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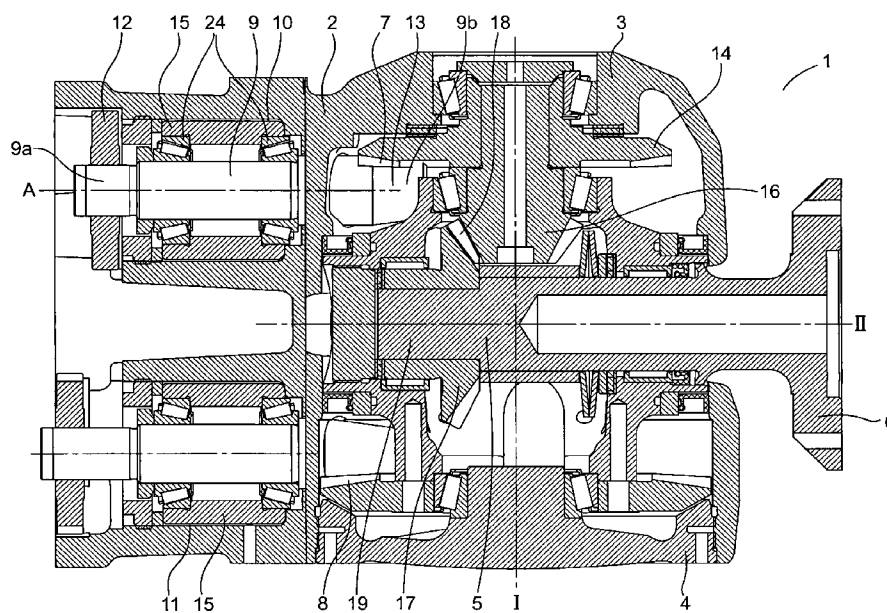
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(54) Title: A DEVICE FOR AN INDUSTRIAL ROBOT



(57) Abstract: The present invention relates to a device (1) for adjusting the backlash in bevel gears (7) in an industrial robot. The bevel gears (7) comprise a first conical gear wheel (13) with a first axis of rotation (A) and a second conical gear wheel (14). The device (1) comprises a displaceably arranged holder member (15) adapted to fix and rotatably journal the first gear wheel (4) for rotation about the first axis of rotation (A).

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A device for an industrial robot

## TECHNICAL FIELD

5 The present invention relates to a method for adjustment of backlash in an industrial robot.

## BACKGROUND ART

10 An industrial robot comprises a manipulator and control equipment. The manipulator comprises at least one robot arm comprising a number of arm parts with connecting joints, where the axes of rotation of the joints define the degrees of freedom of the robot. As an example may be mentioned a  
15 six-axis robot which usually has a fixed foot, a stand that is arranged on the foot and that is rotatable about a first axis, and a first robot arm that is rotatable in relation to the stand about a second axis. At the outer end of the first robot arm, a second robot arm is rotatably journalled for  
20 rotation about a third axis. This second arm is rotatable about a fourth axis, its own longitudinal axis, and at its outer end supports a robot hand provided with a tool attachment, said robot hand being rotatable in two degrees of  
25 tive to the second arm.

The movements of the manipulator are made possible by the arrangement of drive means that bring about rotary motions in the respective joints. Each drive means comprises an  
30 electric motor and a reduction gear. The power supply and the control of an industrial robot of the kind mentioned above are carried out by control equipment, which is not described in more detail in this context.

35 The working range and the capacity for movement of a manipulator depend, among other things, on the reduction gears included. An additional factor that is influenced by the reduction gears is the performance of a robot with respect to precision and/or accuracy. When manufacturing industrial

robots, the aim is to arrive at design solutions which enable reducing the total built-in backlash from the gears included therein as much as possible.

5 According to prior art (Figure 9) in the form of a wrist for an industrial robot, spacers, also called shims, are used to eliminate the backlash from the gears. The method comprises the steps of calculating in advance how large the backlash will be, building together the manipulator/the wrist and  
10 then measuring the actual remaining backlash. When the calculation does not correspond to the physical result, the manipulator/wrist must be detached and the process start over again with a new, hopefully more correct calculation. This is a time-consuming and expensive process.

15

For the above reasons, there is a need of a simple and rapid method to be able to adjust the backlash when mounting gears in a manipulator. This need cannot be satisfied by the prior art.

20

#### SUMMARY OF THE INVENTION

The object of the present invention is to make possible a rapid and simple adjustment of backlash when installing  
25 gears in an industrial robot.

According to a first aspect of the invention, there is provided a device for adjusting the backlash in a gearing with intersecting axes [also referred to below as *bevel gears*]  
30 in an industrial robot. The gearing comprises a first conical gear wheel with a third axis of rotation and a second conical gear wheel with a first axis of rotation, which forms a right angle with the third axis of rotation. The device comprises a displaceably arranged holder member  
35 adapted to fix and rotatably journal the first gear wheel for rotation about the third axis of rotation, which is arranged in parallel with the second axis of rotation.

In an alternative embodiment according to the present invention, the holder member is arranged linearly displaceable in a direction C, which is parallel to the axis of rotation A.

5

In an alternative embodiment, the gearing is a hypoid gearing.

10 In an alternative embodiment, the first conical gear wheel is a pinion.

In an alternative embodiment, the holder member has a continuous channel.

15 In an alternative embodiment, the pinion is journalled so as to be fixed in a continuous channel for rotating about the first axis of rotation A.

20 The inventive concept includes a wrist comprising a device for adjusting the backlash in bevel gears included in the wrist.

25 An alternative embodiment of the device comprises a holder for the pinion, which is adapted to displace the pinion linearly in relation to the gear wheel and hence to adjust the backlash between the teeth of the pinion and the gear wheel in accordance with the independent claim 1.

30 In an alternative embodiment of the device, a tool is adapted to rotatably hold and linearly displace a first gear wheel in a direction perpendicular to the axis of rotation of the gear wheel.

35 According to a second aspect of the invention, there is provided a method for adjusting the backlash in a gearing included in an industrial robot, said gearing comprising a first conical gear wheel with a first direction of rotation and a second conical gear wheel. The invention is characterized in that the first gear wheel is brought to be dis-

placed in a radial direction parallel to the first rotational direction.

5 The inventive concept comprises displacing the first gear wheel and fixing it rotatably so that the backlash in the gearing between the first and second gear wheels is eliminated.

10 The present invention enables an operator to safely install a toothed gearing in a manipulator and then to be certain that the built-in backlash is adjusted and eliminated directly when mounting the manipulator.

15 It is part of the inventive concept that the bevel gears be mounted adjacent to any of the shafts in an industrial robot.

#### BRIEF DESCRIPTION OF THE DRAWINGS

20 Figure 1 is a cross section through a robot wrist comprising a gearing according to the present invention,

Figure 2 is the same cross section as in Figure 1,

25 Figure 3 is a device for elimination of backlash in bevel gears according to the present invention,

Figure 4 is a cross section through bevel gears according to the present invention,

30 Figure 5 is a schematic cross section through bevel gears according to the present invention,

35 Figure 6 is a cross section through bevel gears according to the present invention,

Figure 7a is a cross section through a mounted holder device according to the present invention,

Figure 7b is a cross section through a mounted holder device according to the present invention,

Figure 7c is a cross section through a wrist housing with a  
5 shrunk portion according to the present invention,

Figure 8 is identical with Figure 3,

Figure 9 is the prior art.

10

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

**Figure 1** is a wrist 1 in an industrial robot. The fundamental structure of the wrist 1 comprises an outer fork-shaped wrist housing 2 with two fork branches 3, 4. The  
15 wrist housing 2 accommodates a so-called tilt housing 5 journalled for rotation about a first axis of rotation I. The tilt housing supports, in a manner known per se, a turn disc 6 rotatably journalled about a second axis of rotation  
20 II, on which turn disc a robot tool may be mounted (not shown). The first axis of rotation I is arranged perpendicular to the second axis of rotation II. The wrist comprises first bevel gears 7 for transmitting a rotary motion to the turn disc 6, said gears being described in detail below.  
25 The wrist 1 further comprises second bevel gears 8 for transmitting a rotary motion to the tilt 5, which is also described in detail below.

For transmitting the rotary motion to the turn disc 6, a  
30 first secondary drive shaft is rotatably journalled in the wrist housing 2, said drive shaft extending through a first through-hole/a channel 10 arranged in the longitudinal direction of the housing with a third axis of rotation A arranged in parallel with the axis of rotation II of the turn  
35 disc. The first secondary drive shaft 9, which is axially and radially journalled across a first double row angular contact ball bearing 24, has an inlet end 9a on which is fixedly arranged a first cylindrical gear wheel 12, which engages with a cylindrical gear drive at the end of a first

primary drive shaft (not shown), which may be inserted into the wrist housing, in the robot arm. The second, inner end 9b of the secondary drive shaft is an outlet end which is formed as a first conical gear wheel 13 designed as a hypoid pinion. The first conical gear wheel 13, the hypoid pinion, is adapted to engage with a second conical gear wheel 14 designed as a hypoid wheel. The second conical gear wheel 14 is rotatably journalled about the first axis I, perpendicular to the longitudinal axis of the first secondary drive shaft 9 and located on the outside of the first conical gear wheel 13, viewed from the intersectional point of the first I and second II axes of rotation. The first 13 and second 14 conical gear wheels form the first bevel gears 7, which in the embodiment shown is a hypoid gearing. In the hub of the second conical gear wheel 14, a third conical gear drive 16 is rigidly attached. This gear drive 16 in turn engages with a fourth conical gear wheel 17 that is rotatably journalled in the tilt housing and rigidly connected to the centre shaft 19 of the turn disc. The third 16 and fourth 17 gear wheels form the third bevel gears 18.

For transmitting the rotary motion to the tilt 5, a second secondary drive shaft 20 is rotatably journalled in the wrist housing 2 in a similar manner (Figure 2), said drive shaft 20 extending through a second through-hole/a channel 11 arranged in the longitudinal direction of the housing in parallel with the axis of rotation II of the turn disc. The second secondary drive shaft 20, which is axially and radially journalled across a second double row angular contact ball bearing 25, has an inlet end 20a on which is fixedly arranged a second cylindrical gear wheel 21, which engages with a cylindrical gear drive at the end of a second primary drive shaft (not shown), which may be inserted into the wrist housing, in the robot arm. The second, inner end 20b of the second secondary drive shaft 20 is an outlet end which is formed as a fifth conical gear wheel 22 designed as a hypoid pinion. The fifth conical gear wheel 22, the hypoid pinion, is adapted to engage with a sixth conical

gear wheel 23 designed as a hypoid wheel. The sixth conical gear wheel 23 is fixedly mounted in the tilt housing 5 and rotatably journalled for rotation about the first axis I, perpendicular to the longitudinal axis of the second secondary drive shaft 20 and located on the outside of the fifth conical gear wheel 22, viewed from the intersectional point of the first I and second II axes of rotation. The fifth 22 and sixth 23 conical gear wheels form the second bevel gears 8, which in the embodiment shown is a hypoid gearing.

10

Thus, for transmitting rotary motion to the tilt, a second primary drive shaft is arranged in the robot arm (not shown), and the rotary motion is thus transmitted via the second cylindrical gear wheel 21 to the second secondary drive shaft 20, which in turn, via the second bevel gears 8, sets the tilt housing 5 and hence also the turn disc 6 in rotation about the axis I.

Figure 5 is/shows the tilt 5 in a neutral position where the second axis of rotation II is coaxial, or parallel, to the centre axis of a primary drive shaft and the longitudinal axis about which the actual robot arm may rotate.

To be able to adjust the backlash in the first 7 and second 8 bevel gears, respectively, a holder device 15 is adapted to accommodate and rotatably journal the first 9 and second 20 secondary drive shafts, respectively.

**Figure 3** shows a fundamental device 31 for adjusting gear backlash in bevel gears 33 in an industrial robot. The gearing 33 comprises a first conical gear wheel 34 fixedly mounted on a first shaft 32 for rotation about a first axis of rotation A. The longitudinal axis of the first shaft 32 coincides with the first axis of rotation A. A second conical gear wheel 35 is arranged for rotation about a second axis of rotation B. The gearing is arranged such that the first A and second B axes of rotation intersect each other at right angles. The device 31 comprises a displaceably arranged holder device 36 adapted to fix and rotatably

journal the shaft 32 of the first gear wheel for rotation about the first axis of rotation A.

5 The holder member 36 is arranged linearly and radially displaceable in a direction C, which is parallel to the axis of rotation B of the second conical gear wheel 35. The bevel gears 33 in this embodiment constitute a hypoid gearing and the shaft 32 together with the first conical gear wheel 34 constitutes a pinion.

10

The holder member 36 is designed with a continuous channel 37, which is adapted to receive and accommodate the shaft 32. The shaft 32 is fixedly journalled in the continuous channel 37 for rotation about the first axis of rotation A.

15

The holder member 36 exhibits a cylindrical guide surface 38 with a certain diameter, designated guide diameter 39 in the following. The guide surface has a certain extent along the A-axis. In practice, 1-3 mm is sufficient. The purpose  
20 of the guide surface is to eliminate the risk of angular displacement and obliquity of the holder member 36 in relation to the first axis of rotation A.

The holder member 36 may be designed in different ways, for  
25 example with a flange, which will be described in more detail in the following.

**Figure 4** is a cross section through second bevel gears arranged in a wrist unit in a robot in accordance with  
30 Figures 1 and 2. The following description is relevant to both bevel gears. The backlash in the bevel gears 8 is adjusted by the possibility of displacing the holder member 41 linearly and radially along a linear movement axis C, defined above. A radial displacement of the holder member  
35 41 entails a radial displacement of the first gear wheel 42 in bevel gears 43. The linear movement axis C is arranged perpendicular to the axis of rotation A of the pinion. The holder member 41 in this embodiment is adapted to comprise a sleeve 44 which is formed with a cylindrical guide sur-

face 45. The outer diameter of the sleeve 44 forms a guide diameter 46. The wrist housing 47 is formed with an internally arranged cylindrical hole/passage 48, which will be described with reference to Figure 5.

5

**Figure 5** is a section through the line C, marked in the figure, and perpendicular to axis A in Figure 4. Figure 5 is an enlargement of a cylindrical hole/passage 48. It should be noted that the figure is not drawn to scale. The cylindrical hole/passage 48 is formed for linear guiding of the holder member 41 for displacement in either direction along the C-axis.

The symmetry axis D of the hole/passage 48 across the A-axis is parallel to the linear direction of movement C. The symmetry axis E of the hole/passage 48 is arranged perpendicular to the D-axis. The shape of the hole/passage is made with very high precision and the amount of its propagation along the symmetry axis E shall correspond to the guide diameter 46 of a sleeve 44 on a holder member 41.

A holder member 6 is displaced to the desired position. The amount of the displacement is adapted to the data of the gear in question. This means that the displacement is sufficiently great to adjust the backlash with respect to, among other things, size tolerances. When a holder member 6 has been displaced to the desired position, it is fixed with the aid of some form of fixing joint.

**Figure 6** is an embodiment that comprises a fixing joint in the form of a screw joint 61, which comprises a plurality of fixing elements 62, only one of which is shown in the figure. The fixing elements 62 in this embodiment are screws arranged in a through-hole 63 in the flange and fixed to the wrist housing 64. Hence a first conical gear wheel 65 with a shaft 66 is fixed and rotatably journaled with the aid of a holder member 67 in the desired position in the wrist housing 64, and the backlash between the first conical gear wheel 65 and a second conical gear wheel 69 in

bevel gears 70 is eliminated. The first conical gear wheel 65 is rotatably journalled in the holder member 6 by means of a double row ball bearing 71 and a needle bearing 72. In Figure 6, the first conical gear wheel 65 is in the form of a hypoid pinion.

The displacement of a holder member in a C-direction must take place with high accuracy to avoid obliquity of the holder member. In addition to a guide surface and a guide diameter, the device for elimination of backlash is formed with a supporting surface. In this embodiment, the supporting surface is formed in the wrist housing, in a plane perpendicular to the direction of movement of axis C. A displacement of a holder member does not take place until a plane surface arranged on the holder member makes contact with the supporting surface. The displacement of the holder member takes place when a fixing joint, for example comprising screws, is mounted but not fully tightened.

**Figure 7a** is an embodiment according to Figure 4 where a surface 71a on the holder member 73a during mounting is adapted to make contact with a supporting surface 72a arranged in the wrist housing in the robot. Upon a displacement of the holder member, the movement takes place while the surface 71 on the holder makes contact with the supporting surface 72. In this embodiment, the holder member 73a comprises the guide diameter defined above.

**Figure 7b** is part of Figure 1 or 2, where a surface 71b on the holder member 73b during mounting is adapted to make contact with a supporting surface 72b arranged in the robot wrist housing. Upon a displacement of the holder member 73b, the movement takes place while the surface 71b on the holder makes contact with the supporting surface 72b. In this embodiment, the bearing 74b comprises the guide diameter defined above.

**Figure 7c** is an embodiment with a holder member 73c formed with a surface 71c. During mounting, the surface 71c is

adapted to make contact with a supporting surface 72c arranged in a robot wrist housing according to the above. Upon a displacement of the holder member 73c, the movement takes place while the surface 71c on the holder makes contact with the supporting surface 72b. In this embodiment, a hole/passageway 75c in the wrist housing, along a section L in the longitudinal direction, is formed with a shrunk portion 76c. In this embodiment, the shrunk portion 76c of the wrist housing comprises the guide diameter defined according to the above.

**Figure 7d** is identical with Figure 3 and the holder member comprises the surface 71d for making contact with a supporting surface in the wrist housing.

**Figure 8** is an alternative embodiment with an external tool 81 comprising a guide in the form of a cylindrical hole/passageway. The cylindrical hole/passageway 82 is designed for linear guiding of a shaft 83 fixedly connected to a first conical gear wheel 85, which forms part of bevel gears, in accordance with the embodiments described above. The tool is used for mounting the gearing and more particularly for displacing the shaft 83 in a controlled manner in either direction along the C-axis. It should be noted that the figure is not drawn to scale. The design of the hole/passageway 82 is made with very high precision and the extent of its propagation across the C-axis constitutes the guide diameter as defined according to the above.

**Figure 9** is a prior art wrist for an industrial robot, which in principle comprises an outer fork-shaped wrist housing 52 with two fork branches 53, 54. The wrist housing 52 accommodates a so-called tilt housing 55 journalled for rotation about a first axis of rotation I. The tilt housing supports, in a manner known per se, a turn disc 56 rotatably journalled about a second axis of rotation II, on which turn disc a robot tool may be mounted (not shown). The first axis of rotation I is arranged perpendicular to the second axis of rotation II. The wrist comprises first bevel

gears 57 for transmitting a rotary motion to the turn disc 56, said gears being described in detail below. The wrist further comprises second bevel gears 58 for transmitting a rotary motion to the tilt 55, which is also described in detail below.

For transmitting the rotary motion to the turn disc 56, a first secondary drive shaft 59 is rotatably journalled in the wrist housing 52, said drive shaft extending through a first through-hole/a channel 60 arranged in the longitudinal direction of the housing in parallel with the axis of rotation II of the turn disc. The first secondary drive shaft 59, which is axially and radially journalled across a first double row angular contact ball bearing, has an inlet end 59a on which is fixedly arranged a first cylindrical gear wheel 62, which engages with a cylindrical gear drive at the end of a first primary drive shaft (not shown), which may be inserted into the wrist housing, in the robot arm. The second, inner end 59b of the secondary drive shaft is an outlet end which is formed as a first conical gear wheel 63 designed as a hypoid pinion. The first conical gear wheel 63, the hypoid pinion, is adapted to engage with a second conical gear wheel 64 designed as a hypoid wheel. The second conical gear wheel 64 is rotatably journalled about the first axis I, perpendicular to the longitudinal axis of the first secondary drive shaft 59 and located on the outside of the first conical gear wheel 63, viewed from the intersectional point of the first I and second II axes of rotation. The first 63 and second 64 conical gear wheels form the first bevel gears 57, which in the embodiment shown is a hypoid gearing. In the hub of the second conical gear wheel 64, a third conical gear drive 66 is rigidly attached. This gear drive 66 in turn engages with a fourth conical gear wheel 67 that is rotatably journalled in the tilt housing and rigidly connected to the shaft 69 of the turn disc. The third 66 and fourth 67 gear wheels form third bevel gears 68.

For transmitting the rotary motion to the tilt 55, a second secondary drive shaft 70 is rotatably journalled in the wrist housing 52 in a similar manner, said drive shaft 70 extending through a second through-hole/a channel 61 arranged in the longitudinal direction of the housing in parallel with the axis of rotation II of the turn disc. The second secondary drive shaft 70, which is axially and radially journalled across a second double row angular contact ball bearing, has an inlet end 70a on which is fixedly arranged a second cylindrical gear wheel 71, which engages with a cylindrical gear drive at the end of a second primary drive shaft (not shown), which may be inserted into the wrist housing, in the robot arm. The second, inner end 70b of the second secondary drive shaft 70 is an outlet end which is formed as a fifth conical gear wheel 72 designed as a hypoid pinion. The fifth conical gear wheel 72, the hypoid pinion, is adapted to engage with a sixth conical gear wheel 73 designed as a hypoid wheel. The sixth conical gear wheel 73 is fixedly mounted in the tilt housing 55 and rotatably journalled about the first axis I, perpendicular to the longitudinal axis of the second secondary drive shaft 70 and located on the outside of the fifth conical gear wheel 72, viewed from the intersectional point of the first I and second II axes of rotation. The fifth 72 and sixth 73 conical gear wheels form the second bevel gears 58, which in the embodiment shown is a hypoid gearing.

Thus, for transmitting rotary motion to the tilt, a second primary drive shaft is arranged in the robot arm (not shown), and the rotary motion is thus transmitted via the second cylindrical gear wheel 71 to the second secondary drive shaft 70, which in turn, via the second bevel gears 58, sets the tilt housing 55 and hence also the turn disc 56 in rotation about the axis I. Figure 9 is/shows the tilt 55 in a neutral position, where the second axis of rotation II is coaxial, or parallel, to the centre axis of a primary drive shaft and the longitudinal axis about which the actual robot arm is able to rotate.

Backlash in the bevel gears described above is adjusted with spacers 74, also called shims.

The wrist corresponds, in principle, to the embodiment in  
5 Figures 1 and 2 with the exception of the device for elimination of backlash.

## CLAIMS

1. A device (1) for adjusting the backlash in bevel gears (7) in an industrial robot, said bevel gears (7) comprising  
5 a first conical gear wheel (13) with a third axis of rotation (A) and a second conical gear wheel (14) with a first axis of rotation (I), which forms a right angle with the third axis of rotation (A), **characterized** in that the device (1) comprises a displaceably arranged holder member  
10 (15) adapted to fix and rotatably journal the first gear wheel (13) for rotation about the third axis of rotation (A), which is arranged in parallel with the second axis of rotation (II).
- 15 2. A device according to claim 1, wherein the holder member (15) is arranged linearly and radially displaceable in a direction C, which is parallel to the first axis of rotation (I).
- 20 3. A device according to claim 1, wherein the gearing (7) is a hypoid gearing.
4. A device according to claim 2 or 3, wherein the first conical gear wheel (13) is a pinion.
- 25 5. A device according to claim 4, wherein the holder member (15) has a continuous channel (10) adapted to receive and rotatably journal a secondary drive shaft (9) which is fixedly arranged with the first conical gear wheel (13).
- 30 6. A device according to claim 5, wherein the pinion (4a) is fixedly journalled in the continuous channel (7) for rotation about the third axis of rotation (A).
- 35 7. A wrist for an industrial robot arm comprising a device according to any of claims 1-6, **characterized** in that the third axis of rotation (A) is arranged in parallel with the axis of rotation (II) of a turn disc (6) forming part of the wrist.

8. A method for adjusting the backlash in bevel gears (7) in an industrial robot, said bevel gears (7) comprising a first conical gear wheel (13) with a first direction of rotation (A) and a second conical gear wheel (14),

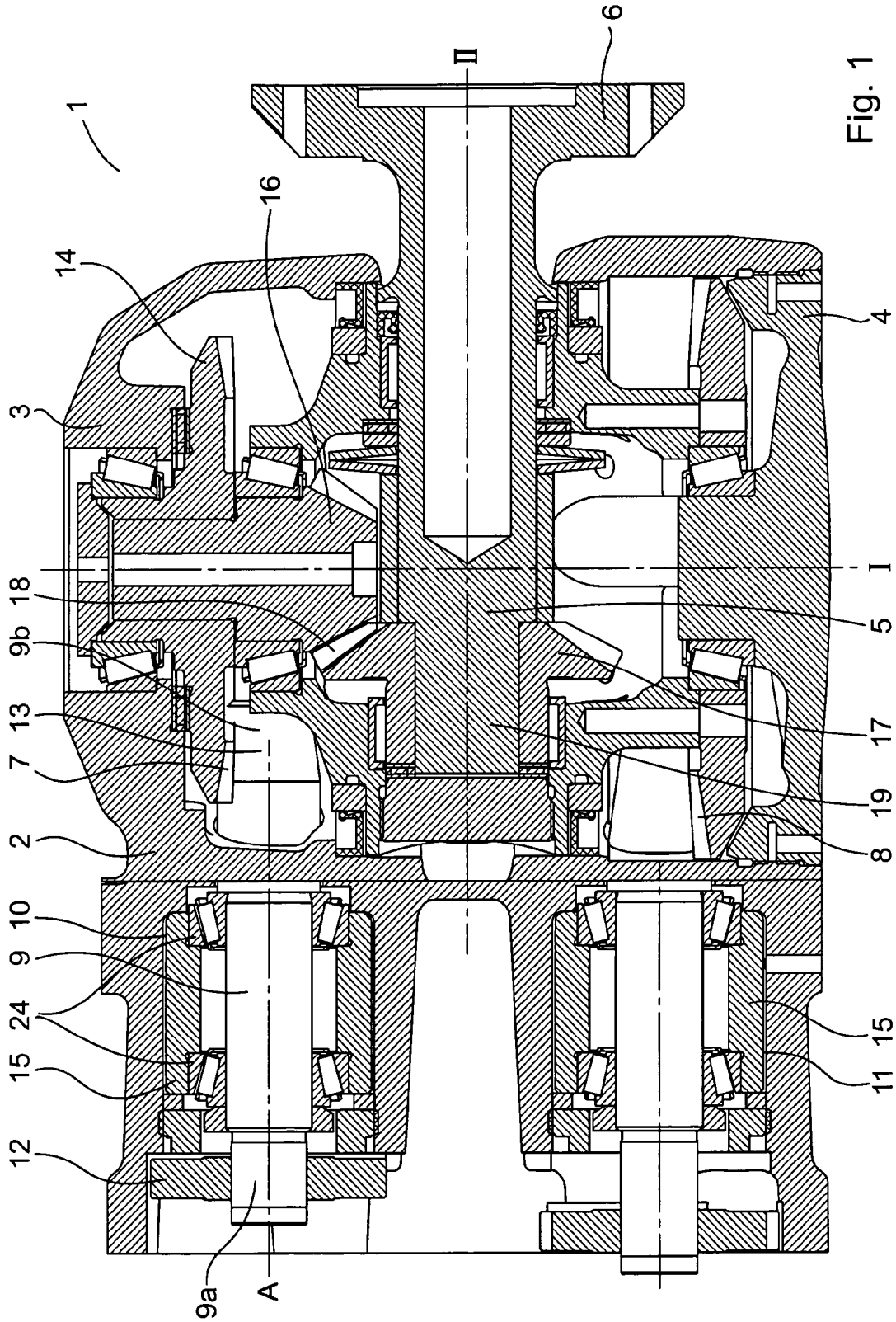
5 **characterized** in that the first gear wheel (13) is brought to be displaced in a radial direction (C) in parallel with the first direction of rotation (I).

9. A method according to claim 8, wherein the first gear  
10 wheel (13) is displaced and fixed rotatably such that the backlash between the first (13) and second (14) gear wheels is eliminated.

15

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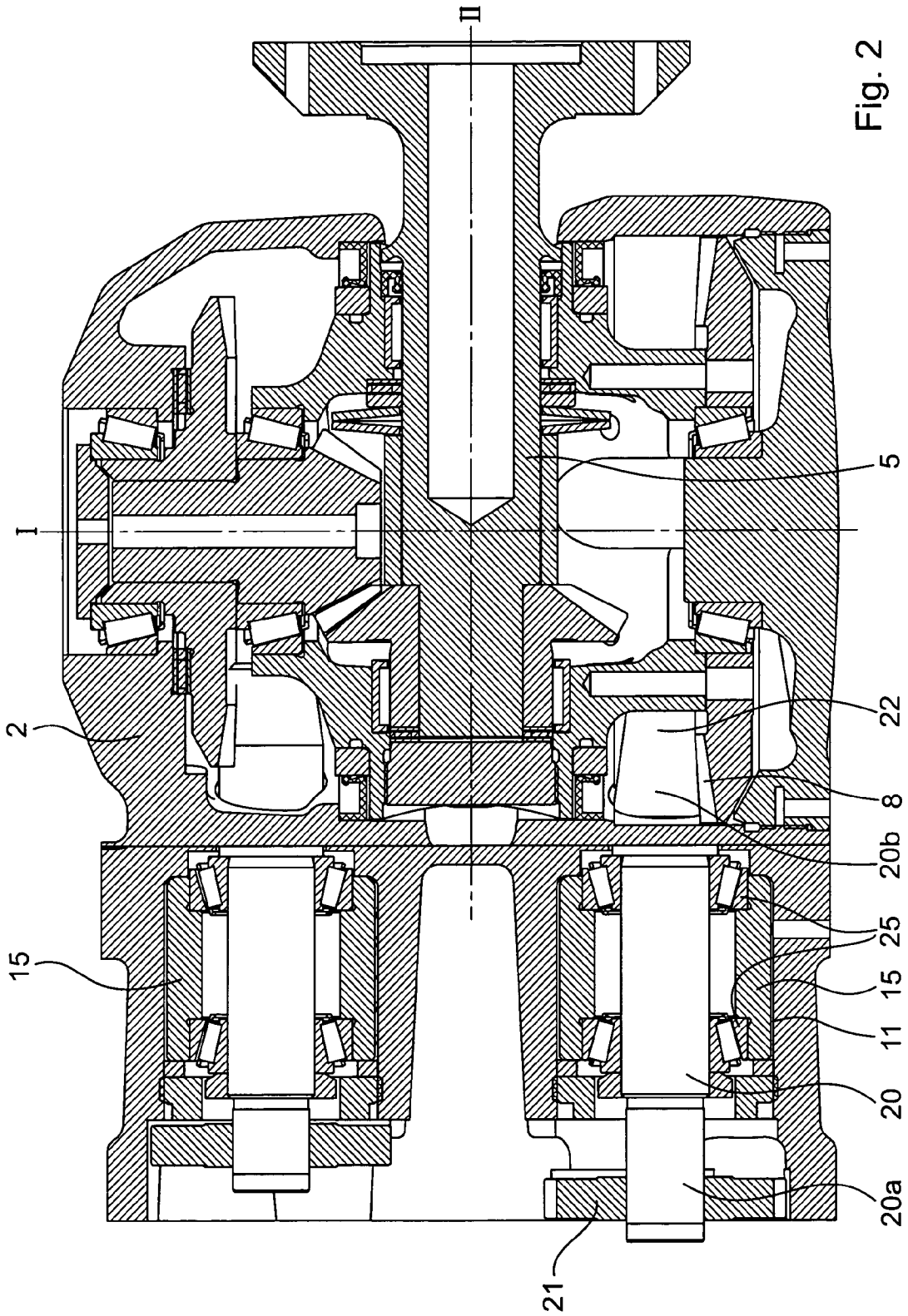


Fig. 2

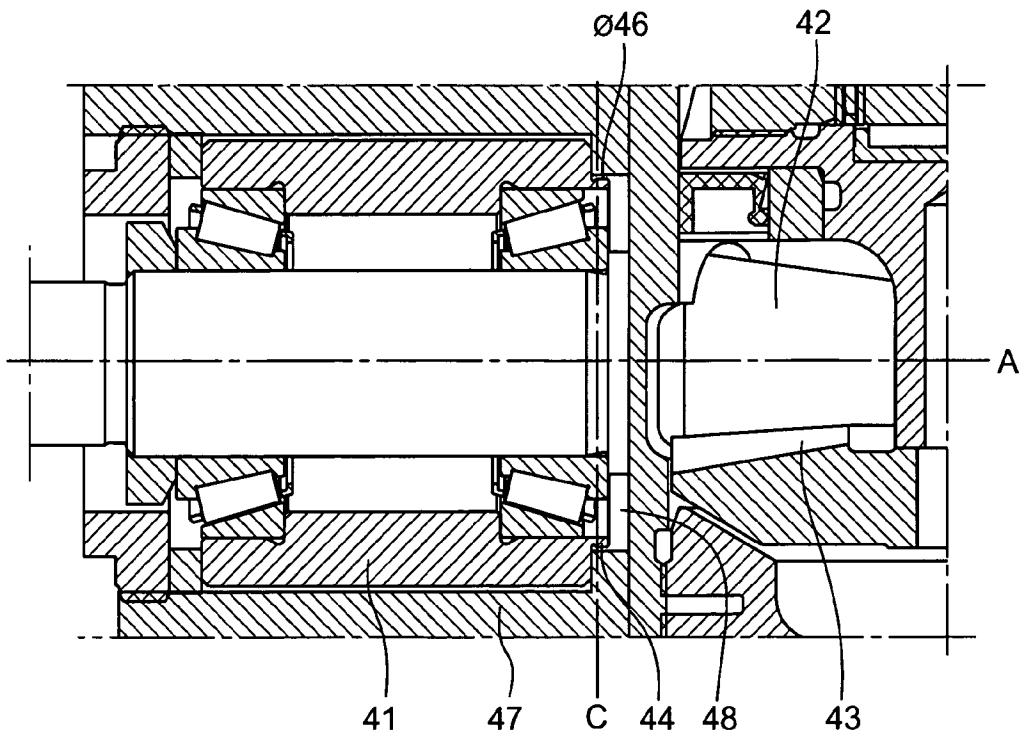
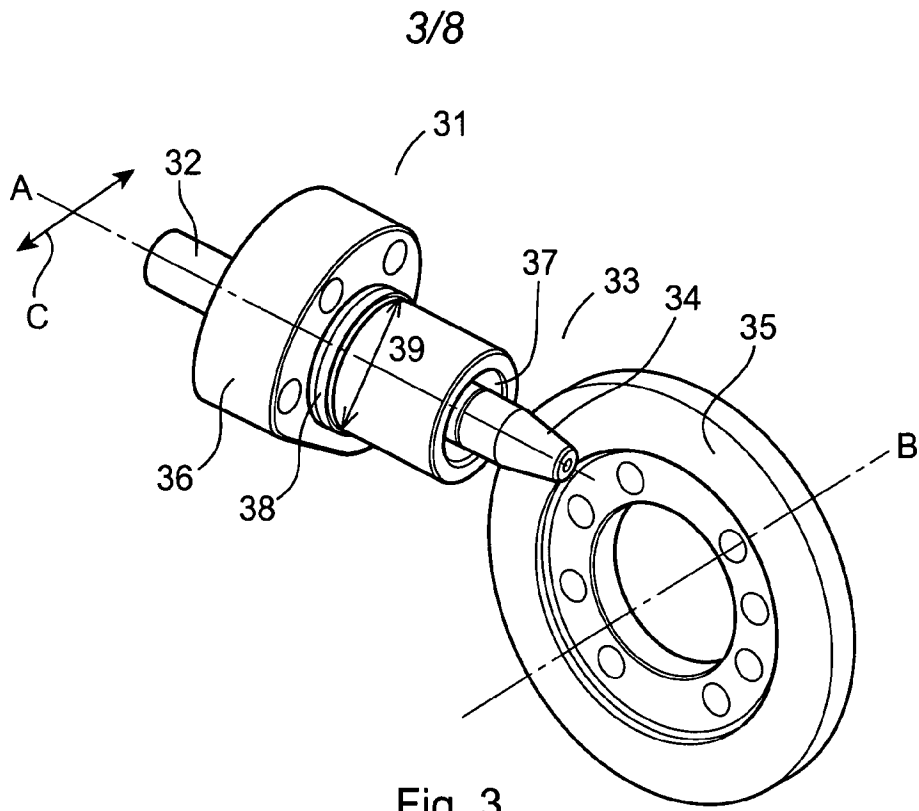


Fig. 4

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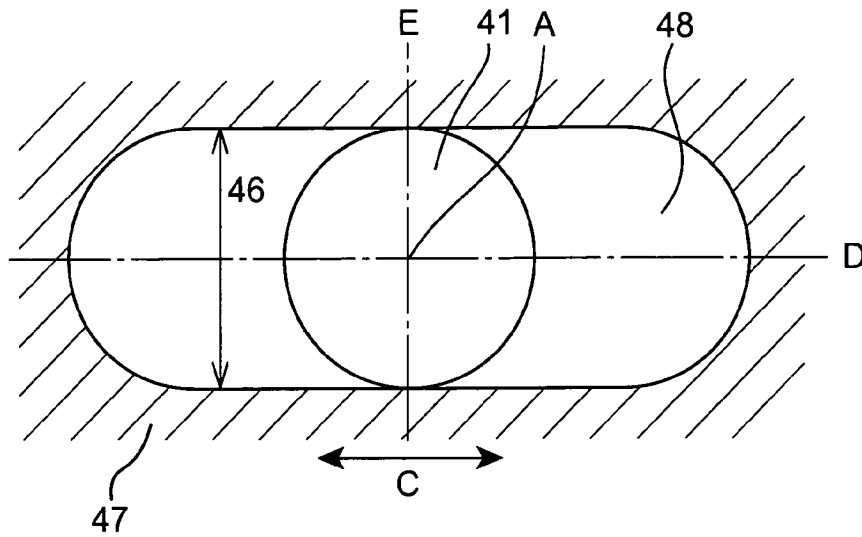


Fig. 5

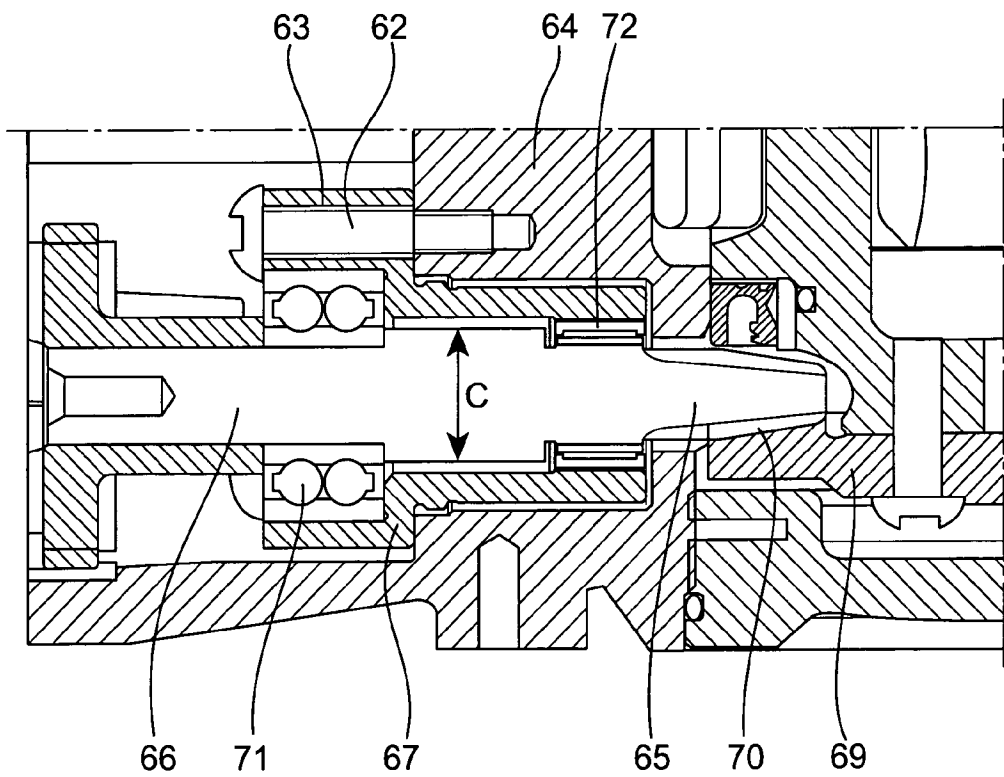


Fig. 6

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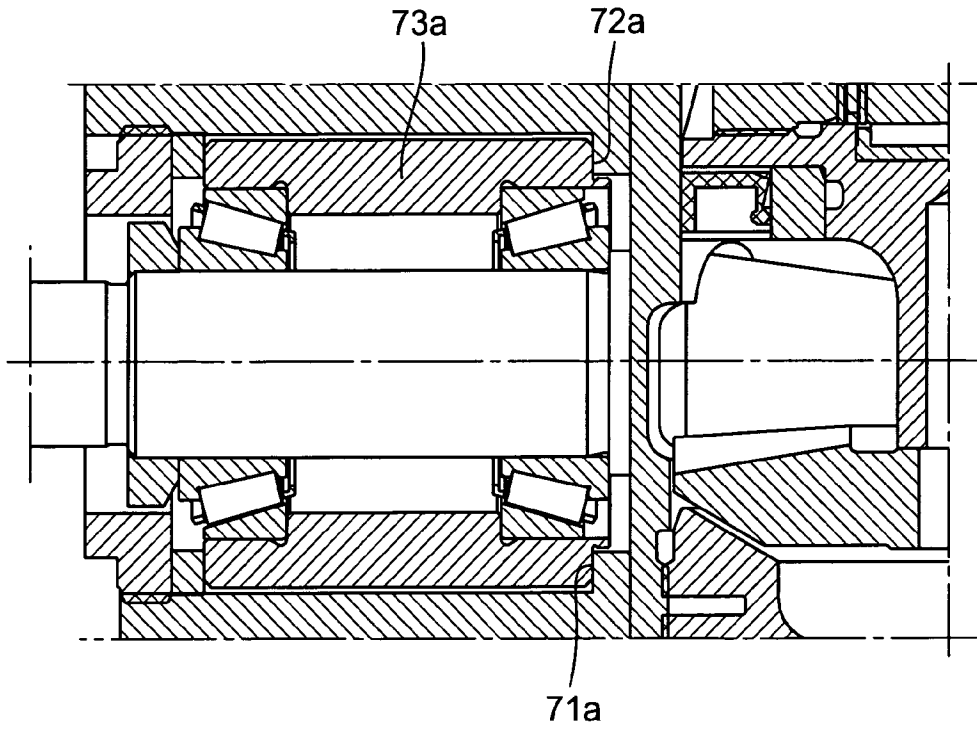


Fig. 7a

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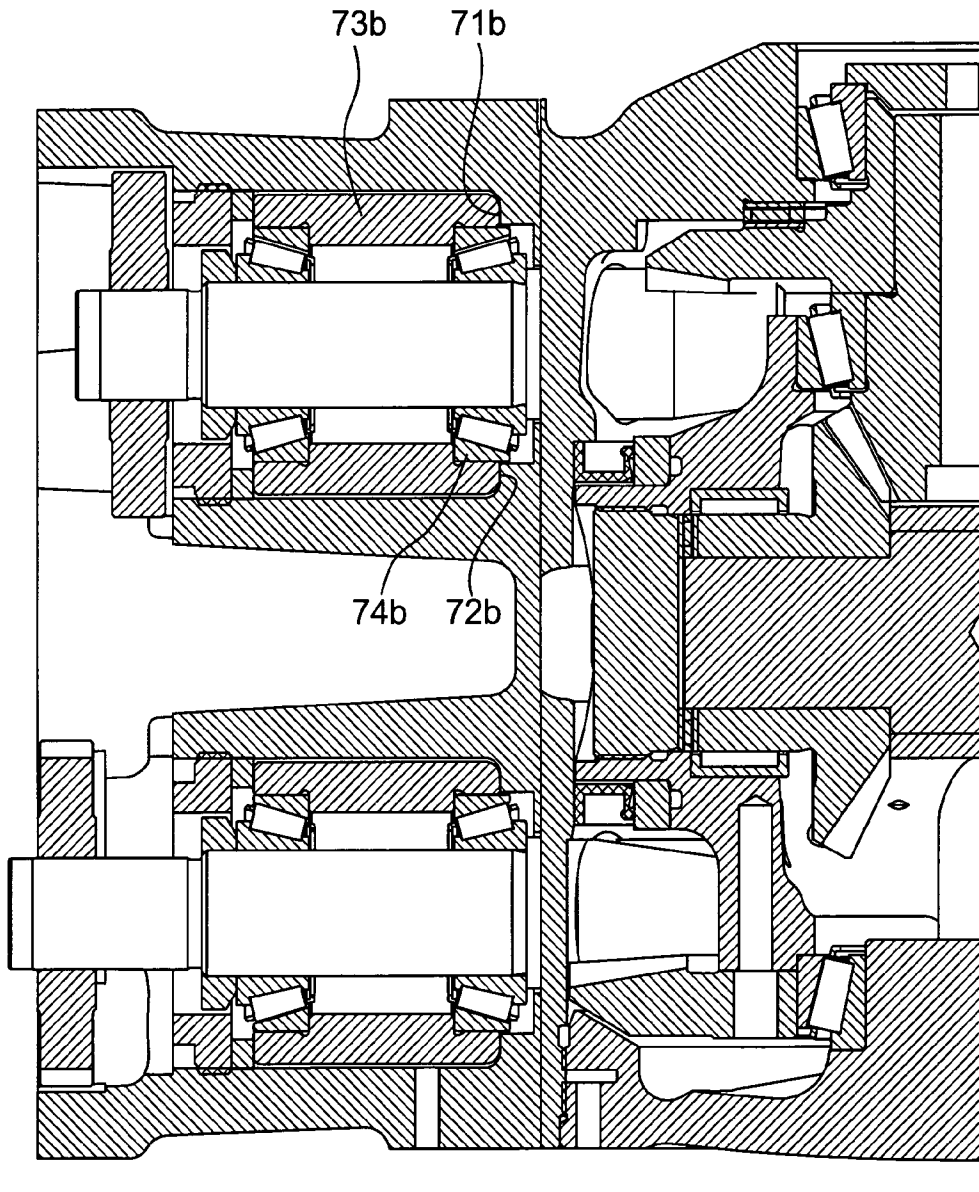


Fig. 7b

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Fig. 7c

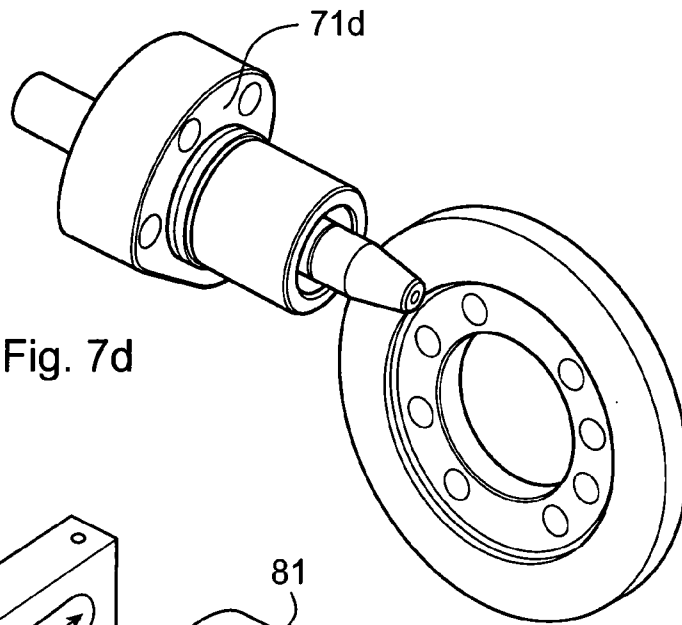


Fig. 7d

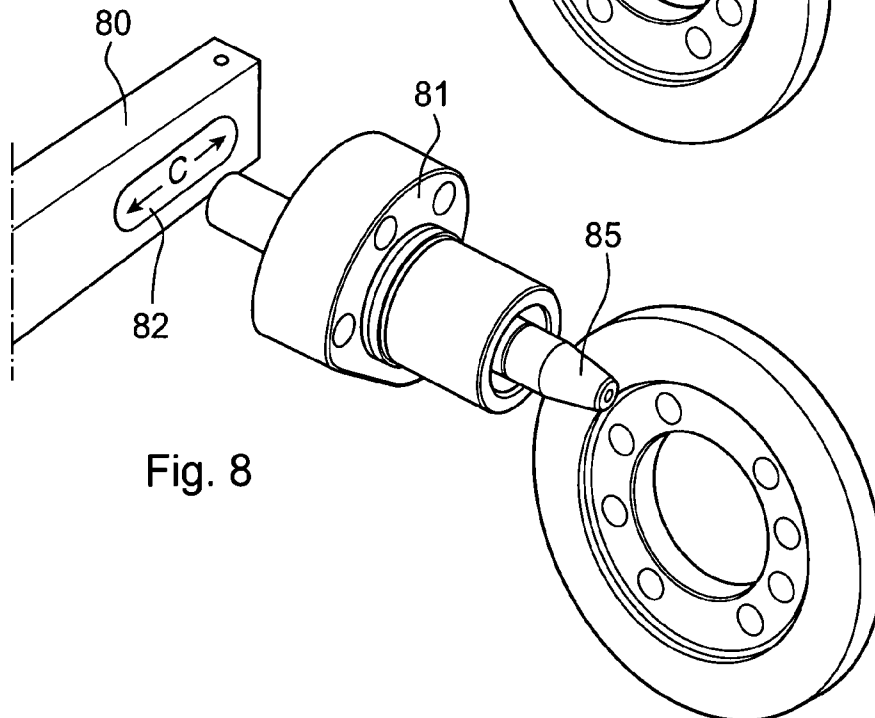
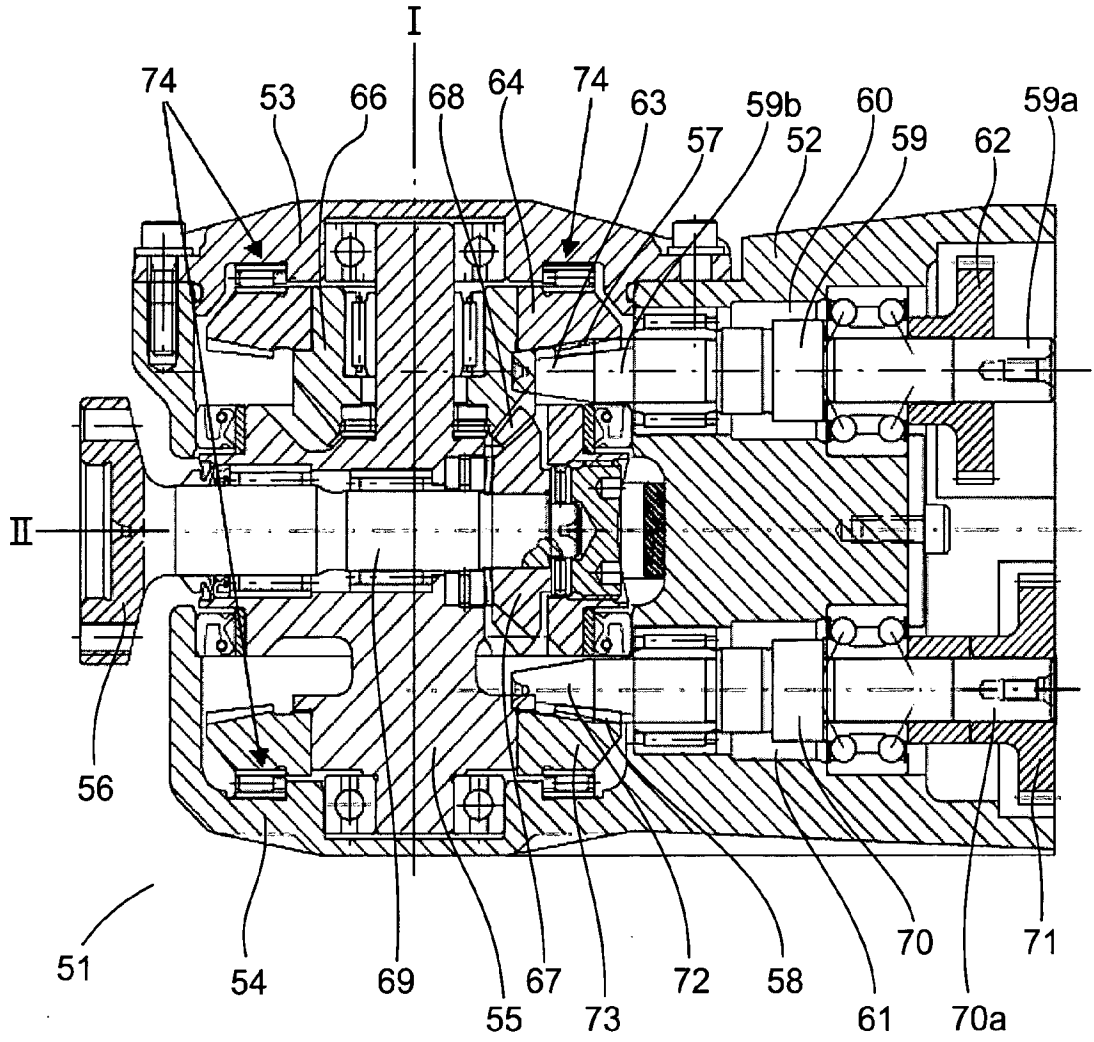


Fig. 8



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Fig. 9