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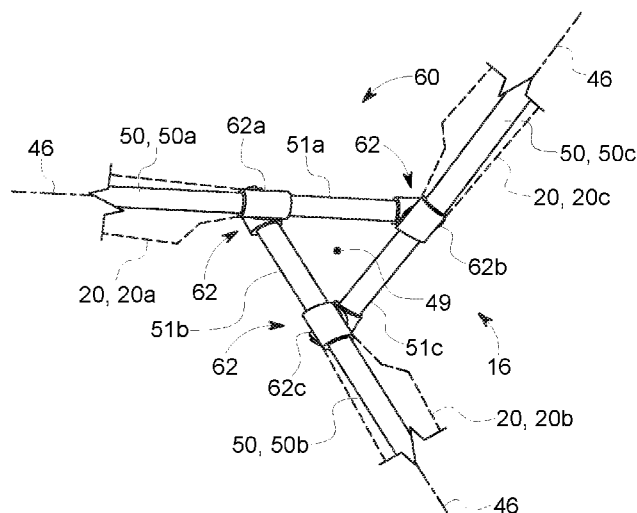


FIG. 4

(57) Abstract: A pitch bearing configuration for a rotor of a wind turbine. The pitch bearing configuration including a plurality of bearing housings, each bearing housing having disposed therein at least two pitch bearing assemblies. The configuration further including at least three rotor blade shafts, each of the rotor blade shafts coupled to two of the plurality of bearing housings and to a rotor blade of the rotor. The two bearing housings, coupled to each shaft of adjacent rotor blades, supports the adjacent rotor blade shafts. The pitch bearing configuration minimizing moment loading on the pitch bearings within each pitch bearing housing. A wind turbine including the pitch bearing configuration is further disclosed.



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PITCH BEARING ARRANGEMENT AT HUB OF WIND TURBINE

BACKGROUND

[0001] The disclosure relates generally to wind turbines and, more particularly, to improved bearing configurations for a wind turbine.

[0002] Wind power is considered one of the cleanest, most environmentally friendly energy sources presently available, and wind turbines have gained increased attention in this regard. A modern wind turbine typically includes a tower, generator, gearbox, nacelle, and one or more rotor blades. The rotor blades capture kinetic energy from wind using known airfoil principles and transmit the kinetic energy through rotational energy to turn a shaft coupling the rotor blades to a gearbox, or if a gearbox is not used, directly to the generator. The generator then converts the mechanical energy to electrical energy that may be deployed to a utility grid.

[0003] To ensure that wind power remains a viable energy source, efforts have been made to increase energy outputs by modifying the size and capacity of wind turbines. One such modification has been to increase the length of the rotor blades. However, as is generally understood, the loading on a rotor blade is a function of blade length, along with wind speed and turbine operating states. Thus, longer rotor blades may be subject to increased loading, particularly when a wind turbine is operating in high-speed wind conditions.

[0004] During the operation of a wind turbine, the loads acting on a rotor blade are transmitted through the blade and into the blade root. Thereafter, the loads are transmitted through a bearing, also referred to as a pitch bearing, disposed at the interface between the cantilevered rotor blade and the wind turbine hub. Typically, conventional pitch bearings include an inner ring, an outer ring, and two rows of balls, also referred to as rolling elements, concentrically disposed within separate raceways defined between inner and outer bearing races, with each rolling element being configured to contact its corresponding raceway at four separate contact points. This type of bearing is commonly referred to as a four-point bearing. In known bearing configurations, the predominant load applied to the bearing by the cantilevered blade is in the form of a moment that pries the bearing inner ring out of the outer ring. Typically, any bearing that is expected to do the job of a pitch bearing should have maximum capacity for moment rather than being designed to handle pure axial or radial load. Inside a bearing, this moment translates into forces on the rolling elements that act mainly parallel to the axis of the blade.

[0005] Unlike regular ball bearings, normal operation of pitch bearings in wind turbines involves oscillations about a set pitch angle as opposed to continuous rotation at high speed in one direction. Under ideal loading conditions, the loads transmitted through the pitch bearing are distributed evenly over all of the rolling elements. However, due to dynamic loading on the pitch bearing and the difference in stiffness between the hub and the rotor blade, only a percentage of the rolling elements actually carry the loads during operation of the wind turbine. As a result, the stresses within such load-carrying rolling elements tend to exceed the design tolerances for the pitch bearing, leading to damage and potential failure of the pitch bearing. Moreover, under dynamic loads, the rolling elements of conventional pitch bearings tend to run up and over the edges of the raceways, resulting in the rolling elements having reduced contact areas with the raceways. This leads to an additional increase in the stresses within the rolling elements, thereby further increasing the potential for damage to the pitch bearing components. In addition, the large bending and shear forces created result in unwanted deflections of the bearing races (potato chip). Similar issues may be present in conventional yaw bearings for wind turbines.

[0006] Thus, it is highly desirable to provide a wind turbine blade bearing configuration that addresses one or more of the issues described above.

BRIEF DESCRIPTION

[0007] These and other shortcomings of the prior art are addressed by the present disclosure, which includes a pitch bearing configuration with the bearings of each adjacent blade supporting each other through the bearing housing. The bearing configuration allows for control of rotational displacement of a rotor blade of a wind turbine to enable as much wind energy as possible to be captured.

[0008] Briefly, one aspect of the present disclosure resides in a pitch bearing for a rotor blade of a wind turbine. The pitch bearing configuration including a plurality of bearing housings and at least three rotor blade shafts. Each bearing housing having disposed therein at least two pitch bearing assemblies. Each of the at least two pitch bearing assemblies including at least one pitch bearing including an inner bearing race, an outer bearing race and a plurality of rolling elements disposed between the inner bearing race and the outer bearing race. Each of the rotor blade shafts is coupled at an inner end to two of the plurality of bearing housings and at an outer end to a rotor blade of the rotor. The two bearing housings coupled to each shaft of adjacent rotor blades, supports the adjacent rotor blades.

[0009] Another aspect of the disclosure resides in a pitch bearing configuration for a rotor of a wind turbine. The pitch bearing configuration including a first bearing housing (62a), a second bearing housing (62b) and a third bearing housing, a first rotor blade shaft, a second rotor blade shaft and a third rotor blade shaft. Each of the first bearing housing, the second bearing housing and the third bearing housing having disposed therein at least two pitch bearing assemblies. The first rotor blade shaft is coupled at an outer end to a first rotor blade of the rotor and coupled at an inner end to the first bearing housing and the second bearing housing. The second rotor blade shaft is coupled at an outer end to a second rotor blade of the rotor and coupled at an inner end to the first bearing housing and the third bearing housing. The third rotor blade shaft is coupled at an outer end to a third rotor blade of the rotor and coupled at an inner end to the second bearing housing and the third bearing housing. The bearing housings coupled to each shaft of adjacent rotor blades, support the adjacent rotor blade shafts.

[0010] Yet another aspect of the disclosure resides in a wind turbine. The wind turbine including a tower, a hub, at least three rotor blades, a pitch bearing configuration rotatably coupling the at least three rotor blades to the hub, a plurality of bearing housings and at least three rotor blade shafts. The at least three rotor blades rotatable in response to wind impinging upon said at least three rotor blades. The pitch bearing configuration including a plurality of bearing housings. Each of the bearing housings has disposed therein at least two pitch bearing assemblies. Each of the rotor blade shafts is coupled to two of the plurality of bearing housings and a rotor blade of the at least three rotor blades. Each of the two bearing housings coupled to each shaft of adjacent rotor blades, support the adjacent rotor blades.

[0011] Various refinements of the features noted above exist in relation to the various aspects of the present disclosure. Further features may also be incorporated in these various aspects as well. These refinements and additional features may exist individually or in any combination. For instance, various features discussed below in relation to one or more of the illustrated embodiments may be incorporated into any of the above-described aspects of the present disclosure alone or in any combination. Again, the brief summary presented above is intended only to familiarize the reader with certain aspects and contexts of the present disclosure without limitation to the claimed subject matter.

DRAWINGS

[0012] These and other features, aspects, and advantages of the present disclosure will become better understood when the following detailed description is read with reference to the accompanying drawings in which like characters represent like parts throughout the drawings, wherein:

[0013] FIG. 1 illustrates a perspective view of one embodiment of a wind turbine, in accordance with one or more embodiments shown or described herein;

[0014] FIG. 2 illustrates a perspective, internal view of the nacelle of the wind turbine shown in FIG. 1, in accordance with one or more embodiments shown or described herein;

[0015] FIG. 3 illustrates a perspective view of one of the rotor blades of the wind turbine shown in FIG. 1, in accordance with one or more embodiments shown or described herein;

[0016] FIG. 4 illustrates a partial isometric view of a portion of the wind turbine shown in FIG. 1, and more particularly a plurality of rotor blades coupled to a pitch bearing configuration including mutual adjacent blade support, in accordance with one or more embodiments shown or described herein;

[0017] FIG. 5 illustrates a partial isometric view of a portion of the wind turbine shown in FIG. 1, and more particularly a pitch bearing configuration including mutual adjacent blade support, in accordance with one or more embodiments shown or described herein;

[0018] FIG. 6 illustrates a partial cross-sectional view of a portion of the wind turbine shown in FIG. 1, and more particularly the pitch bearing configuration including mutual adjacent blade support, in accordance with one or more embodiments shown or described herein;

[0019] FIG. 7 illustrates a partial cross-sectional view of a portion of the wind turbine shown in FIG. 1, and more particularly the pitch bearing configuration including mutual adjacent blade support, in accordance with one or more embodiments shown or described herein;

[0020] FIG. 8 illustrates a partial cross-sectional view of a portion of the wind turbine shown in FIG. 1, and more particularly the pitch bearing configuration including mutual adjacent blade support, in accordance with one or more embodiments shown or described herein;

[0021] FIG. 9 illustrates a partial cross-sectional view of a portion of the wind turbine shown in FIG. 1, and more particularly the pitch bearing configuration including mutual adjacent blade support, in accordance with one or more embodiments shown or described herein;

[0022] FIG. 10 illustrates a partial isometric view of a portion of the wind turbine shown in FIG. 1, and more particularly a plurality of rotor blades coupled to the pitch bearing configuration including mutual adjacent blade support, in accordance with one or more embodiments shown or described herein; and

[0023] FIG. 11 illustrates a partial isometric view of a portion of the wind turbine shown in FIG. 1, and more particularly a plurality of rotor blades coupled to the pitch bearing configuration including mutual adjacent blade support, in accordance with one or more embodiments shown or described herein.

DETAILED DESCRIPTION

[0024] Reference now will be made in detail to embodiments of the disclosure, one or more examples of which are illustrated in the drawings. Each example is provided by way of explanation of the disclosure, not limitation of the disclosure. In fact, it will be apparent to those skilled in the art that various modifications and variations can be made in the present disclosure without departing from the scope or spirit of the disclosure. For instance, features illustrated or described as part of one embodiment can be used with another embodiment to yield a still further embodiment. Thus, it is intended that the present disclosure covers such modifications and variations as come within the scope of the appended claims and their equivalents.

[0025] In general, the present disclosure is directed to bearing configurations for a wind turbine, and more particularly to a pitch bearing configuration including mutual adjacent blade support. More particularly, the pitch bearing configuration provides for bearings of adjacent blades to support each other through a plurality of bearing housings. In an embodiment, the pitch bearing configuration of the wind turbine may include at least two pitch bearing assemblies disposed within each of a plurality of bearing housings. Each pitch bearing including a first raceway and a second

raceway defined between inner and outer bearing races of the respective bearing. In an embodiment, one or more of the pitch bearing assemblies may be configured as a dual pitch bearing including a first pitch bearing and a second pitch bearing configured such that they are separated axially by a distance L_B , thereby removing a significant portion of the bending moment applied to the individual bearings, and transforming substantially the entire load into radial loads. Each of the pitch bearing assemblies is coupled to a rotor blade via a rotor blade shaft, with adjacent rotor blades providing support to one another through the bearing housings and the rotor blade shafts. The disclosed configuration whereby at least two bearing housings, and thus two bearing assemblies, support a single shaft and adjacent rotor blades providing support to one another through the bearing housings will reduce the loads seen in a rotor blade shaft supported by a single pitch bearing, while vastly reducing the moment load carried by any one bearing assembly. By integrating a pitch bearing of adjacent blades into a single bearing housing, each blade structure aids in support of the other blades, rather than just itself, resulting in an overall strengthened system.

[0026] As will be described below, the disclosed bearing configuration(s) including this radial load arrangement may allow the large bending and shear forces that result in the unwanted deflections of the bearing races to be minimized and prevent the ball bearings from becoming stuck in the raceways, thereby decreasing the likelihood of component damage/failure.

[0027] It should be appreciated that the disclosed pitch bearing configuration(s) have been uniquely configured to handle the dynamic loading of a wind turbine. Specifically, due to erratic moment loading and the fact that each bearing is mounted directly to a relatively flexible rotor blade, the bearings must be equipped to handle axial and radial loads that can vary significantly with time.

[0028] Referring now to the drawings, FIG. 1 illustrates a side view of one embodiment of a wind turbine 10. As shown, the wind turbine 10 generally includes a tower 12, a nacelle 14 mounted on the tower 12, and a rotor 16 coupled to the nacelle 14. The rotor 16 includes a rotatable hub 18 and at least one rotor blade 20 coupled to and extending outwardly from the hub 18. For example, in the illustrated embodiment, the rotor 16 includes three rotor blades 20. However, in an alternative embodiment, the rotor 16 may include more than three rotor blades 20. Each rotor blade 20 may be spaced about the hub 18 to facilitate rotating the rotor 16 to enable kinetic energy to be transferred from the wind into usable mechanical energy, and subsequently, electrical energy. For instance, the hub 18 may be rotatably coupled to an electric generator 30 (FIG. 2) positioned within the nacelle 14 to permit electrical energy to be produced.

[0029] Referring now to FIG. 2, a simplified, internal view of one embodiment of the nacelle 14 of the wind turbine 10 shown in FIG. 1 is illustrated. As shown, the generator 30 may be disposed within the nacelle 14. In general, the generator 30 may be coupled to the rotor 16 of the wind turbine 10 for generating electrical power from the rotational energy generated by the rotor 16. For example, the rotor 16 may include a main rotor shaft 17 coupled to the hub 18 for rotation therewith. The generator 30 may then be coupled to the main rotor shaft 17 such that rotation of the rotor shaft 17 drives the generator 30. For instance, in the illustrated embodiment, the generator 30 includes a generator shaft 32 rotatably coupled to the main rotor shaft 17 through a gearbox 34. However, in other embodiments, it should be appreciated that the generator shaft 32 may be rotatably coupled directly to the rotor shaft 17. Alternatively, the generator 30 may be directly rotatably coupled to the rotor shaft 17 (often referred to as a "direct-drive wind turbine").

[0030] Additionally, the wind turbine 10 may include one or more yaw drive mechanisms 36 mounted to and/or through a bedplate 38 positioned atop the wind turbine tower 12. Specifically, each yaw drive mechanism 36 may be mounted to and/or through the bedplate 38 so as to engage a yaw bearing 40 coupled between the bedplate 38 and the tower 12 of the wind turbine 10. The yaw bearing 40 may be mounted to the bed plate 38 such that, as the yaw bearing 40 rotates about a yaw axis (not shown) of the wind turbine 10, the bedplate 38 and, thus, the nacelle 14 are similarly rotated about the yaw axis.

[0031] In general, it should be appreciated that the yaw drive mechanisms 36 may have any suitable configuration and may include any suitable components known in the art that allow such mechanisms 36 to function as described herein. For example, as shown in FIG. 2, each yaw drive mechanism 36 may include a yaw motor 42 mounted to the bedplate 38. The yaw motor 42 may be coupled to a yaw gear 44 (e.g., a pinion gear) configured to engage the yaw bearing 40. For instance, the yaw motor 42 may be coupled to the yaw gear 44 directly (e.g., by an output shaft (not shown) extending through the bedplate 38) or indirectly through a suitable gear assembly coupled between the yaw motor 42 and the yaw gear 44. As such, the torque generated by the yaw motor 42 may be transmitted through the yaw gear 44 and applied to the yaw bearing 40 to permit the nacelle 14 to be rotated about the yaw axis of the wind turbine 10. It should be appreciated that, although the illustrated wind turbine 10 is shown as including two yaw drive mechanisms 36, the wind turbine 10 may generally include any suitable number of yaw drive mechanisms 36.

[0032] In operation an incoming wind, indicated by arrow 48, imparts a rotation on the rotor 16 due to an aerodynamic profile on the rotor blades 20. More specifically, in the illustrated

embodiment, the rotor 16 turns around a substantially horizontal rotor axis 49, which is substantially parallel to the direction of the incoming wind 48. The rotor 16 drives the generator, such that electrical energy is produced from the kinetic energy of the wind 48.

[0033] Referring now to FIG. 3, a partial isometric view of a portion of the wind turbine shown in FIG. 1, and more particularly a rotor blade 20 for coupling to a pitch bearing configuration, is illustrated in accordance with aspects of the disclosure disclosed herein. It is noted that a single rotor blade/shaft configuration is illustrated in FIG. 3, with the associated bearing housing removed. A body 23 of the rotor blade 20 may extend lengthwise between the blade root 21 and the blade tip 22 and may generally serve as the outer shell of the rotor blade 20. As is generally understood, the body 23 may define an aerodynamic profile (e.g., by defining an airfoil shaped cross-section, such as a symmetrical or cambered airfoil-shaped cross-section) to enable the rotor blade 20 to capture kinetic energy from the wind using known aerodynamic principles. Thus, the body 23 may generally include a pressure side 24 and a suction side 25 extending between a leading edge 26 and a trailing edge 27. Additionally, the rotor blade 20 may have a span 28 defining the total length of the body 23 between the blade root 21 and the blade tip 22 and a chord 29 defining the total length of the body 23 between the leading edge 26 and the trailing edge 27. As is generally understood, the chord 29 may vary in length with respect to the span 28 as the body 23 extends from the blade root 21 to the blade tip 22.

[0034] Moreover, as shown, the rotor blade 20 is coupled to a shaft 50 via the pitch bearings, to allow for rotation therewith, as will be described in greater detail below. As will be described, the shaft 50 is supported by bearing housings (not shown) that are shared by adjacent blades, and thus the rotor blade.

[0035] One or more specific embodiments of the present techniques will be described below. In an effort to provide a concise description of these embodiments, not all features of an actual implementation are described in the specification. Referring more specifically to FIGS 4-9, illustrated are various embodiments of a pitch bearing configuration in relation to a wind turbine blade and hub. For the sake of simplicity, only a portion of the wind turbine 10 is shown in FIGs. 4-9. In addition, it should be noted that identical reference numerals denote the same elements throughout the various views.

[0036] Referring now to FIG. 4, a partial, cross-sectional view of a pitch bearing configuration 60 in accordance with aspects disclosed herein. As shown, the pitch bearing

configuration 60 includes rotor blade support for adjacent rotor blades 20a, 20b, 20c (shown in dotted lined) through a plurality of bearing housings 62. In this particular embodiment, the rotor 16 is comprised of three rotor blades 20a, 20b, and 20c, three rotor blade shafts 50a, 50b, and 50c, and three bearing housings 62a, 62b, and 62c. Alternate embodiments may include additional rotor blades, thus requiring additional rotor blade shafts, and bearing housings.

[0037] Referring again to FIG. 4, a first rotor blade 20a is coupled to a first shaft 50a via a first bearing housing 62a. A second rotor blade 20b is coupled to a second shaft 50b via a third bearing housing 62c. A third rotor blade 20c is coupled to a third shaft 50c via a second bearing housing 62b. To provide additional support to each of the shafts 50a, 50b and 50c, and thus the blade 20a, 20b, 20c coupled thereto, respectively, the first shaft 50a is further coupled at an innermost end 51a to the second bearing housing 62b, the second shaft 50b is further coupled at an innermost end 51b to the first bearing housing 62a and the third shaft 50c is further coupled at an innermost end 51c to the third bearing housing 62c. The second bearing housing 62b thus providing additional support to the first shaft 50a, the first bearing housing 62a providing additional support to the second shaft 50b and the third bearing housing 62c providing additional support to the third shaft 50c. Each of the bearing housings 62a, 62b and 62c having housed within at least two pitch bearing assemblies (described presently), so as to vastly reducing the moment load carried by any one bearing. By providing a plurality of pitch bearings coupled to the respective shafts 50a, 50b and 50c, the pitch bearing configuration 60 enables the bearings of each adjacent blade to support one other through a respective bearing housing. This support results in an increase in strength in the overall rotor system in that each blade structure (blade and shaft) helps support the other blade structures, rather than just itself.

[0038] As will be described below, each of the at least two pitch bearing assemblies housed within the bearing housing 62a, 62b, 62c is configured as a two-point (2-P) contact thrust bearing assembly (described below) and may allow each rotor blade 20a, 20b, 20c to be rotated about its pitch axis 46 (e.g., via a pitch adjustment mechanism), thereby allowing the orientation of each blade 20a, 20b, 20c to be adjusted relative to the direction of the wind 48 (FIG. 1). In an exemplary embodiment, the pitch adjustment mechanism may include a pitch drive motor (e.g., an electric motor).

[0039] As further illustrated in FIG. 5, to provide for additional shaft support in the pitch bearing configuration 60, the rotor blade shafts 50a, 50b, and 50c or oriented tangential to one another, with each rotor blade shaft 50a, 50b, and 50c coupled to two of the plurality of pitch bearing

housings 62, and more specifically a plurality of pitch bearing assemblies (described presently) for support. More particularly, each of the rotor blade shafts 50a, 50b, 50c is coupled at an inner end 84 to two of the plurality of bearing housings 62 and at an outer end 86 to a rotor blade 20 of the rotor 16. In an embodiment, as illustrated, the first rotor blade shaft 50a is coupled to the first rotor blade 20a via at least one pitch bearing assembly 64a housed within the first bearing housing 62a and at least one pitch bearing assembly 64b housed within the second bearing housing 62b. The second rotor blade shaft 50b is coupled to the second rotor blade 20b via at least one pitch bearing assembly 66a housed within the first bearing housing 62a and at least one pitch bearing assembly 66b housed within the third bearing housing 62c. The third rotor blade shaft 50c is coupled to the rotor blade 20c via at least one pitch bearing assembly 68a housed within third bearing housing 62c and at least one pitch bearing assembly 68b housed within the second bearing housing 62b. To provide tangential support, the at least one pitch bearing assembly 64a is configured in a substantially stacked radially orientation relative to the at least one pitch bearing assembly 66a within the first bearing housing 62a. The at least one pitch bearing assembly 66b is configured in a substantially stacked radially orientation relative to the at least one pitch bearing assembly 68a within the third bearing housing 62c. The at least one pitch bearing assembly 68b is configured in a substantially stacked radially orientation relative to the at least one pitch bearing assembly 64b within the second bearing housing 62b. Each pitch bearing assembly 64a, 64b, 66a, 66b, 68a and 68b is comprised of a single pitch bearing or a dual pitch bearing, and more particularly a first pitch bearing and a second pitch bearing (described presently). In another embodiment, each pitch bearing assembly 64a, 64b, 66a, 66b, 68a and 68b may be comprised of any number of additional pitch bearings.

[0040] Referring now to FIG. 6, illustrated in a simplified partial cross-sectional view taken through line 6-6 of FIG. 5, illustrating a first embodiment of the pitch bearing assemblies 64a, 66a, 66b and 68a in cross-section. In this particular embodiment, and as best illustrated with respect to the second shaft 50b, each of the pitch bearing assemblies 64a, 66a, 66b and 68a is comprised of a dual pitch bearing, and more particularly a first pitch bearing, and at least one additional pitch bearing supporting a single shaft. Each of the pitch bearing assemblies 64a, 64b (FIG. 5), 66a, 66b, 68a and 68b (FIG. 5) is disposed axially about a central axis 46 of a respective shaft 50a, 50b, 50c and includes a first pitch bearing 70 and at least one additional pitch bearing 72, as best illustrated in pitch bearing assemblies 66a and 66b. In this particular embodiment, each dual pitch bearing includes the first pitch bearing 70 and a second pitch bearing 72. Alternate configuration may include additional pitch bearings. The first pitch bearing 70 and the second pitch bearing 72, of each pitch bearing assembly 66a and 66b, are configured such that they are separated axially by a distance

L_B , thereby removing a significant portion of the bending moment applied to the first pitch bearing 70 and the second pitch bearing 72, and transforming substantially the entire load into radial loads. In an embodiment, the distance L_B is determined by the distance required to reduce the load/moment requirements on the bearings to be within their design capability. In an embodiment, L_B is at least 8% of the total blade length, or at least 0.5m. Additional information regarding dual pitch bearings configured as disclosed herein, may be found in, U.S. Patent Application Serial No. 15/148,231, bearing attorney docket no. 287401-1, Adam Daniel Minadeo et al., "Wind Turbine Bearings," which is incorporated by reference herein in its entirety, and U.S. Patent Application Serial No. 15/166,565, bearing attorney docket no. 310872-1, Michael Colan Moscinski, et al., "Wind Turbine Bearings," which is incorporated by reference herein in its entirety.

[0041] As best illustrated with regard to pitch bearing assemblies 66a and 66b, each of the first pitch bearing 70 and the second pitch bearing 72 includes an outer bearing race 74, an inner bearing race 76, defining a plurality of raceway grooves (not shown), and a plurality of rolling elements 78 disposed between the outer and inner bearing races 74, 76. In the embodiment of FIG. 6, the outer bearing race 74 may generally be configured to be mounted to the bearing housing 62 via suitable fastening mechanisms. Similarly, the inner bearing race 76 may be configured to be mounted to an exterior surface 80 of the shaft 50a, 50b, 50c using any suitable fastening mechanisms. For example, as shown in FIG. 6, the inner bearing races 76 housed within the bearing housings 62a and 62c may be coupled to the exterior surface 80 of the shaft 50b utilizing known coupling means such as, but not limited to, press fit, wedge, and/or a combination of known coupling means.

[0042] As previously alluded to, the first pitch bearing 70 and the second pitch bearing 72 housed within each of the bearing housings 62 and associated with a single shaft 50a, 50b, 50c are separated axially by a distance L_B , thereby removing a significant portion of the bending moment applied to the bearings 70, 72, and transforming substantially the entire load into one or more radial loads. More particularly, the inclusion of the first pitch bearing 70 and the second pitch bearing 72 enables the reduction of forces and moments at the bearing location, as well as reduction of blade tip deflections. In an embodiment, to maintain such axial separation of the first and second pitch bearings 70, 72, a spacer 82 is disposed between the first pitch bearing 70 and the second pitch bearing 72 of each bearing assembly 64a, 64b (FIG. 5), 66a, 66b, 68a and 68b (FIG. 5) housed within a single bearing housing 62. The spacer 82 may also be referred to herein as a load tube. In

this particular embodiment, the spacer 82 is disposed so as to couple the inner bearing races 76 of the first pitch bearing 70 and the second pitch bearing 72 and maintain spacing therebetween.

[0043] As is generally understood, in this particular embodiment, the outer bearing race 74 of each of the first pitch bearing 70 and the second pitch bearing 72 may be configured to be rotated relative to the inner bearing race 76 (via the rolling elements 78) to allow the pitch angle of each rotor blades 20a, 20b, 20c to be adjusted. Such relative rotation of the outer and inner bearing races 74, 76 may be achieved using a pitch adjustment mechanism (not shown), mounted to the shaft(s) or proximate thereto. In general, the pitch adjustment mechanism may include any suitable components and may have any suitable configuration that allows the mechanism to function. For example, the pitch adjustment mechanism may include a pitch drive motor (e.g., an electric motor) (not shown), a pitch drive gearbox (not shown), and a pitch drive pinion (not shown). In such an embodiment, the pitch drive motor may be coupled to the pitch drive gearbox so that the motor imparts mechanical force to the gearbox. Similarly, the gearbox may be coupled to the pitch drive pinion for rotation therewith. The pinion may, in turn, be in rotational engagement with the inner bearing races 76 to result in rotation of the inner bearing races 76 relative to the outer bearing race 74 and, thus, rotation of the rotor blades 20a, 20b, 20c relative to the hub 18 (FIG. 1). Additional information regarding the inclusion of a pitch adjustment mechanism as disclosed herein, may be found in, U.S. Patent Application Serial No. 15/148,231, bearing attorney docket no. 287401-1, as previously cited and U.S. Patent Application Serial No. 15/166,565, bearing attorney docket no. 310872-1 as previously cited, both of which are incorporated by reference herein in their entirety.

[0044] By increasing the axial distance L_B between the two bearing rows, and more particularly, the first pitch bearing 70 and the second pitch bearing 72 of each bearing assembly 64a, 64b (FIG. 5), 66a, 66b, 68a and 68b (FIG. 5), the forces required by the bearings to resist the moment imposed by the overhung blade mass is reduced significantly. As L_B approaches zero, the resultant forces on the pitch bearing rolling elements become more oriented in the axial direction (rotational blade axis). This scenario causes truncation, rolling element bunching, and less uniform contact area between the rolling elements and the internal bearing casing surfaces. The above challenges can be minimized by increasing L_B , thus the reaction forces on the rolling elements becoming more radial.

[0045] Referring now to FIG. 7 illustrated is an alternate embodiment of the pitch bearing assemblies 64a, 66a, 66b and 68a in cross-section. In this particular embodiment, each shaft is supported by a pitch bearing assembly disposed in a first bearing housing and a pitch bearing assembly disposed in a second bearing housing. More particularly, in this particular embodiment

each shaft is supported by a single pitch bearing disposed in a first bearing housing and a dual pitch bearing disposed in the second bearing housing. As best illustrated with regard to shaft 50b, the bearing housing 62a has disposed therein the bearing assembly 66a, comprised of a single pitch bearing 73 and the bearing housing 62c has disposed therein the bearing assembly 66b comprised of a dual pitch bearing, and more particularly, a first pitch bearing 70, and at least one additional pitch bearing 72. In this particular embodiment, the outermost bearing housing associated with a shaft (closest to the blade), and more particularly the bearing housing 62a, has housed therein the single pitch bearing 73, with the innermost bearing housing associated with a shaft, and more particularly the bearing housing 62c, having housed therein the dual pitch bearing, and more particularly, the first pitch bearing 70, and the second pitch bearing 72. Similar to the previously described embodiment, each of the first pitch bearings 70 and the at least one additional, or second, pitch bearing 72 includes an outer bearing race 74, an inner bearing race 76, defining a plurality of raceway grooves (not shown), and a plurality of rolling elements 78 disposed between the outer and inner bearing races 74, 76. In the embodiment of FIG. 7, the outer bearing race 74 may generally be configured to be mounted to the bearing housing 62 via suitable fastening mechanisms. Similarly, the inner bearing race 76 may be configured to be mounted to an exterior surface 80 of the shaft 50a, 50b, 50c using any suitable fastening mechanisms. As is generally understood, in this particular embodiment, the outer bearing race 74 may be configured to be rotated relative to the inner bearing race 76 (via the rolling elements 78) to allow the pitch angle of each rotor blades 20a, 20b, 20c to be adjusted. Such relative rotation of the outer and inner bearing races 74, 76 may be achieved using a pitch adjustment mechanism (not shown), mounted to the shaft(s) or proximate thereto.

[0046] Referring now to FIG. 8 illustrated is an alternate embodiment of the pitch bearings 64a, 66a, 66b and 68a in cross-section. In this particular embodiment, each shaft is supported by a pitch bearing assembly disposed in a first bearing housing and a pitch bearing assembly disposed in a second bearing housing. More particularly, in this particular embodiment each shaft is supported by a dual pitch bearing disposed in a first bearing housing and a single pitch bearing disposed in the second bearing housing. As best illustrated with regard to shaft 50b, the bearing housing 62a has disposed therein the bearing assembly 66a, comprised of a dual pitch bearing, and more particularly, a first pitch bearing 70, and at least one additional pitch bearing 72 and the bearing housing 62c has disposed therein the bearing assembly 66b comprised of a single pitch bearing 73. In this particular embodiment, the outermost bearing housing associated with a shaft (closest to the blade), and more particularly the bearing housing 62a, has housed therein the dual pitch bearing, and more particularly, the first pitch bearing 70, and the second pitch bearing 72, with the innermost bearing

housing associated with a shaft, and more particularly the bearing housing 62c, having housed therein the single pitch bearing 73. Similar to the previously described embodiment, each of the pitch bearings 70 and the at least one additional, or second, pitch bearing 72 includes an outer bearing race 74, an inner bearing race 76, defining a plurality of raceway grooves (not shown), and a plurality of rolling elements 78 disposed between the outer and inner bearing races 74, 76. In the embodiment of FIG. 8, the outer bearing race 74 may generally be configured to be mounted to the bearing housing 62 via suitable fastening mechanisms. Similarly, the inner bearing race 76 may be configured to be mounted to an exterior surface 80 of the shaft 50a, 50b, 50c using any suitable fastening mechanisms. As is generally understood, in this particular embodiment, the outer bearing race 74 may be configured to be rotated relative to the inner bearing race 76 (via the rolling elements 78) to allow the pitch angle of each rotor blades 20a, 20b, 20c to be adjusted. Such relative rotation of the outer and inner bearing races 74, 76 may be achieved using a pitch adjustment mechanism (not shown), mounted to the shaft(s) or proximate thereto.

[0047] Referring now to FIG. 9 illustrated is yet another alternate embodiment of the pitch bearings 64a, 66a, 66b and 68a in cross-section. In this particular embodiment, each shaft is supported by a pitch bearing assembly disposed in a first bearing housing and a pitch bearing assembly disposed in a second bearing housing. More particularly, in this particular embodiment a single pitch bearing is disposed in each bearing housing supporting a shaft. As best illustrated with regard to shaft 50b, the bearing housing 62a has disposed therein a single pitch bearing 73 and the bearing housing 62c has disposed therein a single pitch bearing 73. In this particular embodiment, both bearing housings associated with a single shaft have housed therein the single pitch bearing 73. Similar to the previously described embodiments, each of the pitch bearings 73 includes an outer bearing race 74, an inner bearing race 76, defining a plurality of raceway grooves (not shown), and a plurality of rolling elements 78 disposed between the outer and inner bearing races 74, 76. The inner and outer bearing races 74, 76 may be mounted to the bearing housings and shafts as previously described with the outer bearing race 74 configured to be rotated relative to the inner bearing race 76 (via the rolling elements 78) to allow the pitch angle of each rotor blades 20a, 20b, 20c to be adjusted.

[0048] Referring now to FIGs. 10 and 11, illustrated are two bearing configurations, each having a plurality of blades 20 attached thereto, illustrating the blades 20 in a first operable stage 100 and in

a second operable stage 150, whereby a blade pitch angle has been changed to address an oncoming change in the wind 48.

[0049] Accordingly, disclosed is a pitch bearing configuration incorporating thrust bearing technology and an adjacent blade support configuration that solves many issues in current bearing designs. The pitch bearing configuration disclosed herein offers several advantages over existing pitch bearing designs, including, but not limited to: i) the reduction of forces and moments at the bearing location, as well as reduction of blade tip deflections; ii) minimization of the potato chip effect on the race bearing helping prevent ball bearings from becoming stuck in the race; iii) ability to handle larger diameter rotors; iv) higher reliability (v) increase strength in the overall rotor/bearing configuration by allowing the hub to hold the maximum length of shaft to reduce reaction forces in the bearings, while making a stiffer system due to the mutual support the blades give each other; and v) cost saving.

[0050] It is to be understood that not necessarily all such objects or advantages described above may be achieved in accordance with any particular embodiment. Thus, for example, those skilled in the art will recognize that the disclosed embodiments and techniques described herein may be embodied or carried out in a manner that achieves or optimizes one advantage or group of advantages as taught herein without necessarily achieving other objects or advantages as may be taught or suggested herein.

[0051] Furthermore, the skilled artisan will recognize the interchangeability of various features from different embodiments. For example, various features described, as well as other known equivalents for each feature, may be mixed and matched by one of ordinary skill in this art to construct additional embodiments and techniques in accordance with principles of this disclosure.

[0052] While only certain features of the disclosure have been illustrated and described herein, many modifications and changes will occur to those skilled in the art. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit of the disclosure. This written description uses examples to disclose the disclosure, including the best mode, and also to enable any person skilled in the art to practice the disclosure, including making and using any devices or systems and performing any incorporated methods. The representative examples and embodiments provided herein include features that may be combined with one another and with the features of other disclosed embodiments or examples to form additional embodiments that are still within the scope of the present disclosure. The patentable

scope of the disclosure is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

CLAIMS:

1. A pitch bearing configuration (60) for a rotor (16) of a wind turbine (10), the pitch bearing configuration (60) comprising:

a plurality of bearing housings (62a, 62b, 62c), each bearing housing having disposed therein at least two pitch bearing assemblies (64a, 64b, 66a, 66b, 68a, 68b), each of the at least two pitch bearing assemblies comprising at least one pitch bearing (70, 72, 73) including an inner bearing race (76), an outer bearing race (74) and a plurality of rolling elements (78) disposed between the inner bearing race (76) and the outer bearing race (74); and

at least three rotor blade shafts (50a, 50b, 50c), each of the rotor blade shafts (50a, 50b, 50c) coupled at an inner end (84) to two of the plurality of bearing housings (62a, 62b, 62c) and at an outer end (86) to a rotor blade (20a, 20b, 20c) of the rotor (16),

wherein the two bearing housings (62a, 62b, 62c) coupled to each shaft (50a, 50b, 50c) of adjacent rotor blades (50a, 50b, 50c), supports the adjacent rotor blades (50a, 50b, 50c).

2. The pitch bearing configuration (60) as claimed in Claim 1, further comprising:

a first rotor blade shaft (50a) coupled at an outer end (86) to a first rotor blade (20a) of the rotor (16) and coupled at an inner end (84) to a first bearing housing (62a) and a second bearing housing (62b);

a second rotor blade shaft (50b) coupled at an outer end (86) to a second rotor blade (20b) of the rotor (16) and coupled at an inner end (84) to the first bearing housing (62a) and a third bearing housing (62c); and

a third rotor blade shaft (50c) coupled at an outer end (86) to a third rotor blade (20c) of the rotor (16) and coupled at an inner end (84) to the second bearing housing (62b) and the third bearing housing (62c).

3. The pitch bearing configuration (60) as claimed in Claim 2, wherein:

the first rotor blade shaft (50a) is coupled at the inner end (84) to a pitch bearing assembly (64a) housed in the first bearing housing (62a) and to a pitch bearing assembly (64b) housed in the second bearing housing (62b);

the second rotor blade shaft (50b) is coupled to a second pitch bearing assembly (66a) housed in the first bearing housing (62a) and coupled at the inner end (84) to a first pitch bearing assembly (66b) housed in the third bearing housing (62c); and

a third rotor blade shaft (50c) coupled to a second pitch bearing assembly (68a) housed in the third bearing housing (62c) and coupled at the inner end (84) to a second pitch bearing assembly (68b) housed in the second bearing housing (62b).

4. The pitch bearing configuration (60) as claimed in Claim 3, wherein:
the pitch bearing assemblies each comprise one of a dual pitch bearing or a single pitch bearing.

5. The pitch bearing configuration (60) as claimed in Claim 4, wherein:
the first rotor blade shaft (50a) is coupled to one of a first single pitch bearing (73) or a first dual pitch bearing (70, 72) housed in the first bearing housing (62a) and coupled at the inner end (84) to one of a first single pitch bearing (73) or a first dual pitch bearing (70, 72) housed in the second bearing housing (62b);

the second rotor blade shaft (50b) is coupled to one of a first single pitch bearing (73) or a first dual pitch bearing (70, 72) housed in the third bearing housing (62c) and coupled at the inner end (84) to second single pitch bearing (73) or a second dual pitch bearing (70, 72) housed in the first bearing housing (62a); and

a third rotor blade shaft (50c) coupled to one of a second single pitch bearing (73) or a second dual pitch bearing (70, 72) housed in the second bearing housing (62b) and coupled at the inner end (84) to a second single pitch bearing or a second dual pitch bearing (68b) housed in the third bearing housing (62c).

6. The pitch bearing configuration (60) as claimed in Claim 4, wherein:
the first rotor blade shaft (50a) is coupled to a first dual pitch bearing (70, 72) housed in the first bearing housing (62a) and coupled at the inner end (84) to a first dual pitch bearing (70, 72) housed in the second bearing housing (62b);

the second rotor blade shaft (50b) is coupled to a first dual pitch bearing (70, 72) housed in a third bearing housing (62c) and coupled at the inner end (84) to a second dual pitch bearing (70, 72) housed in the first bearing housing (62a); and

the third rotor blade shaft (50c) is coupled to a second dual pitch bearing (70, 72) housed in the second bearing housing (62b) and coupled at an inner end (84) to a second dual pitch bearing (70, 72) housed in the second bearing housing (62c).

7. The pitch bearing configuration (60) as claimed in Claim 4, wherein each of the pitch bearings (70, 72, 73) comprise:

an inner bearing race (76), an outer bearing race (74) and a plurality of rolling elements (78) disposed between the inner bearing race (76) and the outer bearing race (74).

8. The pitch bearing configuration (60) as claimed in Claim 4, wherein each of the dual pitch bearings (70, 72) comprise a first pitch bearing (70) and a second pitch bearing (72) disposed axially a distance L_B from the first pitch bearing (70).

9. A pitch bearing configuration (60) for a rotor (16) of a wind turbine (10), the pitch bearing configuration (60) comprising:

a first bearing housing (62a), a second bearing housing (62b) and a third bearing housing (62c), each of the first bearing housing (62a), the second bearing housing (62b) and the third bearing housing (62c) having disposed therein at least two pitch bearing assemblies (64a, 64b, 66a, 66b, 68a, 68b);

a first rotor blade shaft (50a) coupled at an outer end (86) to a first rotor blade (20a) of the rotor (16) and coupled at an inner end (84) to the first bearing housing (62a) and the second bearing housing (62b);

a second rotor blade shaft (50b) coupled at an outer end (86) to a second rotor blade (20b) of the rotor (16) and coupled at an inner end (84) to the first bearing housing (62a) and the third bearing housing (62c); and

a third rotor blade shaft (50c) coupled at an outer end (86) to a third rotor blade (20c) of the rotor (16) and coupled at an inner end (84) to the second bearing housing (62b) and the third bearing housing (62c),

wherein the bearing housings (62a, 62b, 62c) coupled to each shaft (50a, 50b, 50c) of adjacent rotor blades (20a, 20b, 20c), support the adjacent rotor blade shafts (50a, 50b, 50c).

10. The pitch bearing configuration (60) as claimed in Claim 9, wherein each of the pitch bearing assemblies (64a, 64b, 66a, 66b, 68a, 68b) are configured as one of a single pitch bearing or a dual pitch bearing.

11. The pitch bearing configuration (60) of Claim 9, wherein one or more of the pitch bearing assemblies (64a, 64b, 66a, 66b, 68a, 68b) comprise:

a first pitch bearing (70) including an inner bearing race (76), an outer bearing race (74) and a plurality of rolling elements (78) disposed between the inner bearing race (76) and the outer bearing race (74); and

a second pitch bearing (72) including an inner bearing race (76), an outer bearing race (74) and a plurality of rolling elements (78) disposed between the inner bearing race (76) and the outer bearing race (74), the second pitch bearing (72) disposed axially a distance L_B from the first pitch bearing (70), thereby minimizing moment loading on the first pitch bearing (70) and the second pitch bearing (72).

12. The pitch bearing configuration (60) as claimed in Claim 11, wherein the inner bearing races (76) are coupled to a respective one of the first rotor blade shaft (50a), the second rotor blade shaft (50b) or the third rotor blade shaft (50c) and the outer bearing races (74) are coupled to a respective one of the first bearing housing (62a), the second bearing housing (62b) or the third bearing housing (62c), the outer bearing races (74) configured rotatable with the respective rotor blade (20a, 20b, 20c).

13. The pitch bearing configuration (60) of Claim 9, wherein one or more of the pitch bearing assemblies (64a, 64b, 66a, 66b, 68a, 68b) comprise a single pitch bearing (73) including an inner bearing race (76), an outer bearing race (74) and a plurality of rolling elements (78) disposed between the inner bearing race (76) and the outer bearing race (74).

14. The pitch bearing configuration (60) as claimed in Claim 13, wherein the inner bearing races (76) are coupled to a respective one of the first rotor blade shaft (50a), the second rotor blade shaft (50b) or the third rotor blade shaft (50c) and the outer bearing races (74) are coupled to a respective one of the first bearing housing (62a), the second bearing housing (62b) or the third bearing housing (62c), the outer bearing races (74) configured rotatable with the respective rotor blade (20a, 20b, 20c).

15. A wind turbine comprising:
a tower;
a hub (18);
at least three rotor blades (20), the at least three rotor blades (20) rotatable in response to wind (48) impinging upon said at least three rotor blades (20); and
a pitch bearing configuration (60) rotatably coupling the at least three rotor blades (20) to the hub (18), the pitch bearing configuration (60) comprising:

a plurality of bearing housings (62a, 62b, 62c), each bearing housing having disposed therein at least two pitch bearing assemblies (64a, 64b, 66a, 66b, 68a, 68b); and

at least three rotor blade shafts (50a, 50b, 50c), each of the rotor blade shafts (50a, 50b, 50c) coupled to two of the plurality of bearing housings (62a, 62b, 62c) and a rotor blade (20a, 20b, 20c) of the at least three rotor blades,

wherein the two bearing housings (62a, 62b, 62c) coupled to each shaft (50a, 50b, 50c) of adjacent rotor blades (50a, 50b, 50c), support the adjacent rotor blades (50a, 50b, 50c).

16. The wind turbine (10) as claimed in Claim 15, comprising three rotor blades (20a, 20b and 20c), three rotor blade shafts (50a, 50b, 50c) and three bearing housings (62a, 62b, 62c).

17. The wind turbine (10) as claimed in Claim 15, comprising four rotor blades, four rotor blades shafts and four bearing housings.

18. The wind turbine (10) as claimed in Claim 15, further comprising:

a first rotor blade shaft (50a) coupled at an outer end (86) to a first rotor blade (20a) of the rotor (16) and coupled at an inner end (84) to a first bearing housing (62a) and a second bearing housing (62b);

a second rotor blade shaft (50b) coupled at an outer end (86) to a second rotor blade (20b) of the rotor (16) and coupled at an inner end (84) to the first bearing housing (62a) and a third bearing housing (62c); and

a third rotor blade shaft (50c) coupled at an outer end (86) to a third rotor blade (20c) of the rotor (16) and coupled at an inner end (84) to the second bearing housing (62b) and the third bearing housing (62c).

19. The wind turbine (10) as claimed in Claim 15, wherein:

the first rotor blade shaft (50a) is coupled to one of a first pitch bearing (70, 72, 73) housed in the first bearing housing (62a) and coupled at an inner end (84) to a first pitch bearing (70, 72, 73) housed in the second bearing housing (62b);

the second rotor blade shaft (50b) is coupled to a first pitch bearing (70, 72, 73) housed in the third bearing housing (62c) and coupled at an inner end (84) to a second pitch bearing (70, 72, 73) housed in the first bearing housing (62a); and

a third rotor blade shaft (50c) coupled to a second pitch bearing (70, 72, 73) housed in the second bearing housing (62b) and coupled at an inner end (84) to a third pitch bearing (70, 72, 73) housed in the second bearing housing (62c).

20. The wind turbine (10) as claimed in Claim 15, wherein one or more of the pitch bearing assemblies (64a, 64b, 66a, 66b, 68a, 68b) comprise a single pitch bearing (73) including an inner bearing race (76), an outer bearing race (74) and a plurality of rolling elements (78) disposed between the inner bearing race (76) and the outer bearing race (74).

21. The wind turbine (10) as claimed in Claim 15, wherein one or more of the pitch bearing assemblies (64a, 64b, 66a, 66b, 68a, 68b) comprise:

a first pitch bearing (70) including an inner bearing race (76), an outer bearing race (74) and a plurality of rolling elements (78) disposed between the inner bearing race (76) and the outer bearing race (74); and

at least one additional pitch bearing (72) including an inner bearing race (76), an outer bearing race (74) and a plurality of rolling elements (78) disposed between the inner bearing race (76) and the outer bearing race (74), the at least one additional pitch bearing (72) disposed axially a distance L_B from the first pitch bearing (70), thereby minimizing moment loading on the first pitch bearing (70) and the at least one additional pitch bearing (72).

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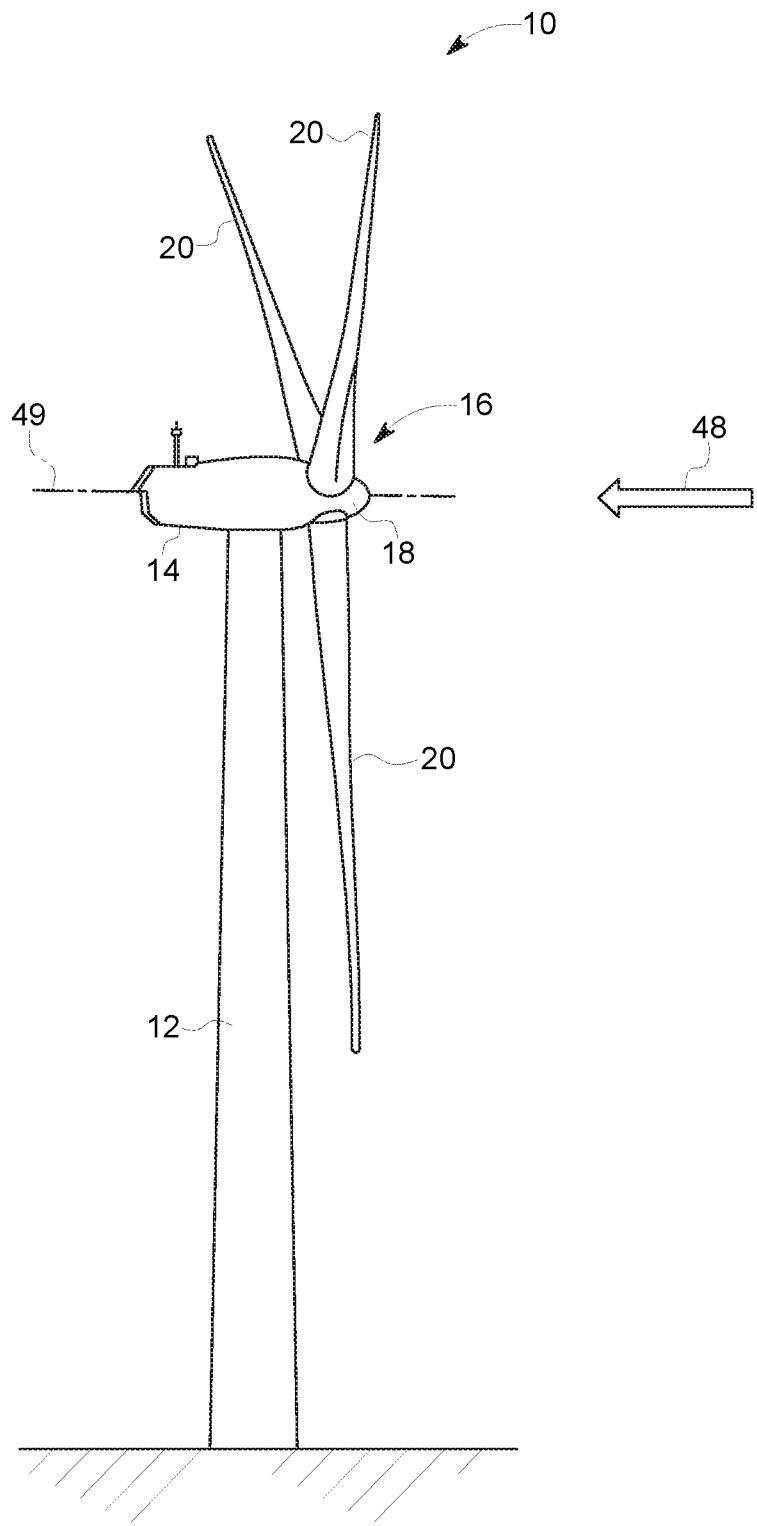


FIG. 1

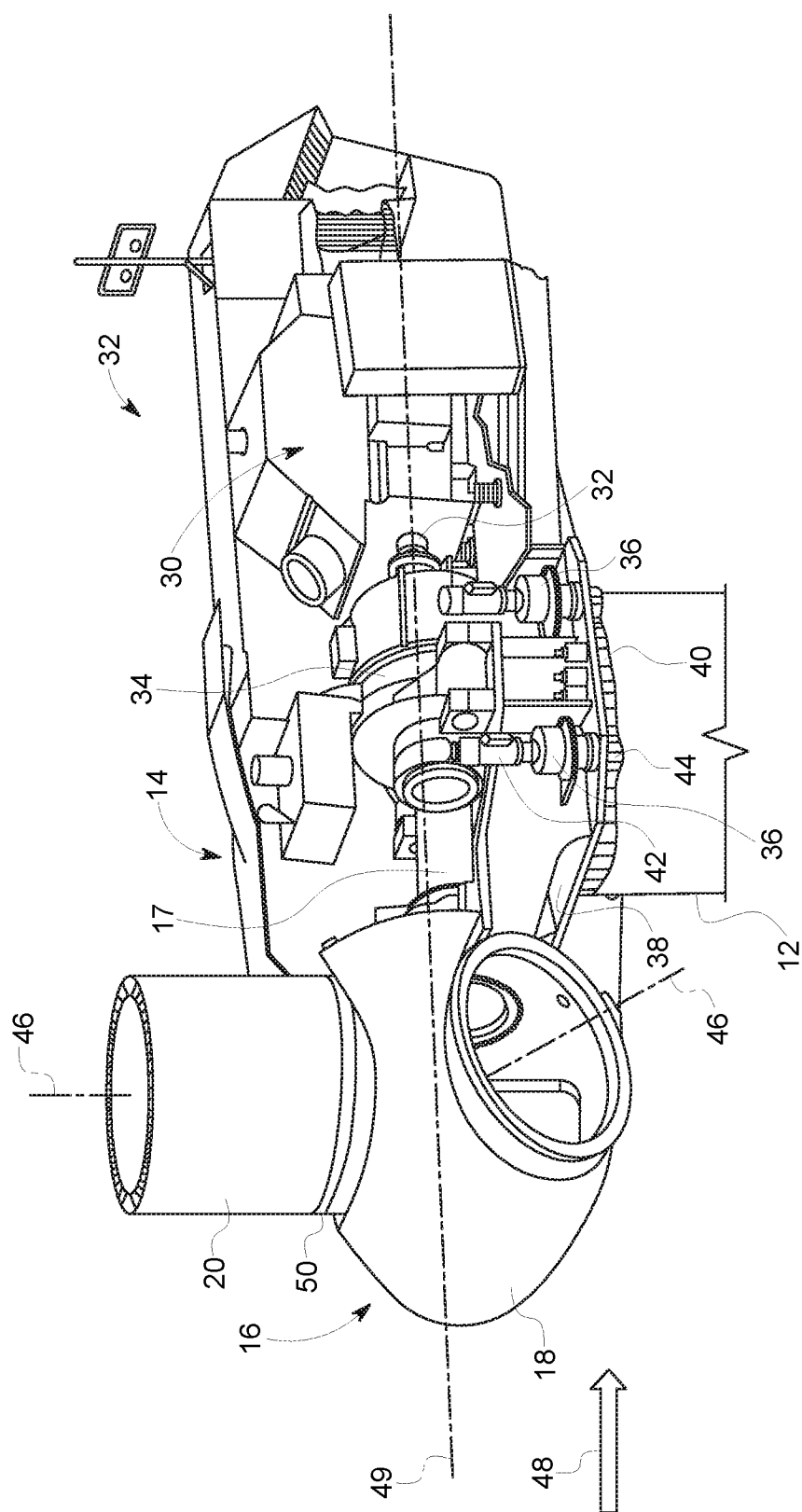


FIG. 2

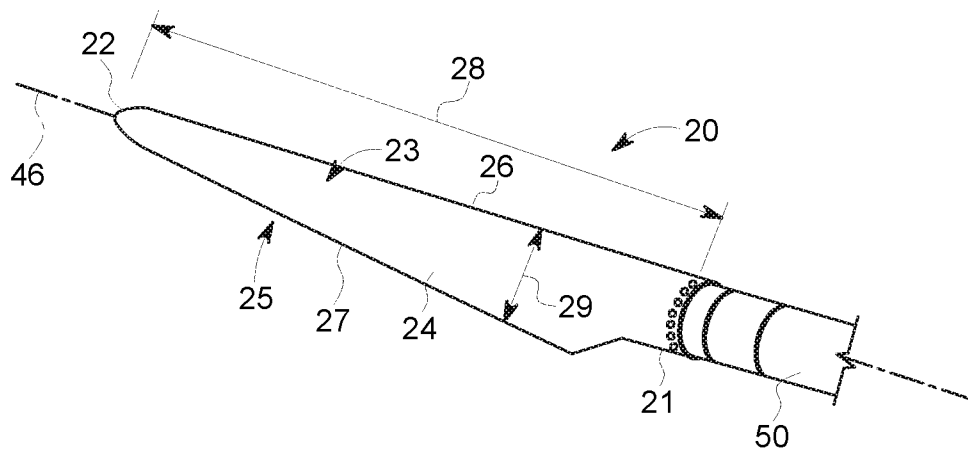


FIG. 3

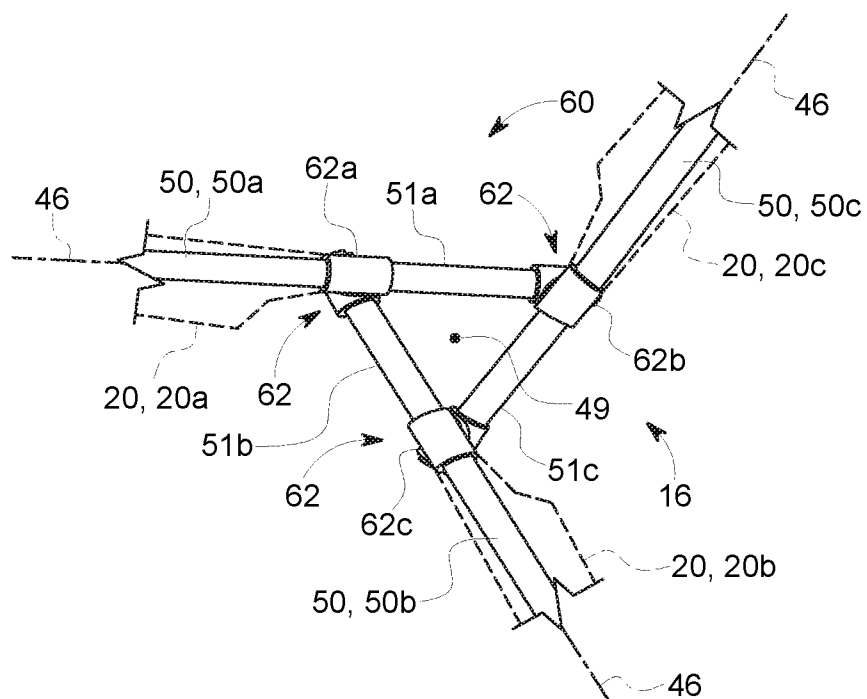


FIG. 4

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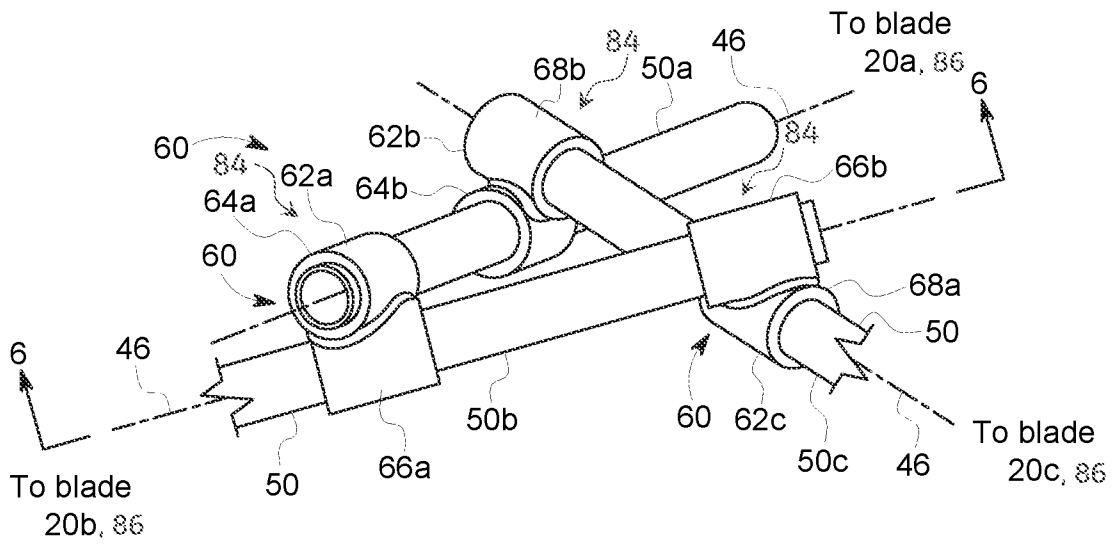


FIG. 5

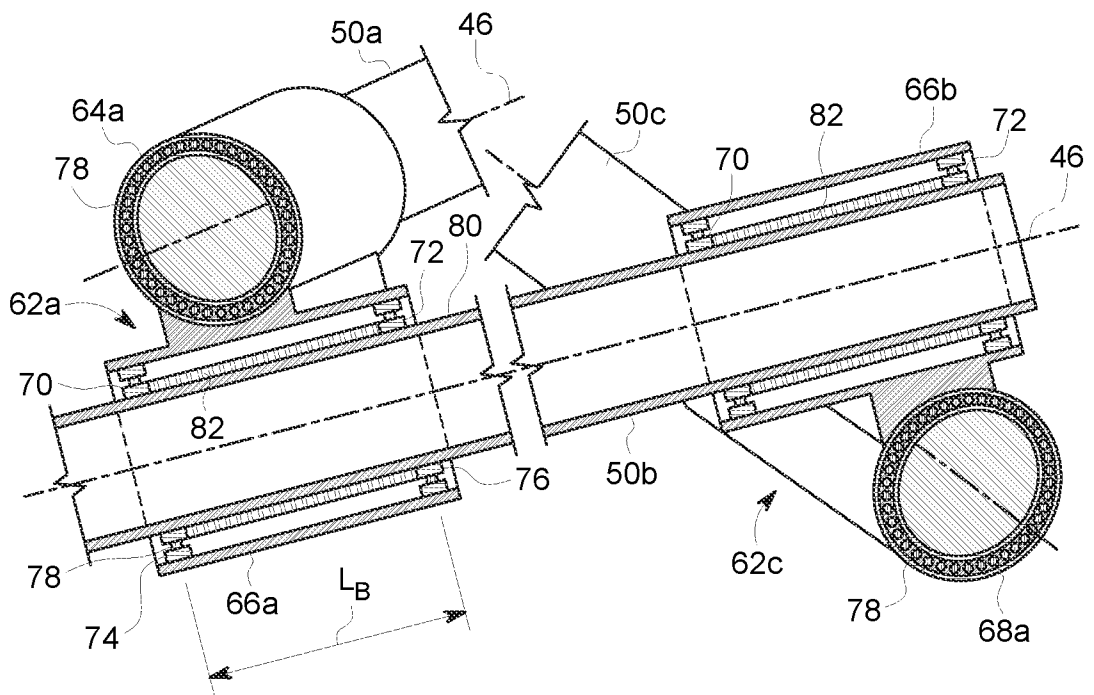


FIG. 6

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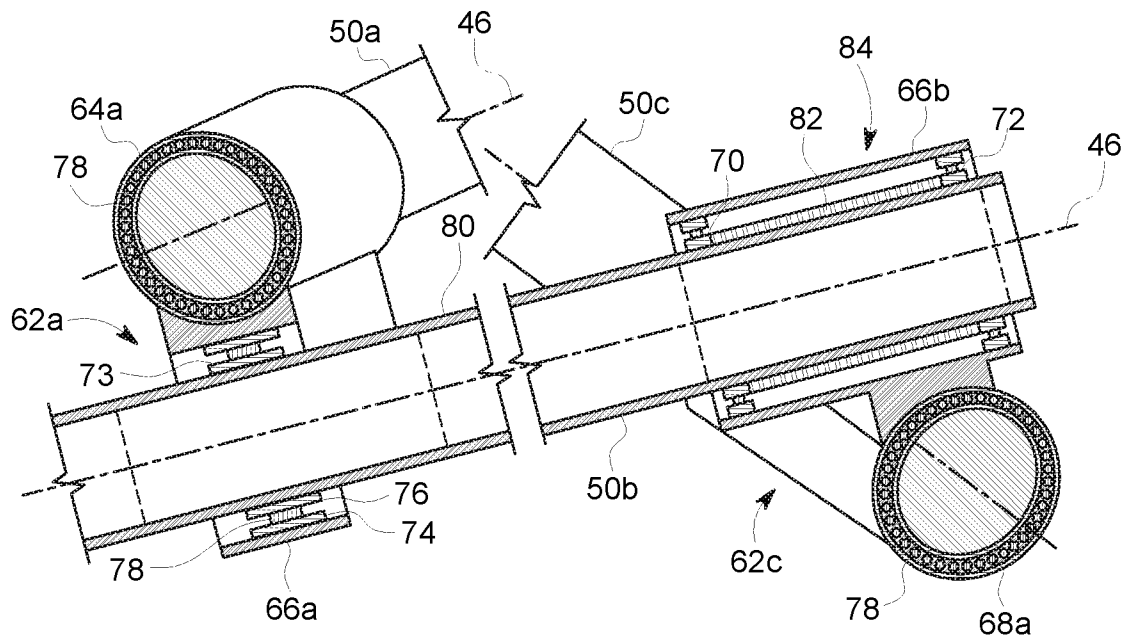


FIG. 7

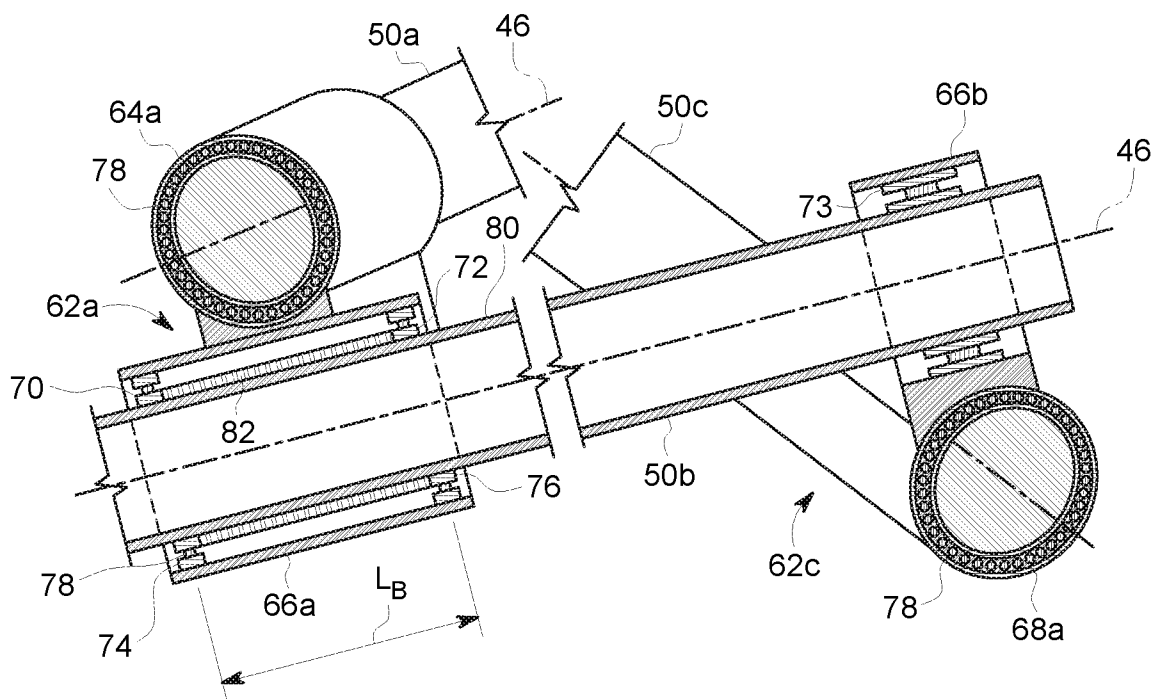


FIG. 8

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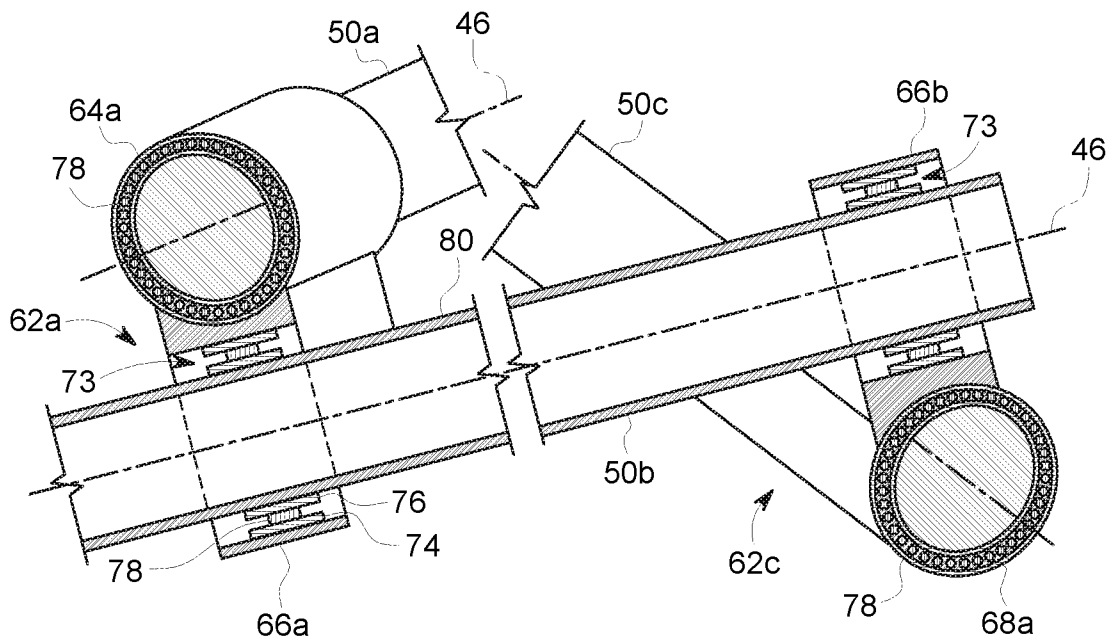


FIG. 9

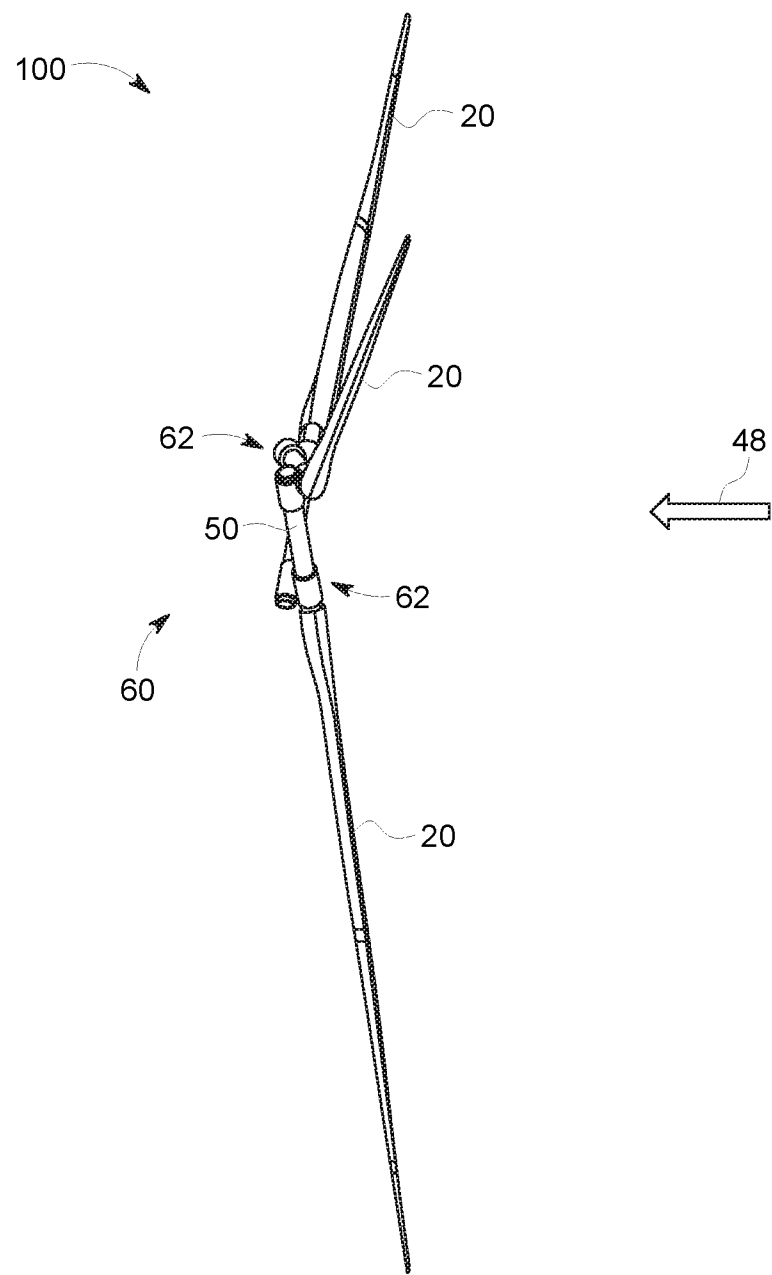


FIG. 10

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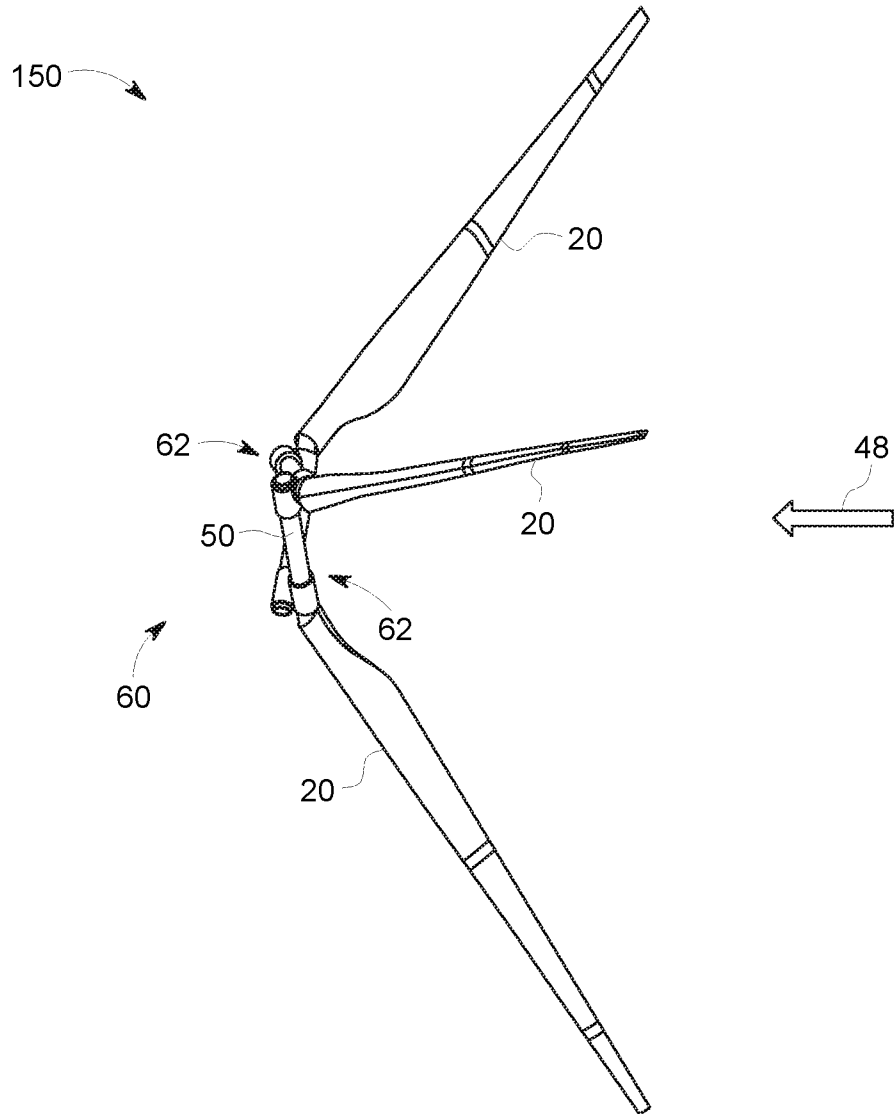


FIG. 11

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/045083

A. CLASSIFICATION OF SUBJECT MATTER
INV. F03D1/06
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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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X	US 7 939 961 B1 (BONNET LAURENT [DE]) 10 May 2011 (2011-05-10) column 9, line 27 - column 10, line 19; figure 3 -----	1-21
X	US 2010/086409 A1 (WHILEY DAVID ANTHONY [GB] ET AL) 8 April 2010 (2010-04-08) abstract; figures 4,7-10 -----	1-21
A	US 2010/143136 A1 (DANIELS JEFFREY MICHAEL [US] ET AL) 10 June 2010 (2010-06-10) figures 3,4 -----	1,9,15



Further documents are listed in the continuation of Box C.



See patent family annex.

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"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

4 April 2017

Date of mailing of the international search report

12/04/2017

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Authorized officer

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2016/045083

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