

(19) **DANMARK**



Patent- og
Varemærkestyrelsen

(12)

Oversættelse af europæisk patentskrift

(10) **DK/EP 2473688 T3**

-
- (51) Int.Cl.: **E 04 H 12/18 (2006.01)** **F 03 D 1/00 (2006.01)** **F 03 D 7/02 (2006.01)**
F 03 D 11/00 (2006.01) **F 03 D 11/04 (2006.01)**
- (45) Oversættelsen bekendtgjort den: **2015-07-27**
- (80) Dato for Den Europæiske Patentmyndigheds bekendtgørelse om meddelelse af patentet: **2015-05-27**
- (86) Europæisk ansøgning nr.: **10814323.1**
- (86) Europæisk indleveringsdag: **2010-08-27**
- (87) Den europæiske ansøgnings publiceringsdag: **2012-07-11**
- (86) International ansøgning nr.: **US2010046979**
- (87) Internationalt publikationsnr.: **WO2011028641**
- (30) Prioritet: **2009-09-05 US 554884** **2010-07-14 US 836089**
- (84) Designerede stater: **AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO SE SI SK SM TR**
- (73) Patenthaver: **Zuteck, Michael D., 601 Clear Lake Road, Clear Lake Shores, TX 77565, USA**
- (72) Opfinder: **Zuteck, Michael D., 601 Clear Lake Road, Clear Lake Shores, TX 77565, USA**
- (74) Fuldmægtig i Danmark: **Budde Schou A/S, Hausergade 3, 1128 København K, Danmark**
- (54) Benævnelse: **Hybrid multielement konisk roterende tårn**
- (56) Fremdragne publikationer:
CN-A- 101 429 923
GB-A- 780 381
US-A- 4 156 580
US-A- 4 180 369
US-A- 4 323 331
US-A- 4 499 034
US-A- 4 979 871
US-A- 5 151 610
US-A1- 2002 069 596
US-A1- 2006 213 145
US-A1- 2007 108 776
US-A1- 2008 084 068
US-A1- 2009 021 019
US-A1- 2009 120 830
US-A1- 2009 126 313
US-A1- 2009 211 173

DESCRIPTION

BACKGROUND TO INVENTION

1. Intended Use

[0001] The invention is an advantageous construction of a rotatable wind turbine tower. The turbine includes the rotor and nacelle. The turbine is attached at the top of the tower and changes direction with the rotation of the tower. The tower has a narrow profile in one dimension and a broad profile in a second dimension. This shape, combined with bearings, allows the tower to change orientation in response to changes in wind direction, aligning the structure with the wind direction to optimally carry the loads, and thereby reducing the weight and cost of the tower.

2. Related Technology

[0002] Wind powered turbines are known. Most of these turbines utilize a stationary tower and the turbine rotates 360° in a horizontal plane at the top of the tower.

[0003] Some attempts have been made to construct a wind turbine with a tower that turns with the direction of the wind. See UK patent 780,381 wherein a rotating tower is stabilized by 3 legs and the turbine and generator are located at ground level. See also UK patent 10, 194 wherein the tower is constructed to turn freely to the wind on two rollers or ball bearings, one being at the base of the girder framework and the other immediately under the "wind wheel" or wind turbine. The rollers or ball bearings under the wind wheel consist of an annular ring designed to prevent the girder framework from having any upward or side motion. The girder framework remains free to revolve by means of rollers attached to the framework. To keep the girder framework or tower in an upright position the annular ring is provided with suitable eyes or holes and securely anchored to the ground by means of steel guy ropes or rods. The rotating truss tower was not aerodynamically shaped.

SUMMARY OF INVENTION

[0004] The specification discloses a tower structure having a wing like shape wherein the wing is set upright on its end, i.e., a narrow crosswind thickness, an expanding along-wind width and a long double tapering structure along its height. Also disclosed is a tower structure having a triangular shape with height.

[0005] The tower structure may have a straight leading edge extending to the height of the structure. The narrow leading edge faces the wind direction and minimizes wind entry or passage drag and turbulence. The tower structure also contains a trailing edge similarly extending to the top of the structure. The trailing edge may bow outward expanding the width of the structure part way up the height of the structure. The trailing edge may taper toward the leading edge proximate to the tower ends. As used herein, the "upper tower segment" means that portion of the tower where the trailing edge tapers above the maximum outward bowing of the trailing edge to the leading edge. A triangular shaped structure discussed below merges the trailing edge into the leading edge proximate to the top of the tower.

[0006] The leading edge may maintain a uniform longitudinal axis. The trailing edge may be configured in a bowed or kinked shape, i.e., the distance between the leading edge and trailing edge can vary along the height of the structure. The leading edge and trailing edge are the primary load bearing elements of the tower that support the turbine weight and thrust.

[0007] The leading edge and trailing edge may be comprised of strong high modulus material such as metal or composite material containing high strength fibers, e.g. unidirectional glass or carbon fibers. The leading edge/trailing edge may also be steel. The leading edge or trailing edge may be in a half circular shape and comprise multiple and attachable segments stacked on top of a lower segment. The stacked segments form a vertical structure, i.e., the leading edge and trailing edge. Each segment can be designed and fabricated to carry calculated loads based upon the segment's position in the structure. Although semi-circular shapes are illustrated, other shapes are possible. For example the leading edge may have an elliptical shape, and the trailing edge may have a flat shape for wind release.

[0008] The side panels of the structure may be comprised of double bias (DB) glass. Other materials that may be used include but are not limited to plastics, fiber reinforced plastics, or panels over diagonal frame bracing. The panels may comprise fiber reinforced composite material wherein the direction of fiber is oriented to the panel load. In one example, the panels may comprise aluminum panels covering steel diagonal framework. In another embodiment, the panels may comprise a fiberglass skin over a foam core. The side panels may be oriented to provide joining between the leading edge and trailing edge. The side panels may also be aerodynamically shaped both in height and width.

[0009] The tower rotates with changes in wind direction. The wind turbine is fixedly mounted to the top end of the tower. As used herein, the term "turbine" includes the rotor and the nacelle. The "nacelle" may include the main rotor bearings, generator, gear box, and associated equipment. The yaw motor will be either at the mid tower collar and upper bearing assembly, or at the tower base. Rotation of the tower and turbine occurs by operation of a lower rotation assembly (hereinafter "bottom bearing assembly") mounted approximately at ground level and an upper bearing assembly attached to the tower below the turbine rotor blades and proximate to the maximum bowing or separation of the trailing edge from the leading edge (hereinafter "mid-tower"). Additional or alternative bearing assemblies may be utilized. An acceptable bearing assembly includes the ability to carry side loads and permit rotation of the tower in 360°.

[0010] The upper bearing assembly comprises an annular structure surrounding the wing shaped tower structure. Activation of the yaw motor and the rotation of the tower through operation of the lower and upper bearing assemblies causes the tower leading edge to continuously point into the wind. This in turn points the turbine, fixed to the top of the tower, into the wind thereby enhancing energy production.

[0011] A second outer annular structure (hereinafter "mid-tower collar") may surround the upper bearing assembly. This second structure may be the attachment for reinforcing and stabilizing guy wires, cables, or rods extending from the tower to the ground. The guy wires may be anchored into the ground. There may be three or more guy wires. For example, three guy wires would be spaced at approximately 120° apart. The second outer annular structure may also provide horizontal reinforcement for the upper bearing assembly.

[0012] In another embodiment, the tower may be a triangular shape. The shape is narrow at the top juncture with the turbine and has a broad base at the bottom. The trailing and leading edges may be joined by a horizontal component at the tower bottom. A structural concept of the invention includes matching the thrust bending moment and taper. Therefore a tower with mid level support will have a double taper, whereas a tower with only a bearing assembly at the base (triangular shaped tower) will have only a single taper. The bearing assembly will be at ground level. The bearing assembly may include a turn table revolving device. This can include a rotatable horizontal disk that supports the tower. A yaw motor located at ground level can be used to turn the tower into the wind.

SUMMARY OF DRAWINGS

[0013] The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate preferred embodiments of the invention. These drawings, together with the general description of the invention given above and the detailed description of the preferred embodiments given below, serve to explain the principles of the invention.

Figure 1 illustrates a side view of the tower structure component including the leading edge and trailing edge. The leading edge is leaning into the wind. Also illustrated is the bottom bearing assembly, the upper bearing assembly and the mid tower collar for anchoring guy wires or synthetic cables. The tower vertical axis of rotation is also illustrated. Also illustrated is the nacelle showing the approximate size of the nacelle to the tower structure. This size may vary considerably. For example, the size of the nacelle would be larger if a large diameter direct drive generator were used.

Figure 2A illustrates a top down cross sectional view of the tower structure showing one embodiment of the leading edge, trailing edge and the side panels. Illustrated are top views of the leading edge **110** and the trailing edge **120**.

Figure 2B illustrates a top view of a cross sectional perspective of a more elliptical tower structure.

Figure 3 illustrates a side view of a tower not according to the invention, forming a triangle shape wherein a vertical leading edge is supported by a straight but angled trailing edge.

Figure 4 illustrates the tower of Figure 1 leaning into the wind wherein multiple side panels are mounted between the leading edge and trailing edges. Panels are mounted on both sides of the tower structure. The vertical axis of rotation is illustrated.

Figure 5 is a top cross sectional view of the tower and the mid-tower collar, upper bearing assembly and the inner collar.

Figure 6 is a side view of the double tapered tower wherein the leading edge leans forward outside of the axis of rotation. The relationship between the tower leading edge and the turbine blade is also illustrated.

DETAILED DESCRIPTION OF INVENTION

[0014] It will be appreciated that not all embodiments of the invention can be disclosed within the scope of this document and that additional embodiments of the invention will become apparent to persons skilled in the technology after reading this disclosure. These additional embodiments are claimed within the scope of this invention.

[0015] The contents of the section entitled Summary of Invention are incorporated into the Detailed Description of the Invention herein.

[0016] The construction of wind turbines and generation of electricity from these turbines has increased significantly in the last ten to twenty years. Most of these turbines utilize rotating blades and a nacelle containing a gear box and generator setting atop of a fixed positioned tower. The rotor and nacelle rotate atop of a stationary tower in response to changes in wind direction. This rotation may involve operation of a yaw motor.

[0017] There has been a goal to increase the size of the wind turbines. This goal encounters problems of transporting large structural components over land to the installation site. It also encounters problems with materials required to withstand wind loads from all directions and the corresponding increase in weight and material costs.

[0018] The wind turbine tower is typically cylindrically shaped and made from steel. The tower may have a tapering shape along the vertical axis. In other examples, the tower may have a derrick frame shape similar to farm windmills. Neither design is aerodynamically shaped, i.e. designed to reduce wind resistance. Since the towers are fixed in place, it is not possible to provide an aerodynamic or structurally efficient shape since the wind direction is variable. Factors of structural efficiency include but are not limited to cost, shape, material, material configuration, overall weight, and functionality.

[0019] The invention subject of this disclosure teaches constructing a tower structure from multiple pieces or segments (elements). Both the leading edge and trailing edge may comprise a plurality of segments stacked on top of a tower segment. The trailing edge may progressively bow away from the linear leading edge. This may form a structurally efficient shape, i.e., the shape produces a substantially constant load upon the leading edge and trailing edge. The shape comprises a progressively dimensioned space between the leading edge and the trailing edge. The leading edge and the trailing edge of the tower are sometimes collectively termed herein as "structural edges". The structural edges are load carrying. The leading edge faces the on coming wind. Conversely the trailing edge is on the lee side of the tower. Rotation of the tower ensures the structure maintains this orientation to the wind. Utilizing this constant orientation, structural tower loads can be predicted based upon varying wind speeds. *This predictability can allow the fabrication of the tower segments tailored to the position of each segment. The tower can be structurally optimized.* Stated differently, each tower segment can be structurally efficient. Each segment can be designed to carry a specific load, allowing for cost effective utilization of materials (hereinafter termed "structural efficiency" or "structurally efficient"). For example the structural segments, including attachment hardware, of the leading edge will experience both compression load and, in high wind, tension loads. The trailing edge segments may more often experience or be subject to compression loading. The segments can also be aerodynamically shaped based upon their position relative to the wind. It will be appreciated that the leading edge is designed to always point into the wind and the trailing edge points away from the wind. The side panels are designed to remain parallel to the wind.

[0020] The segments can be in lengths that allow use of standard transportation methods. As discussed elsewhere herein, the trailing edge segment(s) may be sized to nest in the leading edge segment(s) (or vice versa) during transportation.

[0021] The invention subject of this disclosure teaches a tower that can rotate in reaction to changes in the wind. The tower can be designed to be structurally efficient. The tower rotates with the turbine (including the nacelle). This allows the tower to be designed to decrease the tower's drag in the wind. More important, only the leading edge sees tension from variable wind thrust, with the trailing edge seeing or being subject to corresponding compression. Therefore the materials choice and placement can be optimized for each type of loading, thereby allowing reduction of high strength and high cost materials. In addition, the tapering width allows nearly uniform stress in these main structural members so their material is loaded efficiently, and the side panels

need carry only modest amounts of shear and bending loads. There can be an overall weight savings from carrying the loads in this efficient manner, i.e., "structurally efficient", and transportation costs can be reduced because the tower segments are both smaller and lighter.

[0022] Referencing Figure 6, the tower has a vertical axis of rotation **950**. The axis of rotation extends vertically upward from the bottom bearing assembly (proximate to the tower foundation **360** and pivot stalk **370**) and through the middle of the upper bearing assembly **220**. The tower can be constructed to allow portions of the structure to extend outside the axis of rotation. Particularly the leading edge may lean into the windward direction. This is termed "leaning forward" or "leaning into the wind". It will be appreciated that the tower **100** is leaning to the left and into the wind as shown by vector arrow **975** (representing wind direction). This configuration increases the distance between the tower leading edge and the plane of rotation of the turbine blades. The progressively dimensioned or increased distance between the tower leading edge **110** and the turbine blade **402** is illustrated by distance **401**. This minimizes potential for damage to the turbine blades by striking the tower. It also decreases the moment distribution from rotor thrust that must be carried by the tower and its supports.

[0023] A downwind rotor (not shown) can extend from the trailing edge **120** outside the axis of rotation **950**. This position facilitates the generating of the necessary moment needed to steer the tower into a changed wind direction. The winged shape formed by the straight leading edge and the kinked trailing edge (described below) may provide the necessary moment to steer the tower into a changed wind direction. In another embodiment, a vane structure fixed to the trailing edge can be used.

[0024] In one embodiment of the invention, the tower load is carried by the leading edge **110** and the separate trailing edge **120**. See Figure 1. This allows the sides of the tower structure to be covered with a lower strength load bearing material, i.e., structurally efficient, as started in the preceding paragraph and further discussed in relation to Figure 2. The tower edges define the outline of the wing shaped tower structure **100** illustrated in Figure 1. The tower edges diverge at the tower mid point (kinked or bowed separation of the leading edge and trailing edge). The tower edges merge together at the bottom of the structure and are attached to the bottom bearing assembly **210**. Beneath the bottom bearing assembly (not shown) are a pivot stalk **370** and a foundation **360**.

[0025] In the embodiment illustrated, the leading edge **110** leans forward into the wind. The leading edge is not vertical. The axis of rotation **950** is vertical. As illustrated in Figure 1, the axis of rotation starts at the pivot stalk **370** and extends upward through the center of the upper bearing assembly **220**.

[0026] In one embodiment, (not shown) a hinge component connects the bottom of the leading edge and trailing edge segments with the foundation or with the bottom bearing assembly. Other placements of the bottom hinge are possible. This configuration allows the tower to pivot on the hinge, and the lowering of the tower (and turbine) to be placed on the ground for servicing or repair. It may be found advantageous to attach the hinge to the leading edge, thereby ensuring that the turbine and blades will be facing downward when the tower is lowered. The trailing edge can also be attached with a hinge to the foundation or bottom bearing assembly. Accordingly the tower can be lowered using the leading edge hinge or the trailing edge hinge, depending upon the component of the turbine to be serviced. A hinge also allows the tower to be assembled and then elevated and secured in the vertical position for initial erection.

[0027] The tower edges also merge **240** beneath the attachment fixture or base **350** for the turbine nacelle **351**. The orientation of the tower depicted in Figure 1 to the wind direction is shown by vector arrow **975**. The tower may be rotated in response to changes in the wind by use of a yaw motor or other device. Also illustrated is the progressively dimensioned space **136** between the leading and trailing edges. It is this space that is covered by the secondary load bearing material. See Figures 2 and 4.

[0028] See Figure 2A comprising a cross-sectional top view of the tower structure. Illustrated are the leading edge **110** and trailing edge **120**, side panels **135** and the narrow profile of the tower structure facing the wind **975**. The leading edge defines the narrow profile.

[0029] Referencing Figure 1, because the tower edge separation profile is similar to the linear moment profile from rotor thrust, loads in the leading and trailing edges are fairly constant and therefore a good match to a constant material cross-section. Related to this is that primary structural shear in the side panels and fasteners is low. The side panels may be a composite material. There will be kick loads at the kink **130** in the trailing edge load path, but the mid-tower collar **230** may be installed at this location and may reinforce the trailing edge. Also interior structure such as wide flanges or a bulkhead integrated into the joining of upper and lower tower sections may be used to react to these kick loads. Further, operating fatigue loads in the tower, bearings, cables, and foundation are reduced by positioning the wind turbine mass **350**, **351** upwind of the rotating wind turbine tower axis of rotation. The wind turbine mass may comprise the rotor blades, turbine rotor, nacelle, yaw motor and housing.

[0030] In the embodiment illustrated in Figure 1, the structural edges achieve maximum divergence approximately in the midpoint **130, 131** of the structure **100**, i.e., mid-tower. This forms a maximum kink or widest bowed portion of the wing shaped tower structure. A upper bearing assembly **220** reacts the net loads from the two edges at or near this widest point. The upper tower section is above the upper bearing assembly. Of course, this upper bearing assembly facilitates the rotation of the tower structure. The bearing assembly comprises an annular structure surrounding the wing shaped tower structure **100**. See Figure 2A for a top cross sectional view of the tower structure and the position of the leading edge and trailing edge. Also illustrated in Figure 2A is the narrow profile of the wing shaped tower. This narrow profile, combined with the design of the tower leading edge and trailing edge, minimize wind resistance of the tower and thereby lessens the load upon the tower components.

[0031] A second outer annular structure (mid-tower collar) **230** surrounds the upper bearing assembly **220**. This mid-tower collar may be the attachment for guy wires, cables, or rods **310** extending to the ground that restrain the tower structure at the point of greatest separation **141** (kink or bowed separation) between the load bearing leading edge **110** and trailing edge **120**. One embodiment may incorporate a kink design in the leading edge to facilitate the turning of the tower in response to changes in wind direction by moving tower steering area downwind of the tower rotation axis. Another embodiment comprises placing a downwind rotor substantially downwind of the tower rotation axis. In another embodiment, the turbine is turned by use of a yaw motor.

[0032] In one embodiment, side to side tower stiffness may be increased by adding brace wires or rods that extend from the tower top and bottom to the mid tower bearing assembly. These wires or rods lie in a plane perpendicular to the leading edge to trailing edge plane, and attach near the perimeter of a mid-tower inner collar and rotate with it. The wires or rods extend from the top of the tower along a first side to the tower bottom and similarly extend along the second tower side. They would also attach to and rotate with supplemental bearing inner collars, if any are fitted below the upper bearing.

[0033] With reference to Figure 2A, the leading edge **110** is illustrated to comprise a half circle with a radius. The trailing edge **120** is also illustrated to be a half circle with a radius. The leading edge and trailing edge carry the tension and compression load of the structure, including the rotor and nacelle weight. The leading and trailing edges may comprise steel having a high modulus of elasticity. The radius of the trailing edge can be smaller than the radius of the leading edge. Conversely, the radius of the leading edge can be smaller than the trailing edge. This configuration allows the trailing edge to be stored within the leading edge for transportation (or vice versa).

[0034] The half circle shape enhances the load bearing capacity of the steel, in contrast to an equal thickness of sheet steel, because the curved shape provides self stability against buckling. Continuing to reference Figure 2B, the top cross sectional view shows a tower embodiment having a more elliptical shape. Other embodiments can include a leading edge or trailing edge having a parabolic shape or a shape tapering to a wider or narrower crosswind dimension.

[0035] In addition to the leading edge **110** and trailing edge **120**, Figures 2A and 2B illustrate a third element of the tower, i.e., panels **135** that cover the tower sides. These panels may cover both sides of the tower, creating a hollow interior space **136**. The panels are attached to the leading edge and the trailing edge. Figures 2A and 2B illustrate one method of attachment wherein the panel **135** fits underneath the side edge **137** of the leading edge **110**. Conversely, the side panel fits over **138** the side edge of the trailing edge **120**. The attachment mechanisms can be bolts, screws or clips and are loaded in shear, i.e., the attachment mechanism primarily tries to slide laterally in contrast to being pulled apart. A primary structural or sealant bond may be optionally provided.

[0036] The attachment method described above, i.e., the leading edge fitting over the side panel and the side panel fitting over the trailing edge and in line with the air flow, advantageously minimizes debris and moisture blowing into the joints or hollow space **136** of the tower. The wind direction is illustrated by vector arrow **975**. This attachment method also reduces drag on the tower. The leading edge **110** is pointing into the wind.

[0037] The side panels will experience in-plane, shear and air loads. These secondary loads may be significantly less than the loads of the leading and trailing edges. Accordingly, the side panels may be fabricated of lightweight secondary material. This, of course, reduces the weight of the tower. Side panel materials may include but are not limited to fiberglass, balsa or foam core within fiberglass skin panels, fiber reinforced plastics or non reinforced plastic. A diagonal metal frame structure with metal covering may also be used. The panels may be lower cost materials relative to the material used for the tower edges. The panel surface area will be subject to the force of a changed wind direction. This pressure on the bowed surface spanned by the panels may provide the moment to return the leading edge into the new wind direction.

[0038] The leading edge **110** will experience both compression and tensile loads. The compression load comes from the weight of the rotor and nacelle. The tensile force will arise from, at least in part, the thrust action of the wind on the turbine rotor blades.

When the leading edge is directed into the wind with the turbine operating, there will be thrust induced bending, simultaneous with compression from carrying weight (mass) from the turbine rotor, nacelle and housing. The leading edge must carry the net resultant of these compression and tension loads. The trailing edge **120** will experience compression from the thrust force and from the weight load, and must be stable against buckling. Due to the disparity of these forces and that the tower components are fabricated as separate pieces or segments, the leading edge may be made thinner than the trailing edge (or vice versa), thereby saving on material and transportation costs.

[0039] The lower portion of the tower (below the upper bearing assembly) sees more compression than the upper tower portion due to the load from the anchored and tensioned guy wires. Again, since the tower segments may be fabricated separately, the thickness of the tower leading edge and trailing edge can be greater below the upper bearing assembly.

[0040] Figure 3 illustrates a tower **100** not according to the invention. The tower leading edge **110** may be vertical. The trailing edge **120** slopes in a linear fashion from the junction **240** with the leading edge. This junction supports the nacelle or rotor attachment fixture **350**. The tower enjoys a wider base **371** resting on a ring bearing **171** and a foundation **360**. Wires or rods that extend from the top of the tower to the bottom bearing and add sideways strength and stiffness may be used with this embodiment as well.

[0041] Illustrated in Figure 3 are rotating mechanisms **171A, 171B**, i.e., turntable bearings, turning on the edge of the tower **100** allowing rotation of the tower within the base. Also illustrated is a yaw motor **212** to power the rotation. The leading edge and the trailing edge are connected by a horizontal frame component **211**. The relationship of the leading edge to the wind is illustrated by vector arrow **975** representing the wind direction. Side panels again join the leading and trailing edges in this embodiment. The force of changing wind direction on the panel surface may provide the moment to rotate the leading edge into the new wind direction, if the tower leans away from the wind instead of into it as shown.

[0042] In an alternative embodiment, the tower may rotate on a turntable component. This may comprise a horizontal rotating plate mounted on the foundation. The tower base would be attached to the plate or disk component.

[0043] In another embodiment, a downwind rotor (not shown) is attached to the downwind end of the nacelle, which is still mounted on top of the tower. The downwind rotor provides the mechanism for rotating the tower in response to changes in wind direction. The downwind mounted turbine rotor helps orient the leading edge into the wind. The downwind rotor would be mounted sufficiently distant from the tower vertical axis of rotation to provide the yaw alignment forces. The leading edge may slant (lean) downwind or be oriented into the wind. The trailing edge may be vertical or also slant downwind, to aid the downwind placement of the turbines.

[0044] The ability to choose the thickness, shape, and local radius of curvature of the trailing edge part enhances the buckling stability of the trailing edge while minimizing its weight and cost, i.e., structural efficiency. Similarly, these characteristics could be varied for the leading edge as a function of height to minimize weight and cost. The thickness of the tower i.e., the separation between side panels, could also be varied with height if this provides lower weight and cost, by varying the edge to edge crosswind width dimensions of the leading and trailing edge pieces.

[0045] Figure 4 illustrates the leaning tower structure **100** depicted in Figure 1 with the addition of the side panels **135** spanning the space **136** between the leading edge **110** and trailing edge **120**. The side panels need carry only lesser amounts of shear and bending loads. The vertical axis of rotation is shown extending from the pivot stalk **370** and through the middle of the mid tower collar **230**. It extends outside the tower structure. Figure 2A and 2B illustrate an embodiment of attaching the side panels to the leading and trailing edges.

[0046] Also illustrated are the mid-tower collar **230** and guy wires **310**, the tower structure midpoints **130, 131** and the bearing assembly **220**. Also illustrated is the merging of the leading and trailing edges **240**, the nacelle attachment component **350**, the bottom pivot post **370**, the foundation **360**.

[0047] Figure 5 illustrates an embodiment for supporting the tower and allowing the tower to rotate. Illustrated is a top cross sectional view showing the tower comprising the leading edge **110**, the side panels **135**, and the trailing edge **120**. The tower edges carry rotating bearings **170A** thru **170D** or similar components that are in contact with the circular surface **220** of the bearing assembly. Also illustrated are three guy wires or rods **310A, 310B, 310C**, attached to the mid tower collar **230**. Also shown is the space **136** between the tower edges **110, 120**. The mid-tower collar surrounds the upper bearing assembly and provides structural restraint.

[0048] The tower structure **100** may also include an inner collar **221**. This collar **221** can be a flat plate surrounding the tower

and attached to it at or near its widest point. The inner collar rotates with the tower within the upper bearing assembly. In Figure 5, the area between the bearing assembly **220** and tower **100** is filled with a planar structure, possibly made from a fiat plate, or plate with holes to make it lighter. The bearings may be in a few discrete locations as shown, or distributed more widely around the inside perimeter of the upper bearing assembly **220**. The bearings are external to the tower structure, i.e., "external bearing assembly". The inner collar stops the tower from deforming out of shape at the kink. Alternatively, a planar structure on the inside would restrain the shape and achieve the same result.

[0049] This specification is to be construed as illustrative only and is for the purpose of teaching those skilled in the art the manner of carrying out the invention. It is to be understood that the forms of the invention herein shown and described are to be taken as the presently preferred embodiments. As already stated, various changes may be made in the shape, size and arrangement of components or adjustments made in the steps of the method without departing from the scope of this invention. For example, equivalent elements may be substituted for those illustrated and described herein and certain features of the invention maybe utilized independently of the use of other features, all as would be apparent to one skilled in the art after having the benefit of this description of the invention.

[0050] While specific embodiments have been illustrated and described, numerous modifications are possible, the scope of protection is only limited by the scope of the accompanying claims.

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- GB780381A [0003]

PATENTKRAV

1. Roterende vindturbinetårn (100) omfattende:

- et udvendigt øvre lejringsarrangement (220);
- 5 en forkant (110) og en bagkant (120), som bærer de primære tårntræk og tårntrykbelastninger fra en turbine, nacelle, og rotortrykinduceret udbøjning, idet bagkanten (120) har en maksimalt bugtet eller buet adskillelse (130) fra forkanten (110) i tilstødning til det øvre lejringsarrangement (220), og tilspidses imod forkanten i tilstødning til den øvre og nedre tårnende;
- 10 et strukturelt effektivt, progressivt dimensioneret hult indre rum (136) imellem forkanten (110) og bagkanten (120), som tilvejebringer stort set konstante belastninger i forkanten (110) og bagkanten (120); idet det hule indre rum (136) er progressivt dimensioneret fra den øvre og nedre tårnende imod midten af tårnet;
- 15 sidepaneler (135), som forbinder forkanten (110) og bagkanten (120); en tårnrotationsakse (950), som forløber igennem midten af det øvre lejringsarrangement (220); en midtertårnkrave (230), som omgiver det øvre lejringsarrangement (220); og adskillige barduner, kabler eller stænger (310) fastgjort til midtertårnkraven (230)
- 20 og forløbende til jorden.

2. Roterende vindturbinetårn ifølge krav 1, hvor såvel forkanten som bagkanten er bugtede eller buede bort fra hinanden i tilstødning til det øvre lejringsarrangement.

- 25 4. Roterende vindturbinetårn ifølge krav 1, som yderligere omfatter ét eller flere yderligere lejringsarrangementer under det øvre lejringsarrangement.

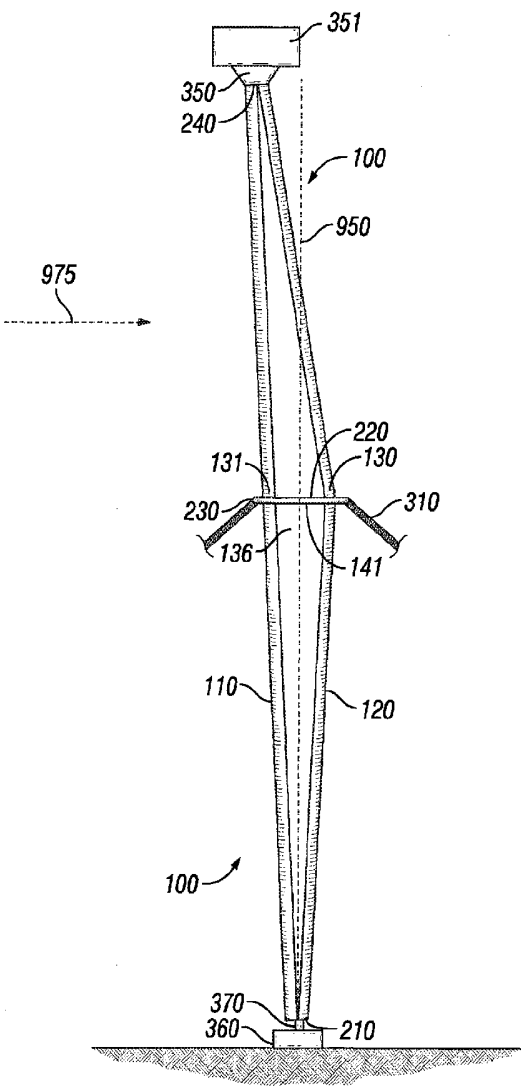
- 5. Roterende vindturbinetårn (100) ifølge krav 1, som yderligere omfatter i det mindste én afstivningswire eller stang (310) på en første side og en modstående anden side,
- 30 fastgjort og forløbende fra en øvre tårnende til en nedre tårnende, fastholdt vinkelret på forkant til bagkantplanet, som er fastgjort til det øvre lejringsarrangement (220) og roterer med dette.

- 6. Roterende vindturbinetårn ifølge krav 1, som yderligere omfatter, at forkanten har
- 35 en første radius og bagkanten har en anden radius, hvor én radius er mindre end den anden radius.

7. Roterende vindturbinetårn ifølge krav 1, som yderligere omfatter, at forkanten og bagkanten er fremstillede af metal, metallegering eller kompositmateriale og de belastningsbærende sidepaneler omfatter et med kerne forsynet kompositmateriale,
5 kompositplade eller ikke strukturel plade over en rammekonstruktion.
8. Vindturbinearrangement omfattende det roterende vindturbinetårn (100) ifølge krav 1 og en vindturbine (351) fast monteret på den øvre ende af vindturbinetårnet (100), idet vindturbinen har en turbinerotor (402), som strækker sig nedstrøms bag
10 bagkanten (120).
9. Roterende vindturbinetårn ifølge krav 1, omfattende et hængsel forbundet i tilstødning til tårnbunden, som gør det muligt at rejse tårnet til vertikalt eller sænke dette til horisontalt.
15
10. Roterende vindturbinetårn (100) ifølge krav 1, omfattende at forkanten (110) hælder fremad imod vinden.
11. Roterende vindturbinetårn (100) ifølge krav 10, hvor den øvre tårndel læner sig
20 fremad imod vinden og derved forøger frigangen imellem en vindturbinerotorvinge (402) og forkanten (110).
12. Roterende vindturbinetårn ifølge krav 10, hvor driftstræthedsbelastninger i tårnet, lejer, kabler og fundament reduceres ved at positionere vindturbinemassen (351)
25 opstrøms for rotationsaksen (950) for det roterende vindturbinetårn.
13. Roterende vindturbinetårn ifølge krav 1, hvor forkanten, bagkanten, og sidepanelerne omfatter adskillige segmenter og hvert segment opretholder den samme orientering i forhold til vinden, og segmenterne er fremstillede til at bære
30 tårnbelastninger, som er specifikke for segmentets position i vindturbinetårnet, og til at have aerodynamiske former i forhold til vinden.
14. Vindturbinetårn ifølge krav 13, hvor segmenterne er af forskellige materialer eller forskellige konstruktioner, med højstyrkematerialer langs de primære belastningsbaner
35 og lettere eller billigere materialer i de sekundære belastningsbaner.

15. Vindturbinetårn ifølge krav 13, hvor forkantsegmenterne er formede til lavfriktionsindføring i en luftstrømning; yderligere omfattende at sidepanelerne er formede til lavfriktionspassage af luftstrømning på tværs af sidetårnsdimensionen, og bagkantpaneler er formede til ønskede frigørelsesegenskaber for luftstrømningen.

DRAWINGS



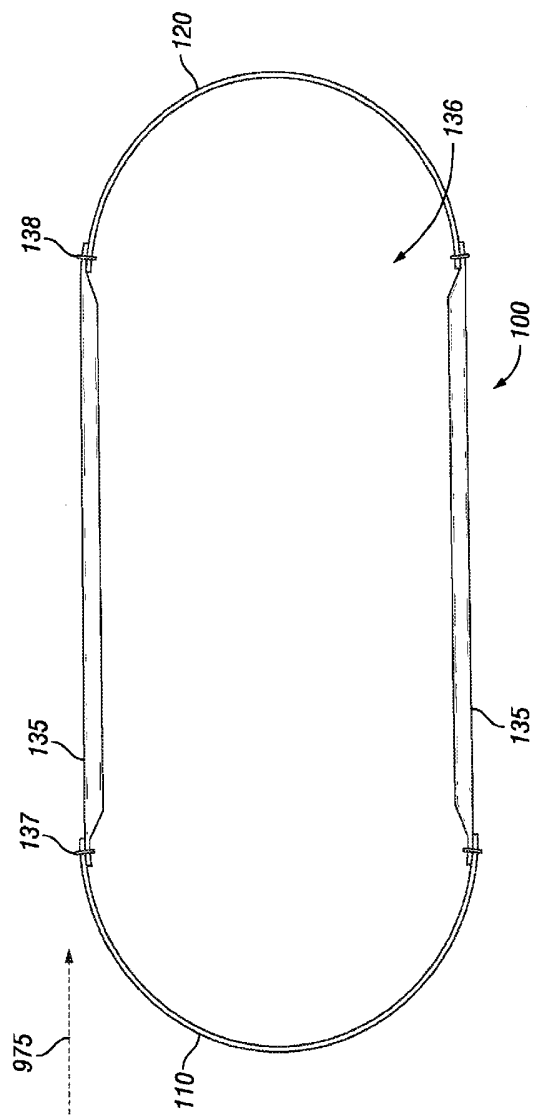


FIG. 2A

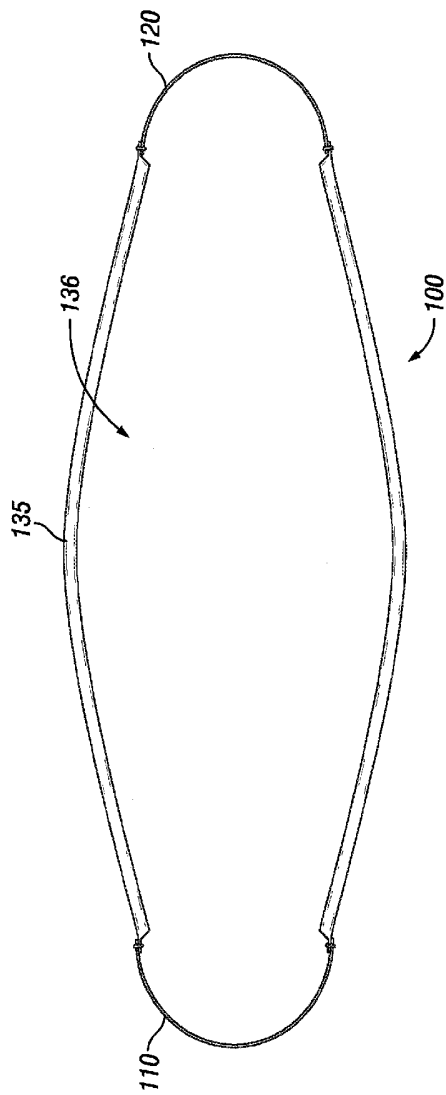


FIG. 2B

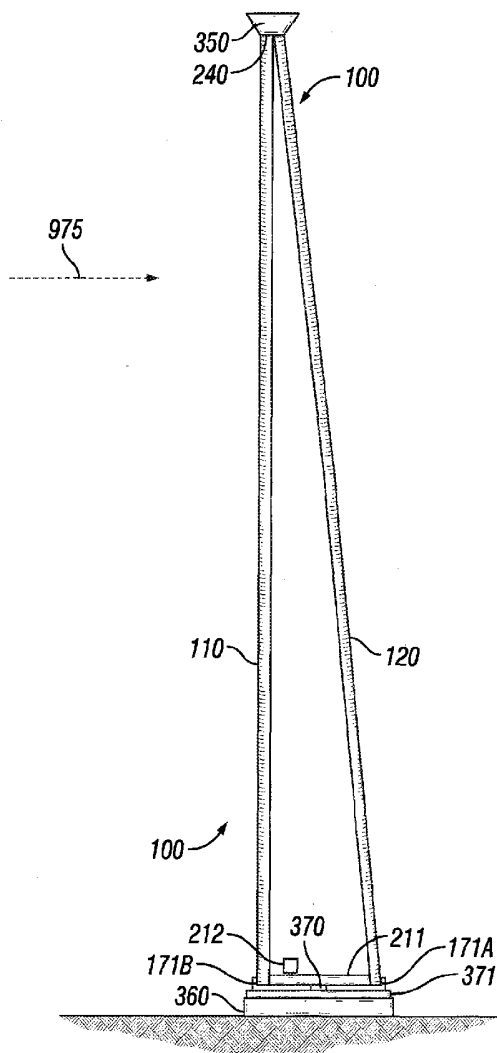


FIG. 3

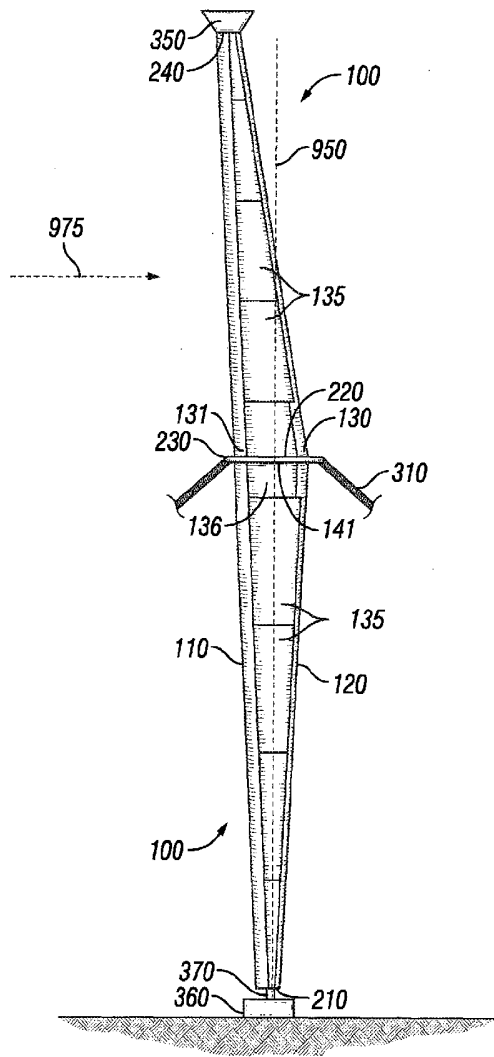


FIG. 4

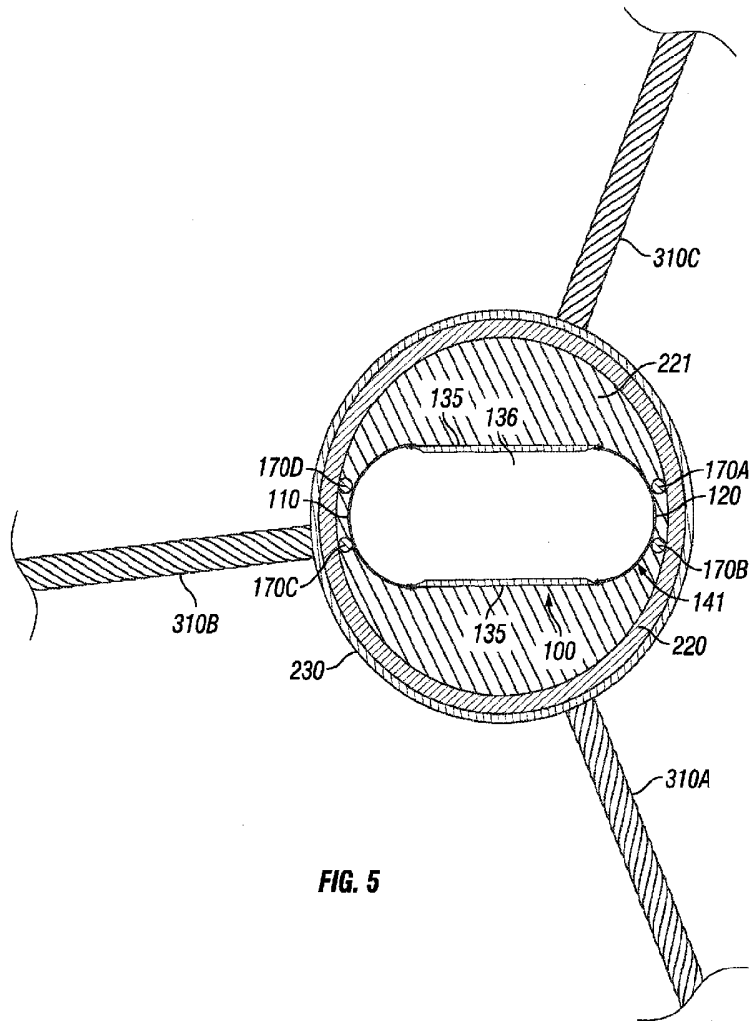


FIG. 5

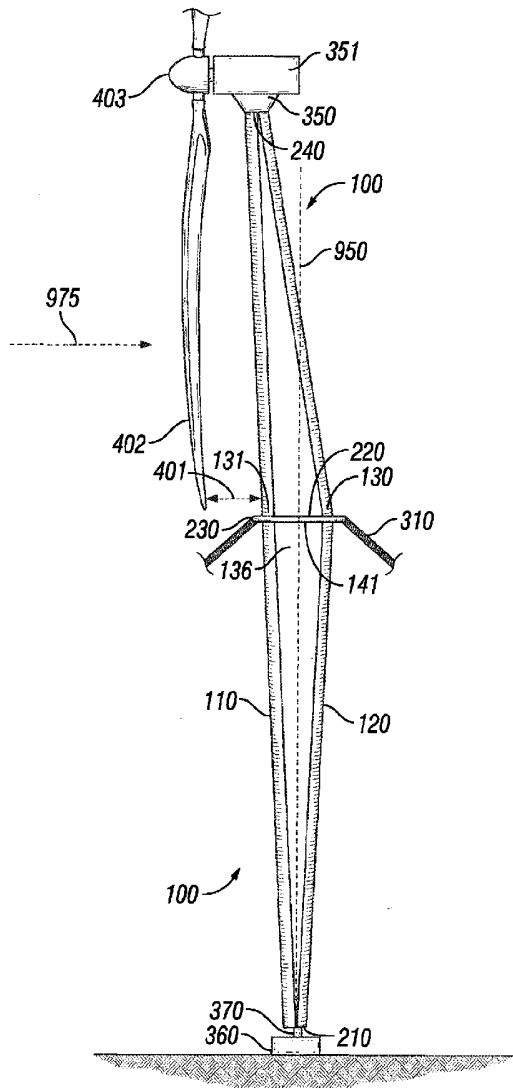


FIG. 6