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Wind turbine rotary connection and wind turbine comprising same

The present invention concerns a wind turbine plain rotary connection for two wind turbine components which are rotatable relative to each other, having a combined axial-radial bearing, wherein the axial-radial bearing has an axial bearing component and a separate radial bearing component.

Rotary connections of the above-indicated kind are generally known. They are used for example to mount rotor blades to the rotor blade hub so that it is possible to ensure a pitch movement of the rotor blades. In addition for example the rotor blade hub and/or the generator rotor of a wind turbine and/or a main shaft of the wind turbine are supported by means of rotary connections, in particular on a machine carrier of the wind turbine. Furthermore for example the machine carrier of the wind turbine is rotatably mounted to the tower of the wind turbine by means of a rotary connection which is referred as a yaw bearing arrangement.

The rotary connection serves in each case principally to carry the axial and radial forces acting on the wind turbine components which are mounted rotatably relative to each other, and also in certain situations of use also to carry tilting moments.

In the state of the art plain bearing arrangements have sometimes been proposed for rotatably mounting components involving high speeds of movement while in relation to rotary movements involving long service lives or low speeds of rotation but in return high levels of loading, rolling bearing arrangements are principally provided.

A general requirement in the design of wind turbines is increasingly that of ensuring the fatigue strength of the wind turbine components while at the same time the aim is to achieve an efficiency as high as possible in the production of electric power. As far as possible the latter is to be linked to ongoing optimisation of the weight of the wind turbines and a reduction in noise emissions, which sometimes entails conflicts between the aims.

On the priority application for the present application the German Patent and Trade Mark Office searched the following state of the art: DE 10 2012 004 329 A1, DE 10 2015 217 510 A1, DE 10 2015 224 912 A1, EP 2 871 377 B1 and WO 2008/152 083 A1.

Consequently the object of the invention was to propose a wind turbine rotary connection which obviates the above-indicated disadvantages to the best possible extent and in that respect resolves the existing conflicts of aims as much as possible. In particular the object of the invention was to provide a wind turbine rotary connection having an alternative bearing concept. Furthermore in particular the object of the invention was to propose a wind turbine rotary connection which contributes to reducing noise emissions and preferably ensures a reduced rotary resistance with undiminished wear resistance.

The object of the invention is attained in a wind turbine rotary connection of the kind set forth in the opening part of this specification by the axial bearing component being in the form of a plain bearing component having a first convexly curved bearing surface and a corresponding second concavely curved bearing surface.

The invention makes use of the realisation that such an axial bearing component, also referred to as a spherical bearing arrangement, can carry very high axial forces in comparison with the structural size thereof and nonetheless has a high degree of angle tolerance in regard to the direction of the forces acting.

By virtue of the fact that the axial bearing component is in the form of a plain bearing component, the rolling noises which are inevitably produced in the state of the art when using rolling bodies are at any event in this respect eliminated, which overall contributes to a reduction in the noise emissions.

An advantageous development of the invention provides that at least one of the two bearing surfaces of the axial bearing component is formed partially or completely from a fibre composite material. Particularly preferably one of the two bearing surfaces of the axial bearing component is formed partially or completely from a fibre composite material and the other of the two bearing surfaces of the axial bearing component is formed partially or completely from a metallic material. The material pairing of metallic material and fibre composite material also provides extremely favourable wear properties, in particular emergency operating properties.

In a preferred configuration the axial bearing component, the radial bearing component or both bearing components (the axial bearing component and the radial bearing component) are of an annular configuration. The significantly increases the flexibility in terms of installation of the rotary connection as a through passage can be provided in the centre of rotation or there is the possibility of mounting on for example a main shaft.

In a first preferred alternative the radial bearing component is in the form of a rolling bearing.

In a second preferred alternative the radial bearing component is also in the form of a plain bearing, in particular selected from one of the following bearing types: cylindrical plain bearing, multi-surface plain bearing, in particular a lemon bore bearing, and segmented plain bearing, preferably with tilt segments. The term lemon bore bearing is used to denote a multi-surface plain bearing having an outer ring which, instead of a circular cross-section, is of a cross-section composed of two or more arcuate taper surfaces so that the arrangement involves regions of differing gap widths along the periphery of the bearing clearance.

In a further preferred configuration of the rotary connection according to the invention the combined axial-radial bearing is a first bearing and the rotary connection additionally has a second bearing.

Particularly preferably the second bearing is also a combined axial-radial bearing with an axial and a separate radial bearing component, wherein the axial bearing component is in the form of a plain bearing component having a first convexly curved bearing surface and a corresponding second concavely curved bearing surface.

Preferably in the second bearing at least one of the bearing surfaces of the axial bearing component is formed partially or completely from a fibre composite material. Further preferably in the case of the second bearing one of the two bearing surfaces of the axial bearing component is formed partially or completely from a fibre composite material and the other of the two bearing surfaces of the axial bearing component is formed partially or completely from a metallic material.

Further preferably in the second bearing the axial bearing component is of an annular configuration. Further preferably in the second bearing the radial bearing component is of an annular configuration. Further preferably in the second bearing the radial bearing component is in the form of a rolling bearing arrangement. Alternatively preferably in the second bearing the radial bearing component is in the form of a plain bearing arrangement, in particular selected from one of the following bearing types: cylindrical plain bearing, lemon bore bearing, segmented plain bearing, preferably with tilt segments.

In a further preferred configuration of the rotary connection the first and the second axial-radial bearing are arranged in directly mutually adjoining relationship and with the axial bearing components in mutually adjacent relationship. Alternatively preferably the first and the second combined axial-radial bearing are arranged in directly mutually adjoining relationship and with the radial bearing components in mutually adjacent relationship.

In a further preferred alternative the first and the second combined axial-radial bearings are arranged in mutually spaced relationship. The spacing in particular of the radial bearing components from each other significantly increases the capability of carrying tilting moment of the rotary connection. The directly mutually adjoining arrangement of the two combined axial-radial bearings can advantageously be used as a moment bearing arrangement.

Particularly preferably the embodiment with directly mutually adjoiningly arranged combined axial-radial bearings is further developed in that the rotary connection further has a third bearing which is arranged spaced in relation to the arrangement of the first and second axial-radial bearings, the third bearing preferably being a radial bearing. Particularly preferably the third bearing is of an annular configuration and in particular is in the form of a plain bearing. Preferably the plain bearing arrangement is selected from one of the following bearing types:

Cylindrical plain bearing, lemon bore bearing, segmented plain bearing, preferably with tilt segments.

This configuration can be used based on the model of a fixed/floating bearing arrangement on the wind turbine.

In a further aspect the invention concerns a wind turbine having the following components:

A number of rotor blades, a rotor blade hub to which the rotor blades are rotatably mounted, a generator having a generator rotor and a generator stator, wherein the generator rotor and the rotor blade hub are coupled together by means of a main shaft and preferably a transmission, a machine carrier to which the generator, in particular the generator stator is mounted, and a tower on which the machine carrier is arranged.

In a wind turbine of the above-indicated kind the invention attains the object as specified hereinbefore in that one, a plurality of or all of the components are mounted rotatably by means of a rotary connection according to one of the above-described preferred embodiments. Particularly preferably in the wind turbine the rotor blades are mounted rotatably to the rotor blade hub. Alternatively or additionally the rotor blade hub and/or the generator rotor and/or the main shaft is mounted to the generator stator. Alternatively or additionally the rotor blade hub and/or the generator and/or the main shaft is mounted rotatably to the machine carrier.

Alternatively or additionally the machine carrier is mounted rotatably to the tower.

In regard to the advantages of the preferred configurations of the wind turbine and its rotary connection attention is directed to the above-described preferred configurations in accordance with the first aspect.

Preferably the rotary connection for mounting the rotor blade hub and/or the generator and/or the main shaft on the generator stator or the machine carrier to the tower is in the form of a hydrodynamic plain rotary connection. In that way it is possible to implement in particular also high rotary speeds with a low level of wear of even substantially wear-free.

In a further preferred configuration in which the rotary connection is adapted to mount the rotor blades to the rotor blade hub and/or to mount the machine carrier to the tower of the wind turbine the rotary connection is preferably in the form of a dry-running plain rotary connection. The speed of rotation with that kind of bearing arrangements is comparatively low and the service lives are comparatively high so that thermal lubrication is not necessary or does not promise any advantages. Here however in particular the emergency running properties of the preferred material pairing as described hereinbefore comprising a fibre composite material and a metallic material become important.

The invention is described in greater detail hereinafter with reference to the accompanying Figures by means of preferred embodiments by way of example. In the Figures:

Figure 1 shows a diagrammatic perspective view of a wind turbine,

Figure 2a shows a diagrammatic sectional view of a pod of the wind turbine of Figure 1 according to a first preferred embodiment,

Figure 2b shows a diagrammatic sectional view of a pod of the wind turbine of Figure 1 according to a second preferred embodiment,

Figures 3a, b show diagrammatic cross-sectional views of a rotary connection according to the invention in two preferred configurations, for a wind turbine as shown in Figure 2a or 2b, and

Figures 4a-f show various preferred diagrammatic bearing arrangements of the rotary connections of Figures 3a and b for a wind turbine as shown in Figure 2a or 2b.

Figure 1 shows a wind turbine 100 comprising a tower 102 and a pod 104. Arranged at the pod 104 is a rotor 106 having three rotor blades 108 and a spinner 110. In operation the rotor 106 is caused to rotate by the wind and thereby drives a generator 101 (Figure 2) in the pod 104.

The pod 104 is shown as a sectional view in Figure 2. The pod 104 is mounted rotatably to the tower 102 and connected driven in generally known manner by means of a yaw drive 112. Also arranged in generally known manner in the pod 104 is a machine carrier 110 having a trunnion 114.

The generator 101 has a generator stator 105 which is fixed by means of the trunnion 114 to the machine carrier 110 in the pod 104. Other possible design configurations which are not excluded by the invention provide for example that the generator stator 105 is joined directly to the machine carrier 110 or a corresponding component part of the pod 104.

The generator 101 shown in Figure 2a has a generator rotor 103 designed in the form of an external rotor. The rotor blades 108 are mounted rotatably relative to the hub 106 with a rotary connection 200 according to the invention.

The hub 106 and the generator rotor 103 are mounted rotatably relative to the trunnion 114 by means of a rotary connection 200.

The machine carrier 110 – and with it the pod 104 – are mounted rotatably relative to the tower 102 by means of a rotary connection 200.

One, a plurality of or all of the rotary connections 200 indicated in Figure 2 are preferably of the design configuration as shown in Figures 3a, b or 4a-f, which are described in greater detail hereinafter.

While Figure 2a showed a wind turbine 100 having an external rotor generator Figure 2b shows an alternative structure having a transmission gear generator. The generator 101 preferably has an internal rotor as its generator rotor, being non-rotatably connected to a main shaft 111. Preferably a gear transmission 113 is interposed between the generator 101 and the main shaft 111. The transmission 113 is preferably connected by means of a torque support 115 to the machine carrier 110 or other structural components of the pod 104 of the wind turbine 100. In addition mounted non-rotatably to the main shaft 110 is the hub 106 and mounted thereto are the rotor blades 108, in that respect involving the same principle as in Figure 2a.

The main shaft is mounted to the pod 104 by means of a rotary connection 200.

In addition the pod 104 is mounted rotatably to the tower 102 by means of a yaw bearing which is also characterised in the form of a rotary connection 200.

In regard also to the embodiment of Figure 2b, attention is directed to following Figures 3a, b and 4a-f, showing different possible configurations for the rotary connections 200.

In Figure 3a a rotary connection 200 is designed in accordance with a first preferred configuration. The rotary connection 200 has a combined axial-radial bearing 1. The bearing 1 has a main body 3 which functions as a carrier. An axial bearing component 5 and a radial bearing component 7 are provided on the carrier 3. The axial bearing component 5 has a first convexly shaped bearing surface 9 and a second corresponding concavely shaped bearing surface 11.

Radially outside and axially adjacent in relation to an axis of rotation R the rotary connection has an inner ring 13 and an outer ring 17 for the radial bearing component 7. Preferably a plurality of plain bearing segments 15 are provided at the inner ring 13 or the outer ring 17 (this is not shown) and particularly preferably the plain bearing segments 15 are arranged pivotably by means of a tilt mechanism 19 on the inner ring 13 (or alternatively the outer ring 17, not shown).

The combined axial-radial bearing 1 shown in Figure 3a is advantageously adapted to carry axial forces F_A acting in the direction of the axis of rotation R, and radial forces F_R acting perpendicularly thereto.

Figure 3b shows an alternative configuration in relation to the combined axial-radial bearing 1 shown in Figure 3a. The combined axial-radial bearing 21 shown in Figure 3b has a carrier 23 of an annular configuration. An axial bearing component 25 with a radial bearing component 27 is provided on the carrier 23, the axial bearing component 25 also being of an annular configuration. The axial bearing component 25 has a first convexly curved bearing surface 29 and a corresponding second concavely curved bearing surface 31. Radially outwardly and axially adjacent to those bearing surfaces the axial-radial bearing 21 has an inner ring 33 and an outer ring 37 of the radial bearing component 27. In addition there are a plurality of plain bearing segments 35 which, similarly to the view in Figure 3a, are in the form of tilt segments with a pivoting mechanism 39 on the inner ring 33 (alternatively however they can also be provided on the outer ring 37).

The axial forces F'_A are carried by the axial bearing component 25 in substantially the same function in relation to the view shown in Figure 3a while the forces F_R acting in the radial direction are carried by the radial bearing component 27.

Figures 4a, b, c, d, e and f show preferred arrangements of the axial-radial bearing 1 shown in Figure 3a. It should be understood that, alternatively to the axial-radial bearing, the axial-radial bearing 21 can also be arranged in the same manner. The arrangement in Figure 3a and Figure 3b respectively shows a first combined axial-radial bearing 1a and a second combined axial-radial bearing 1b which are respectively arranged in directly mutually adjoining relationship. As shown in Figure 3a the two combined axial-radial bearings 1a, b are oriented relative to each other in such a way that the radial bearing components 7 are arranged facing away from each other. In the view in Figure 3b the two combined axial-radial bearings 1a, b are oriented in such a way that the radial bearing components 7 are oriented in mutually facing relationship. The arrangement shown in Figures 4a, b is suitable in particular for a moment bearing arrangement.

The carrying capability for tilting moments, based on arrangements as shown for example in Figures 4a and 4b, is further increased if the two combined axial-radial bearings 1a, b are spaced from each other.

Such configurations are shown by way of example in Figures 4c, d. Here in each case the first combined axial-radial bearing 1a is spaced by a predetermined distance D from the second combined axial-radial bearing 1b. As also in Figures 4a, b shown here are respective configurations in which the radial bearing components 7 are facing towards each other (Figure 4c) or away from each other (Figure 4d). The bearing arrangement shown in Figures 4c, d is suitable in particular as a support bearing arrangement.

Figures 4e, f, as a continuance of the bearing designs already described hereinbefore, set forth two proposals which in addition to the two combined axial-radial bearings 1a, b have a third bearing 1c. The two combined axial-radial bearings 1a, 1b are arranged in directly mutually adjoining relationship, similarly to Figures 4a, b, while the third bearing 1c is arranged at a predetermined distance D spaced therefrom. This kind of bearing is preferably suitable for a fixed/floating bearing arrangement.

In the illustrated variant the third bearing 1c is in the form of a radial plain bearing, a plurality of plain bearing segments 43 being arranged on an inner ring 41, particularly preferably in the form of tilt segments which are fixed to the inner ring 41 by a pivoting mechanism 45.

P a t e n t k r a v

1. Vindenergianlægsdrejeforbindelse (200) til to vindenergianlægsdele (102, 110; 103, 105; 106, 114; 108, 106), som er drejelige om en rotationsakse (R) i forhold til hinanden, med et kombineret aksial-radial-leje (1, 21; 1a, 1b), hvor aksial-radial-lejet har en aksial lejekomponent (5, 25) og en separat radial lejekomponent (7, 27),
kendetegnet ved, at den aksiale lejekomponent (5, 25) er udformet som glidelejekomponent med en første, konvekst hvælvet lejeflade (9, 29) og en tilsvarende anden, konkavt hvælvet lejeflade (11, 31).

2. Drejeforbindelse (200) ifølge krav 1,
hvor mindst en af de to lejeflader (9, 11; 29, 31) af den aksiale lejekomponent (5, 25) er udformet delvist eller helt af et fiberkompositmateriale.

3. Drejeforbindelse (200) ifølge krav 1,
hvor en af de to lejeflader (9, 11; 29, 31) af den aksiale lejekomponent (5, 25) er udformet delvist eller helt af et fiberkompositmateriale, og den anden (11, 9; 31, 29) af de to lejeflader af den aksiale lejekomponent (5, 25) er udformet delvist eller helt af et metallisk materiale.

4. Drejeforbindelse (200) ifølge et af de foregående krav,
hvor den aksiale lejekomponent (5, 25) og/eller den radiale lejekomponent (7, 27) er udformet ringformet.

5. Drejeforbindelse (200) ifølge et af de foregående krav,
hvor den radiale lejekomponent (7, 27) er udformet som et rulleleje.

6. Drejeforbindelse (200) ifølge et af kravene 1 til 4,
hvor den radiale lejekomponent (7, 27) er udformet som glideleje, især udvalgt fra en af de følgende lejetyper:
- cylindrisk glideleje,
- citronspilleje,

- segmenteret glideleje, fortrinsvis med vippesegmenter.

7. Drejeforbindelse (200) ifølge et af de foregående krav, hvor det kombinerede aksial-radial-leje (1, 21) er et første leje (1a), og drejeforbindelsen yderligere har et andet leje (1b).

8. Drejeforbindelse (200) ifølge krav 7, hvor det andet leje (1b) ligeledes er et kombineret aksial-radial-leje (1, 21) med en aksial (5, 25) og en separat radial lejekomponent (7, 27), hvor den aksiale lejekomponent er udformet som glidelejekomponent med en første, konvekst hvælvet lejeflade (9, 19) og en tilsvarende anden, konkavt hvælvet lejeflade (11, 31).

9. Drejeforbindelse (200) ifølge krav 8, hvor det første og det andet aksial-radial-leje (1a, 1b) er anbragt direkte grænsende op til hinanden og med de aksiale lejekomponenter (5, 25) ved siden af hinanden.

10. Drejeforbindelse (200) ifølge krav 8, hvor det første og det andet aksial-radial-leje (1a, 1b) er anbragt direkte grænsende op til hinanden og med de radiale lejekomponenter (7, 27) ved siden af hinanden.

11. Drejeforbindelse (200) ifølge krav 7 eller 8, hvor det første og det andet aksial-radial-leje (1a, 1b) er anbragt i afstand til hinanden.

12. Drejeforbindelse (200) ifølge krav 9 eller 10, med et tredje leje (1c), som er anbragt i afstand til placeringen af det første og andet aksial-radial-leje, hvor
det tredje leje (1c) fortrinsvis er et radialt leje.

13. Vindenergianlæg (100) med følgende anlægsdele:
et antal af rotorvinger (108),
et rotorvingenav (106), på hvilket rotorvingerne (108) er monteret drejebevægeligt,
en generator (101), som har en generatorrotor (103) og en generatorstator (105), hvor generatorrotoren (103) og rotorvingenavet (106) er koblet med hinanden direkte eller ved hjælp af en hovedaksel, og fortrinsvis en gearmekanisme,
en maskinbærer (110), på hvilken generatoren (101), især generatorstatoren (105), er monteret, og et tårn (102), på hvilket maskinbæreren (110) er anbragt,
kendetegnet ved, at en, flere eller samtlige af anlægsdelene er understøttet drejebevægeligt ved hjælp af en drejeforbindelse (200) ifølge et af de foregående krav.

14. Vindenergianlæg (100) ifølge krav 13,
hvor drejeforbindelsen (200) til understøtning af rotorvingenavet (106) og/eller generatorrotoren (103) og/eller hovedakslen på generatorstatoren (105) eller maskinbæreren (110) er udformet som en hydrodynamisk glidedrejeforbindelse.

15. Vindenergianlæg (100) ifølge krav 13 eller 14,
hvor drejeforbindelsen (200) til understøtning af rotorvingerne (108) på rotorvingenavet (106) og/eller drejeforbindelsen (200) til understøtning af maskinbæreren (110) på tårnet (102) er udformet som en tørtløbende glidedrejeforbindelse.

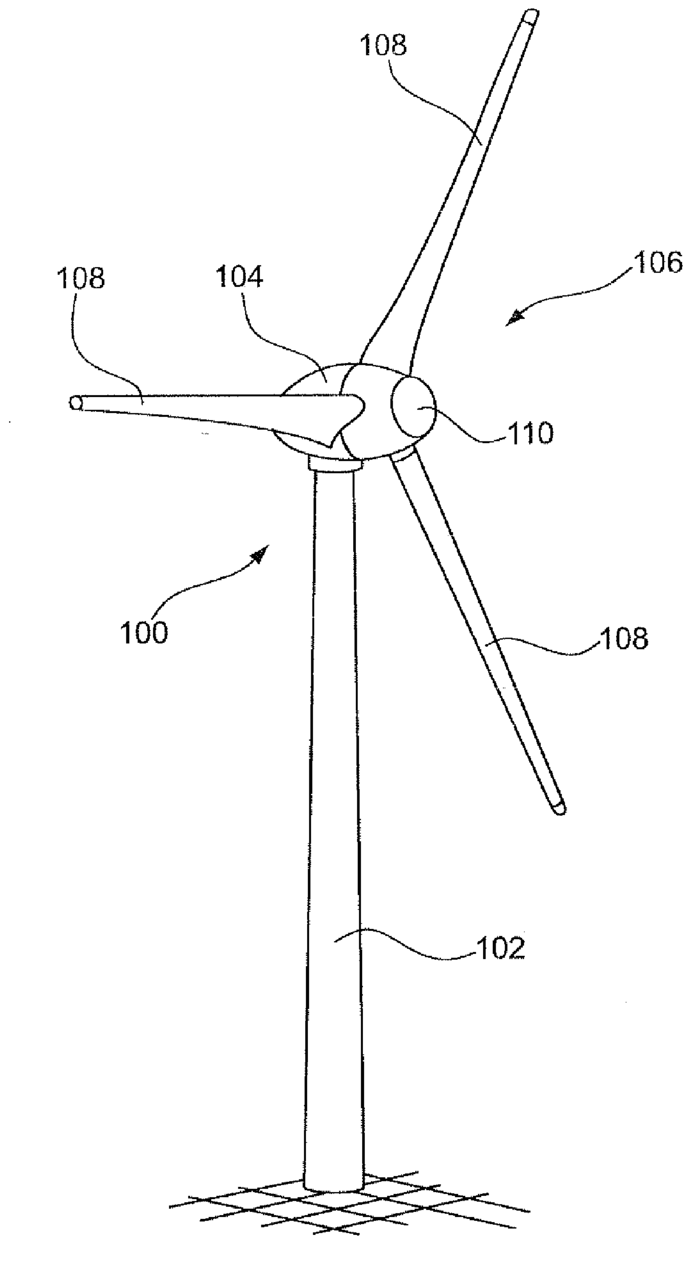

FIG. 1

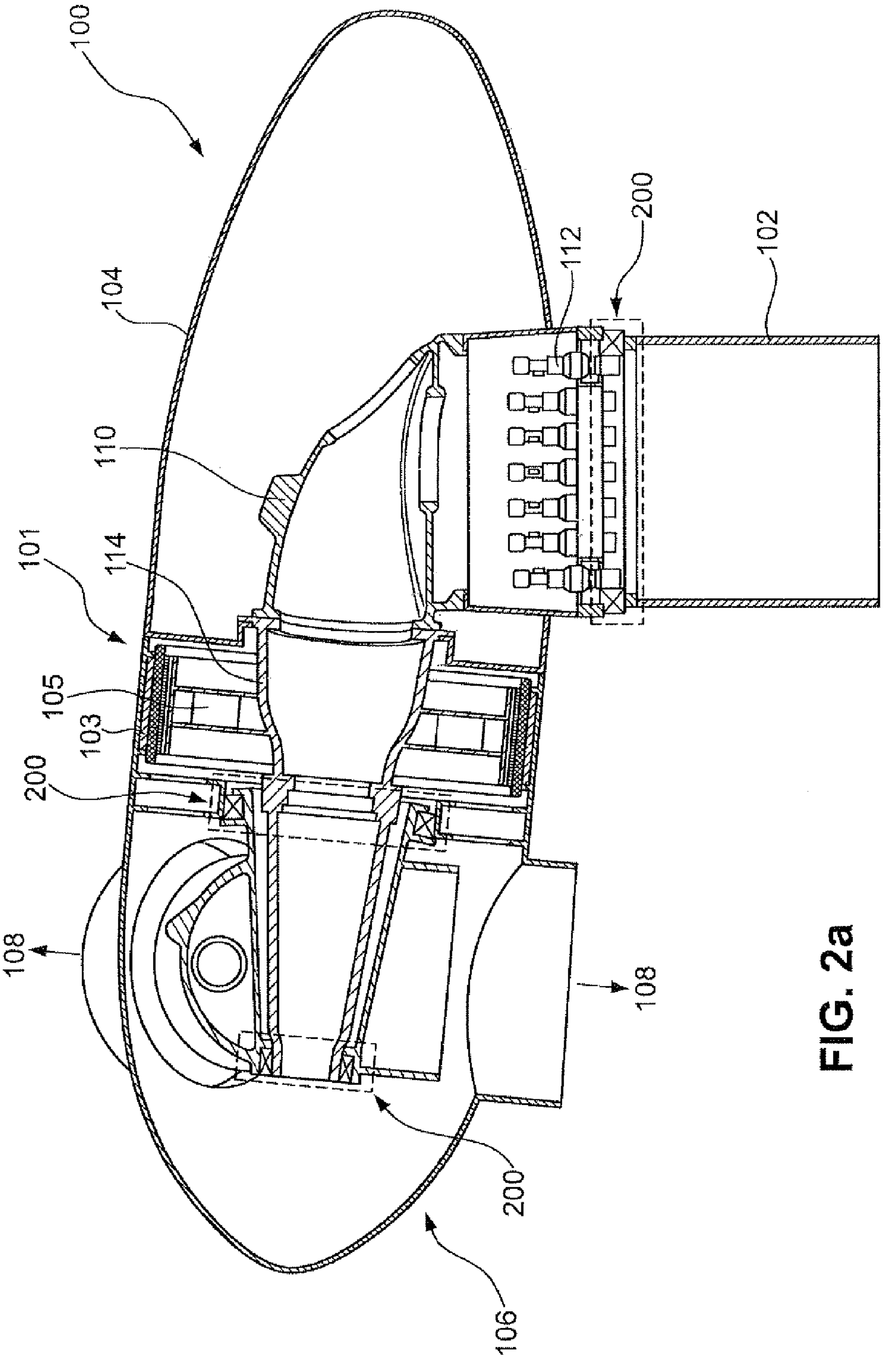

FIG. 2a

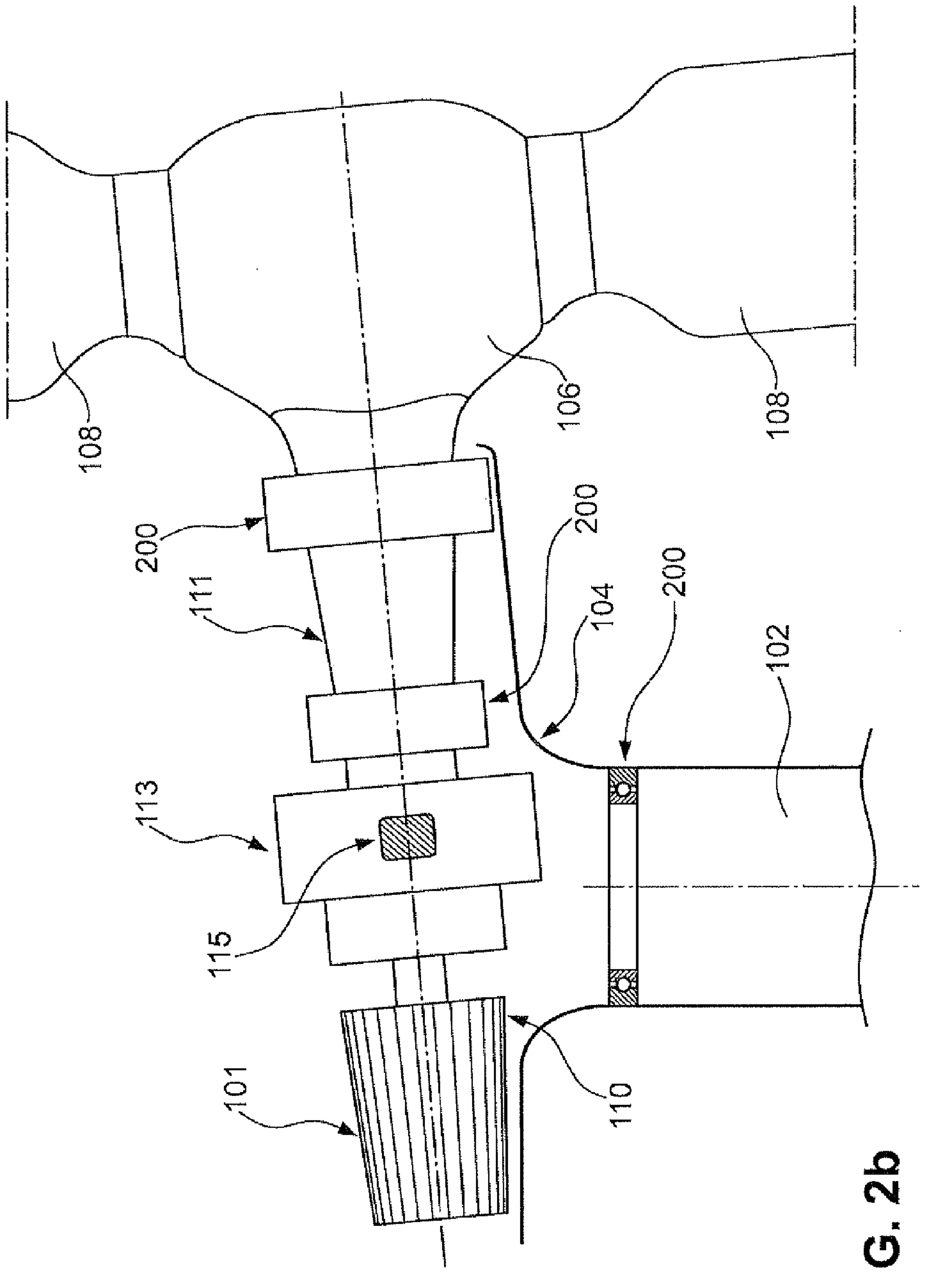

FIG. 2b

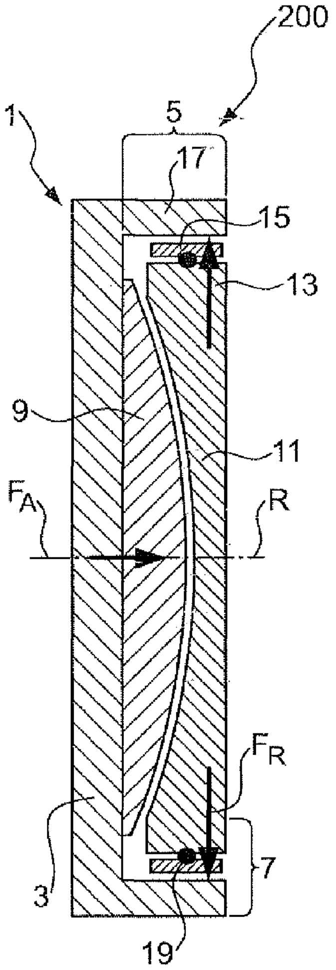
200
1
5
17
15
13
9
11
F_A
R
F_R
7
3
19

FIG. 3a

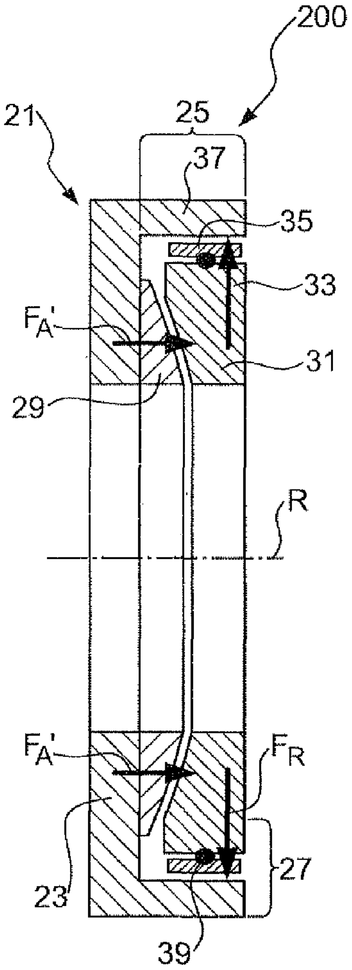
200
21
25
37
35
33
F_A'
31
29
R
F_A'
F_R
27
23
39

FIG. 3b

FIG. 4a

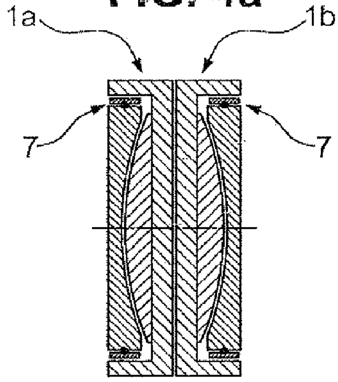

FIG. 4b

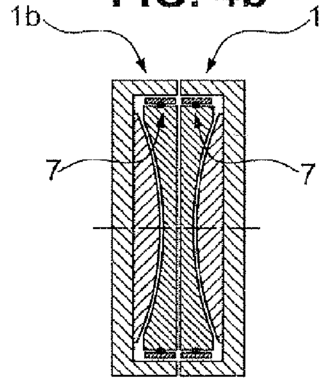

FIG. 4c

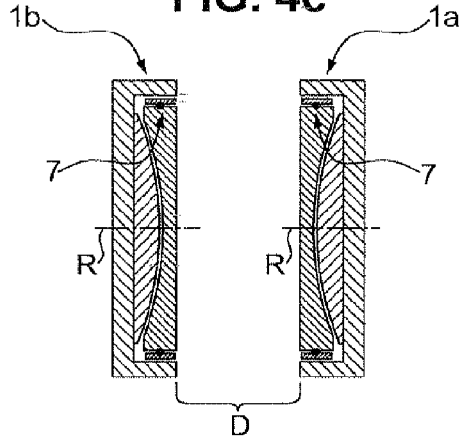

FIG. 4d

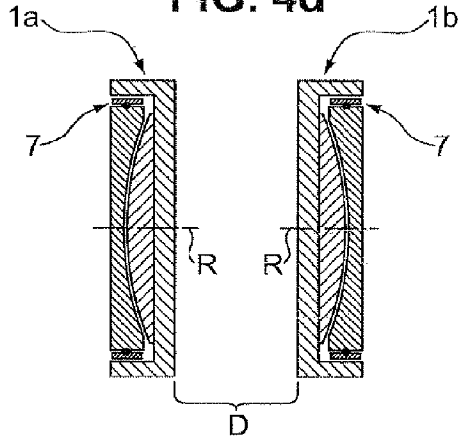

FIG. 4e

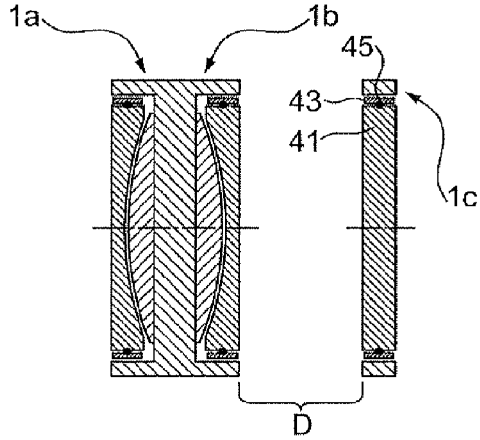

FIG. 4f