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(54) Benævnelse: **LEJE MED TRE OG FLERE RÆKKER AF RULLENDE ELEMENTER**

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DE-A1-102008 049 812
DE-U- 1 976 014
US-A- 3 762 782

BEARING WITH THREE AND MORE ROWS OF ROLLING ELEMENTS

Description

The invention relates to a pivoting bearing, or slewing ring, in installations where the loads imposed are large.

Such a bearing, according to the generic portion of Claim 1, is known from document DE 100 10 295 A.

The wind energy field is particularly involved.

One aim in itself is moreover to propose such a bearing for a blade of a wind turbine hub.

Generally, there already exist bearings capable of being subjected to strong forces, the bearing concerned being interposed and attached between a first structure and a second structure, between which forces then pass through the bearing, one of these forces at least being able to rotate with respect to the other around the axis of rotation of the bearing.

The bearing comprises:

- a first and a second bearing race, wherein one part of the second bearing race extends around the first, radially with respect to said axis of rotation,
- and multiple series of rolling elements (or bodies) each interposed between the first and a second bearing races in annular fashion around said axis.

In certain installations, the loads imposed can be very high, both axially (axis of rotation) and radially to this axis. The moments are also sometimes very high.

In the wind energy field, the blades of wind turbine undergo not only high loads on the axis of the/of each blade (so-called axial loads), but also very high loads exerted radially to the axis of the blade and the hub of the rotor (then called radial loads).

In this case the first and second aforementioned structures could in particular be respectively a wind turbine hub and a blade of the wind turbine, the blade then being capable of turning with respect to the hub around said axis of rotation of the bearing.

The speeds of rotation, the constantly increasing dimensions of the wind turbines, the loads imposed by the wind, but also loads imposed by the pitch angle of the blades, require a constantly increasing bearing strength.

In this regard, it is current practice that the blades can pivot by ten degrees or so around their spanwise axis to promote performance as a function of wind speed.

It is in this general context that one object of the invention is to improve the mechanical strength of the bearings. One corollary is to avoid certain problems connected with the use of slewing rings for wind turbine blades, in particular wear due to vibrations (called false brinelling or FEB).

The solution is described in the characterizing portion of Claim 1.

Very favourably, said at least three rows of rolling elements staggered along said axis of rotation of the bearing will comprise, between two end rows, at least one intermediate row of rolling elements capable of moving along the paths of the first and second bearing races, along periodic contacts.

Thus, increased resistance to loads perpendicular to the axis of rotation of the bearing will be ensured.

Thanks to a/to one such intermediate row(s), effective resistance to such radial loads will be ensured, even if it is weaker than with rollers for example, while still allowing resistance to pivoting due to vibrations, this eliminating wear by FEB, in particular in the wind energy field.

The solution using intermediate rows(s) of rolling elements comprising balls (ball bearings or spherical ball bearings) has been particularly effective, in particular in terms of rigidity and limitation of radial displacement of the races, thus limiting FEB.

The rolling elements of the intermediate row(s) belonging to the three or more rows of rolling elements staggered along the axis of rotation of the bearing are preloaded in a plane perpendicular to this axis of rotation.

In particular for resistance to ever larger overturning moments, the rolling elements of the end rows of said at least three rows of rolling elements are barrel bearings or roller bearings, and more generally rolling elements with linear contact, having in both cases individually an axis of rotation transverse to the axis of rotation of the bearing.

Here, “transverse” indicates generally that the axis of rotation considered crosses the axis of rotation of the bearing, not necessarily perpendicularly.

In particular, a solution using rollers appearing as cylinders of constant cross section and/or with an individual axis of rotation perpendicular to the axis of rotation of the bearing will make it possible to provide for effective strength parallel to the rotation axis of the bearing, hence carrying of the loads so directed, as well as the overturning moments (on wind turbines in particular) with an expected increase in the loading capacity.

Moreover, in arranging the rolling elements of the intermediate row(s) in the same (median) diameter different from those of the two end rows, which themselves will then also be favourably on a common (median) diameter, resistance to vibrations and the mechanical resistance of the assembly, dynamically, will be particularly favoured.

This and the foregoing being specifically pertinent in the wind energy field, it is legitimate that a wind turbine also be considered here, comprising a rotor hub, at least one blade and a bearing, or slewing ring, as presented earlier, the blade being able to rotate with respect to the hub and the rolling elements thus positioned being suited to resist together the loads and moments specific to this field, and more particularly vibrations, thus limiting or eliminating wear due to FEB.

The foregoing features, and those that follow in connection with the more detailed description hereafter, favour the reliability of the pivoting bearing or slewing ring installations in question, as well as the ergonomics of assembly/disassembly, by offering a technically and financially effective solution.

In the examples illustrated in the appended drawings:

- Figure 1 is a schematic of the front of a wind turbine conforming to the solution presented here,
- Figure 2 is a side view,
- Figures 3 and 4 each show a possible embodiment at the location of section III-III of Figure 2,
- Figure 5 is a front view of the slewing ring in question, this one that of Figure 4 (the other embodiments should be imagined in the same manner),
- Figure 6 shows end rollers and intermediate balls,
- Figure 7, which is not part of the object of the claims, shows balls in end and intermediate rows (only the bearing is shown, without the structures attached to it),
- Figure 8, which is not part of the object of the claims, shows balls in end rows and in two intermediate rows,
- and Figures 9, 10, 11 show barrel roller bearings in end rows and balls in one or two intermediate rows.

In Figures 1 and 2 is seen a wind turbine comprising a mast 3 at the head whereof at least one blade, three here, 5a, 5b, 5c, rotate around the horizontal axis 7a of a central hub 7.

Typically, the hub 7 is itself mounted to rotate around a vertical axis 7b with respect to the mast 3, to best orient itself with respect to the wind.

Each blade, and in particular the blade 5c of Figure 2, can pivot by a few degrees or tens of degrees around its spanwise axis 50c, with respect to the hub of the rotor 7, so as to regulate the power and the speed of rotation of the turbine.

In Figures 3, 4, the hub of the rotor is found at 7 and, at 50c, the axis of the blade 5c (50c also designating the axis of rotation of the blades, respectively 9, 90, illustrated).

The preferred angular orientation of each blade, such as the blade 5c, generates considerable radial loads in particular, as well as high bending moments.

The bearings or slew races 9, 90 illustrated comprise respectively a first bearing race 11, 11b, a second bearing race 13, 13b and multiple series of rolling elements 15, 15b, 17, 17b, 170b, 19, 19b (see Figures 3, 4).

The end portions 11a1, 11a2 of the first bearing race which extend around the portion facing the second race, radial to the axis of rotation 50c, serve, with the central nosing 130a of the latter, to hold the rolling elements of the end rows such as 15, 19; 15b, 19b….

Traditionally, each series of rolling elements is arranged in a circle, as shown in Figure 5, this between the first and a second bearing races, in annular fashion around the axis 50c.

In the examples illustrated in Figures 3, 4 these series of rolling elements comprise respectively three and four annular series which are arranged according to respectively three and four staggered rows along said axis 50c.

These rows of rolling elements comprise:

- two end rows (axially) 151, 191; 151b, 191b, each comprising a series of rollers 15, 19; 15b, 19b having individually an axis of rotation 153, 193; 153b, 193b transverse to (intersecting transversely) the axis of rotation 50c of the bearing,

- and respectively one (Figure 3) and two (Figure 4) (axially) intermediate rows 171; 171b, 172b of rolling elements comprising balls: 17, 17b, 170b.

Thus there is axial staging over three or four levels or rows. In other words, the series of rolling elements comprise more than two series of annular series (two rows therefore) of such elements, staggered along the axis 50c.

In Figures 3, 4, the end rows and the intermediate row(s) of these series of rolling elements have median diameters that differ from one another. Here, the end rows are on the same median diameter D1 (measured between the axis 50c and the middle of the rollers 15, 19; 15b, 19b); likewise for the intermediate row(s): median diameter D2 measured in the same manner (balls). In Figures 3, 4 it is the radii (R1, R2) that are shown. Thus these rolling elements, from the end rows on the one hand, and the intermediate row(s) on the other hand, are situated, with respect to said axis of rotation 50c, on different radii, respectively R1, R2.

More generically, what is thus found in the solution presented is one or two annular series of rolling elements 17, 17b, 170b designed to resist at least loads oriented radially or transversely to the axis of rotation 50c of the bearing, this/these series being interposed, in projection along this axis, between the (series of) rolling elements of the two end rows each designed to resist essentially loads oriented parallel or substantially parallel to the axis of rotation of the bearing.

In Figures 3, 4, but also Figure 6, the rollers 15, 19; 15b, 19b are cylinders with substantially constant cross section.

The radius varies very slightly over the length of the roller to obtain a constant pressure distribution; a chamfer at each end makes it possible to reduce edge effects. And the individual axis of rotation of the rollers (such as 155, Figure 3 for that shown at 15) is perpendicular to the axis 50b of rotation of the bearing.

In Figures 3, 4 the rolling elements of the intermediate row(s) 171; 171b, 172b are all identical to one another and situated on a same median diameter centred on the axis 50c (median diameter D2).

Regarding the corresponding balls 17, 17b, 170b, it is recommended, if there are multiple series, that they all have the same diameter, such as D30 in Figure 4, the rollers of the two end rows being also all preferably identical: the diameter labelled D4 in Figure 4, this in particular for applications to bearings for wind turbine blades. In other applications for which an axial load would be preponderant in a preferred direction, the diameter D30 of the rolling body (or elements) 17b, 170b of the intermediate row(s) could be less than D4.

In Figure 3, the intermediate rolling elements, to which belongs 171 which is shown, are located along the direction parallel to the axis 50c on which each is situated, substantially midway between those of the two end rows. The intermediate row 171 being the only one in Figure 3, the diameter D3 of the balls is greater there than the common diameter D30, of the balls of the two successive intermediary rows of Figure 4, but this can vary: the diameter of the ball is the result of a calculation based on the radial loads of the application.

In Figure 4, the balls of the upper 171b and lower 172b intermediate rows are located, again along the direction parallel to the axis 50c on which each is situated, closer to the rollers respectively of the upper end row 151b and the lower end row 191b than to their counterpart balls of the other intermediate row.

Again in Figure 4, and this will preferably be the same in Figure 3, the two median planes of the rolling elements of the two intermediate rows illustrated have been labelled respectively 173a and 173b. As recommended, these rolling elements with periodic contacts are preloaded respectively in one and the other of these planes, which are each perpendicular to the axis of rotation 50c. For this purpose, the diameter of the balls is, in the aforementioned plane slightly greater than the difference of the radii measured from 50c of the bearing races (respectively 23a, 23b) of the races 11b and 13b which receive them. Under load, the loading of these balls will therefore be radial to the axis 50c. This radial load, and possibly preload, orientation, will moreover be the same for the series of balls 17, Figure 3, or for the balls of the intermediate row(s) of Figure 6 and the following. In Figure 3, moreover, the common axis of loading of the rolling elements of the two end rows has been labelled 190. It corresponds to an axial load. It is therefore parallel to the axis 50c. This axis is found, labelled or not, but illustrated in Figure 4, then 6 and the following where there also exists therefore an axial load axis of the rolling elements of the two end rows.

Both in Figure 3 and Figure 4, it will also be noted that one of the races is in multiple parts. Here it is the first bearing race 11, 11b, which is radially outside with respect to the other race, essentially closer to the axis of rotation 50c.

Thus, to facilitate assembly/disassembly and maintenance, the first bearing race 11, 11b is in two parts, respectively 110, 111; 110b, 111b. The preferable joint plane, respectively 21, 21b, is, for transmitting loads, a plane close to the lower end row, here 19 or 19b, to establish a one-piece connection between the rotor hub and the intermediate rows of balls. In the illustration, the joint plane is substantially at the upper end row 151 or 151b which it circumvents to serve locally as an upper rolling path for the rollers of the upper end row, as regards the upper part 110; 110b of this first race. Farther down, the lower complementary part 111; 111b of the same race serves as an outer rolling path of the balls of the intermediate row (Figure 3)/of the intermediate rows (Figure 4), as well as the lower rolling path for the rollers of the lower end row. A similar assembly exists in the embodiments of the following figures.

And it is noted that, radially, for resisting loads and moments, the diameter D40 of the (mid-height) bottom of the path (also called a track) of inner rolling 23 for each ball is less than the diameter D5 of the outer stop, transverse (perpendicular here) to the axis 50c, of each roller, whether it is in the upper (250) or lower (270) row. Thus it is possible to position radially the track of the balls on the closest possible diameter to the diameter D1 of the roller row to limit the length of the central nosing 130a and consequently the bending loads at the base thereof. The nosing 130a is the central portion of the inner race 13 which extends radially until the inner rolling path 23. On either side, it also serves as a central rolling path, for example for the rollers 15, 19.

Either way, all or part of the foregoing features will be implemented so that the rolling elements thus arranged are suited to resist together the loads oriented with radial and axial components with respect to the axis 50c of rotation of the bearing.

Regarding mounting on the hub 7 and the blade 5c, it will also be noted that, on either side of the bearings, the races 11, 13 are fixed respectively to the hub and to the blade.

The screws, with or without heads (dowels) respectively 27 and 29, provide for the aforementioned attachments, parallel to the axis 50c, at two different radial distances from this axis. Figure 5 shows this, with the races, respectively outer 11b and inner 13b (with its teeth 130b on the inner perimeter; anticipated of course in the case of Figure 3).

The threaded rod of each attachment means 27 staggered over the perimeter of the race 11, cooperates with a nut 27a. Each attachment means 29 is screwed directly into the body of the root of the blade 5c, with its head 29a located on the hub side. Thus, the bolts 27, 29 are accessible through the hollow interior of the rotor hub 7.

The difference between the embodiments of Figures 4 and 6 is that the rolling elements of the intermediate rows are radially located in one case farther, in one case less far, from the axis 50c (D2/R2) than are the rolling elements of the end rows.

This positioning on one side or the other is moreover significant for none of the embodiments covered by the solution to be patented here.

Solutions with (axial) end rows with rollers must make it possible to obtain a high axial load, but especially overturning moment capacity, the preponderant load particularly for the very large wind turbines (multi-megawatt). The limitation (by preloading) of the allowed radial movement of the rotating race is also significant.

Figure 7, which is not part of the object of the claims, makes it possible to show that structures other than a rotor hub and a wind turbine blade can be attached to the rotating races of the bearing. The construction of a construction-site crane turret is thus for example involved, this in connection with any one of the structures described here.

In Figures 7, 8 which are not part of the object of the claims, the rolling elements 15c, 19c of the (axial) end rows are balls. They are (substantially) spherical. The same is true of the rolling elements, respectively 17c and 17c, 170c of the (axial) intermediate row(s). The loading axes of the rolling elements are shown, as they are on the following figures.

In Figures 9, 10 moreover, the rolling elements 15d, 19d of the (axial) end rows, although again with periodic contacts with the tracks of the adjacent bearing races (labelled here 11d, 13d) as in Figures 7, 8, are barrel bearings. The axis of rotation of each of these barrel bearings is oriented perpendicularly to the axis 50c of rotation of the bearing. The rolling elements, respectively 17d and 17d, 170d, of the (axial) intermediate row(s), are balls.

As for Figure 11, it shows again that the rolling elements of the intermediate row(s) can be radially located in one case farther, in one case less far (Figure 10) from the axis 50c (D2/R2) than are the rolling elements of the end rows.

Regarding this, it will be noted that the versions with an internal race in two parts (Figures 6-10) or with an external race in two parts (Figures 3, 4, 11) will be useful for positioning the drive gearing 33 which will always be on the race in a single part. Depending on the configurations, the gearing is on the radially inner race or the outer race.

Regarding the scope of the rolling elements with periodic contacts presented (balls, barrels), the present slew ring will preferably have row(s) of elements with two contact zones (often known by the name “two zone (point) contact…”).

As for the use of balls under radial load, it makes it possible to create a pre-loaded assembly which will introduce stiffness and limit radial displacements of the races, thus limiting FEB.

LEJE MED TRE OG FLERE RÆKKER AF RULLENDE ELEMENTER

Patentkrav

1. Leje, der omfatter en omdrejningsakse (50c), og som kan indskydes mellem en første struktur (7) og en anden struktur (5c), idet den første og den anden struktur kan dreje i forhold til hinanden omkring lejets akse, og idet dette leje omfatter:
- et første og et andet rulleleje (130, 150...), hvor en del af det andet rulleleje strækker sig ud omkring det første, radialt i forhold til aksen (50c)
- flere rækker af rullende elementer, der er indskudt mellem det første og det andet rulleleje, på en ringformet måde omkring aksen (50c),
idet de flere rækker af rullende elementer omfatter mindst tre ringformede rækker, hvoraf mindst to er placeret på forskellige radiusser (R1, R2) i forhold til aksen (50c) og er anbragt i mindst tre rækker, der er fordelt langs aksen, og idet de rullende elementer i den eller de mellemliggende rækker af de mindst tre rækker af rullende elementer, der er fordelt langs omdrejningsaksen (50c) for lejet, er forud ladt i et plan vinkelret på omdrejningsaksen, kendetegnet ved, at de rullende elementer i den eller de mellemliggende rækker af de mindst tre rækker af rullende elementer omfatter kugler (17, 17b, 170b), ved, at hver af de to ydre rækker af de mindst tre rækker af rullende elementer, der er forskudt langs omdrejningsaksen (50c) for lejet, omfatter enten en række ruller (15) eller en række sfæriske rullelejer (15d, 19d), der henholdsvis og individuelt har en omdrejningsakse på tværs af lejets omdrejningsakse, samt ved, at diameteren (D40) i bunden i mellemhøjden af banen (23b) til indre rulning (23) af hver kugle (17, 17b, 170b)

er mindre end diameteren (D5) af det ydre anslag, på tværs af aksen (50c), for hver rulle (15) eller hvert sfærisk rulleleje.

2. Leje ifølge krav 1, kendetegnet ved, at de mindst tre rækker af rullende elementer, der er fordelt langs omdrejningsaksen (50c) for lejet, omfatter:
- to ydre rækker, der hver omfatter en række ruller (15b, 19b), der henholdsvis og individuelt har en omdrejningsakse på tværs af lejets omdrejningsakse,
- og mindst en mellemliggende række af rullende elementer, der omfatter kugler (17, 17b, 170b).

3. Leje ifølge krav 1 eller 2, kendetegnet ved, at rullerne (15, 19;15b, 19b) er cylindre med konstant tværsnit.

4. Leje ifølge krav 2, kendetegnet ved, at den individuelle omdrejningsakse (153b, 193b...) for rullerne eller de sfæriske rullelejer (15d, 19d) er vinkelret på lejets omdrejningsakse.

5. Leje ifølge krav 1, kendetegnet ved, at de mindst tre rækker af rullende elementer, der er fordelt langs omdrejningsaksen (50c) for lejet, omfatter:
- to ydre rækker, der hver omfatter en række sfæriske rullelejer (15d, 19d), der henholdsvis og individuelt har en omdrejningsakse på tværs af lejets omdrejningsakse,
- og mindst en mellemliggende række af rullende elementer, der omfatter kugler (17, 17b, 170b).

6. Leje ifølge et af de foregående krav, kendetegnet ved, at det omfatter to mellemliggende rækker af rullende elementer, der er fordelt langs omdrejningsaksen (50c) for

lejet.

7. Leje ifølge et af de foregående krav, kendetegnet ved, at alle de rullende elementer i den eller de mellemliggende rækker er identiske og er placeret ifølge en samme midterst diameter (D2), der er centreret omkring lejets omdrejningsakse (50c).

8. Leje ifølge et af de foregående krav, kendetegnet ved, at et af rullelejerne er i flere dele (110, 111;110b, 111b).

9. Vindmølle, der omfatter et leje ifølge et af de foregående krav, et rotornav (7) som første struktur og mindst én vinge (5c) som anden struktur, idet vingen kan dreje i forhold til navet.

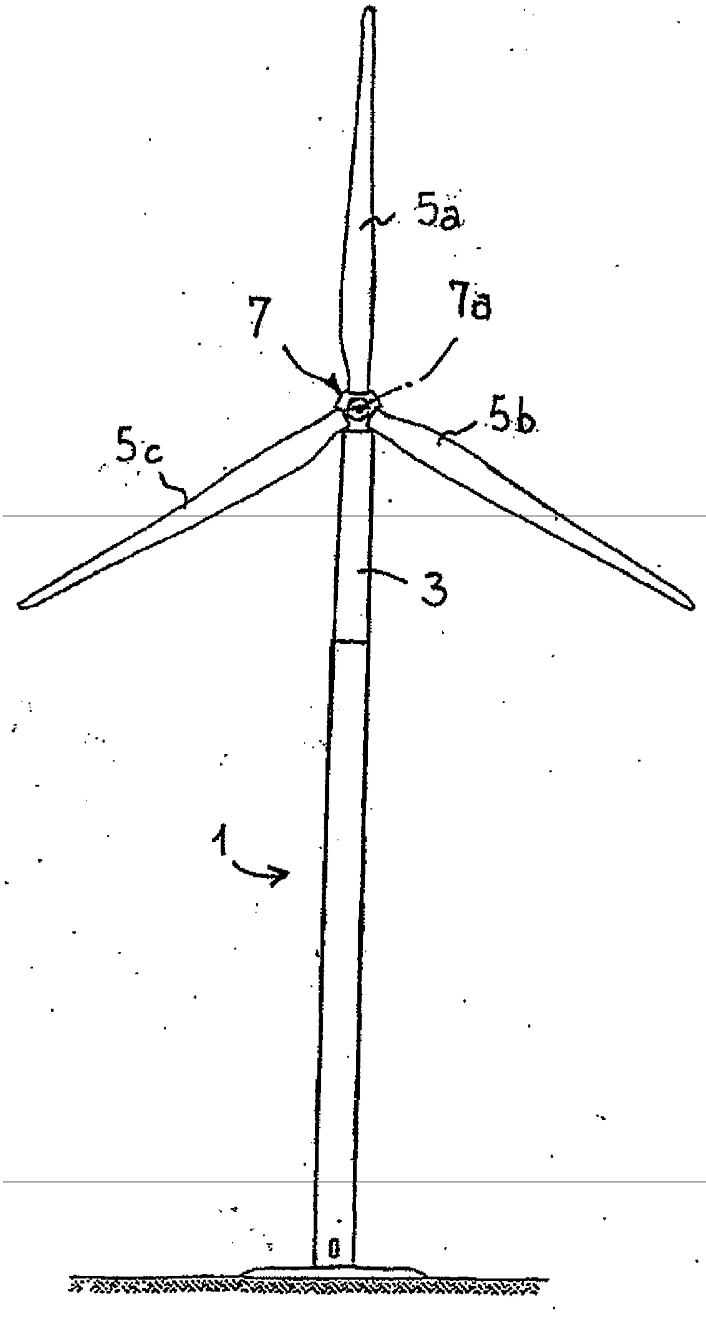

FIG_1

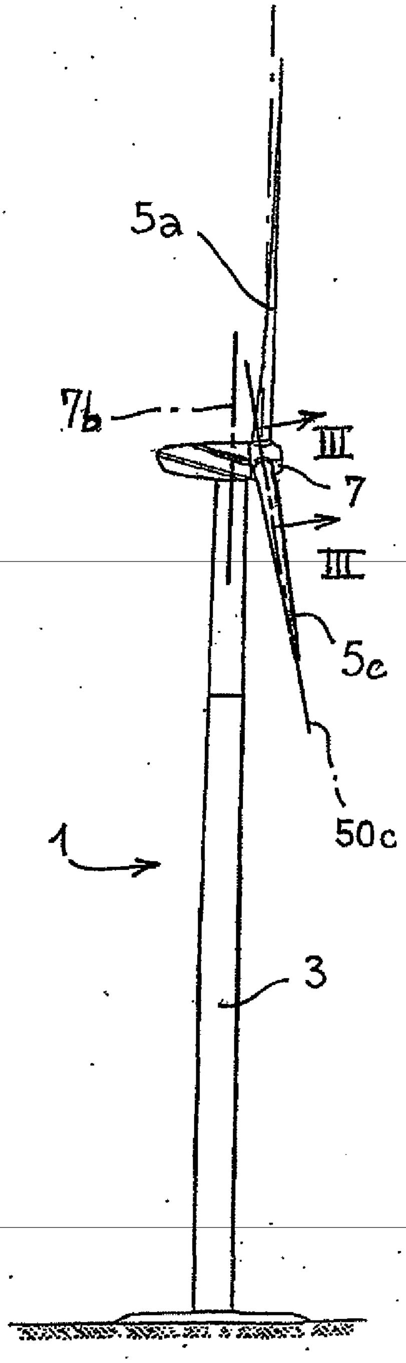

FIG_2

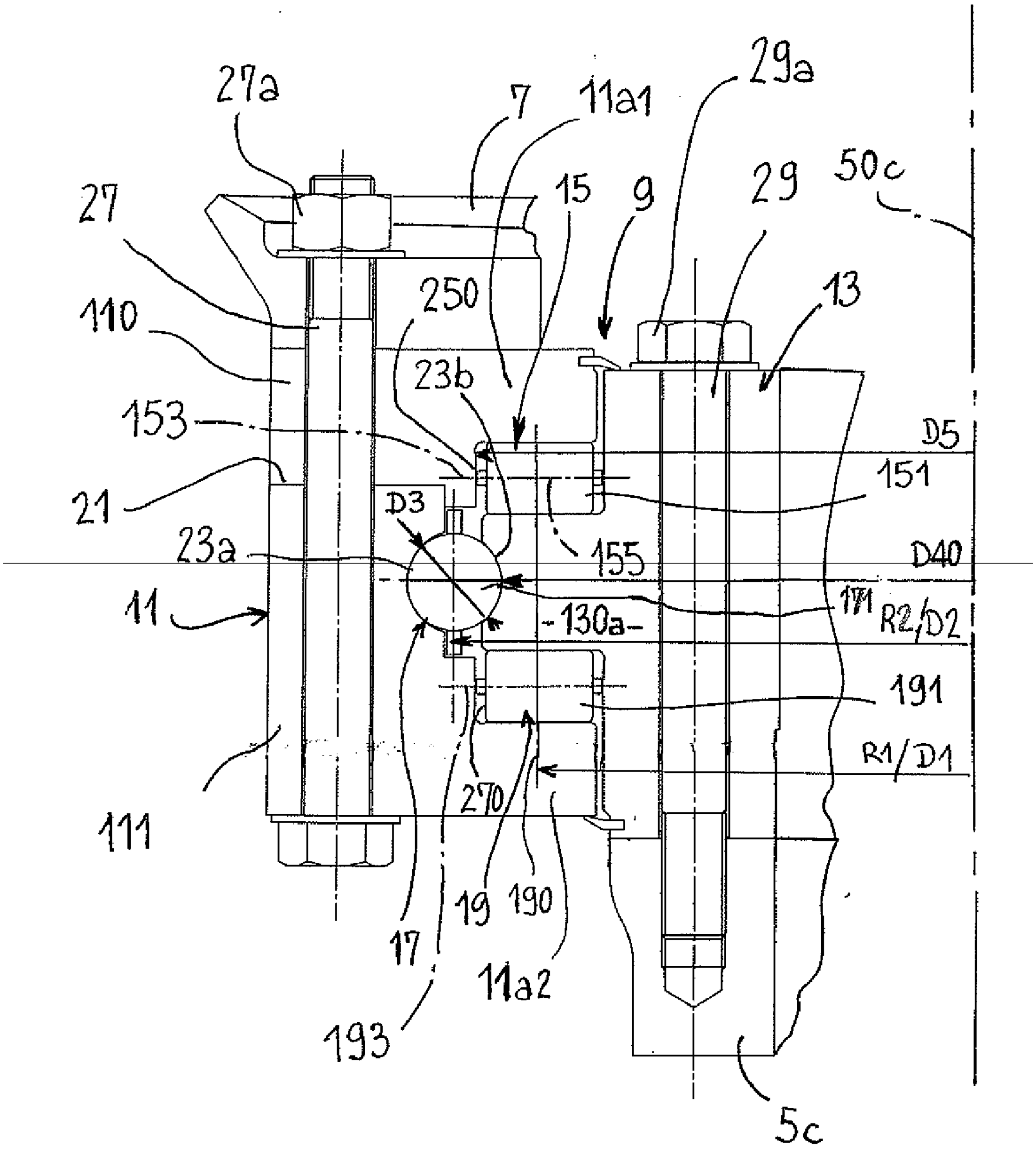
27a
7
11a1
29a
27
15
9
29
50c
13
110
250
23b
153
D5
151
21
D3
155
23a
D40
11
171
R2/D2
130a
191
111
R1/D1
270
19
190
17
11a2
193
5c

FIG.3

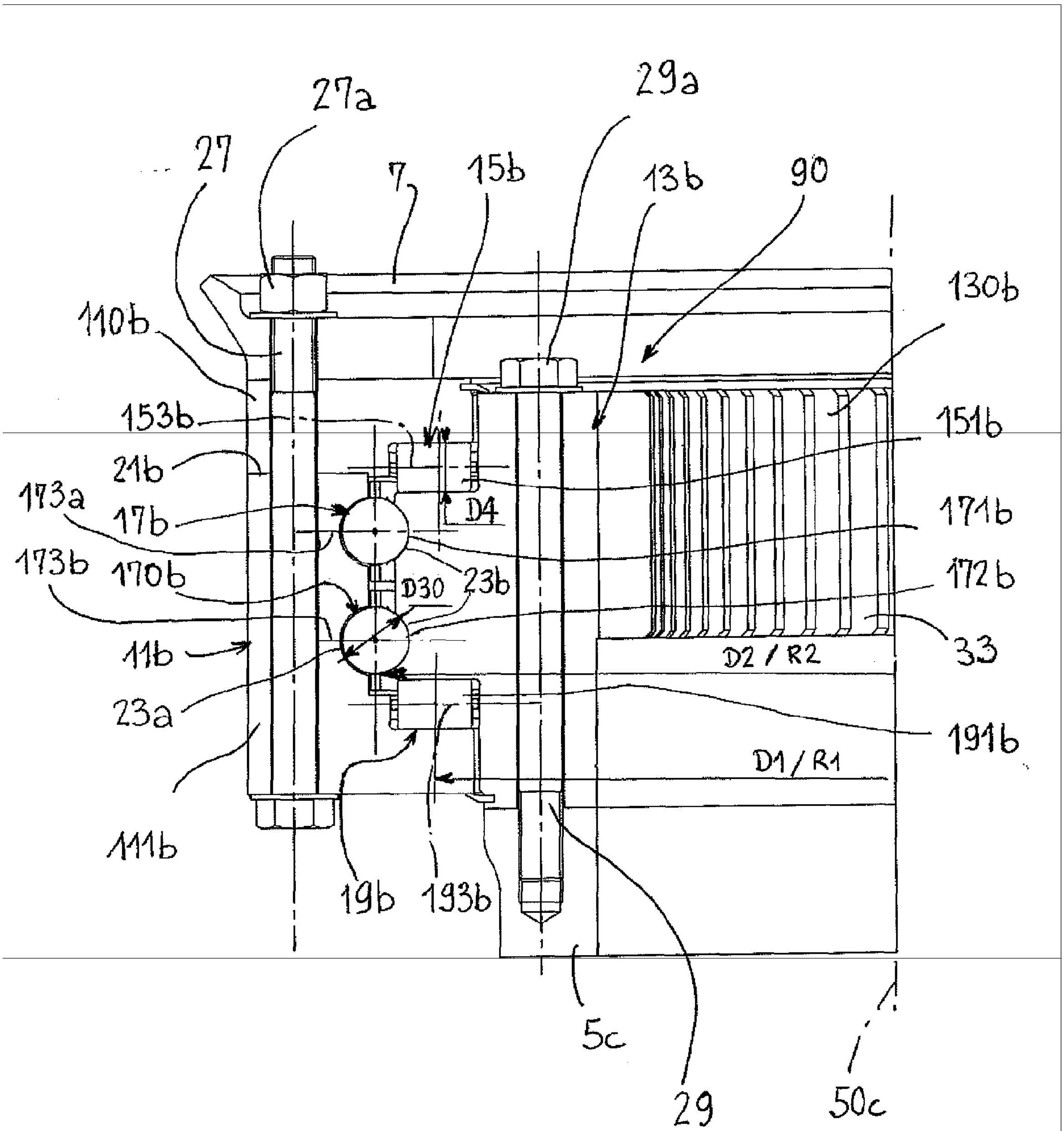
27a
29a
27
7
15b
13b
90
130b
110b
153b
151b
21b
173a
17b
D4
171b
173b
170b
D30
23b
172b
11b
33
D2 / R2
23a
191b
D1 / R1
111b
19b
193b
5c
29
50c

FIG. 4

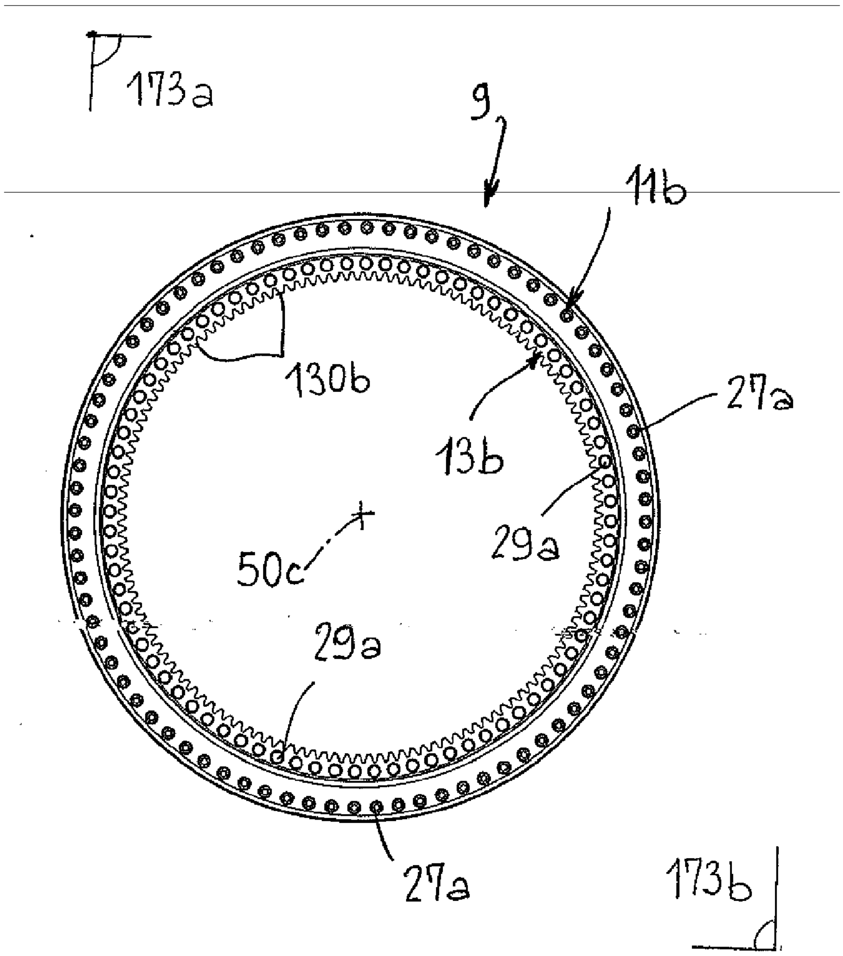

FIG.5

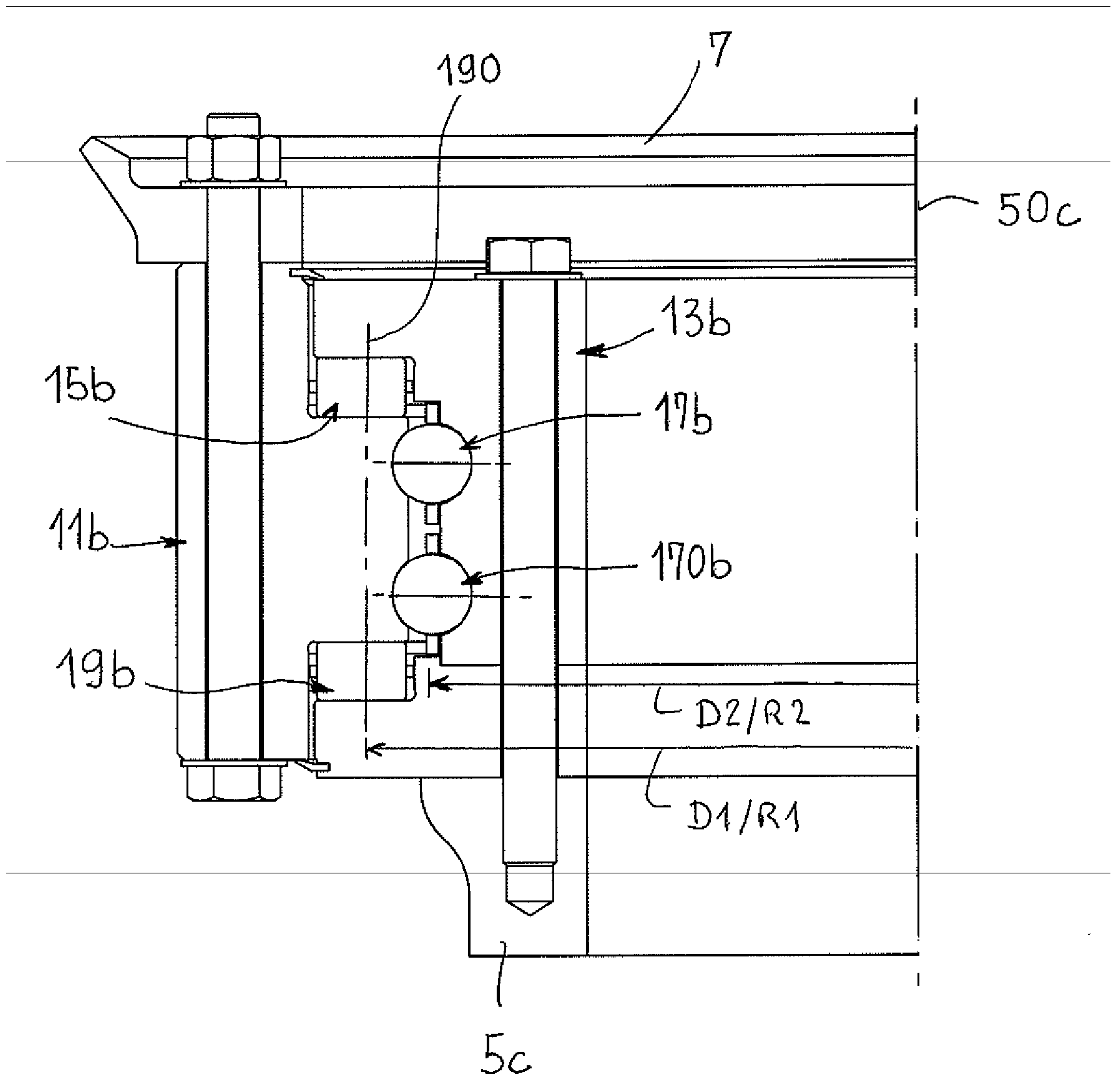

FIG.6

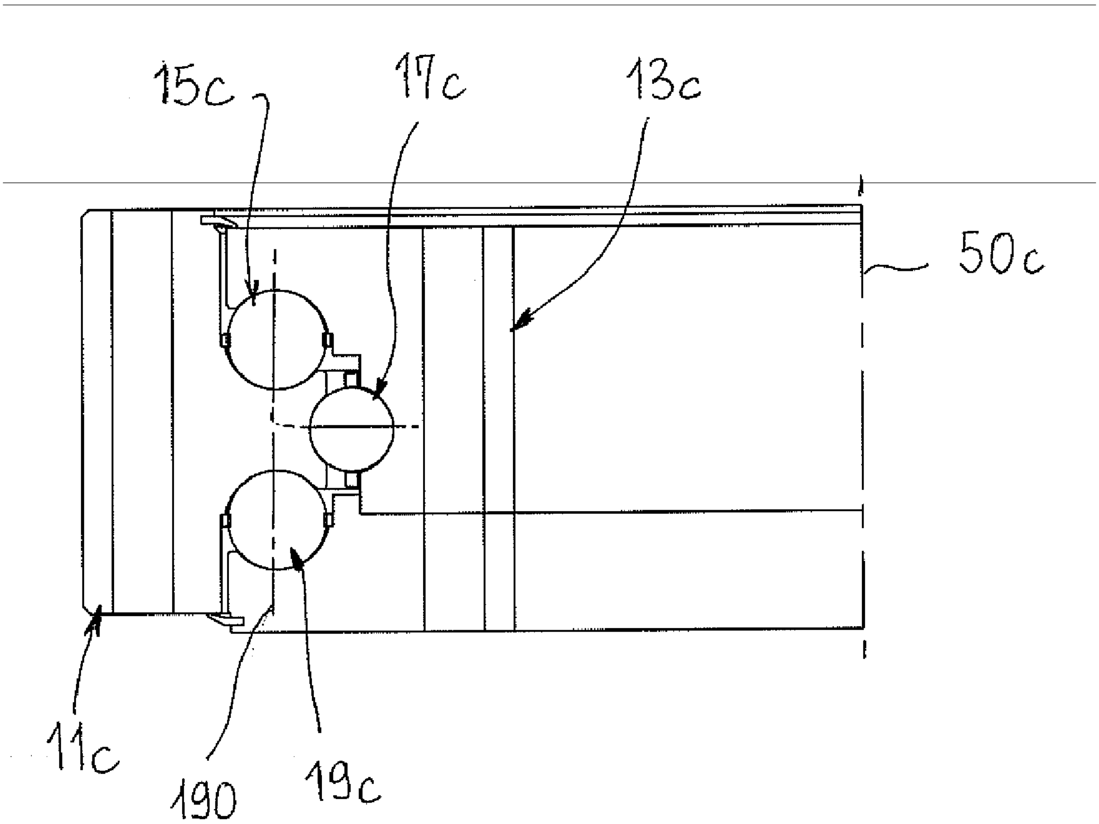

FIG.7

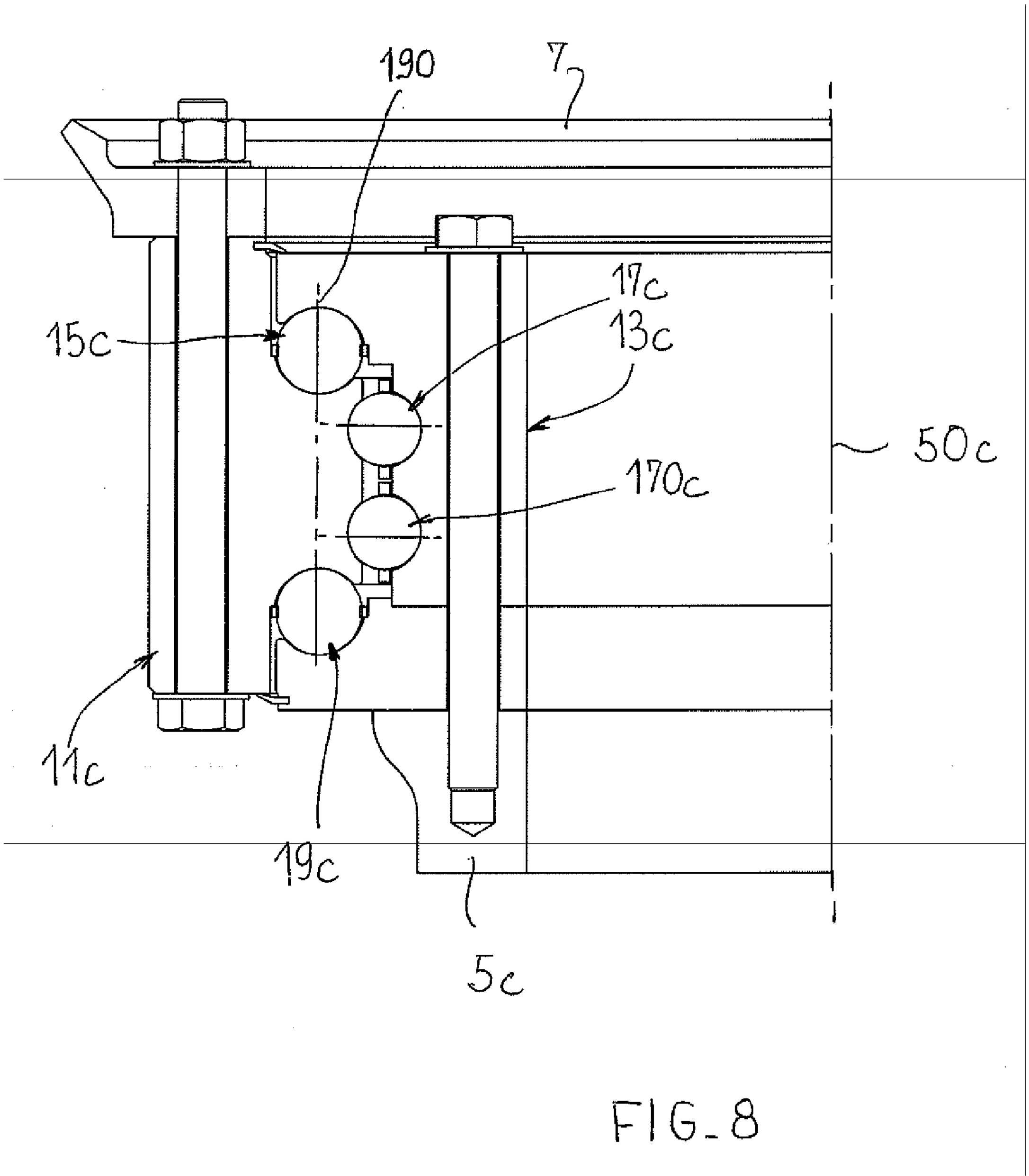

FIG_8

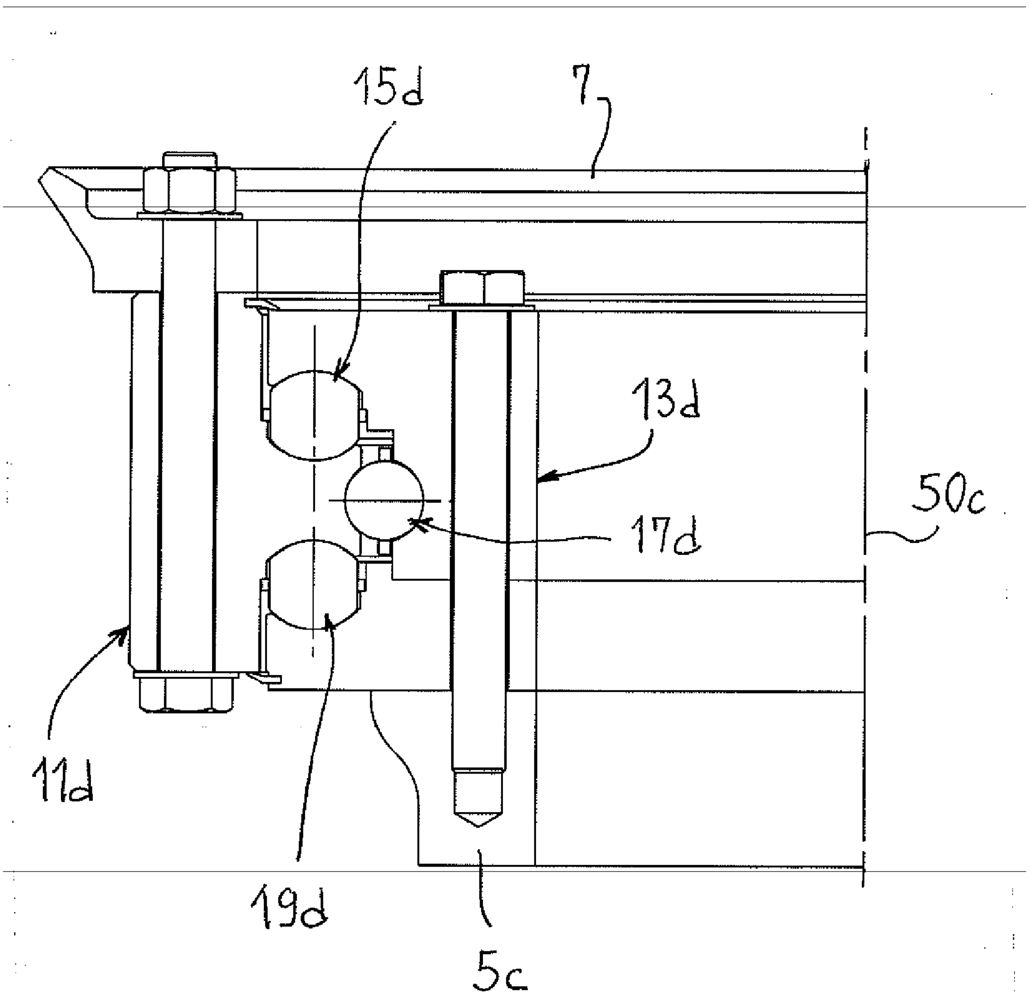

FIG_9

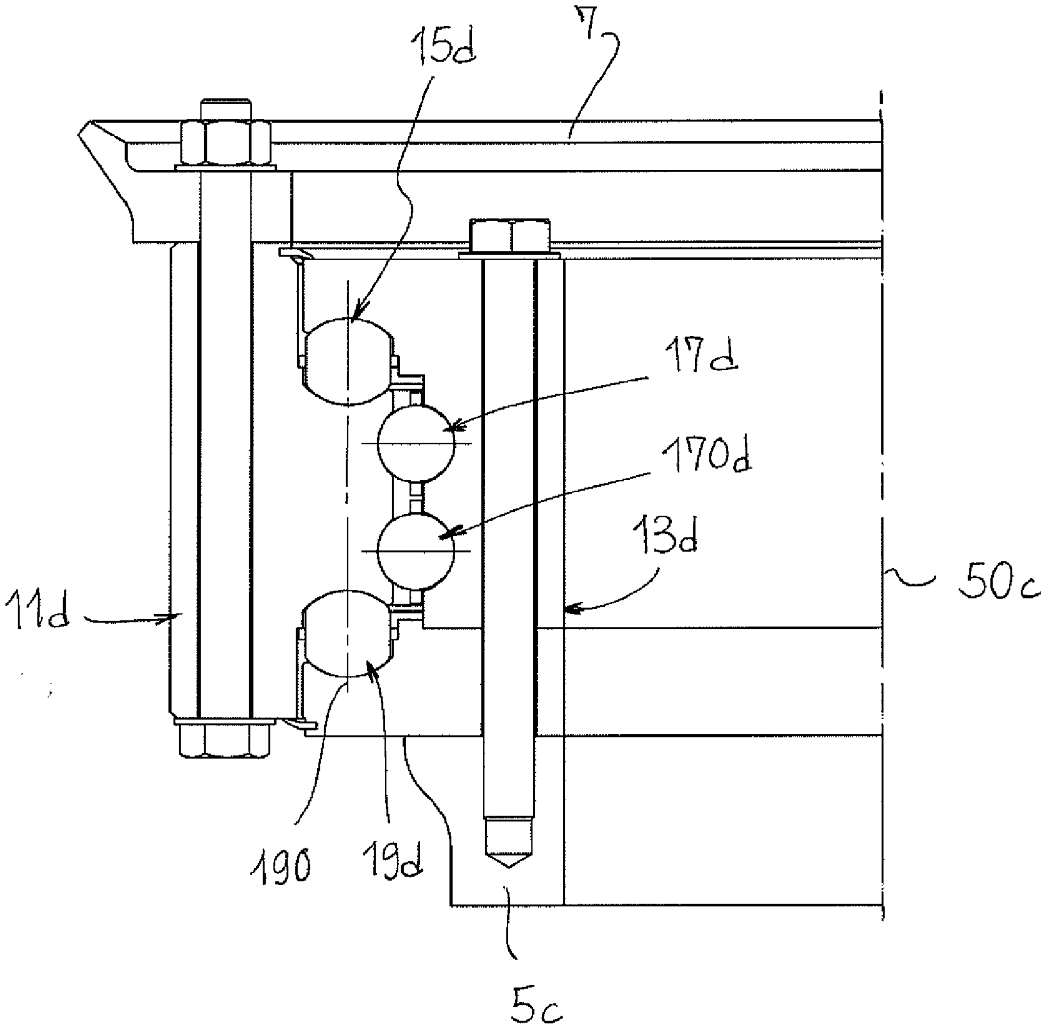

FIG_10

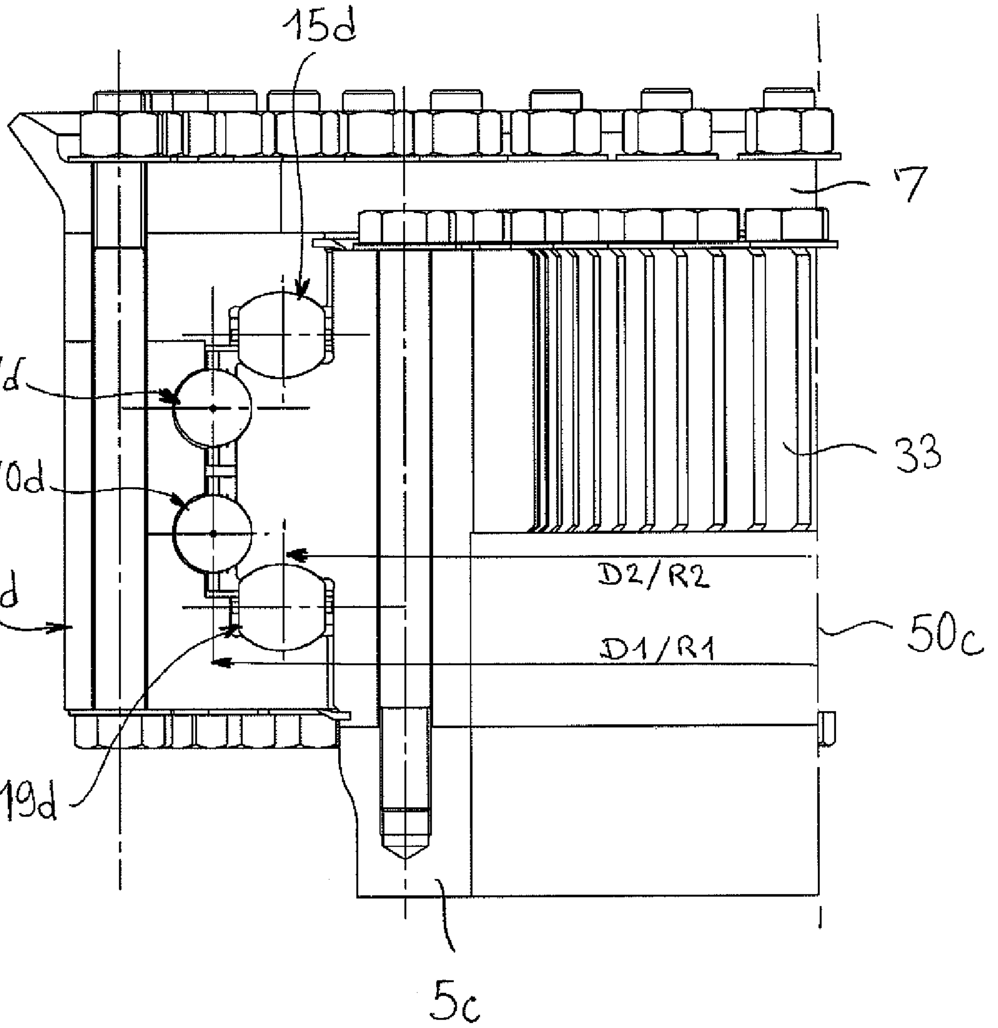

FIG_11