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# (54) ROTATION TRANSMISSION DEVICE

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(2) Date: **Dec. 27, 2015**

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| Oct. 30, 2013 | (JP) | 2013-225481 |
| Nov. 5, 2013 | (JP) | 2013-229682 |
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| Nov. 6, 2013 | (JP) | 2013-229952 |
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***F16H 57/00*** (2006.01)
***G01L 3/10*** (2006.01)

(52) **U.S. Cl.**
CPC ..... ***F16H 57/0037*** (2013.01); ***G01L 3/101*** (2013.01)

## (57) ABSTRACT

A rotation transmission device having a high torque measurement resolution is provided. The rotation transmission device is provided with: a rotary-shaft unit (**6**) having a first and second rotary shaft (**13**, **14**) combined so as to be coaxial and such that the end sections thereof can rotate relative to each other and a torsion bar (**15**) that is provided on the inner-diameter side of the first and second rotary shafts so as to be coaxial therewith, has one end section connected to the first rotary shaft (**13**), and has the other end section connected to the second rotary shaft (**14**); a first gear (**7**) fastened to the outer peripheral surface of the first rotary shaft (**13**); a second gear (**8**) fastened to the outer peripheral surface of the second rotary shaft (**14**); a coupling shaft (**9**) provided on the inner-diameter side of the torsion bar (**15**) so as to be coaxial therewith, having one end section connected to one rotary shaft (**13**), and having the other end section protruding from an end of the torsion bar (**15**) in the axial direction; a first encoder disposed and fixed on the other end of the coupling shaft (**9**) so as to be coaxial with the first rotary shaft (**13**) and having a first detected section (**39**); a second encoder fastened on the other end of the second rotary shaft (**14**) so as to be close to the first encoder and having a second detected section (**40**); and a sensor unit having at least one sensor (**42***a*, **42***b*) that faces the first and second detected sections (**39**, **40**).

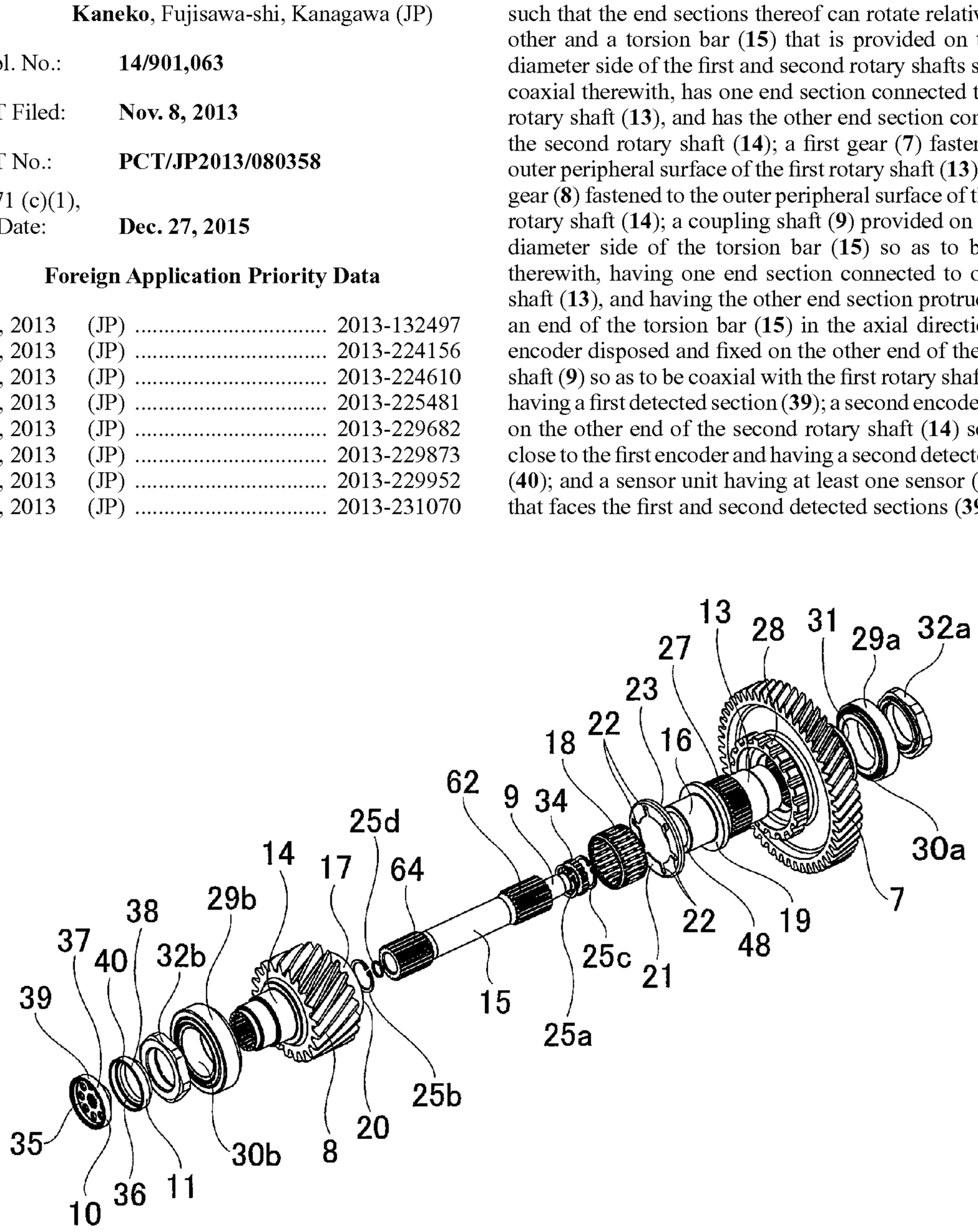
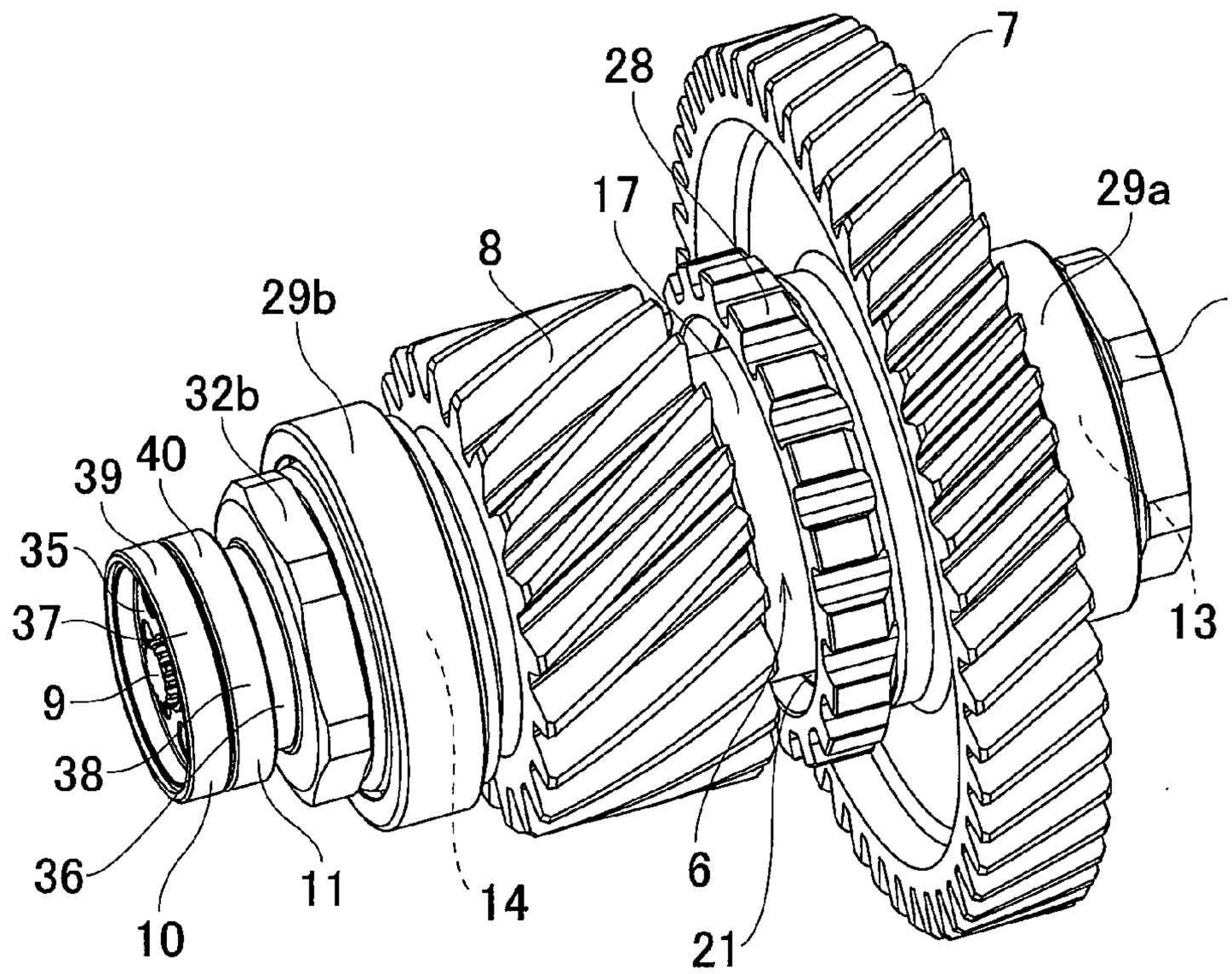


Fig.1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17
29a
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29b
32a
32b
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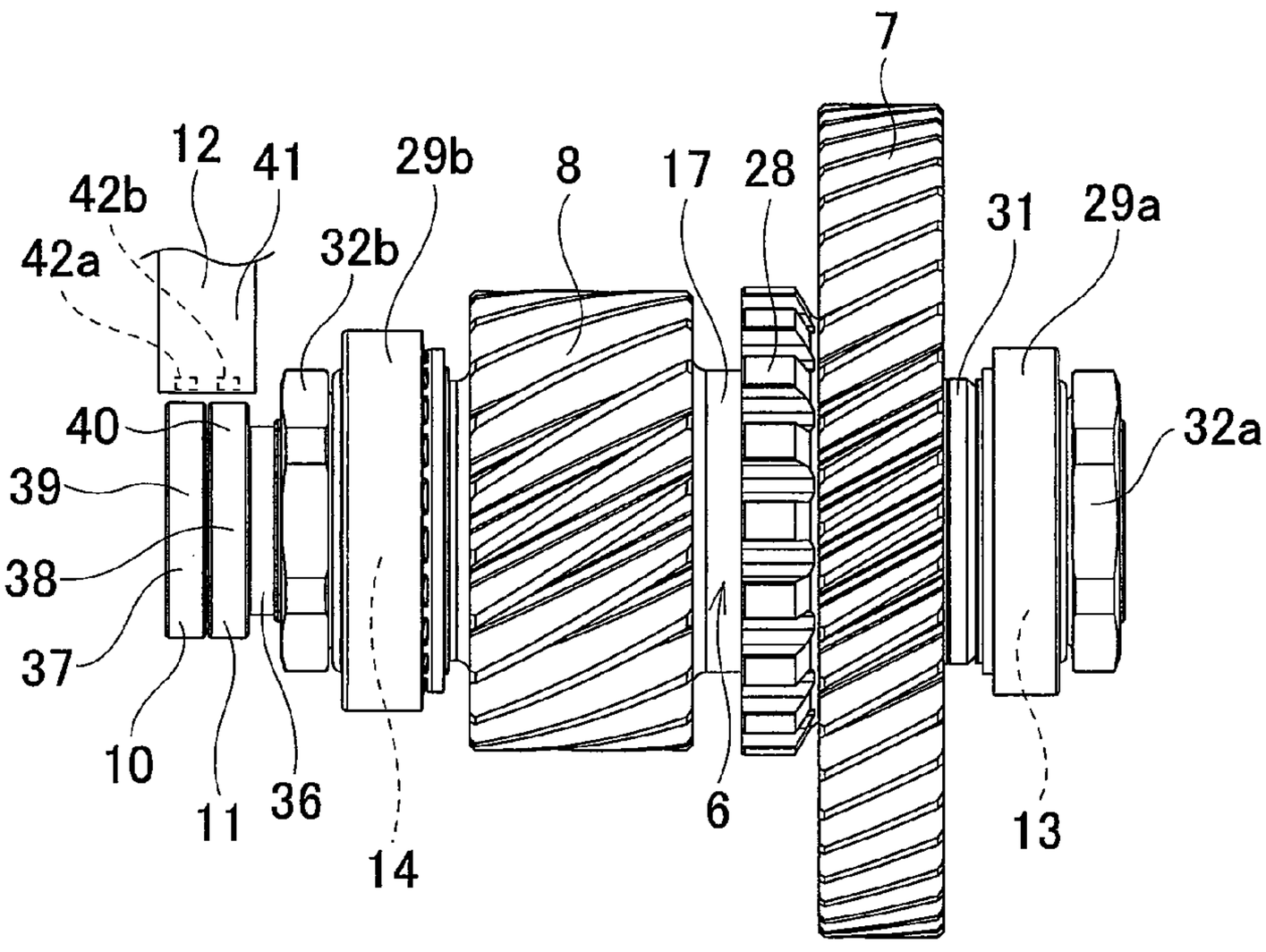
21
13

Fig.2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42b
42a
29b
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29a
32b
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14
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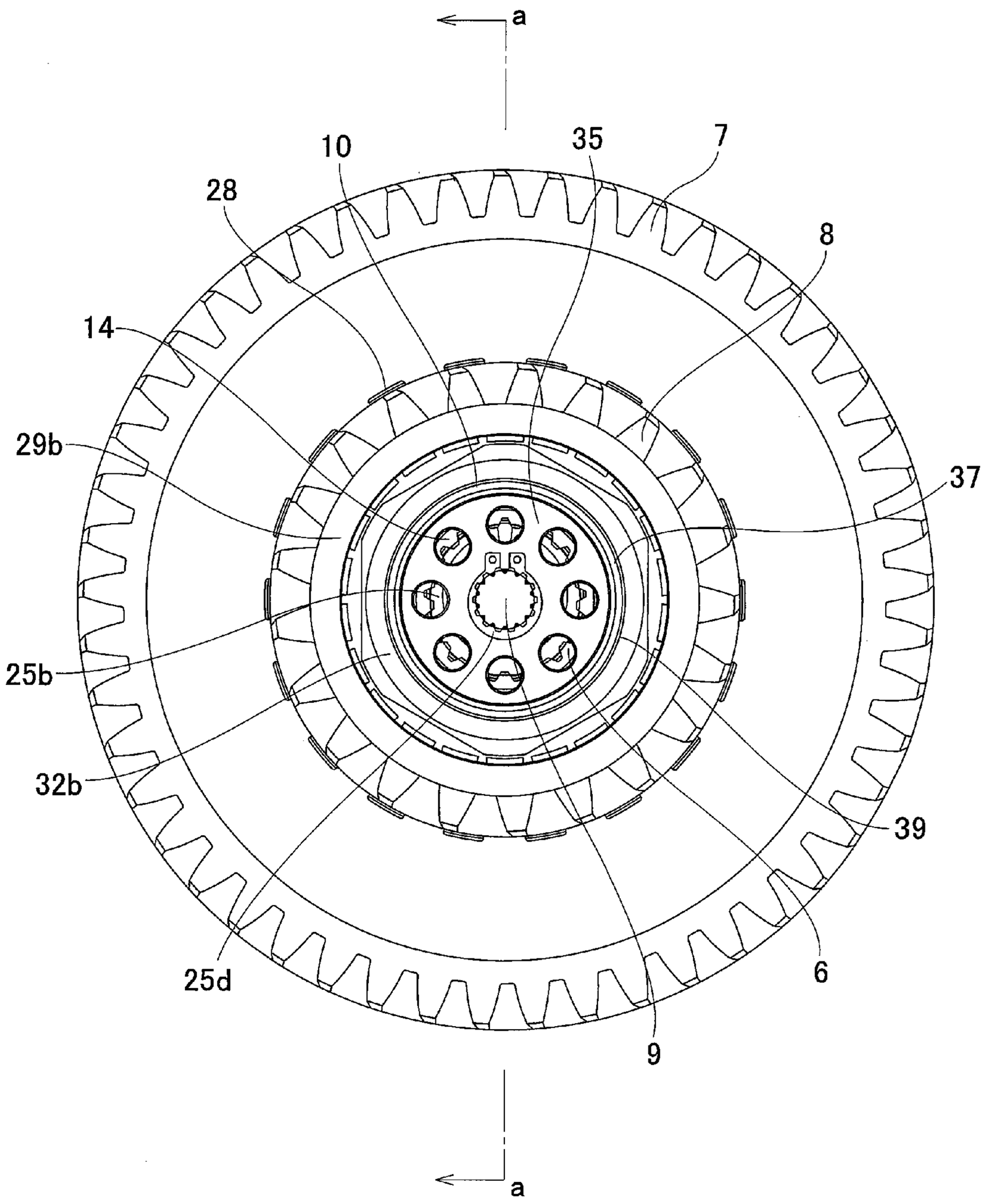
13
32a

Fig.3



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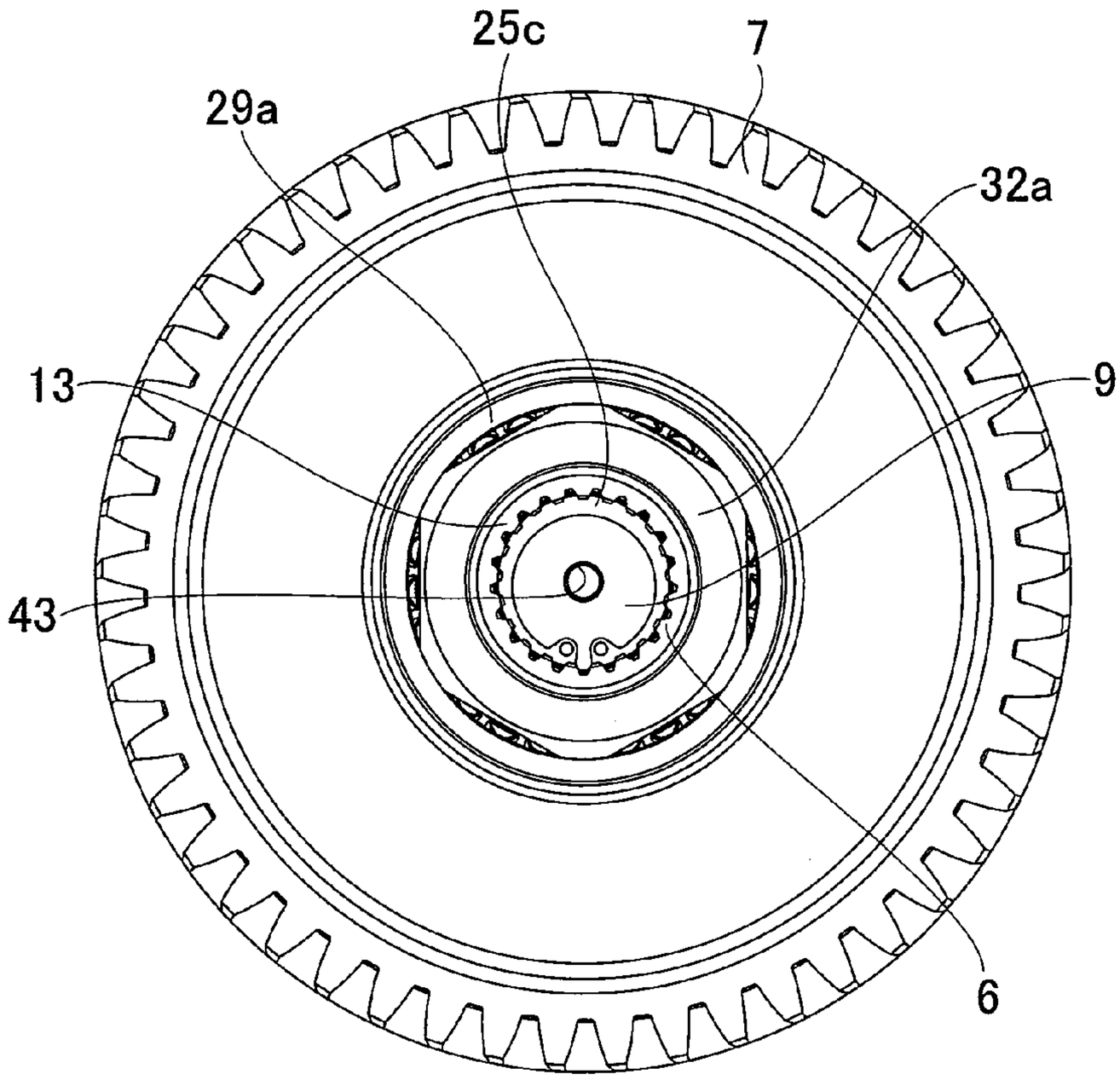
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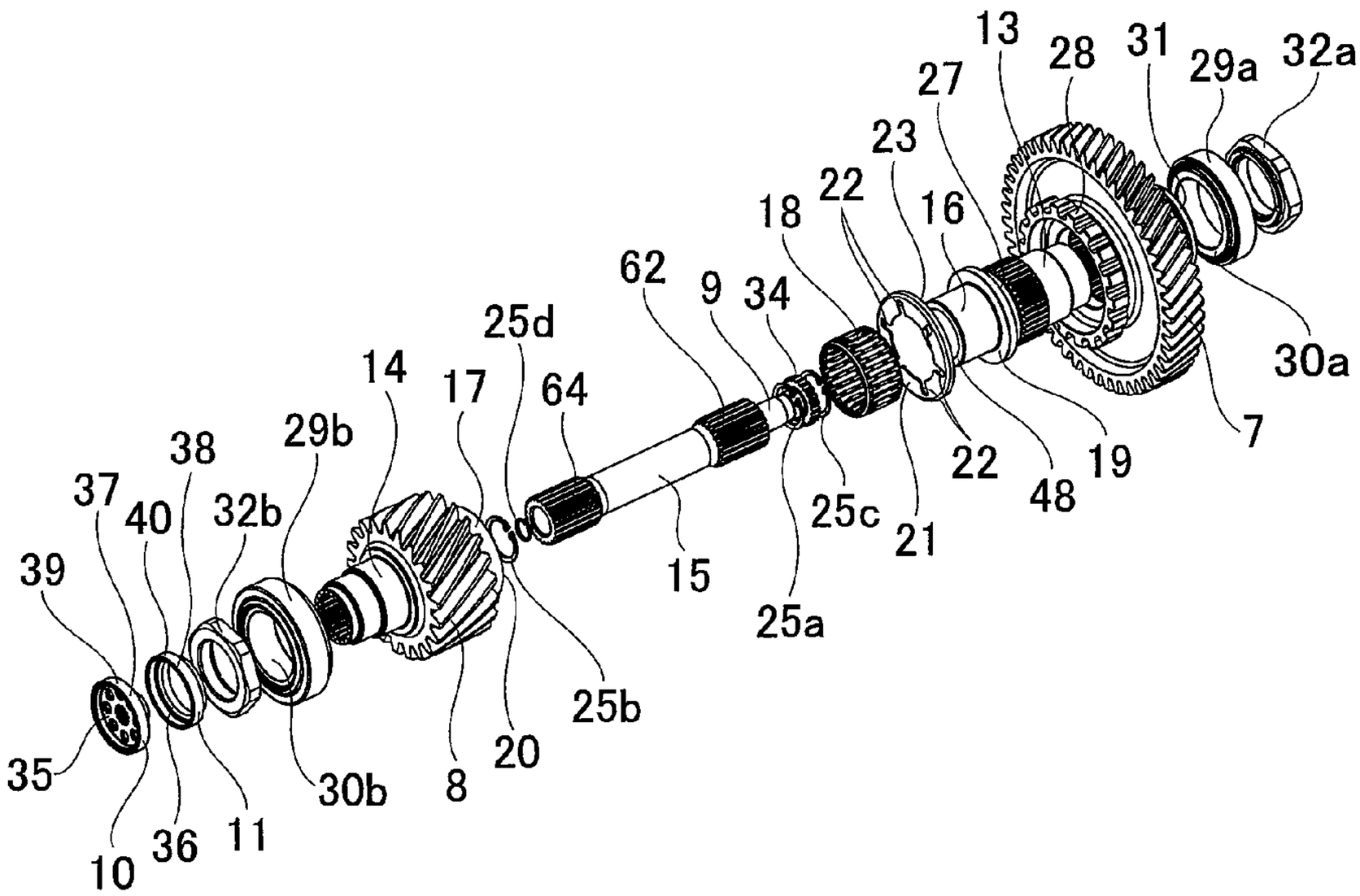
7
29a
32a
13
9
43
6

Fig.5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29a
32a
27
23
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18
16
62
9
34
25d
14
17
64
29b
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37
40
32b
39
15
25c
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22
48
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30a
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25a
25b
20
8
30b
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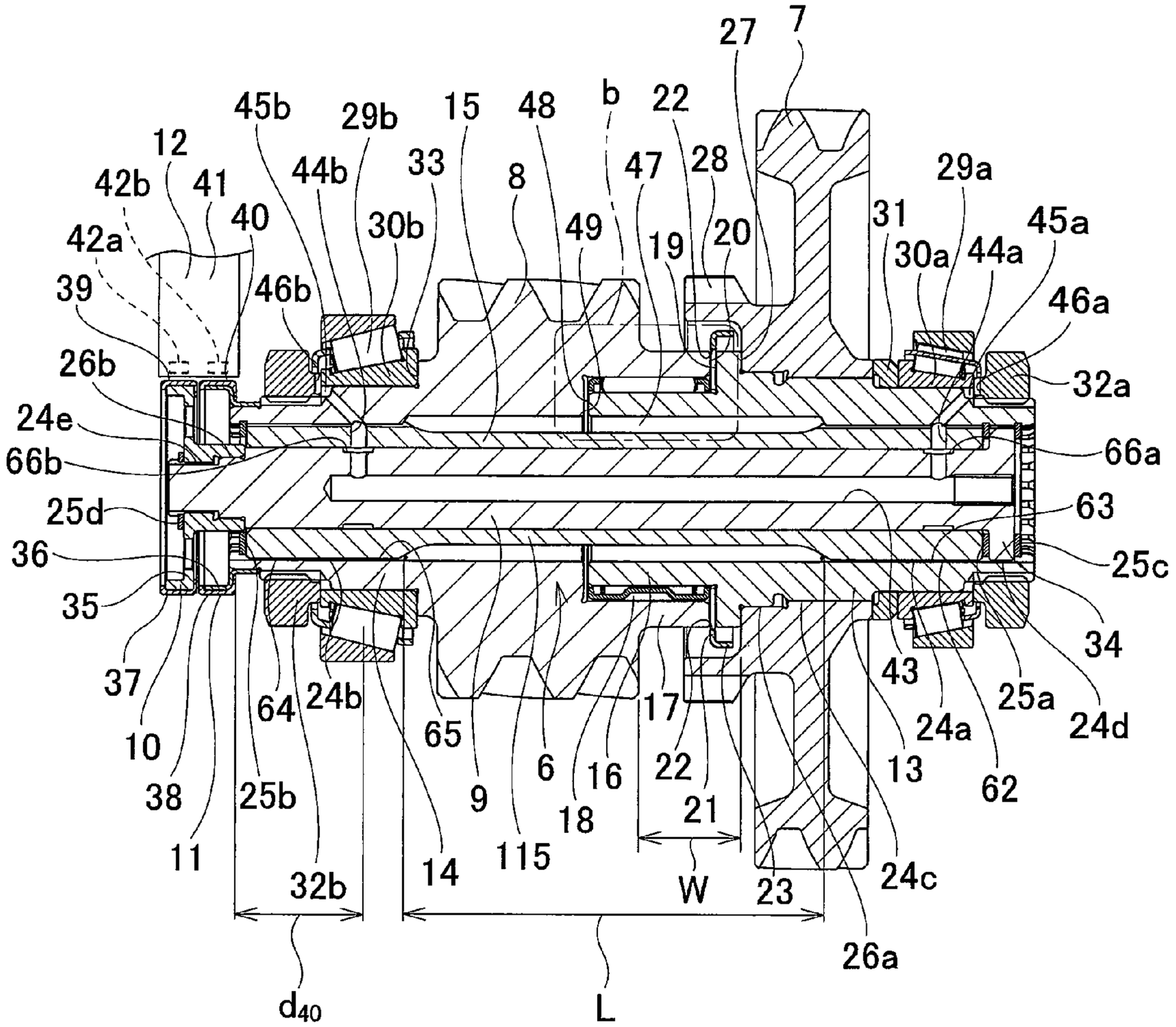
36
11

Fig.6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7
45b
29b
15
48
b
22
12
42b
41
44b
33
8
47
28
29a
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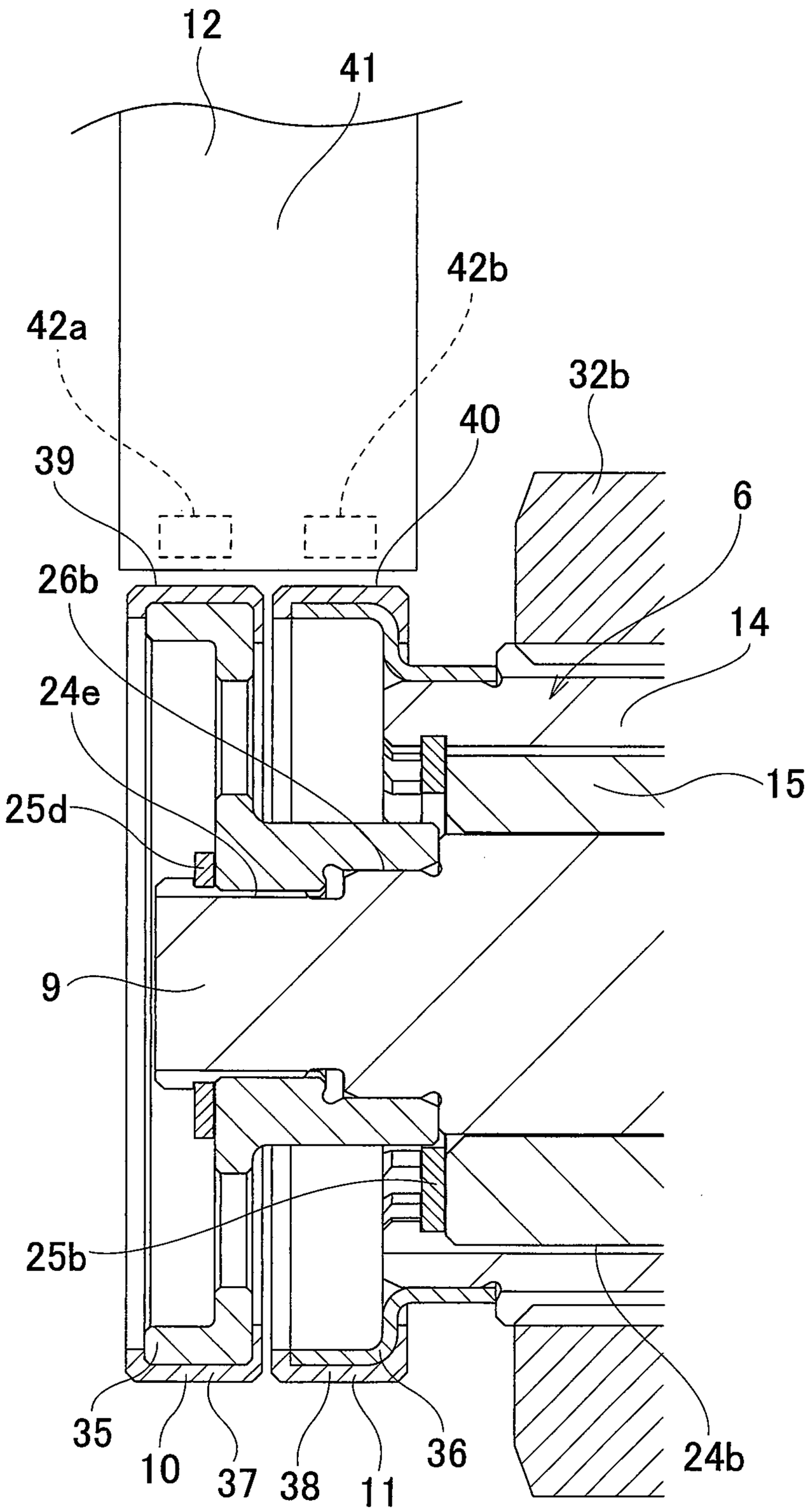
30b
49
19
20
31
45a
42a
30a
44a
39
46b
46a
26b
32a
24e
66a
66b
63
25d
25c
36
35
34
37
43
25a
24d
64
24b
65
17
24a
10
9
6
16
22
13
62
38
25b
18
21
11
115
24c
14
W
23
32b
26a
$d_{40}$
L

Fig.7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42b
42a
32b
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25d
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25b
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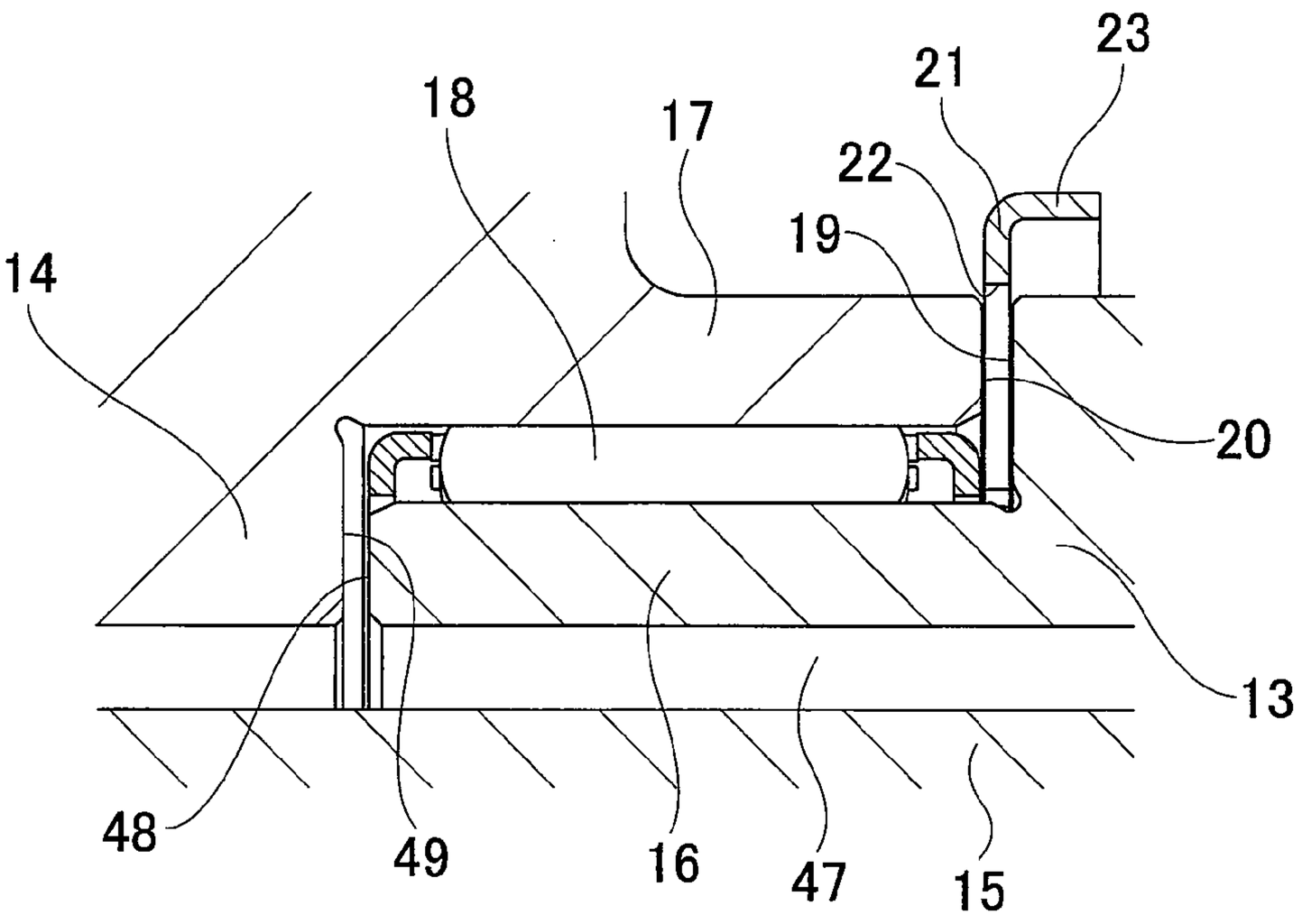
36
24b

Fig.8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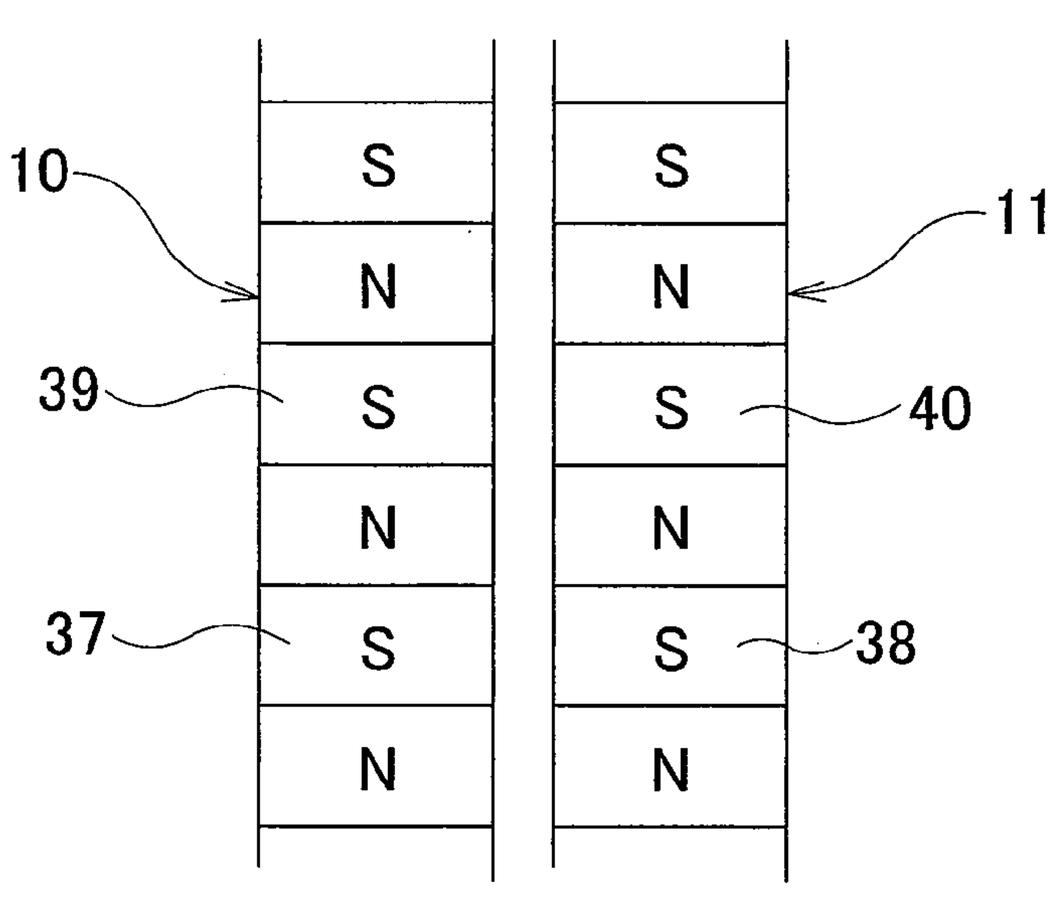
47
15

Fig.9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S
S
38
N
N

Fig.10

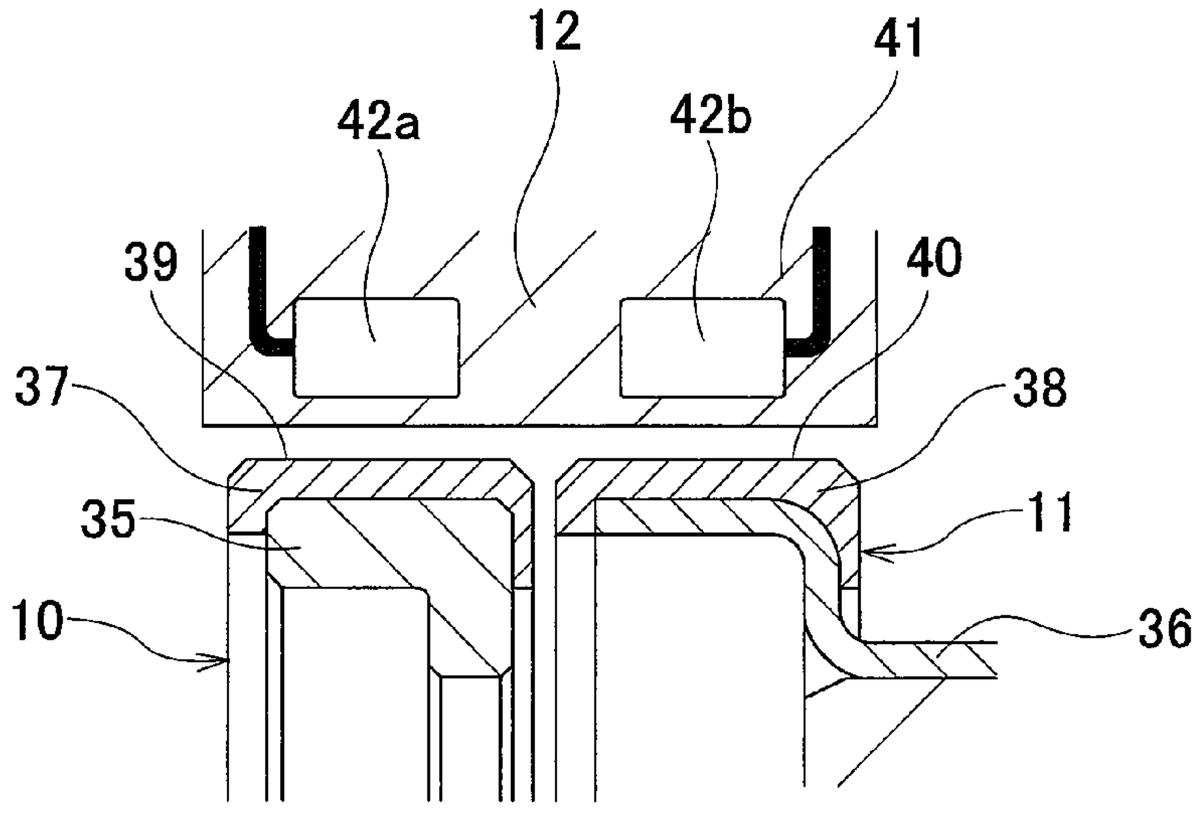
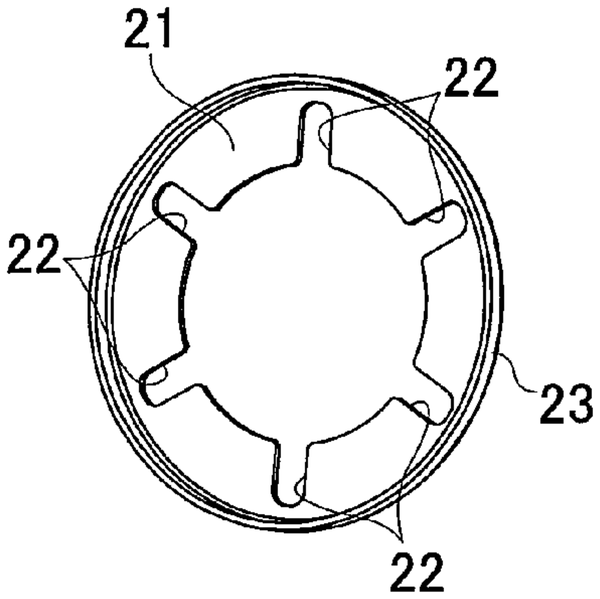



Fig.11 (A)

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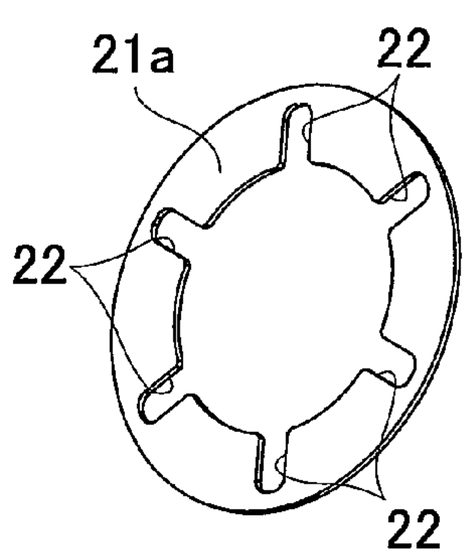
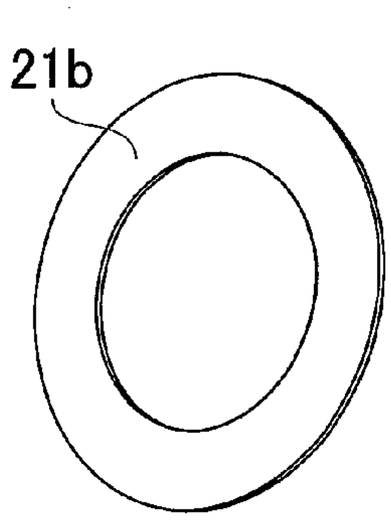



Fig.11 (C)



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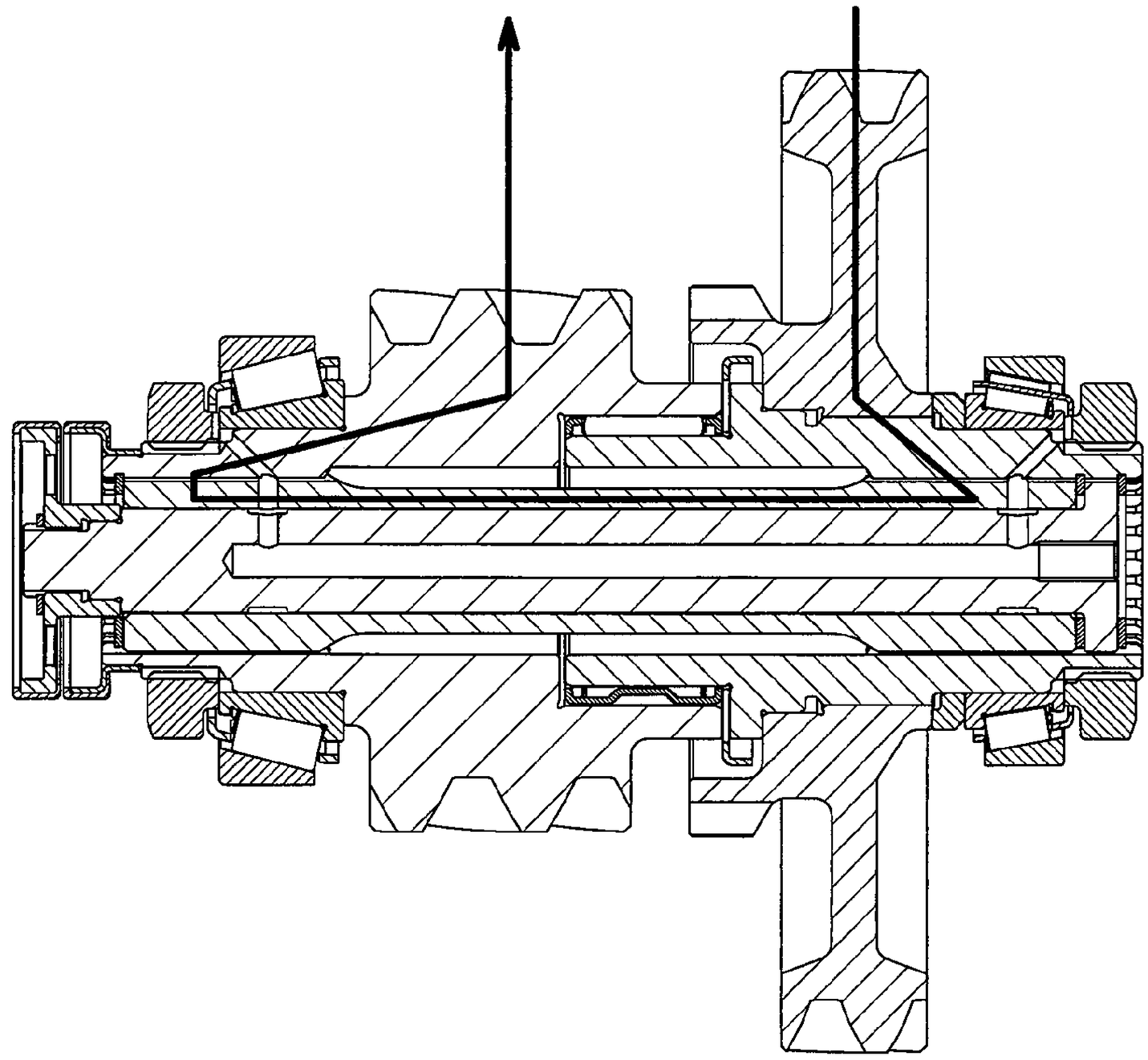

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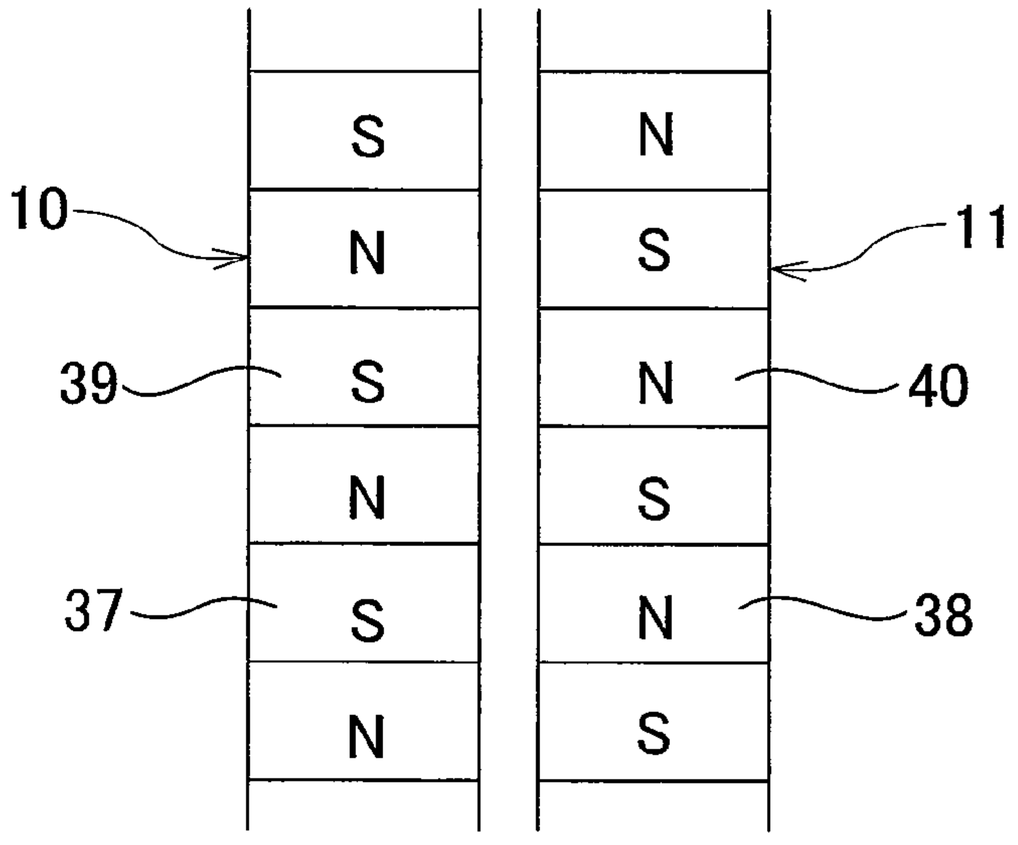

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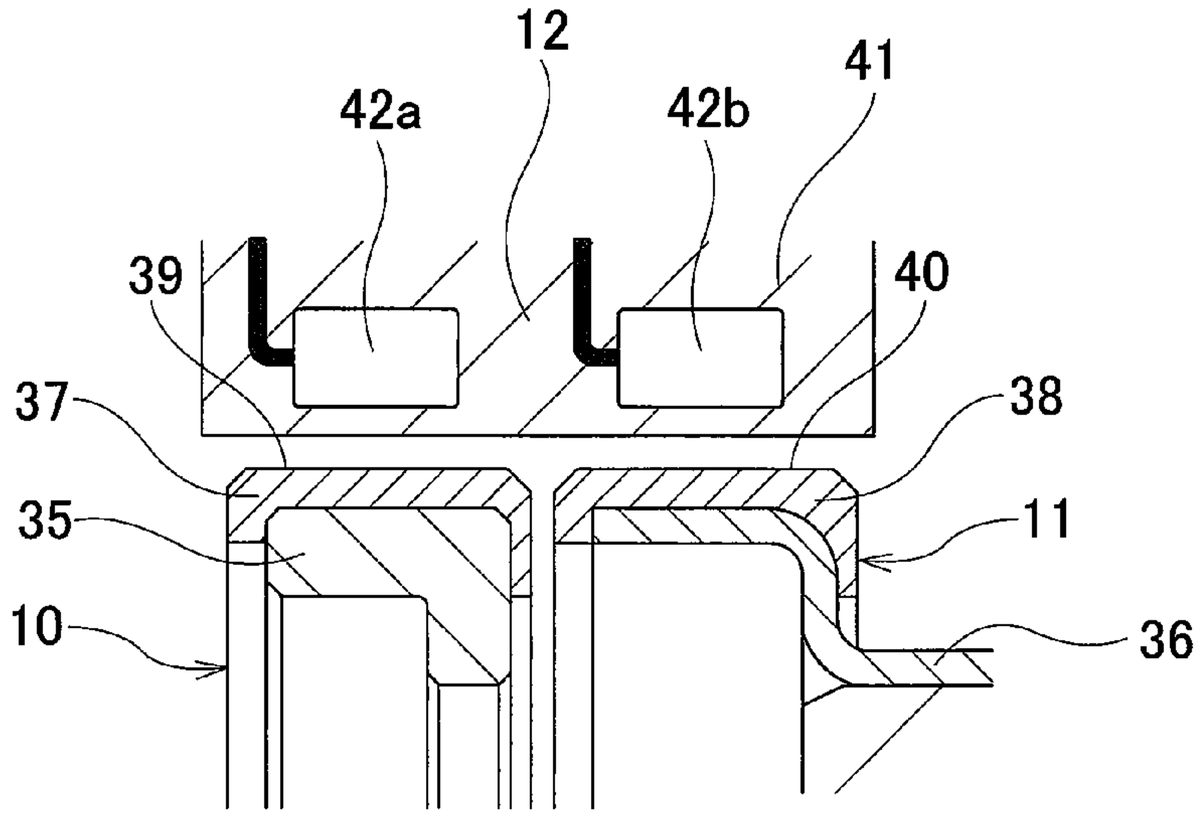
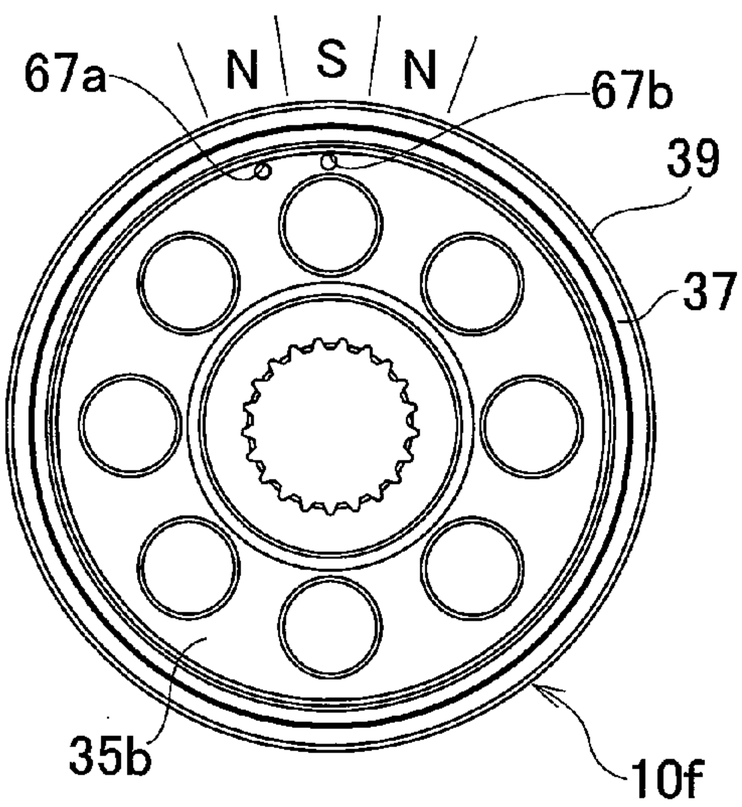



Fig.15 (A)

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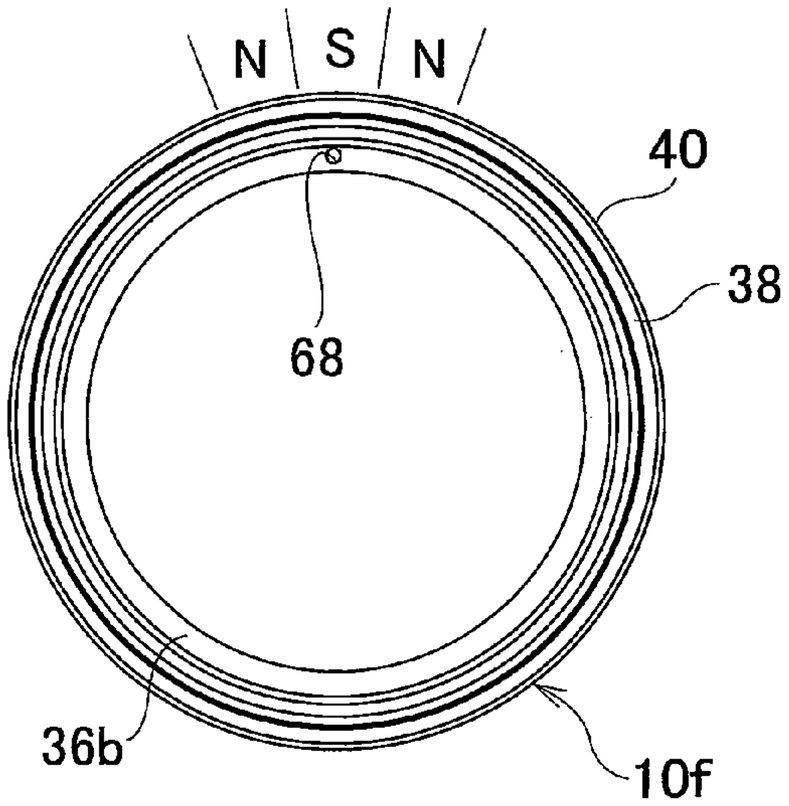


Fig.16

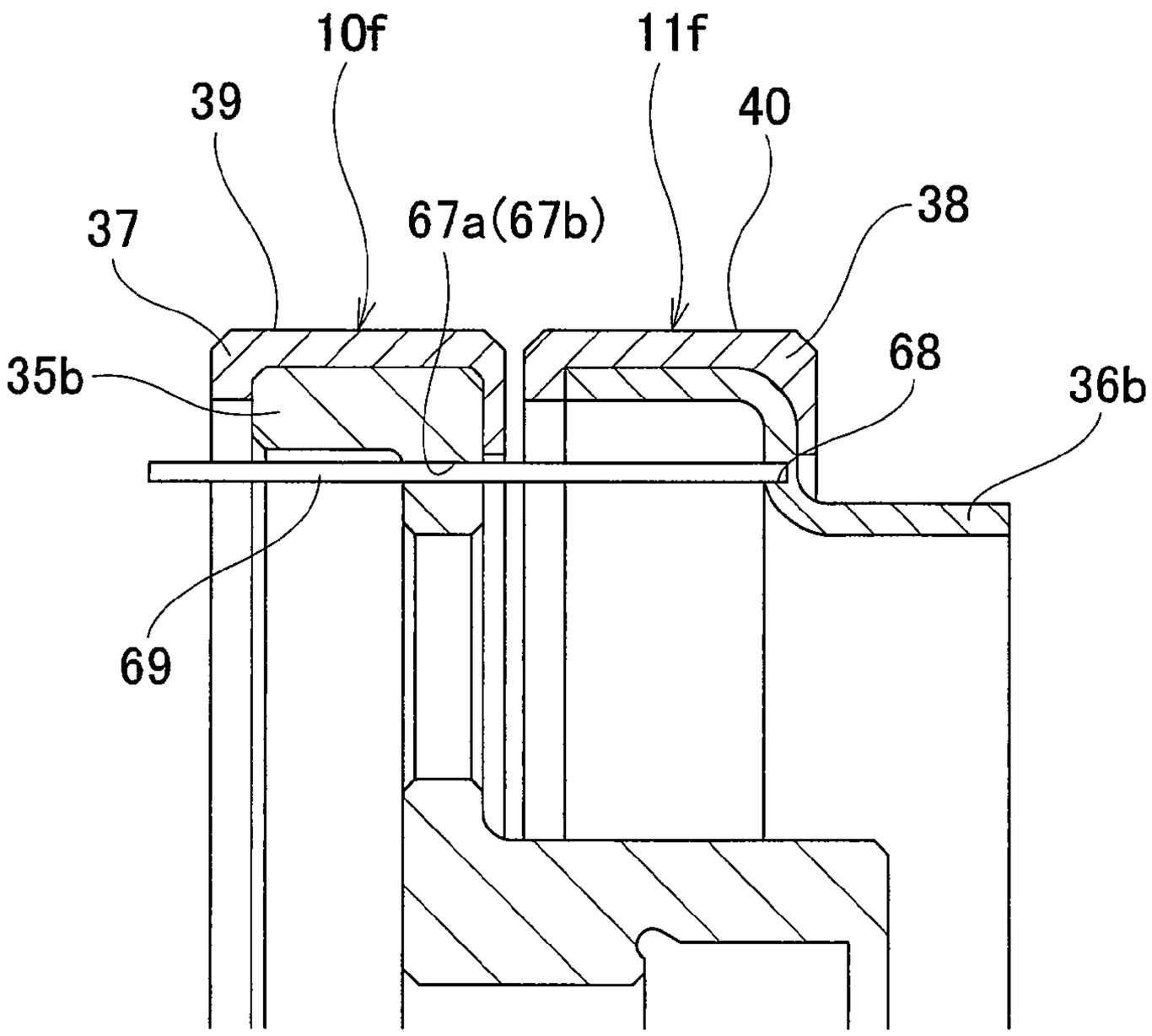
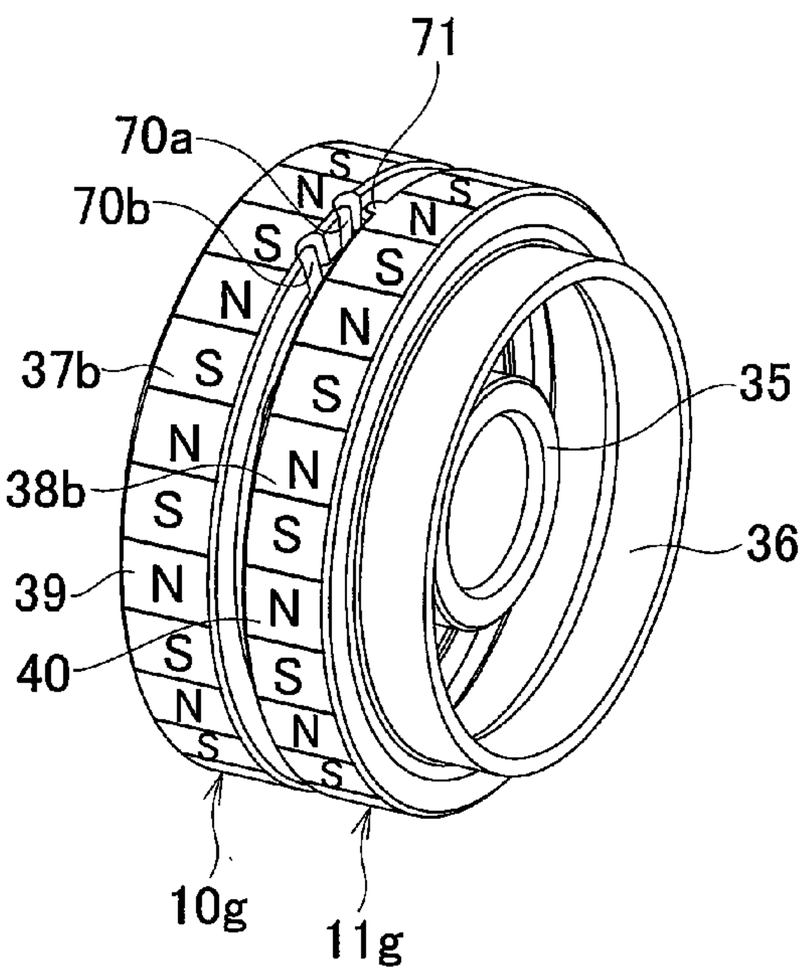


Fig.17 (A)

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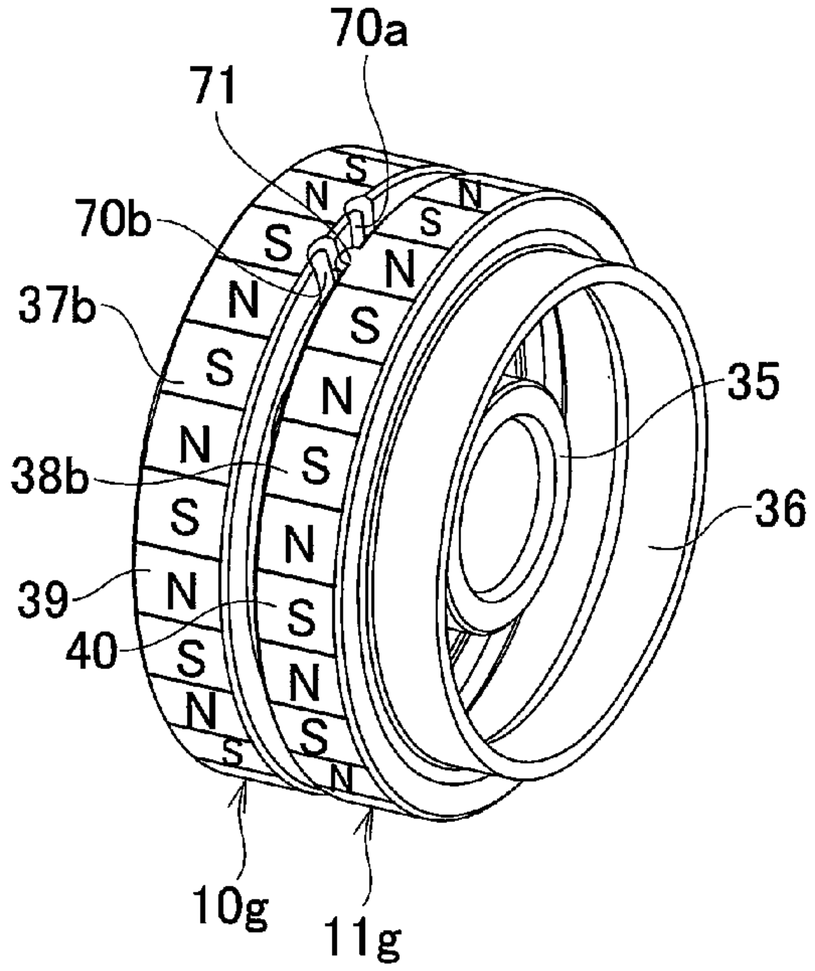
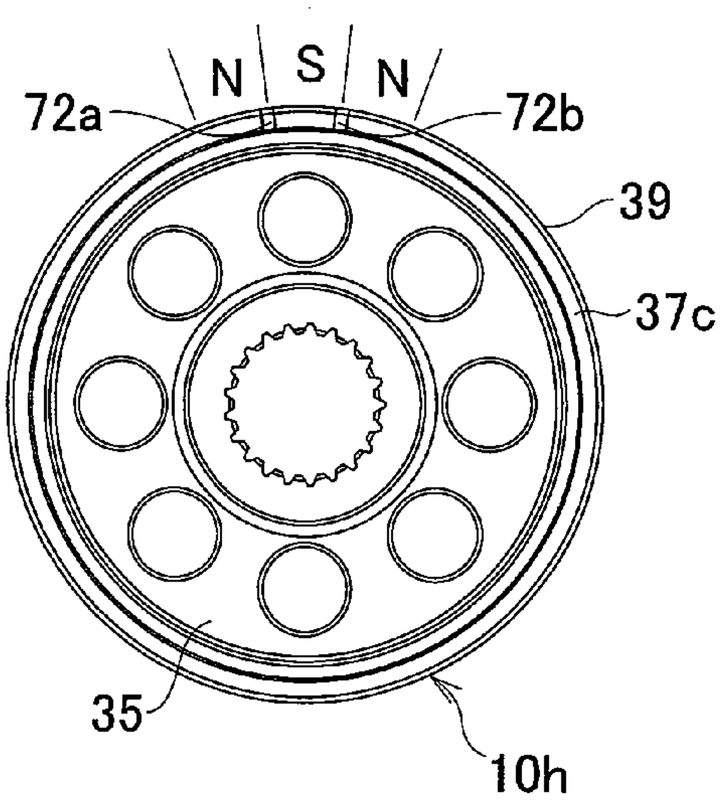



Fig.18 (A)

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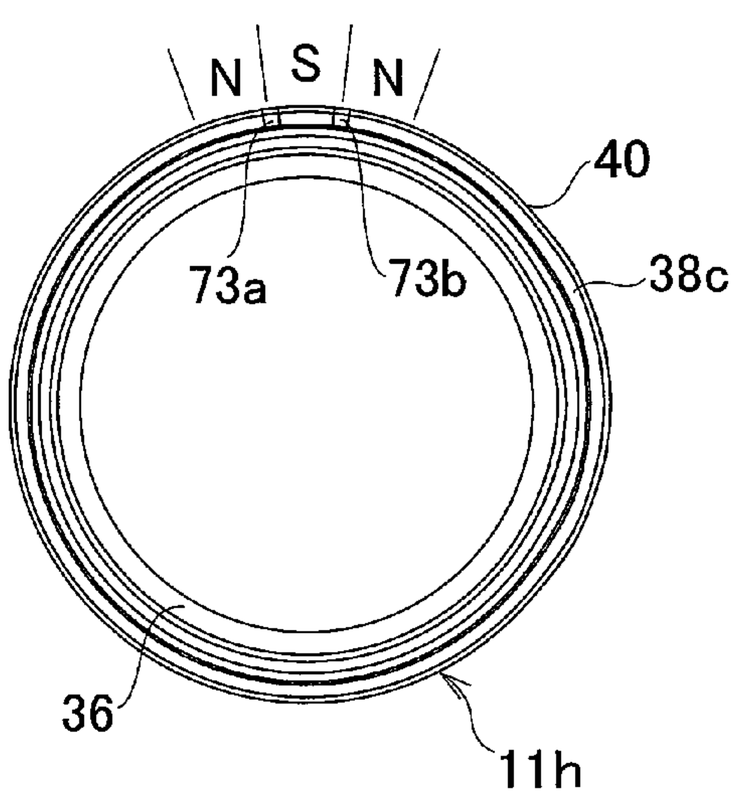

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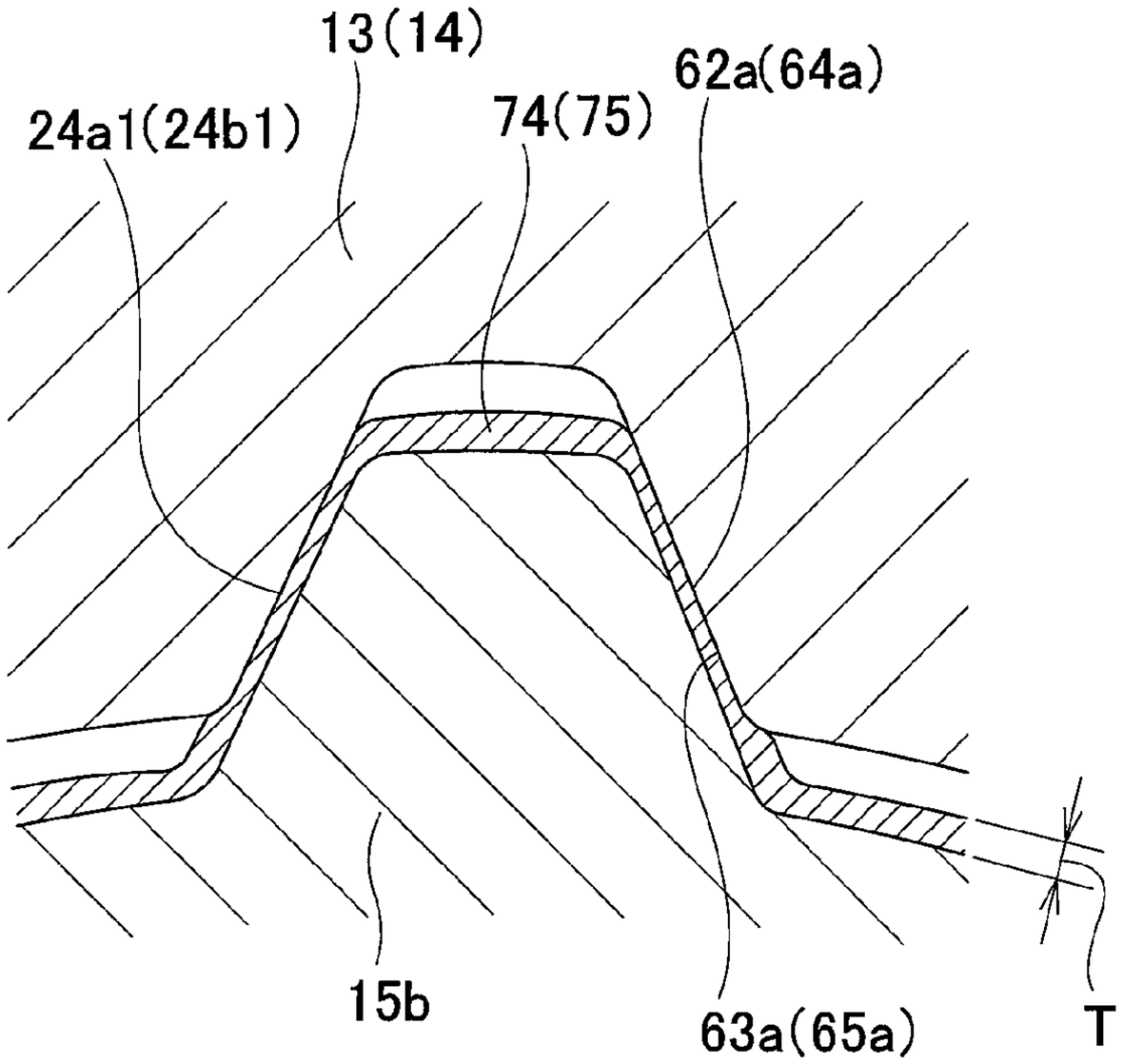
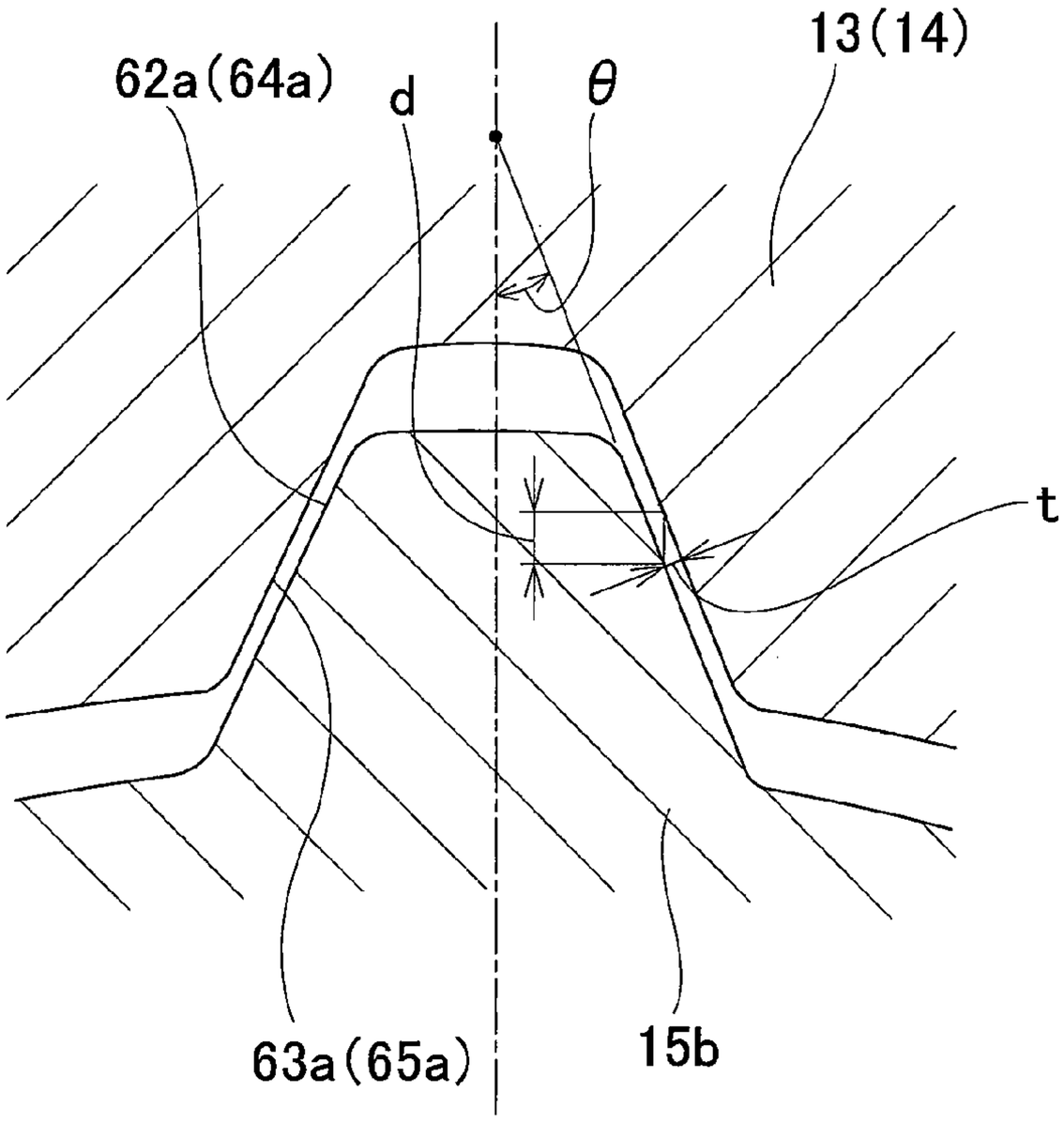

13(14)
62a(64a)
24a1(24b1)
74(75)
15b
63a(65a)
T

Fig.20


62a(64a)
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13(14)
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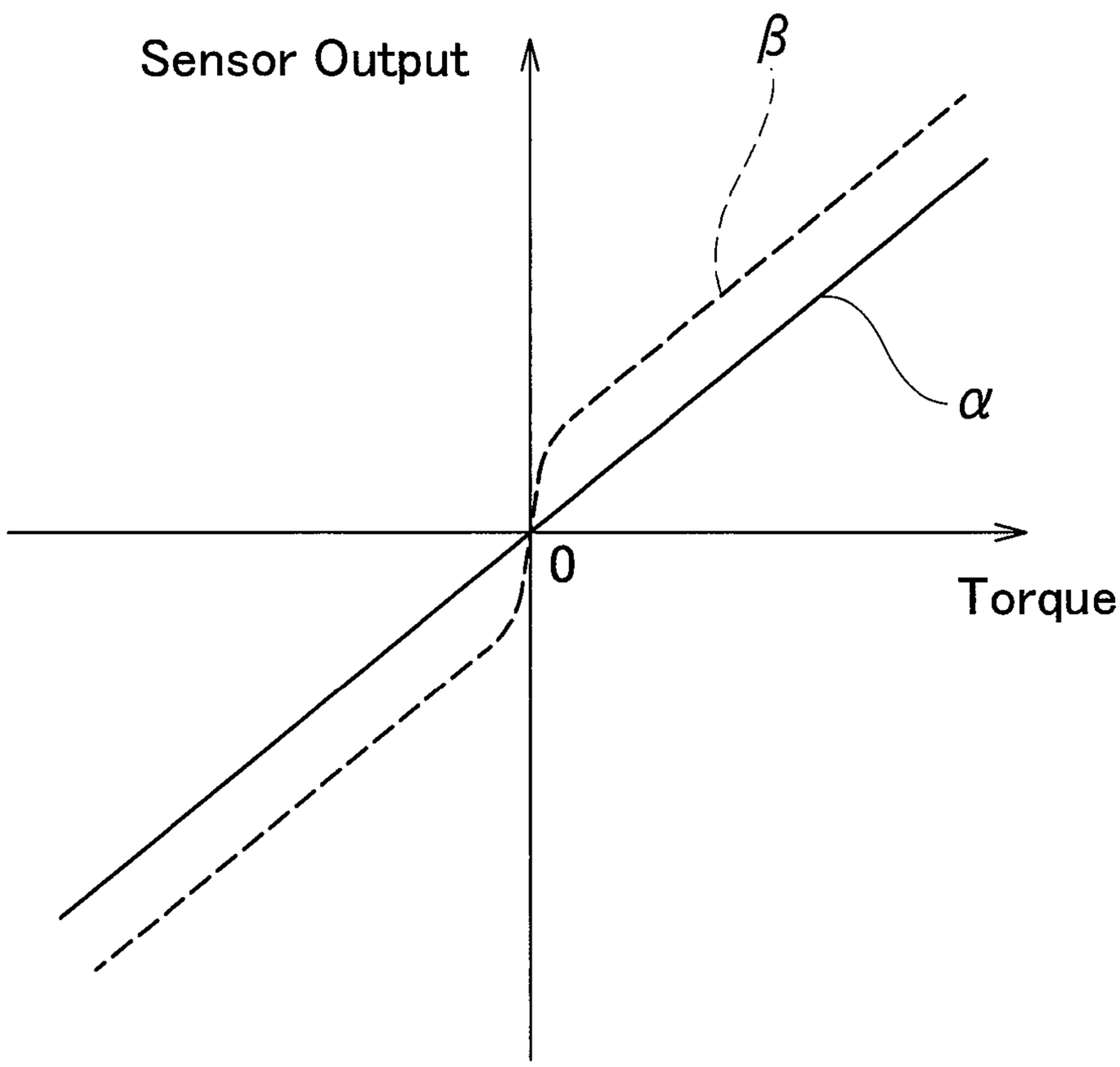
63a(65a)
15b

Fig.21



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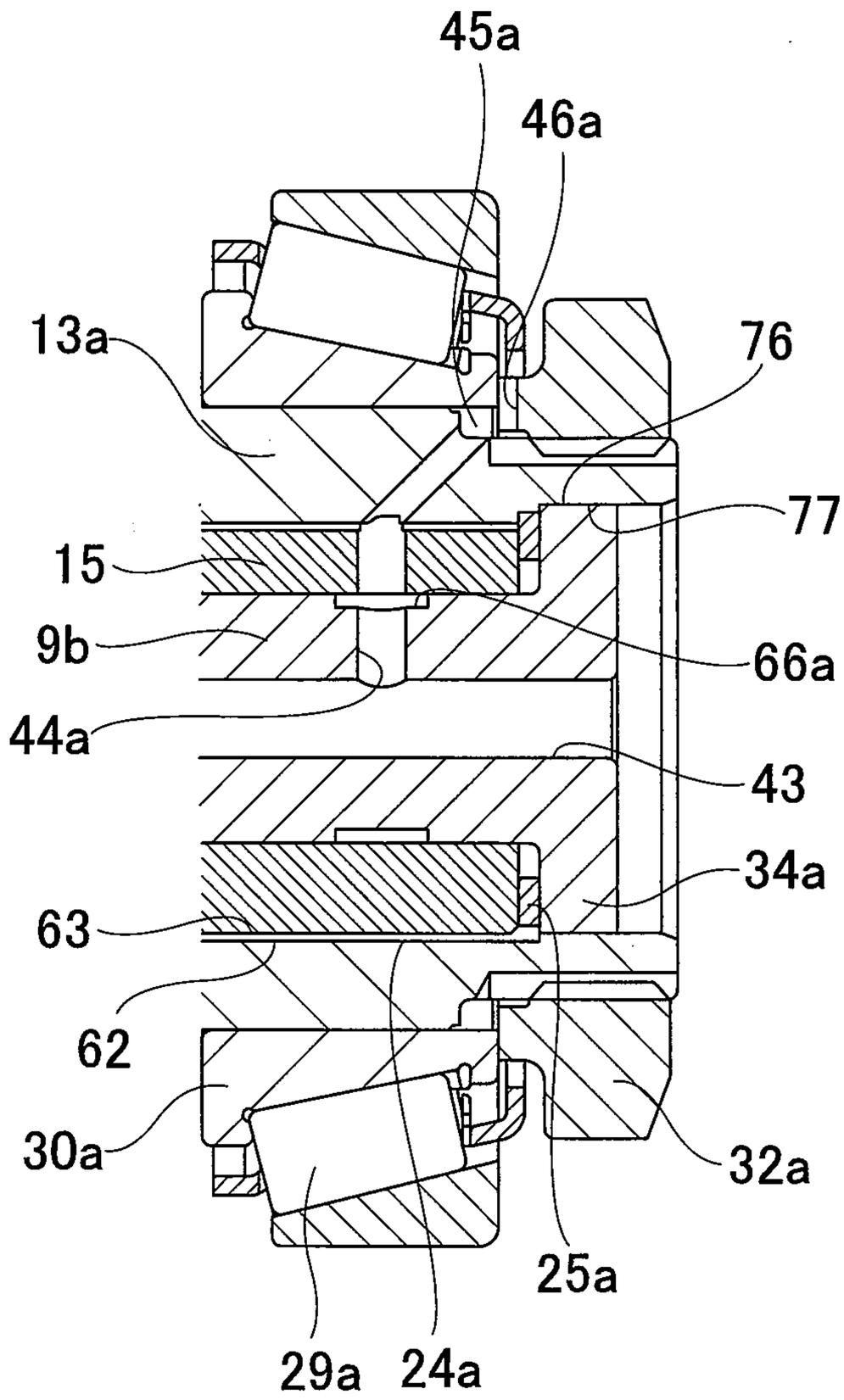

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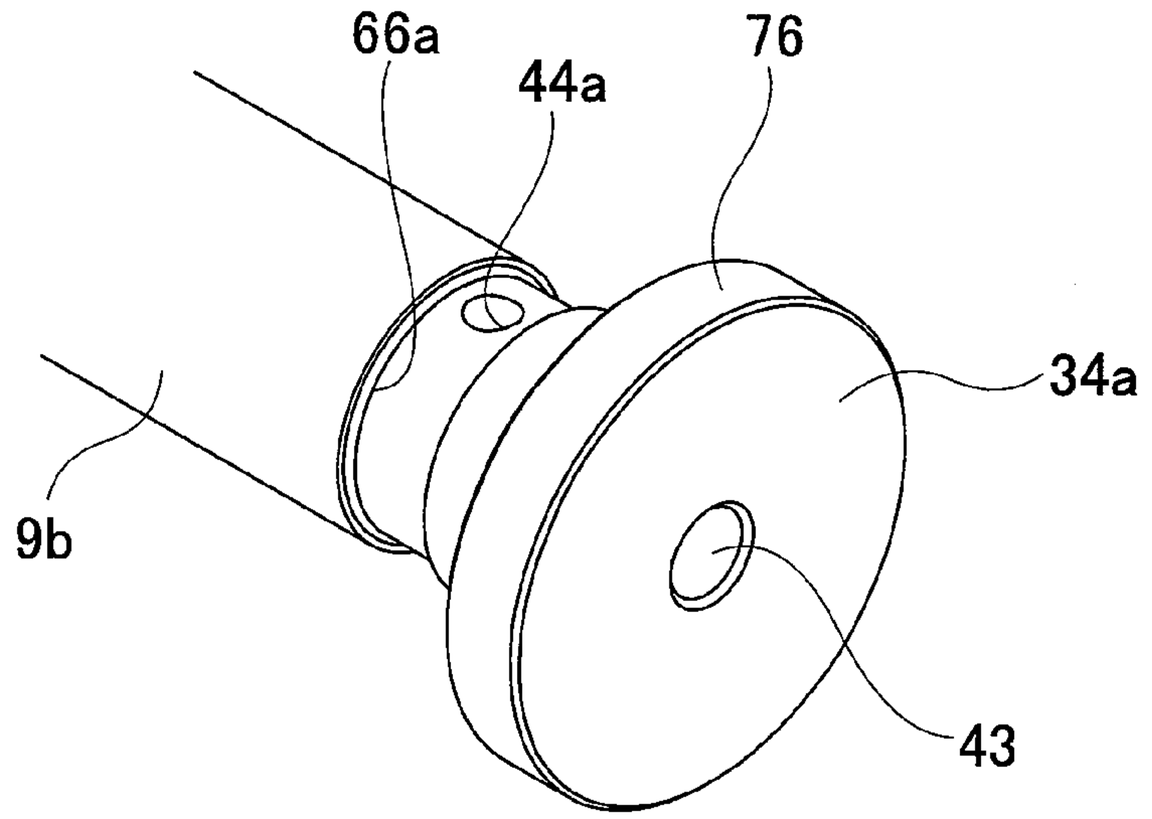
66a
44a
76
34a
9b
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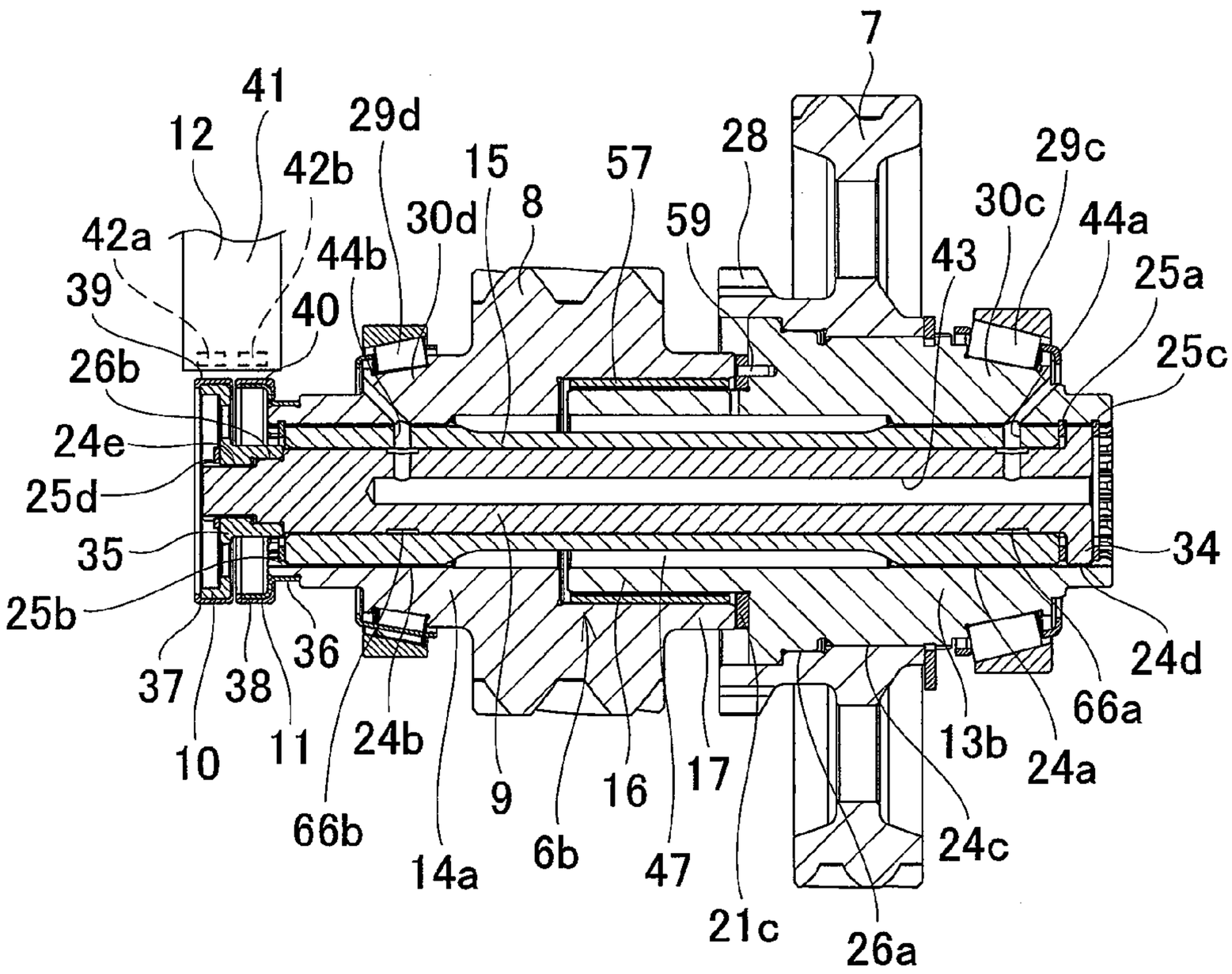
Fig.24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25b
24d
66a
37
38
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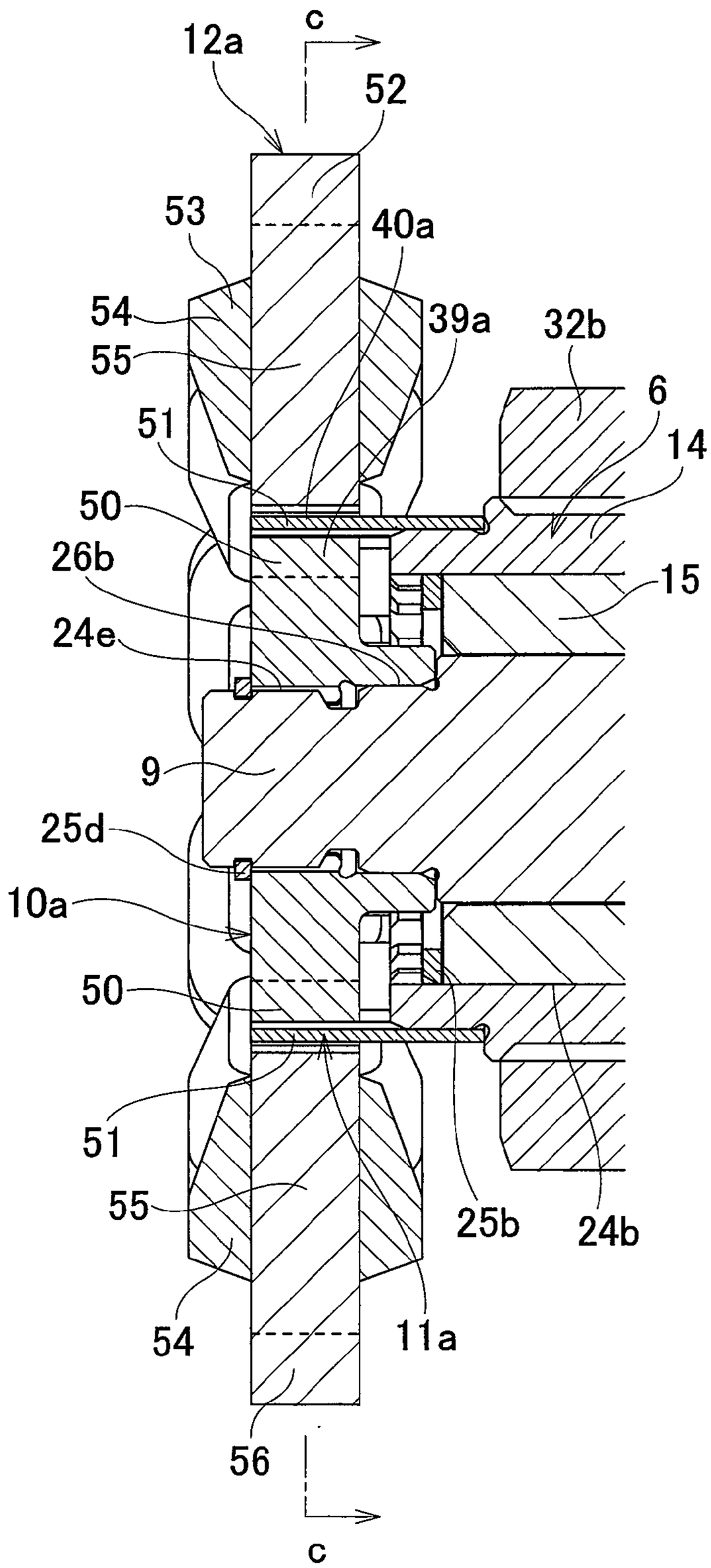
6b
24c
14a
47
21c
26a

Fig.25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25b
24b
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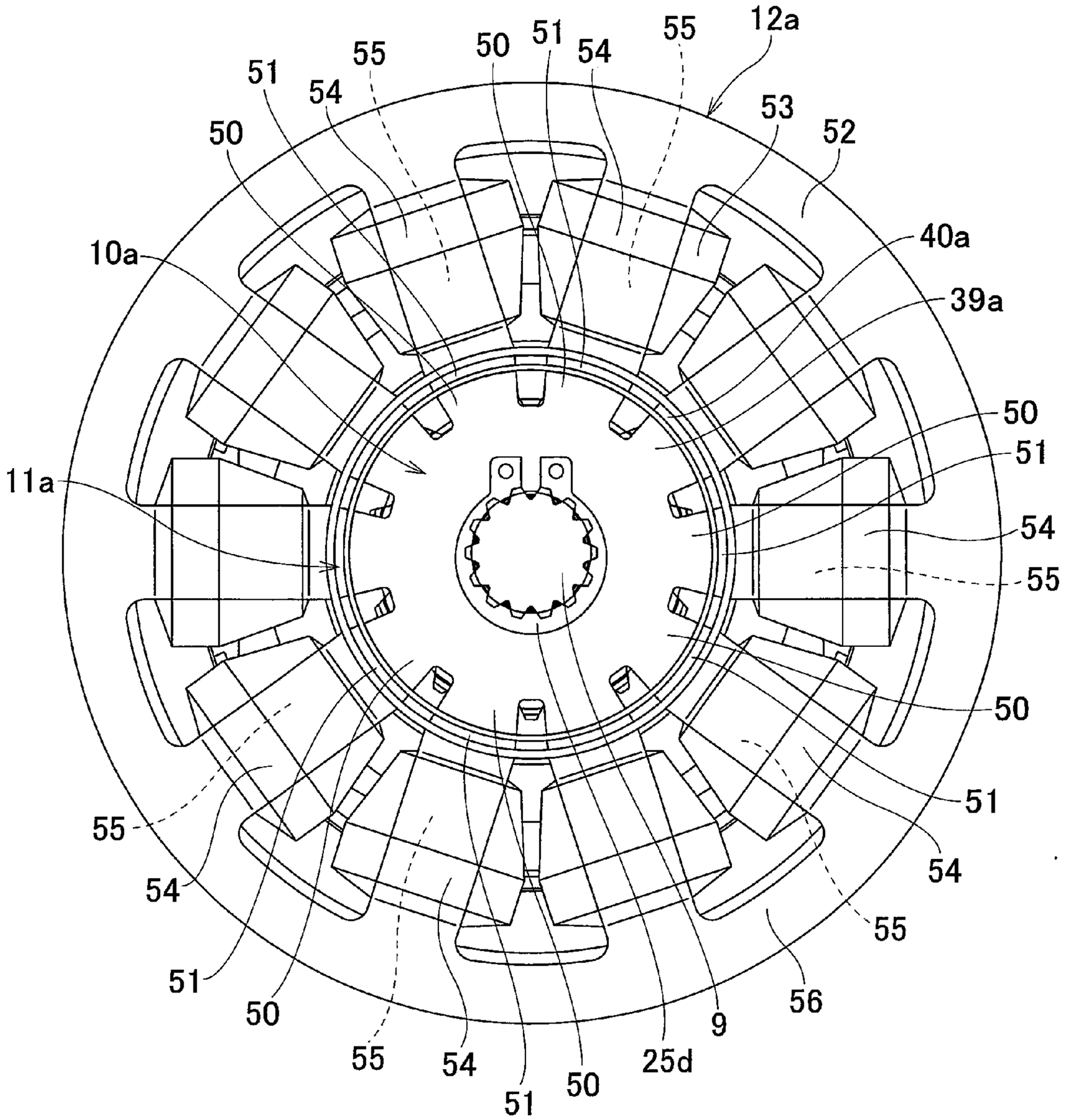
11a
56
C

Fig.26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51
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Fig.27

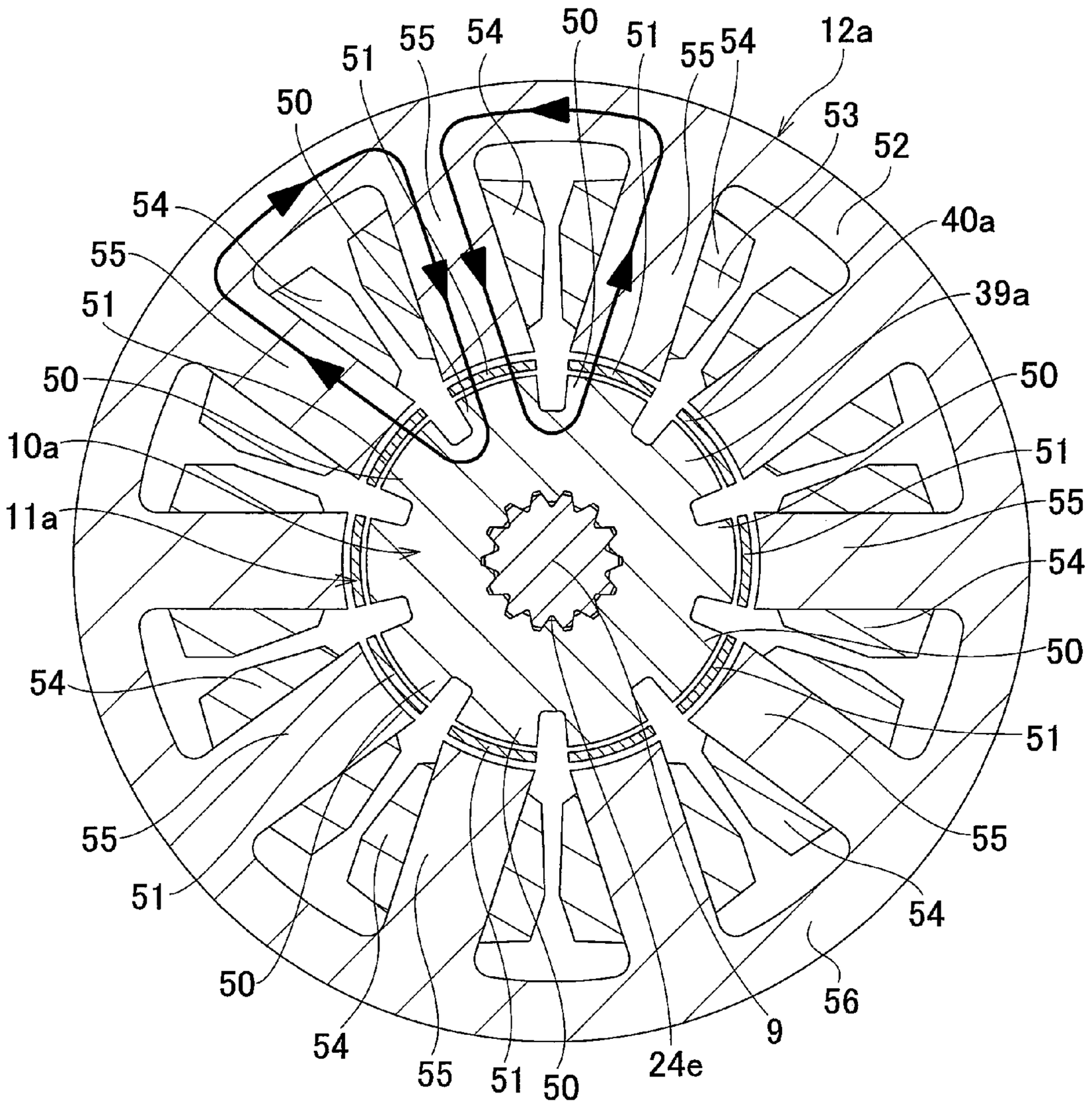
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Fig.28

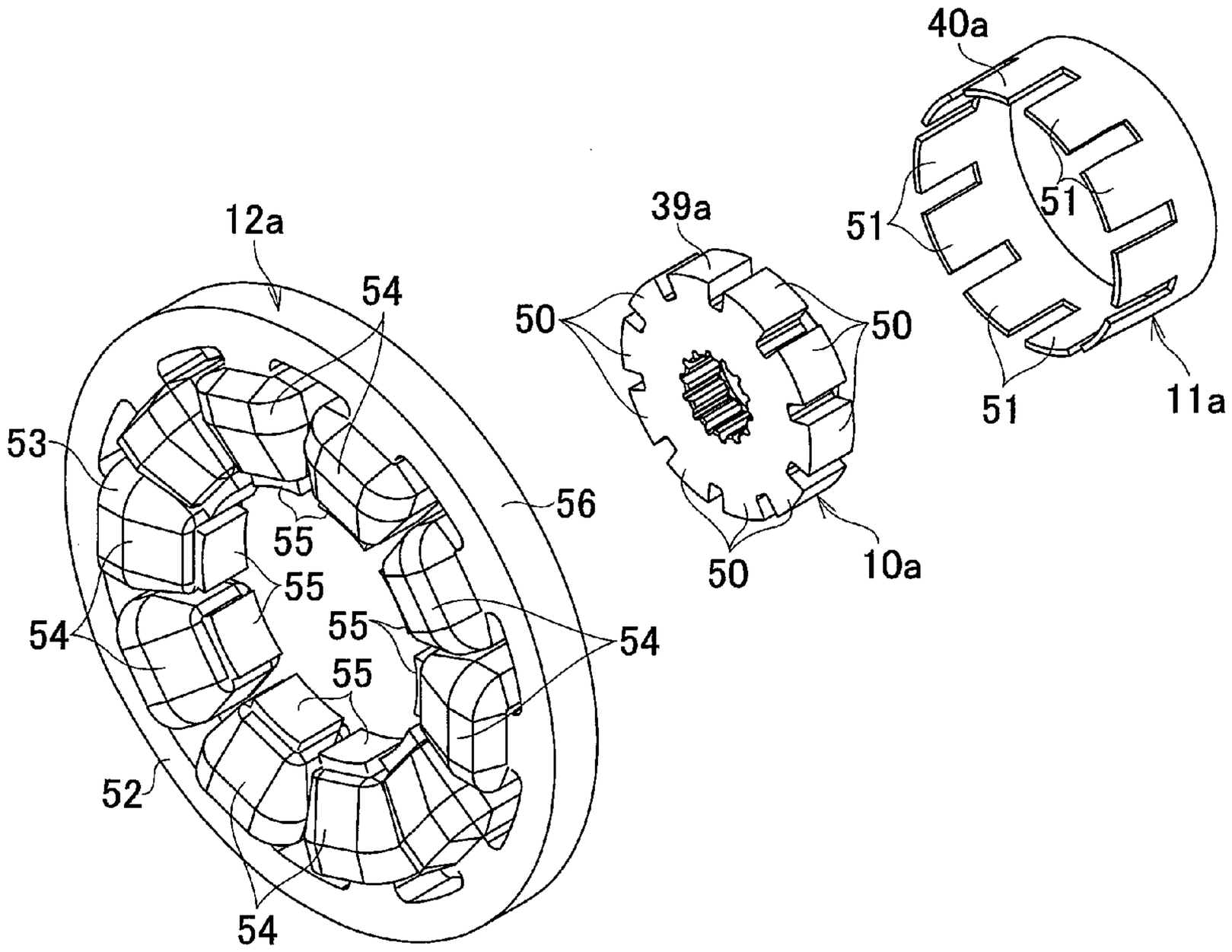


Fig.29 (A)

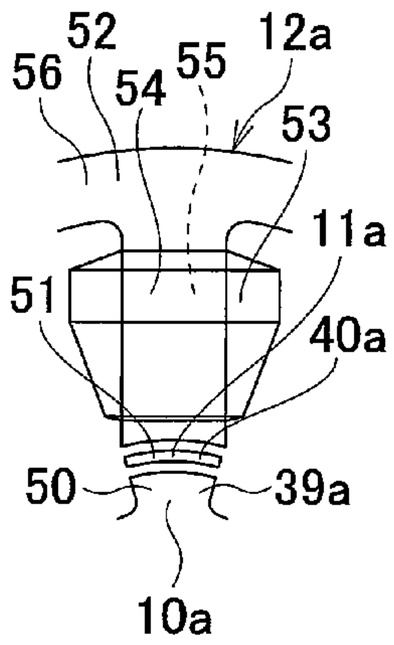



Fig.29 (B)

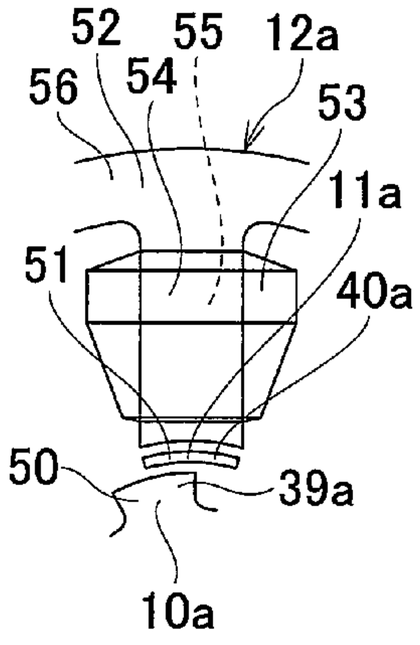



Fig.29 (C)

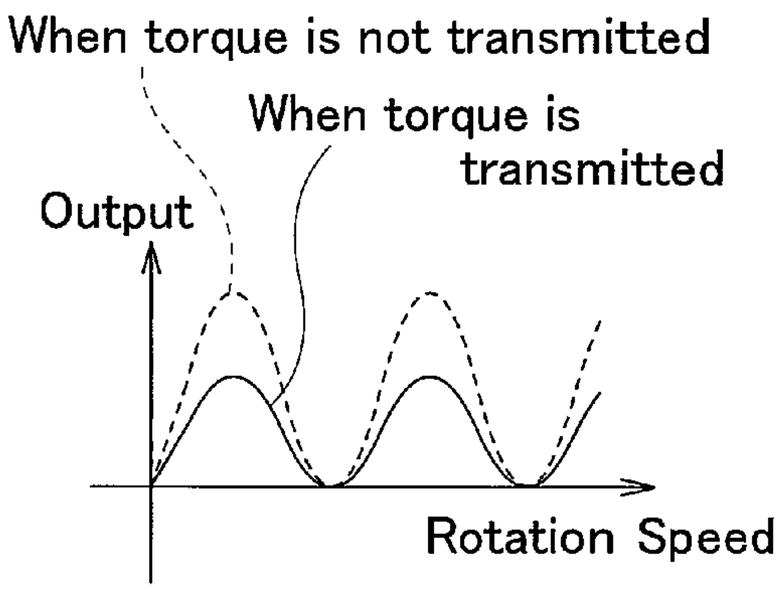
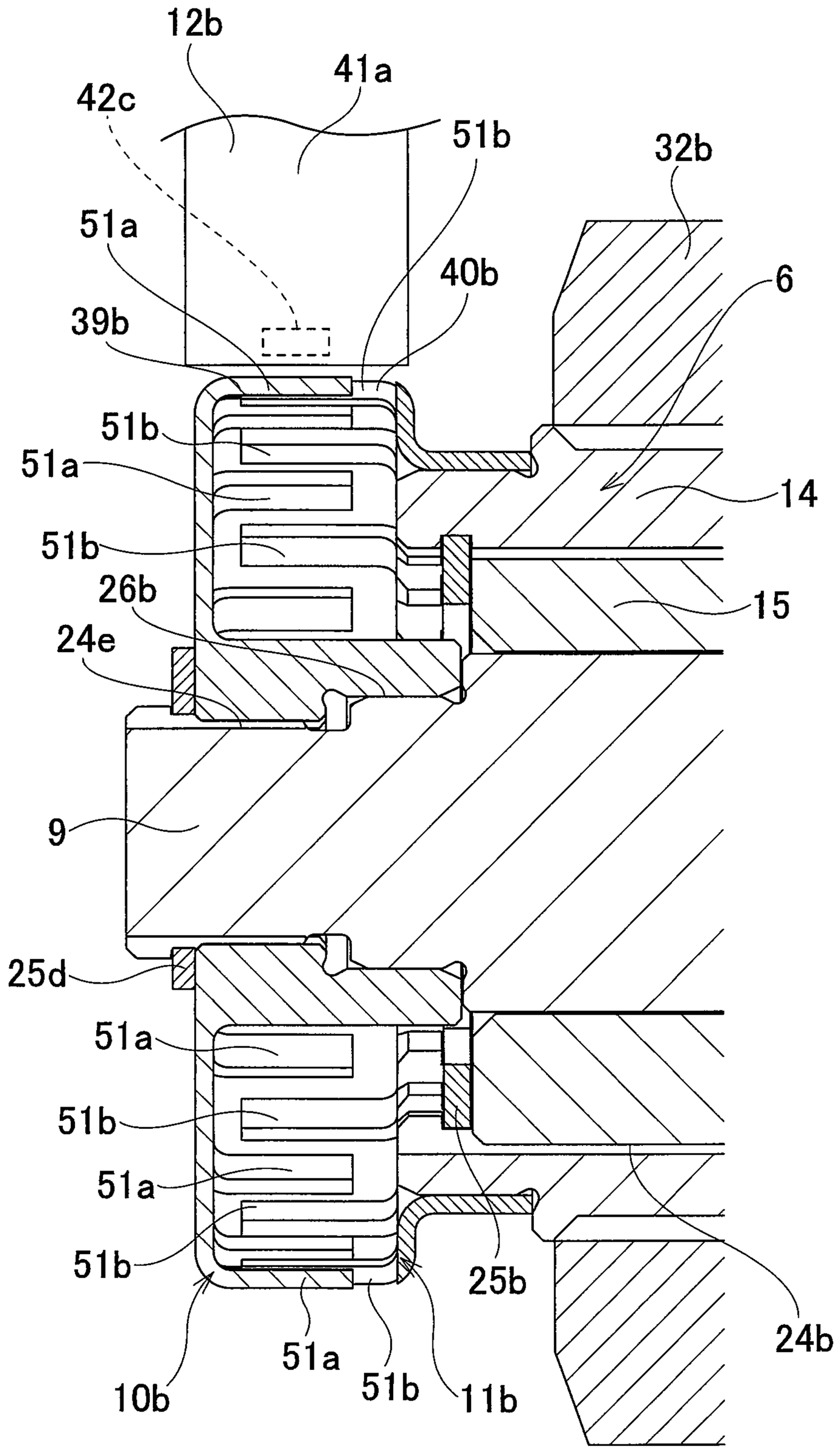


Fig.30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51b
10b
11b

Fig.31

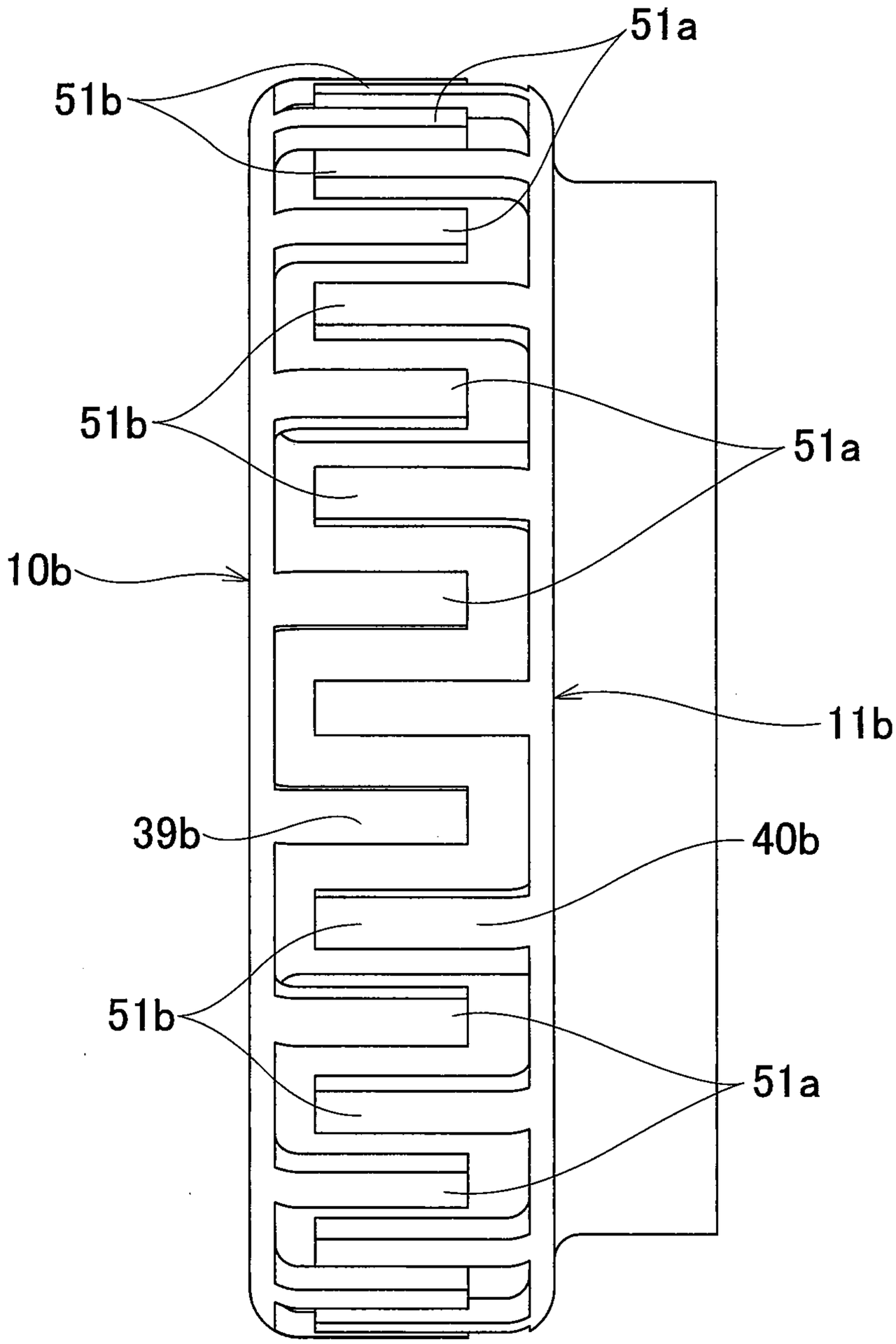


Fig.32

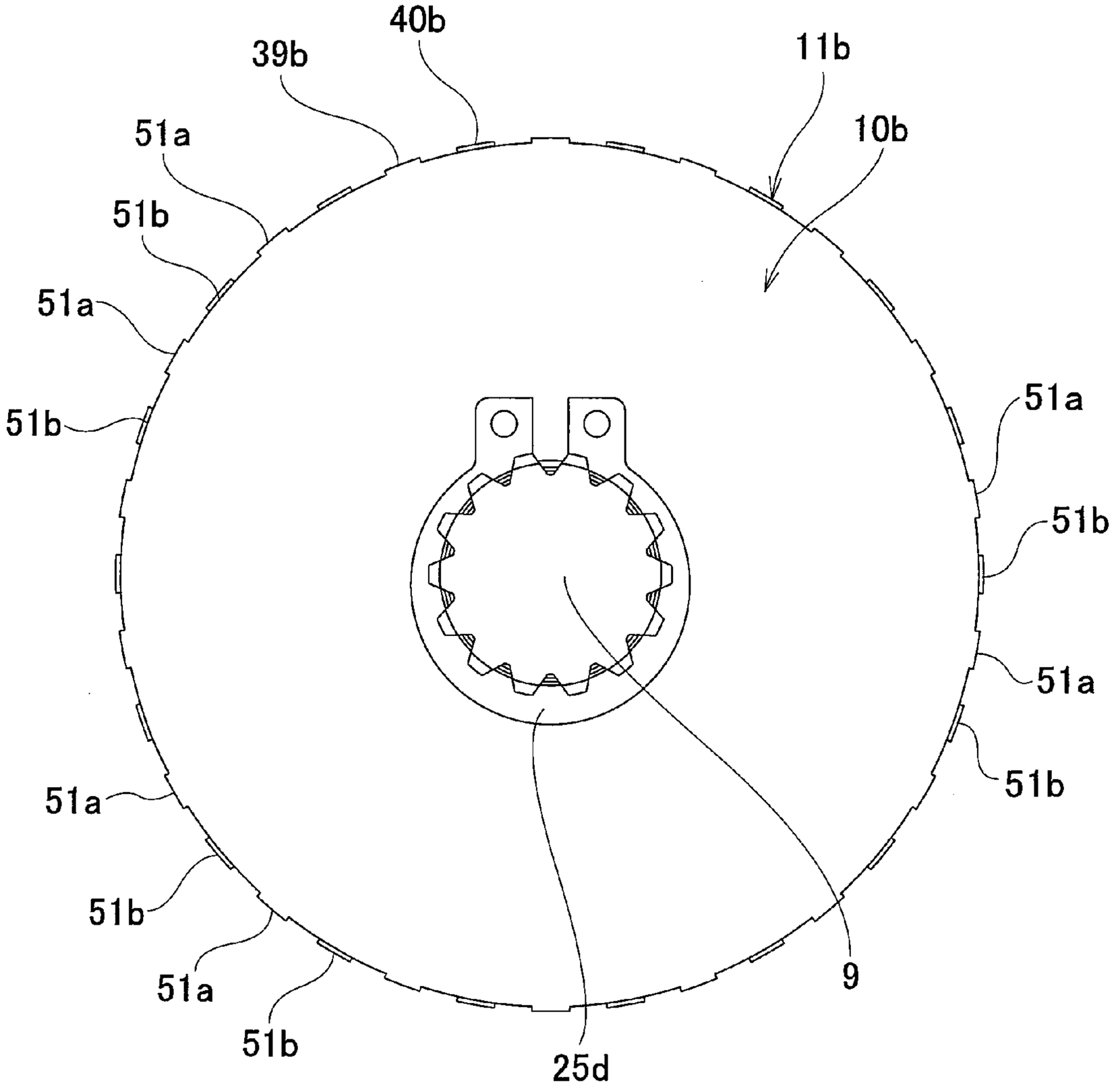

40b
39b
11b
10b
51a
51b
51a
51b
51a
51b
51a
51b
51a
51b
51a
51b
51b
9
25d

Fig.33

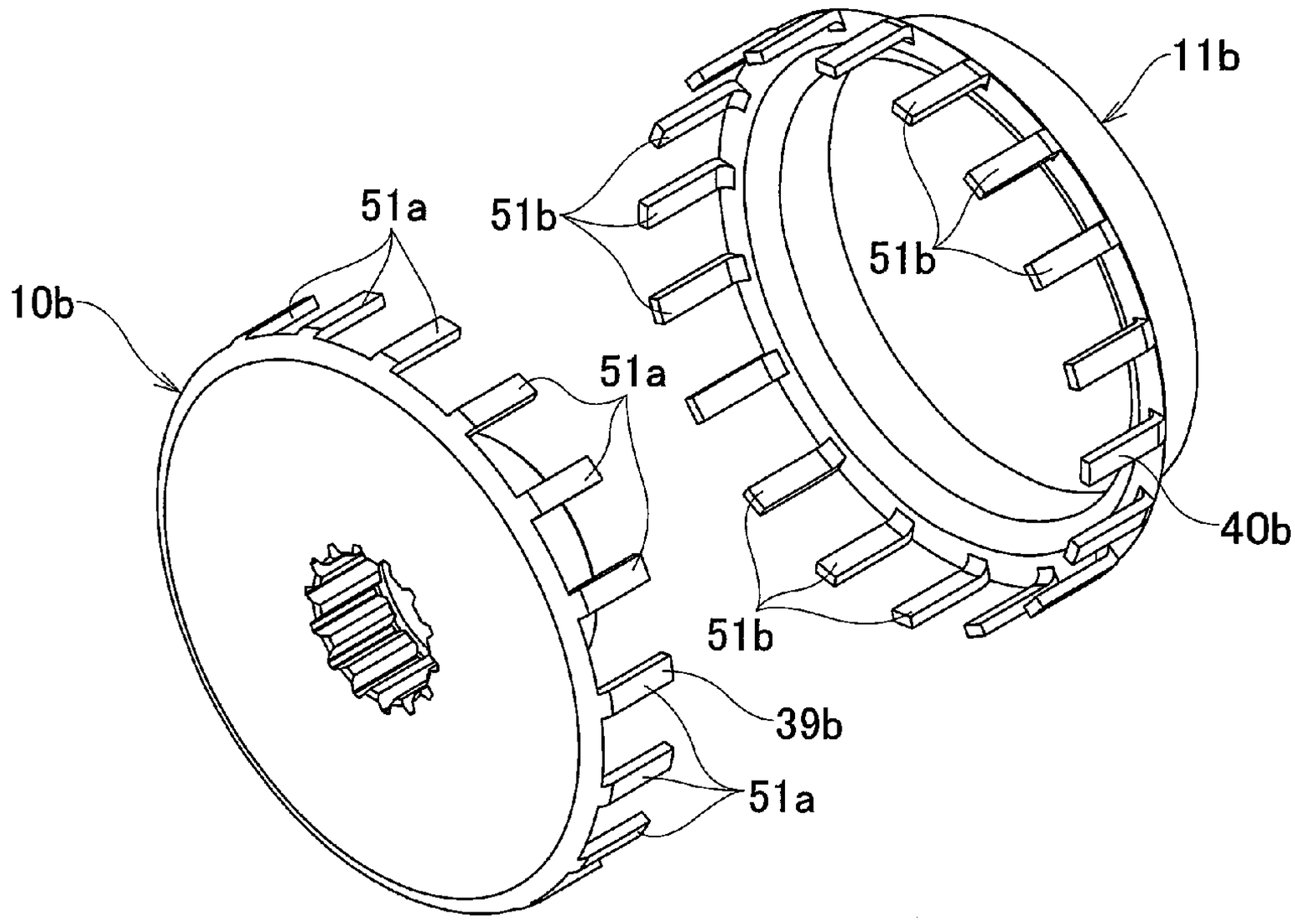



Fig.34 (A)

When torque is not transmitted

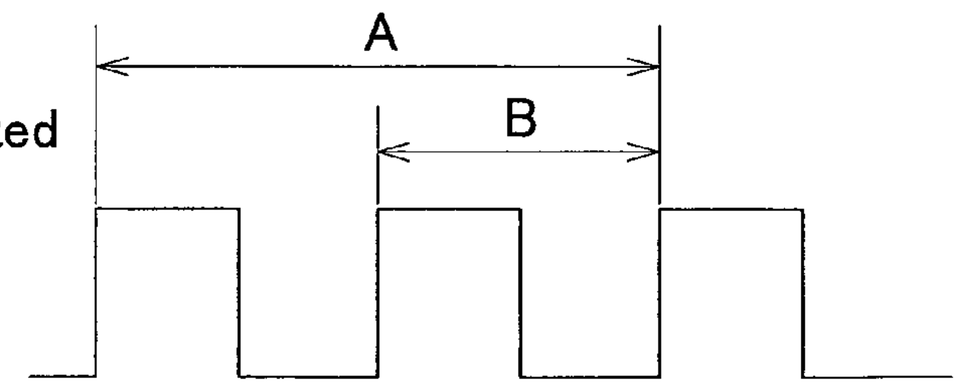



Fig.34 (B)

When torque is transmitted

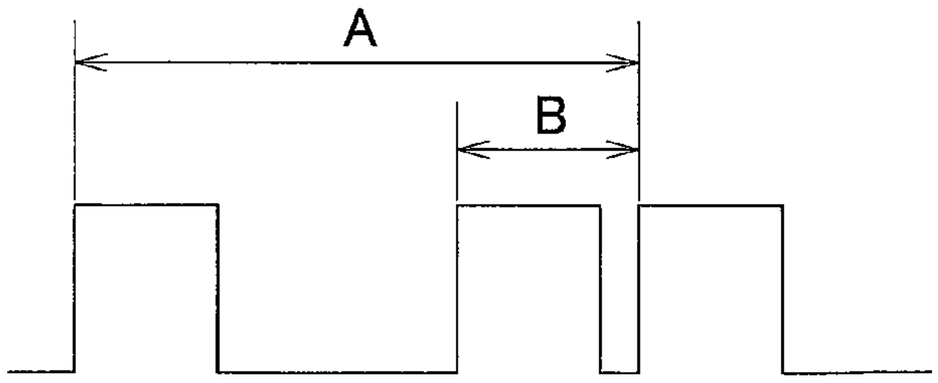


Fig.35

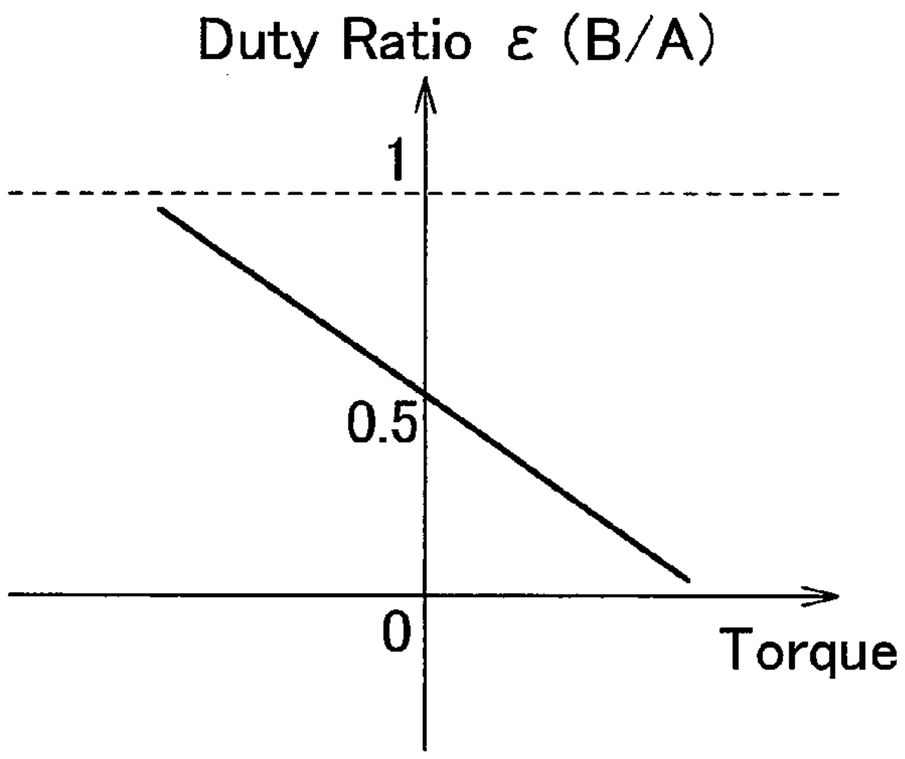

Duty Ratio ε (B/A)
1
0.5
0
Torque

Fig.36

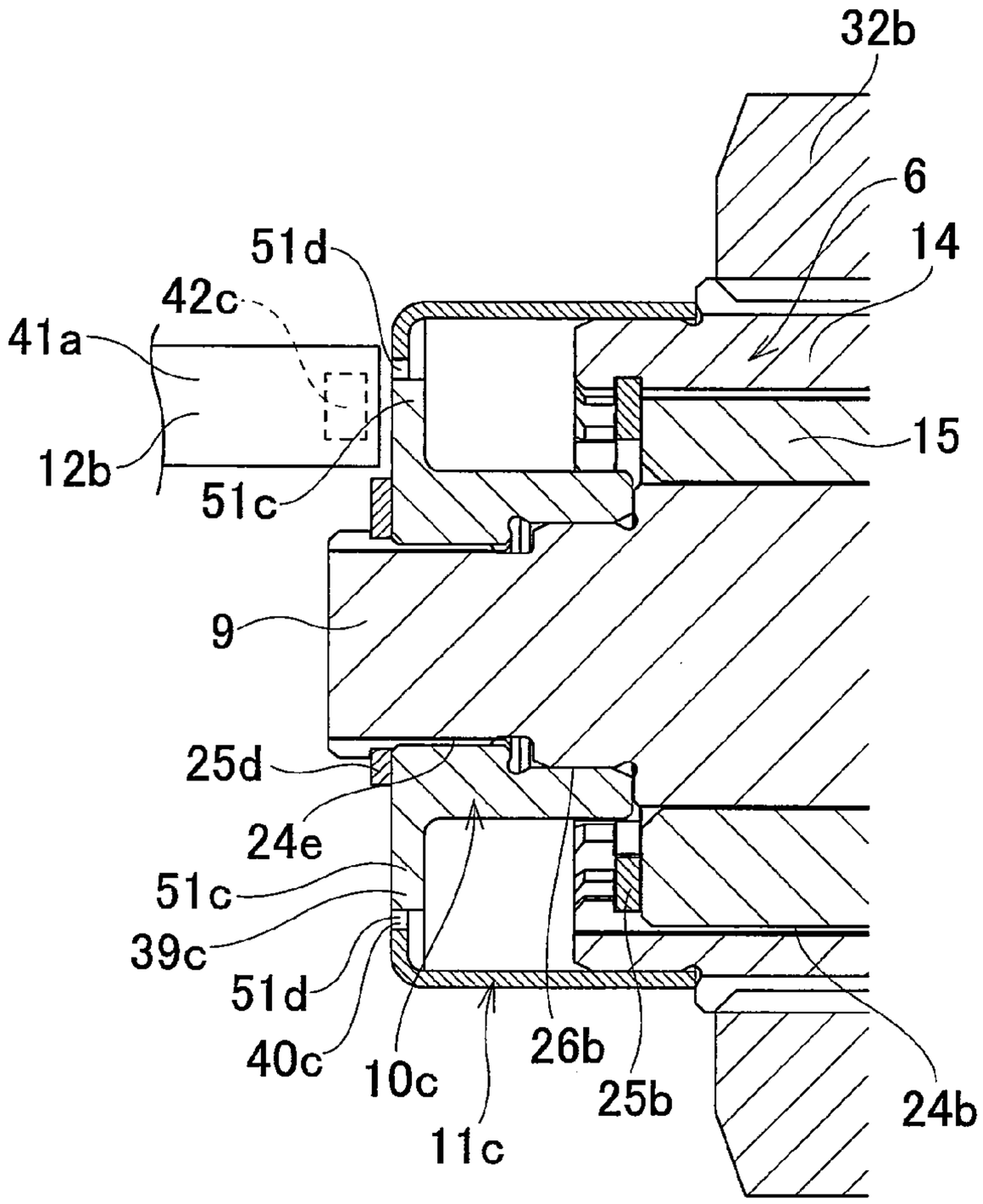

32b
6
14
51d
42c
41a
12b
51c
15
9
25d
24e
51c
39c
51d
40c
10c
11c
26b
25b
24b

Fig.37

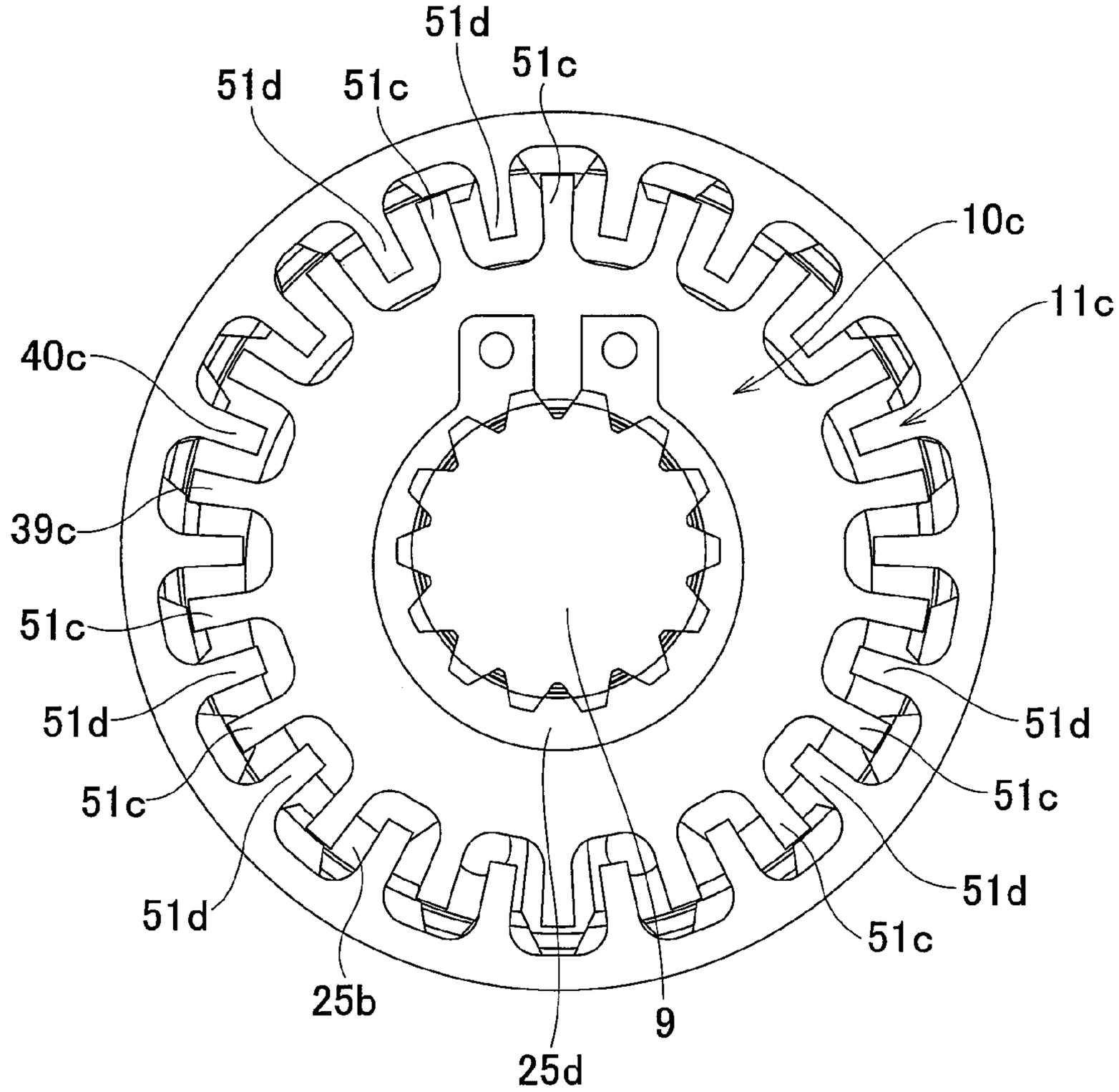

51d
51c
51c
10c
11c
40c
39c
51c
51d
51c
51d
51c
51d
51d
51c
25b
9
25d

Fig.38

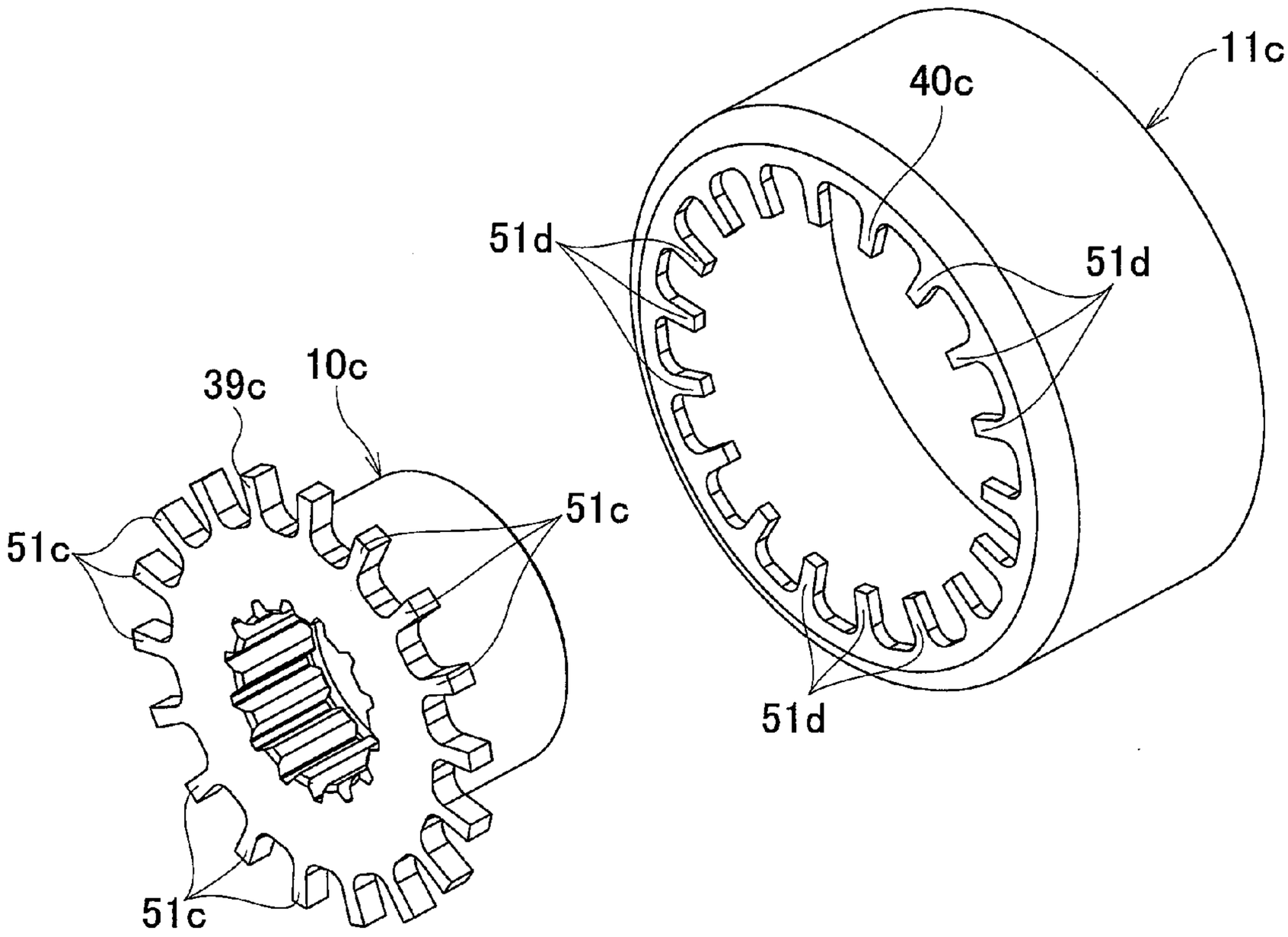


Fig.39

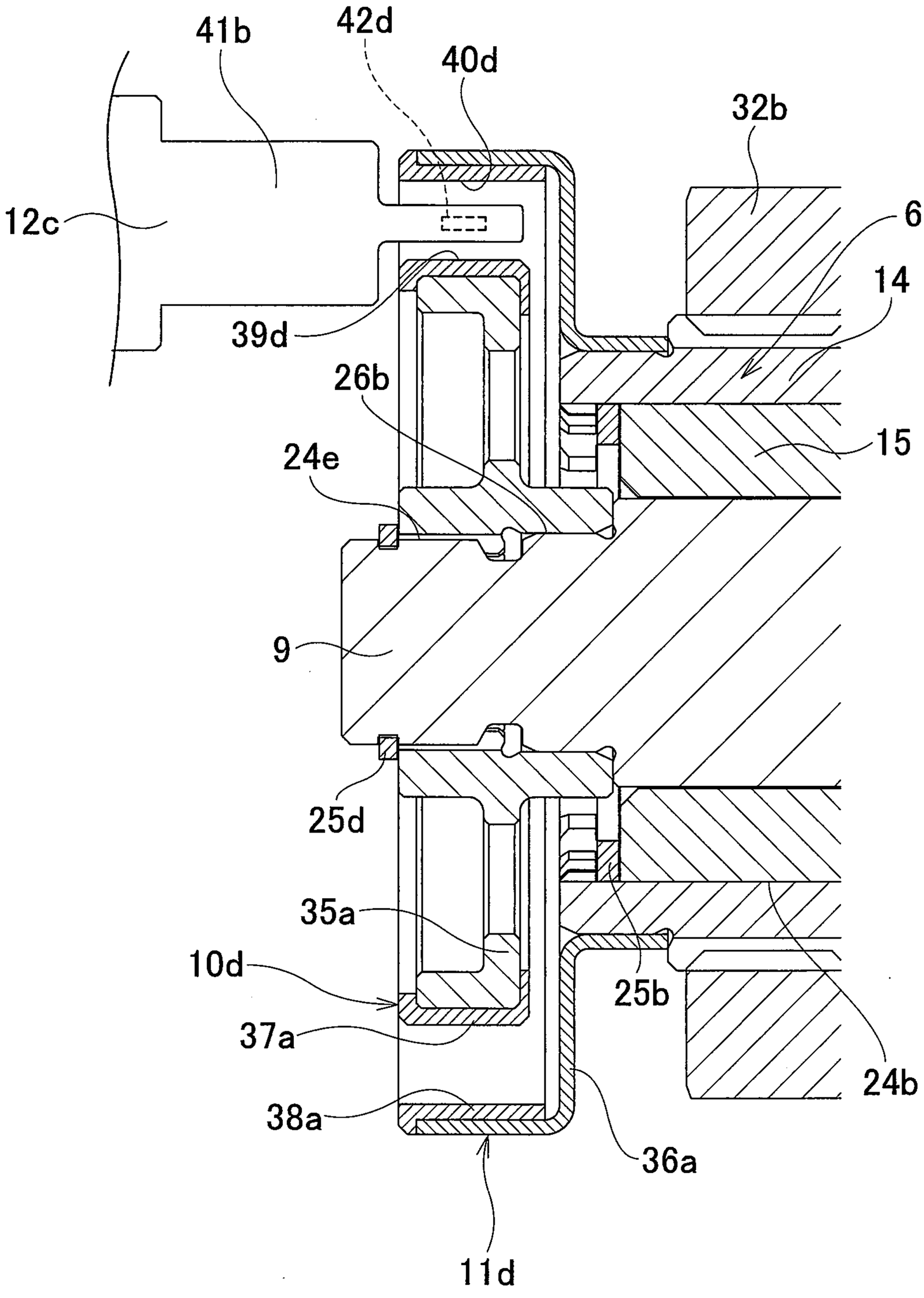

41b
42d
40d
32b
12c
6
14
39d
26b
15
24e
9
25d
35a
10d
25b
37a
24b
38a
36a
11d

Fig.40

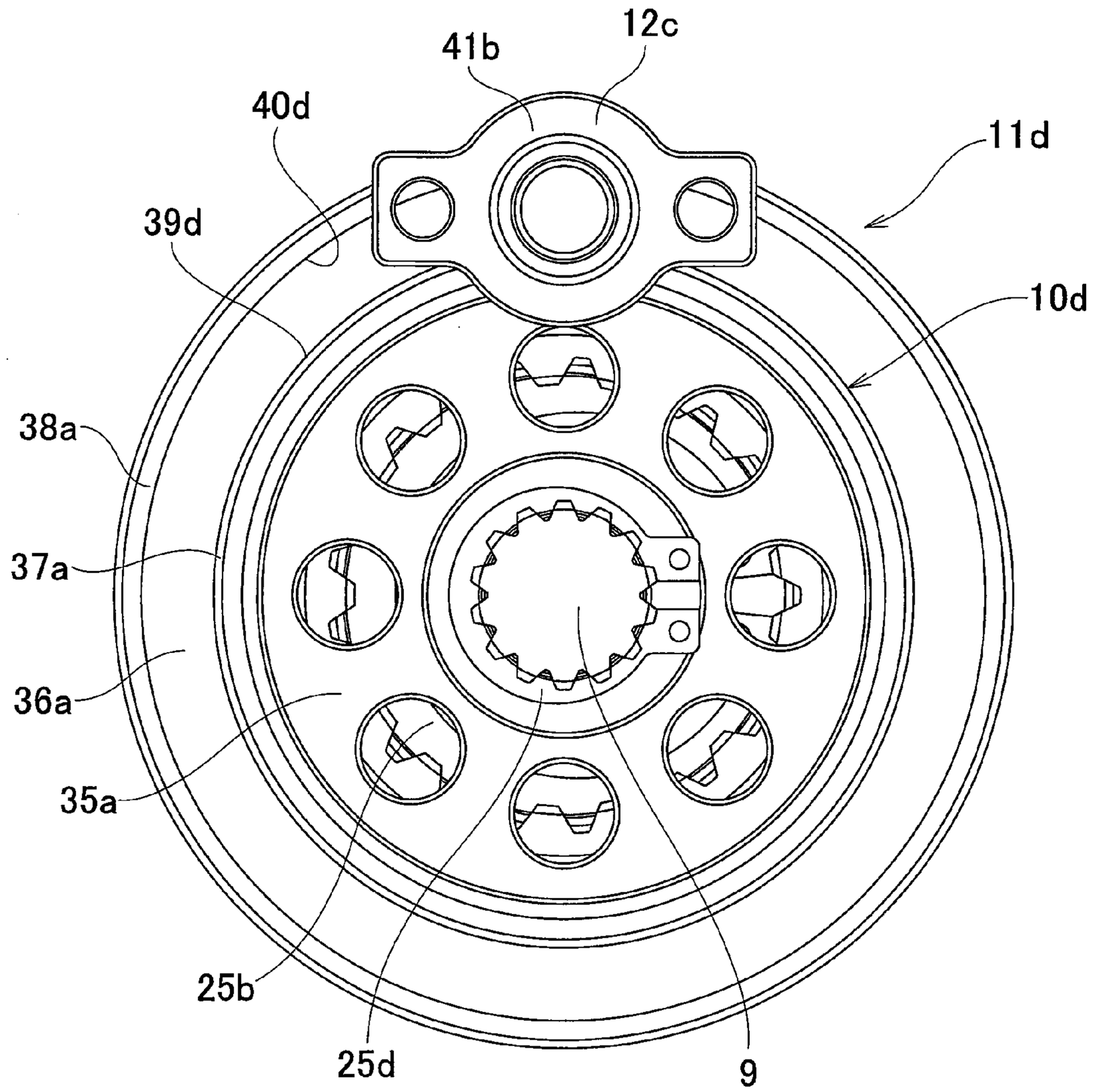
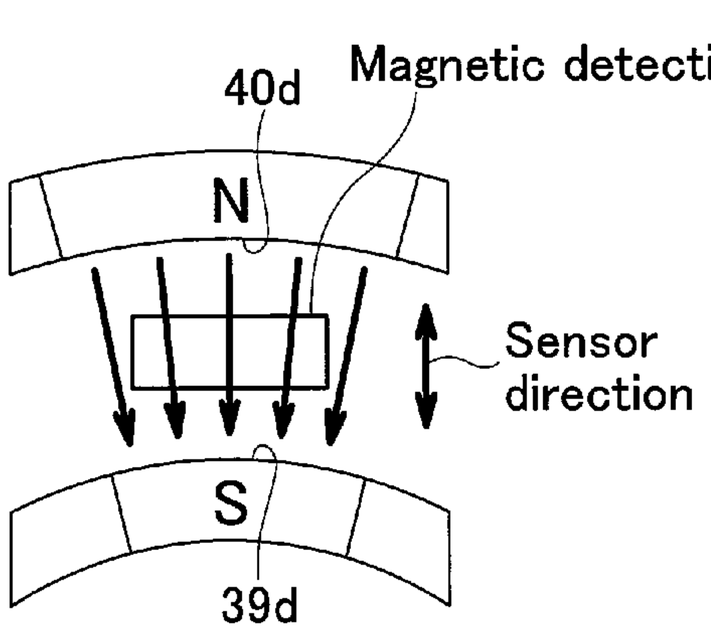


Fig.41 (A)

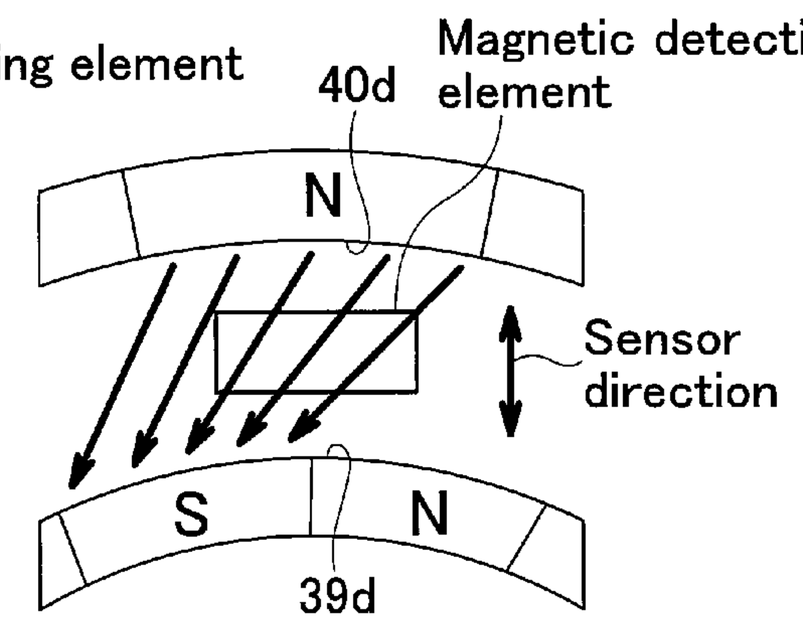
When torque is not transmitted




Without torsion

Fig.41 (B)

When torque is transmitted




With torsion

Fig.42

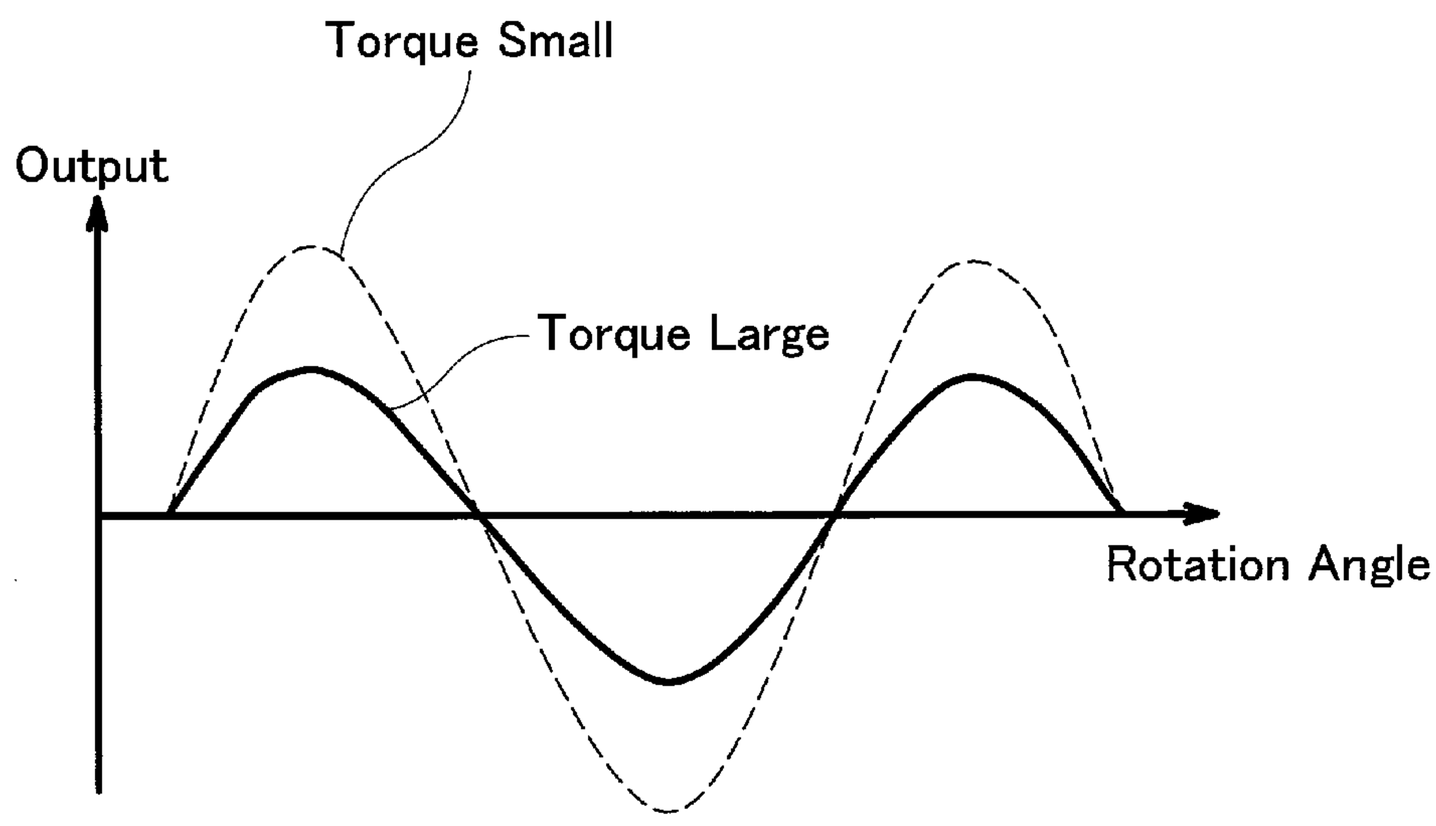


Fig.43

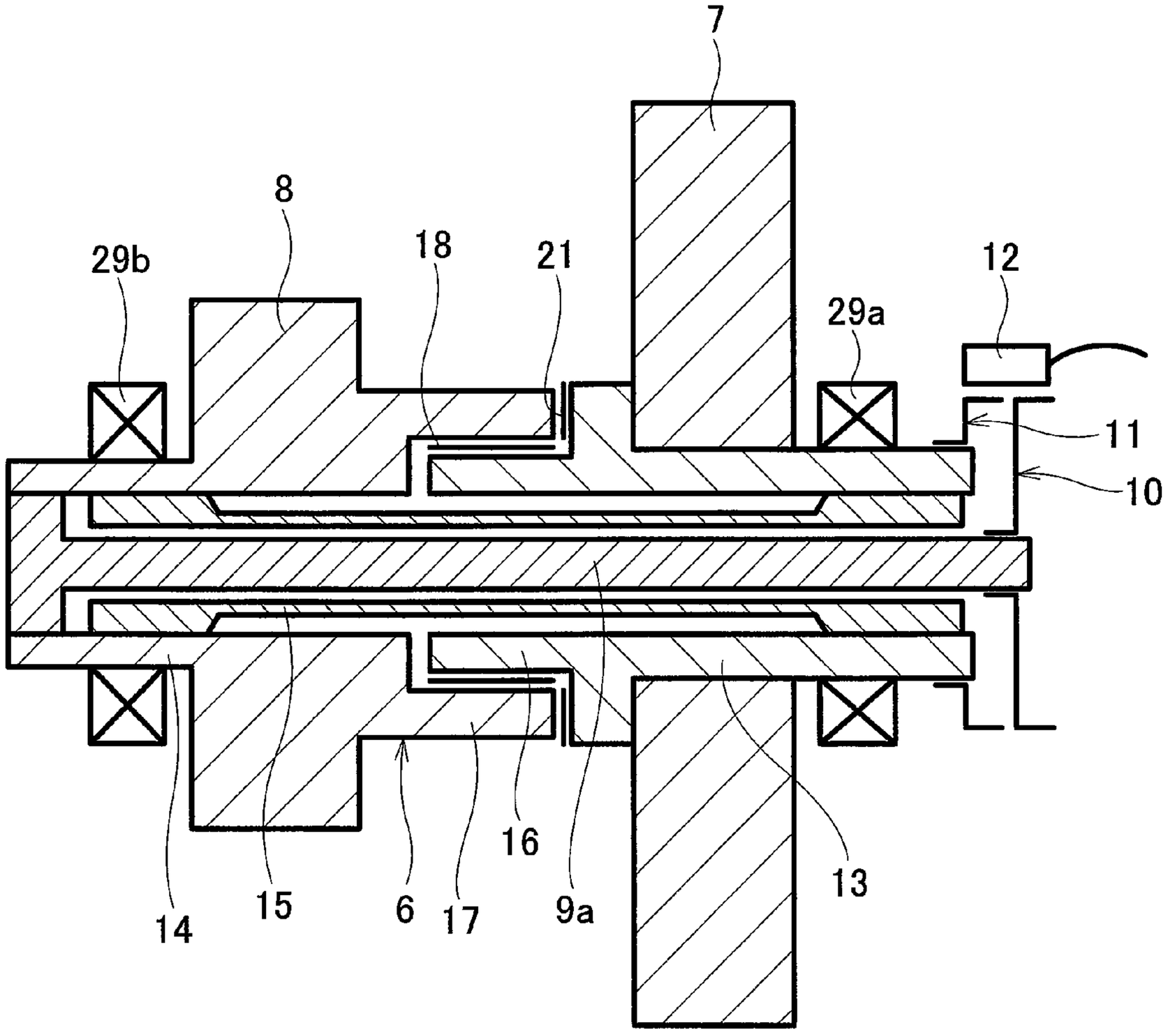


Fig.44

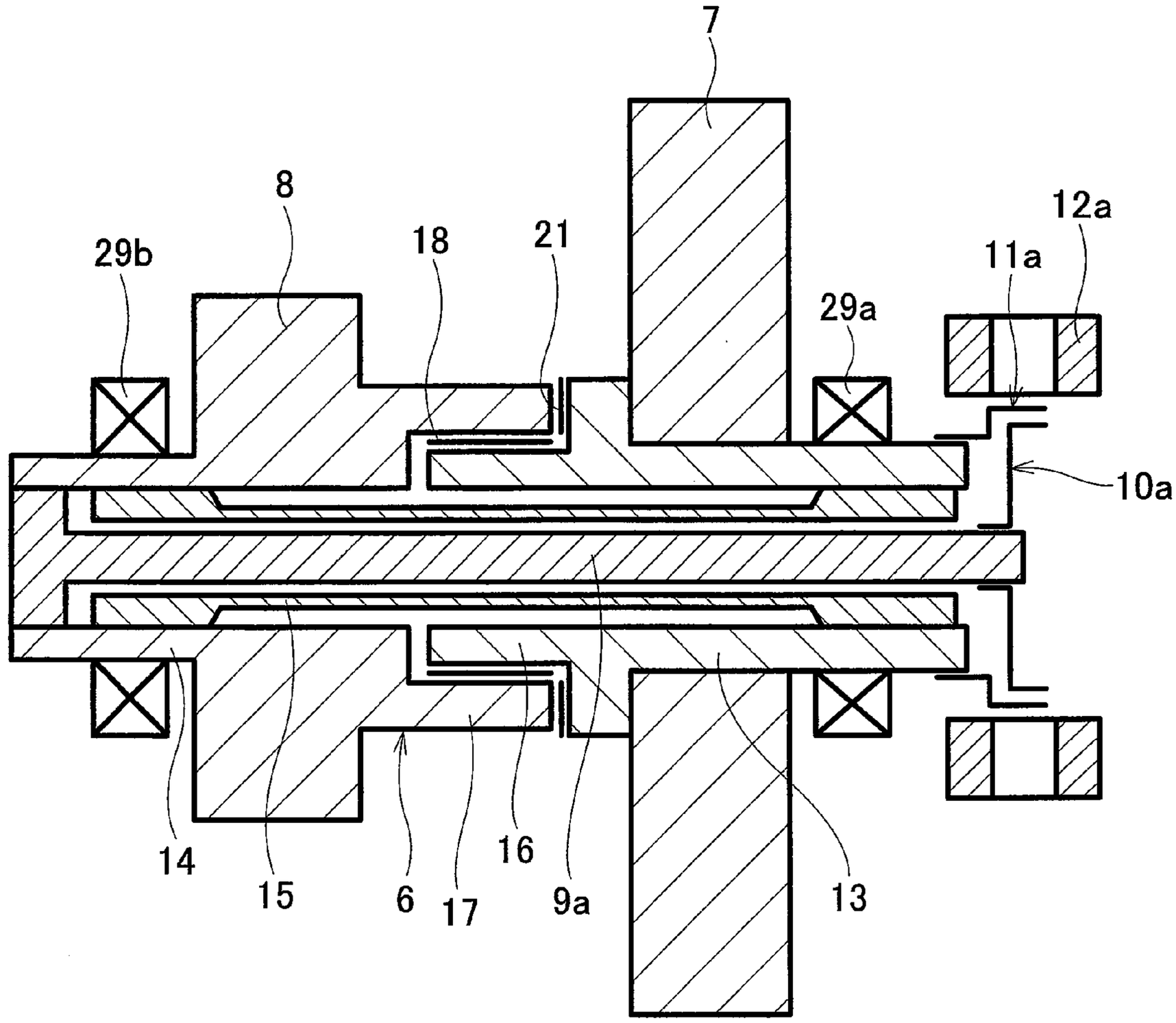


Fig.45

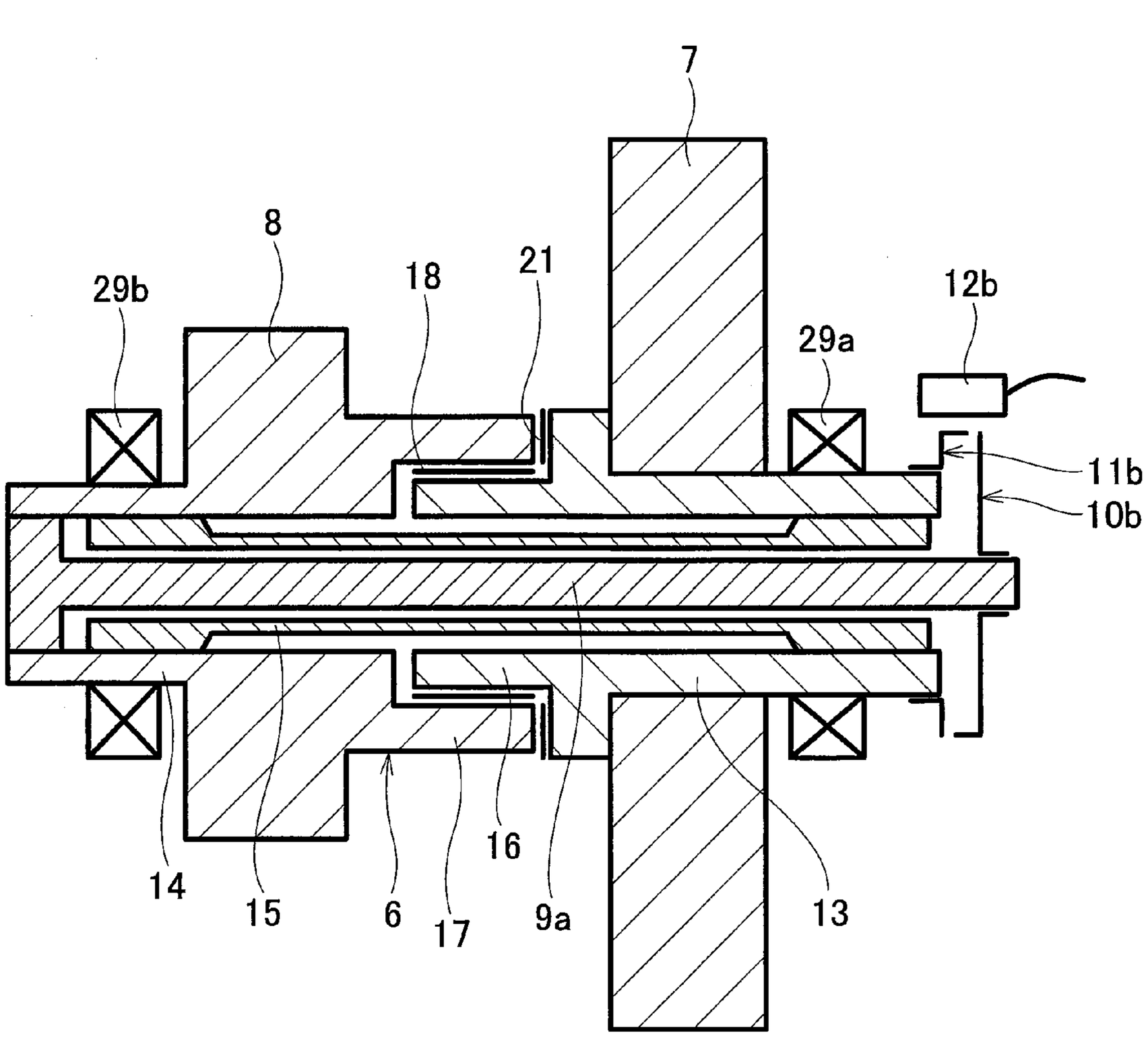


Fig.46

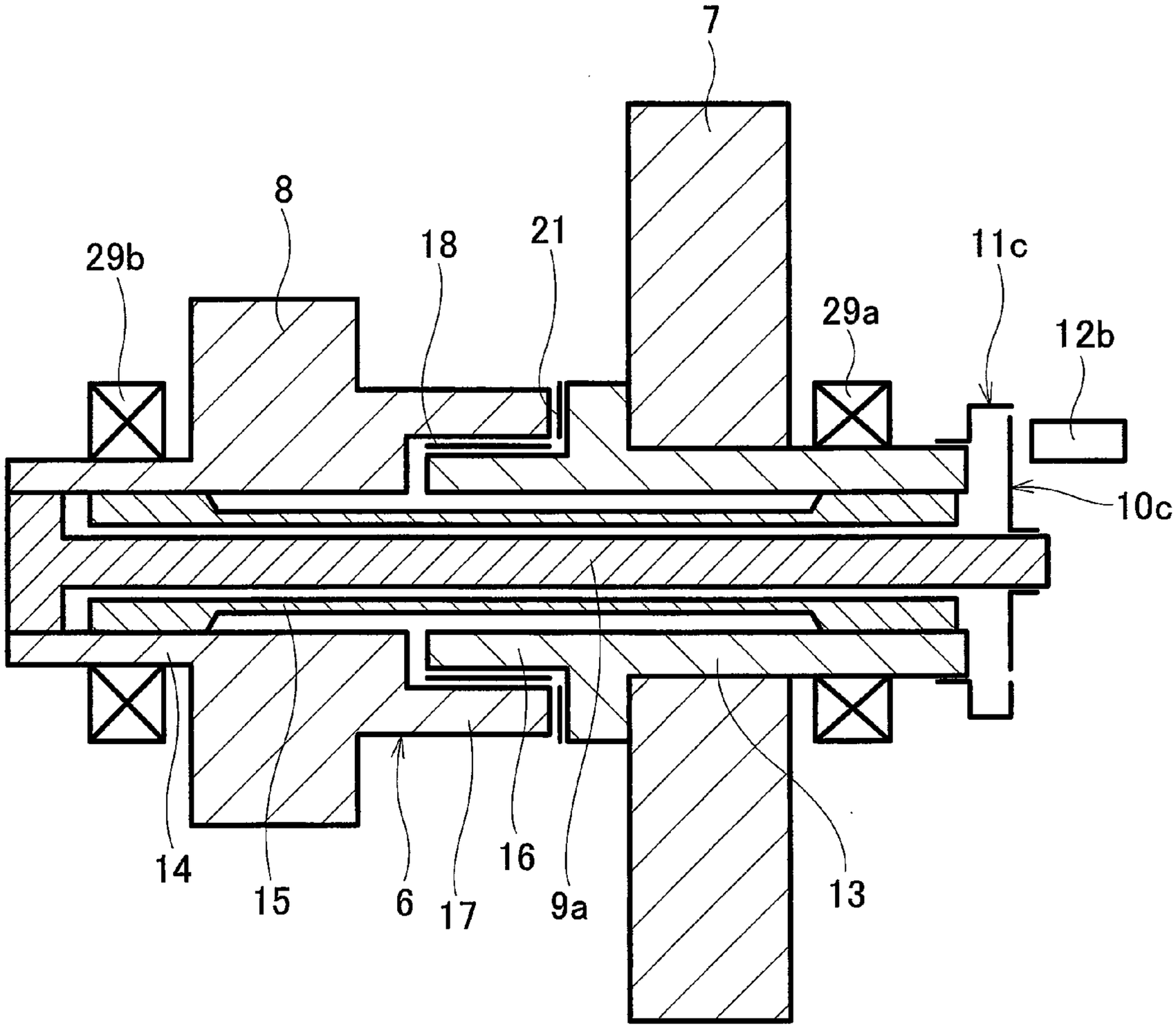


Fig.47

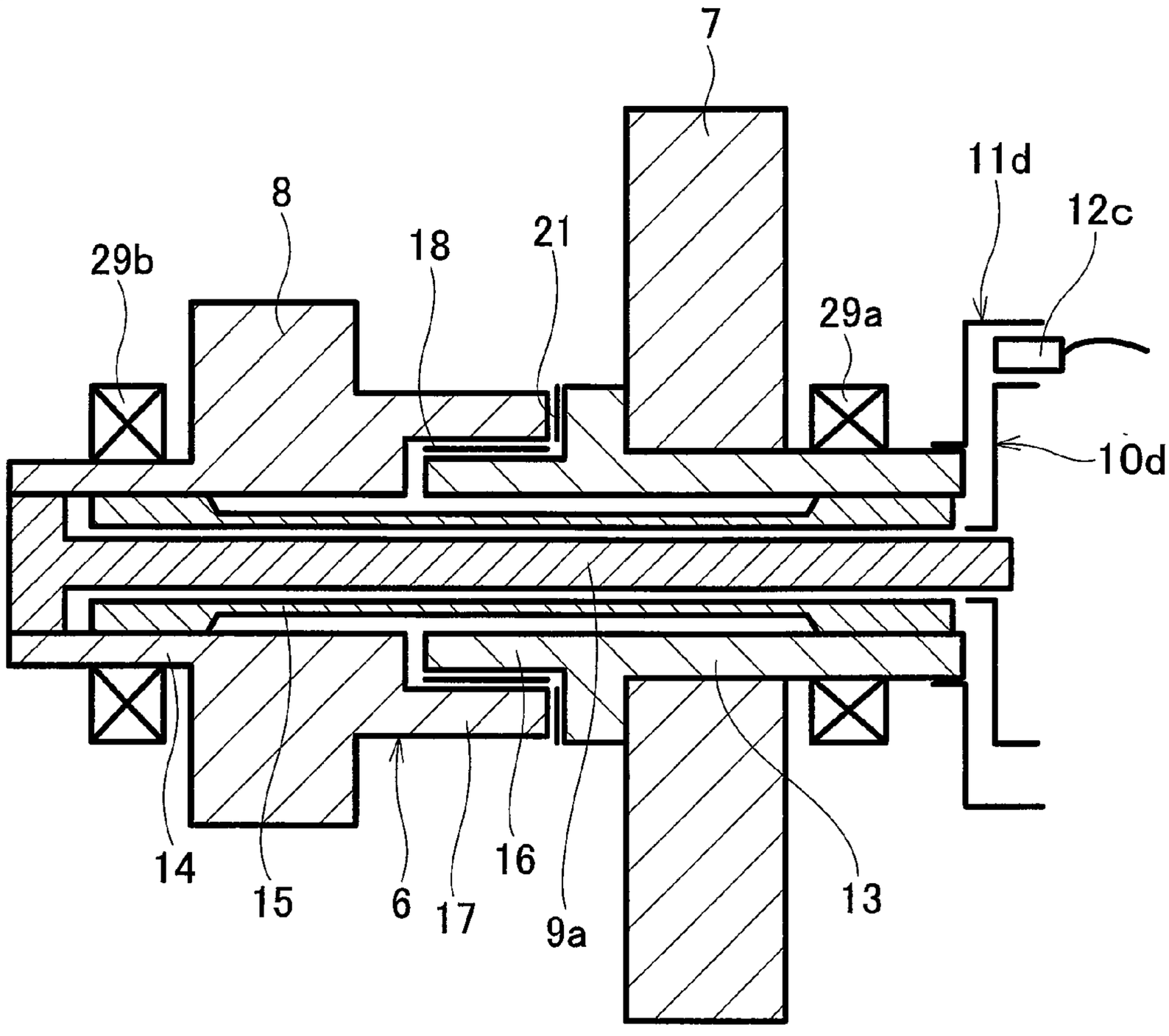

7
11d
12c
8
29b
18
21
29a
10d
14
15
6
17
16
9a
13

Fig.48

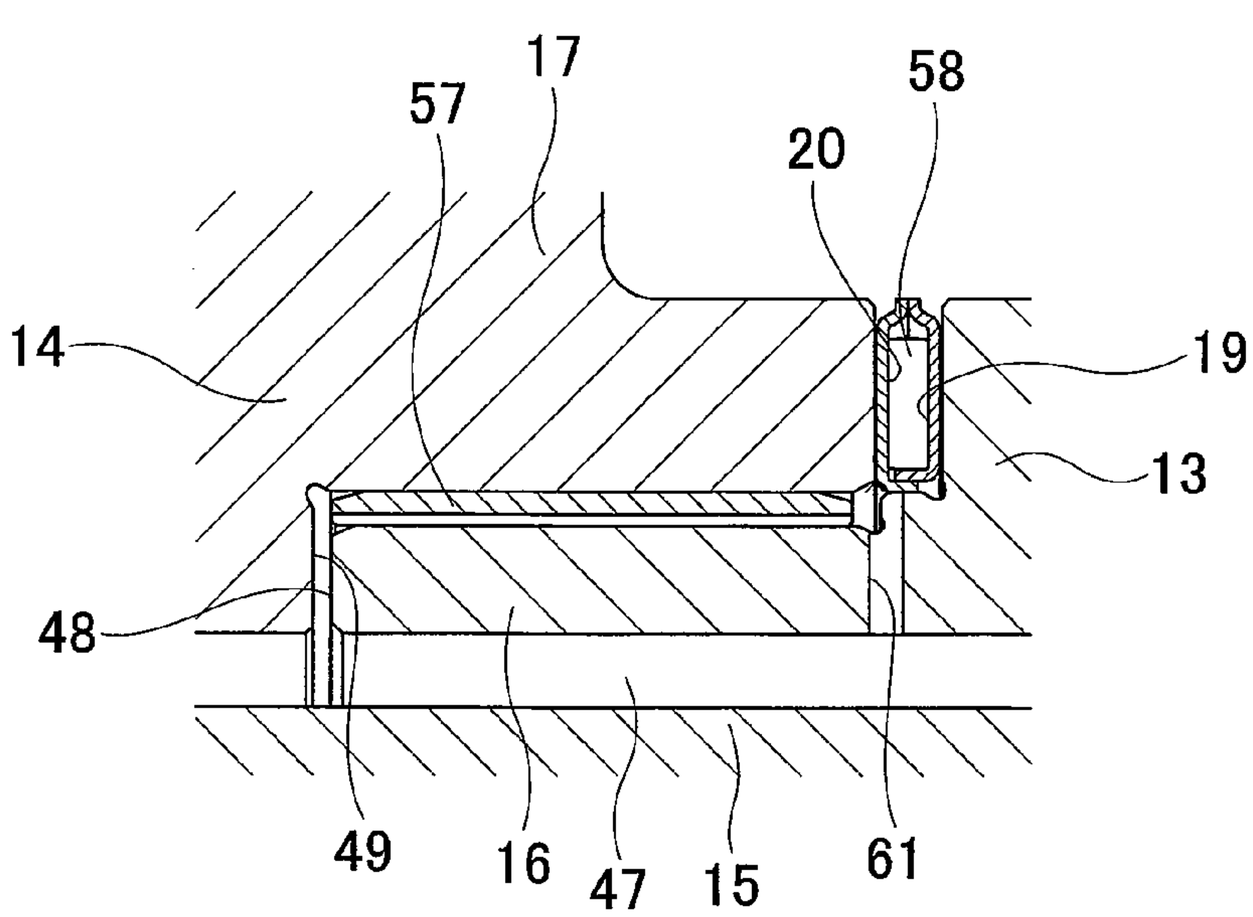

17
57
58
20
14
19
13
48
49
16
47
15
61

Fig.49

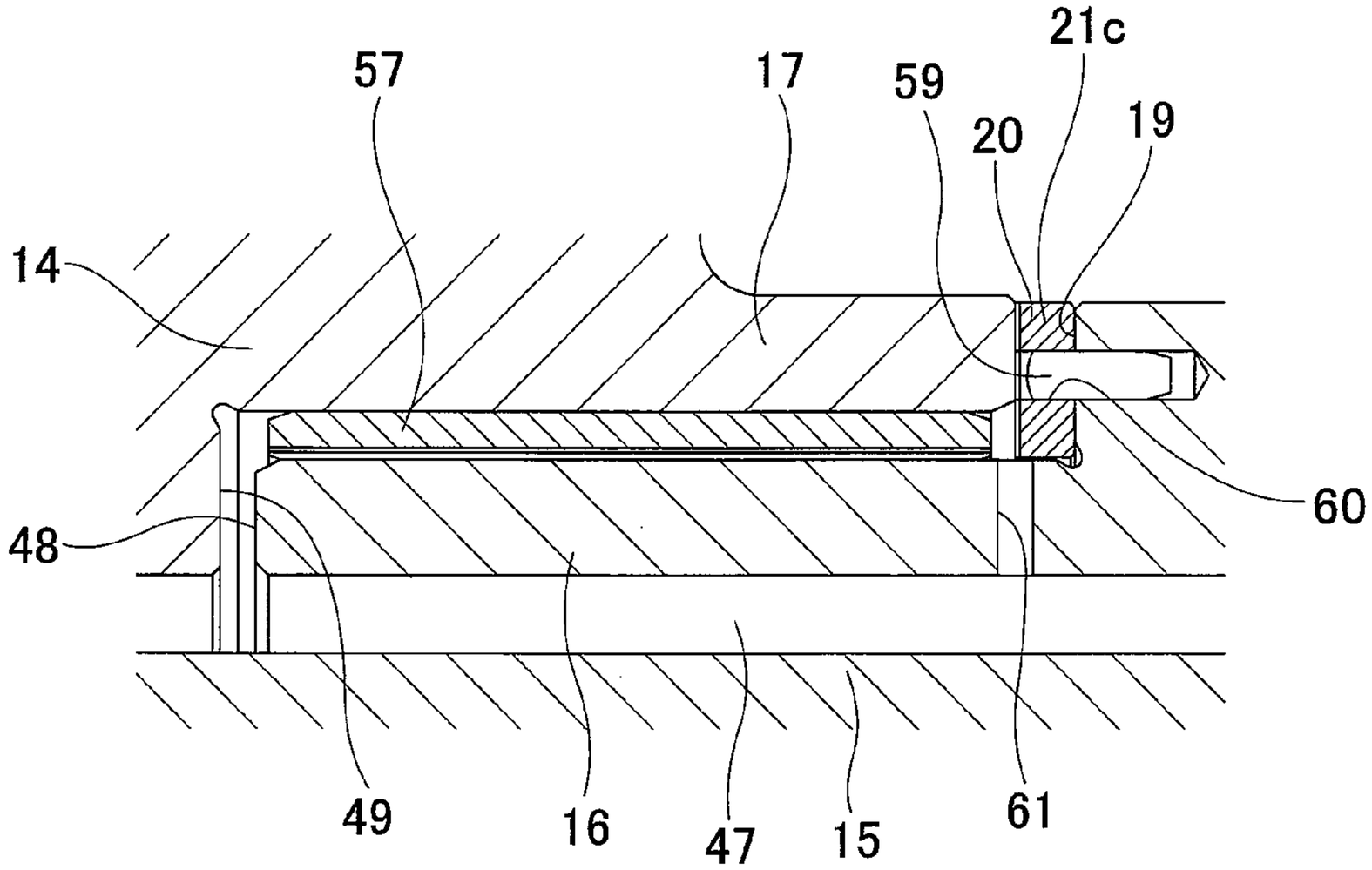



Fig.50

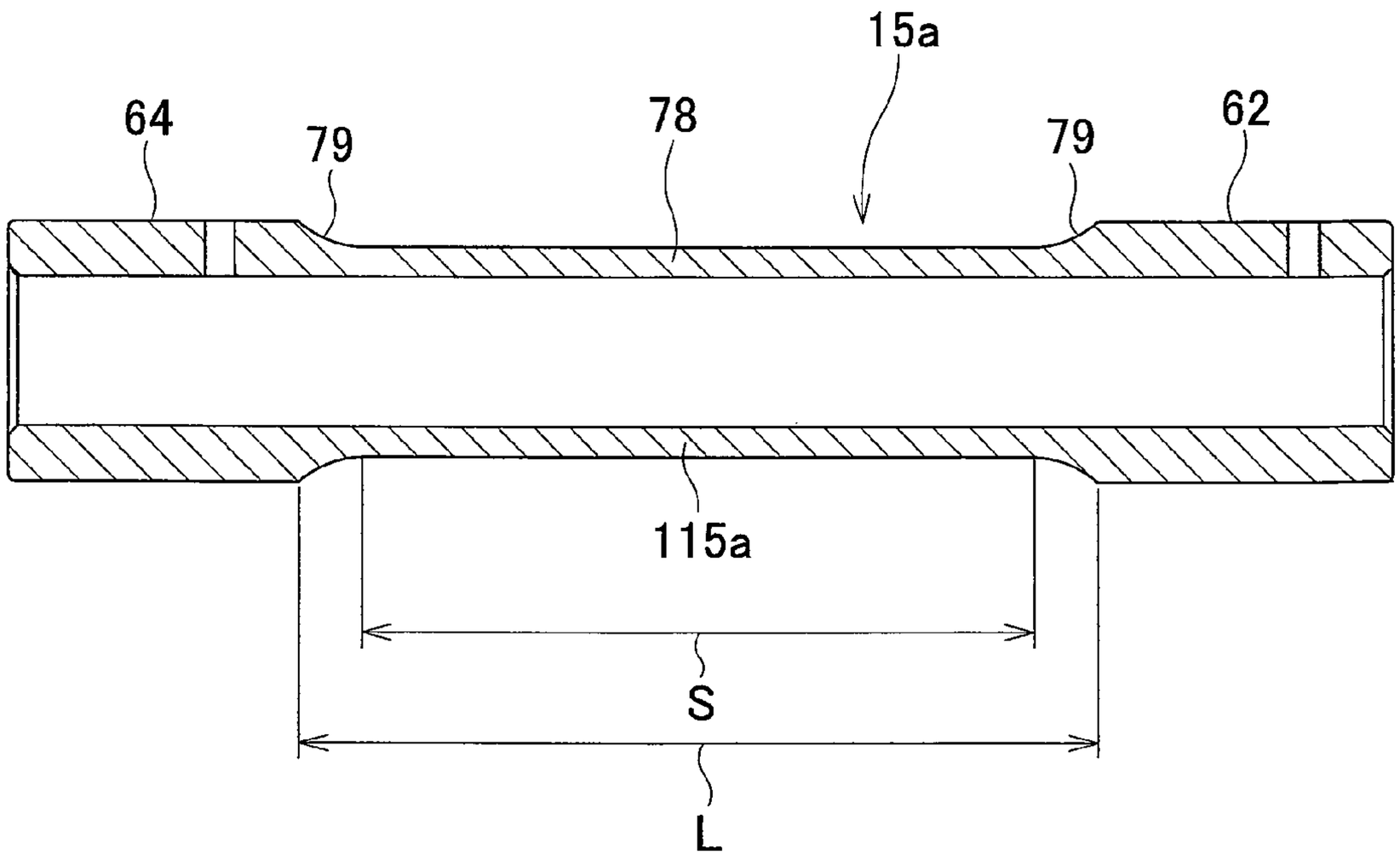


Fig.51

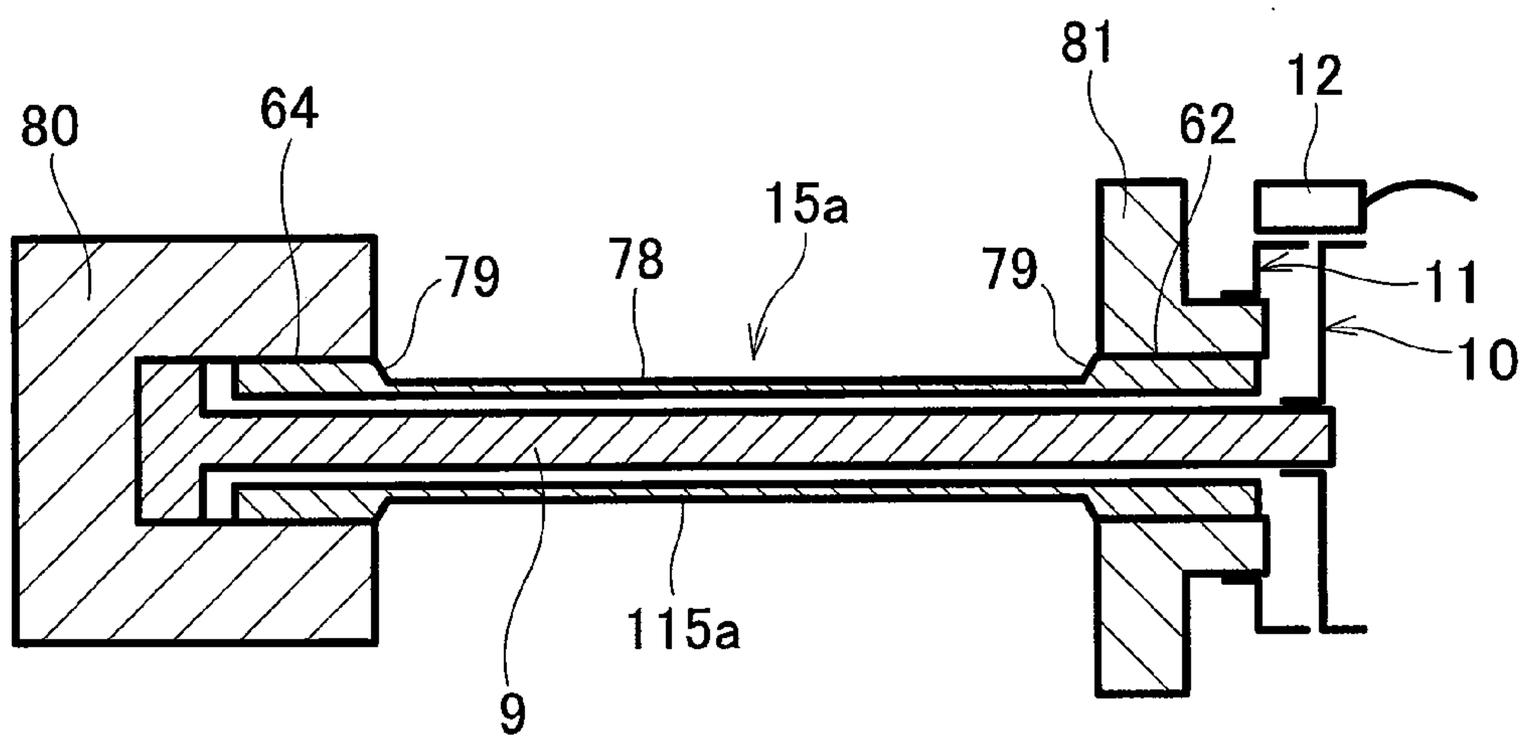

81
12
80
64
62
15a
79
78
79
11
10
115a
9

Fig.52

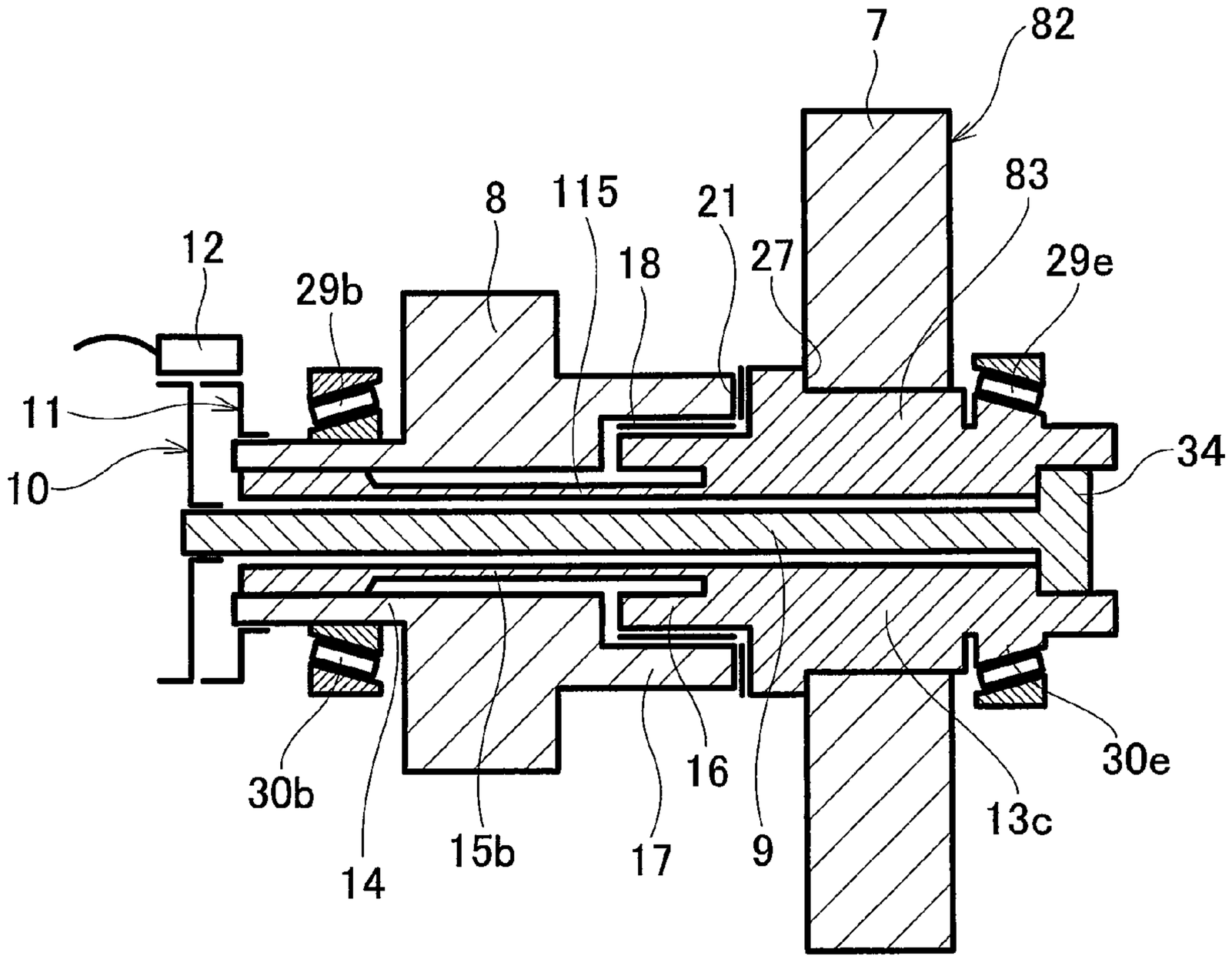

7
82
8
115
21
83
12
18
27
29e
29b
11
34
10
30b
16
30e
13c
14
15b
17
9

Fig.53

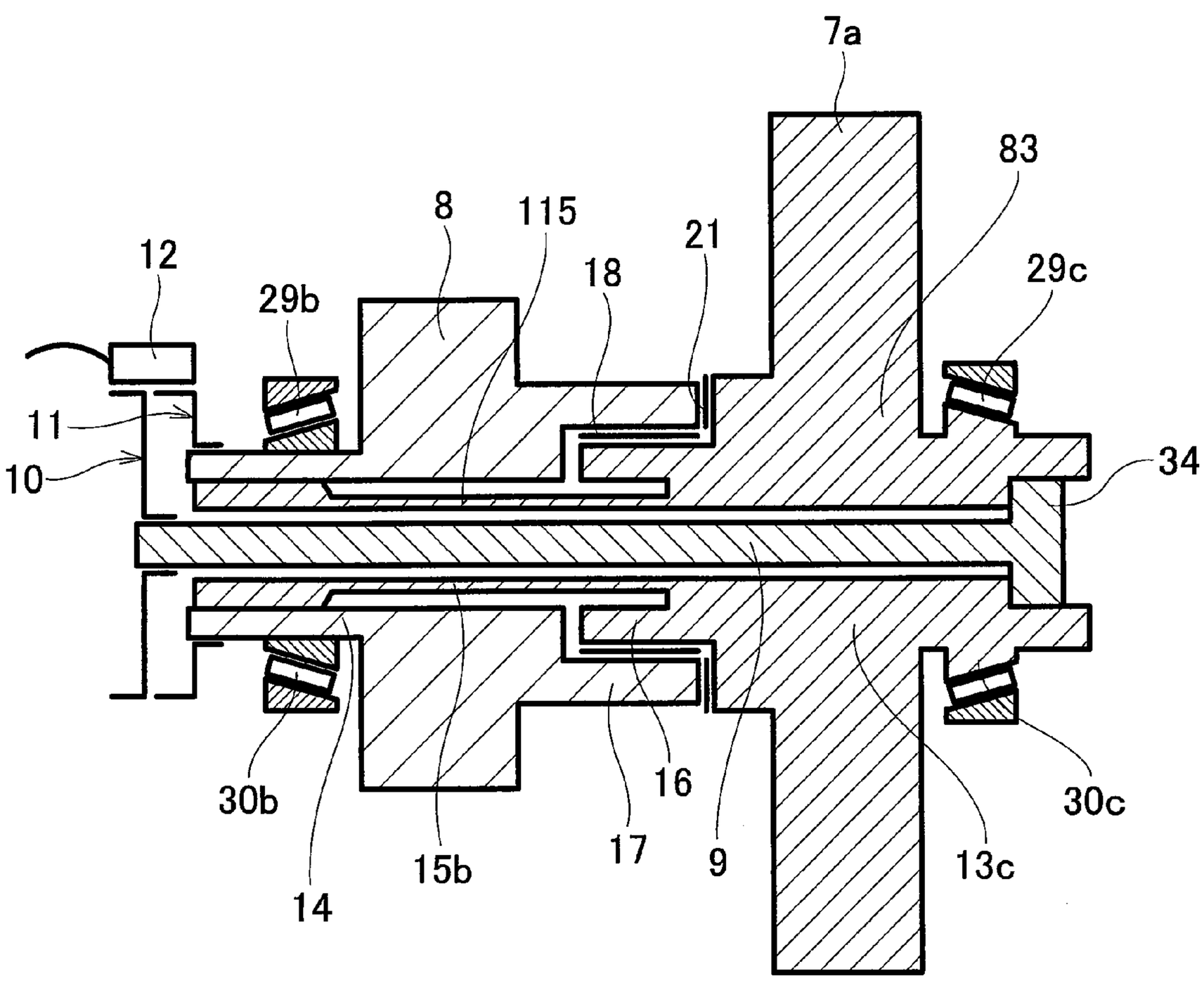


Fig.54

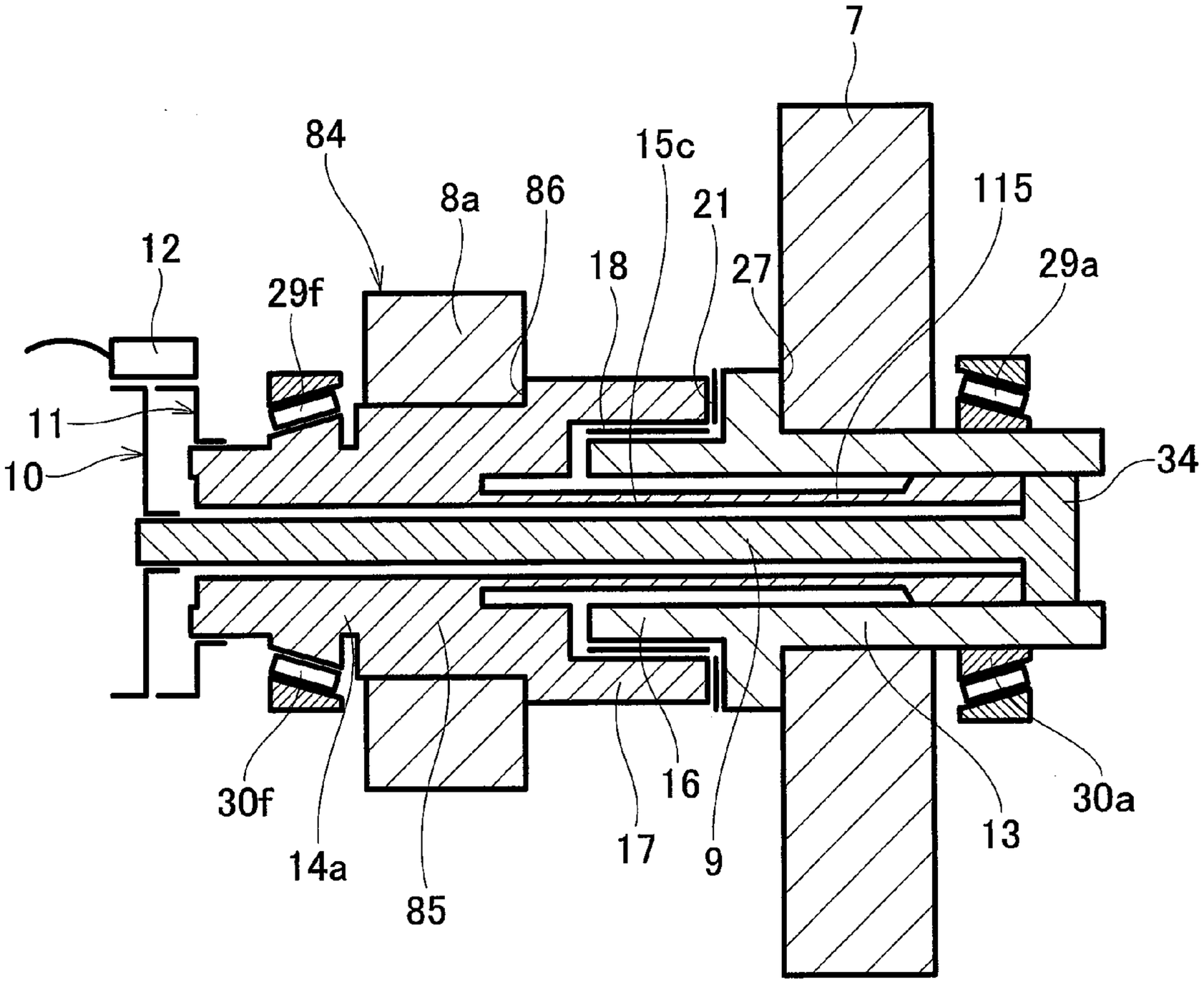

7
84
15c
8a
86
21
115
12
18
27
29a
29f
11
10
34
30f
16
30a
13
14a
85
17
9

Fig.55

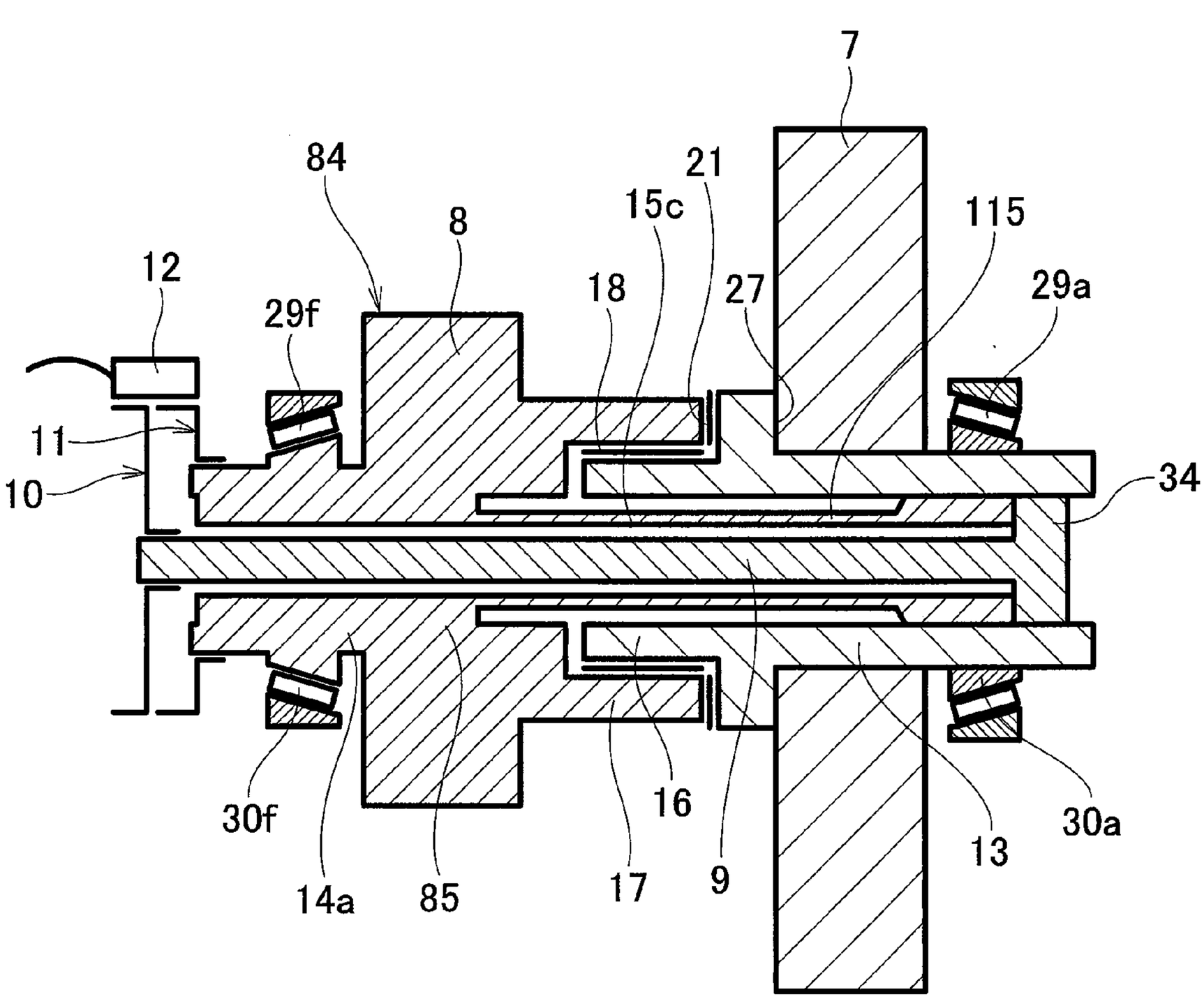


Fig.56

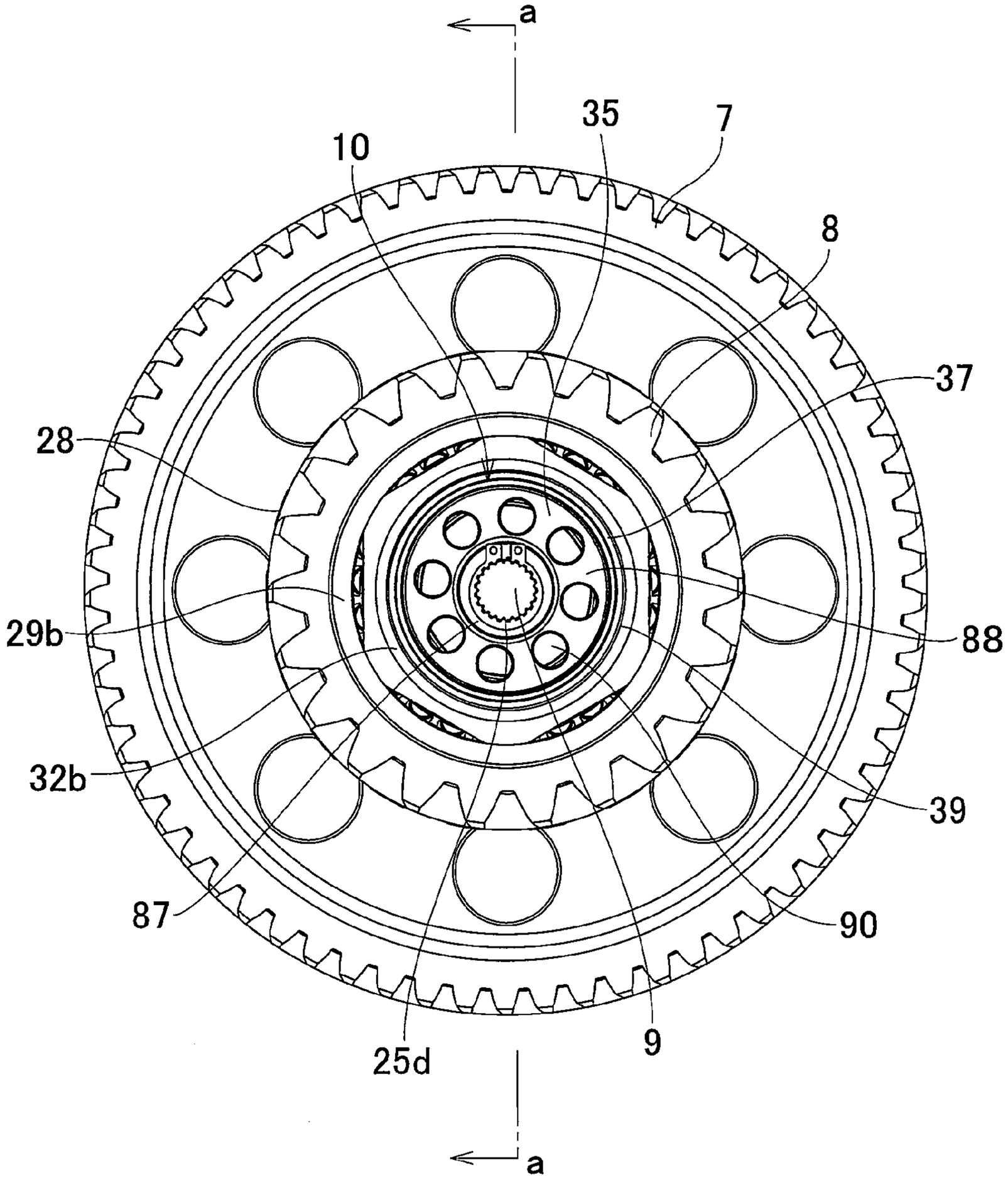


Fig.57

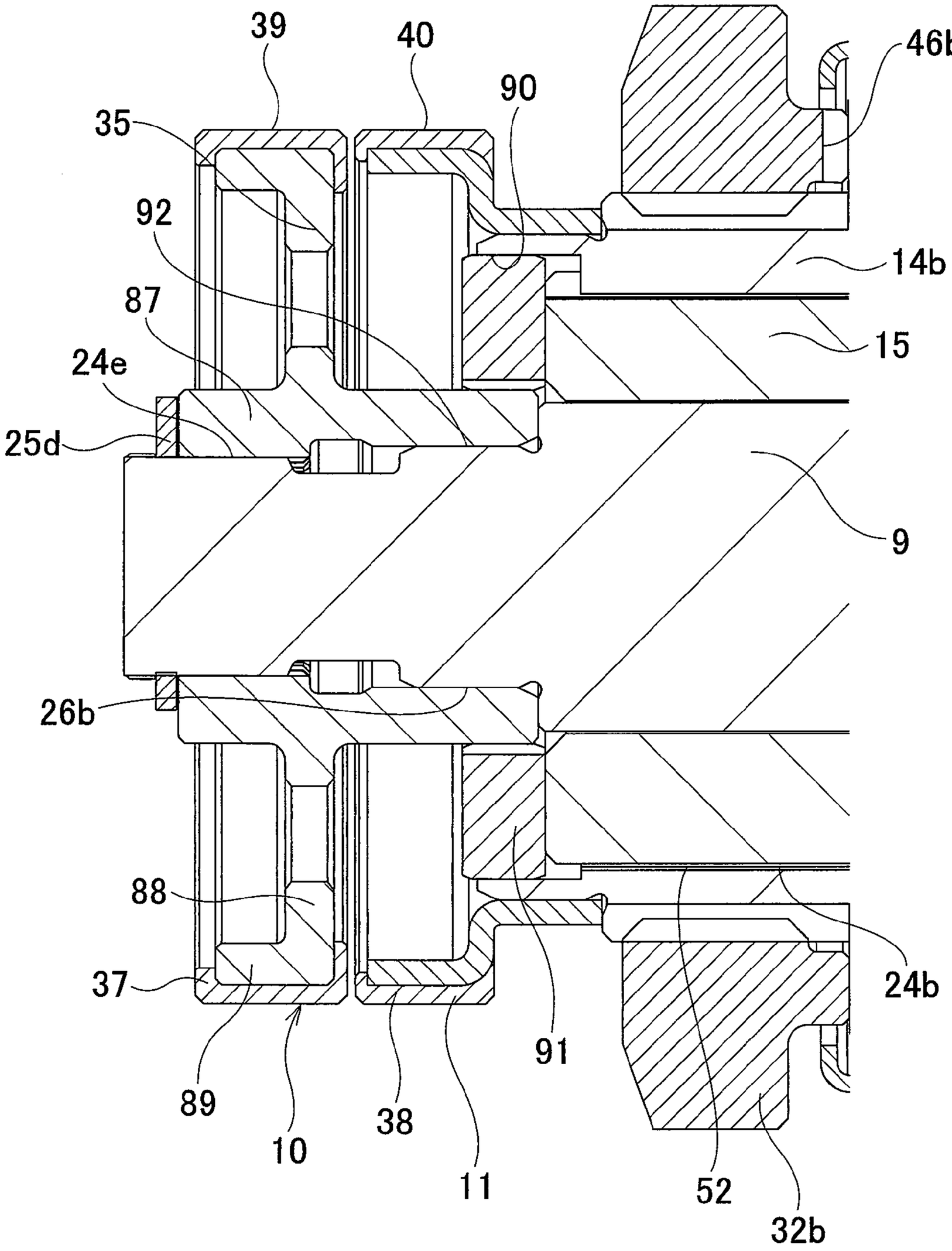

39
40
90
46b
35
92
14b
87
15
24e
25d
9
26b
88
37
24b
91
89
10
38
11
52
32b

Fig.58

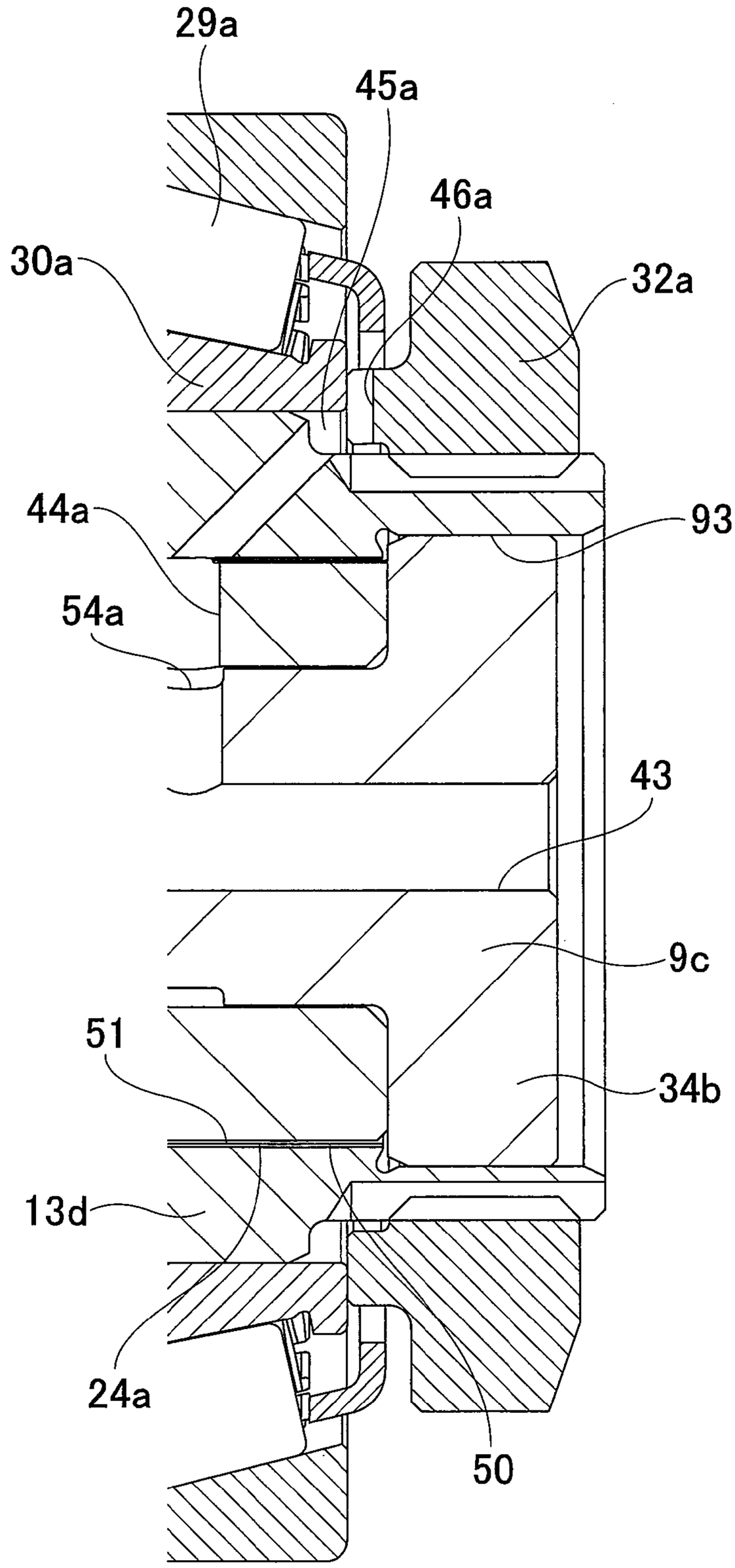
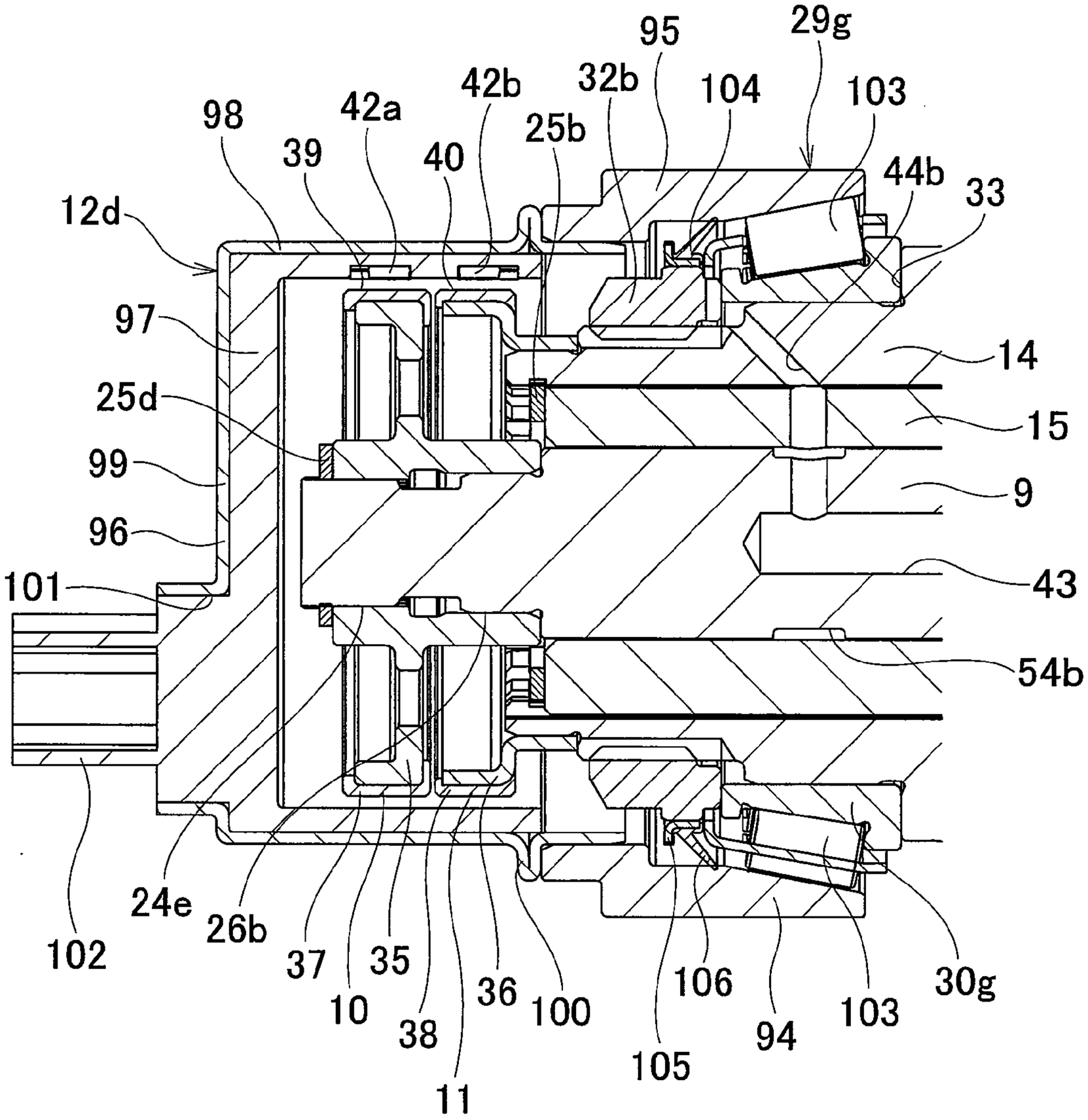


Fig.59


95
29g
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32b
104
103
98
42a
25b
44b
39
40
33
12d
14
97
25d
15
99
9
96
43
101
54b
24e
26b
37
35
36
106
30g
102
10
38
100
94
103
105
11

Fig.60

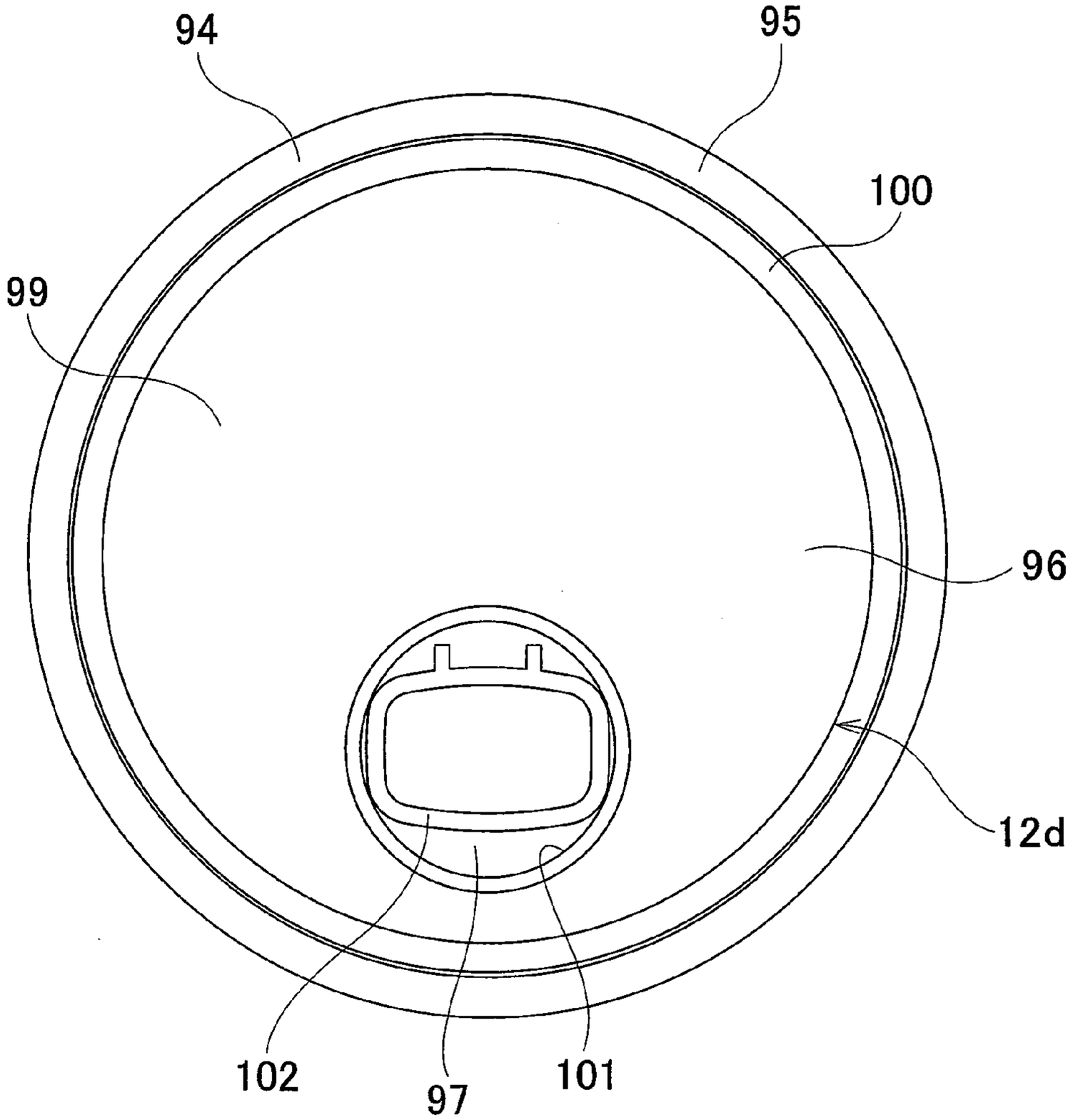


Fig.61

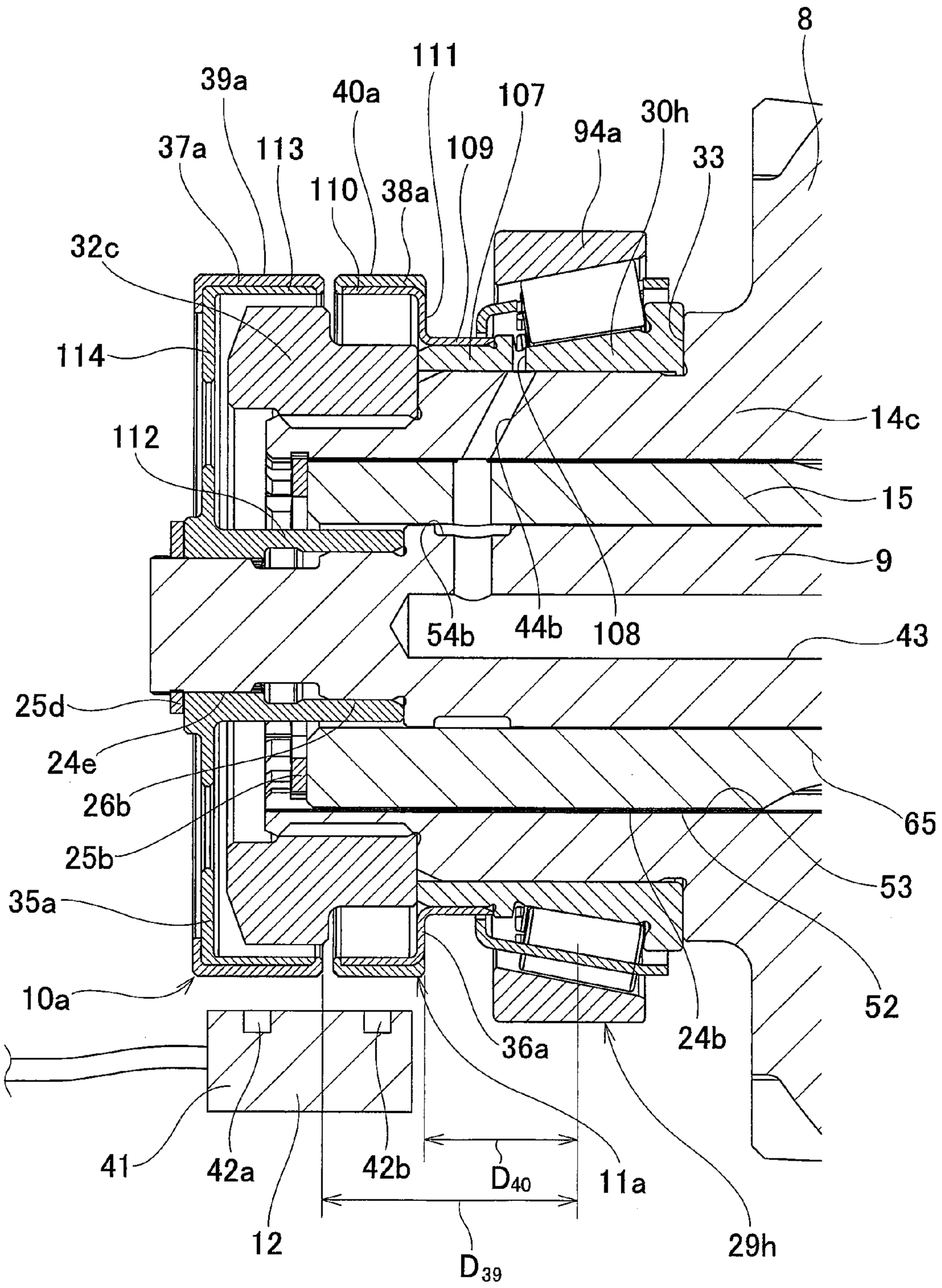

8
111
39a
40a
107
37a
113
109
94a
30h
33
110
38a
32c
114
14c
112
15
9
54b
44b
108
43
25d
24e
26b
65
25b
53
35a
52
10a
36a
24b
41
42a
42b
$D_{40}$
11a
12
29h
$D_{39}$

Fig.62

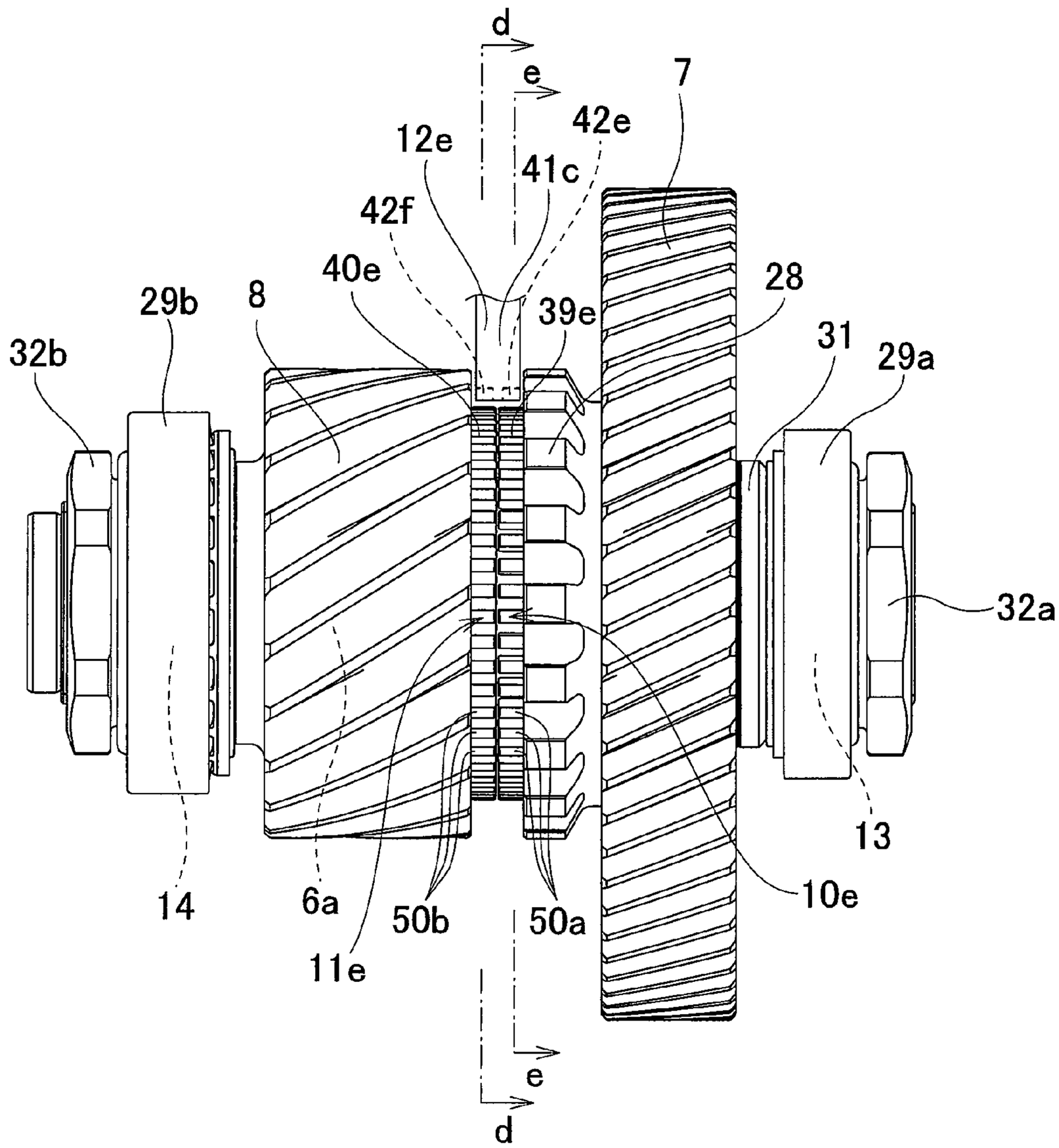

d
e
12e
42e
41c
42f
40e
39e
28
7
8
29b
32b
31
29a
32a
13
14
6a
50b
50a
10e
11e
e
d

Fig.63

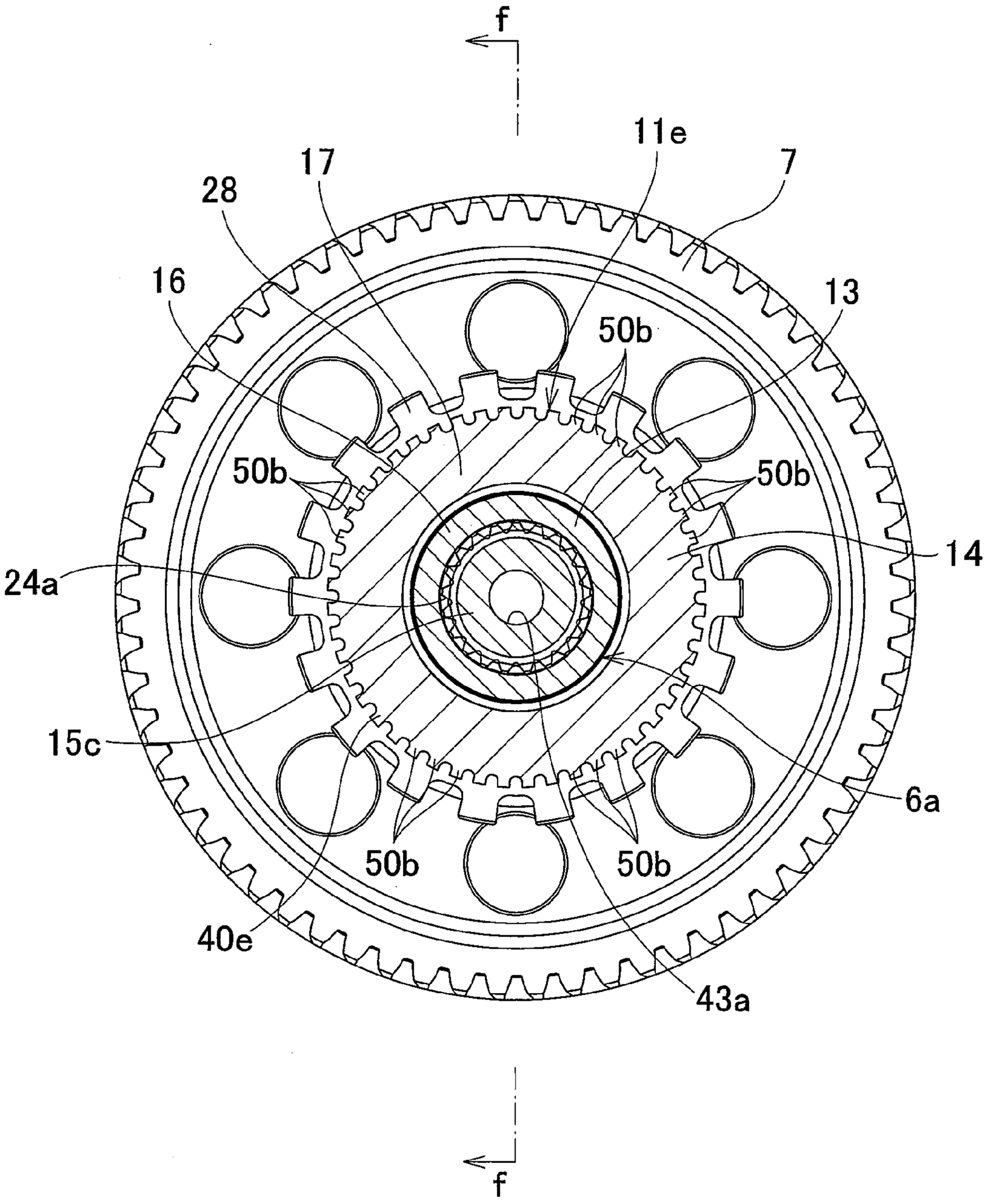


Fig.64

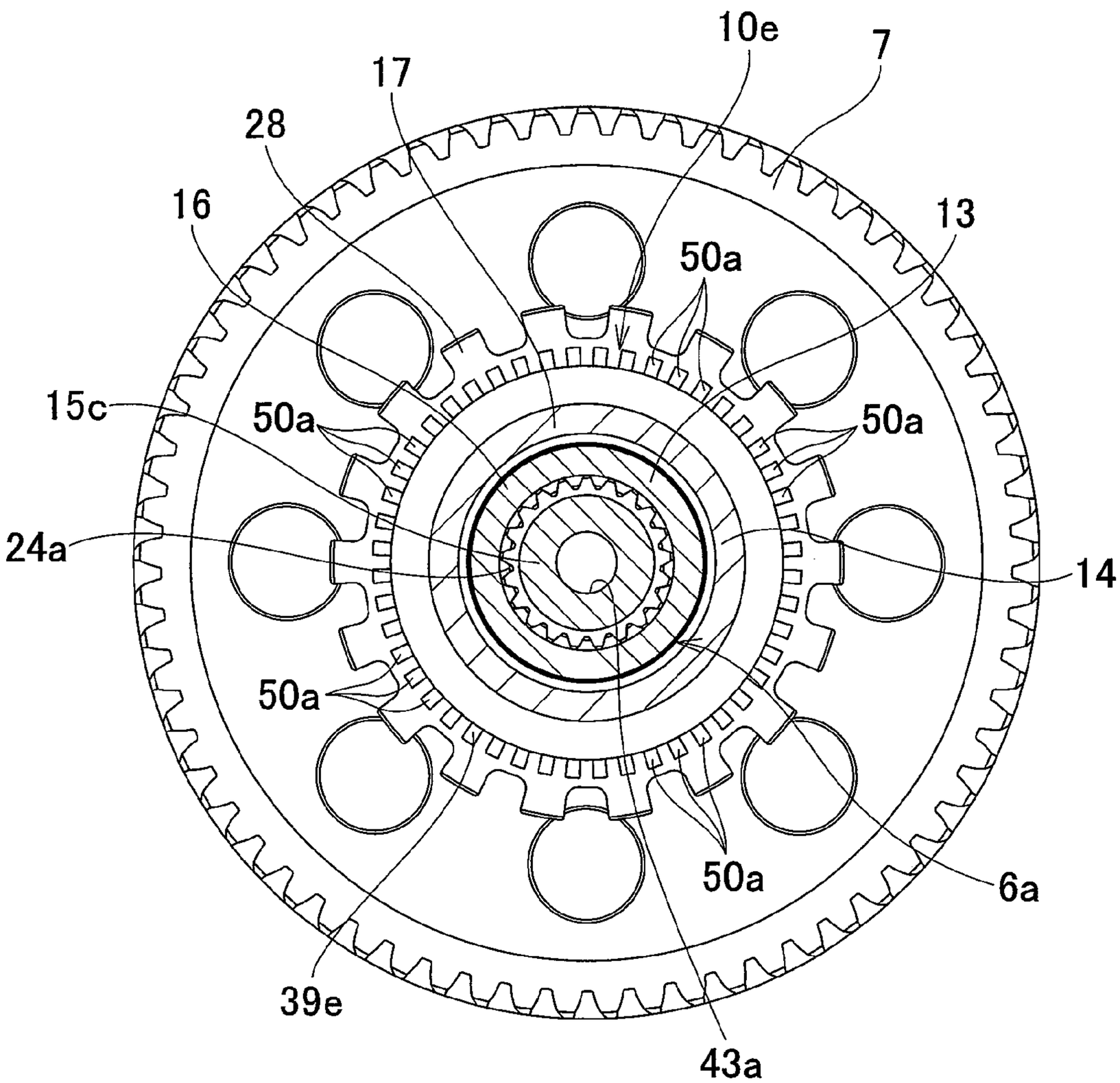


Fig.65

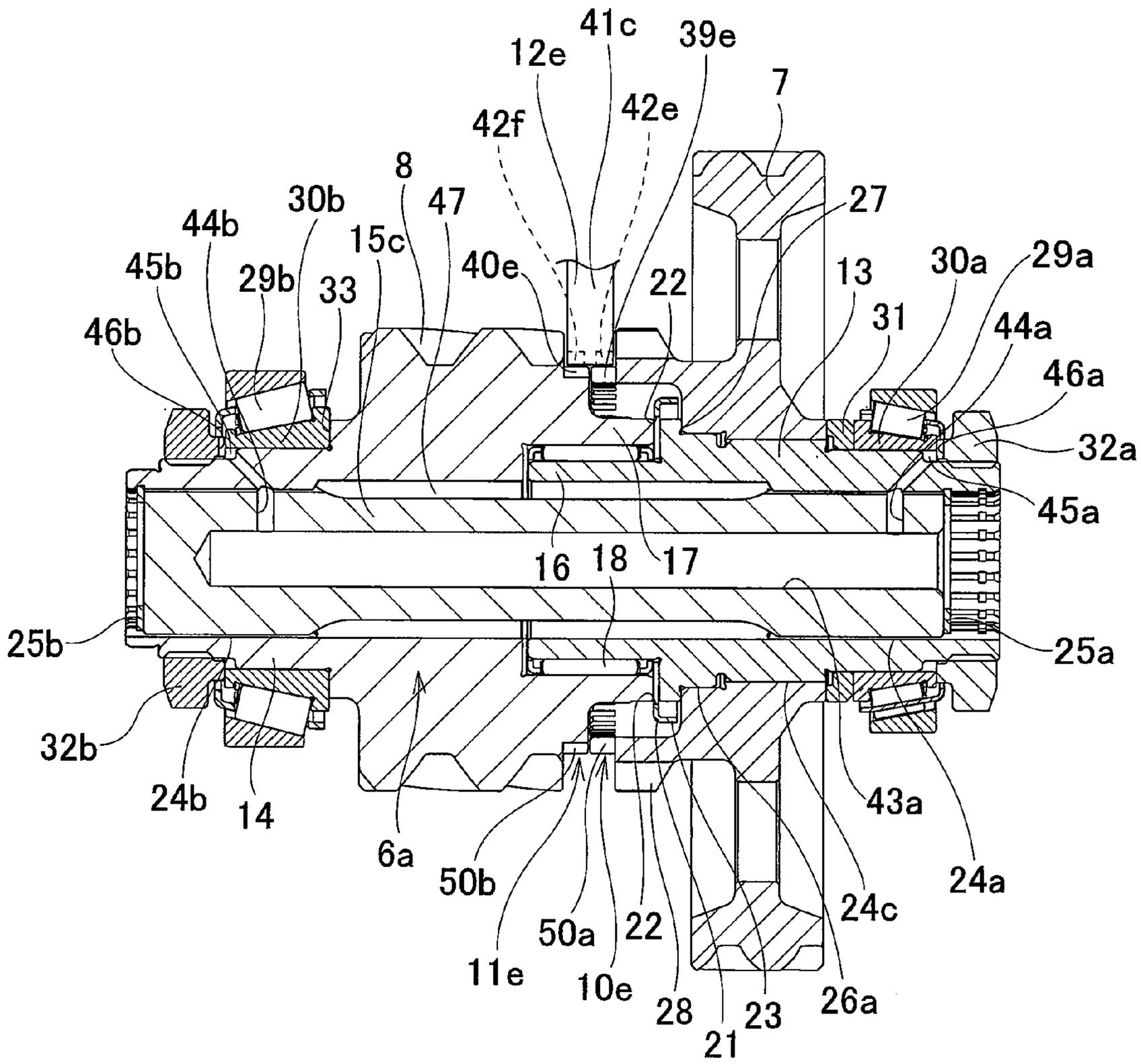

41c
39e
12e
42e
42f
7
8
47
30b
27
44b
15c
40e
22
13
30a
29a
45b
29b
33
31
44a
46b
46a
32a
45a
16
18
17
25b
25a
32b
24b
14
43a
6a
50b
50a
22
24c
24a
11e
10e
28
23
26a
21

Fig.66

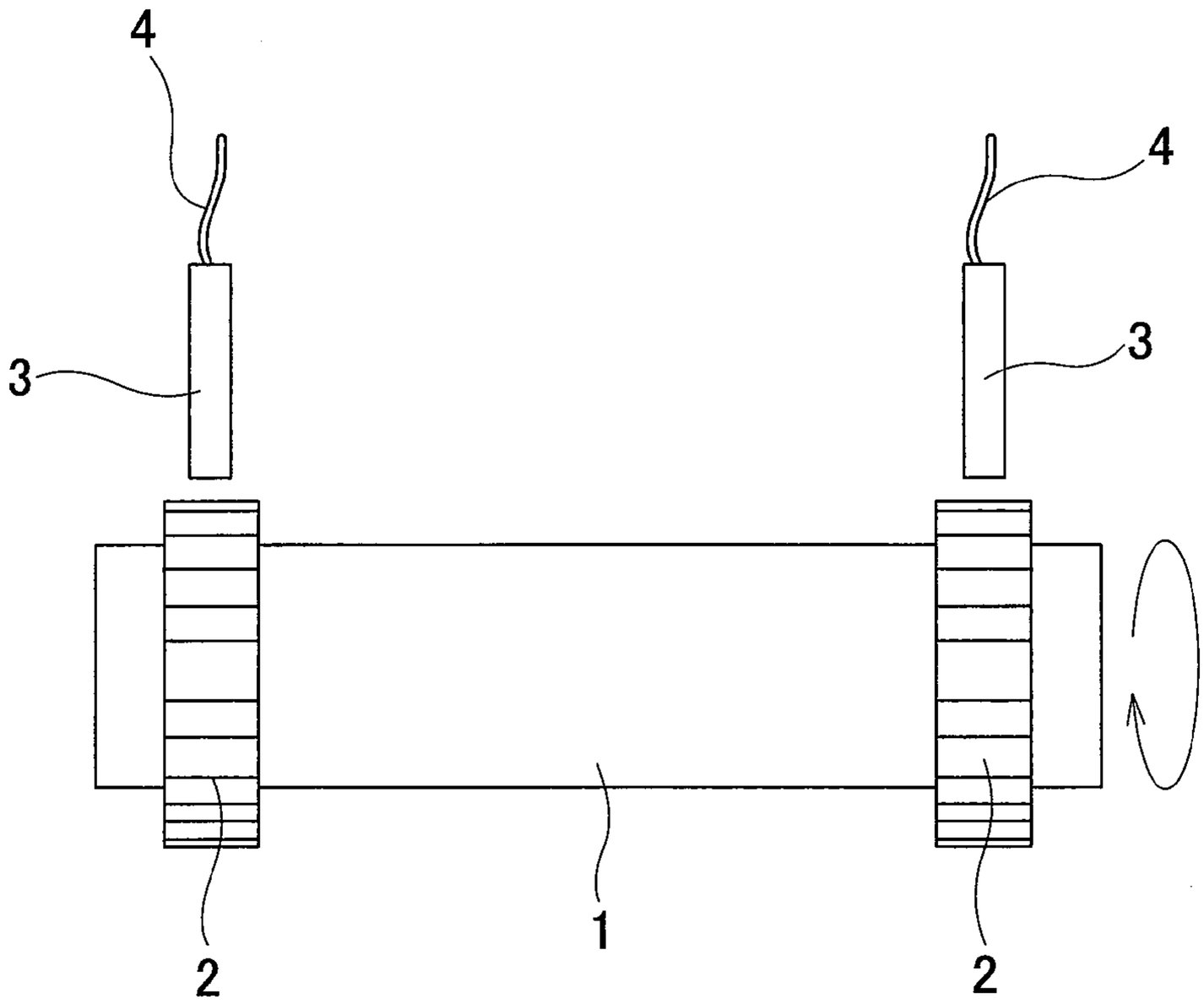
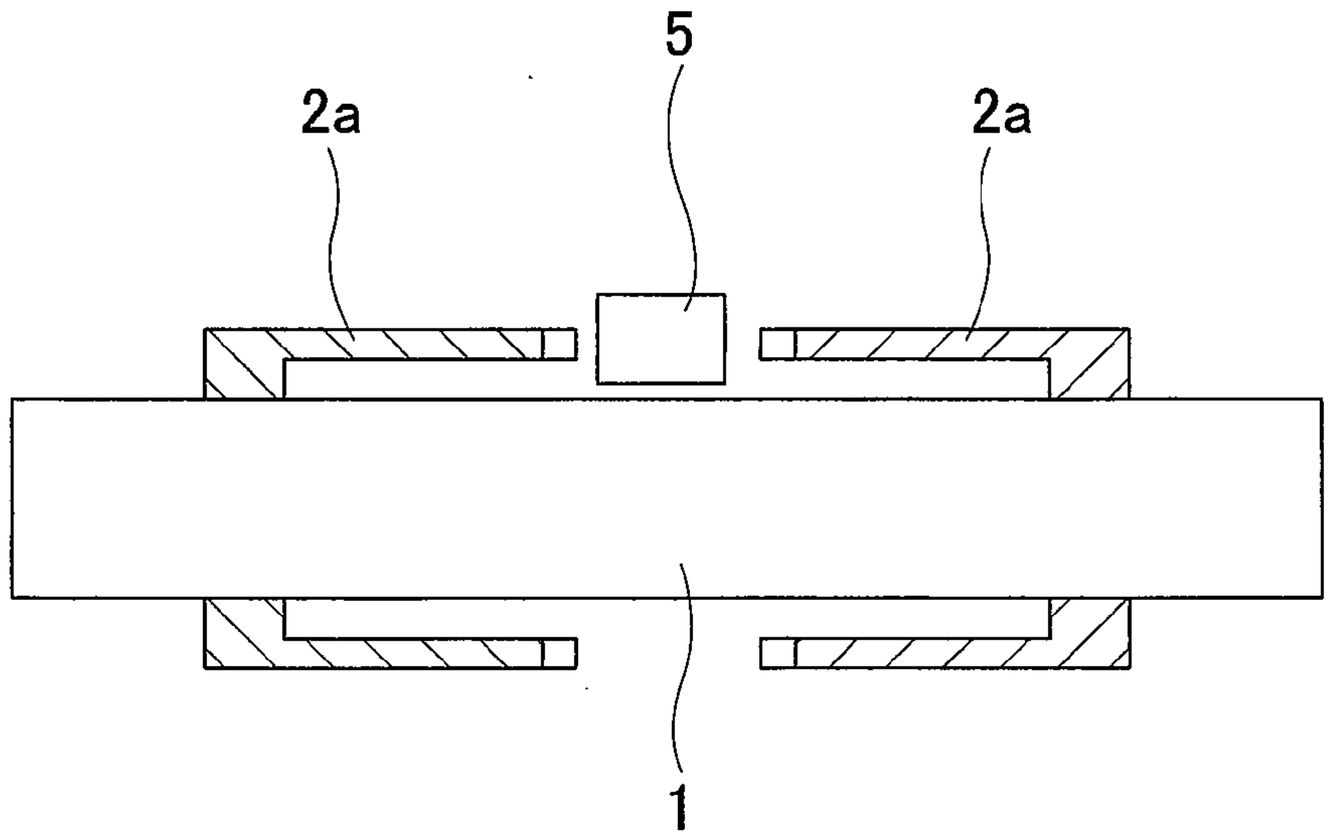



Fig.67



# ROTATION TRANSMISSION DEVICE

## TECHNICAL FIELD

**[0001]** The present invention relates to a rotation transmission device that is assembled in various kinds of machinery such as an automatic transmission for an automobile, and has a function for transmitting torque using a rotary shaft, as well as a function for measuring the torque that is transmitted by that rotary shaft.

## BACKGROUND ART

**[0002]** An automatic transmission for an automobile includes a mechanism that measures the rotational speed of a rotary shaft of the automatic transmission, and measures the torque that the rotary shaft transmits, and then performs transmission control for controlling the automatic transmission itself, or output control for controlling the output of the engine. As such a device for measuring torque is a device disclosed in JPH01254826 (A) that converts the amount of elastic torsional deformation of the rotary shaft that transmits torque to a phase difference of output signals from a pair of sensors, and measures the torque based on the phase difference.

**[0003]** FIG. **66** illustrates a first example of a conventional torque measurement device that includes this kind of construction. This torque measurement device includes a pair of encoders **2** that are fastened on the outside of the rotary shaft **1** at two locations in the axial direction of the rotary shaft **1**, and sensors **3** that correspond to each of the encoders **2** and that are supported in a housing that is not illustrated in the figure. The outer-circumferential surfaces of these encoders **2** function as detected sections, and the magnetic characteristics of these encoders **2** change in an alternating manner at a uniform pitch in the circumferential direction. The pitches at which the magnetic characteristics vary in the circumferential direction on the outer-circumferential surface of these encoders **2** are equal to each other. On the other hand, the sensors **3** are arranged so that the detecting sections of the sensors **3** face the outer-circumferential surfaces of the encoders **2**. These sensors **3** cause the output signals that are outputted from the sensors **3** to change according to the change in the magnetic characteristics on the outer-circumferential surfaces of the encoders **2** that the detecting sections face.

**[0004]** The output signals from the sensors **3** change periodically as the encoders **2** rotate together with the rotary shaft **1**. The frequency and period of this change are values that correspond to the rotational speed of the rotary shaft **1**. Therefore, it is possible to find the rotational speed of the rotary shaft **1** based on that frequency and period. Moreover, as the rotary shaft **1** transmits torque, the rotary shaft **1** undergoes elastic torsional deformation, which causes relative displacement between the encoders **2**. As a result, the phase difference ratio (=phase difference/1 period) between the output signals from the sensors **3** changes. This phase difference ratio is a value that corresponds to the amount of elastic torsional deformation of the rotary shaft **1** due to transmitting torque. Therefore, the torque that the rotary shaft **1** transmits can be found based on this phase difference ratio.

**[0005]** When trying to apply the torque measurement device of this first example of conventional construction to an automatic transmission for an automobile, the torsional rigidity of the rotary shaft **1** that is the target of torque measurement is high, so there is a problem in that it is difficult to sufficiently maintain the amount of elastic torsional deformation of the rotary shaft **1**, and the resolution of the torque measurement becomes low. Moreover, it is necessary to install the two sensors **3** so as to be separated in the axial direction, so there is also a problem in that it becomes difficult to arrange two harnesses **4** that run from these sensors **3**. Furthermore, in order to support the sensors **3** in a highly precise relative positional relationship, it is necessary to provide supporting and fastening sections in the housing, and thus there is also a problem in that processing of the housing becomes complicated.

**[0006]** In regard to this, JPH01254826 (A) discloses a torque measurement device in which the sensors have a unit-like construction. FIG. **67** illustrates a second example of a conventional torque measurement device that has this kind of construction. In this torque measurement device, the detected sections of a pair of encoders **2***a* that are fastened at two locations in the axial direction of the rotary shaft **1** extend toward the center section in the axial direction, and detecting sections of a pair of sensors of a single sensor unit **5** that is placed in the center section in the axial direction of the rotary shaft **1** faces the detected sections of the encoders **2***a*. However, in this case of applying the torque measurement device of this second example of conventional construction to an automatic transmission for an automobile as well, even though the installation of the sensor unit **5** is simplified, it does not mean that the problem of low resolution of the torque measurement has been solved.

**[0007]** Moreover, JPH02017311 (U) discloses a torque measurement device having construction that uses a torsion bar. More specifically, the torque measurement device of this third example of conventional construction is constructed so that encoders are fastened to the outer-circumferential surfaces of a pair of rotary shafts that are arranged along the same line, and these rotary shafts are connected by a torsion bar that undergoes elastic torsional deformation more easily than these rotary shafts. In this case, the amount of relative displacement in the rotational direction between the encoders can be made large due to the elastic torsional deformation of the torsion bar that occurs when transmitting torque, so it is possible to improve the resolution of the torque measurement. However, even when the torque measurement device of this third example of conventional construction is applied to a counter shaft of an automatic transmission for an automobile, it is difficult to sufficiently improve the resolution of the torque measurement. In other words, an input gear and output gear are fastened at two locations in the axial direction of the counter shaft, and the portion of this counter shaft that undergoes elastic torsional deformation during the transmission of torque is only the portion that is between these gears. The space in the axial direction of this portion is small, and it is difficult to sufficiently lengthen the dimension in the axial direction of the torsion bar that is to be placed in this portion, so it is not possible to sufficiently maintain the amount of elastic torsional deformation of the torsion bar.

**[0008]** As other related literature that is related to the present invention is JP2010185478 (A). A torsion bar having high fatigue strength and that is able to handle large stress loads, and a manufacturing method for manufacturing that torsion bar are disclosed in JP2010185478 (A).

## RELATED LITERATURE

### Patent Literature

**[0009]** [Patent Literature 1] JPH01254826 (A)
**[0010]** [Patent Literature 2] JPH02017311 (U)
**[0011]** [Patent Literature 3] JP2010185478 (A)

## SUMMARY OF INVENTION

### Problem to be Solved by Invention

**[0012]** The object of the present invention is to achieve construction of a rotation transmission device that can measure transmitted torque by using only a pair of encoders and one sensor unit, and that can increase the resolution of the torque measurement regardless of whether the space in the axial direction between a pair of gears is large or small.

### Means for Solving Problems

**[0013]** The rotation transmission device of the present invention includes a rotary-shaft unit, a first gear, a second gear, a first encoder, a second encoder and a sensor unit. Of these, the rotary-shaft unit includes: a first rotary shaft and a second rotary shaft that are both hollow, and together with being arranged so as to be concentric with each other, are combined so that the end sections of each are able to rotate relative to each other, and in this state are supported by a housing so as to rotate freely; and a torsion bar that is hollow and concentrically arranged on the inner-diameter side of the first and second rotary shafts, with one end section being connected to the first rotary shaft so that relative rotation is not possible, and the other end section being connected to the second rotary shaft so that relative rotation is not possible.

**[0014]** The first gear is provided in the middle section in the axial direction of the outer-circumferential surface of the first rotary shaft. The second gear is provided in the middle section in the axial direction of the outer-circumferential surface of the second rotary shaft. The first and second gears can be made to be separate from the first and second rotary shafts and fastened to the middle sections in the axial direction of the outer-circumferential surfaces of the first and second rotary shafts, or can be integrally formed with the middle sections in the axial direction of the outer-circumferential surfaces of the first and second rotary shafts.

**[0015]** The first encoder is fastened to one of the first and second rotary shafts so as to be concentric with the one rotary shaft, and has a first detected section that is magnetized so that the magnetic characteristics change in an alternating manner at a uniform pitch. Moreover, a second encoder is fastened to the other of the first and second rotary shafts so as to be concentric with the other rotary shaft, and has a second detected section that is magnetized so that the magnetic characteristics change in an alternating manner at a uniform pitch. The first and second detected sections can be circular ring-shaped, or can be circular disk-shaped. The first and second encoders can be made separate from the rotary shafts, or members that rotate in synchronization with the rotary shafts and fastened to and supported by the rotary shafts or these members, or can be integrally formed with these members.

**[0016]** The sensor unit is supported by the housing, and comprises at least one sensor that faces the first and second detected sections, and causes an output signal to change in correspondence to the change in magnetic characteristics of a portion of the first and second detected section where the at least one sensor faces.

**[0017]** For example, the first encoder is directly or indirectly fastened to an input shaft, which is the first rotary shaft, and the second encoder is directly or indirectly fastened to an output shaft, which is the second rotary shaft.

**[0018]** In one form of the present invention, the torsion bar includes a spring section, which is a portion in the middle section in the axial direction of the torsion bar that undergoes elastic torsional deformation when torque is transmitted; the dimensions of that spring section being larger than the space in the axial direction between the first and second gears.

**[0019]** In this case, preferably, the spring section includes a tube section having a wall thickness in the radial direction in the middle section in the axial direction except for the portions of the edges on both ends in the axial direction that is less than those portions of the edges on both ends in the axial direction, and is such that the inner-circumferential surface and outer-circumferential surface are single cylindrical surfaces that are concentric with each other; the ratio di/do of the inner-diameter dimension di and outer-diameter dimension do of that tube section being within the range $0.5 \leq di/do \leq 0.8$. Alternatively or additionally, the ten-point average roughness Rz of that tube section is within the range $Rz \leq 22$ μm.

**[0020]** In one form of the present invention, one end section and the other end section of the torsion bar are connected to the end sections of the first and second rotary shafts that are opposite the end sections that are combined together. For example, when the end sections of the first and second rotary shafts that are combined together are one end section of the second rotary shaft and the other end section of the first rotary shaft, the one end section of the torsion bar is connected to the one end section of the first rotary shaft, and the other end section of the torsion bar is connected to the other end section of the second rotary shaft.

**[0021]** In one form of the present invention, there is a coupling shaft that is arranged on the inner-diameter side of the torsion bar and arranged concentric with the torsion bar, with one end section thereof being connected to the one rotary shafts so that relative rotation is not possible, and the other end section protruding in the axial direction from the end section of the torsion bar, the first encoder is fastened to the other end section of the coupling shaft, the second encoder is fastened to the end section of the other rotary shaft on the other end section side of the coupling shaft so as to be close to the first encoder, and the first and second detected sections are arranged so as to be close to each other (for example, arranged with a space between of less than 10 mm, and more preferably, less than 5 mm). For example, when the end sections of the first and second rotary shafts that are combined together are taken to be one end section of the second rotary shaft and the other end section of the first rotary shaft, one end section of the torsion bar is connected to the one end section of the first rotary shaft, and the other end section of the torsion bar is connected to the other end section of the second rotary shaft, one end section of the coupling shaft is connected to the one end section of the first rotary shaft, and the other end section of the coupling shaft protrudes in the axial direction of the other end section of the second rotary shaft, and together with the first encoder being fastened to the other end section of the coupling shaft, the second encoder is fastened to the other end section of the second rotary shaft. In this form, the first and second encoders and the sensor unit are arranged on one end section in the axial direction of the rotary-shaft unit (the one end section in the axial direction or the other end section in the axial direction).

**[0022]** In this case, preferably, a sliding bearing is provided between the inner-circumferential surface of the end section of the other rotary shaft on the other end section side of the coupling shaft and the outer-circumferential surface of the coupling shaft or a fitting cylindrical section of a metal core of the first encoder that fits on the coupling shaft.

**[0023]** Alternatively, a rim section is provided on the outer-circumferential surface of the one end section of the coupling shaft, and the coupling shaft is supported by the one rotary shaft so that relative rotation is not possible with the rim section being pressure fitted with the inner-circumferential surface of the end section of the one rotary shaft on the one end side of the coupling shaft.

**[0024]** Alternatively, the other rotary shaft is supported by the housing so as to rotate freely using a rolling bearing that is located between the portion of the outer-circumferential surface of the other rotary shaft that is near the end section on the other end section side of the coupling shaft and the inner-circumferential surface of the housing; and the sensor unit includes a sensor cover and a detecting section that is fastened to and supported by the inside of the sensor cover; and by fastening the sensor cover to and supporting the sensor cover by the end section of the outer ring of the rolling bearing on the other end section side of the coupling shaft of the other rotary shaft so that the first and second encoders are located in a space inside the sensor cover, the detecting section is made to face the first and second detected sections. For example, the second rotary shaft is supported by the housing by a rolling bearing that is located between a portion of the second rotary shaft near the other end and the inner-circumferential surface of the housing, the sensor cover of the sensor unit is fastened to and supported by the end section of the outer ring of the rolling bearing on the other end section side of the second rotary shaft, and the first encoder that is fastened to the other end section of the coupling shaft, and the second encoder that is fastened to the other end section of the second rotary shaft are located in a space inside the sensor cover. In this case, preferably, a seal device is located between the space where plural rolling bodies of the rolling bearing are located and the space on the inside of the sensor cover where the first and second detected sections are located, and functions as a partition between these spaces.

**[0025]** Alternatively, the other rotary shaft is supported by the housing so as to rotate freely using a rolling bearing that is located between the portion of the outer-circumferential surface of the other rotary shaft near the end section on the other end section side of the coupling shaft and the inner-circumferential surface of the housing, and the second encoder is fastened around the outside of the end section of the inner ring of the rolling bearing on the other end section side of the coupling shaft. For example, the second rotary shaft is supported by the housing using a rolling bearing that is located between a portion of the outer-circumferential surface of the second rotary shaft near the other end and the inner-circumferential surface of the housing, and the second encoder is fastened around the outside of the other end section of the inner ring of the rolling bearing.

**[0026]** In this case, the first and second detected sections can both be cylindrical shaped, and at least one end section in the axial direction of the first and second detected sections can be arranged around the outer-diameter side of the end section of the other rotary shaft on the other end section side of the coupling shaft, or of another part that is fastened around the outside of the end section, in a position that overlaps in the radial direction that end section of the other rotary shaft or the other part. For example, at least part of the cylindrical shaped first and second detected sections is arranged around the outer-diameter side of the other end section of the second rotary shaft or of construction that is fastened to the end section, in a position that overlaps these in the radial direction.

**[0027]** In one form of the present invention, the first encoder is fastened to the first rotary shaft in a position between the first and second gears in the axial direction, and the second encoder is fastened to the second rotary shaft in a position between the first and second gears in the axial direction. That is to say, in this form, the first and second encoders and the sensor unit are arranged in the middle section in the axial direction of the rotary-shaft unit.

**[0028]** In one form of the present invention, the rotary-shaft unit is supported by the housing by plural rolling bearings so as to rotate freely; and the first rotary shaft or second rotary shaft is integrally formed with the inner ring of at least one of the plural rolling bearings.

**[0029]** In one form of the present invention, the first rotary shaft or second rotary shaft is integrally formed with the torsion bar.

**[0030]** In one form of the present invention, the sensor unit includes a first sensor that faces the first detected section, and a second sensor that faces the second detected section, and the first and second sensors generate output signals that change in correspondence to the change in magnetic characteristics of the portions of the first and second detected sections that the first and second sensors face; where the first and second detected sections can both be circular ring-shaped and arranged close to each other in the axial direction of the rotary-shaft unit; and in that case, the first and second sensors are made to face the first and second detected sections in the radial direction of the rotary-shaft unit. Moreover, the first and second detected sections can both be circular disk-shaped and arranged close to each other in the radial direction of the rotary-shaft unit; and in that case, the first and second sensors are made to face the first and second detected sections in the axial direction of the rotary-shaft unit.

**[0031]** In one form of the present invention, the first and second encoders are made of a magnetic material; the first and second detected sections include sections with material removed and solid sections that are arranged in an alternating manner at a uniform pitch in the circumferential direction, and are arranged so as to be close to each other and overlap in the radial or axial direction; the sensor unit includes a stator made of a magnetic material, and plural coils that are made of one conducting wire, and is constructed so that when a driving voltage is applied to the conducting wire, the output current or the output voltage from the conducting wire is used as an output signal; the stator includes: plural core sections that are arranged at a uniform pitch in the circumferential direction, extend in the overlapping direction of the first and second detected sections, and the tip-end surfaces face one of the first and second detected sections from one side in the overlapping direction of the first and second detected sections; and a circular ring-shaped rim section that connects together the base-end sections of the plural core sections; and the plural coils are fastened one by one around the plural core sections, and are such that the winding directions of coils that are adjacent in the circumferential direction are opposite each other.

**[0032]** In one form of the present invention, the first and second encoders are made of a magnetic material; the first and second detected sections include sections with material removed and solid sections that are arranged in an alternating manner at a uniform pitch in the circumferential direction,

and the solid sections of the first detected section and the solid sections of the second detected section are arranged in an alternating manner in the circumferential direction with a space in between each in the circumferential direction; and the sensor unit includes one sensor that faces the portion where the solid sections of the first and second detected sections are alternatingly arranged, and the sensor generates an output signal that changes in correspondence to the change in the magnetic characteristics of the portion where the sensor faces the solid sections of the first and second detected sections are alternatingly arranged.

**[0033]** In one form of the present invention, the first and second detected sections include a pair of cylindrical surfaces that face each other in the radial direction or a pair of circular ring surfaces that face each other in the axial direction, and are arranged so the S poles and N poles of these detected sections alternate at a uniform pitch in the circumferential direction; and the sensor unit includes a magnetism-detecting element or coil that is arranged between the first and second detected sections, and the output voltage or output current from that magnetism detecting unit, or the output voltage or output current from the coil is used as the output signal.

**[0034]** Furthermore, preferably the end sections of the first and second rotary shafts are combined in a state in which displacement in a direction in the axial direction toward each other is prevented, the first and second gears are both helical gears, and the directions of inclination of the first and second gears are regulated so as to be directions in which the gear reaction forces in the axial direction that act on the first and second gears during forward operation of the first and second gears (rotation in a direction of rotation that occurs often during use, for example, rotation when the automobile is moving forward) are toward each other (press toward each other).

**[0035]** Moreover, preferably, one of the combination cylindrical sections of the first combination cylindrical section that is provided on the other end section of the first rotary shaft and the second combination cylindrical section that is provided on one end section of the second rotary shaft is inserted into the inner-diameter side of the other combination cylindrical section, a radial bearing (radial rolling bearing, or radial sliding bearing) is placed between the opposing circumferential surfaces of the first and second combination cylindrical sections, and a thrust bearing (thrust rolling bearing, or thrust sliding bearing) is placed between a stepped surface that is provided on the base-end section of the outer-circumferential surface of one of the combination cylindrical sections, and the tip-end surface of the other combination cylindrical section.

**[0036]** In this case, it is possible to use for example, a circular disk shaped thrust washer that is held between the stepped surface and the tip-end surface as the thrust bearing.

**[0037]** In that case, preferably a pair of sections with material removed that connect a pair of spaces that exist in positions on both sides in the radial direction of the portion between the stepped surface and the tip-end surface are formed at one or plural location in the circumferential direction of the thrust washer (preferably, plural evenly spaced locations). As the sections with material removed, it is possible to use slits or through holes that pass through both side surfaces of the thrust washer, or it is also possible to use concave grooves that are provided in at least one of the side surfaces of the thrust washer.

**[0038]** Moreover, preferably the outer-circumferential edge of the thrust washer protrudes outward in the radial direction from a portion between the stepped surface and the tip-end surface, and a reinforcing cylindrical section is formed around the entire outer-circumferential edge.

**[0039]** Furthermore, preferably, a first male spline section that has a first plating layer on the surface layer thereof is provided on the outer-circumferential surface of one end section of the torsion bar, and a first female spline section that is able to engage with the first male spline section is provided on the inner-circumferential surface of the first rotary shaft. Of these, the metal of the first plating layer is a metal that is softer than the metal of the torsion bar and first rotary shaft. By pressure fitting the first male spline section into the first female spline section with interference that is less than the thickness dimension of the first plating layer in the free state (state in which no external forces act) the spline sections are connected with no looseness in the circumferential direction. Together with this, a second male spline section having a second plating layer on the surface layer thereof is provided on the outer-circumferential surface of the other end section of the torsion bar, and a second female spline section that is able to engage with the second male spline section is provided on the inner-circumferential surface of the second rotary shaft. The metal of the second plating layer is a metal that is softer than the metal of the torsion bar and second rotary shaft. By pressure fitting the second male spline section into the second female spline section with interference that is less than the thickness dimension of the second plating layer in the free state (state in which no external forces act) the spline sections are connected with no looseness in the circumferential direction. In this case, the metal material of the first and second plating layers is copper or nickel.

## Effect of Invention

**[0040]** In the case of the rotation transmission device of the present invention, the output signal from the sensor unit changes in correspondence to the rotational speed due to the first and second encoders (first and second detected sections) rotating together with the rotary-shaft unit (first and second rotary shafts). Therefore, when necessary, it is possible to measure the rotational speed based on the output signal from the sensor unit. Moreover, when the rotary-shaft unit transmits torque between the first and second gears, there is relative displacement in the direction of rotation between the first and second gears (between the first and second rotary shafts, and between the first and second encoders) as elastic torsional deformation occurs in the middle section in the axial direction of the torsion bar. As a result of this kind of relative displacement in the direction of rotation between the first and second encoders, the output signal from the sensor unit changes in correspondence to that relative displacement (size of the torque). Therefore, it is possible to measure the torque based on the output signal from the sensor unit.

**[0041]** Particularly, in the case of the present invention, the first rotary shaft that is provided with the first gear in the middle section in the axial direction of the outer-circumferential surface thereof, and the second rotary shaft that is provided with the second gear in the middle section in the axial direction of the outer-circumferential surface are both hollow, the torsion bar is arranged on the inner-diameter side of these rotary shafts and both end sections of the torsion bar are connected to these rotary shafts so that no relative rotation is possible. Therefore, for example, it is possible to make the dimension in the axial direction of the middle section in the axial direction of the torsion bar greater than the space in the

axial direction between the first and second gears, and to sufficiently maintain the amount of elastic torsional deformation of the middle section in the axial direction of the torsion bar that occurs when torque is transmitted. As a result, the case of the present invention differs from construction in which the rotary-shaft unit is one rotary in that it is possible to sufficiently increase the amount of relative displacement in the direction of rotation between the first and second gears (first and second rotary shaft, first and second encoders) that occurs when torque is transmitted, regardless of whether the space in the axial direction between the first and second gears is large or small. Therefore, it is possible to sufficiently increase the resolution of the torque measurement.

**[0042]** Moreover, in the case of the present invention, by adjusting the dimension in the radial direction and the dimension in the axial direction of the middle section in the axial direction of the torsion bar during the design stage, it is possible to easily adjust the torsional rigidity of the middle section in the axial direction. Therefore, when compared with construction in which the rotary-shaft unit is a single rotary shaft, it is easy to plan and design the relationship (gain) between the torque and the amount of relative displacement in the direction of rotation of the first and second encoders.

**[0043]** In one form of the present invention, the first and second encoders can be arranged so as to be concentrated at one end section of the rotary-shaft unit, or more specifically, at one end section of the input shaft, which is the first rotary shaft, or the other end section of the output shaft, which is the second rotary shaft. Therefore, the sensor unit can be supported by a portion of the housing that is near the end section having high rigidity, and thus it is possible to maintain precision of torque measurement by the sensor unit regardless of deformation of the housing due to gear reaction forces in the radial direction that act on the first and second gears (input gear and output gear) when torque is being transmitted.

**[0044]** Furthermore, in one form of the present invention, only one sensor is used, so only one harness that leads from the sensor unit needs to be used, and that harness can be easily installed. Moreover, only one support and fastening section needs to be provided in the housing for the sensor unit, so processing the housing can be performed easily.

## BRIEF DESCRIPTION OF DRAWINGS

**[0045]** FIG. **1** is a perspective view illustrating a rotation transmission device of a first example of an embodiment of the present invention;

**[0046]** FIG. **2** is a side view of the rotation transmission device illustrated in FIG. **1**;

**[0047]** FIG. **3** is an end view of the other end side of the rotation transmission device illustrated in FIG. **1**;

**[0048]** FIG. **4** is an end view of the one end side of the rotation transmission device illustrated in FIG. **1**;

**[0049]** FIG. **5** is an exploded perspective view of the rotation transmission device illustrated in FIG. **1**;

**[0050]** FIG. **6** is a cross-sectional view of section a-a in FIG. **3** of the rotation transmission device illustrated in FIG. **1**;

**[0051]** FIG. **7** is an enlarged view of the other end section of the rotation transmission device illustrated in FIG. **1**;

**[0052]** FIG. **8** is an enlarged view of area b in FIG. **6** (where the end sections of the input shaft and output shaft are combined together);

**[0053]** FIG. **9** is a view as seen from the outer-diameter side of part in the circumferential direction of the first detected section and second detected section of the encoder of the rotation transmission device illustrated in FIG. **1**;

**[0054]** FIG. **10** is an enlarged cross-sectional view of the area of the rotation transmission device illustrated in FIG. **1** where the sensor unit faces the encoders;

**[0055]** FIG. **11**A to FIG. **11**C are perspective views that illustrate three examples of a thrust washer that can be applied in the rotation transmission device illustrated in FIG. **1**;

**[0056]** FIG. **12** is a cross-sectional view for explaining the torque transmission path in the rotation transmission device illustrated in FIG. **1**;

**[0057]** FIG. **13** is a view as seen from the outer-diameter side of the a portion in the circumferential direction of the first detected section and second detected section of the encoder in a rotation transmission device of a second example of an embodiment of the present invention;

**[0058]** FIG. **14** is an enlarged cross-sectional view of the area where the sensor unit faces the encoders in the rotation transmission device of the second example of an embodiment of the present invention;

**[0059]** FIG. **15**A is an end view of a first encoder, and FIG. **15**B is an end view of a second encoder of the rotation transmission device of a third example of an embodiment of the present invention;

**[0060]** FIG. **16** is an enlarged cross-sectional view of the area where the sensor unit faces the encoders in the rotation transmission device of the third example of an embodiment of the present invention, and illustrates a state in which the first encoder and second encoder are joined by pins;

**[0061]** FIG. **17** is a perspective view of a first encoder and a second encoder of a rotation transmission device of a fourth example of an embodiment of the present invention;

**[0062]** FIG. **18**A is an end view of a first encoder, and FIG. **18**B is an end view of a second encoder in a rotation transmission device of a fifth example of an embodiment of the present invention;

**[0063]** FIG. **19** is an enlarged cross-sectional view of a part in the circumferential direction of an involute spline engagement between a torsion bar and input shaft or output shaft in a rotation transmission device of a sixth example of an embodiment of the present invention;

**[0064]** FIG. **20** is an enlarged cross-sectional view of part in the circumferential direction of the involute spline engagement illustrated in FIG. **19**, and illustrates a state before providing a plating layer on the surface of the male involute spline section;

**[0065]** FIG. **21** is a graph illustrating the relationship between the sensor output and the transmitted torque in the rotation transmission device of the sixth example of an embodiment of the present invention;

**[0066]** FIG. **22** is an enlarged cross-sectional view of one end of a rotation transmission device of a seventh example of an embodiment of the present invention;

**[0067]** FIG. **23** is an enlarged perspective view of one end of a coupling shaft that is used in the seventh example of an embodiment of the present invention;

**[0068]** FIG. **24** is a cross-sectional view in the axial direction that illustrates a rotation transmission device together with the sensor of an eighth example of an embodiment of the present invention;

**[0069]** FIG. **25** is an enlarged cross-sectional view of the other end section of a rotation transmission device of a ninth example of an embodiment of the present invention;

**[0070]** FIG. **26** is an end view of the other end side of the rotation transmission device illustrated in FIG. **25**;

**[0071]** FIG. **27** is a cross-sectional view of section c-c in FIG. **25** of the rotation transmission device illustrated in FIG. **25**;

**[0072]** FIG. **28** is an exploded perspective view of the first encoder, the second encoder and the sensor unit of the rotation transmission device illustrated in FIG. **25**;

**[0073]** FIG. **29**A is a view of a part in the circumferential direction of the area where the sensor unit faces the encoders in the rotation transmission device illustrated in FIG. **25**, and illustrates a state in which torque is not transmitted; FIG. **29**B illustrates this part in a state in which torque is transmitted; and FIG. **29**C is a graph illustrating the output signals from the sensor unit of this device when torque is not transmitted and when torque is transmitted;

**[0074]** FIG. **30** is an enlarged vice of the other end section of a rotation transmission device of a tenth example of an embodiment of the present invention;

**[0075]** FIG. **31** is a view as seen from the outer-diameter side of an encoder of the rotation transmission device illustrated in FIG. **30**;

**[0076]** FIG. **32** is an end view of the other end section of the rotation transmission device illustrated in FIG. **30**, and illustrates a state in which the sensor unit is omitted;

**[0077]** FIG. **33** is an exploded perspective view of the encoders of the rotation transmission device illustrated in FIG. **30**, and illustrates a state in which the first encoder and second encoder are separated;

**[0078]** FIG. **34**A is a graph for the rotation transmission device of the tenth example of an embodiment of the present invention, and illustrates the output signal of the sensor unit when torque is not transmitted; and FIG. **34**B is a graph that illustrates the output signal of the sensor unit when torque is transmitted;

**[0079]** FIG. **35** is a graph for the rotation transmission device of the tenth example of an embodiment of the present invention, and illustrates the relationship between the duty ratio s of the output signal of the sensor and the torque;

**[0080]** FIG. **36** is an enlarged cross-sectional view that illustrates the other end section of a rotation transmission device of an eleventh example of an embodiment of the present invention;

**[0081]** FIG. **37** is an end view of the other end side of the rotation transmission device illustrated in FIG. **36**;

**[0082]** FIG. **38** is an exploded perspective view of the encoders of the rotation transmission device illustrated in FIG. **36**, and illustrates a state in which a first encoder and a second encoder are separated;

**[0083]** FIG. **39** is an enlarged cross-sectional view of the other end section of a rotation transmission device of a twelfth example of an embodiment of the present invention;

**[0084]** FIG. **40** is an end view of the other end side of the rotation transmission device illustrated in FIG. **39**;

**[0085]** FIG. **41**A is a schematic drawing illustrating the positional relationship between the magnetic poles of the first detected section and second detected section and the detecting section of the sensor in the area where the sensor unit faces the encoders in the rotation transmission device illustrated in FIG. **39** in a state in which torque is not transmitted; and FIG. **41**B illustrates that positional relationship in a state in which torque is transmitted;

**[0086]** FIG. **42** is a graph illustrating the output signal from the sensor unit of the rotation transmission device of the twelfth example of an embodiment of the present invention;

**[0087]** FIG. **43** is a cross-sectional view illustrating a rotation transmission device of a thirteenth example of an embodiment of the present invention;

**[0088]** FIG. **44** is a cross-sectional view illustrating a rotation transmission device of a fourteenth example of an embodiment of the present invention;

**[0089]** FIG. **45** is a cross-sectional view illustrating a rotation transmission device of a fifteenth example of an embodiment of the present invention;

**[0090]** FIG. **46** is a cross-sectional view illustrating a rotation transmission device of a sixteenth example of an embodiment of the present invention;

**[0091]** FIG. **47** is a cross-sectional view illustrating a rotation transmission device of a seventeenth example of an embodiment of the present invention;

**[0092]** FIG. **48** is an enlarged view illustrating the section where the end sections of the input shaft and output shaft of a rotation transmission device of an eighteenth example of the present invention are combined together;

**[0093]** FIG. **49** is an enlarged view illustrating the section where the end sections of the input shaft and output shaft of a rotation transmission device of a nineteenth example of the present invention are combined together;

**[0094]** FIG. **50** is a cross-sectional view illustrating the torsion bar of a rotation transmission device of a twentieth example of an embodiment of the present invention;

**[0095]** FIG. **51** is a cross-sectional view of a device that was used in testing that was performed for confirming the effect on the durability and precision of torque measurement for the rotation transmission device of the twentieth example of an embodiment of the present invention;

**[0096]** FIG. **52** is a cross-sectional view illustrating a rotation transmission device of a twenty-first example of an embodiment of the present invention;

**[0097]** FIG. **53** is a cross-sectional view illustrating a rotation transmission device of a twenty-second example of an embodiment of the present invention;

**[0098]** FIG. **54** is a cross-sectional view illustrating a rotation transmission device of a twenty-third example of an embodiment of the present invention;

**[0099]** FIG. **55** is a cross-sectional view illustrating a rotation transmission device of a twenty-fourth example of an embodiment of the present invention;

**[0100]** FIG. **56** is a cross-sectional view illustrating a rotation transmission device of a twenty-fifth example of an embodiment of the present invention;

**[0101]** FIG. **57** is an enlarged cross-sectional view of the other end section of the rotation transmission device illustrated in FIG. **56**;

**[0102]** FIG. **58** is an enlarged cross-sectional view illustrating one end section of a rotation transmission device of a twenty-sixth example of an embodiment of the present invention;

**[0103]** FIG. **59** is an enlarged cross-sectional view illustrating the other end section of a rotation transmission device of a twenty-seventh example of an embodiment of the present invention;

**[0104]** FIG. **60** is an end view of the other end section of the rotation transmission device illustrated in FIG. **59**;

**[0105]** FIG. **61** is an enlarged cross-sectional view illustrating the other end section of a rotation transmission device of a twenty-eighth example of an embodiment of the present invention;

**[0106]** FIG. **62** is a side view illustrating a rotation transmission device of a twenty-ninth example of an embodiment of the present invention;

**[0107]** FIG. **63** is a cross-sectional view of section d-d in FIG. **62** of the rotation transmission device illustrated in FIG. **62**;

**[0108]** FIG. **64** is a cross-sectional view of section e-e in FIG. **62** of the rotation transmission device illustrated in FIG. **62**;

**[0109]** FIG. **65** is a cross-sectional view of section f-f in FIG. **63** of the rotation transmission device illustrated in FIG. **62**;

**[0110]** FIG. **66** is a side view illustrating a torque measurement device of a first example of conventional construction; and

**[0111]** FIG. **67** is a side view illustrating a torque measurement device of a second example of conventional construction, and illustrates a state in which part is cut away.

## MODES FOR CARRYING OUT INVENTION

### First Example

**[0112]** FIG. **1** to FIG. **12** illustrate a first example of an embodiment of the present invention. The rotation transmission device of this example is incorporated and used with a counter shaft and counter gear portion of an automatic transmission for an automobile such as a front-wheel drive automobile or a four-wheel drive automobile that uses the same motor and transmission arrangement as a front-wheel drive automobile in which a so-called transverse engine is mounted. The rotation transmission device of this example includes: a rotary-shaft unit **6** that functions as a counter shaft; a first gear, which is an input gear **7**, and a second gear, which is an output gear **8**, that function as counter gears; a coupling shaft **9**, a first encoder **10**, a second encoder **11** and one sensor unit **12**.

**[0113]** The rotary-shaft unit **6** includes: an input shaft **13**, which is a hollow first rotary shaft; an output shaft **14**, which is a hollow second rotary shaft; and a hollow torsion bar **15**. Both the input shaft **13** and the output shaft **14** are formed into a cylindrical shape using steel, are arranged concentric with each other, and the end sections of the input shaft **13** and the output shaft **14** (the other end section of the input shaft **13** and the one end section of the output shaft **14**) are combined together so as to be able to rotate relative to each other. In order to simplify the explanation, the side of the rotary-shaft unit **6** where the input gear **7** and input shaft **13** are located is called the one end side, and the side where the output gear **8** and the output shaft **14** are located is cased the other end side. In this example, in order to combine the end sections of the input shaft **13** and the output shaft **14** together so as to be able to rotate relative to each other, an input-side combination cylindrical section **16**, which is a first combination cylindrical section, is provided on the other end section of the input shaft **13**, and an output-side combination cylindrical section **17**, having an inner diameter that is larger than the diameter of the input-side combination cylindrical section **16**, is provided on the one end section of the output shaft **14**. The input-side combination cylindrical section **16** is inserted into the inner-diameter side of the output-side combination cylindrical section **17**. Moreover, a radial needle bearing **18** is provided between the cylindrical shaped circumferential surfaces of the input-side and output side combination cylindrical sections **16**, **17** that face each other. Furthermore, a circular disk-shaped thrust washer **21**, which is a thrust sliding bearing, is held between a stepped surface **19** that is provided on the base end section of the outer-circumferential surface of the input-side combination cylindrical section **16** and the tip-end surface **20** of the output-side combination cylindrical section **17**. By using this kind of construction, the end sections of the input shaft **13** and the output shaft **14** are combined together in a state so that relative rotation is possible, and so that displacement in the axial direction toward each other is prevented.

**[0114]** In this example, in the thrust washer **21**, as illustrated in detail in FIG. **11**A, slits **22** that are long in the radial direction are formed by removing material at plural locations that are uniformly spaced in the circumferential direction of a circular disk-shaped main portion so as to be open on the inner-circumferential edge of the main portion. Moreover, a reinforcing cylindrical section **23** that is bent in the radial direction at a right angle from the outer-circumferential edge of the main portion of the thrust washer **21** is formed around the entire outer-circumferential edge. The thrust washer **21** is fitted around the base end section of the input-side combination cylindrical section **16** with the edge of the tip end of the reinforcing cylindrical section **23** facing the one end side of the input shaft **13** so that there is no large looseness in the radial direction. The middle section in the radial direction of the main portion of the thrust washer **21** is held between the stepped surface **19** and the tip-end surface **20**. In this state, the slits **22** connect a pair of spaces that exist on both sides in the radial direction of the portion between the stepped surface **19** and the tip-end surface **20** with each other. In other words, in order to achieve this kind of connected state, the diameter of the inscribed circle of the slits **22** (the inner diameter of the main portion of the thrust washer **21**) is made to be smaller than the diameter of the inner-circumferential edge of the tip-end surface **20**, and the diameter of the circumscribed circle of the slits **22** is made to be larger than the diameter of the outer-circumferential edge of the tip-end surface **20**.

**[0115]** The torsion bar **15** is formed into a cylindrical shape using a steel alloy such as carbon steel, and is concentrically arranged on the inner-diameter side of the input shaft **13** and output shaft **14**. One end section of the torsion bar **15** is connected to the input shaft **13** so that relative rotation is not possible, and the other end section is connected to the output shaft **14** so that relative rotation is not possible. In this example, in order to achieve this kind of connected state, the outer-diameter dimensions of both end sections of the torsion bar **15** are made to be a little less than the outer-diameter dimension of the middle section of the torsion bar **15**, and the outer-circumferential surfaces of both end sections of the torsion bar **15** fit with the portion near one end of the inner-circumferential surface of the input shaft **13** and with the portion near the other end of the inner-circumferential surface of the output shaft **14** so that relative rotation is not possible. More specifically, an involute spline connection **24***a* is formed by fitting a first male involute spline section **62**, which is a first male spline section that is provided on the outer-circumferential surface of one end section of the torsion bar **15**, with a first female involute spline section **63**, which is a first female spline section that is provided on the inner-circumferential surface of the one end section of the input shaft

**13** so that there is no looseness in the circumferential direction. Moreover, an involute spline connection **24***b* is formed by fitting a second male involute spline section **64**, which is a second male spline section that is provided on the outer-circumferential surface of the other end section of the torsion bar **15**, with a second female involute spline section **65**, which is a second female spline section that is provided on the inner-circumferential surface of the other end section of the input shaft **14** so that there is no looseness in the circumferential direction. It is also possible to use other construction for preventing rotation such as a key connection as the connections between the torsion bar **15** and the input shaft **13** and output shaft **14**. By holding the torsion bar **15** on both sides in the axial direction by a pair of retaining rings **25***a*, **25***b* that are fastened around the inner-circumferential surfaces of the input shaft **13** and output shaft **14**, the torsion bar **15** is prevented from displacing in the axial direction. In this example, the dimension L of the portion in the middle section in the axial direction of the torsion bar **15** that undergoes elastic torsional deformation when torque is transmitted (portion that is between the involute spline connections **24***a*, **24***b*) is made to be larger than the space W in the axial direction between the input gear **7** and output gear **8** (L>W) (in the example in the figures, L is a little over 4 times W).

**[0116]** The input gear **7** is a helical gear that is formed using a steel alloy such as carbon steel, and is fastened around the outside of the middle section of the input shaft **13**. The connection between the inner-circumferential surface of the input gear **7** and the outer-circumferential surface of the input shaft **13** is formed by arranging a cylindrical connecting section **26***a* that is for maintaining concentricity (connecting section that is formed by pressure fitting together the cylindrical surface sections of the inner-circumferential surface of the input gear **7** and outer-circumferential surface of the input shaft **13**) and an involute spline connection **24***c* that is for preventing relative rotation so as to be adjacent to each other in the axial direction. Moreover, positioning the input gear **7** in the axial direction with respect to the input shaft **13** is accomplished by bringing the inner-circumferential portion of the other end side of the input gear **7** in contact with a stepped surface **27** that is formed on a portion of the middle section of the outer-circumferential surface of the input shaft **13** that is near the other end. In this example, a parking-lock gear **28** is integrally formed with the inner-circumferential portion of the side surface of the other end side of the input gear **7**. When the parking lock is engaged, the tip-end section of a locking member (not illustrated in the figures) engages with a portion in the circumferential direction of the outer-circumferential surface of the parking-lock gear **28**, which makes rotation of the rotary-shaft unit **6** impossible. On the other hand, the output gear **8** is also a helical gear that is formed using a steel alloy such as carbon steel, and is integrally formed with the output shaft **14** in a portion near one end of the middle section of the outer-circumferential surface of the output shaft **14**. It is also possible to separately form the output gear **8** and fasten the output gear **8** around the outside of the output shaft **14**. In this example, when the rotary-shaft unit **6** is rotating in the forward direction (when the automobile is advancing in a forward direction), the torque that is inputted to the input shaft **13** from the input gear **7** is transmitted to the output shaft **14** by way of the torsion bar **15** and outputted from the output gear **8**. When this happens, the middle section in the axial direction of the torsion bar **15** undergoes elastic torsional deformation by an amount that corresponds to the size of the torque.

**[0117]** The rotary-shaft unit **6** is supported so as to be able to freely rotate with respect to a housing (transmission case) that is not illustrated in the figures by a pair of conical roller bearings **29***a*, **29***b* that are arranged such that the contact angles are opposite each other. In this example, in order to install these conical roller bearings **29***a*, **29***b* in the rotary-shaft unit **6**, an inner ring **30***a* of one of the conical roller bearings **29***a* is fitted around a portion near one end of the input shaft **13**. Moreover, a spacer **31** is held between the end surface on the large-diameter side of the inner ring **30***a* and the side surface of the one end side of the input gear **7**. Furthermore, the inner ring **30***a* and the input gear **7** are joined and fastened to the input shaft **13** by pressing the end surface on the small-diameter side of the inner ring **30** with a nut **32***a* that is tightly screwed onto and fastened to the one end section of the outer-circumferential surface of the input shaft **13**. On the other hand, an inner ring **30***b* of the other conical roller bearing **29***b* is fitted around the outside of a portion near the other end of the output shaft **14**. Moreover, the end surface on the large-diameter side of the inner ring **30***b* is brought into contact with a stepped surface **33** that is formed on a portion near the other end of the output shaft **14**. Furthermore, the inner ring **30***b* is fastened to and supported by the output shaft **14** by pressing the end surface on the small-diameter side of the inner ring **30***b* with a nut **32***b* that is tightly screwed onto and fastened to the other end section of the outer-circumferential surface of the output shaft **14**.

**[0118]** In this example, the direction of inclination of the teeth of the input gear **7** and output gear **8**, which are both helical gears, is regulated so that when these gears **7**, **8** are rotating in the forward direction (when the rotary-shaft unit **6** is rotating in the forward direction), the gear reaction forces in the axial direction that act on these gears **7**, **8** are in directions toward each other (press against each other). As a result, when these gears **7**, **8** are rotating in the forward direction, the gear reaction forces in that axial direction that act on the input gear **7** and output gear **8** are able to at least partially cancel each other out. With this kind of construction, the axial loads that are applied to the conical roller bearings **29***a*, **29***b* when these gears **7**, **8** are rotating in the forward direction are suppressed, and the friction loss (dynamic torque) of these bearings **29***a*, **29***b* is suppressed by that amount.

**[0119]** The coupling shaft **9** is concentrically arranged on the inner-diameter side of the torsion bar **15**. When one end section of the coupling shaft **9** is connected to the input shaft **13** so that relative rotation is not possible, the other end section of the coupling shaft **9** protrudes from an opening on the other end side of the output shaft **14**. In order to connect the one end section of the coupling shaft **9** to the input shaft **13** so that relative rotation is not possible, an outward-facing flange-shaped rim section **34** is formed around a portion of the outer-circumferential surface of the one end section of the coupling shaft **9** that protrudes from the opening on the one end side of the torsion bar **15**, and by forming an involute spline connection **24***d* between the outer-circumferential surface of the rim section **34** and the inner-circumferential surface of the input shaft **13**, the rim section **34** and the input shaft **13** fit together so that relative rotation is not possible. For this connection, it is also possible to use other construction for preventing rotation such as a key connection. Furthermore, by holding the rim section **34** on both sides in the axial direction using the retaining ring **25***a* that is fastened around

the inner-circumferential surface of the one end section of the input shaft **13** and another retaining ring **25***c*, the coupling shaft **9** is prevented from displacement in the axial direction. The first male involute spline section **62** of the involute spline connection **24***a* that is provided on the one end section of the torsion bar **15**, and a male involute spline section of an involute spline connection **24***d* that is provided on the rim section **34** of the coupling shaft **9** are provided so as to be connected together on the one end section of the inner-circumferential surface of the input shaft **13**, and the specifications of each are the same. In other words, the involute spline connections **24***a*, **24***d* share the first involute spline section **63** that is provided around the inner-circumferential surface of the one end section of the input shaft **13** as the female involute spline sections of these involute spline connections **24***a*, **24***d*.

**[0120]** The first encoder **10** is concentrically fastened around the outside of the other end section of the coupling shaft **9**. In other words, the first encoder **10** is fastened to and supported by the input shaft **13** via the coupling shaft **9**. Therefore, the first encoder **10** is able to rotate in synchronization with the input shaft **13**. Moreover, the second encoder **11** is concentrically fastened around the outside of the other end section of the output shaft **14**. Therefore, the second encoder **11** is able to rotate in synchronization with the output shaft **14**. The first encoder **10** includes a circular ring-shaped metal core **35** that is made of a magnetic metal and that is fastened around the outside of the other end section of the coupling shaft **9**, and a cylindrical permanent magnet **37** that is fastened around the outer-circumferential surface of a cylindrical section that is located on the outer-circumferential section of the metal core **35**. The second encoder **11** also includes a circular ring-shaped metal core **36** that is made of a magnetic metal and that is fastened around the outside of the other end section of the output shaft **14**, and a cylindrical permanent magnet **38** that is fastened around the outer-circumferential surface of a cylindrical section that is located on the outer-circumferential section of the metal core **36**.

**[0121]** The outer-circumferential surface of the permanent magnet **37** of the first encoder **10** functions as a first detected section **39**, and the outer-circumferential surface of the permanent magnet **38** of the second encoder **11** functions as a second detected section **40**. The first and second detected sections **39**, **40** have the same diameter as each other, are concentric with each other, and are arranged so as to be closely adjacent to each other in the axial direction; for example, are separated in the axial direction by 10 mm or less, and preferably 5 mm or less. Moreover, as illustrated in FIG. **9**, the S poles and N poles of the detected sections **39**, **40** are arranged on these detected sections **39**, **40** so as to alternate at a uniform pitch in the circumferential direction. The total number of magnetic poles (S poles and N poles) is the same for both of these detected sections **39**, **40**. In this example, when torque is not being transmitted, or in other words, when the torsion bar **15** is not in a state of elastic torsional deformation, the detected sections **39**, **40** have not rotated relative to each other in the direction of rotation, and the phases in the circumferential direction of the magnetic poles of the detected sections **39**, **40** coincide with each other. In other words, the poles are arranged so that poles of these detected sections **39**, **40** that are the same as each other are adjacent to each other in the axial direction. In this example, the fitted section where the inner-circumferential surface of the metal core **35** of the first encoder **10** fits with the outer-circumferential surface of the other end section of the coupling shaft **9** is formed by arranging a cylindrical fitting section **26***b* for maintaining concentricity, and an involute spline connection **24***e* for preventing relative rotation so as to be adjacent in the axial direction. Furthermore, the metal core **35** is prevented from coming out by a retaining ring **25***d* that is fastened around the outer-circumferential surface of the other end section of the coupling shaft **9**. On the other hand, the metal core **36** of the second encoder **11** is fastened around the outside of the other end section of the output shaft **14** by an interference fit.

**[0122]** The sensor unit **12** includes a holder **41** made of a synthetic resin, and a first sensor **42***a* and second sensor **42***b* that are embedded in the tip-end section of the holder **41**. A magnetic detecting element such as a Hall element, Hall IC, MR element, GNR element or the like is embedded in the detecting sections of the first and second sensors **42***a*, **42***b*. The sensor unit **12** is supported by a housing so that the detecting section of the first sensor **42***a* closely faces the first detected section **39**, and the detecting section of the second sensor **42***b* closely faces the second detected section **40**. In this example, as illustrated in FIG. **10**, the first and second sensors **42***a*, **42***b* are arranged in opposite directions, and the detecting sections of the first and second sensors **42***a*, **42***b* face the same position in the circumferential direction of detected sections **39**, **40**. As a result, when the transmitted torque is in a rotated state of zero, the phase difference between the output signals of the sensors **42***a*, **42***b* is 180 degrees (the phase difference ratio is 0.5).

**[0123]** Moreover, in this example, an oil inlet passage **43** that is open on only the one end surface of the coupling shaft **9** is provided in the center section in the radial direction of the coupling shaft **9**. Furthermore, oil passages **44***a*, **44***b* are provided in portions near both ends of the coupling shaft **9**, torsion bar **15**, input shaft **15** and output shaft **14**. These oil passages **44***a*, **44***b* connect the portions near both ends of the oil inlet passage **43** with minute ring-shaped spaces **45***a*, **45***b* that are located on the inner-diameter side of the small-diameter end sections of the inner rings **30***a*, **30***b* of the conical roller bearings **29***a*, **29***b*. Furthermore, oil grooves **46***a*, **46***b* that extend in the radial direction are formed at one location or plural locations in the circumferential direction of the tip-end surfaces of the nuts **32***a*, **32***b*. With this kind of construction, lubrication oil that is introduced from the opening on the one end section of the oil inlet passage **43** can pass through the oil passages **44***a*, **44***b*, ring-shaped spaces **45***a*, **45***b* and oil grooves **46***a*, **46***b* and be supplied to the inside of the conical roller bearings **29***a*, **29***b*.

**[0124]** In this example, part of the lubrication oil that is fed into the oil passages **44***a*, **44***b* passes from the middle sections of these oil passages **44***a*, **44***b* through spaces that exist in the involute spline connections **24***a*, **24***b*, and then fed to the outer-circumferential surface of the middle section of the torsion bar **15** and to the inside of a cylindrical space **47** that exists between the inner-circumferential surfaces of the middle sections of input shaft **13** and output shaft **14**. Then, the lubrication oil that is fed inside the cylindrical space **47** passes through the space that exists between the tip-end surface **48** of the input-side combination cylindrical section **16** and a stepped surface **49** that exists at the base-end section of the inner-circumferential surface of the output-side combination cylindrical section **17**, and is supplied to the area where the radial needle bearing **18** is installed and the area where the thrust washer **21** is held so as to lubricate these portions. The lubrication oil that reaches the area where the thrust washer

**21** is held provides lubrication to this area where the thrust washer **21** is held, and also smoothly passes through this area where the thrust washer **21** is held by passing through the plural slits **22** that are provided in the thrust waster **21**. As a result, the supply of lubrication oil to the area where the radial needle bearing **18** is installed and the area where the thrust washer **21** is held is performed efficiently, and the lubricated state of the area where the radial needle bearing **18** is installed and the area where the thrust washer **21** is held becomes good.

**[0125]** Instead of the thrust washer **21** that is illustrated in FIG. **11**A, it is also possible to use a thrust washer **21***a* such as illustrated in FIG. **11**B in which the reinforcing cylindrical section on the outer circumference is omitted, or a simple circular disk-shaped thrust washer **21** such as illustrated in FIG. **11**C in which the reinforcing cylindrical section on the outer circumference and the plural slits are omitted. However, as explained above, from the aspect of improving the lubricated state of the area where the radial needle bearing is installed and the area where the thrust washer is held, preferably a thrust washer **21**, **21***a* having slits **22** such as illustrated in FIG. **11**A and FIG. **11**B is preferred, and furthermore, from the aspect of maintaining the strength of the outer-circumferential section of the thrust washer (particularly the peripheral edge of the slits **22**), using a thrust washer **21** having a reinforcing cylindrical section **23** as illustrated in FIG. **11**A is preferred.

**[0126]** In this example, lubrication oil is also fed from the center section of the oil passages **44***a*, **44***b* into the inside of a minute space that exists between the inner-circumferential surface of the torsion bar **15** and the outer-circumferential surface of the coupling shaft **9** (cylindrical space having a thickness in the radial direction of about 0.2 mm). In order that feeding lubrication oil to the inside of this kind of minute space is performed smoothly, concave grooves **66***a*, **66***b* are provided around the entire circumference of the portion of the outer-circumferential surface of the coupling shaft **9** that is aligned in the axial direction with the oil passages **44***a*, **44***b*. During operation, the lubrication oil that is filled into a minute space that exists between the inner-circumferential surface of the torsion bar **15** and the outer-circumferential surface of the coupling shaft **9** functions as a film damper that dampens small vibration of the coupling shaft **9**.

**[0127]** In the case of the rotation transmission device with a torque measurement device of this example, the output signals from the first and second sensors **42***a*, **42***b* of the sensor unit **12** change periodically as the first and second encoders **10**, **11** rotate together with the input shaft **13** and output shaft **14** of the rotary-shaft unit **6**. Here, the frequency and period of this change are values that correspond to the rotational speed of the rotary-shaft unit **6**. Therefore, by investigating beforehand the relationship between the frequency or period of the output signal from the first and second sensors **42***a*, **42***b* and the rotational speed, it is possible to find the rotational speed based on the frequency or period of these output signals. Moreover, in this example, when the rotary-shaft unit **6** transmits torque between the input gear **7** and output gear **8**, the input gear **7** (input shaft **13**, first encoder **10**) and the output gear **8** (output shaft **14**, second encoder **11**) undergo relative displacement in the direction of rotation as the middle section in the axial direction of the torsion bar **15** undergoes elastic torsional deformation. As a result of the relative displacement in the direction of rotation of the first and second encoders **10**, **11**, the phase difference ratio (=phase difference/1 period) between the output signals from the first and second sensors **42***a*, **42***b* changes. Here, this phase difference ratio is a value that corresponds to the torque that is transmitted by the rotation transmission device. Therefore, by investigating beforehand the relationship between the phase difference ratio of the output signals from the first and second sensors **42***a*, **42***b* and the torque of the rotation transmission device, it is possible to find the torque that is transmitted by the rotation transmission device based on this phase difference ratio.

**[0128]** In this example, the shaft is divided into two, an input shaft **13** and an output shaft **14**; the input gear **7** is fastened around the middle section in the axial direction of the outer-circumferential surface of the input shaft **13**, and the output gear **8** is fastened around the middle section in the axial direction of the outer-circumferential surface of the output shaft **14**; and both the input shaft **13** and output shaft **14** have hollow construction. Moreover, a torsion bar **15** that is connected to the input shaft **13** and the output shaft **14** so that both end sections are not capable of relative rotation is arranged on the inner-diameter side of the input shaft **13** and output shaft **14**, and furthermore, a coupling shaft **9** that supports a first encoder **10** on the other end section is arranged on the inner-diameter side of the torsion bar **15**. In other words, the rotation transmission device with a torque measurement device has a triple structure that includes an input shaft **13** and output shaft **14**, a torsion bar **15** and a coupling shaft **9**. In the case of the rotation transmission device of this example having this kind of construction, torque that is inputted from the input gear **7** is transmitted to the output gear **8** along a path such as illustrated by the arrow in FIG. **12** (input gear **7**→involute spline connection **24***c*→input shaft **13**→involute spline connection **24***a*→torsion bar **15**→involute spline connection **24***b*→output shaft **14**→output gear **8**).

**[0129]** Therefore, in this example, the dimension L in the axial direction of the middle section in the axial direction of the torsion bar **15** is sufficiently longer than the space W between the input gear **7** and the output gear **8** (L>W). Therefore, it is possible to sufficiently maintain the amount of elastic torsional deformation of the middle section in the axial direction of the torsion bar **15** that occurs when transmitting torque. As a result, differing from construction in which the rotary-shaft unit **6** has only a single rotary shaft, it is possible to sufficiently increase the resolution of torque measurement by sufficiently increasing the amount of relative displacement in the direction of rotation between the input gear **7** (input shaft **13**, first encoder **10**) and the output gear **8** (output shaft **14**, second encoder **11**) that occurs during the transmission of torque regardless of whether the space W in the axial direction between the input gear **7** and the output gear **8** is large or small. Moreover, in this example, by adjusting the dimension in the radial direction and dimension in the axial direction of the middle section in the axial direction of the torsion bar **15** during the design stage, it is possible to easily adjust the torsional rigidity of this middle section in the axial direction. Therefore, when compared with construction in which the rotary-shaft unit **6** has only a single rotary shaft, the relationship between the torque that is transmitted by the rotation transmission device and the amount of relative displacement in the direction of rotation of the first and second encoders **10**, **11** (gain) can be easily designed to obtain a desired value.

**[0130]** Moreover, in this example, the sensor unit **12** is a single unit, so it is possible to run only one harness (not illustrated in the figures) from the sensor unit **12**, so it is possible to easily install the required harness. In addition,

only one area inside the housing is needed for supporting and fastening the sensor unit **12**, so processing of the housing is simplified.

**[0131]** Furthermore, in this example, when transmitting torque, it is possible to maintain the precision of torque measurement by the sensor unit **12** regardless of deformation (elastic deformation) of the housing due to gear reaction forces in the radial direction that act on the input gear **7** and output gear **8**. In other words, in this example, the first and second encoders **10**, **11** are arranged so as to be concentrated on the other end side of the output shaft **14**, so the sensor unit **12** can be supported by a portion of the housing that is near the end section with high rigidity. Therefore, even when the housing is deformed due to gear reaction forces, contact between the sensor unit **12** and the first and second encoders **10**, **11** is prevented. Consequently, it is possible to reduce the space between the first detected section **39** of the first encoder **10** and the detected section **40** of the second encoder **11**, and to improve the precision of torque measurement.

**[0132]** Moreover, in this example, when transmitting torque, it is possible to prevent stress that is due to gear reaction forces in the radial direction that act on the input gear **7** and output gear **8** from becoming concentrated in the torsion bar **15**. In other words, the rotary-shaft unit **6** is constructed by combining an input-side combination cylindrical section **16** of the input shaft **13** and an output-side combination cylindrical section **17** of the output shaft **14** together by way of a radial needle bearing **18** and a thrust washer **21**, so gear reaction forces are mainly applied to the connection between the input-side combination cylindrical section **16** and the output-side combination cylindrical section **17**, and supported by the radial needle bearing **18** and thrust washer **21**. As a result, the gear reaction forces are prevented from becoming concentrated in the torsion bar **15**.

**[0133]** In the rotation transmission device of this example, it is also possible to use construction in which the direction that the detected sections of the first and second encoders face the detecting sections of the pair of sensors of the sensor unit is changed from the radial direction to the axial direction. In that case, the detected sections of the first and second encoders are a pair of circular disk-shaped detected sections having radial dimensions that differ from each other, and these detected sections are arranged so as to be concentric with each other when facing in the same axial direction (overlap in the radial direction), and the detecting sections of the pair of sensors of the sensor unit that are arranged so as to be separated in the radial direction of the rotary-shaft unit are made to face these detected sections in the axial direction.

## Second Example

**[0134]** FIG. **13** and FIG. **14** illustrate a second example of an embodiment of the present invention. In this example, when torque is not being transmitted, the phases in the circumferential direction of the magnetic poles of the detected sections **39**, **40** of the first and second encoders **10**, **11** are shifted 180 degrees from each other. In other words, poles of these detected sections **39**, **40** that are different from each other are arranged so as to be adjacent to each other in the axial direction. Moreover, when the pair of sensors **42***a*, **42***b* of the sensor unit **12** are arranged so that each faces in the same direction, the detecting sections of these sensors **42***a*, **42***b* face the same position in the circumferential direction of the detected sections **39**, **40**. As a result, when the transmitted torque is in a rotated state of zero, the phase difference between the output signals of the sensors **42***a*, **42***b* is 180 degrees (the phase difference ratio is 0.5).

**[0135]** In this example, in the state before installing the first and second encoders **10**, **11** in the locations where the encoders **10**, **11** will be used, and the end surfaces in the axial direction of the permanent magnets **37**, **38** of these encoders **10**, **11** that face each other are magnetically stuck together, and as a result, the phase in the circumferential direction of the magnetic poles of these encoders **10**, **11** are shifted 180 degrees from each other. By installing these encoders **10**, **11** in this state, a positional arrangement of the magnetic poles after installation such as illustrated in FIG. **13** is easily achieved. The other construction and functions are the same as in the first example of an embodiment.

## Third Example

**[0136]** FIG. **15**A, FIG. **15**B and FIG. **16** illustrate a third example of an embodiment of the present invention. In this example, as illustrated in FIG. **15**A, two through holes **67***a*, **67***b*, which are both regulating parts, are provided in the metal core **35***b* of the first encoder **10***f* and are separated in the circumferential direction. Moreover, as illustrated in FIG. **15**B, one concave hole **68**, which is a regulating part, is provided in the metal core **36***b* of the second encoder **11***f*. When the center axes of these encoders **10***f*, **11***f* coincide with each other, the positions in the radial direction of the through holes **67***a*, **67***b* and the convex hole **68** are the same as each other. Moreover, the pitch of these through holes **67***a*, **67***b* (distance in the circumferential direction between centers) is the same as the pitch of one magnetization (distance in the circumferential direction between centers of an S pole and N pole that are adjacent in the circumferential direction) of the encoders **10***f*, **11***f*.

**[0137]** In this example, when magnetizing the encoders **10***f*, **11***f* in the manufacturing stage, the center axes of these encoders **10***f*, **11***f* are made to coincide with each other, and a pin **69** is passed through or inserted into one of the through holes **67***a*, **67***b* and into the concave hole **68** as a regulating member so that there is no looseness. As a result the encoders **10***f*, **11***f* can be positioned in the circumferential direction. In this state, S poles and N poles are simultaneously magnetized on the detected sections **39**, **40** of the encoders **10***f*, **11***f* so that the phases in the circumferential direction are the same as each other, and so as to alternate in the circumferential direction at a uniform pitch.

**[0138]** When installing the magnetized encoders **10***f*, **11***f* in the location of use with a positional relationship as illustrated in FIG. **9**, the pin **69** passes through one of the through holes **67***a*, **67***b* and is inserted into the concave hole **68** positions the encoders **10***f*, **11***f* in the circumferential direction, and these encoders **10***f*, **11***f* are then installed in the location of use. On the other hand, when installing the encoders **10***f*, **11***f* in the location of use with a positional relationship as illustrated in FIG. **13**, the through hole of the encoder **10***f* though which the pin **69** is passed is changed from the one though hole of the through holes **67***a*, **67***b* to the other through hole, and then with the relative positional relation in the circumferential direction of the encoders **10***f*, **11***f* shifted an amount of the pitch of one magnetization from the positional relationship at the time of magnetization, the encoders **10***f*, **11***f* are installed and fastened in the location of use, after which the pin **69** is removed from the through hole **67***a* or **67***b* and the concave hole **68**.

**[0139]** By installing the encoders **10***f*, **11***f* in this way, the work of installing these encoders **10***f*, **11***f* in the location of use can be performed easily and accurately. Instead of the concave hole **68**, it is possible to provide a through hole through which the pin **69** can be passed though with no looseness. The other construction and functions are the same as those of the first and second examples of embodiments.

Fourth Example

**[0140]** FIG. **17**A and FIG. **17**B illustrate a fourth example of an embodiment of the present invention. In this example, a pair of concave sections **70***a*, **70***b*, which are regulating sections, are provided in one end surface in the axial direction (the end surface on the second encoder **11***g* side) of the permanent magnet **37***b* of the first encoder **10***g* so as to be separated in the circumferential direction. Moreover, one convex section **71**, which is a regulating section, is provided on one end surface in the axial direction (end surface on the first encoder **10***g* side) of the permanent magnet **38***b* of the second encoder **11***g*. The pitch of the concave sections **70***a*, **70***b* is equal to the pitch of one magnetization of the encoders **10***g*, **11***g*.

**[0141]** In this example, when magnetizing the encoders **10***g*, **11***g* in the manufacturing stage, the ends in the axial direction of the permanent magnets **37***b*, **38***b* of the encoders **10***g*, **11***g* are placed against each other, and by fitting one of the concave sections **70***a*, **70***b* with the convex section **71**, the encoders **10***g*, **11***g* are positioned in the circumferential direction. In this state, the detected sections **39**, **40** of the encoders **10***g*, **11***g* are simultaneously magnetized so that the S poles and N poles are in the same phase in the circumferential direction, and so as to alternate at a uniform pitch in the circumferential direction.

**[0142]** When installing the encoders **10***g*, **11***g* in the location of use with a positional relationship such as illustrated in FIG. **9**, one of the concave sections **70***a*, **70***b* is fitted with the convex section **71**, which positions the encoders **10***g*, **11***g* in the circumferential direction, and then the encoders **10***g*, **11***g* are installed in the location of use. On the other hand, when installing the encoders **10***g*, **11***g* in the location of use with a positional relationship such as illustrated in FIG. **13**, one of the end surfaces in the axial direction of the permanent magnets **37***b*, **38***b* of the encoders **10***g*, **11***g* are placed together, and by fitting the other concave section of the concave sections **70***a*, **70***b* with the convex section **71** as illustrated in FIG. **17**B, the encoders **10***g*, **11***g* are positioned in the circumferential direction, and then the encoders **10***g*, **11***g* are installed in the location of use. As a result, the work of installing the encoders **10***g*, **11***g* in the location of use can be performed easily and accurately. The other construction and functions are the same as in the first and second examples of embodiments.

Fifth Example

**[0143]** FIG. **18** illustrates a fifth example of an embodiment of the present invention. In this example, a pair of markings **72***a*, **72***b*, **73***a*, **73***b* such as concave sections or convex sections, which are regulating sections, are provided on the other end surface in the axial direction (end surface on the side opposite from the second encoder **11***h*) of the permanent magnet of the first encoder **10***h*, and on the one end surface in the axial direction (end surface on the first encoder **10***h* side) so as to be separated in the circumferential direction. The positions in the circumferential direction of the marking **72***a*, **72***b* that are provided on the first encoder **10***h* coincide with the positions in the circumferential direction of two magnetization boundaries (boundaries between S pole and N pole) that are adjacent in the circumferential direction of the detected section **39** of the first encoder **10***h*. Moreover, the positions in the circumferential direction of the marking **73***a*, **73***b* that are provided on the second encoder **11***h* coincide with the positions in the circumferential direction of two magnetization boundaries that are adjacent in the circumferential direction of the detected section **40** of the second encoder **11***h*.

**[0144]** In this example, the work of installing the encoders **10***h*, **11***h* in the location of use is performed in the assembled state, making sure that the positions in the circumferential direction of both the markings **72***a*, **72***b* and the markings **73***a*, **73***b* coincide, or so that the positions in the circumferential direction of the marking **72***a* and the marking **73***b* (or the marking **72***b* and the marking **73***a*) coincide. As a result, the work of installing the encoders **10***h*, **11***h* in the location of use can be performed easily and accurately. The other construction and functions are the same as those of the first and second examples of embodiments.

Sixth Example

**[0145]** FIG. **19** to FIG. **21** illustrate a sixth example of an embodiment of the present invention. In this example, a first plating layer **74** is provided on the surface layer of a first male involute spline section **62***a* that is provided on the outer-circumferential surface of the one end of the torsion bar **15***b*, and a second plating layer **75** is provided on the surface layer of a second male involute spline section **64***a* that is provided on the outer-circumferential surface of the other end section of the torsion bar **15***b*. The first and second plating layers **74**, **75** are formed using a metal such as copper or nickel that are softer than the steel alloy such as carbon steel of the torsion bar **15**, input shaft **13** and output shaft **14** (see FIG. **6**). The first male involute spline section **62***a* (second male involute spline section **64***a*) is press fitted into a first female involute spline section **63***a* that is provided on the inner-circumferential surface of the input shaft **13** (second female involute spline section **65***a* that is provided on the inner-circumferential surface of the output shaft **14**) so that the interference is less than the thickness dimension in the free state of first plating layer **74** (second plating layer **75**). As a result, an involute spline connection **24***a***1** (involute spline connection **24***b***1**) can be formed by fitting the first male involute spline section **62***a* (second male involute spline section **64***a*) with the first female involute spline section **63***a* (second female involute spline section **65***a*) so that there is no looseness in the circumferential direction. In this example, by the first plating layer **74** (second plating layer **75**) being crushed between the teeth surfaces of the first male involute spline section **62***a* (second male involute spline section **64***a*) and the first female involute spline section **63***a* (second female involute spline section **65***a*), a function of eliminating looseness in the in the circumferential direction of the involute spline connection **24***a***1** (involute spline connection **24***b***1**) is achieved. On the other hand, a space remains between the tip of the tooth and bottom of the tooth of the first male involute spline section **62***a* (second male involute spline section **64***a*) and the first female involute spline section **63***a* (second female involute spline section **65***a*), and these spaces function as passages for lubrication oil.

**[0146]** In this example, in order to set the interference described above, the thickness dimension T in the free state of the first plating layer **74** (second plating layer **75**) is greater than the space t between the teeth surfaces in the state before forming the first plating layer **74** (second plating layer **75**) on the first male involute spline section **62***a* (second male involute spline section **64***a*) illustrated in FIG. **20** (T>t). In the state illustrated in FIG. **20**, this space t can be found as t=d·sin θ (θ: angle of the tooth surface with respect to the radial line that is set in the design) based on the measurement of 2d, which is the amount that the first male involute spline section **62***a* (second male involute spline section **64***a*) and first female involute spline section **63***a* (second female involute spline section **65**) can move relative to each other in the radial direction. This space t can also be found by measurement using a conventionally known measurement pin or by using some other method.

**[0147]** In this example as well, the involute spline connections **24***a***1**, **24***b***1** are connections in which there is no looseness in the circumferential direction. Therefore, when the direction of rotation of the input shaft **3**, which is the rotary shaft on the side where torque is inputted, rotates in the reverse direction, it is possible to prevent relative rotation in the space in the circumferential direction in the involute spline connections **24***a***1**, **24***b***1** that is the cause of looseness. In other words, when the direction of rotation of the input shaft **13** is in the reverse direction and relative rotation occurs in the involute spline connections **24***a***1**, **24***b***1** in the spaces in the circumferential direction, relative rotation also occurs between the first and second encoders **10**, **11**. As a result, as illustrated by the dashed line β in FIG. **21**, the characteristic curve that expresses the relationship between the sensor output and the torque suddenly changes and is non-linear when the torque=0 and near 0, so it becomes difficult to accurately measure minute torque. On the other hand, in this example, when the direction of rotation of the input shaft **13** is reversed, the occurrence of relative rotation in the spaces in the involute spline connections **24***a***1**, **24***b***1** that are the cause of looseness is prevented. The occurrence of relative rotation between the first and second encoders **10**, **11** is also prevented. As a result, as illustrated by the solid line a in FIG. **21**, linearity of the characteristic curve that expresses the relationship between the sensor output and the torque is maintained overall, and so it is possible to accurately measure minute torque.

**[0148]** In this example, when press fitting the first and second male involute spline sections **62***a*, **64***a* into the first and second female involute spline sections **63***a*, **65***a*, a large portion of the deformation (elastic deformation or plastic deformation) of the interference area occurs in the first and second plating layers **74**, **75** that are relatively soft. Therefore, the spaces in the circumferential direction that are the cause of looseness in the involute spline connections **24***a***1**, **24***b***1** can be effectively filled in by the first and second plating layers **74**, **75**. Moreover, deformation of the copper or nickel of the first and second plating layers **74**, **75** occurs at a smaller force than the deformation of the steel of the main portion of the involute spline sections **62***a*, **64***a*, **63***a*, **65***a*, so it is possible to keep the force required for performing a press fit low. Moreover, in this example, metal such as copper, nickel or the like that has suitable crushing characteristics and rigidity is used as the metal of the first and second plating layers **74**, **75**, so even when used over a long period of time, it is possible to make it difficult for spaces to occur between the plating layers **74**, **75** and the teeth surfaces of the female involute spline sections **63***a*, **65***a*. In addition to the involute spline connections **24***a***1**, **24***b***1**, it is also possible to apply construction for eliminating looseness in the circumferential direction by using a suitable and relatively soft plating layer in the involute spline connections **24***c* to **24***e* (se FIG. **6**). Moreover, in applications in which it is not necessary to measure minute torque, it is also possible to use connections having a little looseness in the circumferential direction for any of the involute spline connections **24***a* to **24***e* (see FIG. **6**) without applying the construction of this example, and that construction is also within the scope of the present invention. The other construction and functions are the same as those of the first through fifth examples of embodiments.

## Seventh Example

**[0149]** FIG. **22** and FIG. **23** illustrate a seventh example of an embodiment of the present invention. In this example, a rim section **34***a* that is provided on one end section of the coupling shaft **9***b* is fastened around the inside of the one end section of the input shaft **13***a* with an interference fit. More specifically, the outer-circumferential surface of the rim section **34***a* is taken to be a cylindrical surface **76**, and that cylindrical surface **76** is fitted around a cylindrical surface **77** that is provided on the inner-circumferential surface of the other end section of the input shaft **13***a* with an interference fit. With this kind of construction, it is possible to simplify the construction of the portion where the one end section of the coupling shaft **9***b* is connected to the input shaft **13***a* so that relative rotation is not possible, and thus manufacturing cost can be suppressed by that amount. The other construction and functions are the same as those of the first through sixth examples of embodiments.

## Eighth Example

**[0150]** FIG. **24** illustrates an eighth example of an embodiment of the present invention. In this example, of the pair of conical roller bearings **29***c*, **29***d* that support the rotary-shaft unit **6***b* so as to be able to freely rotate with respect to the housing, the inner ring **30***c* of one of the conical roller bearings **29***c* is made so as to be integrated with the input shaft **13***b*, and the inner ring **30***d* of the other conical roller bearing **29***d* is made so as to be integrated with the output shaft **14***a*. As a result, the nuts **32***a*, **32***b* for preventing the inner rings **30***c*, **30***d* from coming out (see FIG. **6**) are eliminated. Moreover, the dimension of the inner diameter of the input gear **7** that is fastened around the outside of the input shaft **13***b* is made to be larger than the dimension of the outer diameter of the inner ring **30***c*. As a result, when installing the input gear **7** onto or removing the input gear **7** from the input shaft **13***b*, the input gear **7** can pass in the axial direction over the inner ring **30***c*. In this example, separate inner rings **30***c*, **30***d*, and nuts **32***a*, **32***b* are eliminated, so it is possible to reduce the number of parts and assembly steps, simplify construction, make construction more compact and lightweight, and reduce manufacturing costs, and it is possible to improve the strength of the rim sections of the inner rings **30***c*, **30***d*, and improve the freedom of placement of the conical roller bearings **29***c*, **29***d*. The other construction and functions are the same as those of the first through seventh examples of embodiments.

## Ninth Example

**[0151]** FIG. **25** to FIG. **29** illustrate a ninth example of an embodiment of the present invention. In this example, the first

encoder **10***a* that is fastened around the outside of the other end section of the coupling shaft **9** is formed into a complete ring shape having an L-shaped cross section using a magnetic metal, and the outer circumference of the first encoder **10***a* functions as a flat gear shaped first detected section **39***a*. In other words, the first detected section **39***a* is constructed so that plural convex sections **50** that protrude to the outer-diameter side from the portion near the outer circumference of the first encoder **10***a* are arranged at a uniform pitch in the circumferential direction. In this example, of the first detected section **39***a*, the convex sections correspond to solid sections, and portions between convex sections **50** that are adjacent in the circumferential direction correspond to sections where material has been removed.

**[0152]** Moreover, the second encoder **11***a* that is fastened around the outside of the other end section of the output shaft **14** is formed into a complete cylindrical shape using magnetic metal plate, and the tip half section that protrudes in the axial direction from the other end surface of the output shaft **14** functions as a comb shaped second detected section **40***a*. In other words, the second detected section **40***a* is constructed so that plural tongue pieces **51** that extend in the axial direction toward the tip end side from the middle section in the axial direction of the second encoder **11***a* are arranged at a uniform pitch in the circumferential direction. The total number of these tongue pieces **51** is the same as the total number of convex section **50**. Moreover, the width in the circumferential direction that is expressed by the center angle of these tongue pieces **51** is equal to the width in the circumferential direction that is expressed by the center angle of the convex sections **50**. In this example, of the second detection section, the tongue pieces **51** correspond to solid sections, and the spaces between tongue pieces that are adjacent in the circumferential direction correspond to sections with material removed.

**[0153]** In this example, with the inner-circumferential surface of the second detected section **40***a* closely facing the outer-circumferential surface of the first detected section **39***a*, the first and second detected sections **39***a*, **40***a* are arranged so as to be concentric with each other, or in other words, so as to overlap in the radial direction. Moreover, when torque is not being transmitted, or in other words, when the torsion bar **15** has not undergone elastic torsional deformation, and the detected sections **39***a*, **40***a* have not undergone relative displacement in the direction of rotation, the phases in the circumferential direction of the convex sections **50** and the tongue pieces **51** coincide with each other.

**[0154]** Furthermore, the sensor unit **12***a* is formed into a complete circular ring shape, and concentrically arranged around the outer-diameter side of the first and second detected sections **39***a*, **40***a*. The sensor unit **12***a* includes a stator **52** made of a magnetic material, and plural coils **54** that are formed using one conducting wire **53**. The stator **52** includes plural core sections **55** that are long in the radial direction, and a circular ring-shaped rim section **56** that connects the base-end sections, on the outer-diameter side of the core sections **55**. The total number of core sections **55** is the same as the total number of convex sections **50** and tongue pieces **51**. Moreover, the width in the circumferential direction that is expressed by the center angle of the tip-end surfaces on the inner-diameter side of the core sections **55** is equal to the width in the circumferential direction of the tongue pieces **51** (width in the circumferential direction of the convex sections **50**). In this example, the end surfaces on the inner-diameter side of such core sections **55** are made to closely face the outer-circumferential surface of the second detected section **40***a*. Moreover, the coils **54**, together with being wound around the core sections **55**, are such that the winding directions of coils that are adjacent to each other in the circumferential direction are opposite each other. Therefore, in this example, the total number of coils **54** is an even number (**10** coils **54** in the example in the figures), and the total number of convex sections **50** and tongue pieces is also an even number.

**[0155]** In this example, the coils **54** have both a driving function for generating a magnetic field, and a detection function for detecting change in the magnetic field. In other words, by applying a driving voltage to the coils **54** (conducting wire **53**), a driving current flows through these coils **54**, and between coils **54** that are adjacent in the circumferential direction, a loop-shaped magnetic fluxes such as illustrated by the bold arrow lines in FIG. **27** flow inside the stator **52** and first and second encoders **10***a*, **11***a*. In this state, when the first and second encoders **10***a*, **11***a* rotate together with the rotary-shaft unit **6**, the density of the loop-shaped magnetic flux periodically changes, and as this occurs, a periodic induced current flows in the coils **54**. As a result, the output of the conducting wire **53**, which is the output of the sensor unit **12***a*, and more specifically, the voltage and current (when the driving voltage is an alternating-current voltage, the peak values or effective values of these) periodically change as illustrated in FIG. **29**C. Here, the frequency (and period) of this output is a value that corresponds to the rotational speed of the rotary-shaft unit **6**. Therefore, by investigating the relationship between the frequency (or period) of this output and the rotational speed, it is possible to find the rotational speed based on this frequency (or period).

**[0156]** In this example, when torque is being transmitted, the encoders **10***a*, **11***a* displace relative to each other in the direction of rotation due to elastic torsional deformation of the torsion bar **15**, and as a result, the phase in the circumferential direction of the convex sections **50** and the tongue pieces **51** of the detected sections **39***a*, **40***a* shift in the order as illustrated from FIG. **29**A to FIG. **29**B. As this occurs, the widths in the circumferential direction of the magnetic paths inside the encoders **10***a*, **11***a*, which are the portions where the convex sections **50** overlap the tongue pieces in the radial direction, decreases. As a result, the size of the output of the conducting wire **53** decreases in the order as illustrated from the dashed line to the solid line in FIG. **29**C. Here, the shift in phase (the amount of decrease in the width in the circumferential direction of the magnetic path) becomes larger the larger the torque becomes. Therefore, the size of the output decreases more the larger the torque becomes. However, the size of the output not only changes due to the torque, but also changes due to the rotational speed. In other words, the size of the induced current that flows in the coils **54** (induced electromotive force in the coils **54**) is proportional to the rate of change in the magnetic flux that passes through the coils **54**. The rate of change of this magnetic flux becomes large in proportion to the rotational speed. Therefore, the size (amplitude) of the output becomes larger in proportion to the rotational speed. In this example, the effect that the torque has on the size of the output, and the effect that the rotational speed has on the size of the output are both investigated beforehand. As described above, the rotational speed is found based on the frequency (or period) of the output, and correction is performed to return the size of the output that has changed due to the effect of the rotational speed to the original size. By doing so, it is possible to accurately find the torque based on the size

of the output after this correction. The driving voltage that is applied to the conducting wire **53** can also be a direct-current voltage, however, in order to increase the resistance to noise, an alternating-current voltage is preferred.

**[0157]** In this example, the sensor unit **12***a* is combined with the stator **52** and coils **54** and does not include precision electronic parts such as a magnetism-detecting device, so has excellent heat resistance and vibration resistance. Moreover, in this example, there is only one output that is used for measuring the rotational speed and the torque, so there is no need for complex signal processing when performing measurement. Consequently, it is possible to use an inexpensive computing device that does not have very high processing capability as the computing device used in performing this signal processing.

**[0158]** It is also possible to use construction wherein the direction in which the detected sections of the first and second encoders face the tip-end surfaces of the core sections of the sensor unit can be changed from the radial direction to the axial direction. In that case, the detected sections of the first and second encoders are a pair of circular disk-shaped detected sections having the same dimensions in the radial direction, and these detected sections are arranged so as to overlap in the axial direction. On the other hand, the core sections of the sensor unit are formed so as to be long in the axial direction. The tip-end surfaces of these core sections can face the detected sections from one side in the axial direction, which is the direction in which these detected sections overlap. The other construction and functions are the same as those of the first through eighth examples of embodiments.

## Tenth Example

**[0159]** FIG. **30** to FIG. **35** illustrate a tenth example of an embodiment of the present invention. In this example, the first encoder **10***b* that is fastened around the outside of the other end section of the coupling shaft **9**, and the second encoder **11***b* that is fastened around the outside of the other end section of the output shaft **14** are formed into a complete circular ring shape using a magnet metal, and each encoder **10***b*, **11***b* includes a comb-shaped cylindrical detection section **39***b* (**40***b*). In other words, the first detected section **39***b* of the first encoder **10***b*, and the second detected section **40***b* of the second encoder **11***b* are formed so that plural tongue pieces **51***a* (**51***b*) that are long in the axial direction are arranged at a uniform pitch in the circumferential direction, and so that the base-end sections of these tongue pieces **51***a* (**51***b*) are connected together. Moreover, the shape and dimensions of the detected sections **39***b*, **40***b* are the same as each other, however, the direction that each faces in the axial direction is opposite of each other. The tongue pieces **51***a* of the first detected section **39***b* and the tongue pieces **51***b* of the second detected section **40***b* are arranged so that when located in a space in the circumferential direction, the tongue pieces alternate one tongue piece at a time in the circumferential direction. In this example, when torque is not being transmitted, the widths in the circumferential direction of the portions between tongue pieces **51***a*, **51***b* that are adjacent in the circumferential direction are all the same. Furthermore, the widths in the circumferential direction of the portions between tongue pieces **51***a*, **51***b* that are adjacent in the circumferential direction are the same as the widths in the circumferential direction of the tongue pieces **51***a*, **51***b*. This is so that the duty ratios when torque is not being transmitted is 0.5. In this example, of the detected sections **39***b* (**40***b*), the tongue pieces **51***a* (**51***b*) correspond to solid sections, and the portions between tongue pieces **51***a* (**51***b*) that are adjacent in the circumferential direction correspond to sections where material has been removed.

**[0160]** In this example, the sensor unit **12***b* includes a holder **41***a* that is made of a synthetic resin, and one sensor **42***c* that is embedded in the tip-end section of the holder **41***a*; and the detecting section of the sensor **42***c* is made to closely face the outer-circumferential surface of the detected sections **39***b*, **40***b* (portions where the tongue pieces **51***a*, **51***b* are arranged in an alternating manner in the circumferential direction). The sensor **42***c* includes a permanent magnet that is magnetized in the direction that the outer-circumferential surfaces of the detected sections **39***b*, **40***b* face the detecting section of the sensor **42***c*, and a magnetic detecting element such as Hall element, Hall IC, MR element, GMR element and the like that is arranged on the end surface of both end surfaces in the magnetized direction of the permanent magnet that faces the outer-circumferential surfaces of the detected sections **39***b*, **40***b*.

**[0161]** In this example, the output signal from the sensor **42***c* of the sensor unit **12***b* periodically changes as the first and second encoders **10***b*, **11***b* rotate together with the rotary-shaft unit **6**. Moreover, as the first and second encoders displace relative to each other in the direction of rotation due to elastic torsional deformation of the torsion bar **15** when torque is being transmitted by the rotary-shaft unit **6**, the widths in the circumferential direction of the portions between tongue pieces **51***a*, **51***b* that are adjacent in the circumferential direction change. More specifically, the widths in the circumferential direction of every other one of the portions between the tongue pieces **51***a*, **51***b* become larger, and the widths in the circumferential direction of the remaining portions become smaller. As a result, the duty ratio $\epsilon$ (=time ratio B/A) of the output signal of the sensor **42***c* changes as illustrated in the order from FIG. **34**A to FIG. **34**B. Here, the amount that the widths in the circumferential direction of the portions between tongue pieces **51***a*, **51***b* that become larger (smaller) is a value that corresponds to the torque that is transmitted by the rotation transmission device, so the duty ratio s is also a value that corresponds to the torque. Therefore, by investigating in advance the relationship between the duty ratio s and the torque such as illustrated in FIG. **35**, the torque can be found based on this duty ratio $\epsilon$. Furthermore, in regard to the output signal of the sensor **42***c*, the 2-pulse period A is a value that corresponds to the rotational speed of the rotary-shaft unit **6**. Therefore, by investigating the relationship between the 2-pulse period A and the rotational speed, it is possible to find the rotational speed based on the 2-pulse period A.

**[0162]** In this example, the detected sections of the first and second encoders **10***b*, **11***b* are made to overlap in the circumferential direction, so it is possible to shorten the dimension in the axial direction of the portions where these detected sections **39***b*, **40***b* are located, and thus construction that conserves space by this amount is possible. Moreover, it is sufficient to install only one magnetism-detecting element in the sensor unit **12***b*, so the cost of the sensor unit **12***b* can be suppressed. The other construction and functions are the same as those of the first through eighth examples of embodiments.

## Eleventh Example

**[0163]** FIG. **36** to FIG. **38** illustrate an eleventh example of an embodiment of the present invention. In this example, the

first detected section **39***c* of the first encoder **10***c* that is fastened around the outside of the other end section of the coupling shaft **9**, and the second detected section **40***c* of the second encoder **11***c* that is fastened around the outside of the other end section of the output shaft **14** are both formed into a comb-like circular ring shape. Moreover, when the positions in the axial direction of these detected sections **39***c*, **40***c* coincide with each other, the tongue pieces **51***c*, **51***d* of the detected sections **39***c*, **40***c* are arranged in an alternating manner in the circumferential direction when located in a space in the circumferential direction. The detecting section of one sensor **42***c* of the sensor unit **12***b* is made to face in the axial direction the side surface in the axial direction of the portion where the tongue pieces **51***c*, **51***d* are arranged.

**[0164]** Except for changing the shape of the detected sections **39***c*, **40***c* to a circular disk shape, and changing the direction in which the detected sections **39***c*, **40***c* face the detecting section of the sensor **42** to the axial direction, the other construction and functions are the same as those of the tenth example of an embodiment.

## Twelfth Example

**[0165]** FIG. **39** to FIG. **42** illustrate a twelfth example of an embodiment of the present invention. In this example, the first encoder **10** that is fastened to and supported by the other end section of the coupling shaft **9** includes a ring-shaped metal core **35***a* that is made of a magnetic material and that is fastened around the outside of the other end section of the coupling shaft **9**, and a cylindrical-shaped permanent magnet **37***a* that is fastened around the outer-circumferential surface of a cylindrical section that exists on the outer circumference of the metal core **35***a*. S poles and N poles are arranged on the first detected section **39***a*, which is the outer-circumferential surface of the permanent magnet **37***a*, at a uniform pitch and so as to alternate in the circumferential direction. On the other hand, the second encoder **11***d* that is fastened to and supported by the other end section of the output shaft **14** includes a ring-shaped metal core **36***a* that is made of magnetic metal sheet and that is fastened around the outside of the other end section of the output shaft **14**, and a cylindrical shaped permanent magnet **38***a* that is fastened around the inner-circumferential surface of a cylindrical section that exists on the outer circumference of the metal core **36***a*. The second detected section **40***d*, which is the inner-circumferential surface of the permanent magnet **38***a*, is concentrically arranged on the outer-diameter side of the first detected section **39***d* so that there is a specified space in the radial direction. In other words, the first and second detected sections **39**, **40***d* face each other through a specified space in the radial direction. There are also S poles and N poles arranged on the second detected section **40***d* at a uniform pitch and so as to alternate in the circumferential direction. The total number of magnetic poles (S poles, N poles) that are arranged on the second detected section **40***d* and the total number of magnetic poles that are arranged on the first detected section **39***d* are the same as each other. Moreover, when torque is not being transmitted, the detected sections **39***d*, **40***d* are arranged so that the centers of different poles face each other in the radial direction.

**[0166]** In this example, the sensor unit **12***c* that is supported by the housing (not illustrated in the figures) includes a holder **41***b* made of a synthetic resin, and one sensor **42***d* that is embedded in the tip-end section of the holder **41***b*; and the sensor **42***d* is arranged so as to be in the center position in the radial direction between the detected sections **39***d*, **40***d*. A magnetism-detecting element such as a Hall element, Hall IC, MR element, GMR element or the like is assembled in the detecting section of the sensor **42***d*, and the sensing direction of that magnetism-detecting element is such that the center section of the element coincides with the radial direction of the first and second detected sections **39***d*, **40***d*. In other words, the sensing direction of this magnetism-detecting element is in the up-down direction in FIG. **41**A and FIG. **41**B, and the magnetic flux density in this up-down direction is proportional to the size of the output (voltage, current) of the magnetism-detecting element, which is the output signal of the sensor unit **12***c*.

**[0167]** In the rotation transmission device of this example, when torque is not being transmitted as illustrated in FIG. **41**A, or in other words, when there is no relative displacement in the direction of rotation between the detected sections **39***d*, **40***d*, the different poles of the detected sections s**39***d*, **40***d* face each other in the radial direction, so the direction of the magnetic flux that passes through the magnetism-detecting element mostly coincides overall with the direction of sensitivity of the detecting element. In other words, in this state, the magnetic flux density in the direction of sensitivity is a maximum, so the output of the magnetism-detecting element is also a maximum. On the other hand, when torque is being transmitted as illustrated in FIG. **41**B, or in other words, when there is relative displacement in the direction of rotation between the detected sections **39***d*, **40***d*, the positional relationship of different poles of the detected sections **39***d*, **40***d* shifts in the circumferential direction, so the direction of the magnetic flux that passes through the magnetism-detecting element becomes inclined overall with respect to the direction of sensitivity of the element. In other words, in this state, the magnetic flux density decreases by the amount of this inclination, and thus the output of the magnetism-detecting element also decreases by that amount. Here, the size of this inclination becomes larger the larger the torque (shift in the circumferential direction) is. Therefore, the output of the magnetism-detecting element becomes a maximum when torque is zero, and becomes small as the torque becomes larger.

**[0168]** When torque is being transmitted, the detected sections **39***d*, **40***d* rotate together with the rotary-shaft unit **6**. Therefore, the output of the magnetism-detecting element has a sinusoidal shape as illustrated in FIG. **42**. The size (amplitude) of this output becomes larger as the torque becomes larger. Therefore, by investigating the relationship between the size of the output and the torque beforehand, the torque can be found based on the size of the output. Moreover, the frequency (and period) of the output is a value that corresponds to the rotational speed of the rotary-shaft unit **6**. Therefore, by investigating the relationship between the frequency (or period) and the rotational speed beforehand, it is possible to find the rotational speed based on the frequency (or period).

**[0169]** When embodying this example, when torque is not being transmitted, the location of the magnetic poles of the detected sections **39***d*, **40***d* are shifted at an electrical angle of 90 degrees with respect to the circumferential direction, or in other words, it is possible to make the center of the magnetic poles of one of the detected sections face in the radial direction the boundary between magnetic poles of the other detected section. In this case, opposite from the explanation above, the output of the magnetism-detecting element

becomes a minimum when torque is not being transmitted, and becomes larger as the torque being transmitted becomes larger.

**[0170]** Moreover, when embodying this example, it is also possible to use a coil instead of using a magnetism-detecting element as the detecting section of the sensor **42***d* of the sensor unit **12***c*. When using a coil, the center axis of the coil is made to coincide with the radial direction of the first and second detected sections **39***d*, **40***d*. When using this kind of construction, as the detected sections **39***d*, **40***d* rotate together with the rotary-shaft unit **6**, the direction and size of the magnetic flux that passes through the coil changes periodically, so the output (voltage, current) of the coil, which is the output signal of the sensor unit **12***c*, changes periodically. The frequency (and period) of this output is a value that corresponds with the rotational speed, so it is possible to find the rotational speed based on the frequency (or period). Moreover, the density of the magnetic flux that passes perpendicular to the coil changes according to the size of the torque (amount of shift in the position in the circumferential direction of the different poles of the detected sections **39***d*, **40***d*). Therefore, the size of the output of the coil changes according to the size of the torque. However, as in the case of the sensor unit **12***a* of the ninth example of an embodiment (see FIG. **25** to FIG. **28**), the size of the output of the coil also changes according to the rotational speed. Therefore, as in the case of the ninth example of an embodiment, after the rotational speed is found based on the frequency (or period) of the output of the coil, correction is performed to return the size of the output that was changed due to the effect of the rotational speed to the original size. By doing so, it is possible to accurately find the torque based on the size of the output after this correction.

**[0171]** In this example as well, it is sufficient to install only one sensor **42***d* in the sensor unit **12***c*, so it is possible to suppress the cost of the sensor unit **12***c*. It is also possible to use construction in which the direction that the detected sections of the first and second encoders face the one sensor of the sensor unit is changed from the radial direction to the axial direction. In that case, the detected sections of the first and second encoders are a pair of circular disk-shaped detected sections that have the same radial dimensions, and are arranged so that these detected sections face each other in the axial direction. The detecting section of the one sensor of the sensor unit is arranged between these detected sections. The other construction and functions are the same as those of the first through eighth examples of embodiments.

## Thirteenth Example

**[0172]** FIG. **43** illustrates a thirteenth example of an embodiment of the present invention. In this example, the first and second encoders **10**, **11** and the sensor unit **12** are arranged so as to be concentrated around one end section of the input shaft **13**. More specifically, the outer-circumferential surface of the other end section (left-end section in FIG. **43** of the coupling shaft **9***a* that is arranged on the inner-diameter side of the torsion bar **15** is connected to the inner-circumferential surface of the other end section of the output shaft **14** by an involute spline connection or key connection so that relative rotation is not possible. Moreover, a retaining ring (not illustrated in the figure) is used to prevent displacement in the axial direction of the coupling shaft **9***a* with respect to the output shaft **14**. On the other hand, one end section of the coupling shaft **9***a* (right-end section in FIG. **43**) protrudes from an opening on the one end side of the input shaft **13**. The first encoder is fastened around the outside of the one-end section of the coupling shaft **9***a*, and the second encoder is fastened around the outside of the one end section of the input shaft **13**. Moreover, with the detecting section of a pair of sensors of the sensor unit **12** facing the detected sections of these encoders **10**, **11**, the sensor unit **12** is supported by the housing (not illustrated in the figure). FIG. **43** is a simplified drawing, and part of the drawing and reference numbers are omitted. The other construction and functions are the same as those of the first example of an embodiment.

## Fourteenth to Seventeenth Examples

**[0173]** FIG. **44** to FIG. **47** illustrate fourteenth to seventeenth examples of embodiments of the present invention. In these examples, the arrangement of the thirteenth example of an embodiment is applied to the construction of the ninth to twelfth examples of embodiments, and the first and second encoders **10***a* to **10***d*, **11***a* to **11***d* and the sensor units **12***a* to **12***d* are arranged so as to be concentrated around one end of the input shaft **13**. FIG. **44** to FIG. **47** are simplified drawings, and part of the drawing and reference numbers are omitted. The other construction and functions are the same as those of the ninth to twelfth examples and thirteenth example of embodiments.

## Eighteenth and Nineteenth Examples

**[0174]** FIG. **48** and FIG. **49** illustrate eighteenth and nineteenth examples of embodiments of the present invention. In the construction of an eighteenth example of an embodiment illustrated in FIG. **48**, in regard to the combination section of the end sections of the input shaft **13** and the output shaft **14**, of the radial bearing and thrust bearing that are installed in this combination section, the radial bearing is a cylindrical sleeve bearing **57**, which is a radial sliding bearing, and the thrust bearing is a thrust needle bearing **58**. The thrust needle bearing **58** is fastened around the outside of the base-end section of the input-side combination cylindrical section **16** so that there is no large looseness in the radial direction, and as a result, the position of thrust needle bearing **58** is set in the radial direction.

**[0175]** On the other hand, in the construction of the nineteenth example of an embodiment illustrated in FIG. **49**, the radial bearing and thrust bearing that are installed in the combination section of the input shaft **13** and output shaft **14** are a cylindrical shaped sleeve bearing **57** and a circular disk-shaped thrust washer **21***c*. By fastening the thrust washer **21***c* around the outside of the base-end section of the input-side combination cylindrical section **16** so that there is no large looseness in the radial direction, the position of the thrust washer **21***c* is set in the radial direction. Moreover, the thrust washer **21***c* is such that by fitting a pin **59** that is embedded in the stepped surface **19** in an engagement hole **60** that is formed in part of the thrust washer **21***c* itself, the position in the circumferential direction of the thrust washer **21***c* is set.

**[0176]** In either case, an oil passage **61** is formed in the base-end section of the input-side combination cylindrical section **16**. Lubrication oil can be supplied though this oil passage **61** from a cylindrical space **47** to the space where the radial bearing is installed and the space where the thrust bearing is installed, which improves the lubrication of these

bearings. The other construction and functions are the same as those of the first through eighteenth examples of embodiments.

Twentieth Example

**[0177]** FIG. **50** illustrates a twentieth example of an embodiment of the present invention. In the rotation transmission device, it is important that that a spring section **115**, which is the portion in the middle section in the axial direction of the torsion bar **15** (see FIG. **5** and FIG. **6**) that undergoes torsional deformation when torque is transmitted, does not break (fracture) due to fatigue even when torque is repeatedly transmitted. Moreover, in order to sufficiently maintain the precision and resolution of torque measurement, it is also important to sufficiently maintain the amount of elastic torsional deformation per unit torque of the torsion bar **15**. In the rotation transmission device of this example, the construction of the torsion bar **15** is devised so that maintaining the durability necessary for preventing the spring section **115***a* of the torsion bar **15** from breaking due to repeated transmission of torque, and maintaining the amount of elastic torsional deformation (twist angle) per unit torque that is required in order to improve the precision and resolution of torque measurement are both achieved to a high degree.

**[0178]** In this example, the spring section **115***a* of the torsion bar **15***a* includes a cylindrical tube section **78** in the middle section in the axial direction except for the portions on both end edges in the axial direction, that has thinner wall thickness than the portions on both end edges in the axial direction, and is a single cylindrical surface of which the inner-circumferential surface and outer-circumferential surface are concentric with each other. In other words, the inner-circumferential surface of the center hole of the torsion bar **15***a*, including the middle section in the axial direction, which is the inner-circumferential surface of the spring section **115***a*, is a single cylindrical surface along the entire length. On the other hand, of the spring section **115***a*, the outer-circumferential surface of the cylindrical tube section **78** is a single cylindrical surface that is concentric with the inner-circumferential surface of the center hole of the cylindrical tube section **78**. Therefore, the wall thickness in the radial direction of the cylindrical tube section **78** is uniform overall. On the other hand, the outer-circumferential surfaces of the portions on both end edges in the axial direction of the spring section **115***a* are inclined in a direction so that the dimension of the diameter becomes larger going toward both ends in the axial direction of the spring section **115***a*, and form a pair of inclined surface sections **79**. The outer-circumferential surface of the cylindrical tube section **78** and a pair of male involute spline sections **62**, **64** on both end sections in the axial direction of the outer-circumferential surface of the torsion bar **15***a* are provided so as to be continuous by way of the pair of inclined surface sections **62**, **64**. Therefore, the portions on both end edges in the axial direction of the spring section **115***a* where the inclined surface sections **79** are provided are such that the wall thickness in the radial direction becomes larger than that of the cylindrical tube section **78**. In other words, the wall thickness in the radial direction of the spring section **115***a* is a minimum in the cylindrical tube section **78**. The dimension s in the axial direction of this cylindrical tube section **78** is greater than the width W in the axial direction of the input gear **7** and the outer gear **8** (see FIG. **6**) (s>W).

**[0179]** The wall thickness in the radial direction of the spring section **115***a* is a minimum in the cylindrical tube section **78**, so the torsional rigidity per unit length of the spring section **115***a* is also a minimum in the cylindrical tube section **78**. Therefore, the amount of elastic torsional deformation per unit length that occurs in the spring section **115***a* when torque is being transmitted becomes a maximum in the cylindrical tube section **78**. The spring section **115***a*, except for the edge portions on both ends in the axial direction, is mostly the cylindrical tube section **78**. Consequently, the amount of elastic torsional deformation that occurs in the spring section **115***a* when torque is being transmitted mostly occurs in the cylindrical tube section **78**. Therefore, in order to achieve with a high degree both the maintenance of durability of the spring section **115***a*, and maintenance of the elastic torsional deformation per unit torque, it is necessary to focus on the construction of the cylindrical tube section **78**. Taking conditions such as these into consideration, in this example, by adjusting the ratio di/do of the inner-diameter dimension di and outer-diameter dimension do of the cylindrical tube section **78**, this ratio di/do is put within the $0.5 \leq di/do \leq 0.8$. Together with this, by performing a polishing process in order to improve the surface roughness of the outer-circumferential surface of the cylindrical tube section **78**, the ten-point average roughness Rz of the outer-circumferential surface of the cylindrical tube section **78** is put within the range $Rz \leq 22$ μm. Furthermore, of the surface of the torsion bar **15***a*, at least the hardness of the outer-circumferential surface of the spring section **115***a* is made to be 450 Hv (and preferably 500 Hv or greater).

**[0180]** Normally, spring steel (JIS G 4801) is used as the material of a typical torsion bar that is used in various kinds of machinery. Spring steel includes silicon manganese steel (SUPE, SUPT), manganese chromium steel (SUP9, SUP9A), chromium vanadium steel (SUP10), manganese chromium boron steel (SUP11A), silicon chromium steel (SUP 12), and chromium molybdenum steel (SUP13); and the mechanical properties of these are a yield stress (0.2% yield strength): 100 to 1100 MPa, and hardness: 350 Hv to 450 Hv.

**[0181]** On the other hand, for the spring section **115***a* of the torsion bar **15***a* of the rotation transmission device with torque measurement device of this example, in order to achieve a high degree of both maintenance of durability and maintenance of elastic torsional deformation per unit torque, using a material having a high yield stress σy and fatigue strength σw as the material of the torsion bar **15***a* is effective; and more specifically, using a material having a yield stress σy of 1100 MPa or greater (and preferably 1200 MPa or greater) and a fatigue strength σw of 500 MPa or greater (an preferably 600 MPa or greater) is effective. Moreover, there is a correlation between the yield stress σy and fatigue strength σw and the hardness, and a hard hardness is preferred. More specifically, as done in this example, making the hardness of at least the outer-circumferential surface of the spring section **115***a* of the surface of the torsion bar **15***a* 450 Hv (upper limit of the hardness of the spring steel material used as the material for a typical torsion bar as described above) or greater (and preferably 500 Hv or greater) is effective. However, in the case that this hardness is too high, the material becomes brittle, and the impact strength greatly decreases. Therefore, this hardness is made to be 850 Hv or less (and preferably, 800 Hv or less).

**[0182]** In order to make the hardness of at least the outer-circumferential surface of the spring section **115***a* of the

surface of the torsion bar **15***a* 450 Hv or greater, a material having a higher carbon concentration than the spring steel (JIS G 4801, carbon concentration of 0.45 to 0.65%) that is used as the material of a typical torsion bar is used as the metal material of the torsion bar **15***a*, for example. In other words, the carbon concentration of the metal material of the torsion bar **15***a* is 0.65% or greater (and preferably, 0.7% or greater). As a result, when martensite is generated by performing a tempering and annealing process on the metal material of the torsion bar **15***a*, the hardness can be improved. However, when this carbon concentration becomes too high, large carbides are generated, and thus workability greatly worsens and toughness greatly decreases. Therefore, the carbon concentration is made to be 1.5% or less (and preferably, 1.25% or less, and even more preferably, 1.2% or less). More specifically, high carbon chromium bearing steel (carbon concentration: 0.9 to 1.1%) or carbon tool steel (carbon concentration: 0.65 to 1.5%) is used as the metal material of the torsion bar, and tempering is performed at 800 to 860° C., after which annealing is performed at 150 to 500° C.

**[0183]** Alternatively, spring steel is used as the metal material of the torsion bar **15***a*, and the torsion bar **15***a* is made by performing annealing at a temperature (450° C. or less, and preferably 400° C.) that is lower than the annealing temperature (450 to 570° C.) for normal spring steel. More specifically, the torsion bar **15***a* is made by performing tempering of the spring steel at 800 to 880° C., and then performing annealing at 150 to 450° C.

**[0184]** Alternatively, it is possible to perform a carburizing process or carbo-nitriding process on the surface of the torsion bar **15***a*. In other words, by performing a carburizing process or carbo-nitriding process, it is possible to deposit much carbide of nitride onto the surface of the torsion bar **15***a*. More specifically, the torsion bar **15***a* is made by performing a carburizing process in a carburizing gas atmosphere of propane, methane, butane gas or the like at 700° C. to 900° C. on a machine structure carbon steel (JIS G 4052) or machine structure alloy (JIS G 4053: nickel chromium steel, nickel chromium molybdenum steel, chromium steel, chromium molybdenum steel, manganese steel, manganese chromium steel or the like), or performing a carbo-nitriding process in a mixed atmosphere of a carburizing gas and ammonia gas, and then performing an annealing process at 150° C. to 500° C. As a result, it is possible to sufficiently maintain the wear resistance of the connecting sections (male involute spline sections **62**, **64** or key sections) that are provided on the outer-circumferential surfaces of both end sections of the torsion bar **15***a* that connect with the input shaft **13** or output shaft **14** (see FIG. **5** and FIG. **6**).

**[0185]** Alternatively, it is also possible to perform a shot-peening process on the outer-circumferential surface of the torsion bar **15***a*. More specifically, the torsion bar **15***a* is made by performing a tempering process at 830° C. to 870° C. on a spring steel material, and then performing an annealing process at 460° C. to 570° C., and when necessary, further performing a polishing process, and then finally performing a shot-peening process. Shot-peening balls made of a material such as steel, glass or ceramic and having a diameter of 0.1 to 1 mm are used in the shot-peening process. By performing this kind of shot-peening process, not only is it possible to improve the hardness of the torsion bar **15***a*, but it is also possible to improve the fatigue strength by generating compressive residual stress. The compressive residual stress on the surface layer of the torsion bar **15***a* is preferably 200 MPa or greater. In addition to the outer-circumferential surface of the torsion bar **15**, the shot-peening process can also be performed on the inner-circumferential surface.

**[0186]** In this example, the ratio di/do of the inner-diameter dimension di and the outer-diameter dimension do of the cylindrical tube section **78**, and the ten-point average roughness of the outer-circumferential surface Rz of the cylindrical tube section **78** are kept within the respective ranges described above ($0.5 \leq di/d \leq 0.8$, $R \leq 22$ μm), so it is possible to maintain at a high degree both durability and the amount of elastic torsional deformation of the spring section **115***a*, of which the cylindrical tube section **78** is the main portion.

**[0187]** In other words, in this example, the ratio di/do of the inner-diameter dimension di and outer-diameter dimension do of the cylindrical tube section **78** is 0.8 or less ($di/do \leq 0.8$), so the maximum shear stress that acts on the outer-circumferential surface of the cylindrical tube section **78** can be kept low. At the same time, the ten-point average roughness Rz of the outer-circumferential surface of the cylindrical tube section **78** is 22 μm or less ($Rz \leq 22$ μm), so even when the maximum shear stress is repeatedly applied to the outer-circumferential surface of the cylindrical tube section **78**, it is possible to make it difficult for cracking, which is the start of fatigue fracture, to occur on the outer-circumferential surface of the cylindrical tube section **78**.

**[0188]** In this example, the ratio di/do of the inner-diameter dimension di and outer-diameter dimension do of the cylindrical tube section **78** is 0.5 or greater ($0.5 \leq di/do$), so it is possible to prevent the wall thickness (torsional rigidity) in the radial direction of the cylindrical tube section **78** from becoming excessively large, and thus it is possible to sufficiently maintain the amount of elastic torsional deformation per unit torque in the spring section **115***a*.

**[0189]** Furthermore, in this example, of the surface of the torsion bar **15***a*, the hardness of the outer-circumferential surface of at least the spring section **115***a* is 450 Hv or greater (and preferably, 500 Hv or greater). Therefore, it is possible to more easily maintain the durability of the spring section **115***a* of the torsion bar **15***a*.

**[0190]** For the spring section **115***a* of the torsion bar **15***a*, it is important to maintain at a high degree, both the durability required for preventing fatigue fracture due to repeatedly transmitting torque, and the amount of elastic torsional deformation per unit torque that is necessary for improving the precision and resolution of torque measurement.

**[0191]** When torque T is applied to the cylindrical tube section **78** (outer-diameter dimension do, inner-diameter dimension di, dimension in the axial direction s, modulus of rigidity G), which is the main part of the spring section **115***a* of the torsion bar **15***a*, the maximum shearing stress τmax that acts on the cylindrical tube section **78** is as expressed by Equation (1). The maximum shearing stress max acts on the outer-circumferential surface of the cylindrical tube section **78**.

$$\tau_{max} = \frac{16 \cdot T \cdot d_o}{\pi \cdot (d_o^4 - d_i^4)} \tag{1}$$

**[0192]** Moreover, the twisting angle ϕ of the cylindrical tube section **78** when a torque T is applied to the cylindrical tube section **78** is as expressed by Equation (2)

$$\phi = \frac{32 \cdot T \cdot s}{G \cdot \pi \cdot (d_o^4 - d_i^4)} \quad (2)$$

**[0193]** As can be understood from Equation (1), when the inner-diameter dimension di is made small with respect to the outer-diameter dimension do, the maximum shearing stress τmax becomes small by that amount, so it become difficult for fatigue fracture to occur in the cylindrical tube section **78**. Therefore, the durability of the spring section **115***a*, of which the cylindrical tube section **78** is the major part, is improved the smaller the inner-diameter dimension di is with respect to the outer-diameter dimension do.

**[0194]** On the other hand, as can be understood from Equation (2), as the inner-diameter dimension di becomes large with respect to the outer-diameter dimension do, the twisting angle ϕ becomes larger by that amount. In other words, the amount of elastic torsional deformation of the cylindrical tube section **78** becomes larger. Therefore, the amount of elastic torsional deformation per unit torque of the spring section **115***a*, of which the cylindrical tube section **78** is the major part, becomes larger the larger the inner-diameter di is with respect to the outer-diameter dimension do.

**[0195]** As can be understood from the explanation above, in order to maintain at a high degree both durability and the amount of elastic torsional deformation per unit torque for the spring section **115***a*, it is necessary to keep the ratio di/do of the inner-diameter dimension di and outer-diameter dimension do of the cylindrical tube section **78** within a specified range.

**[0196]** In the following, testing that was performed in order to confirm the effect of the invention will be explained. In this testing, the effect that the ratio di/do of the inner-diameter dimension di and outer-diameter dimension do of the cylindrical tube section **78** has on the durability and the amount of elastic torsional deformation per unit torque of the spring section **115***a*, or in other words, the precision (resolution) of torque measurement was investigated.

**[0197]** In order for this, as a test specimen, plural torsion bars **15***a* having ratios di/do of the inner-diameter dimension di and outer-diameter dimension do of the cylindrical tube section **78** that were different from each other were prepared, and testing of these specimens was performed by applying a torque load to the spring section **115***a*. More specifically, in order to perform this testing, a tester such as illustrated in FIG. **51** was used. In other words, of the torsion bar **15***a*, one end section that is separated from the spring section **115***a* (left end section in FIG. **51**) and one end section of the coupling shaft **9** that is passed through the center hole of the torsion bar **15***a* (left end section in FIG. **51**) are fastened around the inside of a fixed first fastener **80**, and of the torsion bar **15***a*, the other end section that is separated from the spring section **115***a* (right end section in FIG. **51**) is fastened around the outside of a movable second fastener **81**. Moreover, a first encoder **10** is fastened around the outside of the other end section (right end section in FIG. **51**) of the coupling shaft **9**, and a second encoder **11** is fastened around the outside of the second fastener **81**. Furthermore, with the detecting sections of a pair of sensors of a sensor unit **12** facing the detected sections of the first and second encoders **10**, **11**, the sensor unit **12** is supported by and fastened to a fixed support (not illustrated in the figure). In this state, a hydraulic device (not illustrated in the figure) rotates the second fastener **81**, which applies a torque to the spring section **115***a* of the torsion bar **15***a*. The other test conditions are as given below.

<Torsion Bar **15***a*>

Material: DSUP9A (manganese chromium steel)

Outer-diameter dimension do of the cylindrical tube section **78**: 30 mm

Inner-diameter dimension do of the cylindrical tube section **78**: Differs for each specimen.

Axial direction dimension s of the cylindrical tube section **78**: 80 mm

Ten-point average roughness of the outer-circumferential surface of the cylindrical tube section: Approx. 60 μm

<Durability Test>

**[0198]** Using the tester described above, a fixed torque T that was selected from among the range 500 to 2000 Nm was repeatedly applied as a load to the spring section **115***a* of the torsion bar **15***a* test specimen at a frequency of 20 Hz. Then, the size of the fatigue limit torque Tw, which is the torque T at the limit where fatigue failure does not occur in the cylindrical tube section **78** even after loading is repeatedly applied a total of $1.0\times10^7$ times, was found.

<Torque Measurement Precision (Resolution) Test>

**[0199]** The tester described above was used, and a 500 Nm torque T was repeatedly applied as a load to the spring section **115***a* of the torsion bar **15** specimens. When doing this, the variation width in the torque measurement values that was found based on the phase difference ratio of the output signals from the pair of sensors, and the measurement error of the torque measurement was found by dividing the variation width by the torque T (500 Nm) load.

**[0200]** The results (fatigue limit torque Tw, torque measurement error) of the tests above are given in Table 1.

TABLE 1

| di/do | Fatigue limit torque Tw (Nm) | Torque measurement error |
|---|---|---|
| 0.9 | 550 | 5% |
| 0.8 | 1050 | 5% |
| 0.7 | 1200 | 5% |
| 0.6 | 1350 | 6% |
| 0.5 | 1500 | 6% |
| 0.4 | 1600 | 12% |
| 0.3 | 1700 | 21% |

**[0201]** When using a rotation transmission device that is installed in a transmission of an automobile, fatigue fracture must not occur even when a torque T of 1000 Nm or less is repeatedly applied, or in other words, the rotation transmission device must have a fatigue limit torque Tw that is greater than 1000 Nm. As can be clearly seen from the test results in Table 1, in order to sufficiently maintain the durability of the spring section **115***a* in order to meet this demand, it is necessary that the radio di/do be 0.8 or less (di/do≤0.8).

**[0202]** On the other hand, in regard to the precision (resolution) of the torque measurement, as can clearly be seen from the test results in Table 1, when the ratio di/do becomes 0.5 or greater (0.5≤di/do), the error of the torque measurement rapidly decreases (6% or less). Therefore, in order to sufficiently maintain the precision (resolution) of torque measurement, the ratio di/do should be 0.5 or greater (0.5≤di/do).

**[0203]** From the test results described above, it was learned that in order to maintain at a high degree both the durability and the amount of elastic torsional deformation per unit torque, or in other words, the precision (resolution) of torque measurement, for the spring section **115***a* of the torsion bar **15***a*, the ratio di/do should be kept within the range 0.5≤di/do≤0.8.

**[0204]** Incidentally, when a torque load is applied to the spring section **115***a* of the torsion bar **15***a*, the maximum shearing stress τmas in Equation (1) acts on the outer-circumferential surface of the cylindrical tube section **78**. Therefore, when the cylindrical tube section fractures due to fatigue, first, cracking occurs on the outer-circumferential surface, and that cracking progresses toward the inside until fracture occurs. In this case, when the surface roughness of the outer-circumferential surface is large, minute unevenness on the outer-circumferential surface becomes the cause of concentrated stress, and it becomes easy for cracking to occur, so the fatigue strength decreases by that amount.

**[0205]** Therefore, in order to investigate the effect that the surface roughness of the outer-circumferential surface of the cylindrical tube section **78** has on the fatigue strength, the inventors performed additional testing. In other words, in the previous testing, material (material having a ten-point average roughness Rz of the outer-circumferential surface of the cylindrical tube section **78** of about 60 μm) that was obtained by performing only heat treatment of the spring section **115***a* as in the case of a typical torsion bar that is assembled and used in various machinery was used for each of the plural torsion bar **15***a* specimens. However, in this additional testing, plural torsion bars **15***a* were prepared as the test specimens so that the ratio di/do of the inner-diameter dimension di and outer-diameter dimension do of the cylindrical tube section **78** was 0.6 for each, and so that the ten-point average roughness Rz of the outer-circumferential surface of the cylindrical tube section **78** differed from each other. The ten-point average roughness Rz was adjusted by polishing the outer-circumferential surface of the cylindrical tube section **78** after heat treatment of the spring section **115***a* was performed. The size of the fatigue limit torque Tw of the cylindrical tube section **78** was investigated for these specimens under the same conditions as in the previous testing. The results (fatigue limit torque Tw) of this additional testing are given in Table 2.

TABLE 2

| Ten-point average roughness Rz (μm) | Fatigue limit torque Tw (Nm) |
|---|---|
| 60 | 1350 |
| 51 | 1400 |
| 39 | 1450 |
| 33 | 1500 |
| 22 | 1600 |
| 9 | 1600 |

**[0206]** As can clearly be seen from the test results in Table 2, when the ten-point average roughness Rz becomes 22 μm or less (Rz≤22 μm), the fatigue limit torque Tw becomes sufficiently large, and becomes a fixed size (1600 Nm). From this it was learned that by making the ten-point average roughness Rz 22 μm or less (Rz≤22 μm), it is possible to prevent minute unevenness on the outer-circumferential surface of the cylindrical tube section **78** from becoming the source of concentrated stress, and is useful for sufficiently maintaining the durability of the spring section **115***a*.

**[0207]** In the explanation above, an example was given of a case of applying the construction of the torsion bar **15** of this example to the construction of the first example of an embodiment. However, this example is not limited to this, and it is also possible to apply this construction to other examples of embodiments of the present invention.

## Twenty-First Example

**[0208]** FIG. **52** illustrates a twenty-first example of an embodiment of the present invention. A feature of the rotation transmission device of this example the reduction in manufacturing cost by integrating part of the members of this device. In other words, an input-side rotating body **82** is constructed by fastening an input gear **7** around the outside of the middle section in the axial direction of an input-side unit **83** so as to be concentric with the input-side unit **83**, and so as to be able to rotate in synchronization with the input-side unit **83**. Moreover, the input-side unit **83** is an integrally formed part that is formed by integrating together an input shaft **13***c*, an inner ring **30***e* of a conical roller bearing **29***e* that supports the input shaft **13***c* so as to be able to freely rotate with respect to the housing, and a torsion bar **15***b*. The input-side unit **83** is such that a stepped surface **27** that faces one end side in the axial direction of the input shaft **13***c* is provided around the outer-circumferential surface of the middle section in the axial direction. The input-side unit **83** is made by performing plastic working such as forging or by cutting a metal material such as a chromium steel like SCr420 or SCM420, or a chromium molybdenum steel such as SCM420 or the like, and then performing heat treatment such as carburizing or carbo-nitriding.

**[0209]** Moreover, the input gear **7** is positioned in the axial direction with respect to the input-side unit **83** by the portion near the inner circumference of one side surface (left side surface of FIG. **52**) coming in contact with the stepped surface **27**. In this state, the input gear **7** is prevented from displacing in the axial direction with respect to the input-side unit **83** by a retaining ring engaging with a portion on the outer-circumferential surface of the input-side unit **83** that comes in contact with the one end side in the axial direction of the input gear **7**. In this example, the inner-diameter dimension of the input gear **7** is larger than the outer-diameter dimension of the inner ring **30***e*. As a result, input gear **7** is able to pass over the inner ring **30***e* when installing the input gear **7** in the input-side unit **83** or removing the input gear from the input-side unit **83**.

**[0210]** In this example, the input shaft **13***c*, the inner ring **30***e* of the conical roller bearing **29***e* that supports the input shaft so as to be able to freely rotate with respect to the housing, and the torsion bar **15***b* are integrally formed, so it is possible to suppress the cost of managing parts and the assembly cost. Furthermore, there is no need for parts such as the retaining ring **25***a*, spacer **31**, nut **32***a* and the like that are used for assembling the members **13***c*, **30***e*, **15***b* so as not to separate from each other; and from this aspect as well, it is possible to suppress the cost of managing parts. As a result, it is possible to reduce the manufacturing cost of the rotation transmission device.

**[0211]** When embodying this example, it is also possible to integrally form an output shaft **14**, and an inner ring **30***b* of a conical roller bearing **29***b* that supports the output shaft **14** so as to rotate freely with respect to the housing. As a result, it is

possible to further suppress the cost of managing parts and the assembly cost, and thus it is possible to further reduce the manufacturing cost of the rotation transmission device. The other construction and functions are the same as those of the first through twentieth examples of embodiments.

Twenty-Second Example

**[0212]** FIG. **53** illustrates a twenty-second example of an embodiment of the present invention. In this example, in addition to the inner ring **30***e*, input shaft **13***c* and torsion bar **15***b*, the input gear **7***a* is also integrally formed. Therefore, the input gear **7***a* does not need to be formed as an independent part, and thus it is possible to eliminate parts such as the retaining ring for preventing the input gear **7***a* from displacing in the axial direction with respect to the input shaft **13***c*. Consequently, it is possible to suppress the cost for managing parts and the assembly cost by that amount, and thus it is also possible to further reduce the manufacturing cost of the rotation transmission device. The other construction and functions are the same as those of the twenty-first example of an embodiment.

Twenty-Third Example

**[0213]** FIG. **54** illustrates a twenty-third example of an embodiment of the present invention. In this example, an output-side rotating body **84** is formed by fastening an output gear **8***a* around the outside of the middle section in the axial direction of an output-side unit **85** so as to be concentric with the output-side unit **85**, and so as to be able to rotate in synchronization with the output-side unit **85**. The output-side unit **85** is an integrally formed part by integrally forming an output shaft **14***a*, an inner ring **30***f* of a conical roller bearing **29***f* that supports the output shaft **14***a* so as to rotate freely with respect to a housing, and a torsion bar **15***c*. The output-side unit **85** is such that a stepped surface **86** that faces toward the other end side in the axial direction of the output shaft **14***a* is provided around the outer-circumferential surface of the middle section in the axial direction. The output-side unit **85** is made by performing plastic working such as forging or by cutting a metal material such as a chromium steel like SCr420 or SCM420, or a chromium molybdenum steel such as SCM420 or the like, and then performing heat treatment such as carburizing or carbo-nitriding.

**[0214]** The output gear **8***a* is positioned in the axial direction with respect to the output-side unit **85** by one side surface (right side surface in FIG. **54**) of the output gear **8***a* coming in contact with the stepped surface **86**. In this state, the output gear **8***a* is prevented from displacement in the axial direction with respect to the output-side unit **85** by a retaining ring or the like engaging with a portion on the outer-circumferential surface of the output-side unit **85** that is in contact with the other side in the axial direction of the output gear **8***a*. The inner-diameter dimension of the output gear **8***a* is larger than the outer-diameter dimension of the inner ring **30***d*, so it is possible to pass the outer gear **8***a* in the axial direction over the inner ring **30***f* when installing the outer gear **8***a* in the output-side unit **85** or removing the output gear **8***a* from the output-side unit **85**.

**[0215]** In this example, the output shaft **14***a*, the inner ring **30***f* of the conical roller bearing **29***f* and the torsion bar **15***c* are integrally formed, so it is possible to suppress the cost of managing parts and assembly costs. Furthermore, there is no need for parts such as a retaining ring **25***b* and nut **32***b* that are used for assembling these members **14***a*, **30***f*, **15***c* so as not to separate from each other, and so from this aspect as well, it is possible to suppress the cost of managing parts. Therefore, it is possible to reduce the manufacturing cost of the rotation transmission device.

**[0216]** When embodying this example as well, it is also possible to integrate the input shaft **13**, and inner ring **30***a* of the conical bearing **29***a* that supports the input shaft **13** so as to rotate freely with respect to the housing. In that case, it is necessary to make the inner-diameter dimension of the input gear **7** larger than the outer-diameter dimension of the inner ring **30***a* so that the input gear **7** is able to pass in the axial direction over the inner ring **30***a* when installing or removing the input gear **7**. By integrating the input shaft **13** and inner ring **30***a*, it is possible to further suppress the cost of managing parts and assembly costs, and thus it is possible to further reduce the manufacturing cost of the rotation transmission device with torque measurement device. In addition to the input shaft **13** and inner ring **30***a*, it is also possible to integrate the input gear **7**. The other construction and functions are the same as those of the first through twentieth examples of embodiments.

Twenty-Fourth Example

**[0217]** FIG. **55** illustrates a twenty-fourth example of an embodiment of the present invention. In this example, in addition to the inner ring **30***f*, the output shaft **14***a* and torsion bar **15***c*, the output gear **8** is also integrally formed. Therefore, there is no need to form the output gear **8** as an independent part, and it is possible to eliminate installing parts for preventing the output gear **8** from displacing in the axial direction with respect to the output shaft **14***c*. Consequently, it is possible to suppress the cost of managing parts and the assembly cost, and to further reduce the manufacturing cost of the rotation transmission device by that amount. The other construction and functions are the same as those of the twenty-third example of an embodiment.

Twenty-Fifth Example

**[0218]** FIG. **56** and FIG. **57** illustrate a twenty-fifth example of an embodiment of the present invention. In this example, the amount of run-out of the first encoder **10** with respect to the second encoder **11** that is associated with error in the torque measurement is kept small by improving the concentricity of the centers of rotation of the first and second encoders **10**, **11**. In this example as well, the first encoder **10** is concentrically fastened around the other end section of the coupling shaft **9**. The first encoder has a metal core **35** made of a magnetic metal, and a permanent magnet **37**. The metal core **35** includes: a cylindrical shaped fitting cylindrical section **87** that fits onto the coupling shaft **9**; an outward-facing flange shaped wheel section **88** that is provided around the middle section in the axial direction of the fitting cylindrical section **87**; and a cylindrical section **89** that is provided in a direction toward one end side in the axial direction of the coupling shaft **9** from the outer-circumferential edge of the cylindrical section **89**. Moreover, the permanent magnet **37** is fastened around the entire outer-circumferential surface of the cylindrical section **89**.

**[0219]** In this example, a sliding bearing **91** that is made of a material that slides easily such as oil-impregnated metal, synthetic resin or the like is provided between a large-diameter section **90** that is provided on the outer-circumferential

surface of the other end section of the output shaft **14***b* and the outer-circumferential surface of one end section (right-end section in FIG. **57**) of the fitting cylindrical section **87**. More specifically, first, the coupling shaft **9** is supported by the input shaft **13** by connecting the outer-circumferential surface of a rim section **34** that is formed on one end section of the coupling shaft **9** and the inner-circumferential surface of one end section of the input shaft **13** by an involute spline connection **24***d*. In this state, the rim section **34** is held on both sides in the axial direction by a pair of retaining rings **25***a*, **25***c* that are fastened around the inner-circumferential surface of the input shaft **13**, which prevents the coupling shaft **9** from displacing in the axial direction with respect to the input shaft **13**. Next, the hollow cylindrical shaped torsion bar **15** is inserted into the inner-diameter sides of the input shaft **13** and output shaft **14***b* from the opening on the other end side of the output shaft **14***b*. Then an involute spline connection **24***a* is formed by connecting a first male involute spline section **62** that is provided on the outer-circumferential surface of one end section of the torsion bar **15** with a first female involute spline section **63** that is provided on the inner-circumferential surface of one end section of the input shaft **13**, and an involute connection **24***b* is formed by connecting a second male involute spline section **64** that is provided on the outer-circumferential surface of the other end section of the torsion bar **15** with a second female spline section **65** that is provided on the inner-circumferential surface of the other end section of the output shaft **14***b*. As a result, the torsion bar **15** is supported on the inner-diameter side of the input shaft **13** and output shaft **14***b*. Next, the sliding bearing **91** is pressure fitted into the large-diameter section of the output shaft **14***b*, and one side surface (right-side surface in FIG. **57**) of the sliding bearing **91** is pressed against the other end surface of the torsion bar **15**. By doing so, the torsion bar **15** is held on both sides in the axial direction between the retaining ring **25***a* and sliding bearing **91**, which prevents the torsion bat **15** from displacing in the axial direction with respect to the input shaft **13** and the output shaft **14***b*. Next, by fastening the metal core **36** of the second encoder **11** around the outside of the other end section of the output shaft **14***b*, the second encoder **11** is supported by the output shaft **14***b* so as to be concentric with the output shaft **14***b*, and so as to rotate in synchronization with the output shaft **14***b*. Next, an involute connection **24***e* for preventing the relative rotation with respect to a cylindrical surface connecting connection **26***b* for maintaining concentricity is formed by fastening the fitting cylindrical section **87** of the metal core **35** of the first encoder **10** onto a small-diameter section **92** that is provided on the other end section of the coupling shaft **9**, and a retaining ring **25***d* prevents the metal core **35** from displacing in the axial direction. As a result, the first encoder **10** is fastened to and supported by the input shaft **13** by way of the coupling shaft **9** so as to be concentric with the input shaft **13**, and so as to be able to rotate in synchronization with the input shaft **13**, and the outer-circumferential surface of one end section (right-end section in FIG. **57**) of the fitting cylindrical section **87** is made to slide over or closely face the inner-circumferential surface of the sliding bearing.

**[0220]** The procedure for assembling the rotation transmission device of this example is not limited to the procedure described above. In other words, it is also possible to insert the coupling shaft **9** into the inner-diameter side of the torsion bar **15** after the torsion bar **15** is supported on the inner-diameter side of the input shaft **13** and output shaft **14***b*, or it is also possible to pressure fit the sliding bearing **91** into the other end section of the output shaft **14***b* and then support the torsion bar **15** with the rim section **34** of the coupling shaft **9** prevented from displacement in the axial direction with respect to the input shaft **13** by the pair of retaining ring **25***a*, **25***c*.

**[0221]** Moreover, it is also possible to cause the outer-circumferential surface of the sliding bearing **91** to slide over or closely face the large-diameter section **90** of the output shaft **14***b* by pressure fitting the sliding bearing **91** onto the outer-circumferential surface of one end section of the fitting cylindrical section **87** of the metal core **35** of the first encoder **10**.

**[0222]** In this example, a sliding bearing **91** is provided between the large-diameter section **90** that is provided on the inner-circumferential surface of the other end section of the output shaft **14***b* and the outer-circumferential surface of one end section of the fitting cylindrical section **87** of the metal core **35** of the first encoder **10**, so it is possible to keep the amount of run-out of the first encoder **10** with respect to the second encoder **11** that is associated with the error in torque measurement small. In other words, the inner-circumferential surface of the sliding bearing **91** that is pressure fitted into the large-diameter section **90** is made to slide over or closely face the outer-circumferential surface of the fitting cylindrical section **87** that is fastened around the outside of the other end section of the coupling shaft **9**, so it is possible to improve the concentricity between the center of rotation of the first encoder **10** that is fastened to and supported by the other end section of the coupling shaft **9** and the center of rotation of the second encoder **11** that is fastened to and supported by the output shaft **14***b*. As a result, it is possible to keep the amount of run-out of the first encoder **10** with respect to the second encoder **11** small.

**[0223]** In this example, one side surface of the sliding bearing **91** that is pressure fitted into the large-diameter section **90** of the output shaft **14***b* is pressed against the other end surface of the torsion bar **15**. Therefore, when compared with the case when the torsion bar **15** is held on both sides in the axial direction by retaining rings **25***a*, **25***b* that are fastened around the inner-circumferential surfaces of the input shaft **13** and output shaft **14** (**14***a*) (see FIG. **6**), it is possible to effectively prevent looseness in the axial direction of the torsion bar **15** with respect to the input shaft **13** and output shaft **14***b*. Moreover, it is not necessary to provide a fastening groove for fastening the retaining ring **25***b* (see FIG. **5** and FIG. **6**) in the inner-circumferential surface of the other end section of the output shaft **14***b*, so it is possible to shorten the dimension in the axial direction of the output shaft **14***b*, and thus it is possible to make the rotation transmission device more compact and lightweight.

## Twenty-Sixth Example

**[0224]** FIG. **58** illustrates a twenty-sixth example of an embodiment of the present invention. A feature of this example, and in the twenty-fifth example of an embodiment, is to keep the amount of run-out of the first encoder **10** with respect to the second encoder **11** that is associated with error in torque measurement small by improving the concentricity of the centers of rotation of the first and second encoders **10**, **11**. In this example, the coupling shaft **9***c* is supported by the input shaft **13***d* so as to be concentric with the input shaft **13***d* and so as to rotate in synchronization with the input shaft **13***d* by pressure fitting an outward-facing flange shaped rim sec-

tion **34***b* that is formed around the outer-circumferential surface of one end section of the coupling shaft **9***c* into a large-diameter section **93** that is provided around the inner-circumferential surface of one end section of the input shaft **13***d*. Then, the other side surface (right-side surface in FIG. **58**) of the rim section **34***b* is pressed against one end surface (right-end surface in FIG. **58**) of the torsion bar **15**, directly, or in other words, not by way of another member.

**[0225]** In this example, the coupling shaft **9***c* is supported by the input shaft **13***d* by pressure fitting the rim section **34***b* of the coupling shaft **9***c* into the large-diameter section of the input shaft **13***d*. Therefore, when compared with the case of supporting the coupling shaft **9** by the input shaft by way of the involute spline connection **24***a*, it is possible to improve the concentricity of not only the center axis of the coupling shaft **9***a* and the center axis of the input shaft **13***a*, but the center axis of the output shaft **14** as well. As a result, it is possible to further improve the concentricity of the centers of rotation of the first and second encoders **10**, **11**, and thus it is possible to keep the amount of run-out of the first encoder **10** with respect to the second encoder **11** that is associated with error in torque measurement small.

**[0226]** Moreover, in this example, the other side surface of the rim section **34***b* that is pressure fitted into the large-diameter section **93** of the input shaft **13***d* is pressed against one end surface of the torsion bar **15**. Therefore, compared with the case of holding the torsion bar **15** on both sides in the axial direction by the retaining rings **25***a*, **25***b* that are fastened around the inner-circumferential surfaces of the input shaft **13** and output shaft **14**, it is possible to effectively prevent looseness in the axial direction of the torsion bar **15** with respect to the input shaft **13***a* and output shaft **14**. Furthermore, there is no need to provide fastening grooves around the inner-circumferential surface of the other end section of the input shaft **13***a* for fastening the retaining ring **25***a*, **25***c*, so it is possible to shorten the dimension in the axial direction of the input shaft **13***d*, and thus it is possible to make the rotation transmission device more compact and lightweight. The twenty-fifth example and twenty-six example of embodiments can be embodied at the same time.

## Twenty-Seventh Example

**[0227]** FIG. **59** and FIG. **60** illustrate a twenty-seventh example of an embodiment of the present invention. In this example, the construction of the sensor unit **12***d*, and the construction for supporting the sensor unit **12** by the housing (not illustrated in the figures) is devised in order to simplify positioning of the sensor unit **12***d* with respect to the first and second encoders **10**, **11**, and to improve the reliability of the torque measurement.

**[0228]** In this example, the output shaft **14** is supported by a conical roller bearing **29***g* that is located between a portion near the other end (left end in FIG. **59**) of the outer-circumferential surface of the output shaft **14** and the inner-circumferential surface of the housing so as to rotate freely with respect to the housing. However, the half of the outer ring **94** of the conical roller bearing **29***g* near the other end side in the axial direction functions as an extended cylindrical section **95** that protrudes further in the axial direction than the end section on the small-diameter side of the inner ring **30***g* of the conical roller bearing **29***g*. The inner-circumferential surface of the extended cylindrical section **95** is screwed onto the other end section of the outer-circumferential surface of the output shaft **14** and tightened so as to face the outer-circumferential surface of a nut **32***b*.

**[0229]** In this example, the sensor unit **12** includes a sensor cover **96**, a sensor holder **97**, and a first and second sensor **42***a*, **42***b*. The sensor cover **96** is formed using metal sheet into a cylindrical shape with a bottom, and includes a cover cylinder section **98** and a cover bottom plate section **99** that covers the opening on the base end of the cover cylinder section **98**. Moreover, an outward-facing flange shaped rim section **100** is provided on the portion near the tip end of the outer-circumferential surface of the cover cylinder section **98**, and a through hole **101** is provided in part of the cover bottom plate section **99** (portion near the outer circumference in the example in the figure). The sensor holder **97** is formed into a complete cylindrical shape with a bottom using a synthetic resin, and is fastened to and supported by the inner surface of the sensor cover **96** by insert molding or adhesive. First and second sensors **42***a*, **42***b* are embedded in the cylindrical portion of the sensor holder **97** that is located on the inner-diameter side of the cover cylinder section **98**. Moreover, a connector section **102** that is provided on part of the sensor holder **97** protrudes through the through hole **101** to the outside of the sensor cover **96**. The end section of a harness for the output signals from the first and second sensors **42***a*, **42***b* can be connected to or disconnected from this connector section **102**.

**[0230]** In this example, the sensor unit **12***a* having construction such as described above is fastened to and supported by the housing by way of an outer ring **94**. More specifically, the tip-end section of the cover cylinder section **98** of the sensor cover **96** is pressure fitted into the inner-circumferential surface of the tip-end section of the extended cylindrical section of the outer ring **94** and connected with an interference fit. Moreover, the sensor unit **12***d* is positioned in the axial direction with respect to the outer ring **94** by bringing the side surface of a rim section **100** that is provided on the portion near the tip end of the outer-circumferential surface of the cover cylinder section **98** into contact with the tip-end surface of extended cylindrical section **95**. Then, in this state, the first and second encoders **10**, **11** are placed in a space on the inside of the sensor cover **96**, and detecting sections of the first and second sensors **42***a*, **42***b* are made to face first and second detected sections **39**, **40** of the first and second encoders **10**, **11**.

**[0231]** In this example, a seal ring **104** is installed between a space where plural rollers **103** of the conical roller bearing **29***g* are located, and a space on the inside of the sensor cover **96** where the first and second detected sections **39**, **40** are arranged, and functions as a seal device for partitioning between these spaces. The seal ring **104** includes a circular ring-shaped metal core **105** having an L-shaped cross section, and a circular ring-shape seal member **106** that is reinforced by the metal core **105**. The metal core **105** fits around the outer-circumferential surface of the tip-end section of the nut **32**, which is a cylindrical surface, by an interference fit, and the tip-end edge of the seal lip of the seal member is made to come in contact with the inner-circumferential surface of the base-end section of the extended cylindrical section **95**, which is a cylindrical surface. As a result, lubrication oil that includes foreign magnetic matters such as iron powder that is supplied to the space where the conical rollers **75** are located is prevented from passing through the portion between the inner-circumferential surface of the extended cylindrical sec-

tion **95** and the outer-circumferential surface of the tip-end section of the nut **32***b*, and getting into the space inside the sensor cover **96**. By doing so, a drop in the reliability of the output signals from the sensor unit **12** due to lubrication oil that includes foreign magnetic matters such as iron powder is prevented from adhering to the tip-end surfaces of the first and second encoders **10**, **11**, and the sensor unit, and disturbance in the regular and periodic magnetic change in the circumferential direction of the first and second encoder **10**, **11** is prevented. This kind of seal device is not limited to this seal ring **104**, and various forms can be used. For example, it is also possible to use a seal member in which a metal core fits around the inner-circumferential surface of the extended cylindrical section **95**, and the tip-end edge of the seal lip comes in sliding contact with the surface of the nut **32***b* (or output shaft **14**). In either case, using a seal device having good seal characteristics, and for which the sliding resistance between the tip-end edge of the seal lip and the opposing surface is kept low is preferred.

**[0232]** In this example, the sensory unit **12***d* is fastened to and supported by the outer ring **94** of a conical roller bearing **29***c* that is installed between the output shaft **14** and the housing. Therefore, when compared with construction in which the sensor unit **12** and the rotary-shaft unit **6** (see FIG. **6**) that supports the first and second encoders **10**, **11** are separately fastened to and supported by the housing, it is easier to maintain the positioning precision of the sensor unit **12***d* with respect to the first and second encoders **10**, **11**. Moreover, it is possible to assemble the sensor unit **12***d* and rotary-shaft unit **6** in a specified positional relationship before assembly inside the housing, and that positional relationship does not move after that, so from this aspect, maintaining positional precision becomes easier.

**[0233]** In this example, the first and second detected sections **39**, **40** and the detecting sections of the first and second sensors **42***a*, **42***b* are arranged inside the sensor cover **96**, and a seal ring **104** is installed between the space inside the sensor cover **96** and the space where the plural conical rollers **103** of the conical roller bearing **29***g* are located so as to be a partition between these spaces. Therefore, it is possible to suppress or prevent lubrication oil that is inside the housing and that includes magnetic foreign matter (including lubrication oil that is supplied to the space where the conical rollers **103** are located) from adhering to the first and second detected sections **39**, **40** and the detecting sections of the first and second sensors **42***a*, **42***b*. As a result, it is possible to further improve the reliability of torque measurement.

**[0234]** In this example, the first and second encoders **10**, **11** are housed in a space inside the sensor cover **96**, so, for example, the first and second encoders **10**, **11** are prevented from bumping the housing and becoming damaged when assembling the sensor unit **12***d* and rotary-shaft unit **6** in the housing after the sensor unit **12***d* and rotary-shaft unit **6** (see FIG. **6**) have been assembled. Moreover, in the stage before assembling portions other than the housing inside the housing, it is possible to check the output signals of the first and second sensors **42***a*, **42***b*. Furthermore, in the completed state, even when there is deformation of the housing, it is difficult for the positional relationship of the first and second detected sections **39**, **40** and the detecting sections of the first and second sensors **42***a*, **42***b* to change. From this aspect as well, it is possible to improve the reliability of the torque measurement.

**[0235]** The rolling bearing for supporting the input shaft and output shaft so as to freely rotate with respect to the housing is not limited to a conical roller bearing, and it is also possible to use other types of bearings such as an angular ball bearing. The other construction and functions are the same as those of the first through twenty-sixth examples of embodiments.

## Twenty-Eighth Example

**[0236]** FIG. **61** illustrates a twenty-eighth example of an embodiment of the present invention. In this example as well, the construction of the installation location of the first and second encoders **10***a*, **11***a* is devised in order to improve the precision of torque measurement. In other words, the inner ring **30***h* of a conical roller bearing **20***h* for supporting the output shaft **14***c* so as to rotate freely with respect to the housing is fastened around a portion near the other end of the output shaft **14***c*, and the end surface on the large-diameter side of the inner ring **30** is made to come in contact with a stepped surface **33** that s formed in a portion near the other end of the outer-circumferential surface of the output shaft **14***c*. Then, in this state, the inner ring **30***h* is fastened around the outside of the output shaft **14***c* by pressure fitting the end surface on the small-diameter side of the inner ring **30***h* with a nut **32***c* that is screwed onto the other end section of the outer-circumferential surface of the output shaft **14***c* and tightened. Particularly, in this example, a cylindrical shaped extended cylindrical section **107** that protrudes in the axial direction from the inner-diameter side of the outer ring **94***a* of the conical roller bearing **29***h* is integrally provided on the end section on the small-diameter side of the inner ring **30***h*, which is the end section on the other end side of the output shaft **14***c*. Moreover, a through hole **108** in the radial direction is provided in a portion near the small-diameter side of the inner ring **30***h*. Lubrication oil can be supplied from an oil passage **44***b* through this through hole **108** to the inside of the conical roller bearing **29***h*.

**[0237]** In this example, the metal core **36***a* of the second encoder **11***a* is fastened around the outside of the extended cylindrical section **107**. In other words, the second encoder **11***a* is fastened around the outside of a portion near the other end of the output shaft **14***c* by way of the extended cylindrical section **107** of the inner ring **30***h*. Moreover, the metal core **36***a* of the second encoder **11***a* is formed into a complete circular ring shape having a crank shaped cross section, and includes a small-diameter cylindrical section **109** and large-diameter cylindrical section **110** that are arranged so as to be concentric with each other, and a ring section **111** that connects the edges on the ends in the axial direction of these cylindrical sections **109**, **110**. A cylindrical shaped permanent magnet **38***a* is fastened to the outer-circumferential surface of the large-diameter cylindrical section **110**. The second encoder is fastened to the inner ring **30***h* by fastening the small-diameter cylindrical section **109** of the metal core **36***a* around the outside of the extended cylindrical section **107** of the inner ring **30***h* with an interference fit. Moreover, in this state, the large-diameter cylindrical section **110** and permanent magnet **38***a* are arranged on the other-diameter side of half (right half in FIG. **61**) in the axial direction of the nut **32***c* in positions that overlap in the radial direction with this half in the axial direction. In other words, in this example, the cylindrical shaped second detected section **40***a*, which is the outer-circumferential surface of the permanent magnet **38***a*, is arranged on the outer-diameter side of half in the axial direc-

tion of the nut **32***c* so as to overlap in the radial direction this half in the axial direction (and other end section of the output shaft **14***c*).

**[0238]** Moreover, the metal core **35***a* of the first encoder **10***a* is formed into a complete circular ring shape with a C-shaped cross section, and includes a small-diameter cylindrical section **112** and a large-diameter section **113** that are arranged so as to be concentric with each other, and a ring section **114** that connects the end sections in the axial direction of these cylindrical sections **112**, **113**. A cylindrical-shaped permanent magnet **37***a* is fastened around the outer-circumferential surface of the large-diameter cylindrical section **113**. The small-diameter cylindrical section **112** of the first encoder **10***a* is fastened around the outside of the other end section (left-end section in FIG. **61**) of the coupling shaft **9**. The connection between the inner-circumferential surface of the small-diameter cylindrical section **112** and the outer-circumferential surface of the other end section of the coupling shaft **9** is formed by arranging a cylindrical connection **26***b* for maintaining concentricity and an involute spline connection **24***e* for preventing relative rotation so as to be adjacently in contact with each other in the axial direction. Moreover, the small-diameter cylindrical section **112** is prevented from coming apart from the coupling shaft **9** by a retaining ring **25***d* that is fastened around the outer-circumferential surface of the other end section of the coupling shaft **9**. In this state, one end section (right-end section in FIG. **61**) and the middle section in the axial direction of the large-diameter cylindrical section **113** and permanent magnet **37***a* are arranged on the outer-diameter side of the other half (left half in FIG. **61**) in the axial direction of the nut **32***c* in positions that overlap in the radial direction this other half in the axial direction. In other words, in this example, one end section and middle section in the axial direction of the cylindrical-shaped first detected section **39***a*, which is the outer-circumferential surface of the permanent magnet **37***a*, is arranged around the outer-diameter side of the other half in the axial direction of the nut **32***c*, in a position that overlaps in the radial direction the other half section (or output shaft **14***c*) in the axial direction.

**[0239]** As a result, the first detected section **39***a* and second detected section **40***a* are adjacent in the axial direction and are arranged close to each other (for example, arranged so as to be separated by a space of 5 mm or less in the axial direction). The sensor unit **12** is fastened to and supported by the housing so that of the first and second sensor **42***a*, **42***b* of the sensor unit **12**, the detecting section of the first sensor **42***a* closely faces in the radial direction the first detected section **39***a*, and the detecting section of the second sensor **42***b* closely faces in the radial direction the second detected section **40***a*.

**[0240]** In this example, the cylindrical shaped second detected section **40***a* of the second encoder **11***a* is arranged around the outer-diameter side of half in the axial direction of the nut **32***c* so as to overlap in the radial direction that half in the axial direction, so compared with the first example of an embodiment, it is possible to shorten the distance D**40** in the axial direction from the center section in the axial direction of the array of rolling bodies of the conical roller bearing **29***h* to the second detected section **40***a*. Therefore, it is possible to keep displacement and inclination in the radial direction of the second detected section **40***a* that occurs as the output shaft **14***c* bends about the conical roller bearing **29***h* as a fulcrum due to the gear reaction force in the radial direction that acts on the output gear **8** being applied to the output shaft **14** when torque is being transmitted, small. Furthermore, of the cylindrical shaped first detected section **39***a* of the first encoder **10***a* that is fastened around the outside of the other end section of the coupling shaft **9**, the one end section to middle section in the axial direction is arranged around the outer-diameter side of the other half in the axial direction of the nut **32***c* in a position that overlaps in the radial direction this other half in the axial direction. Therefore, when compared with the first example of an embodiment, it is possible to shorten the distance D**39** in the axial direction from the center section in the axial direction of the array of rolling bodies of the conical roller bearing **29***h*. Consequently, even when the coupling shaft **9** bends about the conical roller bearing **29***h* as a fulcrum due to gear reaction force in the radial direction when torque is being transmitted, it is possible to keep displacement and inclination in the radial direction of the first detected section **39***a* that occurs due to this bending, small.

**[0241]** Therefore, in this example, when compared with construction in which the entire second detected section **40** of the second encoder **11** that is fastened around the outside of the other end section of the output shaft **14**, and the entire first detected section **39** of the first encoder **10** that is fastened around the other end section of the coupling shaft **9** are arranged in a portion that protrudes further toward the other side in the axial direction than the other end section of the output shaft **14**, such as in the case of the first example of an embodiment, it is possible to prevent contact between the first and second detected sections **39***a*, **40** and the tip-end surface of the sensor unit **12** even when the space between the first and second detected sections **39***a*, **40***a* and the tip-end surface of the sensor unit **12** is small, and regardless of whether elastic deformation such as bending of the members occurs due to gear reaction force in the radial direction that acts when torque is being transmitted. Moreover, it is possible to reduce shifting between the centers of rotation of the first and second detected sections **39***a*, **40***a* that occurs due to displacement or inclination in the radial direction of the first and second detected sections **39***a*, **40***a*. As a result, when compared with the case of the first example of an embodiment, it is possible to further improve the precision of torque measurement.

**[0242]** In this example, from one end section to the middle section in the axial direction of the first detected section **39***a*, and the second detected section **40***a* are arranged around the outer-diameter side of the nut **32***c* that is screwed onto and fastened the outer-circumferential surface of the other end section of the output shaft **14***c* in positions that overlap in the radial direction with the nut **32***c*. Therefore, when compared with construction in which the entire first and second detected sections **39**, **40** are arranged in a portion that protrudes further toward the other side in the axial direction than the other end section of the output shaft **14** such as in the first example of an embodiment, it is possible to shorten the dimension in the axial direction of the rotation transmission device. As a result, it is possible to make the rotation transmission device more compact and lightweight. The other construction and functions are the same as those of the first through twenty-seventh examples of embodiments.

## Twenty-Ninth Example

**[0243]** FIG. **62** to FIG. **65** illustrates a twenty-ninth example of an embodiment of the present invention. In this example, the first and second encoder **10***e*, **11***e*, and the sensor

unit **12***e* are arranged in the middle section of the rotary-shaft unit **6***a*, in a portion between the input gear **7** and output gear **8** in the axial direction.

**[0244]** In order for this, the first encoder **10***e* is integrally formed on the tip-end surface (left-end surface in FIG. **62** and FIG. **65**) of a parking-lock gear **28** that is integrally formed in a portion near the inner circumference on one side surface of the input gear **7**. In other words, the first encoder **10***e* is formed by arranging plural magnetic metal convex sections **50***a* that are integrally formed so as to protrude in the axial direction from the tip-end surface of the parking-lock gear **28** so as to have a uniform pitch in the circumferential direction. The entire first encoder **10***e* functions as a first detected section **39***e*. The first encoder **10***e* is fastened to the input shaft **13** by way of the input gear **7** and parking-lock gear **28**. Moreover, the second encoder **11***e* is integrally formed with a portion that is near the outer-circumferential surface of the output shaft **14**, and that is adjacent in the axial direction to the output gear **8**. In other words, the second encoder **11***e* is formed by arranging plural magnetic metal convex sections **50***b* that are integrally formed so as to protrude in the radial direction from a portion near on end of the outer-circumferential surface of the output shaft **14** so as to have a uniform pitch in the circumferential direction. The entire second encoder **11***e* functions as a second detected section **40***e*. In this example, the first and second encoders **10***e*, **11***e* have the same outer-diameter dimensions, and are arranged so as to be concentric with each other and so as to be closely adjacent to each other in the axial direction. The total number of convex sections **50***a* and the total number of convex sections **50***b* are the same as each other. Moreover, the width in the circumferential direction of the convex sections **50***a* and the width in the circumferential direction of the convex sections **50***b* are the same as each other. Furthermore, when torque is not being transmitted, the phases in the circumferential direction of the convex sections **50***a* and convex sections **50***b* coincide.

**[0245]** The sensor unit **12***e* includes a holder **41***c* that is made of a synthetic resin, and first and second sensors **42***e*, **42***f* that are embedded in the tip-end sections of the holder **41***c*. The sensor unit **12***e* is supported by a housing (not illustrated in the figures) so that the detecting section of the first sensor **42***e* closely faces the outer-circumferential surface of the first encoder **10***e* (first detected section **39***e*), and the detecting section of the second sensor **42***f* closely faces the outer-circumferential surface of the second encoder **11***e* (second detected section **40***e*). Each of the sensors **42***e*, **42***f* includes a permanent magnet that is magnetized in the direction that the outer-circumferential surface of the encoder **10***e*, **11***e* faces the detecting section of the sensor **42***e*, **42***f*; and a magnetism-detecting element such as a Hall element, Hall IC, MR element, GMR element or the like that is located in the end surface of both end surfaces in the direction of magnetization of the permanent magnet. One permanent magnet can also be shared as the permanent magnet of the sensors **42***e*, **42***f*.

**[0246]** In this example, there is no coupling shaft on the inner-diameter side of the torsion bar **15***c*. An oil inlet passage **43***a* that is on only one end surface is provided in the center section in the radial direction of the torsion bar **15***c*. In this example, lubrication oil that enters inside the oil inlet passage **43***a* through the opening on one end section of the oil inlet passage **43***a* is supplied to the inside of a pair of oil passages **44***a*, **44***b* that are provided in portions near both ends of the rotary-shaft unit **6***a*.

**[0247]** In this example, as in the first example of an embodiment, the frequency (and period) of the output signals from the first and second sensors **42***e*, **42***f* of the sensor unit **12***e* is a value that corresponds to the rotational speed of the rotary-shaft unit **6***a*. Therefore, it is possible to find the rotational speed based on the frequency (or period). Moreover, the phase difference ratio (=phase difference/1 period) between the output signals of the first and second sensors **42***e*, **42***f* is a value that corresponds to the torque that is transmitted by the rotary-shaft unit **6***a* between the input gear **7** and the output gear **8**. Therefore, it is possible to find the torque based on this phase difference ratio. The other construction and functions are the same as those of the first example of an embodiment.

**[0248]** When embodying the construction of each of the examples of embodiments described above, as long as there are no evident contradictions in the construction, it is possible to freely combine the construction of the examples of embodiments.

## INDUSTRIAL APPLICABILITY

**[0249]** The form of a transmission in which the present invention is assembled and used is not particularly limited as long as the construction has a counter shaft and a counter gear, and it is possible to use various kinds of transmissions such as an automatic transmission (AT), continuously-variable transmission (CVT), manual transmission (MT) and the like. Moreover, the rotational speed and torque that are measured can be used for other control of an automobile besides transmission control. Furthermore, a motor that is placed on the up-stream side of the transmission does not absolutely need to be an internal-combustion engine such as a gasoline engine or a diesel engine, and it is also possible for the motor to be an electric motor that is used, for example, in a hybrid automobile or an electric automobile. In either case, present invention can be widely applied to various kinds of machinery in which it is necessary to transmit torque by a rotary shaft, and to measure the torque that is transmitted by the rotary shaft.

**[0250]** Furthermore, when embodying the present invention, it is necessary to measure the torque, however, except for construction in which voltage is generated in a coil (when using an induced electromotive force), it is not necessary to measure the rotational speed. Even when knowing the rotational speed is necessary, it is possible to measure that rotational speed by using separate and simple construction.

## EXPLANATION OF REFERENCE NUMBERS

**[0251]** **1** Rotary shaft
**[0252]** **2**, **2***a* Encoder
**[0253]** **3** Sensor
**[0254]** **4** Harness
**[0255]** **5** Sensor unit
**[0256]** **6**, **6***a* Rotary-shaft unit
**[0257]** **7** Input gear
**[0258]** **8** Output gear
**[0259]** **9**, **9***a*, **9***b* Coupling shaft
**[0260]** **10**, **10***a* to **10***h* First encoder
**[0261]** **11**, **11***a* to **11***h* Second encoder
**[0262]** **12**, **12***a* to **12***e* Sensor unit
**[0263]** **13**, **13***a* to **13***c* Input shaft
**[0264]** **14**, **14***a* to **14***c* Output shaft
**[0265]** **15**, **15***a* to **15***c* Torsion bar
**[0266]** **16** Input-side combination cylinder
**[0267]** **17** Output-side combination cylinder

[0268] **18** Radial needle bearing
[0269] **19** Stepped surface
[0270] **20** Tip-end surface
[0271] **21**, **21***a* to **21***c* Thrust washer
[0272] **22** Slit
[0273] **23** Reinforcing cylindrical section
[0274] **24***a* to **24***e*, **24***a***1**, **24***b***1** Involute spline connection
[0275] **25***a* to **25***d* Retaining ring
[0276] **26***a*, **26***b* Cylindrical connecting section
[0277] **27** Stepped surface
[0278] **28** Packing-lock gear
[0279] **29***a* to **29***h* Conical roller bearing
[0280] **30***a* to **30***h* Inner ring
[0281] **31** Spacer
[0282] **32***a* to **32***c* Nut
[0283] **33** Stepped surface
[0284] **34** Rim section
[0285] **35**, **35***a*, **35***b* Metal core
[0286] **36**, **36***a*, **36***b* Metal core
[0287] **37**, **37***a* to **37***c* Permanent magnet
[0288] **38**, **38***a* to **38***c* Permanent magnet
[0289] **39**, **39***a* to **39***e* First detected section
[0290] **40**, **40***a* to **40***e* Second detected section
[0291] **41**, **41***a* to **41***c* Holder
[0292] **42***a* to **42***f* (First, Second) Sensor
[0293] **43**, **43***a* Oil inlet passage
[0294] **44***a*, **44***b* Oil passage
[0295] **45***a*, **45***b* Ring-shaped space
[0296] **46***a*, **46***b* Oil groove
[0297] **47** Cylindrical space
[0298] **48** Tip-end surface
[0299] **49** Stepped surface
[0300] **50**, **50***a*, **50***b* Convex section
[0301] **51**, **51***a* to **51***d* Tongue piece
[0302] **52** Stator
[0303] **53** Conducting wire
[0304] **54** Coil
[0305] **55** Core
[0306] **56** Rim section
[0307] **57** Sleeve bearing
[0308] **58** Thrust needle bearing
[0309] **59** Pin
[0310] **60** Engagement hole
[0311] **61** Oil passage
[0312] **62**, **62***a* First male involute spline section
[0313] **63**, **63***a* First male involute spline section
[0314] **64**, **64***a* Second female involute spline section
[0315] **65**, **65***a* Second female involute spline section
[0316] **66***a*, **66***b* Concave groove
[0317] **67***a*, **67***b* Through hole
[0318] **68** Concave hole
[0319] **69** Pin
[0320] **70***a*, **70***b* Concave section
[0321] **71** Convex section
[0322] **72***a*, **72***b* Marking
[0323] **73***a*, **73***b* Marking
[0324] **74** First plating layer
[0325] **75** Second plating layer
[0326] **76** Cylindrical surface
[0327] **77** Cylindrical surface
[0328] **78** Tube section
[0329] **79** Inclined surface section
[0330] **80** First fastener
[0331] **81** Second fastener
[0332] **82** Input-side rotating body
[0333] **83** Input-side unit
[0334] **84** Output-side rotating body
[0335] **85** Output-side unit
[0336] **86** Stepped surface
[0337] **87** Fitting cylindrical section
[0338] **88** Ring section
[0339] **89** Cylindrical section
[0340] **90** Large-diameter section
[0341] **91** Sliding bearing
[0342] **92** Small-diameter section
[0343] **93** Large-diameter section
[0344] **94**, **94***a* Outer ring
[0345] **95** Extended cylindrical section
[0346] **96** Sensor cover
[0347] **97** Sensor holder
[0348] **98** Cover cylinder section
[0349] **99** Cover bottom plate section
[0350] **100** Rim section
[0351] **101** Through hole
[0352] **102** Connector section
[0353] **103** Conical roller
[0354] **104** Seal ring
[0355] **105** Metal core
[0356] **106** Seal ring
[0357] **107** Extended cylindrical section
[0358] **108** Through hole
[0359] **109** Small-diameter cylindrical section
[0360] **110** Large-diameter cylindrical section
[0361] **111** Ring section
[0362] **112** Small-diameter cylindrical section
[0363] **113** Large-diameter cylindrical section
[0364] **114** Ring section
[0365] **115**, **115***a* Spring section

What is claimed is:

**1**. A rotation transmission device comprising:

a rotary-shaft unit that comprises: a first rotary shaft and a second rotary shaft that are both hollow, and together with being arranged so as to be concentric with each other, are combined so that the end sections of each are able to rotate relative to each other, and in this state are supported by a housing so as to rotate freely; and a torsion bar that is hollow and concentrically arranged on the inner-diameter side of the first and second rotary shafts, with one end section being connected to the first rotary shaft so that relative rotation is not possible, and the other end section being connected to the second rotary shaft so that relative rotation is not possible;

a first gear that is provided in the middle section in the axial direction of the outer-circumferential surface of the first rotary shaft;

a second gear that is provided in the middle section in the axial direction of the outer-circumferential surface of the second rotary shaft;

a first encoder that is fastened to one of the first and second rotary shafts so as to be concentric with that one rotary shaft, and comprising a first detected section that is magnetized so that the magnetic characteristics change in an alternating manner at a uniform pitch;

a second encoder that is fastened to the other of the first and second rotary shafts so as to be concentric with that other rotary shaft, and comprising a second detected section that is magnetized so that the magnetic characteristics change in an alternating manner at a uniform pitch; and

a sensor unit that is supported by the housing, and comprises at least one sensor that faces the first and second detected sections, and causes an output signal to change in correspondence to the change in magnetic characteristics of a portion of the first and second detected section where the at least one sensor faces.

**2**. The rotation transmission device according to claim **1**, wherein the torsion bar comprises a spring section, which is a portion in the middle section in the axial direction of the torsion bar that undergoes elastic torsional deformation when torque is transmitted; the dimensions of that spring section being larger than the space in the axial direction between the first and second gears.

**3**. The rotation transmission device according to claim **2**, wherein the spring section comprises a tube section having a wall thickness in the radial direction in the middle section in the axial direction except for the portions of the edges on both ends in the axial direction that is less than the portions of the edges on both ends in the axial direction, and is such that the inner-circumferential surface and outer-circumferential surface are single cylindrical surfaces that are concentric with each other; the ratio di/do of the inner-diameter dimension di and outer-diameter dimension do of that tube section being within the range $0.5 \leq di/do \leq 0.8$.

**4**. The rotation transmission device according to claim **2**, wherein the spring section comprises a tube section having a wall thickness in the radial direction in the middle section in the axial direction except for the portions of the edges on both ends in the axial direction that is less than those portions of the edges on both ends in the axial direction, and is such that the inner-circumferential surface and outer-circumferential surface are single cylindrical surfaces that are concentric with each other; the ten-point average roughness Rz of that tube section being within the range $Rz \leq 22$ μm.

**5**. The rotation transmission device according to claim **1**, wherein the torsion bar is such that the one end section and the other end section are connected to the end sections of the first and second rotary shafts that are opposite the end sections that are combined together.

**6**. The rotation transmission device according to claim **1**, further comprising a coupling shaft that is arranged on the inner-diameter side of the torsion bar and arranged concentric with the torsion bar, with one end section being connected to one of the rotary shafts so that relative rotation is not possible, and the other end section protruding in the axial direction from the end section of the torsion bar; and wherein

the first encoder is fastened to the other end section of the coupling shaft;

the second encoder is fastened to the end section on the other end section side of the coupling shaft of the other rotary shaft so at to be close to the first encoder; and

the first and second detected sections are arranged so as to be close to each other.

**7**. The rotation transmission device according to claim **6**, wherein a sliding bearing is provided between the inner-circumferential surface of the end section on the other end section side of the coupling shaft of the other rotary shaft and the outer-circumferential surface of the coupling shaft or a fitting cylindrical section of a metal core of the first encoder that fits on the coupling shaft.

**8**. The rotation transmission device according to claim **6**, wherein the coupling shaft comprises a rim section on the outer-circumferential surface of the one end section, and the coupling shaft is supported by that rim section being pressure fitted with the inner-circumferential surface of the end section on the one end side of the coupling shaft of the one rotary shaft so that relative rotation with respect to that one rotary shaft is not possible.

**9**. The rotation transmission device according to claim **6**, wherein

the other rotary shaft is supported by a rolling bearing that is located between the portion of the outer-circumferential surface of the other rotary shaft that is near the end section on the other end section side of the coupling shaft and the inner-circumferential surface of the housing so as to rotate freely with respect to the housing; and

the sensor unit comprises a sensor cover and a detecting section that is fastened to and supported by the inside of the sensor cover; and by fastening the sensor cover to and supporting the sensor cover by the end section of the outer ring of the rolling bearing on the other end section side of the coupling shaft of the other rotary shaft so that the first and second encoders are located in a space inside the sensor cover, the detecting section is made to face the first and second detected sections.

**10**. The rotation transmission device according to claim **9**, wherein a seal device is located between the space where plural rolling bodies of the rolling bearing are located and the space on the inside of the sensor cover where the first and second detected sections are located, and functions as a partition between these spaces.

**11**. The rotation transmission device according to claim **6**, wherein

the other rotary shaft is supported by a rolling bearing that is located between the portion of the outer-circumferential surface of that other rotary shaft near the end section on the other end section side of the coupling shaft and the inner-circumferential surface of the housing so as to rotate freely with respect to the housing; and

the second encoder is fastened around the outside of the end section of the inner ring of the rolling bearing on the other end section side of the coupling shaft.

**12**. The rotation transmission device according to claim **11** wherein

the first and second detected sections are both cylindrical shaped; and

at least one end section in the axial direction of the first and second detected sections is arranged around the outer-diameter side of the end section of the other rotary shaft on the other end section side of the coupling shaft, or another part that is fastened around the outside of that end section, in a position that overlaps in the radial direction that end section of the other rotary shaft or that other part.

**13**. The rotation transmission device according to claim **1**, wherein

the first encoder is fastened to the first rotary shaft in a position between the first and second gears in the axial direction; and

the second encoder is fastened to the second rotary shaft in a position between the first and second gears in the axial direction.

**14**. The rotating transmission device according to claim **1**, wherein

the rotary-shaft unit is supported by the housing by plural rolling bearings so as to rotate freely; and

the first rotary shaft or second rotary shaft is integrally formed with the inner ring of at least one of the plural rolling bearings.

**15**. The rotation transmission device according to claim **1**, wherein the first rotary shaft or second rotary shaft is integrally formed with the torsion bar.

**16**. The rotation transmission device with torque measurement device according to claim **1**, wherein

the sensor unit comprises a first sensor that faces the first detected section, and a second sensor that faces the second detected section; and

the first and second sensors generate output signals that change in correspondence to the change in magnetic characteristics of the portions of the first and second detected sections that the first and second sensors face.

**17**. The rotation transmission device according to claim **1**, wherein

the first and second encoders are made of a magnetic material;

the first and second detected sections comprise sections with material removed and solid sections that are arranged in an alternating manner at a uniform pitch in the circumferential direction, and are arranged so as to be close to each other and overlap in the radial or axial direction;

the sensor unit comprises a stator made of a magnetic material, and plural coils that are made of one conducting wire, and is constructed so that when a driving voltage is applied to the conducting wire, the output current or the output voltage from the conducting wire is used as an output signal;

the stator comprises: plural core sections that are arranged at a uniform pitch in the circumferential direction, extend in the overlapping direction of the first and second detected sections, and the tip-end surfaces face one of the first and second detected sections from one side in the overlapping direction of the first and second detected sections; and a circular ring-shaped rim section that connects together the base-end sections of the plural core sections; and

the plural coils are fastened one by one around the plural core sections, and are such that the winding directions of coils that are adjacent in the circumferential direction are opposite each other.

**18**. The rotation transmission device according to claim **1**, wherein

the first and second encoders are made of a magnetic material;

the first and second detected sections comprise sections with material removed and solid sections that are arranged in an alternating manner at a uniform pitch in the circumferential direction, and the solid sections of the first detected section and the solid sections of the second detected section are arranged in an alternating manner in the circumferential direction with a space in between each in the circumferential direction; and

the sensor unit comprises one sensor that faces the portion where the solid sections are alternatingly arranged, and that sensor generates an output signal that changes in correspondence to the change in the magnetic characteristics of the portion where the sensor faces the solid sections of the first and second detected sections are alternatingly arranged.

**19**. The rotation transmission device according to claim **1**, wherein

the first and second detected sections comprise a pair of cylindrical surfaces that face each other in the radial direction or a pair of wheel surfaces that face each other in the axial direction, and are arranged so the S poles and N poles of these detected sections alternate at a uniform pitch in the circumferential direction; and

the sensor unit comprises a magnetism-detecting element or coil that is arranged between the first and second detected sections, and the output voltage or output current from that magnetism detecting unit, or the output voltage or output current from the coil is used as the output signal.

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