +X direction side of the inner gear 74. A hemispherical protrusion 74b is formed in each of the gaps between neighboring movement limiting raised portions 75, formed in a total of six locations. When the inner gear 74 is contained in the first position 41 of the second housing 40, depicted in FIG. 5, the apices of the six protrusions 74b will contact the stepped surface 46a (FIG. 5 and 6) that is the boundary between the first position 41 and the second position 42 of the second housing 40. The form of contact between the protrusion 74b and the stepped surface 46a is that of a point contact, given that it is a contact between a spherical surface and a plane. The inner gear 74 is made from, for example, a synthetic resin. Note that, as described below, the inner gear 74 is formed from a synthetic resin of a hardness that is less than that of the synthetic resin from which the second housing 40, depicted in FIG. 9, is formed.

[0049] As illustrated in FIG. 9, the second housing 40 and the inner gear 74 are physically separate, and when the actuator 1 is not operating, a gap is formed therebetween. Because of this, the inner gear 74 is in a floating state within the second housing 40, allowing rotation around the axial direction, and movement in the direction that is per-

pendicular to the axial direction, within the second housing 40, in an amount commensurate with the gap that is provided between the inner gear 74 and the second housing 40. Additionally, through the movement limiting raised portion 75 that is formed on the inner gear 74 contacting the pair of stoppers 45, further movement of the inner gear 74 is prevented.

[0050] The second planetary gear mechanism 80, which is another planetary gear mechanism, comprises, for example, a sun gear 81, three planetary gears 82, a carrier 83 that supports the three planetary gears 82 rotatably, and an output shaft 86, as depicted in FIG. 8. Note that while, for convenience in the perspective diagram in FIG. 8, only two planetary gears 82 are illustrated, another planetary gear 82 is provided at a position that is on the back side, hidden by the carrier 83.

[0051] The sun gear 81 is an outer gear whereon sun tooth portions 81a are formed on the outer peripheral surface, for example, and is secured (connected), in a state wherein the axes are aligned together, to the carrier 73 of the first planetary gear mechanism 70, depicted in FIG. 7. Through this, with the rotation of the carrier 73 of the first planetary gear mechanism 70, the sun gear 81 will rotate identically to the rotation of the carrier 73 of the first planetary gear mechanism 70 (linked so as to be synchronized). That is, the sun gear 81, accompanying rotation of the carrier 73 of the first planetary gear mechanism 70, rotates at the same rotational speed as the carrier 73 of the first planetary gear mechanism 70, in that the same rotational direction as the carrier 73 of the first planetary gear mechanism 70. The sun tooth portions 81a have, for example, helical teeth that are cut at an angle in respect to the axis of the sun gear 81. That is, the sun gear 81 is, for example, a helical gear.

[0052] The planetary gear 82 is, for example, an outer gear wherein planetary tooth portions 82a are formed on the outer peripheral surface thereof. The planetary tooth portions 82a have, for example, helical teeth that are cut at an angle in respect to the axis of the planetary gear 82. That is, the planetary gear 82 is, for example, a helical gear. Three planetary gears 82, for example, are disposed at equal spacing on the same circle centered on the axis of the second planetary gear mechanism 80. The sun gear 81 is positioned between the three planetary gears 82, where the sun tooth portions 81a mesh with the respective planetary tooth portions 82a of the three planetary gears 82. Additionally, the planetary gear 82 meshes with the inner tooth portions 47 that are formed on the second housing 40, depicted in FIG. 5 and FIG. 6.

[0053] The carrier 83 has, for example, a gear retaining portion 84 for holding the planetary gears 82, and an output shaft retaining portion 85 for holding the output shaft 86. The gear retaining portion 84 is formed in, for example, a cylindrical shape, where three containing openings 84a, for containing the planetary gears 82, are formed in the outer peripheral surface thereof. Each of the individual planetary gears 82 is attached

rotatably, by a pin 87 that faces in the axial direction, within the respective containing opening 84a, as illustrated in FIG. 3. The planetary gears 82 are attached in a state wherein a portion of the planetary tooth portion 82a protrudes from the outer peripheral surface of the carrier 83. This makes it possible to mesh the planetary tooth portions 82a with the inner tooth portions 47 that are formed on the second housing 40. Moreover, the output shaft retaining portion 85, as illustrated in FIG. 8, is formed as a cylinder with a diameter that is smaller than that of the gear retaining portion 84, and a fitting hole 85a, for holding the output shaft 86, is formed in the center portion of the output shaft retaining portion 85.

[0054] The output shaft 86 is, for example, held on the carrier 83, and rotates together with the carrier 83. The output shaft 86 has an output gear 86a that has, on the shaft, teeth of a knurled shape. That is, the output shaft 86 structures, for example, a gear that has teeth of a knurled shape.

[0055] (OPERATION OF THE ACTUATOR 1)

An example of the operation of the actuator 1 will be explained next. First, when the motor 10, depicted in FIG. 4, operates, the rotary shaft 12 rotates in a first direction or a second direction. The explanation below will be for the case wherein the rotary shaft 12 rotates in the first direction.

[0056] Note that the first direction, in relation to the directions of rotation of each of the members, is the clockwise direction for the case when all of the members are viewed from the direction indicated by the arrow AII shown in FIG. 1. On the other hand the second direction, in relation to the directions of rotation of each of the members, is the counterclockwise direction for the case when all of the members are viewed from the direction indicated by the arrow AII shown in FIG. 2.

[0057] When the rotary shaft 12 rotates in the first direction, the sun gear 71, depicted in FIG. 3 and FIG. 7, rotates in the first direction, accompanying the rotation of the rotary shaft 12. Accompanying rotation of the sun gear 71 in the first direction, the three planetary gears 72 that mesh with the sun gear 71 each rotate in the second direction. Moreover, because the planetary gears 72 mesh with the inner gear 74, they rotate (revolve) in the first direction around the axis of the first planetary gear mechanism 70, through the rotation in the second direction. Accompanying the rotation (revolution) of the planetary gears 72, the carrier 73 rotates in the first direction, centered on its own axis.

[0058] In this way, when the carrier 73 rotates in the first direction, the sun gear 81, depicted in FIG. 3 and FIG. 8, which is secured by the carrier 73, will rotate in the first direction. Accompanying rotation of the sun gear 81 in the first direction, the three planetary gears 82 that mesh with the sun gear 81 each rotate in the second direction. Moreover, because the planetary gears 82 mesh with the inner tooth portions 47,

depicted in FIG. 5 and FIG. 6, they rotate (revolve) in the first direction around the axis of the second planetary gear mechanism 80, through the rotation in the second direction. Accompanying the rotation (revolution) of the planetary gears 82 in the first direction, the carrier 83 rotates in the first direction, centered on its own axis. Given this, the rotation of the carrier 83 is transmitted to the output shaft 86 that is held on the carrier 83.

[0059] While the description above was an explanation for the case wherein the rotary shaft 12 rotated in the first direction, if the rotary shaft 12 were rotated in the second direction, then the explanation of the operation of the actuator 1 would be identical, with only the directions of rotation of each of the gears being reversed.

[0060] As described above, the second housing 40 and the inner gear 74 are physically separated. Additionally, when the actuator 1 is not operating, a gap is formed between the second housing 40 and the inner gear 74. Given this, when the actuator 1 operates, the inner gear 74 can rotate around the axis of the second housing 40, or move in a direction that is perpendicular to the axis, by an amount commensurate with the gap that is provided. For example, when the inner gear 74 is rotated in the first direction (clockwise) from the state shown in FIG. 9, each of the plurality of movement limiting raised portions 75, formed on the inner gear 74, will soon make linear contact with the corresponding stoppers 45 that are formed on the second housing 40, as depicted in FIG. 12. Through this, the inner gear 74 will be unable to rotate further in the clockwise direction. Because the stoppers 45 are formed in pairs, the rotation of the inner gear 74, around the axis, will be limited through the same linear contact even if the inner gear 74 were rotated in the second direction (the counterclockwise direction).

[0061] Moreover, the inner gear 74 moves, from the state depicted in FIG. 9, in a direction that is perpendicular to the axis, moving, for example, upward in the figure. Given this, as depicted in FIG. 13, the movement limiting raised portions 75 in the upper portion in the figure, formed on the inner gear 74, make linear contact with the pairs of stoppers 45 that are formed on the second housing 40. Through this, the inner gear 74 will be unable to move further in the upward direction, and the movement in the direction perpendicular to the axis will be limited. Moreover, in this case, the apexes 75b of the inner gear 74 (more specifically, the apexes 75b of the movement limiting raised portions 75) will not contact the second housing 40 (or, more specifically, the inner wall 44a of the round cylinder 44). Note that the limitation on the movement of the inner gear 74 in the directions perpendicular to the axis is not limited to upward movement of the inner gear 74. Because the six movement limiting raised portions 75 and pairs of stoppers 45 are arranged with equal spacing in the circumferential direction, they are able to limit movement of the inner gear 74 in a variety of directions, such as the vertical direction, crosswise direction, and diagonal direction.

[0062] (Effects)

Given the embodiment set forth above, even if, in the structural unit wherein the inner gear 74 and the second housing 40 are separated, the inner gear 74 were to move during operation of the actuator 1, the stoppers 45 and the movement limiting raised portions 75 would make linear contact, limiting the movement of the inner gear 74. FIG. 12 shows the state of linear contact between the inner gear 74 and the second housing 40 through rotation of the inner gear 74 around the axis. In this case the pairs of stoppers 45 and the movement limiting raised portions 75 make contact in all six locations, and the forms of contact are the same for all. Because of this, a single contact location, wherein the contact is at the top in the figure, will be explained referencing the enlarged view in FIG. 12. As illustrated in the figure, the location of contact between the connecting portion 45b of the stopper 45, illustrated through a bulging convex curve, and the slanted edge portion 75a of the movement limiting raised portion 75, illustrated by a straight line, can be depicted as a contact point P1. That is, the contact will be in an extremely limited range. Note that the cross-section of the second housing 40 and the cross-section of the inner gear 74 are of constant shapes and sizes in the axial direction. Because of this, the contact between the connecting portion 45b and the slanted edge portion 75a will be a contact between a convex curved surface that does not have a curve in the direction that is parallel to the axis, and a plane that is parallel to the axis. Because of this, the contact between the inner gear 74 and the second housing 40 will be linear contact, along the axial direction that is parallel to the X axis, as with the contact region 90 shown in FIG. 14.

[0063] Moreover, FIG. 13 shows the state of contact between the second housing 40 and the inner gear 74 through movement of the inner gear 74 in a direction that is perpendicular to the axis, for example, movement in the upward direction in the figure. As depicted in FIG. 13, the locations of contact between the second housing 40 and the inner gear 74 are the four locations indicated by the contact points P2 through P5. As shown in the enlarged view in FIG. 13, the contact points P2 and P3 are the locations of contact between the connecting portion 45b of the stopper 45, illustrated through a bulging convex curve, and the slanted edge portion 75a of the movement limiting raised portion 75, illustrated by a straight line. In the same manner as with the above, such locations of contact are linear contact between the two, given that it is contact of a convex curved surface, which has no curve in a direction that is parallel to the axis, and a plane that is parallel to the axis. Moreover, the contacts between the stoppers 45 and the movement limiting raised portions 75 at the contact points P4 and P5 will also be linear contacts, because they are contacts between convex curved surfaces and planes.

[0064] In this way, through providing pairs of stoppers 45 having chevron shapes that have convex curved surfaces, and structuring so as to insert, therebetween, triangular

movement limiting raised portions 75 that have planar inclined surfaces, the contacts between the outer peripheral surfaces of the inner gear 74 and the inner peripheral surfaces of the second housing 40 can be caused to be linear contacts, even when the inner gear 74 has rotated around the axis, and even when it has moved in a direction perpendicular to the axis. Because the contact area between the outer peripheral surface of the inner gear 74 and the inner peripheral surface of the second housing 40, which, in this way, make linear contact, is small, the transmission to the second housing 40 of the vibration from the inner gear 74 during operation will be reduced. The vibration of the second housing 40 that is produced through transmission from the first planetary gear mechanism 70 is suppressed thereby, thus making it possible to suppress the noise that is produced from the planetary gear device 20 accompanying vibration caused by the first planetary gear mechanism 70.

[0065] Note that the "linear contact" described in the present specification is a state of contact wherein the contacting part forms a line, and does not indicate only a state of contact that would be illustrated by a single point or a plurality of points that are the contact points in each individual cross-section, but rather, as depicted in FIG. 14, a state of contact in a form wherein the width W is considered to be adequately small, when compared to the length L in the contact region 90 is included. Moreover, the "linear contact" used in the present specification further includes a state of contact wherein the contact is discontinuous (contacting sporadically) so that the width W in the contact region 90 will form a line when an imaginary line is drawn along the axial direction. Moreover, the "linear contact" used in the present specification further includes a state of contact wherein the width W in the contact region 90 forms a line that describes an angled line, rather than being in the axial direction. Moreover, the "linear contact" used in the present specification further includes a state of contact wherein the contact is discontinuous (contacting sporadically) so that the width W in the contact region 90 will form a line when an imaginary line is drawn as an angled line, rather than along the axial direction.

[0066] Moreover, a hemispherical protrusion 74b is formed on the end face of the inner gear 74 in the +X direction side, where the protrusion 74b contacts the stepped surface 46a of the second housing 40 (FIG. 5 and 6). The form of contact between the protrusion 74b and the stepped surface 46a can be kept to a contact in a limited range, that is, a point contact. This can reduce the transmission, to the second housing 40, of vibration from the inner gear 74 that is in operation.

[0067] Moreover, as depicted in FIG. 11, having the cross-section of the movement limiting raised portion 75, sectioned by a plane that is perpendicular to the axis, be a triangle, to structure with the apex 75b, which is narrow at the tip, facing outward, allows the inner gear 74 to be removed easily from the mold during injection molding.

This can improve the yield.

[0068] Moreover, as depicted in FIG. 15, the movement limiting raised portions 75 are formed with straight slanted edge portions 75a on both sides in a cross-section that is sectioned by a plane that is perpendicular to the axial direction. Moreover, FIG. 15 illustrates, as a reference example for a movement limiting raised portion 75, a movement limiting raised portion 100 of a shape wherein both sides are bulged, illustrated by the double dotted lines. Comparing the two, the cross-sectional area of the movement limiting raised portion 75 is smaller than the cross-sectional area of the movement limiting raised portion 100 by an amount commensurate with the area of the region indicated by the hatching. Given this, the present embodiment is able to reduce the load on the motor 10, and also reduce the manufacturing cost, by reducing the weight of the inner gear 74. Furthermore, because of the reduction in weight of the inner gear 74 that will operate, the present invention can reduce (suppress) the impact when the inner gear 74 contacts the second housing 40, thus making it possible to reduce (suppress) the vibration of the second housing as well.

[0069] Moreover, the inner gear 74 is formed from a synthetic resin of a hardness that is less than that of the synthetic resin for forming the second housing 40. From the perspectives of mechanical strength, wear resistance, thermal durability, and the like, preferably the synthetic resin for forming the inner gear 74 and the second housing 40 uses an engineering plastic or a super engineering plastic. These synthetic resins may be, for example, ultrahigh polymer polyethylene (UHPE), polyphenylene sulfide (PPS), polyarylate (PAR), polyacetal (POM), polyamide (PA), polycarbonate (PC), polybutylene terephthalate (PBT), polyether sulfone (PES), polyether ether ketone (PEEK), or the like.

[0070] The synthetic resin for forming the inner gear 74 and the second housing 40 may be identical materials or may be different materials. They may be selected as appropriate in a range that produces the effects of the present invention.

[0071] Among the synthetic resins described above, the synthetic resin that is relatively soft, suitable for forming the inner gear 74, preferably uses, for example, an ultrahigh polymer polyethylene (UHPE), polyphenylene sulfide (PPS), polyarylate (PAR), polyacetal (POM), or polyamide (PA). Moreover, preferably the relatively hard synthetic resin that is suitable for forming the second housing 40 uses, for example, polycarbonate (PC), polybutylene terephthalate (PBT), polyether sulfone (PES), polyphenylene sulfide (PPS), polyether ether ketone (PEEK), polyacetal (POM), or polyamide (PA). Moreover, when synthetic resin materials having identical main components are used for the synthetic resin materials for forming the inner gear 74 and the second housing 40, preferably the synthetic resin for forming the second housing 40 will be harder, through changing, for example, the density of the synthetic resin.

- [0072] By forming the inner gear 74 from a synthetic resin of a hardness that is less than that of the second housing 40, in this way, the impact when the inner gear 74 contacts the second housing 40 can be ameliorated, making it possible to reduce (suppress) the vibration produced in the second housing 40. Through this, the present invention is able to reduce (suppress) the noise caused by vibration of the second housing 40, enabling also a further reduction (suppression) in the noise when the inner gear 74 collides with the second housing 40. It is thus possible to suppress the noise produced from the planetary gear device 20 accompanying vibration caused by the first planetary gear mechanism 70.
- [0073] Moreover, in the present embodiment the structure wherein the housing and the inner gear are separated is applied to only the first planetary gear mechanism that rotates at a high speed, and is not applied to the second stage planetary gear mechanism that rotates at a low speed. That is, in the present embodiment the structure wherein the inner gear is caused to float is used in the mechanism that rotates at a high speed, and which tends to produce large vibration and noise, where a housing structure wherein inner teeth are formed is used in the mechanism that rotates at a low speed, wherein the vibration and noise tends to be relatively less. Through this, the present embodiment not only suppresses the vibration and noise of the planetary gear device caused by the planetary gear mechanism, but also can prevent an increase in the number of components, beyond that which is necessary, in the planetary gear device, and prevent an increase in the assembly operations and assembly cost. Thus it is able to achieve a reduction in manufacturing cost of the planetary gear device. In this way, two mechanisms having different structures may be employed, as appropriate, depending on the form of rotation of the planetary gear mechanism, where the two mechanisms may be used in parallel.
- [0074] Another embodiment according to the present invention will be explained next, but there are many features that are the same as in the first embodiment. Given this, the explanation below will center on the features that are different, and those features that are the same will be assigned identical reference symbols, and detailed explanations thereof will be omitted.

Example 2

- [0075] In the first embodiment, six movement limiting raised portions 75, as depicted in FIG. 7, were formed with the full width of the inner gear 74. However, in the second embodiment, the six movement limiting raised portions 275 are formed in only a portion of the range of the full width of the inner gear 274, where this point differs from that of the structure in the first embodiment. Note that the other structures are identical to the structures in the first embodiment. As depicted in FIG. 16, movement

limiting raised portions 275 are formed over only about half of the width in the axial direction (the X axial direction), on the +X axial direction side of the inner gear 274. Note that the cross-section of the movement limiting raised portion 275 is a triangle. On the other hand, the movement limiting raised portions 275 are not formed on the -X axial direction side of about the center of the inner gear 274. Through the inner gear 274 being contained at the first position 41 of the second housing 40, as depicted in FIG. 17, the movement limiting raised portions 275 that are formed on only the +X axial direction side of the center are inserted between the pairs of stoppers 45. This makes it possible to make the length of linear contact along the X axial direction between the movement limiting raised portions 275 and the stoppers 45 about half as long as in the first embodiment. Through this, the contact area between the outer peripheral surface of the inner gear 274 and the inner peripheral surface of the second housing 40 can be reduced even further, reducing the transmission of the vibration from the inner gear 274 to the second housing 40 during operation.

Example 3

[0076] The movement limiting raised portions 275 provided on the inner gear 274 in the second embodiment were provided over about half the width thereof on the +X axial direction side. On the other hand, the movement limiting raised portions 375a are provided over about one quarter of the width, from the end portion in the +X axle direction side, as depicted in FIG. 18, on the inner gear 374 in the third embodiment, and movement limiting raised portions 375b are provided over about one quarter of the width thereof from the end portion in the -X axial direction side. The cross sections of the movement limiting raised portions 375a and of the movement limiting raised portions 375b are triangles. As depicted in FIG. 19, when the inner gear 374 is contained in the first position 41 of the second housing 40, the movement limiting raised portions 375a that are formed from the end portion on the +X axial direction side and the movement limiting raised portions 375b that are formed from the end portion on the -X axial direction side are inserted between pairs of stoppers 345. To enable insertion of the movement limiting raised portions 375b, formed on the end portion on the -X axial direction side, the pairs of stoppers 345 are formed so as to be longer in the -X axial direction when compared to the pairs of stoppers 45 in the second embodiment. Because of this, the pairs of stoppers 345 are provided extending over essentially the entire range of the space wherein the second housing 40 contains the inner gear 374, as depicted in FIG. 19.

[0077] The movement limiting raised portions 375a are formed over one quarter of the X axial direction width of the inner gear 374, and the movement limiting raised portions 375b are formed over one quarter said width. That is, both together are formed over

about one half the width of the inner gear 374. Because of this, the contact area between the outer peripheral surface of the inner gear 374 and the inner peripheral surface of the second housing 40 can be reduced to half of that in the first embodiment, reducing the transmission of vibration from the inner gear 374 to the second housing 40 during operation. Moreover, because movement limiting raised portions 375a and movement limiting raised portions 375b that contact the pairs of stoppers 345 are provided at both end portions of the inner gear 374, the orientation of the inner gear 374 can be stabilized, without tilting. This can suppress the vibration and noise that is caused by the inner gear 374 during operation. Moreover, when the planetary gears mesh at the center of the inner gear 347, the vibration and noise can be suppressed even more through the provision of the stoppers 345 at both end portions.

[0078] Note that, as depicted in FIG. 19, the pairs of stoppers 345 that are formed on the second housing 40 need not be formed continuously over the entire range of the space wherein the inner gear 374 is contained. For example, the stoppers may be provided at only the locations corresponding to the movement limiting raised portions 375a and the movement limiting raised portions 375b, with the parts therebetween omitted.

Example 4

[0079] In an inner gear 474 according to a fourth embodiment, as depicted in FIG. 20, a plurality of movement limiting raised portions 475a through 475f (which may be termed "movement limiting raised portions 475," as a general term), which are narrow in width in the X axial direction, are provided with equal spacing from the +X direction side to the -X direction side. The cross-section of the movement limiting raised portion 475 is a triangle. The movement limiting raised portion 475a is provided at an end portion of the inner gear 474 on the +X axial direction side. Additionally, the movement limiting raised portion 475f is provided at an end portion of the inner gear 474 on the -X axial direction side. When the inner gear 474 is contained at the first position 41 in the second housing 40, as depicted in FIG. 21, the movement limiting raised portions 475 are inserted between pairs of stoppers 345. The pairs of stoppers 345 are formed continuously across the entire range of the space wherein the second housing 40 contains the inner gear 474, so as to enable insertion of the movement limiting raised portions 475, formed with equal spacing from the end portion on the +X side to the end portion on the -X side of the inner gear 474. Through this, the form of contact between the movement limiting raised portions 475 and the pairs of stoppers 345 will be a form wherein the parts with linear contact between the individual movement limiting raised portions 475a through 475f and the pairs of stoppers 345 will be lined up in a line along the X axial direction, with prescribed spacing therebetween.

[0080] In this way, ranges wherein movement limiting raised portions 475 are and are not provided on the inner gear 474 are provided alternately. The total length of linear contact between the movement limiting raised portions 475 and the stoppers 345 along the X axial direction can be shortened thereby. Through this, the contact area between the outer peripheral surface of the inner gear 474 and the inner peripheral surface of the second housing 40 can be reduced even further, reducing the transmission of the vibration from the inner gear 474 to the second housing 40 during operation. Moreover, the inner gear 474 can contact the pairs of stoppers 345 that are formed on the second housing 40 through a plurality of movement limiting raised portions 475a through 475f that are arranged with equal spacing, thus making it possible to stabilize the orientation of the inner gear 474, so as to not tilt. This can suppress the vibration and noise that is caused by the inner gear 374 during operation.

Example 5

[0081] In the embodiments set forth above the regions of contact were limited to narrow ranges through structuring so as to produce linear contact, in the X axial direction, between the pairs of stoppers and the movement limiting raised portions. However, the direction in which linear contact is produced is not limited to being along the X axial direction, but rather may be set arbitrarily. For example, it may be along a direction that is perpendicular to the X axial direction, or may be along the direction that is between the X axial direction and a direction that is perpendicular to the X axial direction. A form wherein the linear contact is produced between the pairs of stoppers in the movement limiting raised portions in a direction that is perpendicular to the X axial direction will be explained as a fifth embodiment.

[0082] As depicted in FIG. 22, the inner gear 574, as with the inner gear 74 in the first embodiment, depicted in FIG. 7, has movement limiting raised portions 575, with cross-sections that are triangles, formed across the entire width of the inner gear 574. However, the cross-sectional sizes of the triangles of the movement limiting raised portions 575 are formed so as to be different depending on the position in the X axial direction. This point differs from that of the inner gear 74 in the first embodiment, which had movement limiting raised portions 75 that were of a constant cross-sectional size, regardless of the position in the X axial direction. The cross-sectional size of the movement limiting raised portion 575, as depicted in FIG. 22, is smallest at the end portion 575a on the +X axial direction side and the end portion 575b on the -X axial direction side of the inner gear 574, and becomes gradually larger toward the center along the X axial direction. Given this, the cross-section of the movement limiting raised portion 575 is at a maximum at the center portion 575c in the X axial direction.

[0083] Moreover, the outer surfaces of the pair of stoppers 45 in the first embodiment is a

curved surface made up from a standing portion 45a, a connecting portion 45b, and an apex 45c, as depicted in FIG. 10. On the other hand, as depicted in FIG. 23, the pair of stoppers 245a have straight slanted edge portions 245 that each stand from the inner wall 244a of the round cylinder 244. Given this, each of the pair of stoppers 245 has a cross-section that is a triangle, and the slanted edge portions 245a form flat regions.

[0084] Note that in FIG. 23 and FIG. 24, the dotted lines that describe the movement limiting raised portion 575 show the cross-sections of the movement limiting raised portions 575 at the end portions 575a and 575b (FIG. 22) of the inner gear 574. On the other hand, the solid lines show the cross-section of the movement limiting raised portion 575 at the center portion 575c (FIG. 22) of the inner gear 574 in the X axial direction. As described above, the cross-section of the movement limiting raised portion 575 in the center portion 575c of the inner gear 574 is larger than the cross-section of the movement limiting raised portion 575 at the end portions 575a and 575b of the inner gear 574. As depicted in FIG. 23, the inner gear 574 moves in a direction that is perpendicular to the axis, for example, upward, from a state wherein it is not in contact with the second housing 240. Given this, the movement limiting raised portions 575 are inserted between the pairs of stoppers 245, as depicted in FIG. 24, and soon the planes that structure the slanted edge portions 245a of the pair of stoppers 245 will contact the slanted edge portion 575d of the movement limiting raised portion 575. Note that the cross-sectional size of the movement limiting raised portion 575 is a maximum at the center portion 575c (FIG. 22). Because of this, the movement limiting raised portion 575 makes contact with the stopper 245 at the slanted edge portion 575d in the center portion 575c (FIG. 22), but does not contact a stopper 245 at the slanted edge portion 575d other than at the center portion 575c (FIG. 22) (for example, at the parts indicated by the dotted line). Given this, the inner gear 574 can contact the second housing 240 (FIG. 23) only on the line L1, as depicted in FIG. 22. That is, the outer peripheral surface of the inner gear 574 and the inner peripheral surface of the second housing 240 can make linear contact along the direction that is perpendicular to the X axis. Note that while, in FIG. 22 the line L1 of linear contact is illustrated for only a single movement limiting raised portion 575, linear contact can be made similarly along the lines that are perpendicular to the axis in the other movement limiting raised portions 575 as well.

[0085] Note that while in the above the explanation was for a case wherein the inner gear 574 moved in a direction that is perpendicular to the axis, linear contact can be made along a direction that is perpendicular to the X axis in the same way even when contact with the second housing 240 is through rotation around the axis. In this way, it is possible to limit the contact between the outer peripheral surface of the inner gear 574 and the inner peripheral surface of the second housing 240 to be linear contact, thus

making it possible to reduce the transmission of the vibration from the operating inner gear 574 to the second housing 240.

Example 6

- [0086] While in the embodiments described above the explanations were for structures wherein the contact between the pairs of stoppers and the movement limiting raised portions formed linear contacts, other forms of contact are possible insofar as they can reduce the area of contact. An embodiment wherein the contacts between the stoppers and the movement limiting raised portions are point contacts will be explained next as a sixth embodiment.
- [0087] As depicted in FIG. 25, the movement limiting raised portions 675 are formed across the entire width of the inner gear 674. The movement limiting raised portions 675, as depicted in FIG. 25 through FIG. 27, have a first position 675a that has a cross-section that is a triangle and that extends in the X axial direction, and convex second positions 675b that are provided on each of the inclined surfaces of the first position 675a. The second position 675b has a square pyramid shape that is defined by a bottom face 675c (FIG. 26) that is coincident with the rectangular inclined surfaces of the first position 675a, and by an apex P. Consequently, the location of the second position 675b that is furthest from the first position 675a is the apex P. Note that the pairs of stoppers 245 are structured similarly to that which is described in FIG. 23. That is, on the outer surfaces of the pairs of stoppers 245, planar regions are structured from slanted edge portions 245a.
- [0088] As depicted in FIG. 26, the inner gear 674 moves in a direction that is perpendicular to the axis, for example, upward, from a state wherein it is not in contact with the second housing 240. Given this, as depicted in FIG. 27, the movement limiting raised portion 675 is inserted between the pair of stoppers 245, and soon the apex P contacts the slanted edge portions 245a of the pair of stoppers 245. This type of contact is a point contact by the plane that forms the slanted edge portion 245a of the pair of stoppers 245 and the apex P of the second position 675b that has a square pyramid shape.
- [0089] Note that while in the above the explanation was for a case wherein the inner gear 674 moved in a direction that is perpendicular to the axis, the apex P can be caused to form a point contact with the pair of stoppers 245 even when the contact with the second housing 240 is through rotation around the axis. In this way, the range of contact between the outer peripheral surface of the inner gear 674 and the inner peripheral surface of the second housing 240 can be kept to a range that can be termed a point contact. This can reduce the transmission, to the second housing 240, of vibration from the inner gear 674 that is in operation.

Example 7

- [0090] In the sixth embodiment, the structure was to enable a point contact with the pair of stoppers 245 at a single point through the provision of the second position 675b of a square pyramid shape at each of the inclined surfaces of the movement limiting raised portion 675; however, there is no particular limitation on the number of point contacts. A form that enables point contacts with the pair of stoppers at a plurality of locations on a single inclined surface of a movement limiting raised portion will be explained next.
- [0091] As depicted in FIG. 28, the movement limiting raised portions 775 are formed across the entire width of the inner gear 774. The movement limiting raised portion 775 has a first position 775a, with a cross-section that is a triangle, extending along the X axial direction, and four second positions 775b that are laid out in a line on each of the inclined surfaces of the triangular first positions 775a, as depicted in FIG. 28 through FIG. 30. Each of the second positions 775b form truncated circular cones, laid out in a line along the X axial direction. Note that the pairs of stoppers 245 are structured similarly to that which is described in FIG. 23. That is, on the outer surfaces of the pairs of stoppers 245, planar regions are structured from slanted edge portions 245a.
- [0092] As depicted in FIG. 29, the inner gear 774 moves in a direction that is perpendicular to the axis, for example, upward, from a state wherein it is not in contact with the second housing 240. Given this, as depicted in FIG. 30, the movement limiting raised portion 775 is inserted between the pair of stoppers 245, and soon the second positions 775b of the truncated circular cone shape contacts the pair of stoppers 245. This type of contact is a contact between the plane that forms the slanted edge portion 245a of the pair of stoppers 245 and the second position 775b that is the truncated circular cone. Through this, the inner gear 774 and the second housing 240 can be made to form point contacts at four locations along the X axial direction.
- [0093] Note that while in the above the explanation was for a case wherein the inner gear 774 moved in a direction that is perpendicular to the axis, the second position 775b of the circular cone shape can be caused to form a point contact with the pair of stoppers 245 even when the contact with the second housing 240 is through rotation around the axis. In this way, the range of contact between the outer peripheral surface of the inner gear 774 and the inner peripheral surface of the second housing 240 can be kept to a range that can be termed a point contact. This can reduce the transmission, to the second housing 240, of vibration from the inner gear 774 that is in operation.

Modified Examples

- [0094] The present invention is not limited to the embodiments described above, but rather

a variety of modifications and applications are possible. In the embodiments described above, pairs of stoppers 45 are provided in the second housing 40, and movement limiting raised portions 75 that are inserted between the pairs of stoppers 45 are provided on the inner gear 74. However, the present invention is not limited thereto, but rather the locations wherein the pairs of stoppers 45 and the movement limiting raised portions 75 are provided may be switched, so that the movement limiting raised portions 75 are provided on the inner peripheral surface of the second housing 40 and the pairs of stoppers 45 are provided on the outer peripheral surface of the inner gear 74.

[0095] While the cross sections of the pairs of stoppers 45 were chevron shapes and the cross sections of the movement limiting raised portions 75 were triangular, instead the cross-sectional shapes may be switched, with the cross sections of the pairs of stoppers being triangular and the cross sections of the movement limiting raised portions that are inserted between the stoppers being chevron shapes.

[0096] Moreover, there is no particular limitation on the number of locations wherein the pairs of stoppers 45 and the corresponding movement limiting raised portions 75 are disposed, where it may be a larger number of locations than the six locations given in the embodiments described above, or a smaller number of locations.

[0097] Moreover, while in the first embodiment a convex curved surface of the pair of stoppers 45 was caused to contact a plane of the movement limiting raised portion 75, to cause a linear contact therebetween, linear contacts can be achieved through causing contacts of other shapes as well. Another embodiment that achieves linear contact will be explained next in reference to FIG. 31. The point of difference from the structure depicted in the enlarged view can FIG. 9 is that the cross-section of the movement limiting raised portion (first raised portion) 175 is not that of a triangle, but instead is a rounded chevron shape. Note that the structure of the second housing 40 is the same as the structure depicted in the enlarged view in FIG. 9. In FIG. 31, the inner gear 174, when the actuator is not operating, is indicated by the solid line. Moreover, the inner gear 174, depicted by the double dotted line, is in the state wherein it has moved upward, through the operation of the actuator, to contact the second housing 40. As depicted in FIG. 31, the contact between the pair of stoppers 45 and the movement limiting raised portions 175 is contact between convex curved surfaces, so will be linear contact at the contact points P6 and P7 between the pairs of stoppers 45 and the movement limiting raised portions 175. In this way, in the present embodiment a linear contact is achieved through causing the convex curved surfaces, which are bulging, to contact each other.

[0098] Moreover, there is no limitation thereto, where the linear contact may be achieved through the second housing 40 having locally concave parts with large curvature, the

inner gear 74 having convex curved surfaces with less curvature, where the concave curved surfaces with high curvature contact the convex curved surfaces that are bulging. The actual structure for achieving linear contact is arbitrary.

[0099] Note that in another example for achieving the linear contact described above, the configuration of the inner gear in the location that makes linear contact may be swapped with the configuration of the second housing.

[0100] Moreover, while the actuator 1 was provided with a two-stage planetary gear mechanism of a first planetary gear mechanism 70 and a second planetary gear mechanism 80, as the reduction mechanism for reducing the rotation of the motor 10, the number of stages can be set arbitrarily. For example, the reduction ratio may be increased through providing three or more stages of planetary gear mechanisms, or the structure may include only a single-stage planetary gear mechanism.

[0101] Moreover, in the embodiments set forth above, a configuration was used wherein the structure wherein the housing and the inner gear were separate was applied only to the first planetary gear mechanism 70, which is the first-stage mechanism that rotates at a high speed, and a housing that was formed with inner teeth on the inner peripheral surface thereof was used in the second planetary gear mechanism 80, which is the second-stage mechanism that rotates at a low speed. However, a structure wherein the housing and the inner gear are separated may be used also in the second planetary gear mechanism 80 that is the second-stage mechanism, to achieve a reduction in vibration and noise.

[0102] Moreover, while in the embodiments set forth above the explanation was for a case wherein a reduction gear was used for reducing the rotation inputted from the motor 10 and outputting it from an output gear 86a, there is no limitation to this application. For example, the part that is provided with the output shaft 86, depicted in FIG. 8, may be used as the input side and connected to the rotary shaft of a motor, and the part that is provided with the sun gear 71, depicted in FIG. 7, may be used as the output side, and connected to the output shaft. This would increase and output the rotation of the motor, to be used as an increasing the mechanism. In this case as well, preferably the structure wherein the inner gear and the housing are separated is employed due to the higher-speed operation of the first planetary gear mechanism 70 that is shown in FIG. 7. Moreover, because the rotation of the motor is transmitted directly to the second planetary gear mechanism 80 that is depicted in FIG. 8, preferably the structure wherein the inner gear and the housing are separated is employed, as necessary. Moreover, the present invention may also be applied to industrial equipment such as robots and machine tools, and to playground equipment such as so-called "teacups."

[0103] When using the present invention in various applications, the separate structural units for the inner gear and the housing are applied to the planetary gear mechanism

that operates at the highest speed, when planetary gear mechanisms are provided in three or more stages. This can reduce effectively the vibration and noise that is produced. Moreover, because there is little vibration and noise produced by the planetary gear mechanism that operates at the lowest speed, a structure is applied that is equipped with a housing where inner teeth are formed on the inner peripheral surface. This eliminates the need for the separate structures, more than necessary, for the inner gear and the housing, making it possible to avoid increases in the number of components and increases in the assembly operation and assembly costs, thus making it possible to suppress production costs.

[0104] Moreover, while in the embodiments set forth above the explanation was for each of the gears used for transmitting the power from the motor 10 to the output shaft 86 being helical gears, other gears may be used instead. Spur gears, for example, may be used. While this tends to produce more play at the locations wherein the teeth mesh, when compared to the case of using helical gears, the structure of the present invention can be used even in such a case to reduce (suppress) vibration and noise of the planetary gear device.

[0105] Moreover, while the explanations were for cases wherein they separate structural units for the inner gear and the housing were used in a portion of the planetary gear device, the application is not limited thereto, but may be used as a portion of another gear mechanism.

[0106] In the embodiment set forth above the planetary gear mechanism of the planetary gear device was achieved through three planetary gears; however, the present invention is not limited thereto. In the present invention, the planetary gear device may be achieved through the use of a planetary gear mechanism that uses, for example, a single planetary gear or a plurality, other than three, of planetary gears.

[0107] Moreover, the planetary gear device to which the present invention is applied may be applied to a variety of machines and apparatuses that use reducing mechanisms or increasing mechanisms, such as automobiles, robots, industrial equipment, playground equipment, or the like.

[0108] Moreover, while in the second embodiment the movement limiting raised portions 275 were formed on the +X axial direction side of the inner gear 274, they may be formed on the -X axial direction side instead. In this case, the pairs of stoppers 45 formed on the second housing 40 extend to the -X axial direction side, so that the movement limiting raised portions that are formed on the -X axial direction side will be inserted between the pairs of stoppers.

[0109] Moreover, in the inner gear 474 according to the fourth embodiment, depicted in FIG. 20, the movement limiting raised portions 475 were disposed with equal spacing. However, the distances between neighboring movement limiting raised portions 475

may be varied arbitrarily, and the movement limiting raised portions 475 may be disposed at different intervals. Moreover, six movement limiting raised portions 475 were provided along the X axial direction on the inner gear 474. However, the number of movement limiting raised portions 475 formed along the X axial direction may be determined arbitrarily.

[0110] Moreover, in embodiments 2 through 4, depicted in FIG. 16 through FIG. 21, the widths, in the X axial direction, of the movement limiting raised portions formed on the inner gear were narrow, or the plurality of movement limiting raised portions were laid out with equal spacing along the X axial direction, to cause continuous contact with the pairs of stoppers in the X axial direction. However, such a correspondence relationship can be reversed, where the movement limiting raised portions are continuous in the X axial direction, and the widths of the pairs of stoppers, in the X axial direction, may be reduced, or may be divided into a plurality of stoppers and laid out with equal spacing in the X axial direction.

[0111] Moreover, while in the inner gear 674 according to the sixth embodiment, depicted in FIG. 25, the apex P was positioned in the center of the inclined surfaces of the first position 675a, the position of the apex P may be changed arbitrarily through changing the shape of the square pyramid.

[0112] Moreover, while in the inner gear 774 according to the seventh embodiment, depicted in FIG. 28, the second positions 775b, of the truncated circular cones, were laid out in a line along the X axial direction, how the second positions 775b are laid out may be determined arbitrarily. For example, the second positions may be arranged in a grid shape horizontally and vertically, or may form a zigzag pattern.

[0113] Moreover, in embodiments 5 through 7, depicted in FIG. 22 through FIG. 30, a feature was added for having linear contact or point contact of the pairs of stoppers with the movement limiting raised portions of the inner gears. However, these features may be provided on the pairs of stoppers instead. For example, the structure in the fifth embodiment wherein the cross-sectional size of the movement limiting raised portions are varied along the X axial direction, as depicted in FIG. 22, may be applied to the pairs of stoppers, where the cross sections of the stoppers are varied along the X axial direction so as to be at a maximum in the center. The structure that corresponds to the second position 675b that has the square pyramid shape depicted in FIG. 25, in the sixth embodiment, may be formed in the pairs of stoppers instead. In the seventh embodiment, the structure corresponding to the second position 775b that is a truncated circular cone, shown in FIG. 28, may be formed for the pairs of stoppers instead.

Reference Signs List

[0114] 1: Actuator

10: Motor
11: Motor Main Unit
12: Rotary Shaft
20: Planetary Gear Device
30: First Housing
30a: Opening
40: Second Housing
41: First Position
42: Second Position
43: Third Position
43a: Opening
44: Round Cylinder
44a: Inner Wall
45: Stopper (Second Raised Portion)
45a: Standing Portion
45b: Connecting Portion
45c: Apex
46: Round Cylinder
47: Inner Tooth Portion
50: Housing
60: Planetary Gear Mechanism
70: First Planetary Gear Mechanism
71: Sun Gear
71a: Sun Tooth Portion
72: Planetary Gear
72a: Planetary Tooth Portion
73: Carrier
73a: Containing Opening
74: Inner Gear
74a: Inner Tooth Portion
74b: Outer Peripheral Surface
75: Movement Limiting Raised Portion (First Raised Portion)
75a: Slanted Edge Portion
75b: Apex
75c: Notched Portion
76 Pins
80: Second Planetary Gear Mechanism
81: Sun Gear

81a: Sun Tooth Portion
82: Planetary Gear
82a: Planetary Tooth Portion
83: Carrier
84: Gear Retaining Portion
84a: Containing Opening
85: Output Shaft Retaining Portion
85a: Fitting Hole
86: Output Shaft
86a: Output Gear
87 Pins
90: Contact Region
140: Second Housing
141: Concave Part
174: Inner Gear
175: Movement Limiting Raised Portion (First Raised Portion)
240: Second Housing
244: Round Cylinder
245: Stopper
245a: Slanted Edge Portion
274: Inner Gear
275: Movement Limiting Raised Portion
345: Stopper
374: Inner Gear
375a, b: Movement Limiting Raised Portions
474: Inner Gear
475: Movement Limiting Raised Portion
574: Inner Gear
575: Movement Limiting Raised Portion
674: Inner Gear
675: Movement Limiting Raised Portion
774: Inner Gear
775: Movement Limiting Raised Portion

Claims

- [Claim 1] An apparatus for suppressing noise produced in a planetary gear device, comprising:
an inner gear having a first raised portion formed on an outer peripheral surface of the inner gear, the first raised portion extending in an axial direction from one side of the inner gear to another side of the inner gear; and
a housing having a second raised portion formed on an inner peripheral surface of the housing, the second raised portion extends in the axial direction from one side of the housing to another side of the housing, wherein the housing is configured to contain the inner gear such that a gap exists between the inner peripheral surface of the housing and the outer peripheral surface of the inner gear, wherein movement of the inner gear within the interior of the housing is limited through linear contact between the first raised portion and the second raised portion.
- [Claim 2] The apparatus of claim 1, wherein one of the first raised portion and the second raised portion is formed in a pair with a space therebetween, and the other raised portion is disposed so as to be inserted between the raised portion that is formed in a pair, and wherein a surface on one of the first raised portion and the second raised portion that contacts a surface on the other raised portion is curved.
- [Claim 3] The apparatus of claim 2, wherein the second raised portion is formed in a pair with a space therebetween, and the first raised portion has a cross-section that is triangular when sectioned by a plane that is perpendicular to the axial direction, and the first raised portion contacts the second raised portion at an inclined surface that is formed in a plane.
- [Claim 4] The apparatus of claim 1, wherein a surface on one of the first raised portion and the second raised portion that contacts a surface on the other raised portion is a convex curved surface and a surface on the other of the first raised portion and the second raised portion that contacts the surface is a plane.

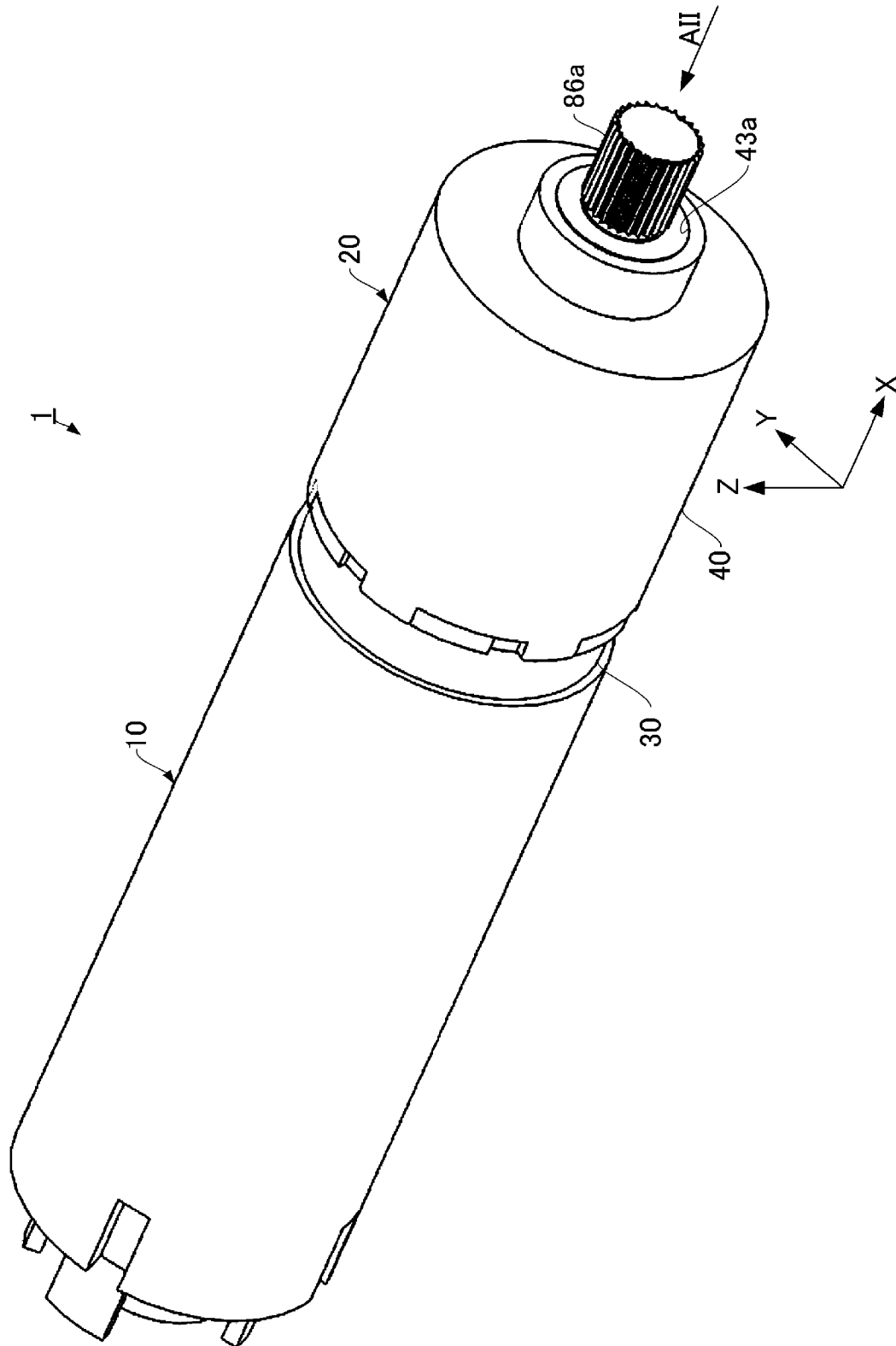
- [Claim 5] The apparatus of claim 1, wherein a portion of the first raised portion and a portion of the second raised portion that contact each other are convex curved surfaces.
- [Claim 6] The apparatus of claim 1, wherein a surface on one of the first raised portion and the second raised portion that contacts a surface on the other raised portion is a convex curved surface and a surface on the other of the first raised portion and the second raised portion that contacts the surface is a convex curved surface.
- [Claim 7] The apparatus of any one of claims 1 through 6, wherein the first raised portion and the second raised portions make linear contact along the axial direction, and
wherein the length of linear contact of the first raised portion and the second raised portion is less than the axial-direction width of the inner gear.
- [Claim 8] The apparatus of any one of claims 1 through 6, wherein a length with which the first raised portion extends on the inner gear is less than a width of the inner gear in the axial direction.
- [Claim 9] The apparatus of claim 8, wherein the first raised portion extends from only one end of the inner gear.
- [Claim 10] The apparatus of claim 8, wherein the first raised portion extends from both ends of the inner gear, and
wherein a total length of the first raised portions extending from both ends is less than the axial direction width of the inner gear.
- [Claim 11] The apparatus of any one of claims 1 through 6, wherein a plurality of first raised portions is provided on the inner gear along the axial direction, spaced at intervals from each other.
- [Claim 12] The apparatus of any one of claims 1 through 6, wherein the movement of the inner gear within the interior of the housing is limited through linear contact between the first raised portion and the second raised portion in a direction that is perpendicular to the axial direction.
- [Claim 13] The apparatus of claim 12, wherein one of the first raised portion and the second raised portion has a cross-section that is a triangle when sectioned by a plane that is perpendicular to the axial direction, wherein the cross-sectional size of the triangle varies depending on the position in the axial direction, and
wherein contact between the first raised portion and the second raised portion is at a position where the cross-sectional size of the triangle is at a maximum.

- [Claim 14] An apparatus for suppressing noise produced in a planetary gear device, comprising:
an inner gear having a first raised portion formed on an outer peripheral surface of the inner gear;
a housing with a second raised portion formed on an inner peripheral surface thereof, wherein the housing is configured to contain the inner gear such that a gap is provided between the inner peripheral surface and the outer peripheral surface,
wherein movement of the inner gear within the interior of the housing is limited through point contact between the first raised portion and the second raised portion.
- [Claim 15] The apparatus of claim 14, wherein the first raised portion is formed so as to extend from one side of the inner gear to another side of the inner gear in the axial direction, and the second raised portion is formed so as to extend from one side of the housing to another side of the housing in the axial direction.
- [Claim 16] The apparatus of claim 15, wherein a protrusion is formed on the first raised portion or the second raised portion at the location of contact between the first raised portion and the second raised portion, and the first raised portion and the second raised portion make point contact through the protrusion.
- [Claim 17] The apparatus of claim 16, wherein a plurality of the protrusions are formed along the axial direction.
- [Claim 18] The apparatus of claim 16 or 17, wherein the first raised portion has a cross-section that is triangular when sectioned by a plane that is perpendicular to the axial direction, and the protrusion is formed on an inclined surface that forms a plane.
- [Claim 19] The apparatus of any one of claims 1 through 6 and 14 through 17, wherein the inner gear and the housing are made from a synthetic resin, and
wherein the inner gear is formed from a synthetic resin of a hardness that is less than that of the synthetic resin used to form the housing.
- [Claim 20] A planetary gear device comprising:
the apparatus for suppressing noise produced in a planetary gear device any one of claims 1 to 6 and 14 to 17;
one or more planetary gears that mesh with the inner gear;
a sun gear that meshes with the one or more planetary gear and is positioned at the center of the one or more planetary gears; and

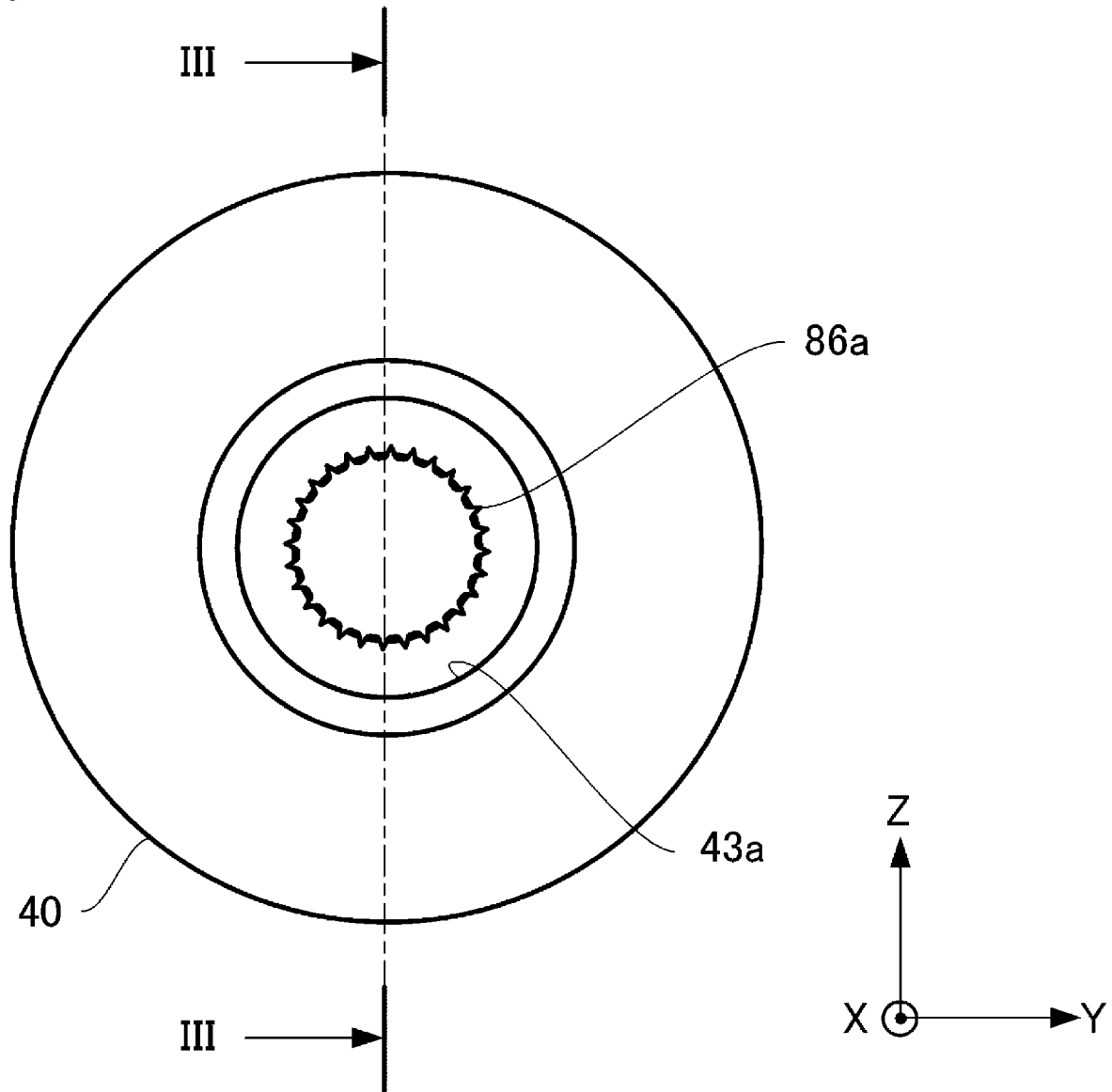
- a carrier that supports the one or more planetary gears rotatably.
- [Claim 21] The planetary gear device as set forth in claim 20, further comprising:
a second sun gear that rotates with the carrier;
one or more second planetary gears that are disposed on the periphery of the second sun gear, and that mesh with the second sun gear;
a second carrier that supports one or more second planetary gears rotatably; and
a second housing with inner teeth formed on the inner peripheral surface thereof and that mesh with the one or more second planetary gears, wherein the housing and the second housing are formed integrally.
- [Claim 22] A planetary gear device, comprising:
at least two stages of planetary gear mechanisms that each comprises:
a sun gear;
one or more planetary gears, arranged on the periphery of the sun gear, for meshing with the sun gear; and
a carrier that supports the one or more planetary gears rotatably, wherein of the at least two stages of planetary gear mechanisms, the planetary gear mechanism that operates at the highest speed comprises the apparatus for suppressing noise produced in a planetary gear device any one of claims 1 to 6 and 14 to 17, where the one or more planetary gears of the planetary gear mechanism and the inner gear mesh; and wherein of the at least two stages of the planetary gear mechanism, the planetary gear mechanism that operates at the lowest speed comprises a housing with inner teeth formed on an inner peripheral surface thereof and that mesh with the one or more planetary gears of the planetary gear mechanism.
- [Claim 23] An actuator comprising:
the planetary gear device as set forth in claim 20; and
a motor, connected to the planetary gear device, for driving the planetary gear device.
- [Claim 24] An actuator comprising:
the planetary gear device as set forth in claim 21; and
a motor, connected to the planetary gear device, for driving the planetary gear device.
- [Claim 25] An actuator comprising:
the planetary gear device as set forth in claim 22; and
a motor, connected to the planetary gear device, for driving the

planetary gear device.

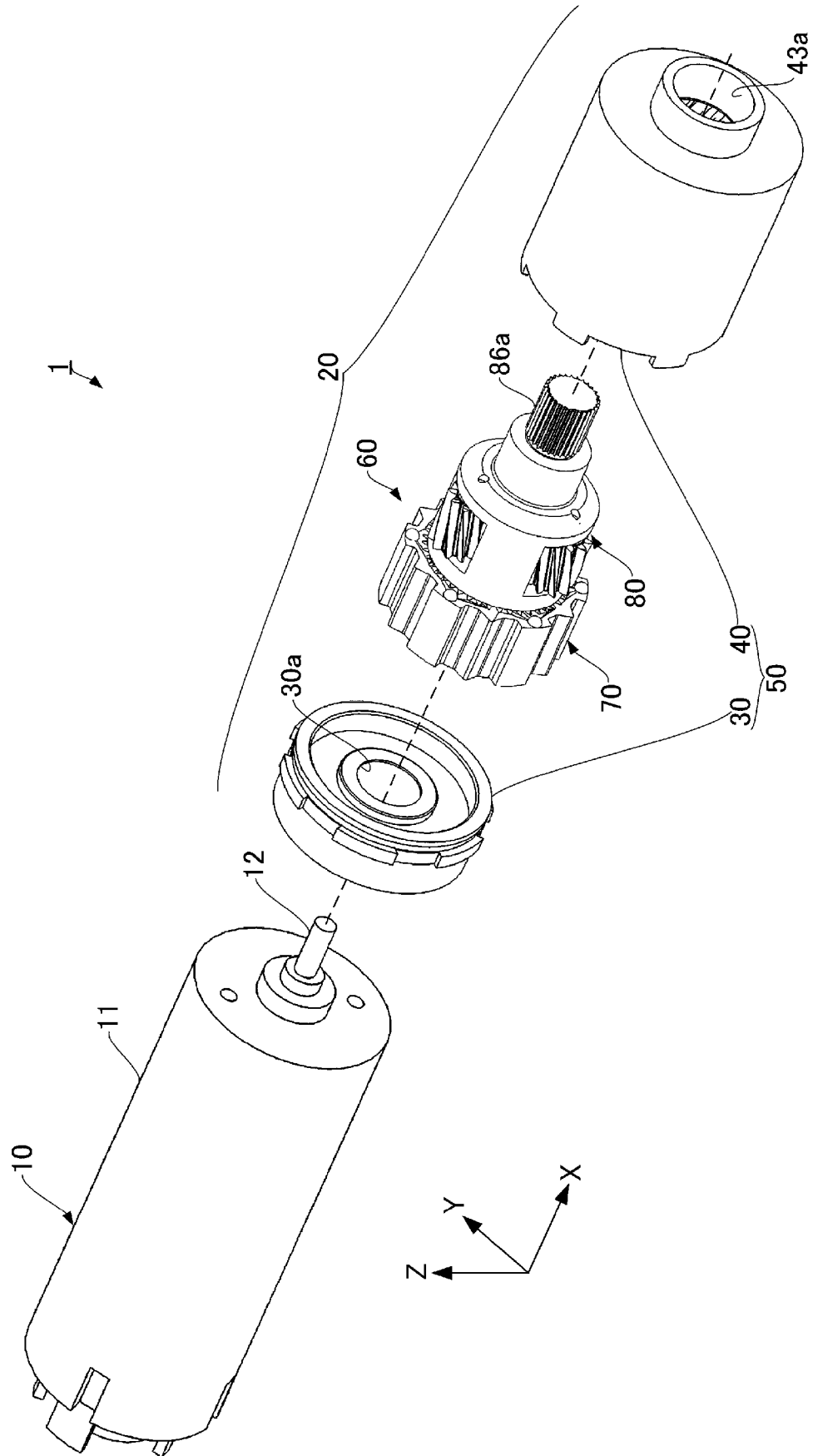
[Fig. 1]



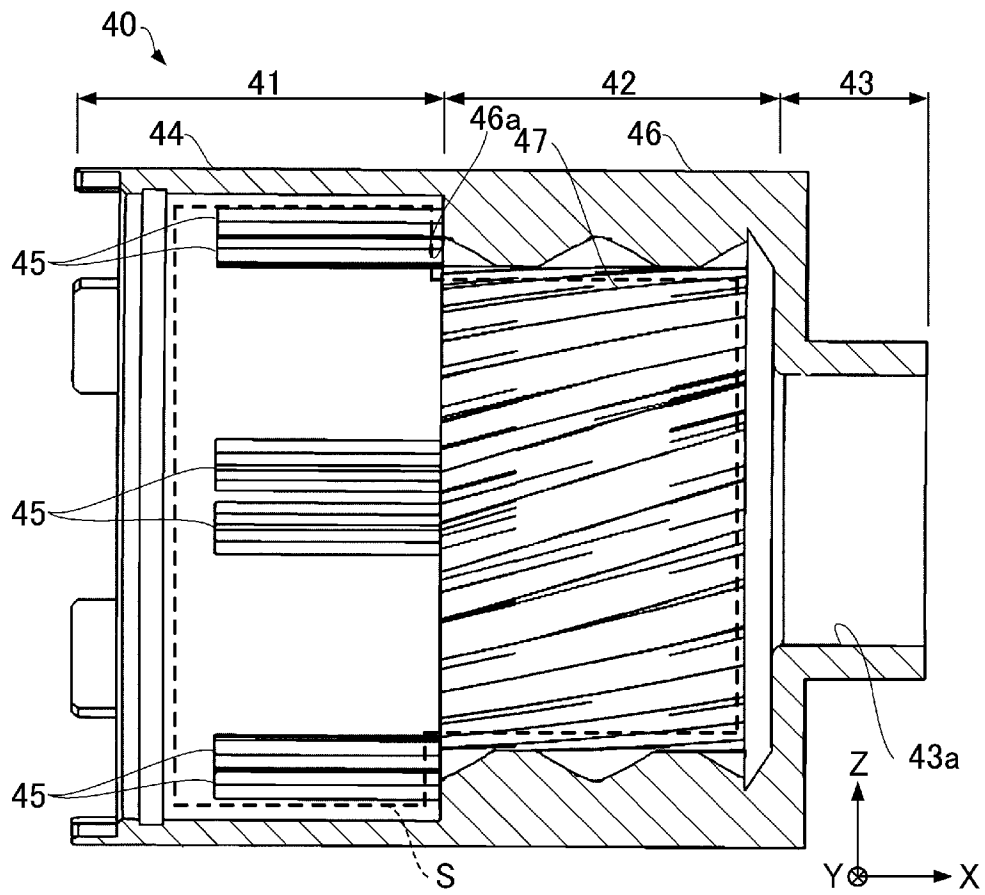
[Fig. 2]



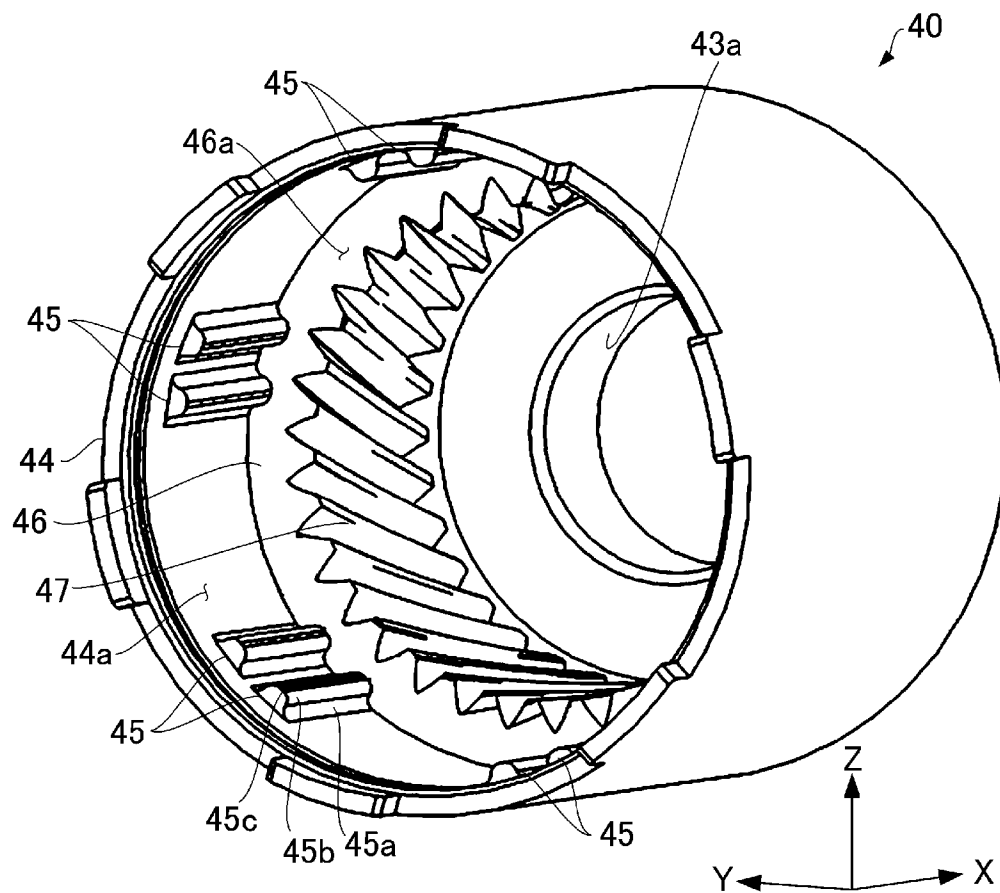
[Fig. 4]



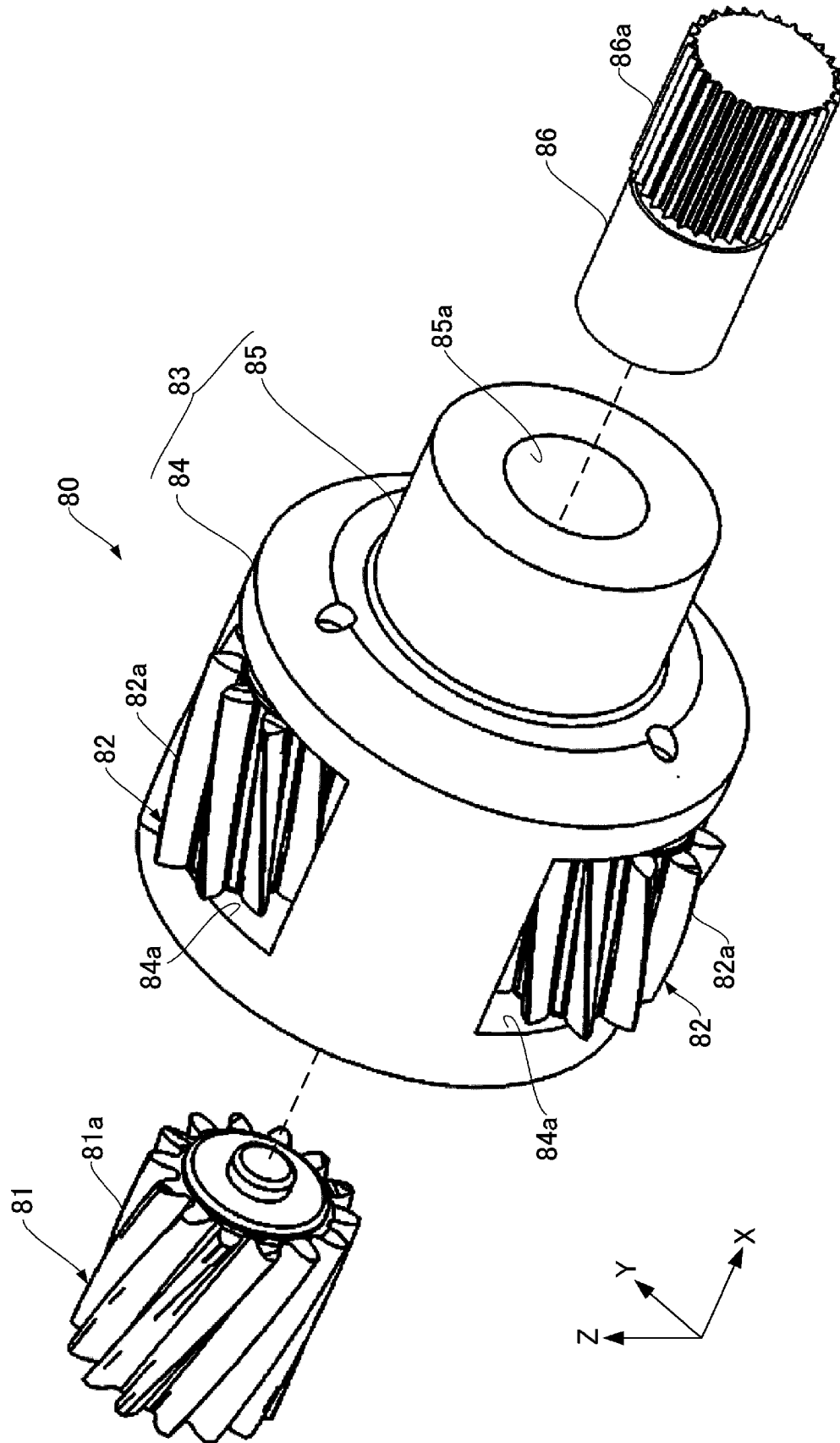
[Fig. 5]



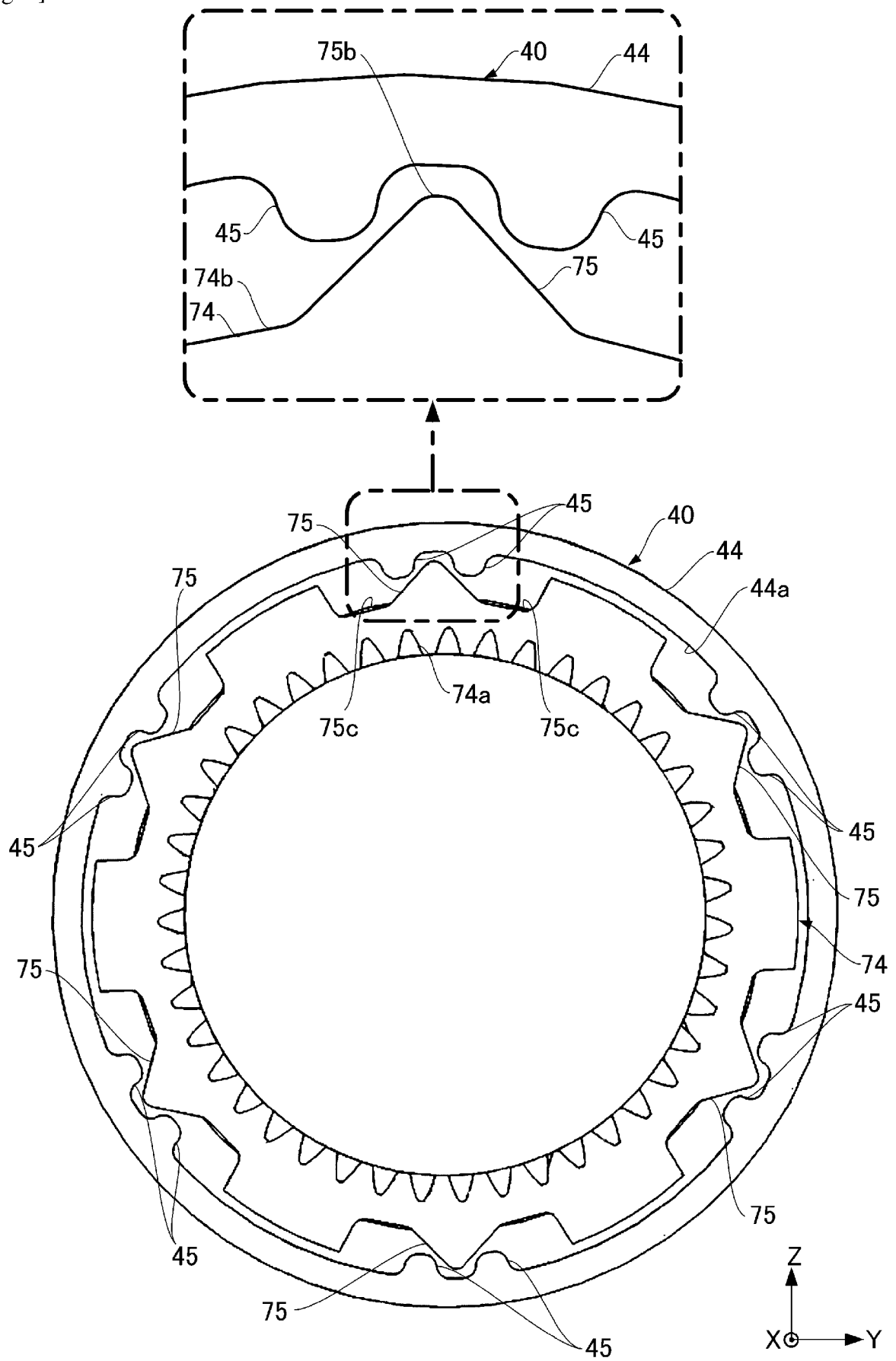
[Fig. 6]



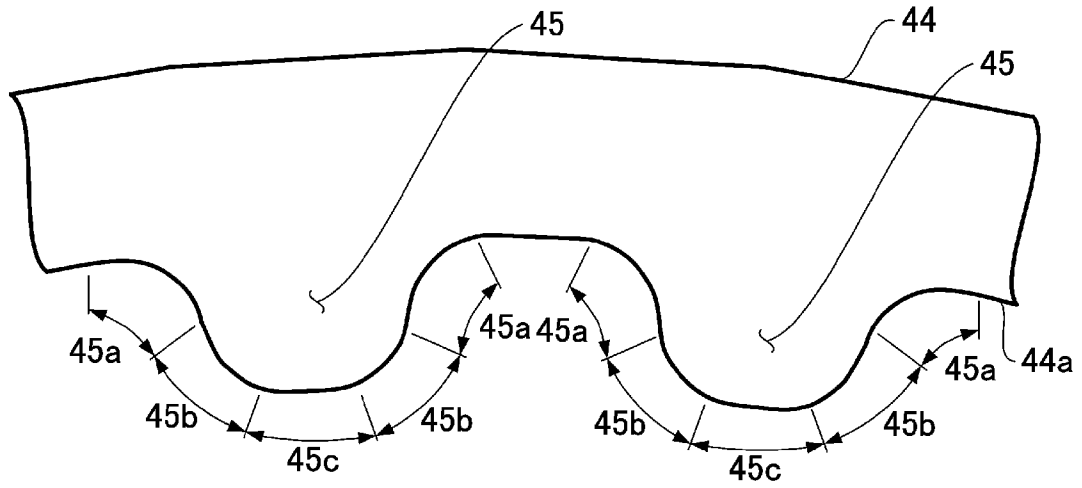
[Fig. 8]



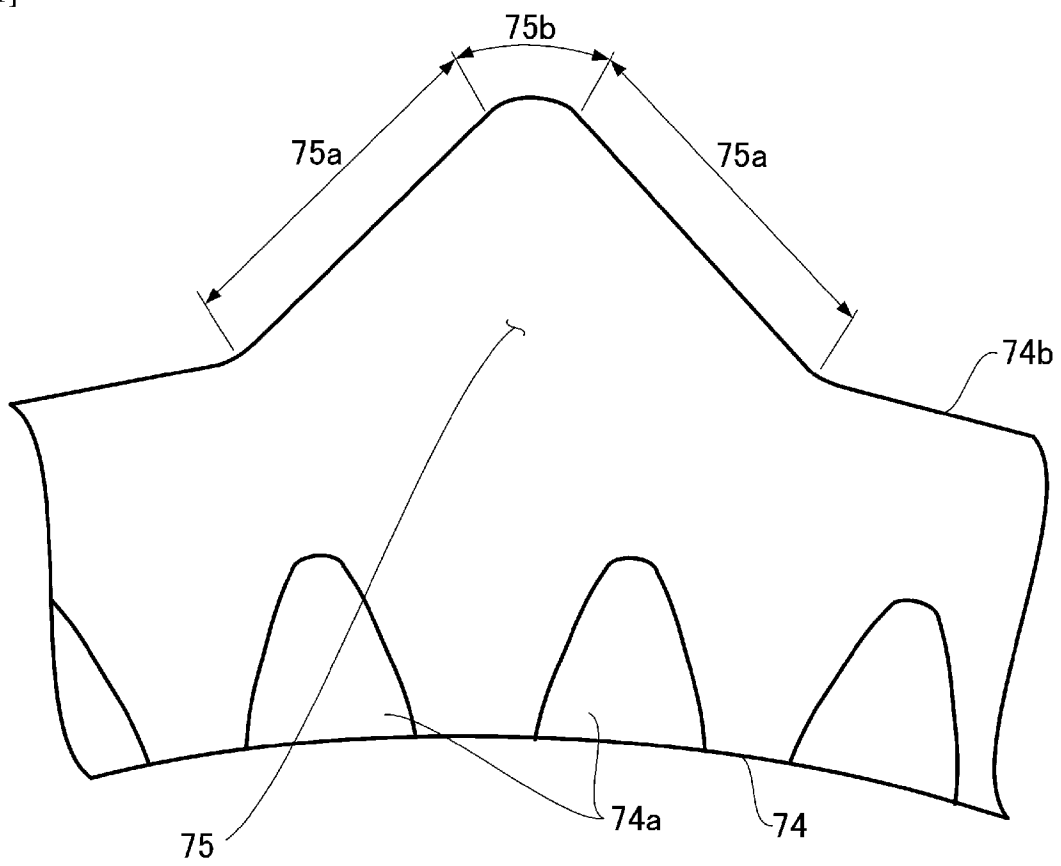
[Fig. 9]



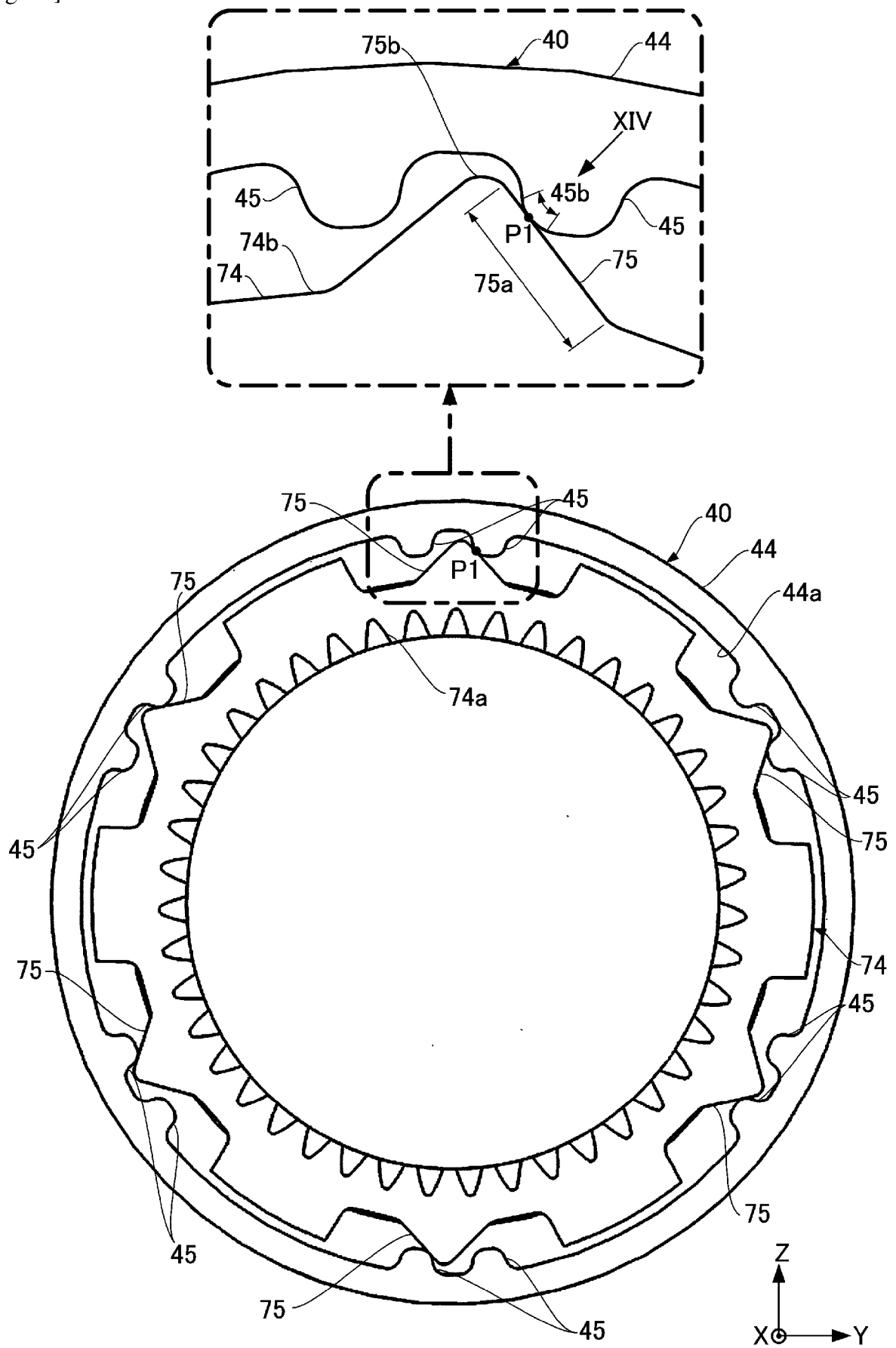
[Fig. 10]



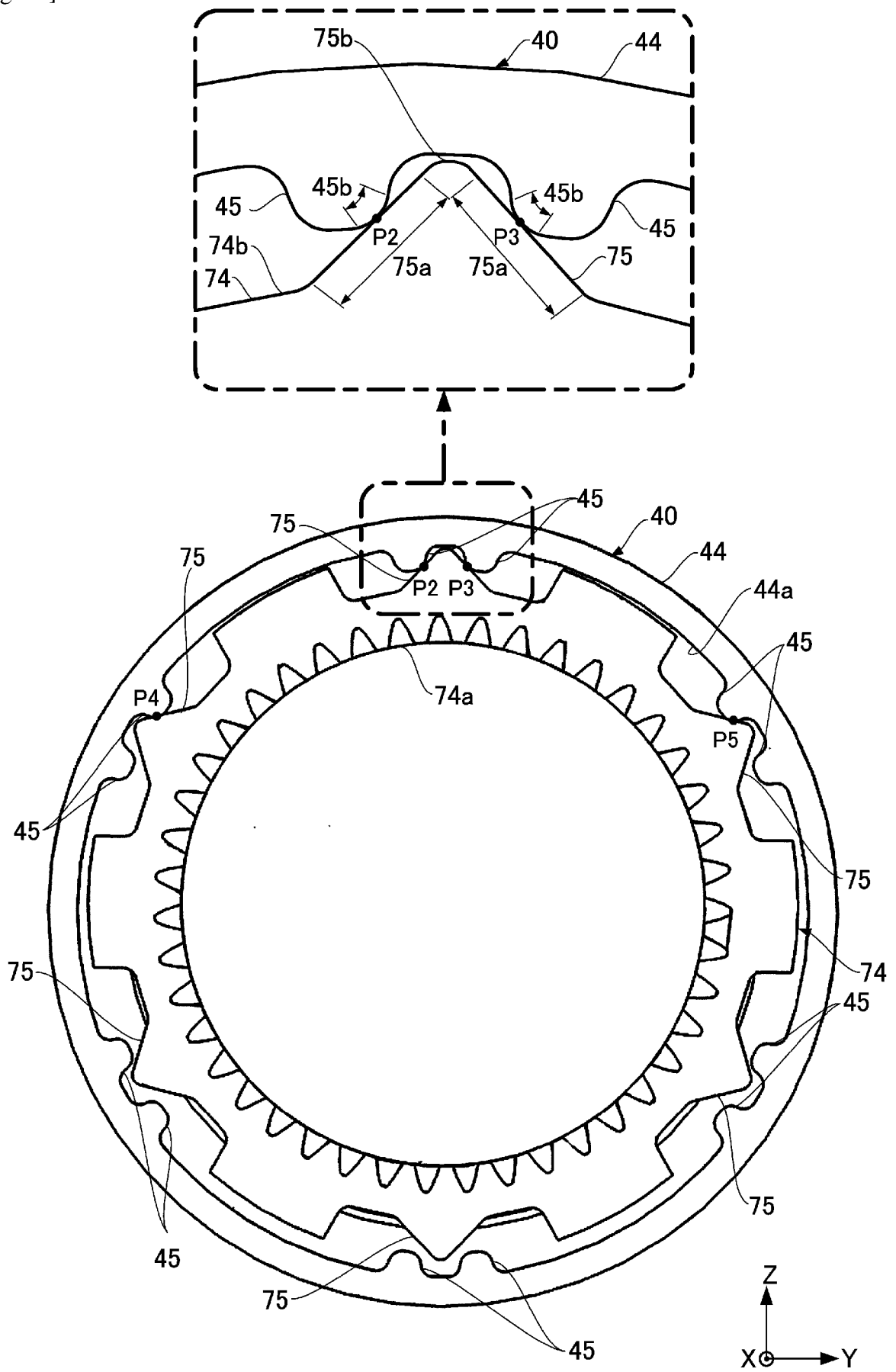
[Fig. 11]



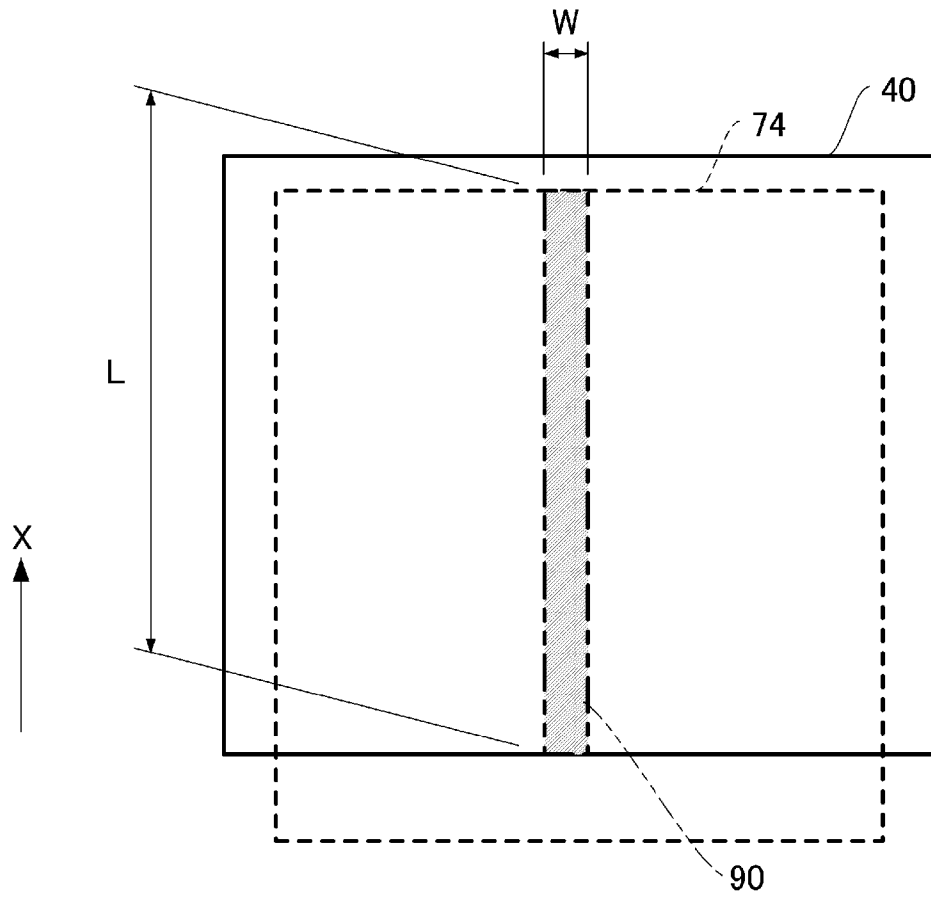
[Fig. 12]



[Fig. 13]



[Fig. 14]



[Fig. 15]

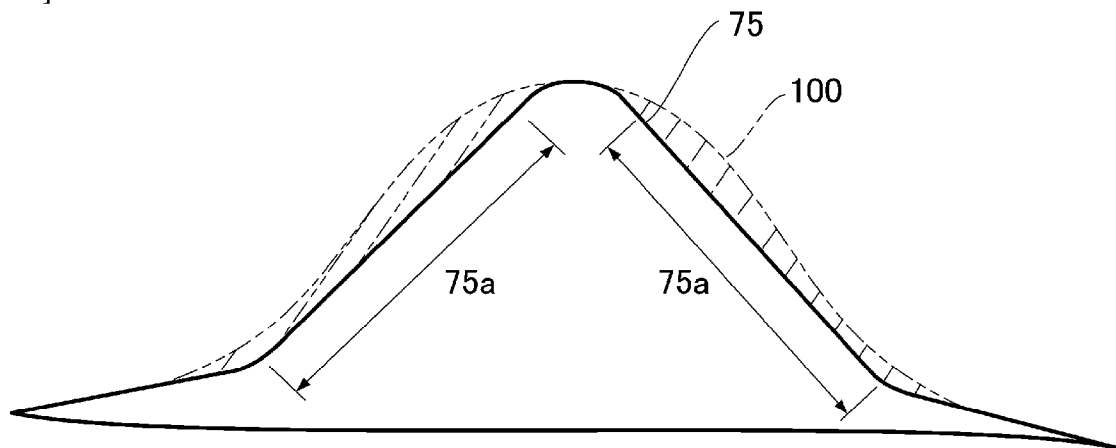
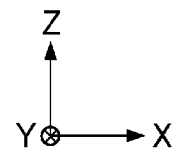
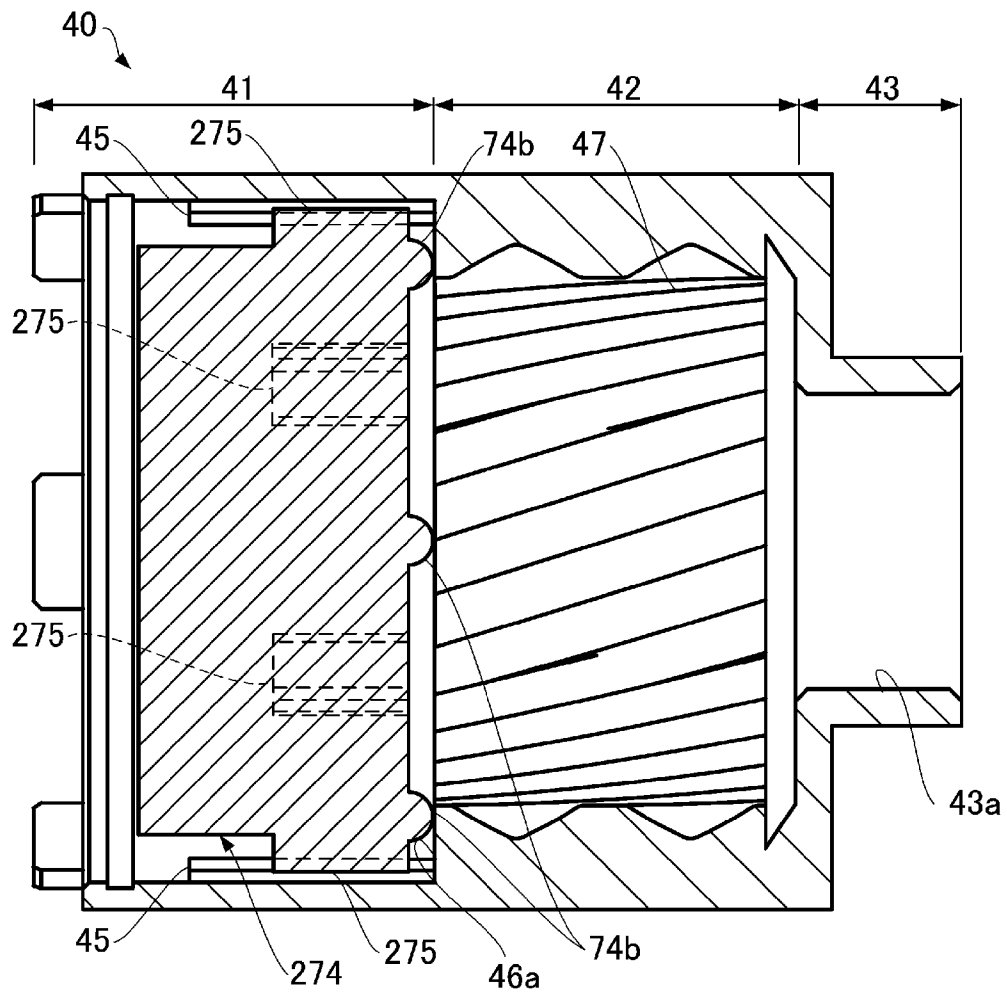
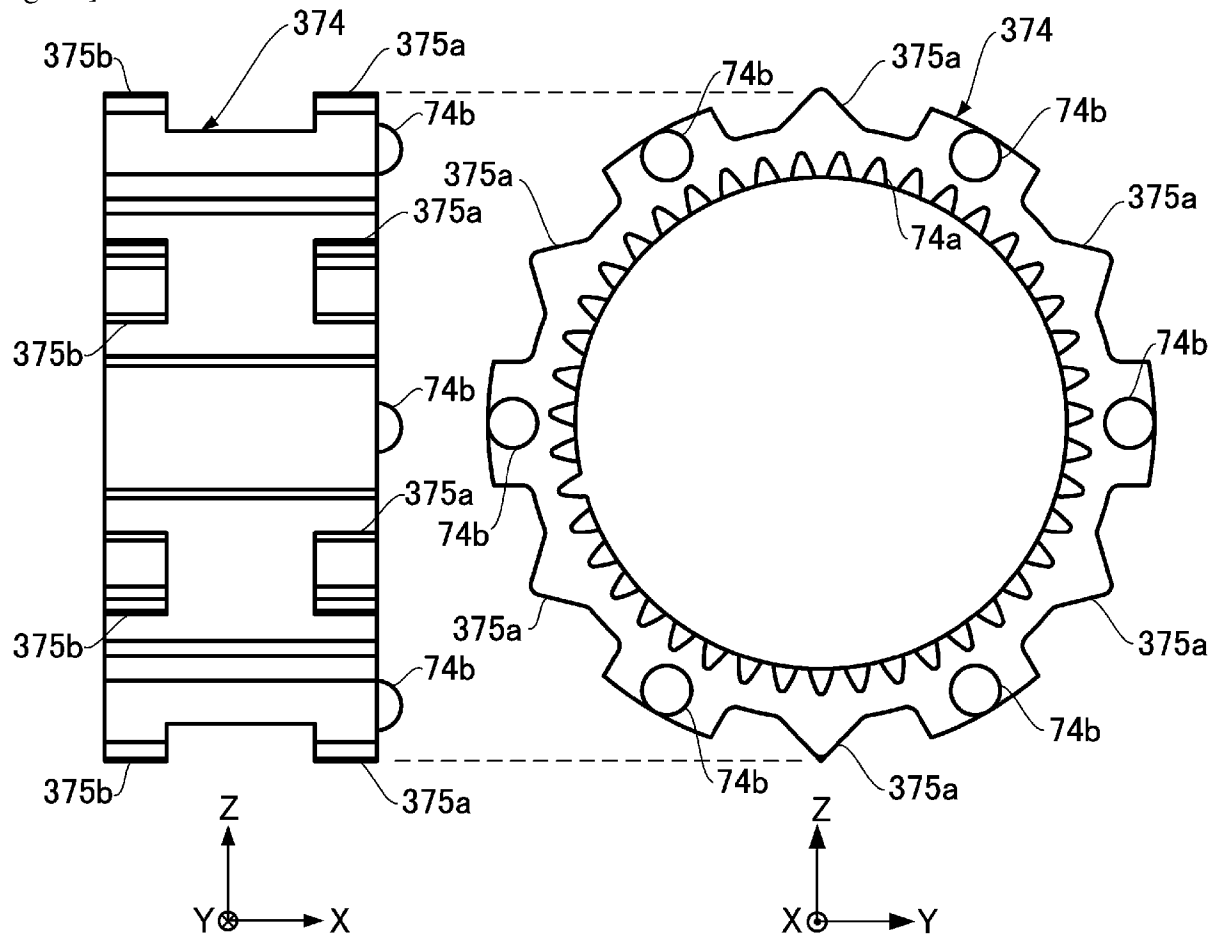


Fig. 1 is a schematic diagram of a gear assembly. It consists of two main parts: a cross-sectional view on the left and a top-down view on the right. The cross-sectional view shows a gear housing 274 with internal features 275 and 74b. The top-down view shows a gear 74a with teeth 275 and mounting holes 74b. Both views include a coordinate system with Z, X, and Y axes.

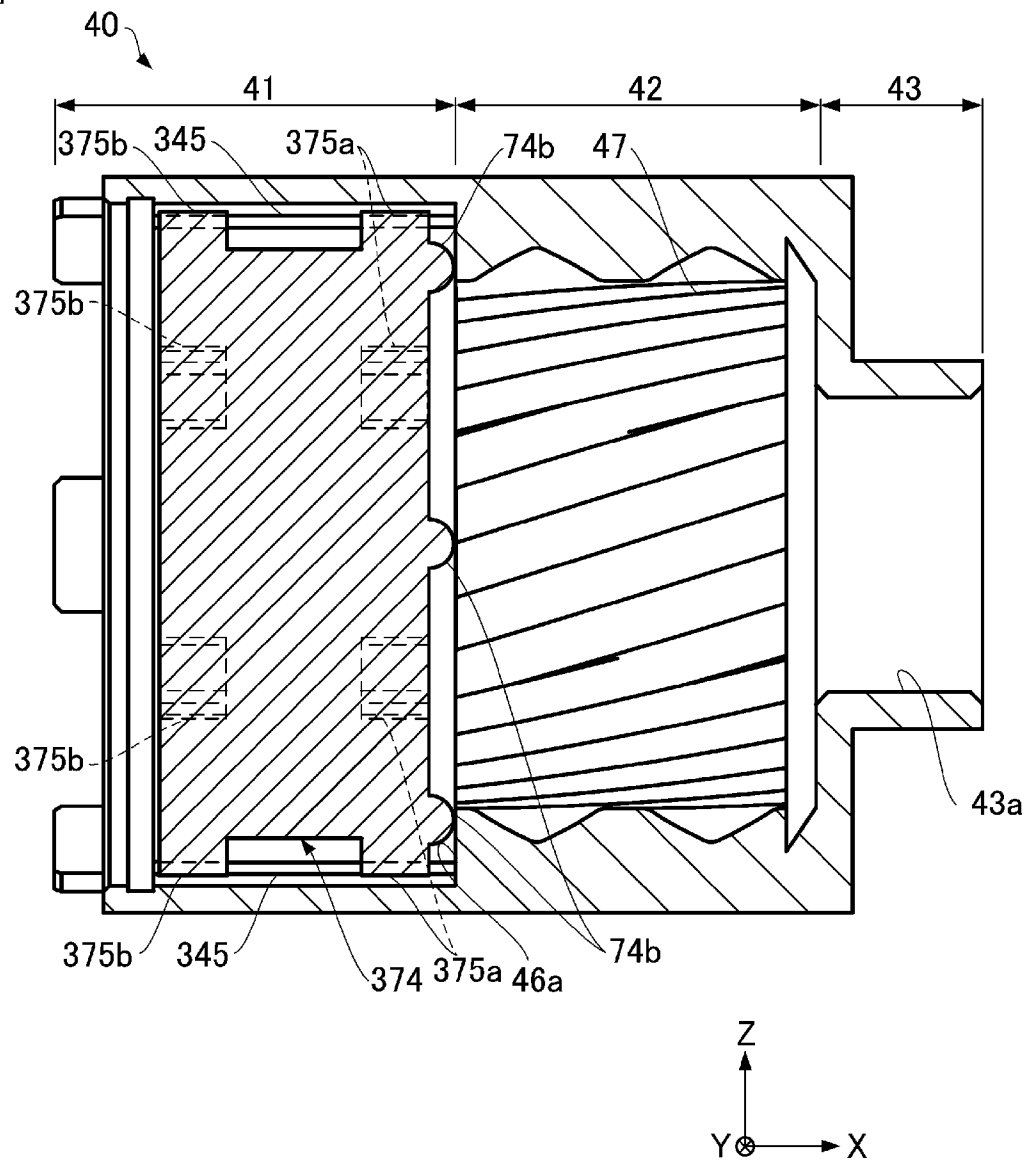
[Fig. 17]



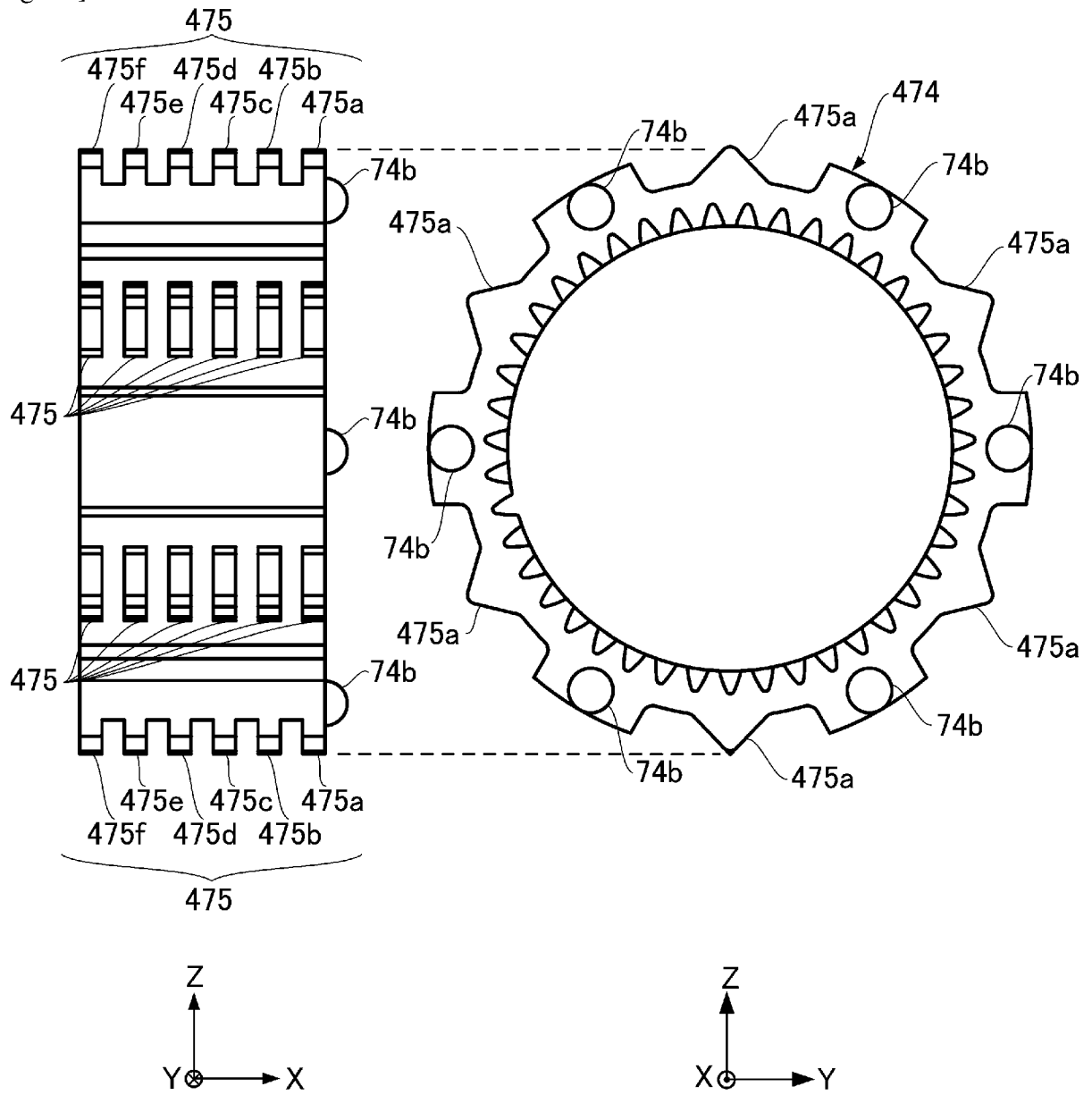
[Fig. 18]



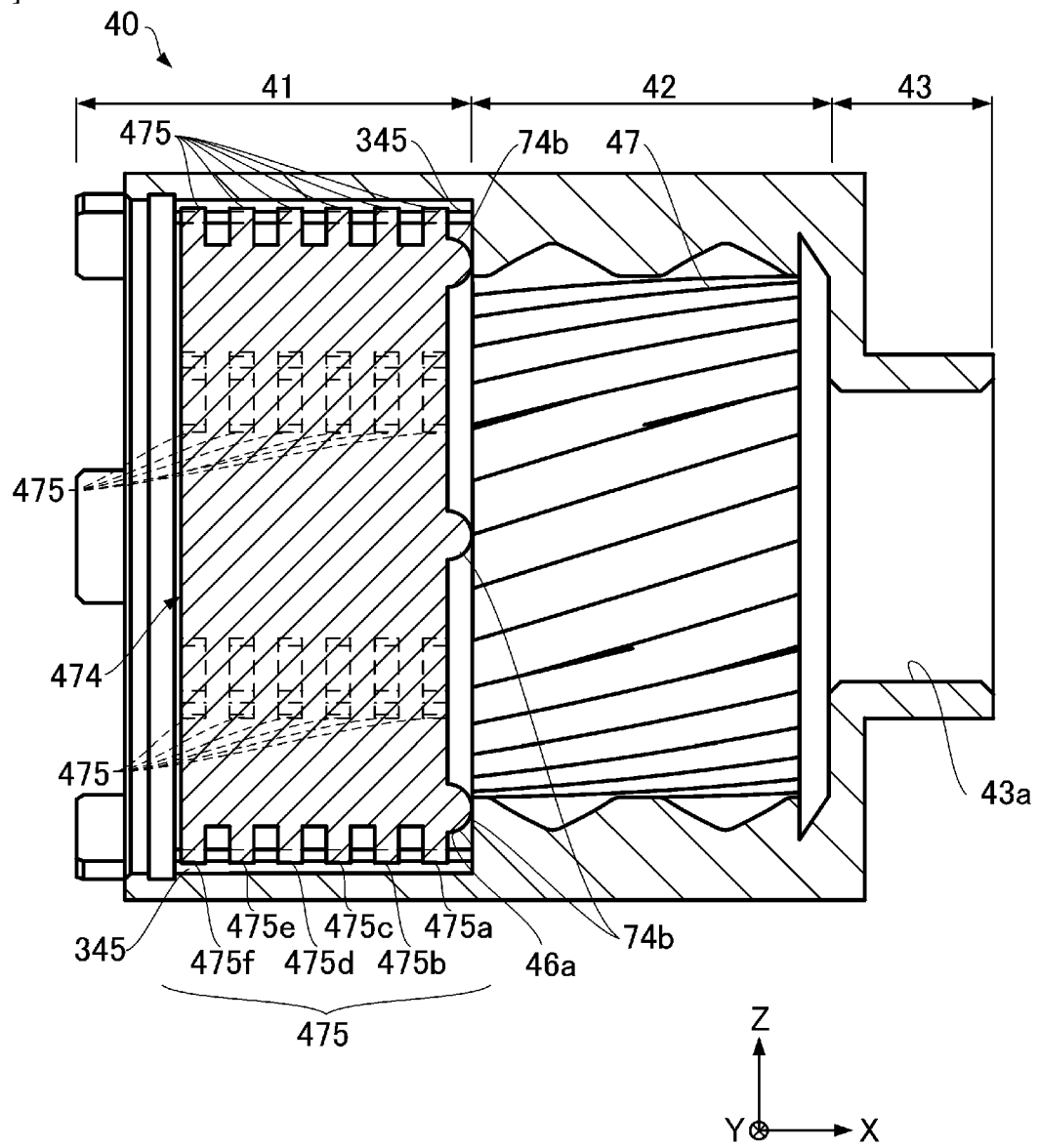
[Fig. 19]



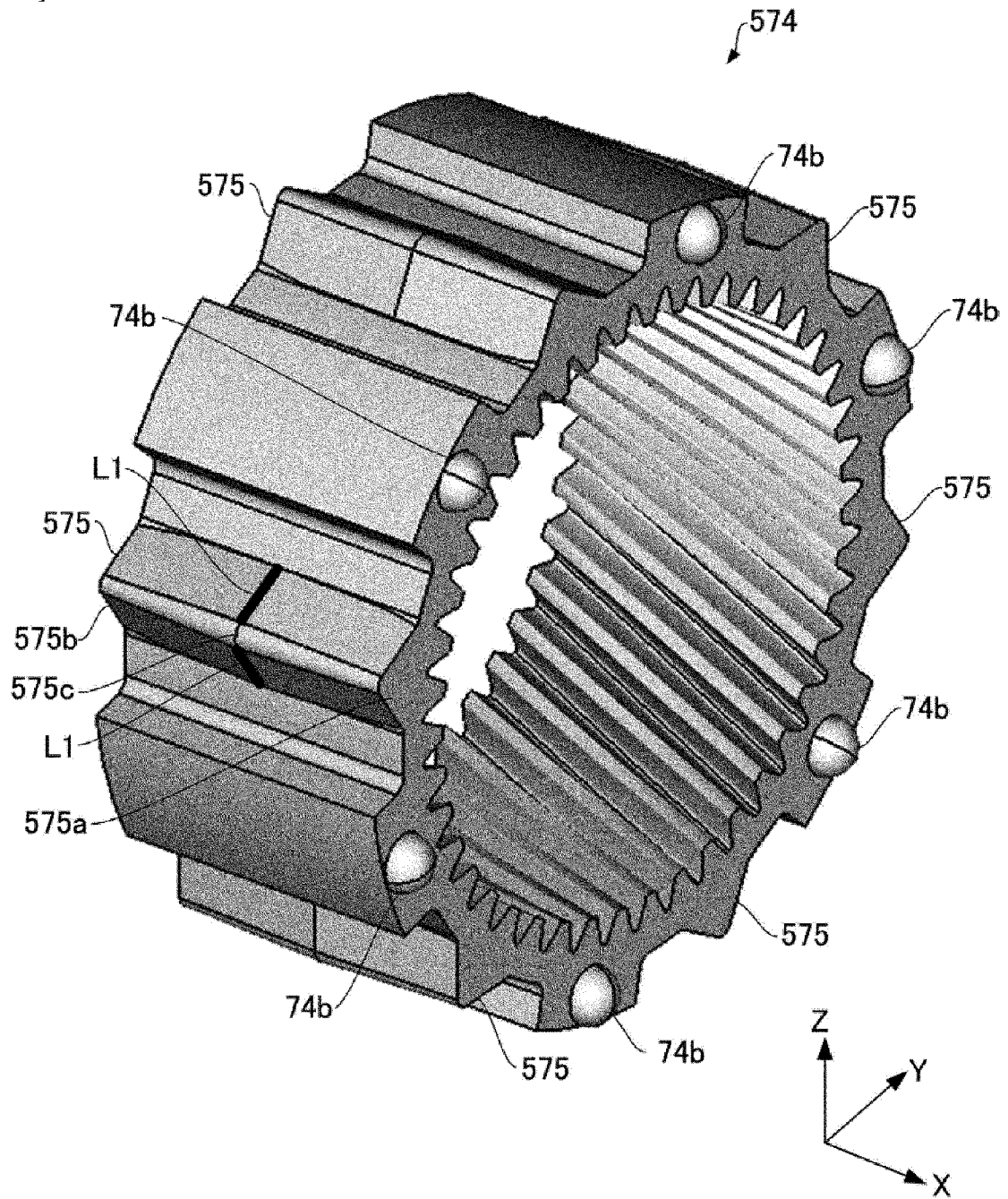
[Fig. 20]



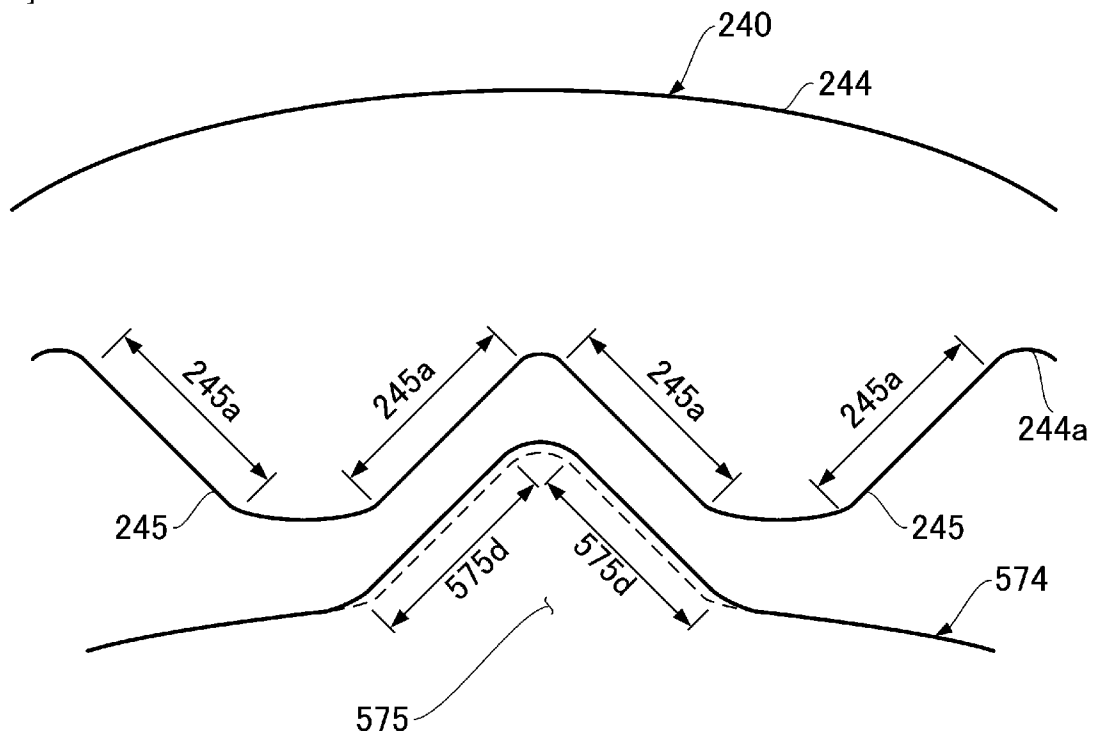
[Fig. 21]



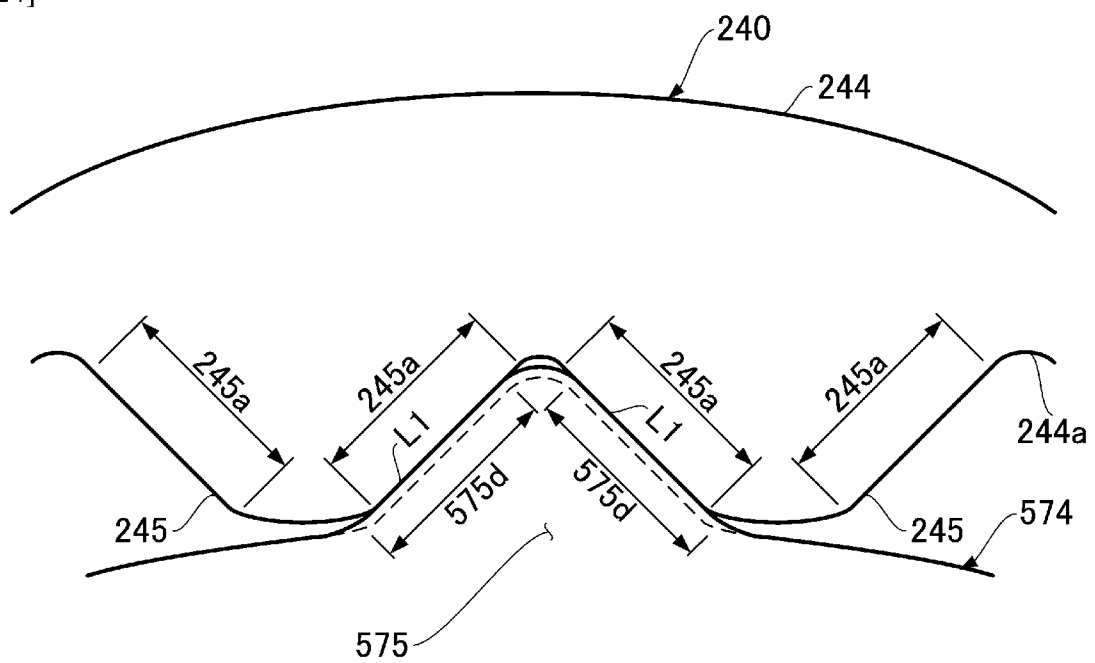
[Fig. 22]



[Fig. 23]



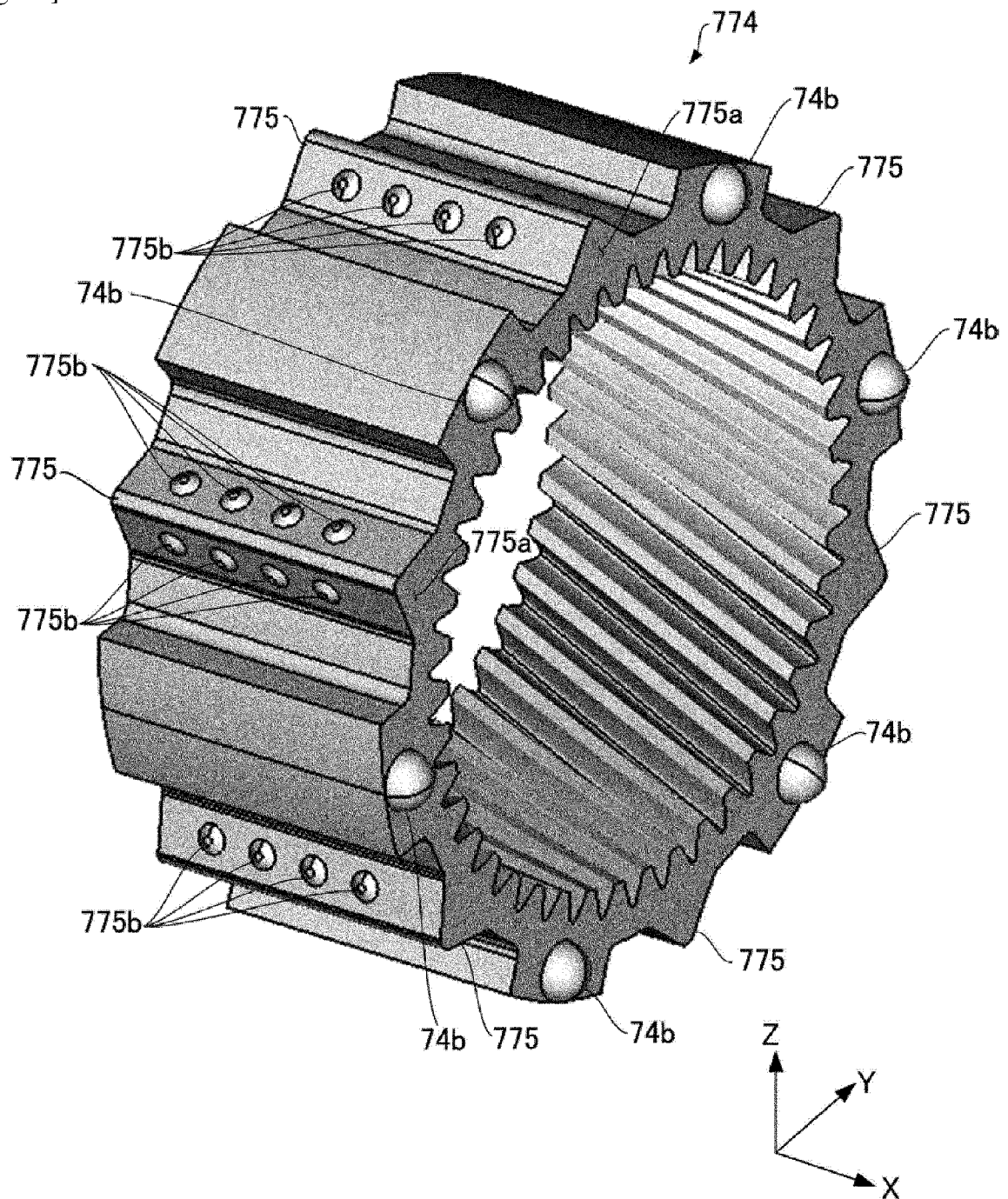
[Fig. 24]



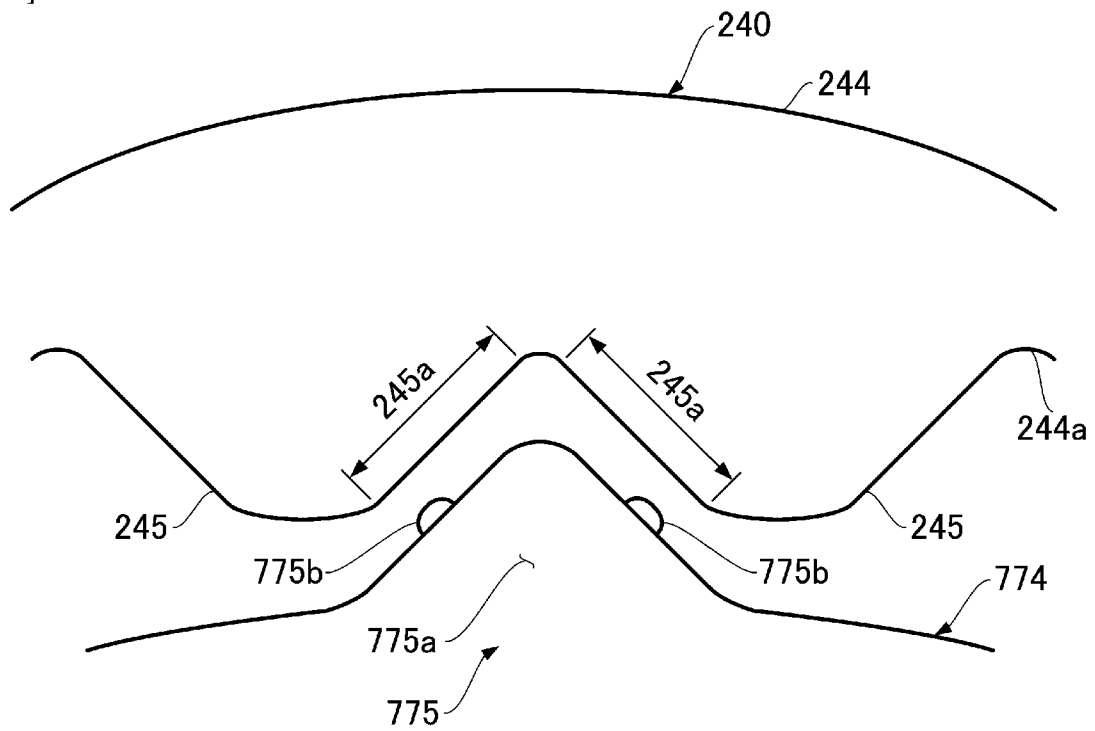
This diagram shows a cross-sectional view of a semiconductor device. It features a substrate 240 with a wavy top surface 244. A thin layer 245 is deposited on the substrate. The layer 245 has a wavy profile that follows the substrate's topography. The distance between the peaks of the wavy layer 245 is labeled 245a. The layer 245 is shown to have a thickness P. A dashed line 675 indicates a specific layer or interface within the device, with labels 675a, 675b, and 675c indicating different regions or features. A label 674 points to a specific feature on the right side of the device.

Diagram illustrating a cross-sectional view of a semiconductor device. The device includes a substrate 240 with a top layer 244. A central region 245 contains a structure 675, which is flanked by regions 244a and 245. The structure 675 is defined by a layer 674 and includes features 675a, 675b, and 675c. The structure 675 is flanked by regions 244a and 245, and a layer 674 is shown at the bottom.

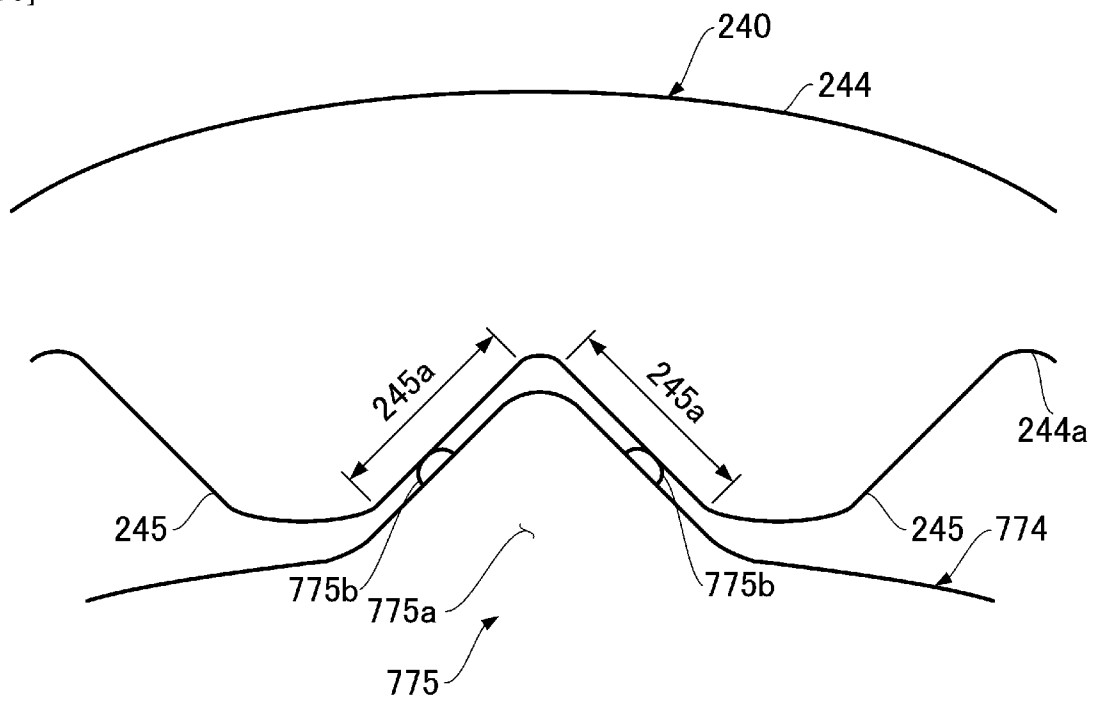
[Fig. 28]



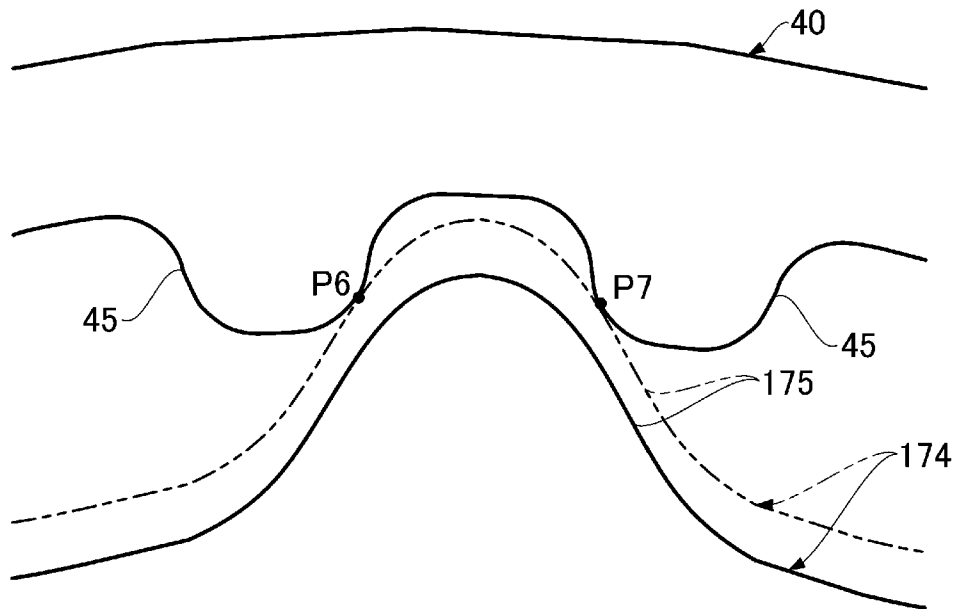
[Fig. 29]



[Fig. 30]



[Fig. 31]



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2020/029530

A. CLASSIFICATION OF SUBJECT MATTER

F16H 1/28(2006.01)i; **F16H 1/46**(2006.01)i; **H02K 7/116**(2006.01)i; **F16H 57/028**(2012.01)i; **F16H 57/032**(2012.01)i;
F16H 55/06(2006.01)i; **F16H 55/12**(2006.01)i
 FI: F16H1/28; F16H1/46; F16H55/06; F16H57/028; H02K7/116; F16H57/032; F16H55/12 Z

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F16H1/28; F16H1/46; H02K7/116; F16H57/028; F16H57/032; F16H55/06; F16H55/12

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996
 Published unexamined utility model applications of Japan 1971-2020
 Registered utility model specifications of Japan 1996-2020
 Published registered utility model applications of Japan 1994-2020

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2019/0063555 A1 (FUJI XEROX CO., LTD.,) 28 February 2019 (2019-02-28) paragraphs[0054]-[0077], figures 1-2	1-25
A	JP 4-39446 A (MATSUURA SANGYO CO; LTD.) 10 February 1992 (1992-02-10) Page2, lower left column, line 3-Page3, upper right column, line 1	1-25

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:

“A” document defining the general state of the art which is not considered to be of particular relevance
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 “O” document referring to an oral disclosure, use, exhibition or other means
 “P” document published prior to the international filing date but later than the priority date claimed

“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
 “X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
 “Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
 “&” document member of the same patent family

Date of the actual completion of the international search

28 September 2020

Date of mailing of the international search report

13 October 2020

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 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo
 100-8915, Japan**

Authorized officer

OKAMOTO Kentaro 3J 3830

Telephone No. **+81-3-3581-1101 Ext. 3328**

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Information on patent family members

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