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[Continued on next page]

(54) Title: PITCH AND ROLL ROBOT JOINT AND INDUSTRIAL ROBOT

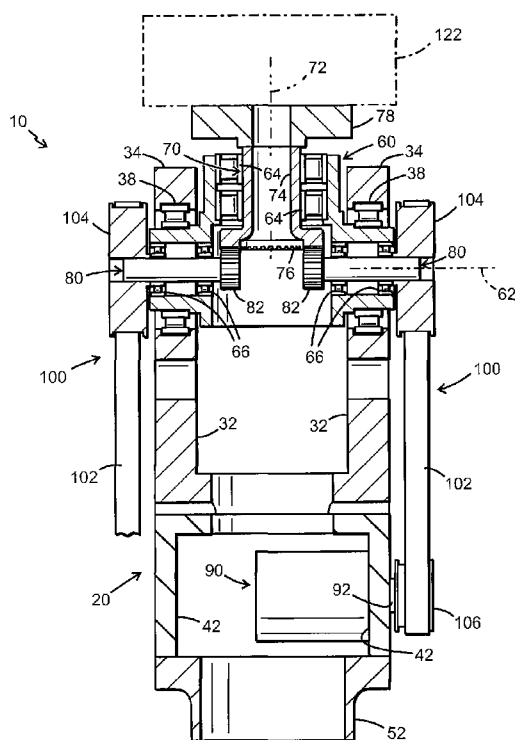


FIG. 2

(57) Abstract: A pitch and roll robot joint (10) including a differential gear, comprising a base structure (20), a pitch housing (60) rotationally supported in the base structure (20), a roll shaft (70) rotationally supported in the pitch housing (60) and including a planet gear wheel (76) of said differential gear wheel, left and right transversally oriented drive shafts (80) rotationally supported in the pitch housing (60), each drive shaft including a side gear wheel (82) of said differential gear in engagement with the planet gear wheel (76) for providing pitch movement to the pitch housing (60) and roll movement to the roll shaft (70). According to the invention, the joint has left and right drive transmissions (100), each transmission being in operative engagement between a respective pair of a motor shaft (92) and one of said drive shafts (80).

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Pitch and roll robot joint and industrial robot

TECHNICAL FIELD

5 This invention relates to a pitch and roll robot joint including a differential gear. The invention also relates to an industrial robot having such a robot joint.

BACKGROUND

From US 4,608,884 is previously known a joint of a hand element or wrist of a
10 robot. The housing of the hand element is pivoted around a first axis while resting between two fork arms on the end of the boom connected to the robot arm. Two reduction gears, which can be separately driven, are provided in the housing and are arranged coaxially to the first axis. The reduction gears are arranged to drive coaxial bevel gears which, in their turn, are engaged with additional bevel gears supported
15 by the housing and extended at right angle to the previous bevel gears. The shaft of one of the bevel gears supports a flange which rotates around a secondary rotary axis running at a right angle to the first axis. In such a robot wrist joint the drive shafts are capable of commonly driving both the pitch and roll movements, thus getting the advantage of an even distribution of the load torque to the motors. The prior art embodiments of this type of robot wrist joint, however, need extensive gearing that adds
20 to weight and complexity.

DISCLOSURE OF THE INVENTION

An object of the invention is to further develop a robot joint of the kind described above that has fewer components in order to be more lightweight and less
25 complicated.

According to one aspect of the invention, is defined a pitch and roll robot joint including a differential gear, comprising a base structure, a pitch housing rotationally supported in the base structure, a roll shaft rotationally supported in the pitch housing
30 and including a planet gear wheel of said differential gear, left and right transversally oriented drive shafts rotationally supported in the pitch housing, each drive shaft including a side gear wheel of said differential gear in engagement with the planet gear wheel for providing pitch movement to the pitch housing and roll movement to the roll shaft, characterized by the robot joint having left and right drive transmissions, each

transmission being in operative engagement between a respective pair of a motor shaft and one of said drive shafts. Thereby both transmissions may be of identical and simple design and located laterally away from the joint, providing space for interior cabling in the joint. This may be suitable when the joint is a wrist joint. The invention is, however, not restricted to wrist joints but may also be applied to other joints in a robot structure.

Another advantage is the symmetric arrangement allowing extensive use of components common to both sides and minimizing out-of balance loads about the roll axis.

While the motor shafts may be oriented for example perpendicularly to the drive shafts, in an embodiment of the invention, the motor shafts are transversely oriented, i.e. with motor shafts in parallel with the drive shafts. Thereby, the drive transmissions may be further simplified by not needing any angled gear connections.

While the motors may be located rearwardly away from the joint, for example in a robot boom structure supporting a wrist joint, or in a corresponding connection part when the joint is used elsewhere in a robot, in one embodiment of the invention the joint has a pair of motors, each having one of said transversally oriented motor shafts.

According to another embodiment of the invention the roll shaft is provided with a through-going axial cavity. As thereby also both ends of the joints are free from internal components, sufficient space will be provided for arranging axially internal cabling all the way through the joint, for example, up to an end effector, in case the joint is a wrist joint.

Each drive transmission can be a belt transmission.

Alternatively, each drive transmission can be a gear transmission.

By using any of such transmissions, the motors may be located at a desired distance away from the pitch housing – in the base structure or in a rearward structure such as a robot boom supporting a wrist, in case the joint is a wrist joint, or a corresponding connection part when the joint is used elsewhere in a robot.

The motors can further be arranged in a spaced lateral side-by-side configuration. Thereby the internal cabling may extend in the space between the motors.

In another embodiment the planet gear is a crown gear and the side gear is a crown gear pinion gear wheel. As thereby the necessary gear engagement force in the planet gear will be oriented substantially in the forward direction of the joint only,

this force will be fully absorbed by the radial bearings of the drive shafts of the side gears with little or no need of further axial and radial support, for example by shims or counteracting gear wheels as common in other types of differential gears. Accordingly, the necessary components of the planet gear may thereby be minimized, saving weight and leaving space for internal cabling in the joint.

As indicated above, the robot joint may suitably be wrist joint.

The invention is also concerned with an industrial robot having at least one robot joint according to the invention.

Other features and advantages of the invention will be apparent from the appended claims and the following detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will now be described in more detail by way of embodiments, given as examples only, and with reference to the enclosed drawings, in which:

FIG. 1 is a rearward side view of a robot joint according to the invention having belt drive transmissions;

FIG. 2 is a is a sectional side view of the robot joint shown in FIG. 1;

FIG. 3 is a rear end perspective view of the robot joint shown in FIG. 1;

FIG. 4 is a diagrammatic side view with parts broken away of a robot joint according to the invention having gear drive transmissions;

FIGS. 5A and 5B are rearward respective side and sectional views of a pitch housing according to the invention; and

FIG 6 is a schematic illustration of a six-axis industrial robot.

In the drawing, corresponding components are throughout designated by the same numerals.

DETAILED DESCRIPTION OF EMBODIMENTS

In FIG. 6 is schematically illustrated a conventional six-axis industrial robot. However, it is apparent that the invention is not limited to such a robot, but may be used also in robots with more or less axes. The illustrated robot has a stand 1 that is rotatably mounted on a base 2, which enables it to rotate about a vertical axis A. A lower robot arm 3 is connected to the stand and is pivotably mounted about an axis 4. The lower robot arm 3 supports the robot's upper arm 5. The lower and upper ro-

bot arms are pivoted about an axis 6. The upper arm 5 is rotatable about an axis B that coincides with the longitudinal axis of the upper arm. The upper arm supports a wrist part 7 at its outer end, said wrist part comprising a tilt part 8 that is rotatable about an axis C and a turning disc 9 that is rotatable about an axis D. An end effector
5 such as a robot tool or other desired attachment is mountable on the rotatable turn disc 9. In order to drive the connected parts in rotation about the respective axes A, B, C, D, 4, 6, motors and the necessary gearing are provided.

The axes A, B and D are axes where a roll movement is obtained and the axes 4, 6 and C are axes where a pivoting movement or pitch is obtained. Accord-
10 ingly, the robot has three pitch and roll modules where a pitch and roll joint according to the present invention may be used, namely the joint between the base 2 and the lower arm 3 which is located in the stand 1 and includes the axes A and 4, the joint between the lower arm 3 and the upper arm 5 which includes the axes B and 6, and the joint between the upper arm 5 and the wrist part 7 which includes the axes C and
15 D. In FIG. 6 the robot is illustrated as having a wrist joint designed as a pitch and roll joint 10 according to the invention, as an example.

The details of the inventive pitch and roll joint 10 are described in relation to an embodiment of the invention in a robot wrist. The pitch and roll wrist embodiment of a robot joint 10 shown in the drawings is adapted for connection to a boom 12 or corre-
20 sponding connection part of a diagrammatically depicted industrial robot 14 (FIG.1). In the embodiment shown, the wrist joint 10 has a base structure 20 that may be considered to have a U-shaped forward portion 30, a box-shaped intermediate portion 40 and a rearward boom-connecting portion 50 comprising a hollow pipe 52.

As apparent for example from FIG. 3, the base structure 20 is further formed
25 with a hollow axial interior or a through-going axial passage to allow unobstructed passage through the wrist joint 10 of flexible cabling 120 (FIG. 1) capable of supplying power and control signals to a diagrammatically depicted end effector 122 (FIG. 1, 2) attached to the wrist joint 10.

The U-shaped forward portion 30 of base structure 20 has a pair of lateral
30 flanges 32 defining a space therebetween for a generally T-shaped pitch housing 60, which in the case of a wrist joint is a tilt housing. The pitch housing 60 is rotationally supported by the lateral flanges 32 about a transverse pitch axis 62. In the embodiment shown, pitch housing 60 is supported by roller bearings 38 (FIG. 2). Each roller

bearing 38 is retained in a circular recess defined by the corresponding flange 32 and an end piece 34 that clamps the bearing 38 in place by means of screw joints 36.

Retaining means such as one or more washers 124 (FIG. 1) may be provided for example in the pitch housing 60 to keep the cabling 120 clear from the gear wheels supported in the pitch housing 60. As indicated in FIG. 1 cabling 120 may also have a slack for allowing the rotational movement of pitch housing 60. The slack may, however, alternatively be present in robot components (not shown) rearward of the wrist joint 10.

As best seen in FIGS. 2 and 5B, a roll shaft 70 having an axial bore 74 is rotationally supported by roller bearings 64 in the pitch housing 60 about a roll axis 72 extending in a radial plane to the pitch axis 62 in the pitch housing 60. A hollow front end flange 78 of roll shaft 70 is adapted for attachment to the end effector 122, in the case of a wrist joint. When the joint is used elsewhere in a robot the front end is adapted for connection to another corresponding robot part. A rear end of roll shaft 70 is provided with a planet gear wheel 76 forming part of a differential gear yet to be described in more detail.

Left and right drive shafts 80 are rotationally supported about the pitch axis 62 in the pitch housing 60 via respective pairs of roller bearings 66. An inner end of each drive shaft 80 is provided with a side gear wheel 82 meshing with the planet gear wheel 76 to complete the resulting differential gear. While other combinations of gear wheels may be used in embodiments of the invention, such as two pairs of opposing angled gear wheels, e.g. bevel gears, as in a conventional differential gear, in the shown embodiment, the single planet gear wheel 76 is a crown gear wheel and the two side gear wheels 82 are crown gear pinion wheels. This arrangement does not need any close alignment of the drive shafts 80 in the axial direction thereof in order to secure sufficient gear engagement as compared to a traditional differential gear having an angled gear engagement.

In the FIG. 1-3 embodiment, each drive shaft 80 is driven by a respective electric motor 90 via a belt transmission 100 comprising a belt 102, a drive shaft pulley 104 and a motor shaft pulley 106. In an alternative embodiment diagrammatically shown in FIG. 4, each transmission 100 may alternatively comprise a gear transmission 80 having, for example, four serially meshing gear wheels, i.e. a gear wheel 108 connected to the drive shaft 80, intermediate gear wheels 110, 112 freely journalled

to the base structure 20, and a gear wheel 114 connected to the motor shaft 92. The transmission may also be a sprocket chain transmission (not shown).

5 The motors 90 have transversally oriented motor shafts 92 and are, in the shown embodiment, located in the intermediate box-shaped portion 40 of the base structure 20, supported to lateral walls 42 of portion 40. As apparent from FIG. 3, the motors 90 are also spaced from each other not to obstruct the internal axial passage of wrist joint 10. As indicated above, motors 90 may also be located away (not shown) from the base structure 20.

10 The joint functions as follows. When the two motors are simultaneously driven in the same direction at the same speed, the pitch part of the joint will rotate and the roll will not. When the two motors are simultaneously driven at the same speed in opposite directions, the roll part of the joint will rotate and the pitch will not. Any other combination of motor movements will make both pitch and roll move simultaneously.

15 The foregoing detailed description is given primarily for clearness of understanding and no unnecessary limitations are to be understood therefrom. Modifications will become obvious to those skilled in the art upon reading this disclosure and may be made without departing from the spirit of the invention or the scope of the appended claims.

Claims

1. A pitch and roll robot joint (10) including a differential gear, comprising:
 - a base structure (20);
 - a pitch housing (60) rotationally supported in the base structure (20);
 - a roll shaft (70) rotationally supported in the pitch housing (60), and including a planet gear wheel (76) of said differential gear;
 - left and right transversally oriented drive shafts (80) rotationally supported in the pitch housing (60), each drive shaft including a side gear wheel (82) of said differential gear in engagement with the planet gear wheel (76) for providing pitch movement to the pitch housing (60) and roll movement to the roll shaft (70);

characterized by

 - left and right drive transmissions (100), each transmission being in operative engagement between a respective pair of a motor shaft (92) and one of said drive shafts (80).
2. The robot joint according to claim 1, wherein it comprises a pair of motors (90), each motor having a transversally oriented motor shaft (92).
3. The robot joint according to claim 1 or 2, wherein said roll shaft (70) is provided with a through-going axial cavity (74).
4. The robot joint according to any of the previous claims, wherein said drive transmission comprises a belt transmission (100).
5. The robot joint according to any of the previous claims, wherein said drive transmission comprises a gear transmission (100).
6. The robot joint according to any of the previous claims, wherein the motors (90) are arranged in a spaced lateral side-by-side configuration.
7. The robot joint according to any of the previous claims, wherein said planet gear (64) is a crown gear and said side gear wheel is a crown gear pinion gear wheel (82).

8. The robot joint according to any of the previous claims, wherein the joint is a wrist joint (10).

9. An industrial robot (14) having at least one robot joint (10) according to any one of the previous claims.

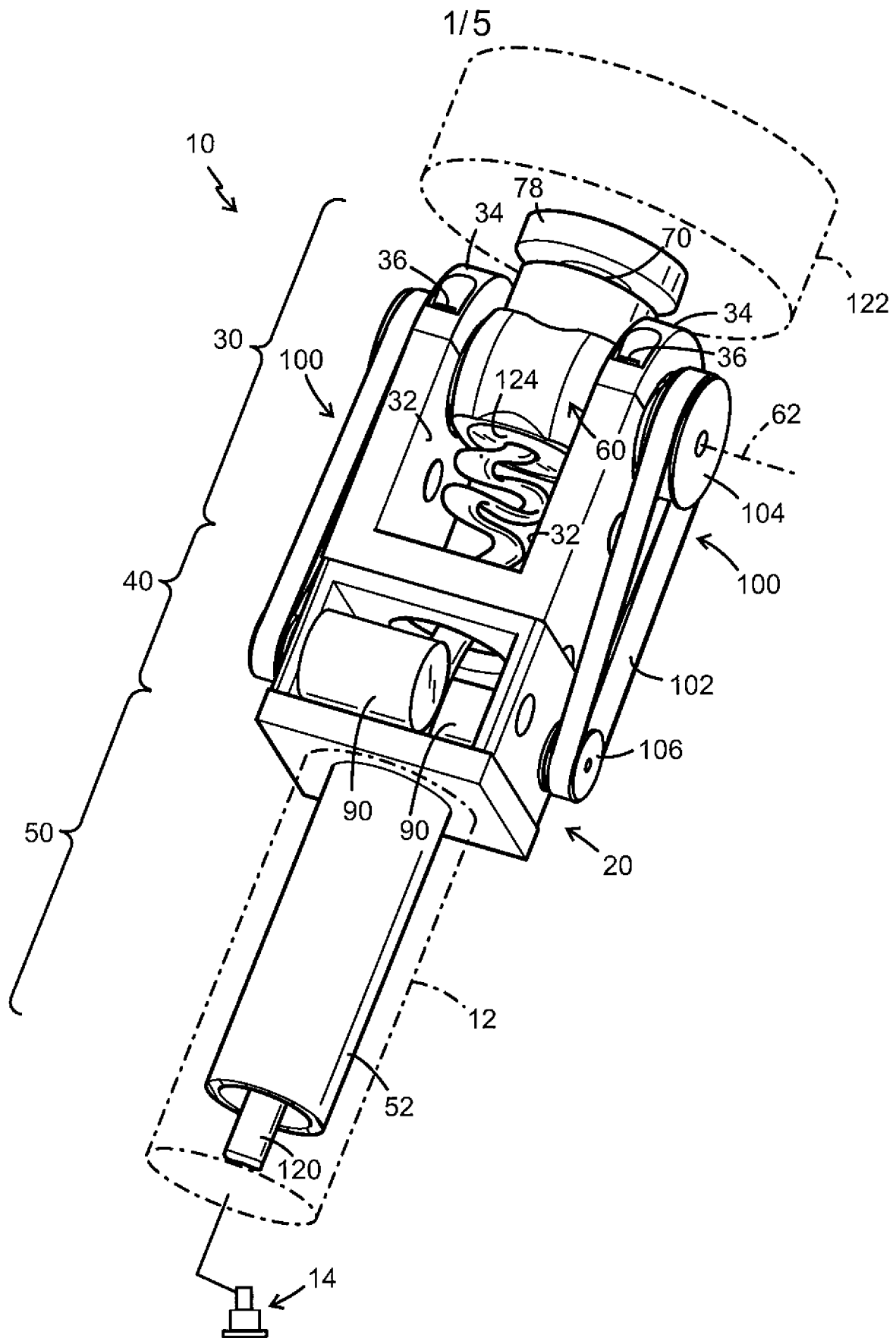


FIG. 1

2/5

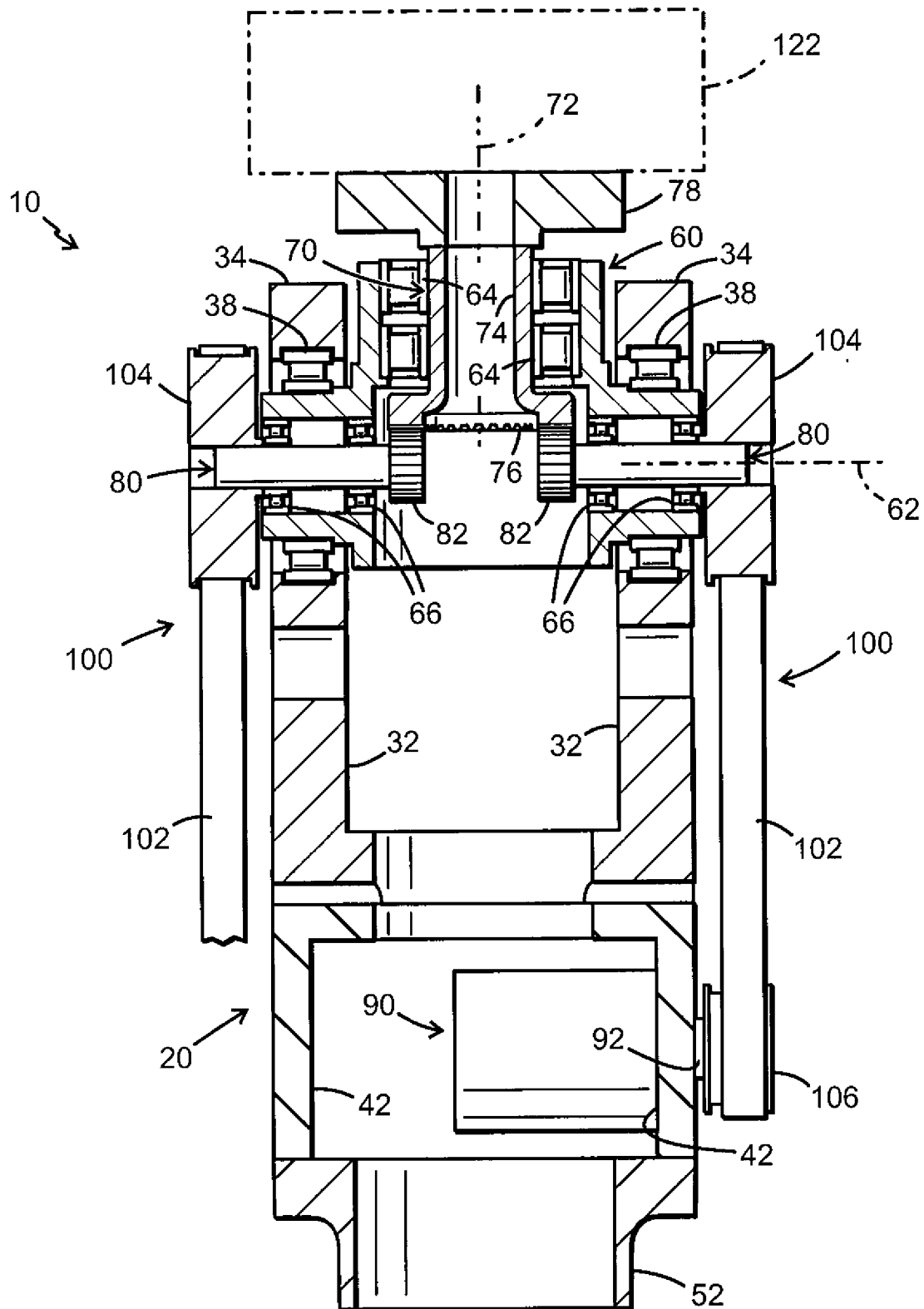


FIG. 2

3/5

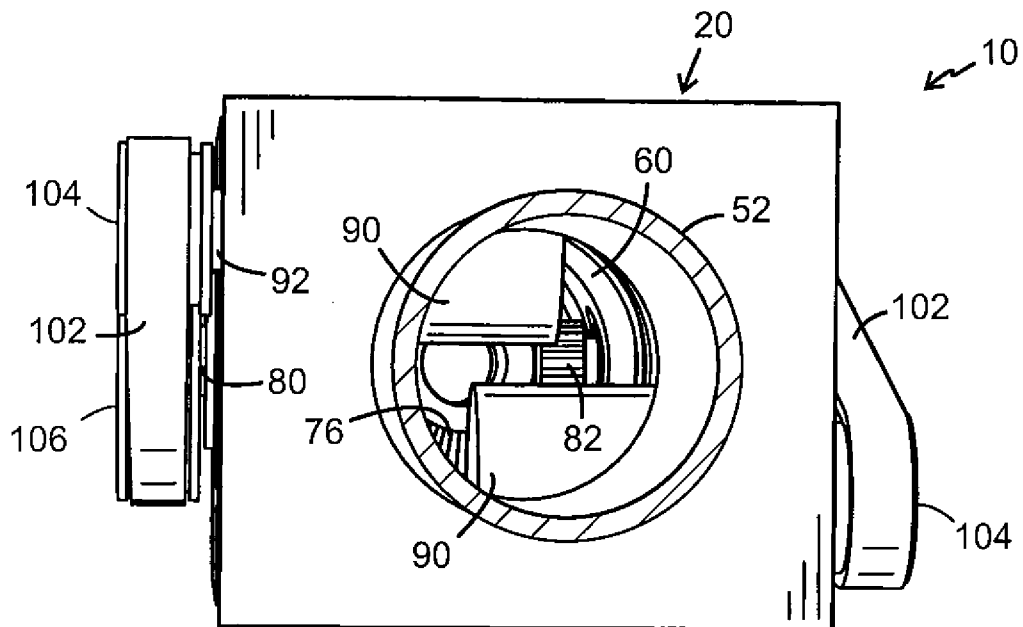


FIG. 3

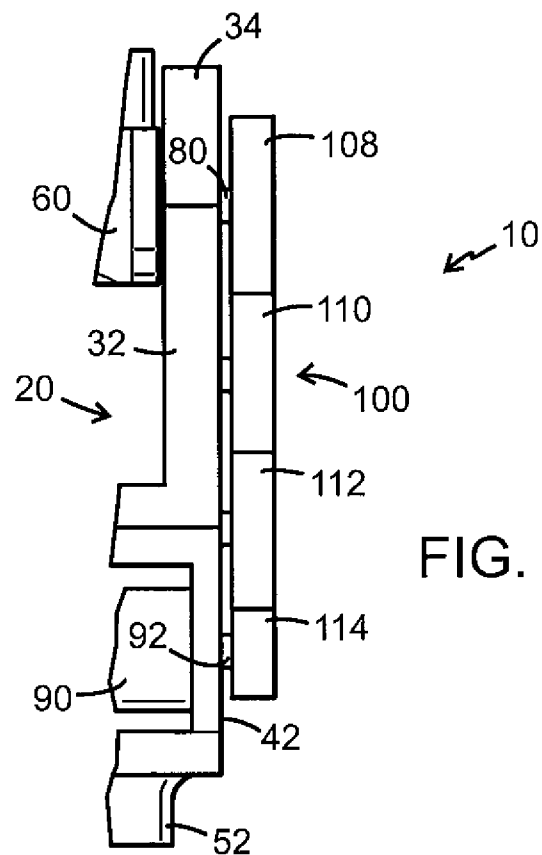


FIG. 4

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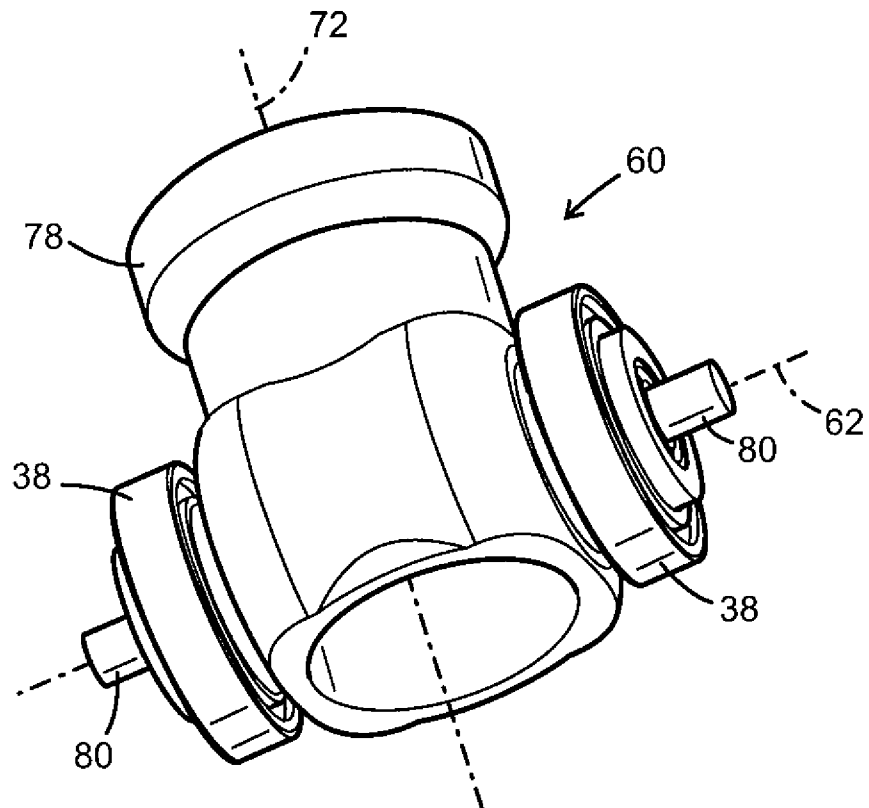


FIG. 5A

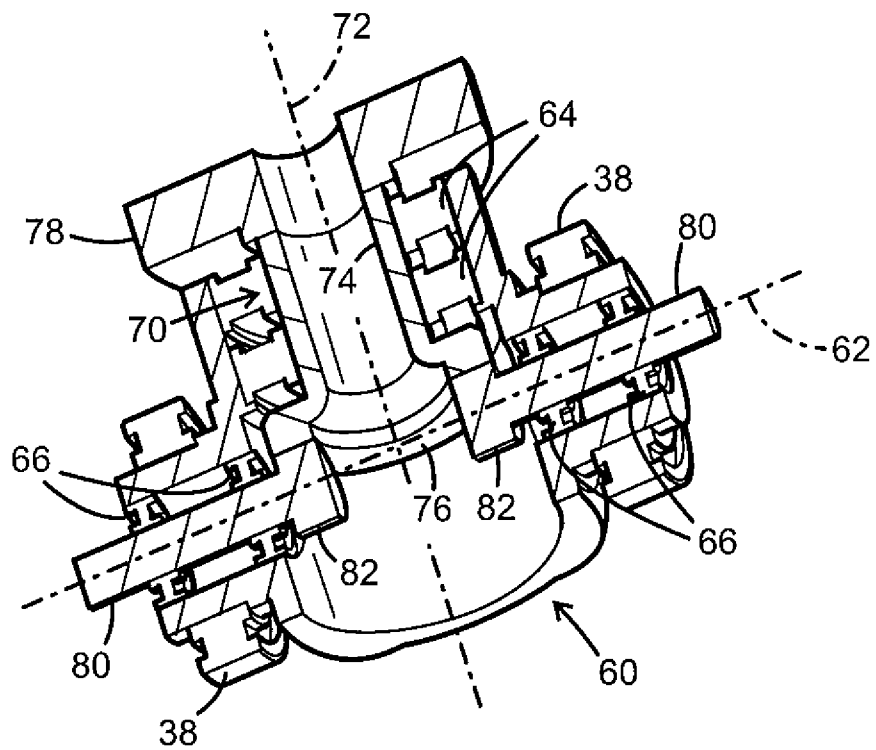


FIG. 5B

5/5

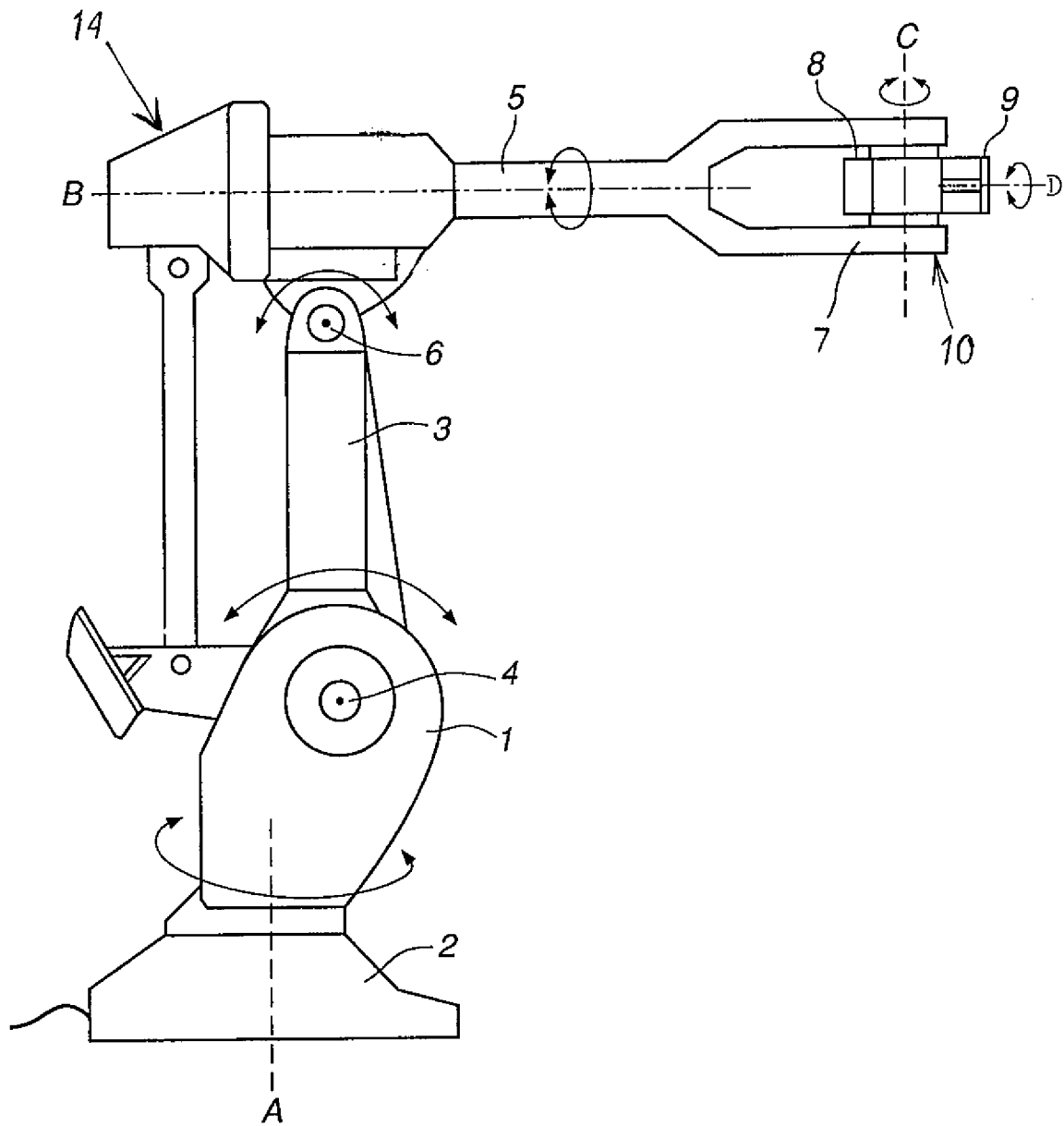


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2009/055537

A. CLASSIFICATION OF SUBJECT MATTER

INV. B25J9/10 B25J9/12 B25J17/02 B25J19/00

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B25J

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	-----	2,3,6,7
Y	US 2008/016979 A1 (YASUMURA MITSUHIRO [JP] ET AL) 24 January 2008 (2008-01-24) figure 4	2,6
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Y	US 5 549 016 A (NAKAKO TORU [JP] ET AL) 27 August 1996 (1996-08-27) column 3, lines 18-34; figure	7
Y	US 4 972 735 A (TORII NOBUTOSHI [JP] ET AL) 27 November 1990 (1990-11-27) figure 4	
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Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search

27 November 2009

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Name and mailing address of the ISA/

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INTERNATIONAL SEARCH REPORT

International application No

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 63 010087 U (-) 22 January 1988 (1988-01-22) figure 1 -----	5

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2009/055537

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