



(51) International Patent Classification:

F16C 35/073 (2006.01) F03D 80/70 (2016.01)

(21) International Application Number:

PCT/DK2018/050023

(22) International Filing Date:

02 February 2018 (02.02.2018)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

PA 2017 70127 21 February 2017 (21.02.2017) DK

(71) Applicant: VESTAS WIND SYSTEMS A/S [DK/DK];

Hedeager 42, 8200 Aarhus N (DK).

(72) Inventor: HEUSER, Lutz; Nevigeser Straße 331, 42553

Velbert (DE).

(81) Designated States (unless otherwise indicated, for every

kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every

kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ,

(54) Title: WIND TURBINE MAIN ROTOR ARRANGEMENT HAVING MEANS TO PREVENT ANGULAR CREEP OF OUTER BEARING RING

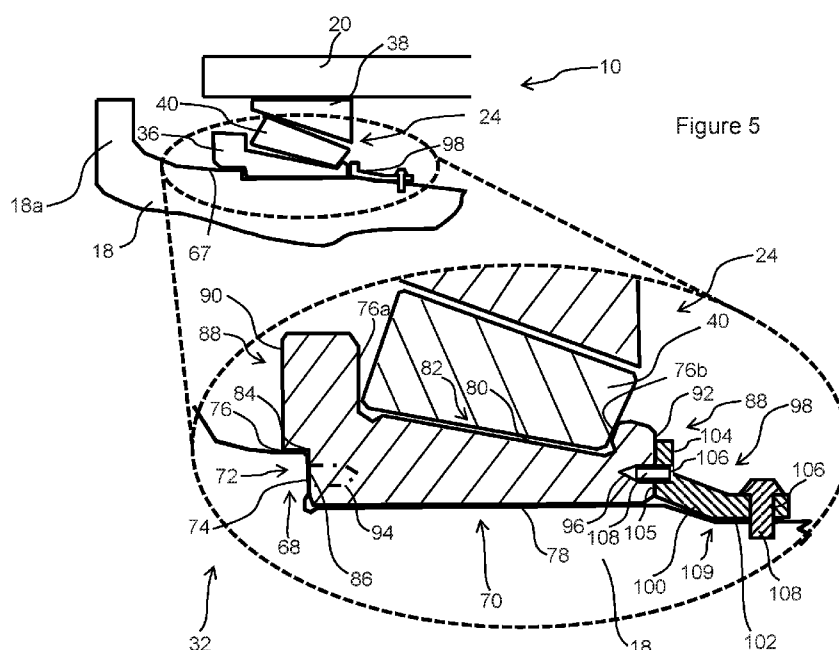


Figure 5

(57) Abstract: A main rotor arrangement for a wind turbine, comprising a main rotor shaft that extends in an axial direction and includes a hub connection flange at its hub-connection end, wherein the hub connection flange extends radially inwardly so as to transition into a generally cylindrical shaft region, wherein the shaft region includes a bearing abutment. A forward bearing includes an inner ring, an outer ring and a roller set, wherein the inner ring is carried on the shaft region and abuts against the bearing abutment. A retainer element is attachable to the shaft region and is configured to prevent circumferential movement of the inner ring relative to the main rotor shaft. The main rotor arrangement of the invention should be considered in the context of a utility-scale wind turbine, which would typically have a power rating of at least 1MW. A benefit of the invention is that the retainer element provides an elegant means to guard against circumferential 'creep' of the bearing relative to the shaft. Such a 'creep' phenomenon can occur under heavy bearing loads and

TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

WIND TURBINE MAIN ROTOR ARRANGEMENT HAVING MEANS TO PREVENT ANGULAR CREEP OF OUTER BEARING RING

TECHNICAL FIELD

5

The invention relates to a main rotor shaft for a wind turbine, and particular an arrangement for a main bearing for use with that shaft.

BACKGROUND

10

Although many different types of wind energy generators exist today, the most common type is the horizontal axis wind turbine or "HAWT". HAWTs, hereinafter simply 'wind turbines', are in widespread use in on-shore and off-shore settings.

15

In order to capitalise on economies of scale, there has been a general trend for wind turbines to be designed with ever larger rotor disc diameters in an effort to increase the energy capture potential, thereby lowering the average cost of energy production. This principle has contributed to year-on-year increases in global installed capacity in an effort to re-balance the energy generation mix away from non-renewables such as oil and gas, towards renewables such as wind and solar.

20

However, the upward trend of wind turbine size comes with its challenges since the wind turbine towers must be taller, the blades must be longer and stronger, and the nacelles must be larger and heavier. The centrepiece of the wind turbine can be considered to be the main rotor shaft, since it carries the hub and rotor blades and harnesses the rotational energy generated by the blades so that it can be converted to electrical energy by the generator. The main rotor shaft and, thus, the housing within which it supported, therefore must be incredibly robust to withstand the huge forces generated during energy production. What's more, the main rotor shaft is typically designed to with a life comparable to the rated lifetime of the wind turbine itself, which is usually in the region of 20 years.

25

30

In one arrangement, the main rotor shaft extends through a main shaft or 'bearing' housing and is rotatably supported within that housing by two main shaft bearings: a forward bearing supports the end of the shaft near to the hub, that is the 'front' or 'forward' end, and a rear bearing support the end of the shaft distal from the hub, that is the 'back' or 'rear' end. The bearings function to ensure that the main rotor shaft can rotate smoothly and also transfers axial loads and bending moments to a bed-plate or base-frame via the main bearing

35

housing. This arrangement is generally effective at decoupling the gearbox of the wind turbine from the axial and bending forces of the main rotor shaft, so that only torque is transferred to the gearbox.

- 5 The trend towards heavier blades and hubs means that the main rotor shaft and, therefore, the supporting bearings, are required to deal with higher loads, and so there is constant pressure to design the rotor shaft assemblies to handle the loads more effectively. It is against this background that the invention has been devised.

10 SUMMARY OF THE INVENTION

The invention provides a main rotor arrangement for a wind turbine, comprising a main rotor shaft that extends in an axial direction and includes a hub connection flange at its hub-connection end, wherein the hub connection flange extends radially inwardly so as to transition into a generally cylindrical shaft region, wherein the shaft region includes a bearing
15 abutment. A forward bearing includes an inner ring, an outer ring and a roller set, wherein the inner ring is carried on the shaft region and abuts against the bearing abutment. A retainer element is attachable to the shaft region and is configured to prevent circumferential movement of the inner ring relative to the main rotor shaft.

20 The main rotor arrangement of the invention is to be considered in the context of a utility-scale wind turbine, which would typically have a power rating of at least 1MW. The invention therefore extends to such a wind turbine comprising a main rotor arrangement in accordance with the invention.

25 A benefit of the invention is that the retainer element provides an elegant means to guard against circumferential 'creep' of the bearing relative to the shaft. Such a 'creep' phenomenon can occur under heavy bearing loads and can cause undesirable wear at the interface between the shaft and the bearing.

30 The size and relative dimensions of the main rotor shaft may be such that the diameter of the second shaft portion may fall in the range of 80% and 98% of the diameter of the first shaft portion; and the diameter of the first shaft portion may fall in the range of 25% and 200% of the length of the main rotor shaft.

35 The retainer element may be removably fastened to the shaft region by any means, for example by bolts or a bonding medium. The retainer element may take the form of relatively

thin structures that are positioned on the shaft, extend towards the bearing and so as to engage the bearing in some way to prevent circumferential movement thereof. Several such retainer elements of this type may be used to increase the force with which circumferential creep can be prevented. In other embodiments, the retainer element may extend
5 circumferentially, and so be shaped like a partial ring. Two or more such ring-like components can be joined together to provide a retaining ring that extends about the shaft, is connected thereto, and engages with the bearing so prevent circumferential creep.

In any of these embodiment, the retainer element may have an arm portion that opposes the
10 bearing and includes engagement means for engaging bearing, and particularly the inner ring thereof. The engagement means may include a locking element that cooperates with the retainer element and the bearing so as to lock the bearing to the retainer element. The engagement element may be in the form of a pin or bolt, that is received through corresponding holes in the bearing and retainer element, but it may also be in the form of
15 cooperating/meshing teeth, for example.

Within the scope of this application it is expressly intended that the various aspects, embodiments, examples and alternatives set out in the preceding paragraphs, in the claims and/or in the following description and drawings, and in particular the individual features
20 thereof, may be taken independently or in any combination. That is, all embodiments and/or features of any embodiment can be combined in any way and/or combination, unless such features are incompatible. The applicant reserves the right to change any originally filed claim or file any new claim accordingly, including the right to amend any originally filed claim to depend from and/or incorporate any feature of any other claim although not originally
25 claimed in that manner.

BRIEF DESCRIPTION OF DRAWINGS

Embodiments of the invention will now be described, by way of example only, with reference
30 to the accompanying drawings, in which:

Figure 1 is a front view of a wind turbine, comprising a main rotor arrangement according to the invention;

Figure 2 is a schematic view of a drivetrain of the wind turbine of Figure 1, including a main rotor arrangement;

Figure 3 is a perspective view of a main rotor arrangement;

Figure 4 is a longitudinal section view of the main rotor arrangement comprising known arrangements of main shaft and main bearings;

Figure 5 is an illustrative view of a main shaft arrangement in accordance with an embodiment of the invention;

5 Figure 6 is a perspective view of a portion of a main rotor shaft in accordance with an embodiment of the invention; and

Figure 7 is a perspective view of a locking member of a main shaft arrangement in accordance with an embodiment of the invention in isolation.

DETAILED DESCRIPTION

10

The present invention relates to an improved arrangement for a main bearing and main rotor shaft of a wind turbine. The arrangement includes a retainer element that is configured to apply an axial retaining force to the main bearing to prevent axial and circumferential movement of the bearing on the rotor shaft.

15

With reference to Figure 1, a wind turbine 2 includes a nacelle 4 that is supported on a generally vertical tower 6, which is itself mounted to a foundation 8. The foundation 8 may be on the land, or wholly or partially underwater. The nacelle 4 houses a number of functional components, some of which are shown schematically in Figure 2, by way of example. Such a configuration would be well known to a skilled person.

20

Here, the nacelle 4 is shown as housing at least in part, the main rotor arrangement 10, a gearbox 12 and a generator 14. For brevity, some typical components have been omitted from Figure 2 as they are not central to this discussion, for example a power converter and yaw drive. However, the presence of such components is implicit and such component would be well understood by the skilled reader.

25

The main rotor arrangement 10 includes a hub 16 coupled to a main rotor shaft 18, which is rotatably supported in a main shaft housing 20 by a bearing arrangement 22. Note that the main shaft housing 20 is sometimes referred to in the art as a main bearing housing, and will be referred to as such from now on. In this embodiment, the bearing arrangement 22 comprises a forward bearing 24 and a rear bearing 26. The hub 16 is connected to a plurality of rotor blades 27, although three blades are typical in a HAWT. The blades 27 are acted on by the wind and therefore torque is applied by the hub 16 to the main rotor shaft 18 which causes it to rotate within a main bearing housing 20.

30

35

An input or 'forward' portion of the main rotor shaft 18 comprises a hub connection flange 18a, by which means the main rotor shaft 18 is connected to, and driven by, the hub 16. Here the flange 18a is shown as being connected to a further flange 29 that is associated with the hub 16, such that the two flanges form a coupling between the hub 16 and the main rotor shaft 18. The flange 18a can therefore be considered to be at the hub-connection end of the main rotor shaft 18.

An output portion 18b of the shaft 18 provides input drive to the gearbox 12. The gearbox 12 steps up the rotational speed of the main rotor shaft 18 via internal gears (not shown) and drives a high-speed gearbox output shaft 28. The high-speed output shaft 28 in turn drives the generator 14, which converts the rotation of the high-speed output shaft 28 into electricity. The electrical energy generated by the generator 14 may then be converted by other components (not shown here) as required before being supplied to the grid, for example, or indeed any electrical consumer. So-called "direct drive" wind turbines that do not use gearboxes are also known. The gearbox 12 may therefore be considered optional.

At this point it should be noted that although in this embodiment two support bearings 24, 26 are shown that provide support to the main rotor shaft 18 at forward and rearward positions, arrangements are also known in which the rearward bearing is omitted and, instead, rear support for the main rotor shaft 18 may be provided by the generator 14.

The main bearing housing 20 is supported on a base frame 30, which can also be known as a bed plate. Although not shown here, the base frame 30 may be coupled to a yaw drive at the upper part of the wind turbine tower 6 to enable the base frame 30 and, thus, the entire nacelle 4 to yaw with respect to the tower 6 so as to enable the direction of the hub 16 to be adjusted with respect to the wind direction.

The base frame 30 is typically a cast component, for example of iron or steel, and has the function to transfer the main shaft loads from the shaft 18, through the bearings 24, 26, the main bearing housing 20, and the base frame 30, and into the wind turbine tower 6.

Figures 3 and 4 illustrate a more practical realisation of a main bearing housing 20 and main rotor shaft 18 for a better understanding of the configuration of the relevant components.

It should be noted that whilst the general layout of the main shaft housing 20 and main rotor shaft 18 shown in Figures 3 and 4 is applicable to the present invention, the main inventive

concept is not illustrated in these drawings (but will be described later with particular reference to Figures 5, 6 and 7). However, Figures 3 and 4 should assist in providing useful context for the present invention.

- 5 Referring to Figures 3 and 4, the main rotor shaft 18 is tapered along its length to provide a relatively larger circumference at the forward end 32 of the shaft 18 and a relatively smaller circumference at the rearward end 34 of the shaft 18. It should be noted that it is not essential that the main rotor shaft 18 is tapered. However, this configuration may provide certain advantages as it allows the shaft 18 to support a larger forward bearing 24, capable
10 of more effectively managing the substantial loads applied to it in use.

The forward and rear bearings 24, 26 are situated between the main rotor shaft 18 and main bearing housing 20, at forward and rearward positions respectively along the length of the shaft 18. The forward and rear bearings 24, 26 together enable the main rotor shaft 18 to
15 freely rotate with respect to the main bearing housing 20 during wind turbine operation, about a rotor axis R that extends through the centre of the main rotor shaft 18.

The forward and rear bearings 24, 26 each include an inner ring 36, an outer ring 38 and a plurality of generally cylindrical rolling elements 40, more simply referred to as rollers,
20 supported therebetween. Note that the inner ring may sometimes in the art be referred to as a cone, whereas the outer ring may sometimes be referred to as a cup. A typical wind turbine bearing, for use in utility-scale applications, typically exceeding 1MW in power output, must withstand high loads and operate reliably over an extended lifetime. In this embodiment, the forward and rear bearings 24, 26 are tapered roller bearings having
25 tapered inner and outer races 42, 44 and tapered rolling elements 40 designed to accommodate combined axial and radial loads. It should be noted at this point that the bearings in practice would also include a roller cage that keeps the rollers in a spaced configuration about the circumference of the cup and cone of the bearing, although this feature is not illustrated here for clarity. In other embodiments, different types of bearings
30 may be used, for example cylindrical roller bearings or spherical roller bearings (not shown). Cylindrical roller bearings utilise rows of cylindrical rolling elements that are in linear contact with races of the inner and outer rings. Spherical roller bearings include two rows of barrel-shaped rolling elements, which are supported between an outer race and two inclined inner ring races. Because the centre of the sphere of the outer ring race is at the bearing axis,
35 these bearings are self-aligning and can withstand misalignment of the shaft relative to the housing.

The main bearing housing 20 comprises a front flared portion 46 that defines a forward bearing seat 48 and a rear flared portion 50 that defines a rear bearing seat 52. To secure the bearings 24, 26 in position, the main rotor shaft 18 includes a forward bearing retainer 54 or 'rib' for retaining the forward bearing 24 in the front bearing seat 48 and a rear bearing retainer groove 56 for holding a backing element such as a rear bearing clip 58, circlip, lock nut or similar structure that retains the rear bearing 26 in the rear bearing seat 52.

Focusing now on the forward bearing retainer 54, and with particular reference to Figure 4, a standard forward bearing retainer 54 of the current state of the art may comprise a rib 60 in the form of a protrusion that extends radially outwards from an outer surface 62 of the main rotor shaft 18, and extends about the entire circumference of the main rotor shaft 18. This retaining rib 60 includes an abutment surface (not shown) facing away from the forward (hub) end 32 of the shaft 18, against which a corresponding abutment surface (not shown) of the inner ring 36 of the forward bearing 24 contacts in use.

In this way, the forward bearing 24 is located at the correct position along the length of the shaft 18, and is prevented from drifting towards the hub-end 32 of the shaft 18 during operation. However, this configuration provides no means for preventing axial or circumferential movement of the forward bearing 24 on the rotor shaft 18. That is to say, the forward bearing 24 of the main rotor arrangement 10 described above is not restricted from shifting about the circumference of the main rotor shaft 18 or from shifting away from the hub-end of the main rotor shaft 18 in an axial direction along the main rotor shaft during wind turbine 2 operation. Movement of the bearing 24 from its correct position may result in damage to the bearing 24 or other turbine components, and may impair proper operation of the wind turbine 2. Furthermore, the above-described arrangement presents challenges in terms of the processing time and material cost associated with machining the retaining rib 60 into the main rotor shaft 18. For example, the retaining rib 60 must be precisely dimensioned and positioned on the shaft 18, resulting in strict tolerance requirements that increase the cost and time required to produce this retaining feature 54. Thus, any enhancement to the configuration of the main rotor arrangement 10 to address these issues would be beneficial.

Figure 5 shows a main rotor arrangement 10 in accordance with an embodiment of the present invention. Specifically, Figure 5 shows a portion of the main rotor arrangement 10 in the vicinity of the forward bearing 24. At its outermost point, the flange 18a is in a plane that is perpendicular to the axis of the rotor shaft 18.

The hub connection flange 18a of the main rotor shaft 18 extends radially inwardly towards the rotor axis R (shown in Figure 2) such that the flange 18a transitions along the length of the shaft into a generally cylindrical shaft region 67 including a first shaft portion 68 having a first diameter and a second shaft portion 70 having a second diameter. The first shaft portion 68 transitions to the second shaft portion 70 at a bearing abutment 72, the first and second shaft portions 68, 70 being spaced axially along the rotor shaft 18. The bearing abutment 72 takes the form of a shoulder that defines a step extending about the circumference of the rotor shaft 18 between the first and second shaft portions 68, 70, such that the second diameter of the second shaft portion 70 is smaller than the first diameter of the first shaft portion 68. The shoulder 72 provides a shoulder surface 74 against which the forward bearing of the main rotor arrangement abuts in use. This configuration of the main rotor shaft 18 is further illustrated in Figure 6, which shows a portion of the main rotor shaft 18 in isolation from the main shaft housing 20 and bearings 24, 26.

In this specific embodiment of the invention, the diameter of the first shaft portion 68 is approximately 1600mm, whereas depth of the shoulder 72 is approximately 80mm, although it is envisaged that the depth should be no greater than 100mm. The diameter of the second shaft portion 70 is approximately 95% of the diameter of the first shaft portion 68. The diameter of the first shaft portion 68 of the main rotor shaft 18 is approximately 50% of the length of the main rotor shaft 18. It should be noted that these dimensions are specific to this embodiment, and may vary in other embodiments on the invention. Specifically, in other embodiments the diameter of the second shaft portion 70 may fall anywhere in the range of 80% and 98% of the diameter of the first shaft portion 68, and the diameter of the first shaft portion 68 may fall anywhere in the range of 25% and 200% of the length of the main rotor shaft 18.

The shoulder surface 74 provides the transition region between outer surfaces 76, 78 of the first and second shaft portions 68, 70, respectively. In this embodiment of the invention the shoulder surface 74 is substantially perpendicular to the outer surfaces 76, 78 of the first and second shaft portions 68, 70, but it should be noted that this is not essential. In this context, although it is currently envisaged that the shoulder surface 74 is vertical, some variation may be tolerated, and expected. For example, the shoulder surface 74 may be inclined with respect to the outer surfaces 76, 78 such that, in some embodiments, the shoulder surface 74 forms an angle with the outer surface 78 of the second shaft portion 70 that is up to 10° off-vertical. Furthermore, the shoulder surface 74 may be inclined to provide either a slope or an overhanging ledge between the first and second shaft portions 68, 70. In this way, the

shape and size of the shoulder 72 may vary, provided the shoulder 72 is still able to perform its required function as a robust stop for the inner ring 36 of the forward bearing 24.

The inner ring 36 of the forward bearing 24 comprises a slanting radially outer surface 80 defining an inner ring raceway or track 82 in which the rolling elements 40 of the forward bearing 24 are received and guided between front and rear guiding ribs or flanges 76a, 76b defined by respective walls or ribs 88. The inner ring also defines a stepped radially inner surface 84 that includes a shoulder abutment surface 86 of the inner ring 36. The side ribs 88 of the inner ring 36 comprise a first, relatively large side rib 90 and a second, relatively small, side rib 92, where the first side rib 90 is located closer to the hub-end 32 of the main rotor shaft 18 than the second side rib 92 when assembled on the rotor shaft 18 for use. The inner ring 36 of the forward bearing 24 further includes two openings provided at opposing sides of the inner ring 36; a first opening 94 provided in the shoulder abutment surface 86 of the inner ring 36 and a second, fastener-receiving opening 96 located on the opposing second side rib 92 of the inner ring 36. The first and second openings 94, 96 may be used during transport of the bearing 24.

Referring to Figures 5 and 7, the main rotor arrangement 10 further comprises a retainer element 98.

The retainer element 98 is configured to retain the forward bearing 24 in its correct circumferential position along the main rotor shaft 18 of the wind turbine 2 during operation, such that the forward bearing 24 sits between the retainer element 98 and a corresponding retaining feature of the main rotor shaft 18 in use (for example, a shoulder 72 or retaining rib 60 of the main rotor shaft). For this, the retainer element 98 is positioned next to the forward bearing 24 on the main rotor shaft 18, and may abut or brace against the forward bearing 24 to prevent the forward bearing 24 from moving circumferentially on the main rotor shaft 18 during use. The retainer element 98 may include e.g. a pin or bolt for engaging with a corresponding feature of the inner ring 36, as will be described later. Other forms of engagement means, such as teeth, are also envisaged. In some embodiments, just a single retainer element 98 may be included in the arrangement 10, or a plurality of retainer elements 98 may be equally spaced about the circumference of the main rotor shaft 18 to ensure the forward bearing 24 does not drift out of position at any point about the shaft 18. Another possible alternative is to provide the retainer element 98 in two semi-circular parts configured to form a closed loop or ring when assembled on the main rotor shaft 18 for use. In certain embodiments, the retainer element 98 may also function to prevent axial movement of the forward bearing 24 on the main rotor shaft 18.

The retainer element 98 comprises a main body 100 including a shaft attachment portion 102 and a retaining arm 104. The shaft attachment portion 102 and arm 104 of the retainer element 98 are provided at opposing ends of the main body 100 and each include a fixing hole 106 for receiving a bolt or screw (or other appropriate fastening means) in use. The shaft attachment portion 102 transitions to the main body 100 at an elbow 109 such that the main body 100 is slightly angled with respect to the shaft attachment portion 102. In this way, the shape of the retainer element 98 corresponds to the shape of the rotor shaft 18 in the region of the shaft 18 on which the retainer element 98 sits in use. In other embodiments, the angle between the main body 100 and the shaft attachment portion 102 of the retainer element 98 may vary in dependence on the shape of the main rotor shaft 18. The arm 104 is provided as a flange extending from the main body 100 of the retainer element 98. In use, a retaining portion 105 of the arm 104 may abut or brace against the inner ring 36 of the forward bearing 24 to secure the inner ring 36 in position on the rotor shaft 18. Alternatively, the retainer element 98 may be positioned to provide a small gap between the arm 104 and the inner ring 36.

Four retainer elements 98 are included in the main rotor arrangement 10, spaced equidistantly about the circumference of the main rotor shaft 18 to prevent the forward bearing 24 from shifting away from the rotor shaft shoulder 72 about the circumference of the shaft 18. However, other embodiments of the invention may include fewer retainer elements 98, or additional retainer elements 98. Furthermore, the retainer elements 98 may not be spaced equidistantly from each other about the circumference of the main rotor shaft 18, but may be clustered or spaced at varying intervals about the circumference of the rotor shaft 18. The retainer element 98 may also be configured to extend a significant way about the circumference of the shaft, so as to be shaped like a ring, either fully or in part. The shape and dimensions of the retainer element 98 may also vary in other embodiments of the invention in dependence on, for example, the corresponding shape of the rotor shaft 18 in the region of the retainer element or the required strength of the retainer element for a forward bearing 24 of a given size.

When the main rotor arrangement 10 is assembled for use, the forward bearing 24 is positioned between the main rotor shaft 18 and the main shaft housing 20, and is received in the forward bearing seat 48. The inner ring 36 of the forward bearing abuts the shoulder 72 of the main rotor shaft 18, such that the shoulder abutment surface 86 of the inner ring 35 bears against the shoulder surface 74 of the rotor shaft 18. The retainer element 98 is positioned so that the arm 104 abuts or opposes the second side rib 92 of the inner ring 36.

Fasteners 108 are received in the fixing holes 106 of the arm 104 and the rotor attachment portion 102 to secure the retainer element 98 to the inner ring 36 of the forward bearing 24 and to the main rotor shaft 18. In this embodiment of the invention the retainer element 98 is removably attached to the forward bearing 24 and rotor shaft 18 by means of screws.

5 However, other appropriate engagement means 108 may be used in other embodiments. For example, pins or dowels may removably attach the retainer element 98 to the forward bearing 24 or main rotor shaft 18, or a more permanent attachment method such as gluing or riveting may be used. Alternatively or additionally, the retainer element 98 may be secured to the forward bearing 24 and/or rotor shaft 18 by means of cooperative gripping

10 features, for example serrations or teeth, provided on the retainer element 98, bearing 24, and/or main rotor shaft 18. Furthermore, it should be noted that the retainer element 98 may be attached to the forward bearing 24 using different fastening means to those used to attach the retainer element 98 to the main rotor shaft 18. When assembled on the main rotor shaft 18 in this way, the retainer element 98 acts to retain the inner ring 36 in abutment with

15 the bearing abutment 72 of the main rotor shaft 18. In this way, the retainer member 98 retains the forward bearing 24 in its correct circumferential position on the main rotor shaft 18 and thereby prevents movement of the forward bearing 24 in a circumferential direction about the surface of the rotor shaft 18. As already mentioned above, in other embodiments of the invention the retainer member 98 may be configured to engage with the forward

20 bearing 24 in various different ways. For example, the retaining member 98 may be configured to apply an axial force on the forward bearing 24 to retain the bearing 24 in place. Alternatively, a small gap may separate the retainer element 98 from the forward bearing 24 when assembled on the main rotor shaft 18 for use, such that the retainer element 98 guards against significant movement of the forward bearing 24 without initially contacting the

25 forward bearing 24. This arrangement allows the retainer element 98 to be less precisely positioned on the main rotor shaft 18 on assembly and allows the forward bearing to elastically deform due to external loading or an intentional preload.

It should be noted that the retainer element 98 is not limited for use on the specific main rotor shaft 18 arrangement that has been described in the above embodiment. For example,

30 the retainer element 98 may be included in an arrangement in which the main rotor shaft 18 is provided with a forward bearing retainer 54 in the form of a retaining rib 60 (as is standard in the current state of the art), rather than the bearing abutment 72 described in the above embodiment of the invention.

35 It should be noted that the specific embodiments described above are provided as examples of how the inventive concept may be implemented. However, the skilled person would

appreciate that various modification could be made to those specific embodiments without departing from the inventive concept as defined by the appended claims.

Claims:

1. A main rotor arrangement (10) for a wind turbine (2), comprising:

5 a main rotor shaft (18) that extends in an axial direction and includes a hub connection flange (18a) at its front end, wherein the hub connection flange (18a) extends radially inwardly so as to transition into a generally cylindrical shaft region (67), wherein the shaft region (67) includes a bearing abutment (72);

a forward bearing (24) including an inner ring (36), an outer ring (38) and a roller (40), and wherein the inner ring (36) is carried on the shaft region (67) and abuts
10 against the bearing abutment (72);

a retainer element (98) that is attachable to the shaft region (67) and positioned to prevent circumferential movement of the inner ring (36) relative to the main rotor shaft (18).
2. A main rotor arrangement (10) as claimed in claim 1, wherein the retainer element
15 (98) is removably fastened to the shaft region (67).
3. A main rotor arrangement (10) as claimed in claim 1 or claim 2, wherein the retainer element (98) has an arm (104) that opposes the forward bearing (24).
4. A main rotor arrangement (10) as claimed in claim 3, wherein the retainer element
20 includes engagement means for engaging the inner ring (36) of the forward bearing (24).
5. A main rotor arrangement (10) as claimed in claim 4, wherein the engagement means includes a locking element that extends between the retainer element and the inner ring (36).
6. A main rotor arrangement (10) as claimed in any of the preceding claims, wherein
25 said retainer element (98) includes a pin, a bolt, or teeth for engaging with a corresponding feature of the inner ring (36).
7. A main rotor arrangement (10) as claimed in any of the preceding claims, wherein said retainer element (98) is further adapted for prevented axial movement of the forward bearing (24) on the main rotor shaft (18).
- 30 8. A main rotor arrangement (10) as claimed in any of the preceding claims, wherein said retainer element (98) comprises a main body (100) including a shaft attachment

portion (102) and a retaining arm (104); said shaft attachment portion (102) and retaining arm (104) of the retainer element (98) being provided at opposing ends of the main body (100) and each including a fixing hole (106) adapted for receiving a fastening means.

- 5 9. A main rotor arrangement (10) as claimed in any of the preceding claims, wherein said retainer element (98) comprises a main body (100) including a shaft attachment portion (102) and a retaining arm (104); wherein said main body (100) is slightly angled with respect to the shaft attachment portion (102) such that the shape of the retainer element (98) corresponds to the shape of the rotor shaft (18) in the region of the shaft (18) on which the retainer element (98) sits in use.
- 10 10. A main rotor arrangement (10) as claimed in any of the preceding claims, wherein at least four retainer elements (98) are included in the main rotor arrangement (10), spaced substantially equidistantly about the circumference of the main rotor shaft
- 15 11. A main rotor arrangement (10) as claimed in any of the preceding claims, wherein the main rotor shaft (18) includes a first shaft portion (68) and a second shaft portion (70), and wherein the second shaft portion (70) has a narrower diameter than the first shaft portion (68) so as to define a stepped shoulder therebetween, wherein the first shaft portion (68) is proximal to and blends into the hub connection flange (18a).
- 20 12. A main rotor arrangement as claimed in claim 11, wherein the stepped shoulder defines the bearing abutment (72).
13. A main rotor arrangement (10) as claimed in claim 11 or claim 12, wherein the retainer element (98) is secured to the second shaft portion (70) of the main rotor shaft (18).
- 25 14. A main rotor arrangement (10) as claimed in any of claims 11 to 13, wherein the diameter of the first shaft portion (68) falls in the range of 25% and 200% of the length of the main rotor shaft (18).
15. A main rotor arrangement (10) as claimed in any of claims 11 to 14, wherein a depth of the shaft shoulder (72) is no greater than 100mm.
- 30 16. A main rotor arrangement (10) as claimed in any preceding claim, wherein the shaft shoulder (72) is a substantially perpendicular step.

17. A main rotor arrangement (10) as claimed in any preceding claim, comprising a plurality of retainer elements (98) arranged circumferentially about the main rotor shaft (18).
- 5 18. A utility-scale wind turbine (2) comprising a tower (6), a nacelle (4) mounted to the tower, a hub (16) associated with the nacelle and connected to a plurality of wind turbine blades (27), wherein the hub is mounted to a main rotor arrangement (10) as claimed in any of claims 1 to 17.

1 / 6

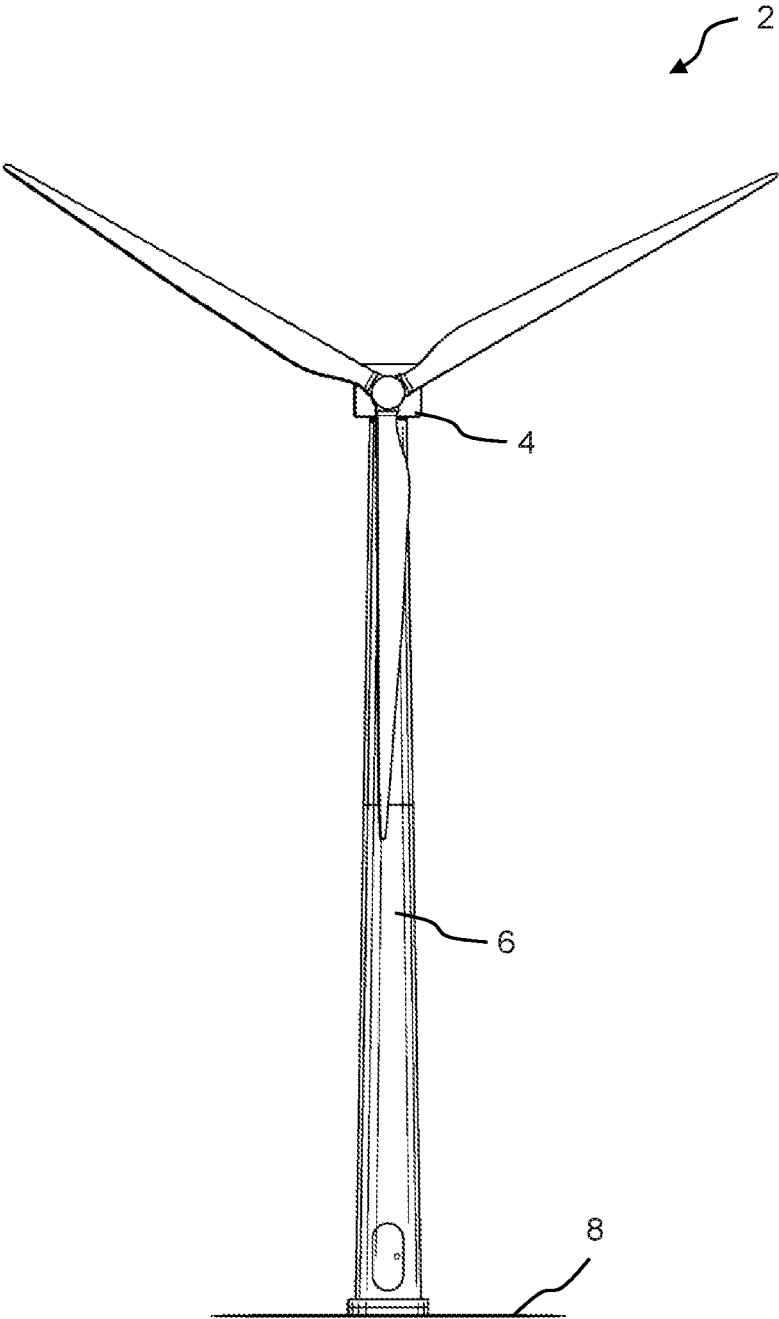


Figure 1

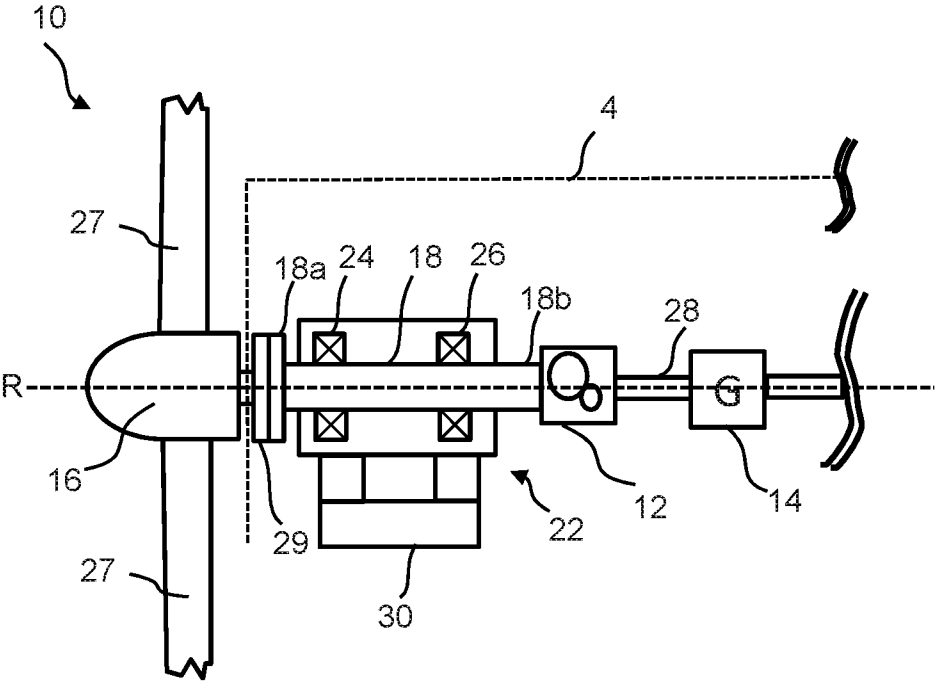


Figure 2

3 / 6

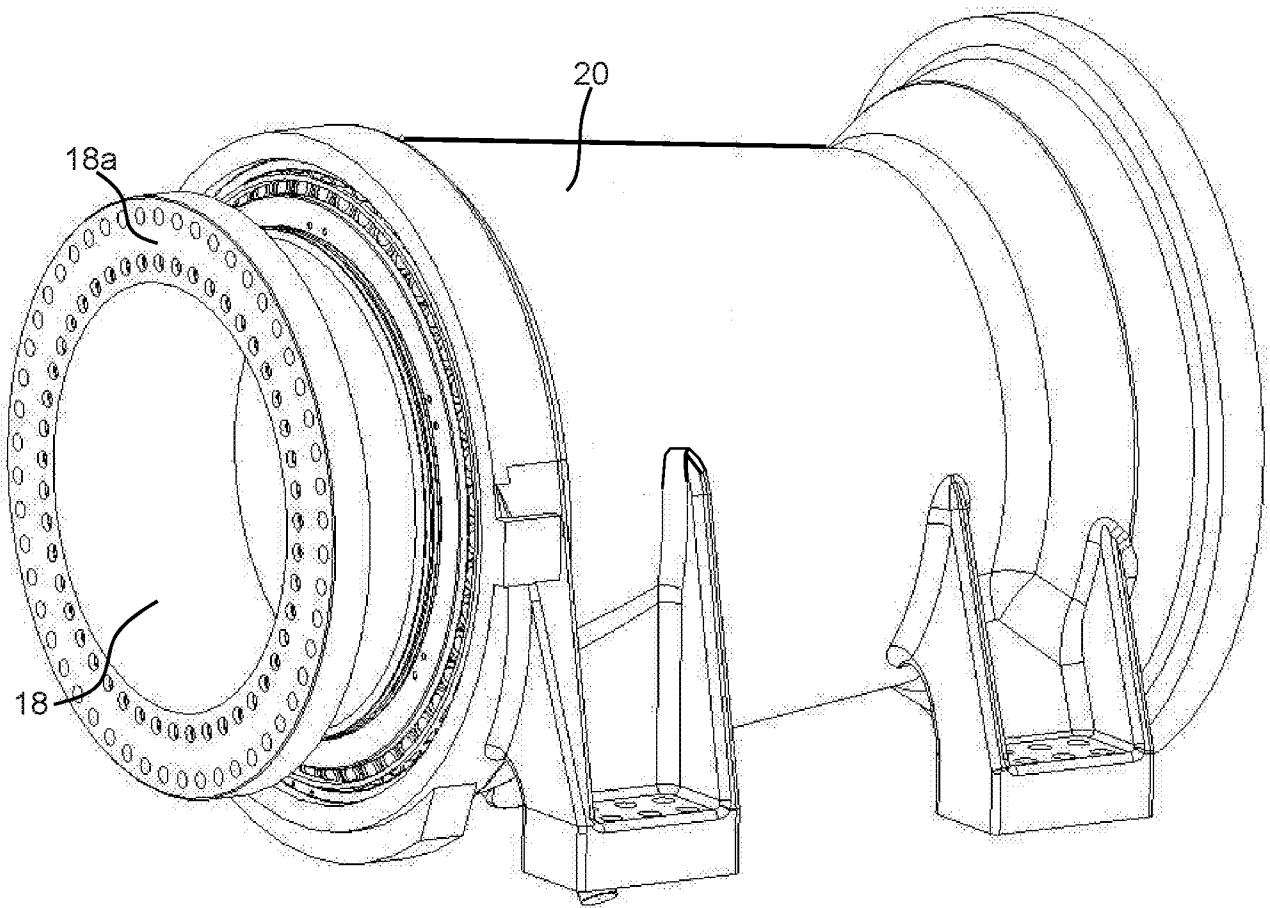
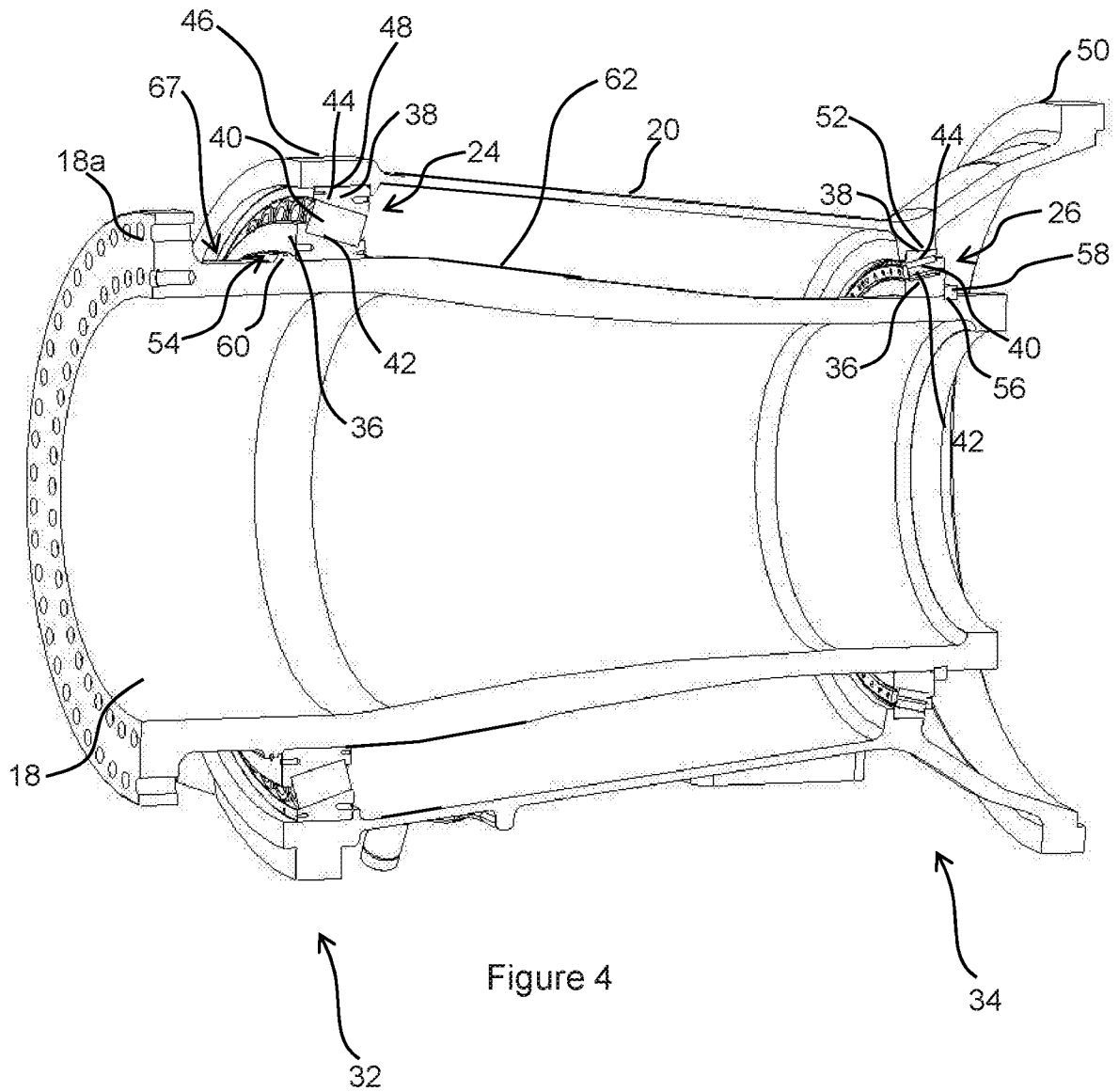


Figure 3

4 / 6



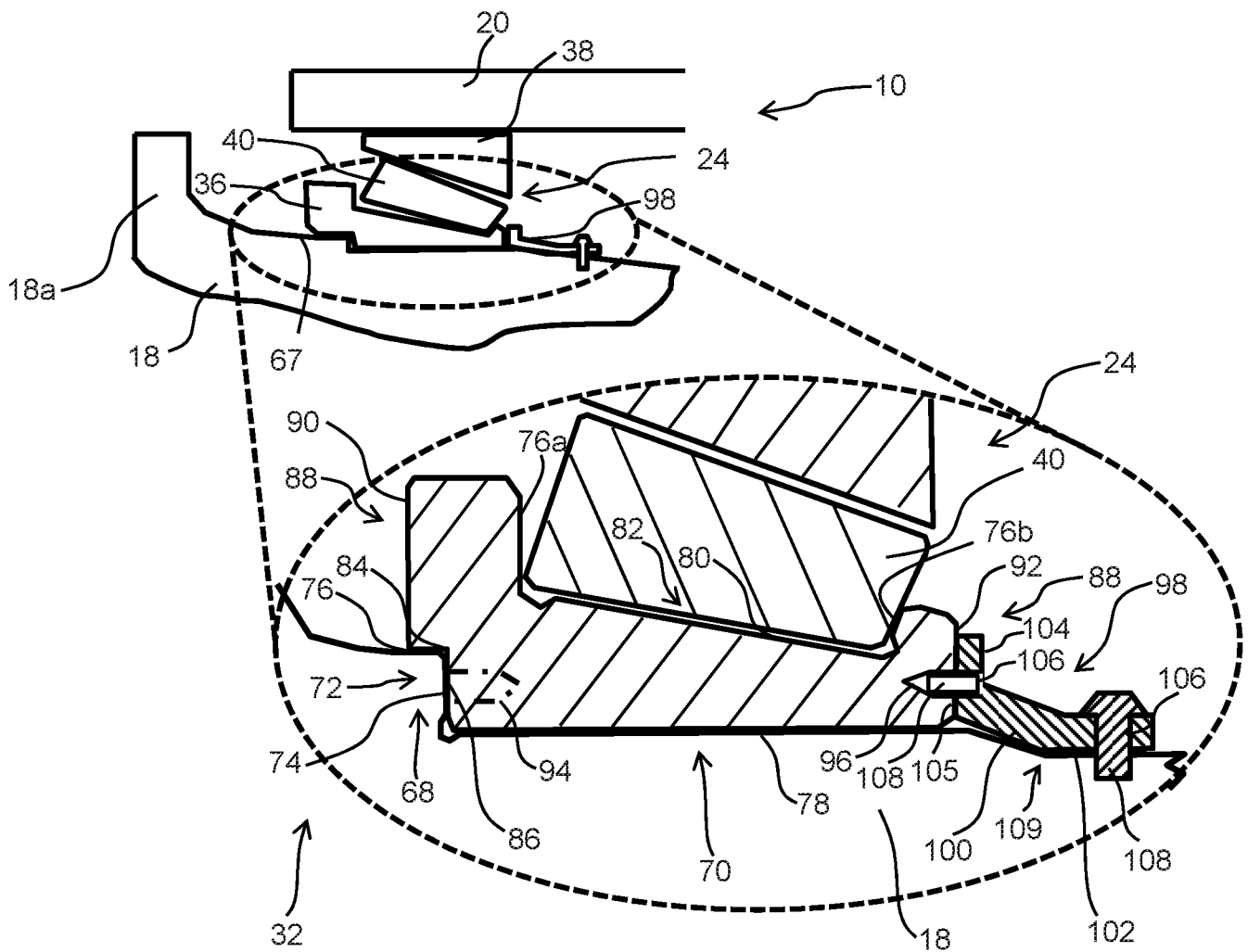


Figure 5

6 / 6

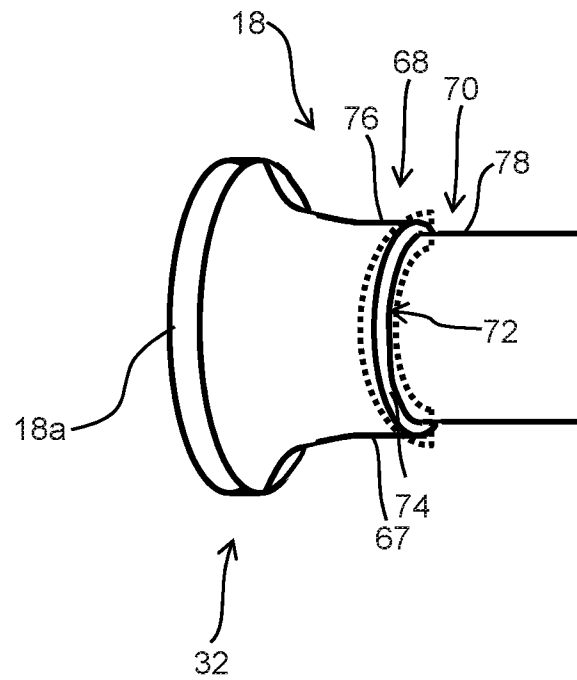


Figure 6

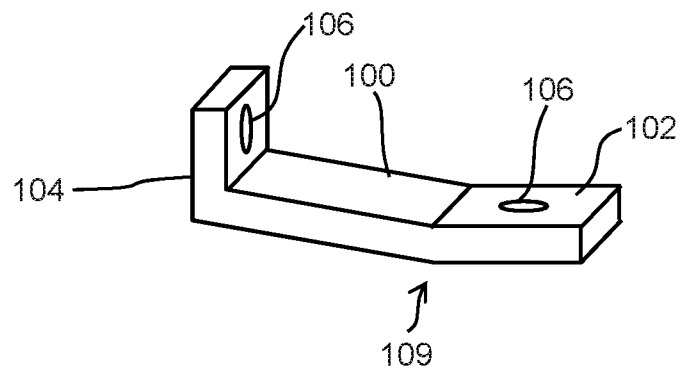


Figure 7

INTERNATIONAL SEARCH REPORT

International application No

PCT/DK2018/050023

A. CLASSIFICATION OF SUBJECT MATTER
 INV. F16C35/073 F03D80/70
 ADD.

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)
 F03D F16C

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 practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 10 2004 058905 A1 (SKF AB [SE]) 14 June 2006 (2006-06-14) paragraph [0028]; figures 2,4 -----	1,2,4,5, 7,11-16, 18
X	EP 2 754 893 A1 (MITSUBISHI HEAVY IND LTD [JP]) 16 July 2014 (2014-07-16) figures 4-6 -----	1,2,4,5, 7,11,12, 14-16,18
X	DE 10 2009 015827 A1 (SKF AB [SE]) 7 October 2010 (2010-10-07) paragraphs [0017], [0027], [0053]; figures 1-3 ----- -/-	1-5,7, 12, 14-16,18



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

16 April 2018

Date of mailing of the international search report

23/04/2018

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
 NL - 2280 HV Rijswijk
 Tel. (+31-70) 340-2040,
 Fax: (+31-70) 340-3016

Authorized officer

Biloen, David

INTERNATIONAL SEARCH REPORT

International application No

PCT/DK2018/050023

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 2 772 646 A2 (MITSUBISHI HEAVY IND LTD [JP]) 3 September 2014 (2014-09-03) figure 1 -----	1,2,4,5, 7,10-12, 14-18
X	WO 2014/031055 A1 (SKF PUBL AB [SE]) 27 February 2014 (2014-02-27) figure 1 -----	1,2,18

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/DK2018/050023

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 102004058905 A1	14-06-2006	NONE	

EP 2754893	A1	16-07-2014	EP 2754892 A1 16-07-2014
			EP 2754893 A1 16-07-2014
			WO 2014002296 A1 03-01-2014
			WO 2014002297 A1 03-01-2014

DE 102009015827 A1	07-10-2010	CN 102449331 A	09-05-2012
		DE 102009015827 A1	07-10-2010
		EP 2414692 A1	08-02-2012
		WO 2010112229 A1	07-10-2010

EP 2772646	A2	03-09-2014	EP 2772646 A2 03-09-2014
			JP 2014167273 A 11-09-2014

WO 2014031055	A1	27-02-2014	CN 104541079 A 22-04-2015
			EP 2888494 A1 01-07-2015
			JP 2015526641 A 10-09-2015
			KR 20150042788 A 21-04-2015
			US 2015219076 A1 06-08-2015
			WO 2014031055 A1 27-02-2014
