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- (73) Patenthaver: **Defontaine, Rue Saint Eloi, 85530 La Bruffière, Frankrig**
- (72) Opfinder: **ERRARD, Germain, 3, rue Saint Christophe, 44210 PORNIC, Frankrig**
Jacquemont, Eric, 6 rue Georges Caillaud, 44190 Clisson, Frankrig
DELACOU, Jean-Michel, 8 Le Montet, Saint Jallet, 16190 Saint-Plantaire, Frankrig
- (74) Fuldmægtig i Danmark: **Novagraaf Brevets, Bâtiment O2, 2 rue Sarah Bernhardt CS90017, F-92665 Asnières-sur-
Seine cedex, Frankrig**
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[0001] The invention relates to a pivoting bearing, or slewing ring, on installations where the experienced forces are significant.

[0002] Such a bearing, according to the preamble of claim 5 1, is known from document DE 10 2008 049812.

[0003] The field of wind energy is particularly concerned.

[0004] An aim in itself is moreover to propose such a bearing for a blade of a wind turbine rotor hub.

10 [0005] In general, there are already bearings likely to undergo considerable forces, the bearing concerned being interposed and attached between a first structure and a second structure between which forces then pass, via the bearing, one at least of these structures being rotatable with respect one 15 another, about the axis of rotation of the bearing.

[0006] 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,
- 20 - and multiple series of rolling elements (or bodies), each interposed between the first and second bearing races, in annular fashion about said axis.

[0007] On some installations, the experienced forces can be very high both axially (axis of rotation) and radially with 25 respect to this axis. The moments are also sometimes very significant.

[0008] In the field of wind energy, the wind turbine blades undergo not only significant forces in the axis of the/each blade (called axial forces), but also very 30 significant forces exerted radially with respect to the axis of the blade and of the rotor hub (called radial forces).

[0009] In this case, the aforementioned first and second structures may particularly be respectively a wind turbine

rotor hub and a wind turbine blade, wherein the blade can turn with respect to the hub about said axis of rotation of the bearing.

[0010] The rotational speeds, the ever increasing
5 dimensions of the wind turbines, the forces imposed by the wind, but also forces related to the pitch angle of the blades impose an ever increased resistance of the bearings.

[0011] In this regard, it is common for the blades to be able to pivot by about ten degrees about their axis of
10 elongation to promote the efficiency as a function of the power of the wind.

[0012] It is in this general context that an object of the invention is to improve the mechanical strength of the bearings. A corollary is to prevent some problems linked to
15 the use of slewing rings for the wind turbine blades, particularly the wear caused by vibrations (False Brinelling, FBE, false Brinell effect).

[0013] The solution is described in the characterizing part of claim 1.

[0014] Thus, a high resistance to forces perpendicularly
20 to the axis of rotation of the bearing will be ensured.

[0015] Thanks to such one or more intermediate rows, an efficient resistance to these radial forces will be ensured, even if it is weaker than with roller bearings, for example,
25 while allowing resistance to the pivotal movements caused by vibrations, this eliminating the wear by FBE in particular in the field of wind energy.

[0016] A solution with one or more intermediate rows of rolling elements comprising balls (ball bearings or spherical
30 ball bearings) has been particularly efficient, particularly in terms of rigidity and limitation of the radial displacements of the races, thus limiting the FBE.

[0017] Also favorably, the rolling elements of the one or more intermediate rows belonging to the three rows, or more, of rolling elements staggered along said axis of rotation of the bearing are preloaded in a plane perpendicular to this axis of rotation.

[0018] For particularly the resistance to the increasingly important overturning moments, it is envisaged that the rolling elements of the end rows of said at least three rows of rolling elements can be barrel rolling elements or roller bearings and more generally rolling elements with linear contacts, having in both cases, individually, an axis of rotation transverse to the axis of rotation of the bearing.

[0019] Here "transverse" generally indicates that the considered axis of rotation crosses the axis of rotation of the bearing, not necessarily perpendicularly.

[0020] In particular a solution with roller bearings presented as cylinders of constant section and/or with individual axis of rotation perpendicular to the axis of rotation of the bearing, will allow ensuring an efficient resistance parallel to the axis of rotation of the bearing, therefore the absorption of the thus directed forces, as well as the overturning moments (particularly on the wind turbines), with an expected increase in load capacity.

[0021] Moreover, by disposing the rolling elements of the one or more intermediate rows on the one and the same (median) diameter different from the rolling elements of the two end rows, that will then also be favorably on a common (median) diameter, the resistance to vibrations and the mechanical strength of the assembly will be particularly favored in dynamics.

[0022] This and the above being specifically relevant in the field of wind energy, it is legitimate that a wind turbine comprising a rotor hub, at least one blade and one bearing, or

slewing ring, as presented above, are also concerned here, wherein the blade can turn with respect to the hub and the thus disposed rolling elements being adapted to hold together the forces and moments specific to this field, and very particularly the vibrations, thus limiting, even eliminating, the wear by FBE.

[0023] The foregoing characteristics, or even those that follow in conjunction with the more detailed description hereafter and the dependent claims, favor the reliability of the concerned installations with pivoting bearing or slewing ring, as well as the mounting/dismounting ergonomics, offering a technically and financially efficient solution.

[0024] In the examples illustrated in the appended drawings:

- 15 - Figure 1 is a front diagram of a wind turbine in accordance with the solution presented here,
- Figure 2 is a side view,
- Figures 3 and 4 each show a possible embodiment at the cross-section III-III of Figure 2, which is not part of the object of the claims,
- 20 - Figure 5 is a front view of the concerned slewing ring, here that of Figure 4 (the other embodiments must be imagined in the same way),
- Figure 6 shows end roller bearings and intermediate balls; this embodiment is not part of the object of the claims,
- 25 - Figure 7 shows balls in end and intermediate rows (only the bearing, without the structures attached thereto, is shown),
- 30 - Figure 8 shows balls in end rows and on two intermediate rows,

- and Figures 9, 10, 11 show barrel rolling elements or roller bearings in end rows and balls on one or two intermediate rows.

[0025] Figures 1 and 2 show a wind turbine 1 comprising a mast 3 at the top of which at least one blade, here three, 5a, 5b, 5c, rotate about the horizontal axis 7a of a central hub 7.

[0026] Typically, the hub 7 is itself rotatably mounted about a vertical axis 7b with respect to the mast 3, to be best oriented relative to the wind.

[0027] Each blade, and particularly the blade 5c of Figure 2 can pivot by a few degrees or about ten degrees about its axis of elongation 50c, with respect to the rotor hub 7, so as to regulate the power and the rotational speed of the turbine.

[0028] Figures 3, 4 show in 7 the rotor hub and in 50c the axis of the blade 5c (50c also identifying the axis of rotation of the illustrated bearings, respectively 9, 90).

[0029] The preferred angular orientation of each blade, such as the blade 5c, particularly generates significant radial forces, as well as high bending moments.

[0030] The illustrated bearings or slewing rings 9, 90, 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 (cf. Figures 3, 4).

[0031] The end parts 11a1, 11a2 of the first bearing race which extend around the parts facing the second race, radially with respect to the axis of rotation 50c, are used, with the central nose 130a of the second race, to maintain the rolling elements of the end rows such as 15, 19; 15b, 19b...

[0032] Traditionally, each series of rolling elements is arranged in a circle, as shown in Figure 5, this between the

first and second bearing races, in annular fashion about said axis 50c.

[0033] In the examples illustrated in Figures 3, 4, these series of rolling elements comprise respectively three and
5 four annular series which are arranged respectively in three and four rows staggered along said axis 50c.

[0034] These rows of rolling elements comprise:

- two (axially) end rows 151, 191; 151b, 191b, each comprising a series of roller bearings 15, 19; 15b, 19b
10 having, individually, an axis of rotation 153, 193; 153b, 193b, transverse to (across-cutting) 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
15 elements comprising balls: 17, 17b, 170b.

[0035] There is thus an axial staging on three or four levels or rows. In other words: the series of rolling elements comprise more than two annular series (therefore two rows) of such elements, staggered along the axis 50c.

20 [0036] In Figures 3, 4, the end rows and the one or more intermediate rows of these series of rolling elements have different median diameters therebetween. Here, the end rows are on the one and the same median diameter D1 (measured between the axis 50c and the middle of the roller bearings 15,
25 19; 15b, 19b), likewise for the one or more intermediate rows: the median diameter D2 is measured in the same way (balls). In Figures 3, 4, it is the radius (R1, R2) that are shown. Thus, these rolling elements, on the one hand of the end rows and on the other hand of the one or more intermediate rows are
30 situated, with respect to said axis of rotation 50c, on different radius, respectively R1, R2.

[0037] More generically, the presented solution therefore presents one or two annular series of rolling elements 17,

17b, 170b adapted to hold at least forces oriented radially or transversely with respect 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 adapted to essentially hold forces oriented parallel or substantially parallel to the axis of rotation of the bearing.

[0038] In Figures 3, 4, but also in Figure 6, the roller bearings 15, 19; 15b, 19b are cylinders of substantially constant section.

[0039] The radius varies very slightly along the roller bearing to obtain a constant pressure distribution, a drop at each end allows reducing the edge effects. And the individual axis of rotation of the roller bearings (such as 155 in Figure 3 for the one shown in 15) is perpendicular to the axis 50b of rotation of the bearing.

[0040] In Figures 3, 4, the rolling elements of the one or more intermediate rows 171; 171b, 172b are all identical and positioned along one and the same median diameter centred on the axis 50c (median diameter D2).

[0041] Regarding the corresponding balls 17, 17b, 170b, it is recommended, if there are multiple series, that they all have the one and the same diameter, such as D30 in Figure 4, the roller bearings of the two end rows being also preferably all identical: diameter marked D4 in Figure 4, this particularly for the wind turbine blade bearing applications. In other applications for which an axial force would be predominant in a preferred direction, the diameter D30 of the rolling bodies (or elements) 17b, 170b of the one or more intermediate rows could be smaller than D4.

[0042] In Figure 3, the intermediate rolling elements, to which the represented one 171 belongs, are positioned, along the direction parallel to the axis 50c on which each one is

positioned, substantially halfway between those of the two end rows. Since the intermediate row 171 is unique in Figure 3, the diameter D3 of the balls is therein greater than the common one D30, of the balls of the two successive
5 intermediate rows in Figure 4, but this can vary: the diameter of the ball is the result of a calculation from the radial forces of the application.

[0043] In Figure 4, the balls of the respectively upper 171b and lower 172b intermediate rows are positioned, again
10 along the direction parallel to the axis 50c on which each one is positioned, closer to the roller bearings respectively of the upper end row 151b and the lower end row 191b than their mating balls in the other intermediate row.

[0044] Again Figure 4, and preferably likewise in Figure
15 3, identifies respectively 173a and 173b the two median planes of the rolling elements of the two illustrated intermediate rows. As recommended, these rolling elements with point contacts are preloaded respectively in both of these planes, which are each perpendicular to the axis of rotation 50c. For
20 this, the diameter of the balls is, in the aforementioned plane, slightly greater unlike the radius measured from 50c of the rolling tracks (respectively 23a, 23b) of the races 11b and 13b which accommodate them. Under stress, the load of these balls will be therefore radial to the axis 50c. This
25 radial orientation of the load, and possibly of the preload, will moreover be the same for the series of balls 17, Figure 3, or even for the balls of the one or more intermediate rows of Figure 6 and the following Figures. Figure 3 moreover identifies 190, the common axis of loading of the rolling
30 elements of the two end rows. It corresponds to an axial load. It is therefore parallel to the axis 50c. This axis is identified or not, but illustrated in Figure 4, then in Figure

6 and the following Figures where there is therefore also an axial load axis of the rolling elements of the two end rows.

[0045] In both Figure 3 and Figure 4, it will also be noted that one of the races is in multiple parts. It is here
5 the first bearing race 11, 11b, which is radially external with respect to the other race, essentially closer to the axis of rotation 50c.

[0046] Thus, to facilitate the mounting/dismounting operations and the maintenance, the first bearing race 11,
10 11b, is in two parts, respectively 110, 111; 110b, 111b. The preferable parting plane, respectively 21, 21b is, for the transmission of the forces, a plane close to the lower end row, here 19 or 19b, to establish a one-piece connection between the rotor means and the rows of intermediate balls. In
15 the illustration, the parting plane is substantially at the level of the upper end row 151 or 151b that it bypasses to serve locally as an rolling path higher than the roller bearings of the upper end row, as regards the upper part 110; 110b of this first race. Below, the complementary lower part,
20 111; 111b of this same race, serves as a rolling path external to the balls of the one (Figure 3) or more (Figure 4) intermediate rows, as well as a rolling path lower than the roller bearings of the lower end row. A similar mounting exists on the embodiments of the following figures.

25 [0047] And it is noted that, radially, for the resistance to forces and moments, the diameter D40 of the bottom (halfway up) of the internal rolling path (also called track) 23 of each ball is smaller than the diameter D5 of the external abutment, transverse (here perpendicular) to the axis 50c, of
30 each roller bearing, whether it is from the upper (250) or lower (270) row. Thus, the track of the balls can be positioned radially on a diameter as close as possible to the diameter D1 of the row of roller bearings to limit the length

of the central nose 130a and consequently the bending stresses at the base thereof. The nose 130a is the central part of the internal race 13 which extends radially up to the internal rolling path 23. On either side, it also serves as a central
5 rolling path, for example to the roller bearings 15, 19.

[0048] In any event, all or part of the preceding characteristics will be implemented so that the rolling elements thus disposed are adapted to hold together forces oriented with radial and axial components with respect to the
10 axis 50c of rotation of the bearing.

[0049] Regarding the mounting on the hub 7 and the blade 5c, it will also be noted that, on either side of the rolling elements, the races 11, 13 are attached respectively to the hub and to the blade.

15 [0050] The headed or headless screws (studs), respectively 27 and 29, provide the above-mentioned attachments, parallel to the axis 50c, at two different radial distances from this axis. Figure 5 shows this, with the respectively outer 11b and inner 13b races (with its teeth
20 130b in the inner periphery; of course predictable in the case of Figure 3).

[0051] The threaded rod of each attachment means 27 staggered on the periphery of the race 11 cooperates with a nut 27a. Each attachment means 29 is screwed directly into the
25 body of the root of the blade 5c, with its head 29a positioned on the hub side. Thus, the bolts 27, 29 are accessible through the hollow interior of the rotor hub 7.

[0052] The difference between the examples of Figures 4 and 6 is that the rolling elements of the intermediate rows
30 are radially positioned, in a case farther, in a case less far, from the axis 50c ($D2/R2$) than are the rolling elements of the end rows.

[0053] This disposition on one side or the other is moreover not decisive for any of the embodiments covered by the solution patentable here.

[0054] Solutions with (axially) end rows with roller
5 bearings must allow obtaining a large axial load capacity but especially overturning moment capacity, which load is predominant in particular on very large wind turbines (multi mega Watts). The limitation (by the preload) of the authorized radial movement of the rotating race is also substantial.

10 [0055] Figure 7 shows that structures other than a rotor hub and a wind turbine blade can be attached to the rotating races of the bearing. The embodiment of a construction crane turret is thus for example concerned, in conjunction with any one of the embodiments described here.

15 [0056] In Figures 7, 8, the rolling elements 15c, 19c of the (axially) end rows are balls. They are (substantially) spherical. The same applies for the rolling elements, respectively 17c and 17c, 170c, of the one or more (axially) intermediate rows. The axes of loading of the rolling elements
20 are represented, as they are in the following figures.

[0057] In Figures 9, 10 moreover, the rolling elements 15d, 19d of the (axially) end rows, although again with point contacts with the tracks of the adjacent bearing races (here marked 11d, 13d) as in Figures 7, 8, are barrel rolling
25 elements. The axis of rotation of each of these barrel rolling elements is oriented perpendicular to the axis 50c of rotation of the bearing. The rolling elements, respectively 17d and 17d, 170d, of the one or more (axially) intermediate rows are balls.

30 [0058] As for Figure 11, it again shows that the rolling elements of the one or more intermediate rows can be radially positioned in a case farther, in a case less far (Figure 10),

from the axis 50c ($D2/R2$) than are the rolling elements of the end rows.

[0059] In this regard, it will be noted that the versions with an inner race in two parts (Figures 6-10) or with an
5 outer race in two parts (Figures 3, 4, 11) will be useful for the positioning of the drive teeth 33 which will always be done on the race in one part. Depending on the configurations, the teeth are on the radially internal race or on the external race.

10 [0060] Regarding the ranges of the presented rolling elements with point contacts (balls, barrels), the present slewing ring will be preferably with a row/rows of rolling elements with two contact zones (often known as "two zone (point) contact...").

15 [0061] As for the use of radially loaded balls, it allows making a preloaded mounting that will introduce rigidity and limit the radial movements of the races, thus limiting the FBE.

Patentkrav

1. Leje, der har en rotationsakse (50c) og kan placeres mellem en første struktur (7) og en anden struktur (5c), den første og anden struktur kan roteres i forhold til hinanden omkring lejeaksen, hvor dette leje omfatter:

– en første og en anden lejeskål (130, 150...), hvori en del af den anden lejeskål strækker sig omkring den første, radialt i forhold til nævnte akse (50c), – og flere serier af rulleelementer placeret mellem den første og anden lejeskål, på en ringformet måde omkring nævnte akse (50c), nævnte flere serier af rulleelementer omfatter mindst tre ringformede serier, hvoraf mindst to er placeret, i forhold til nævnte akse (50c), på forskellig radius (R1, R2), og er arrangeret på mindst tre rækker, der er forskudt langs nævnte akse, og rulleelementerne på én eller flere mellemliggende rækker af nævnte mindst tre rækker af rulleelementer, der er forskudt langs nævnte rotationsakse (50c) af det leje, der er forbelastet i et plan vinkelret på nævnte rotationsakse, de to enderækker på nævnte mindst tre rækker af rulleelementer, der er forskudt langs nævnte rotationsakse (50c) for lejet, omfatter hver en række rulleelementer med punktkontakter (15c, 19c) **kendetegnet ved, at** rulleelementerne for én eller flere mellemliggende rækker af nævnte mindst tre rækker af rulleelementer omfatter rulleelementer med punktkontakter (17c, 170c).

2. Lejet i henhold til krav 1, **kendetegnet ved, at** nævnte mindst tre rækker af rulleelementer, der er forskudt langs nævnte rotationsakse (50c) af lejet, omfatter:

– to enderækker, der hver omfatter en serie af kugler (15c, 19c),
– og mindst en mellemliggende række rulleelementer, der omfatter kugler (17, 17b, 170b).

3. Lejet i henhold til krav 1, **kendetegnet ved, at** nævnte mindst tre rækker af rulleelementer, der er forskudt langs nævnte rotationsakse (50c) af lejet, omfatter:

- 5 – to enderækker, der hver omfatter en række tøndeformede rulleelementer (15d, 19d), der har, individuelt, en rotationsakse tværgående på lejets rotationsakse, – og mindst én mellemliggende række rulleelementer, der omfatter rulleelementer med punktkontakter.

- 10 **4.** Lejet i henhold til ét af de foregående krav **kendetegnet ved, at** det omfatter to mellemliggende rækker af rulleelementer, der er forskudt langs nævnte rotationsakse (50c) af lejet.

- 15 **5.** Lejet i henhold til ét af de foregående krav, **kendetegnet ved, at** rulleelementerne i den ene eller flere mellemliggende rækker alle er identiske og placeret langs én og samme mediandiameter (D2) centreret på nævnte rotationsakse (50c) af lejet.

- 20 **6.** Lejet i henhold til ét af de foregående krav, **kendetegnet ved, at** én af skålene er i flere dele (110, 111; 110b, 111b).

7. Vindturbine, der omfatter et leje i henhold til ét af de foregående krav, et rotornav (7) som første struktur og mindst ét blad (5c) som anden struktur, hvori bladet kan dreje i forhold til navet.

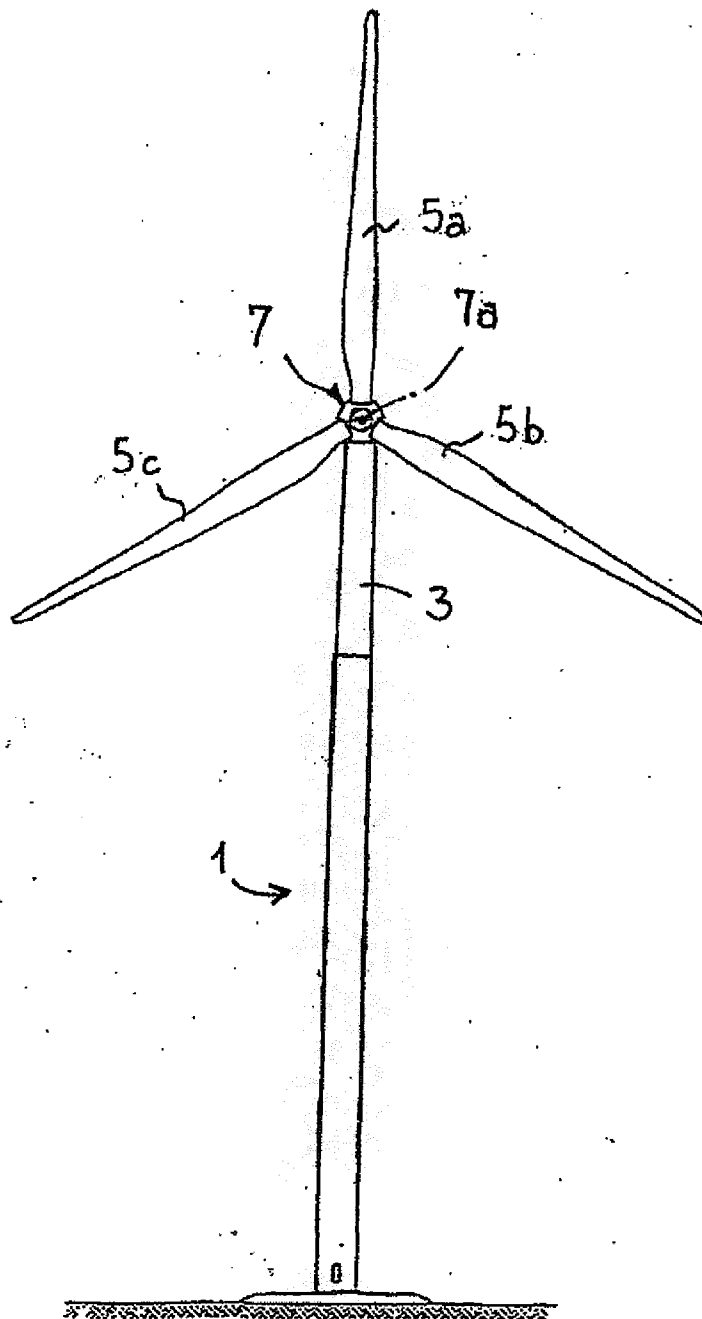


FIG. 1

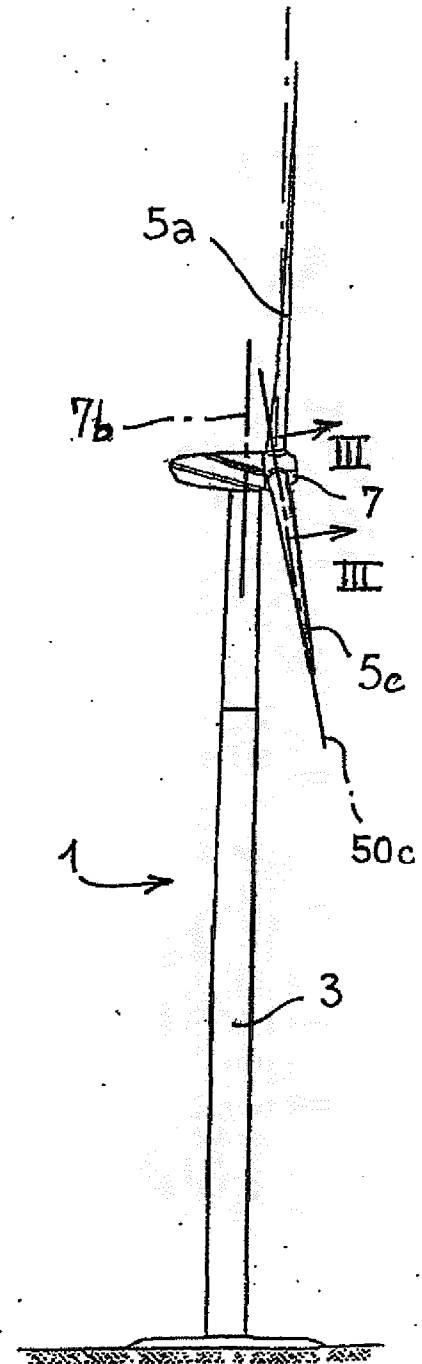


FIG. 2

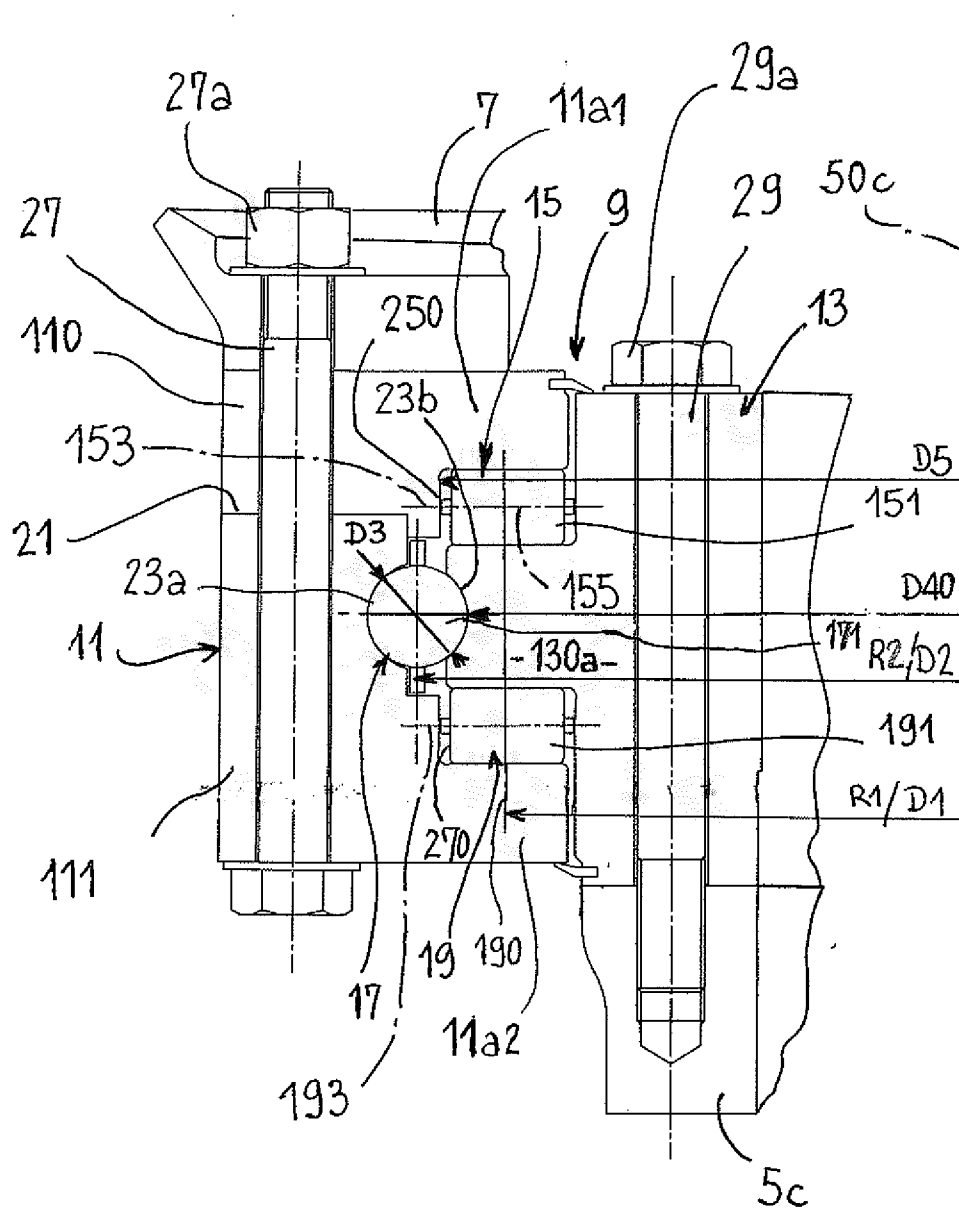


FIG. 3

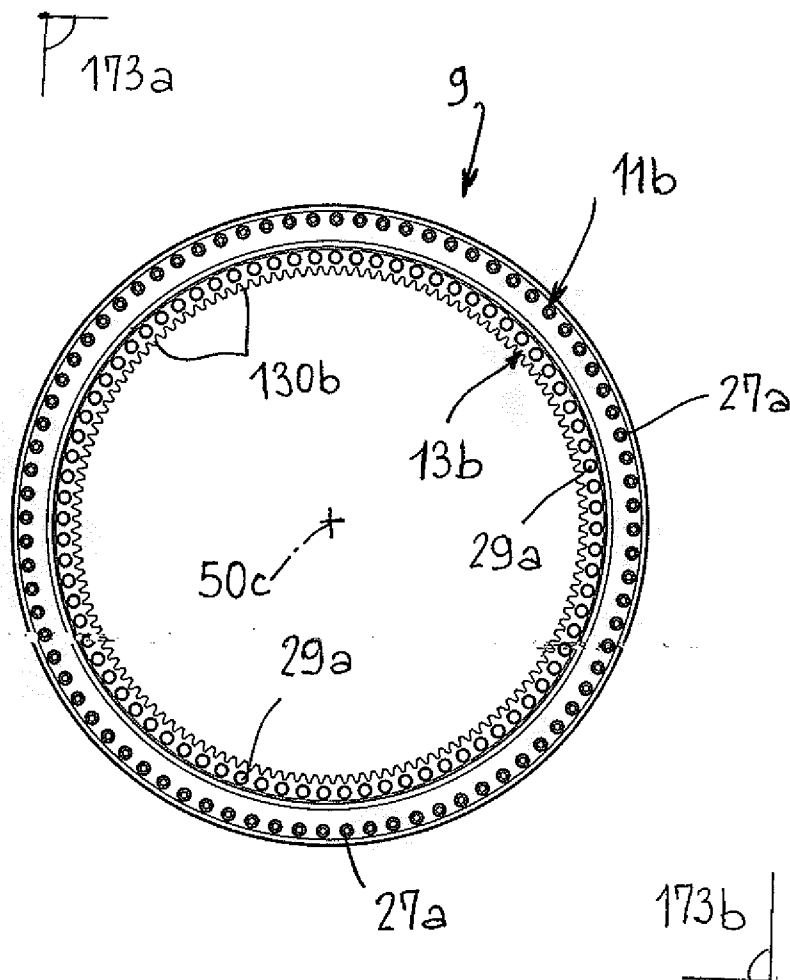


FIG. 5

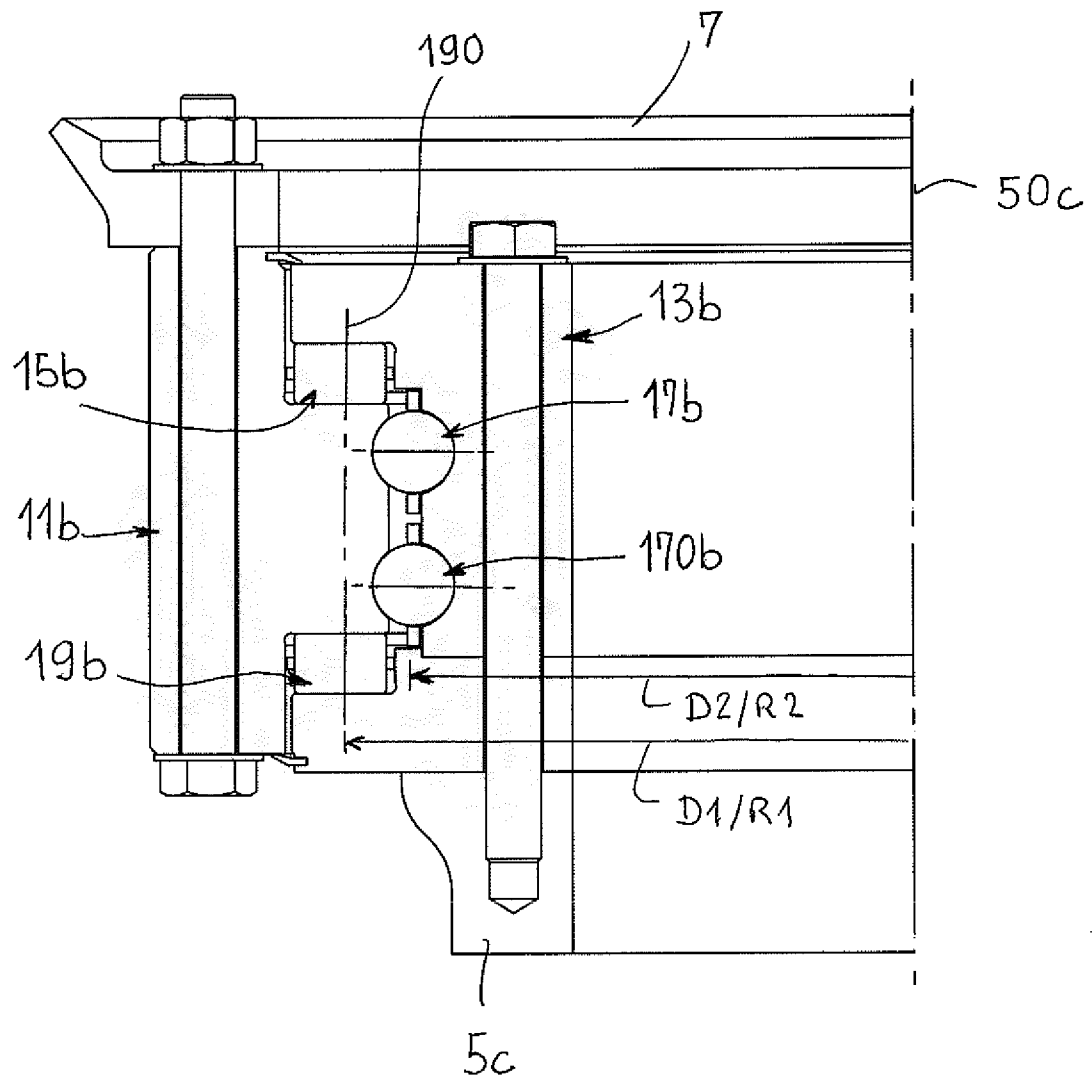


FIG. 6

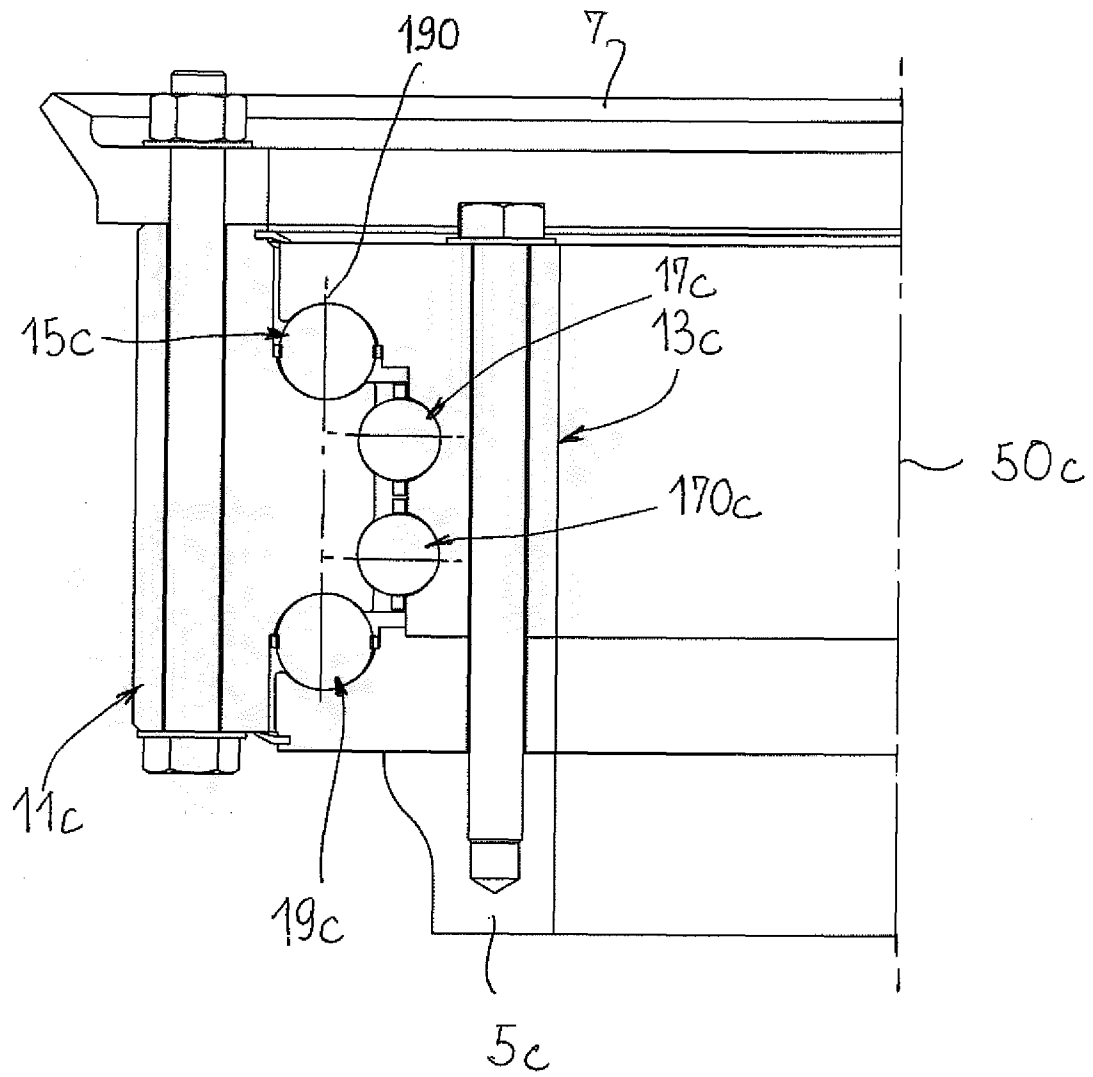


FIG. 8

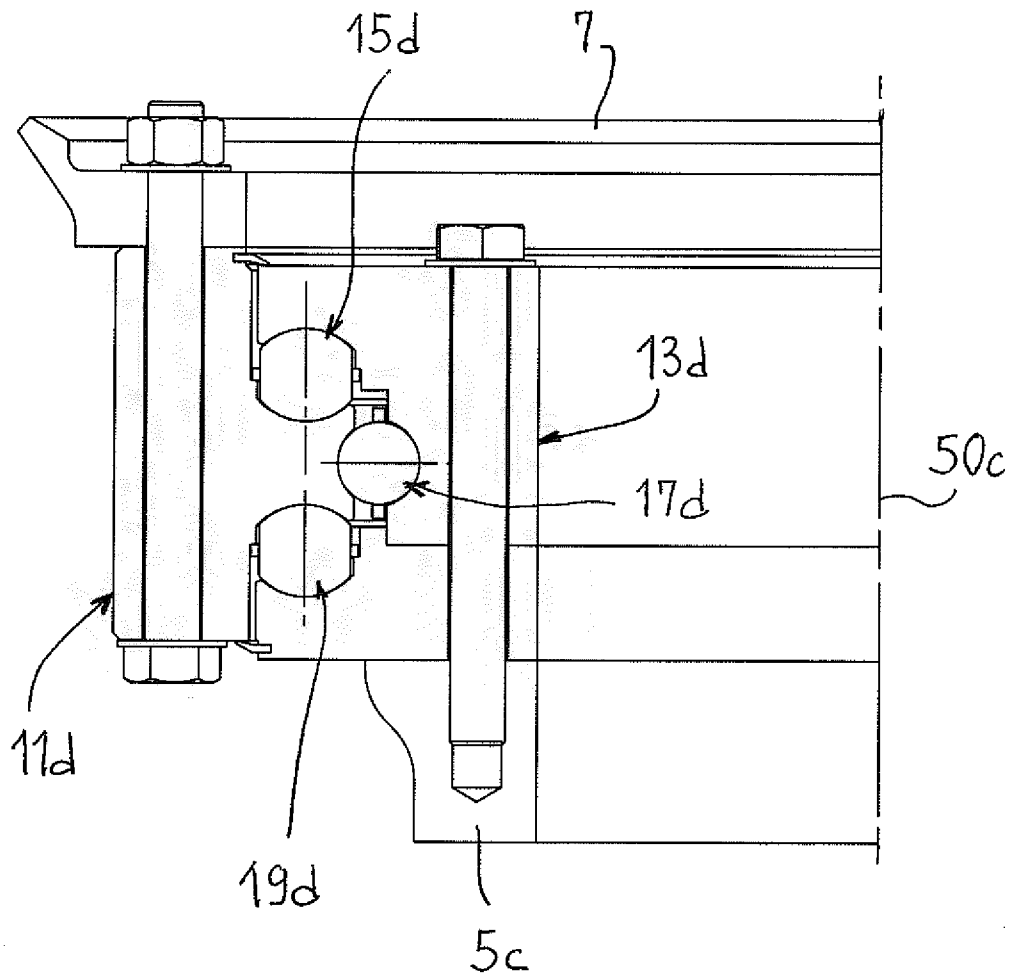


FIG. 9

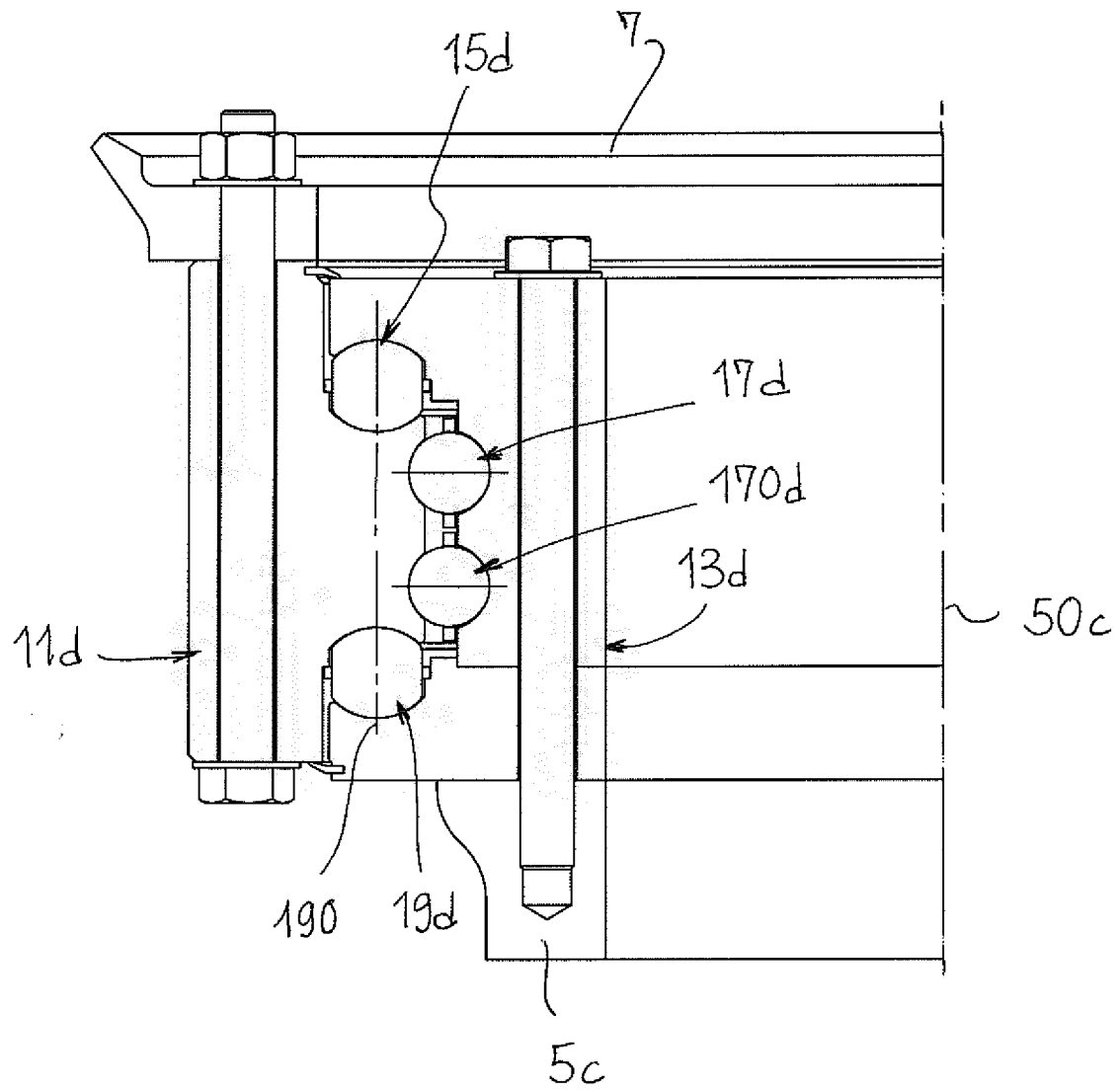


FIG. 10

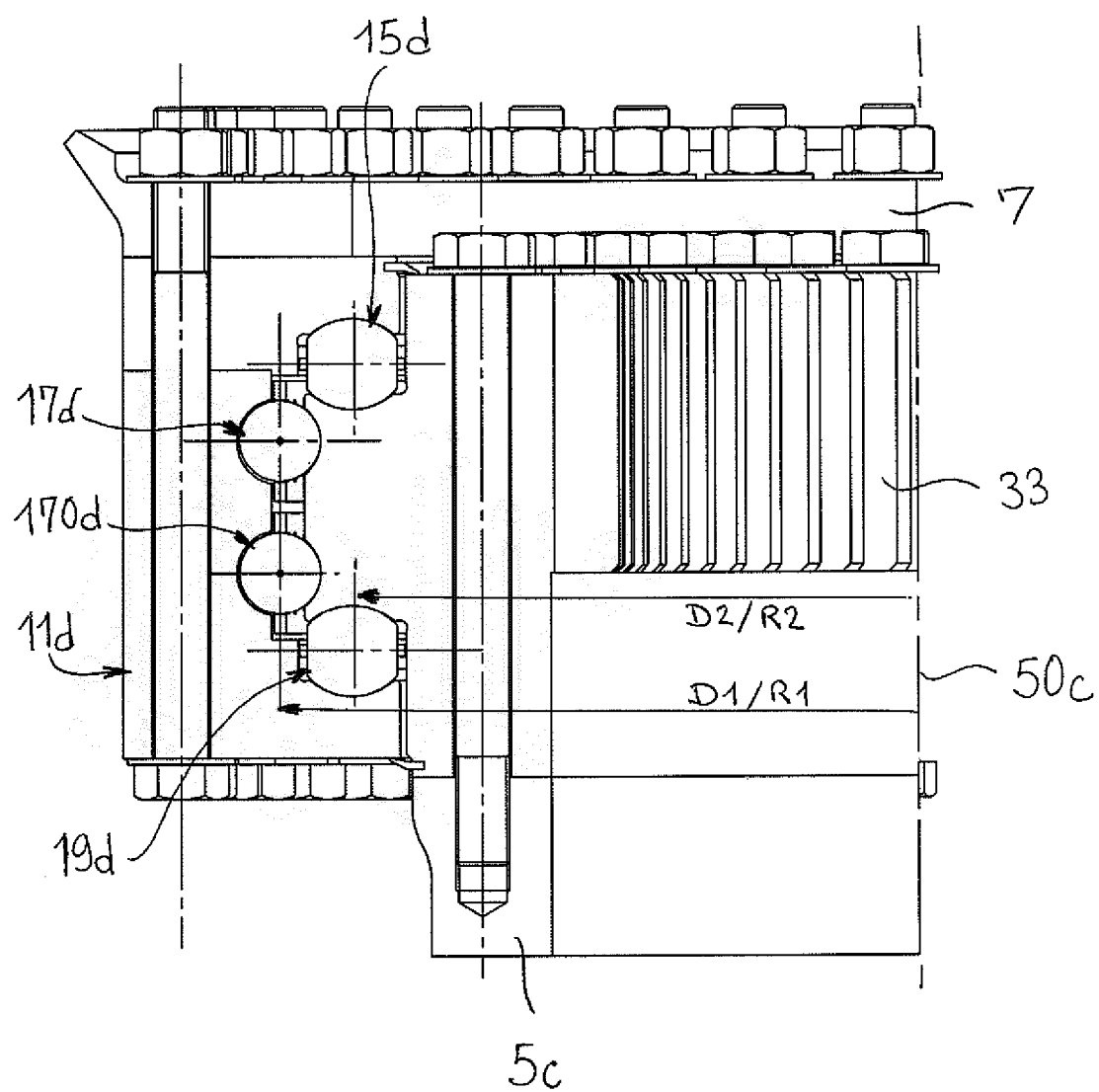


FIG-11