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(54) Title: HORIZONTAL AXIS WIND TURBINE

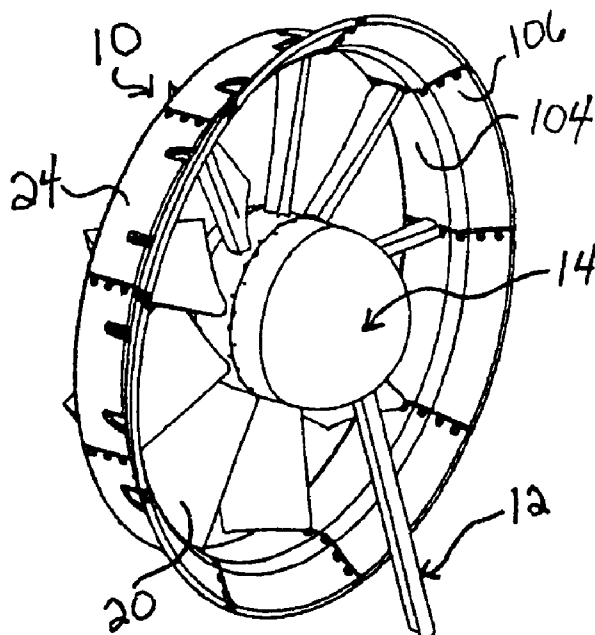


FIG. 1

(57) Abstract: A generally horizontal axis wind turbine for generating energy is disclosed. The wind turbine comprises a plurality of radially extending and evenly distributed wind blades movably mounted between a rotatable hub and a circumscribing outer rim. The hub and the outer rim are generally shaped to redirect the wind toward the blades which are preferably shaped as airplane wings.



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Title of the Invention

[0001] Horizontal Axis Wind Turbine.

5 Cross-Reference to Related Applications

[0002] The present patent application claims the benefits of priority of U.K. Patent Application No. 0810149.5, entitled "Horizontal Axis Wind Turbine" and filed at the U.K. Intellectual Property Office on June 4, 2008, the content of which is
10 incorporated herein by reference.

Field of the Invention

[0003] The present invention generally relates to wind turbines and, more
15 particularly, to horizontal axis wind turbines.

Background of the Invention

[0004] Horizontal axis wind turbines are known in the art and are useful in producing
20 electrical energy out of wind power. Such wind turbines of the prior art generally consist of a fixed hub portion fastened at a distal end of a support structure, and a rotatable hub portion that includes a central hub assembly having a plurality of radially projecting, elongated wind blades. The fixed hub portion typically conceals an electrical power generating means having a rotatable power input transmission
25 shaft engaged with the rotatable central hub assembly. The rotatable central hub assembly typically conceals a mechanism that allows the wind blades to twist about their longitudinal axes so that the angle of twist or pitch angle may be varied to suit variations in wind speed.

30 [0005] Typical horizontal axis wind turbines configurations of the prior art are illustrated through U.S. Patent No. 7,365,447 to Yoshida (2008), U.S. Patent No. 7,246,991 to Bosche (2007), U.S. Patent No. 7,204,673 to Wobben (2007), U.S. Patent No. 7,121,795 to Moroz (2006), U.S. Patent No. 6,902,370 to Dawson (2005), and U.S. Patent No. 6,619,918 to Redsford (2003).

[0006] While these prior art devices generally offer a horizontal axis wind turbine that produces electrical energy out of wind power, they also entail one or more of the following disadvantages:

- 5 a. They are generally equipped with elongated, 20 to 30 meters narrow wind blades whose distal tip ends can reach considerably high rotational speeds, even during normal wind speed condition. Such high rotational speed at the tip end of the blades exposes the latter to high centrifugal forces and prolonged mechanical stress, rendering the
10 blades prone to mechanical failure. Moreover, the high speed of revolution of the distal tip ends of the blades generally produces higher noise levels.
- b. They generally require a clutch and brake mechanism to slow down and stop the rotatable hub portion, which significantly raises the
15 complexity and cost of manufacturing of the wind turbine.
- c. Their elongated wind blades are typically constructed as a metal or composite shell on a stiffening inner structural assembly, which generally results in sturdy but heavy wind blades. Furthermore, the
20 metal or composite shells of the blades are typically prone to ice accumulations due to a high dew point period on the surface of the latter, which often result in an unbalance and, eventually, a severe mechanical failure of the wind blades.
- d. Typically, there is vortex formation and loss of load-bearing at the tip
25 end of the wind blades.

[0007] Against this background, there exists a need for a new and improved horizontal axis wind turbine that avoids some or all of the aforementioned disadvantages.

30 **Summary of the Invention**

[0008] It is a general object of the present invention to provide a new and improved horizontal axis wind turbine of a downwind type. According to a preferred though not limitative embodiment of the present invention, the wind turbine generally comprises,

at its upwind end, a fixed hub portion (or nacelle), and at its downwind end, a rotatable hub assembly. The fixed hub portion is mounted on a support structure and encloses an electrical or mechanical power generating means equipped with a rotatable power transmission input shaft extending horizontally in a downwind
5 direction. Depending on the particular configuration of the wind turbine, the fixed hub portion or nacelle can be either fixedly mounted or pivotally mounted to the support structure. The rotatable hub assembly is typically rigidly fastened at the downwind end of the rotatable transmission shaft and generally comprises a central hub structure having a plurality of wind blades radially projecting therefrom. The wind blades are
10 further pivotally mounted to an outer rim circumscribing the tip ends of the blades.

[0009] The central hub structure is provided with actuating means for allowing the wind blades to synchronously rotate about their longitudinal axes, so that the pitch angle can be varied to maximize the efficiency of the wind turbine depending on the
15 wind conditions of the area.

[0010] The wind blades are proportionally wider and shorter than conventional wind turbine blades of the prior art and have a cross-section that is more resembling the teardrop-shaped cross-section of a conventional airplane wing, than the typical cross-
20 section of a conventional wind turbine blade. In that sense, the shape of the wind blades is preferably optimized for load bearing instead of speed.

[0011] In addition, the wind blades are preferably mounted at a slight angle with respect to the plane of rotation of the turbine. More particularly, the leading edges of
25 the wind blades extend slightly axially in the downwind direction as they radially extend between the base ends of the wind blades located near the hub and the tip ends of the wind blades located near the outer rim. By being slightly angled in the downwind direction, the wind blades direct the incoming wind toward their tip ends, forcing the wind turbine to substantially automatically align itself with the wind
30 direction, even at low wind condition.

[0012] Furthermore, the wind blades may be advantageously manufactured as a polyester shell, using a rotational moulding process, and injected with high density polyurethane.

[0013] The upwind or front end hub portion has a substantially rounded configuration for deflecting the incoming wind, and has an outer diameter that is proportionally larger relative to the size of the adjacent wind blades when compared to conventional
5 wind turbine configurations.

[0014] The outer rim has a substantially funnel-shaped configuration, with the flared open portion oriented upwind in order to deflect the incoming wind inwardly toward the tip ends of the wind blades. In an alternate embodiment, the outer rim may be
10 replaced with individual wing tips fastened in an upwind orientation at the distal end of each wind blade.

[0015] The combination of the round upwind hub portion and the funnel-shaped outer rim forces the incoming wind toward the wind blades, thereby contributing to a more
15 efficient wind energy harvesting.

[0016] The main advantages of the present invention is a horizontal axis wind turbine:

- a. whose relatively large wind blade configuration integrating the cross-section profile of an airplane wing, confers considerable load-bearing
20 qualities to the rotatable hub assembly of the wind turbine, even at low velocity winds. Furthermore, the rotation of the rotatable hub assembly is mainly derived from a vacuum effect, or lift effect, on the downwind side of the blades, rather than from a wind deflection on the upwind side of the blades, as is the case with conventional wind turbine blades
25 of the prior art;
- b. whose adjustable pitch angle of the wind blades allows to maximize the efficiency of the wind turbine relative to wind conditions, as well as forcing a stall condition of the airplane wing-shaped wind blade, in order to slow down and stop the rotatable hub assembly of the wind
30 turbine when required. Thus, the wind turbine does not require a brake or clutch mechanism and, hence, is relatively simpler and more economical to manufacture;
- c. whose wind blade configuration also allows for a wind turbine that is turning at a relatively low revolution rate while still producing a

- considerable energy output for its size. Compared to prior art wind turbines, the low revolution rate of the wind blades offers many advantages such as, among others, the tip end of the blades are less exposed to high centrifugal forces and prolonged mechanical stress and, thus, is less prone to mechanical failure, or at least minimize the damages when a mechanical failure do occur. Moreover, a low revolution wind turbine produces lower noise levels, and is more secure to operate overall;
- 5
- d. whose relatively large front hub portion and funnel-shaped outer rim deflect the incoming wind toward the intermediate wind blades portion of the wind turbine and, thus, significantly increase the overall efficiency of the latter, particularly more so concerning the air deflected by the outer rim toward the tip end of the wind blades, where there is the highest torque gain;
- 10
- e. whose outer rim furthermore minimize vortex formation and loss of load-bearing at the tip end of the wind blades;
- 15
- f. whose wind blades preferably simple polyester shell construction, injected with high density polyurethane, offers a light and sturdy rotatable hub assembly, which is as well faster and more economical to manufacture than conventional wind turbine blades of the prior art. Furthermore, the typically high surface finish of a polyester shell structure significantly reduces the dew point period of the wind blades, which is a common cause of icing accumulation, unbalance and eventual breakage of wind blades, a recurrent problem among metal or composite wind turbine blades of the prior art.
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- 25

[0017] Other advantages and novel features of the present invention will be obvious upon an understanding of the illustrative embodiments about to be described or will be indicated in the appended claims, and various advantages not referred to herein will occur to one skilled in the art upon employment of the invention in practice.

30

Brief Description of the Drawings

[0018] The above and other objects, features and advantages of the invention will become more readily apparent from the following description, reference being made to the accompanying drawings in which:

5 [0019] Figure 1 is a front, or upwind perspective view of an exemplary horizontal axis wind turbine in accordance with the present invention.

[0020] Figure 2 is a rear, or downwind perspective view of the wind turbine of Fig. 1.

[0021] Figure 3 is a front, or upwind elevation view of the wind turbine of Fig. 1.

[0022] Figure 4 is a rear, or downwind elevation view of the wind turbine of Fig. 1;

10 [0023] Figure 5 is a side elevation view of the wind turbine of Fig. 1, the opposite side being a mirror image thereof.

[0024] Figure 6 is a cross-sectional view taken along section line VI-VI of the wind turbine shown in Fig. 5.

15 [0025] Figure 7 is an enlarged detailed view of the encircled section identified as VII in Fig. 6, which shows a pivot support means for a tip end of a blade provided through a portion of the outer rim;

[0026] Figure 8 is a side elevation view of a hub structure assembly, here shown with a wind turbine blade having one end pivotally engaged in one of the radially extending pivot support means of the hub.

20 [0027] Figure 9 is a front, or upwind elevation view of the hub structure assembly shown in Fig. 8.

[0028] Figure 10 is a front, or upwind end perspective view of the hub structure assembly shown in Fig. 8.

[0029] Figure 11 is an enlarged detailed view of the encircled section identified as XII in Fig. 10.

25 [0030] Figures 12A to 12C illustrate a side elevation view, a top plan view and a front elevation view respectively, of an arched modular segment of the outer rim.

[0031] Figures 13A to 13D illustrate a side elevation view, a trailing edge view, a base perspective view and a top plan view respectively, of a wind turbine blade.

30 [0032] Figures 14A to 14D illustrate a front elevation view, a front perspective view, a side elevation view and a rear elevation view respectively, of a front hub cover.

[0033] Figures 15A to 15D illustrate a front elevation view, a rear perspective view, a side elevation view and a rear elevation view respectively, of a rear hub cover.

Detailed Description of the Preferred Embodiment

[0034] A novel horizontal axis wind turbine will be described hereinafter. Although the invention is described in terms of specific illustrative embodiments, it is to be understood that the embodiments described herein are by way of example only and that the scope of the invention is not intended to be limited thereby.

[0035] Figs. 1 to 4 show the various aspects of a preferred though exemplary embodiment of a horizontal axis wind turbine 10 in accordance with the principles of the present invention. The wind turbine 10 generally comprises a support structure 12 typically pivotally mounted to a base or foundation (not shown), a fixed hub portion or nacelle having a cover 14 on the upwind, or wind intake end of the turbine, and a rotatable hub assembly 15 disposed downwind of the support structure 12. Thus, the wind turbine 10 is of the downwind type, having a rotatable hub assembly 15 downwind of a support structure 12.

[0036] The rotatable hub assembly 15 generally comprises a central hub portion, here represented by a rear hub cover 18, having a plurality of wind turbine blades 20 radially projecting from a cylindrical portion 22 of the rear hub cover 18, to an outer rim 24. The wind turbine blades 20 can twist or pivot about their longitudinal axes 21 (see Figs. 13A and 13B) so that the pitch angle may be varied to suit variations in wind speed. Concealed within the cylindrical portion 22 of the rear hub cover 18, there is a hub structure assembly 16 for adjusting the pitch angle of the wind blades 20, which will be described hereinafter.

[0037] Now referring to Figs. 8 to 11, a hub structure assembly 16 is generally represented by a substantially annular-shaped framework having an upwind, front end 26 and a downwind, rear end 28. The hub structure assembly 16 generally comprises at its core a pair of parallel disc-shaped members 30, 32 that are centrally axially aligned along an imaginary horizontal central axis 33 representing the main horizontal axis about which the wind turbine 10 rotates (as best illustrated in Fig. 10). A pair of correspondingly aligned central holes 34 provided through the pair of disk-shaped members 30, 32 are for receiving therein a central power transmission shaft of an electrical power generating means (not shown) rigidly fastened at the upper distal end

of the support structure 12, and preferably concealed in the cavity 122 within the front hub cover 14 of the nacelle.

[0038] Still referring to Figs. 8 to 11, a plurality of right triangular frame members 36, having a right side 38 whose distal ends 40 are rigidly fixed to corresponding edge portions of the disk-shaped members 30, 32, are radially projecting therefrom. In turn, the projecting distal ends 42 of the right triangular frames 36 are rigidly linked to one another through intermediate elongate members 44. At a mid portion along the length of each elongate member 44, there is rigidly fixed a hub cover fastening member 45 whose role will be described more below.

[0039] A blade support sleeve 46 is rigidly fixed longitudinally along a distal end portion of a radially extending right side 48 of the triangular frame members 36. The blade support sleeve 46 is suitably sized to freely and slidably receive therein a pivot support pin 50 extending at the base end 52 of a wind blade 20 (as best shown in Fig. 13A to 13D). A protruding end of the pivot support pin 50, on the inner end 54 of the support sleeve 46, is fixedly coupled to one end of a radially extending blade actuating arm 56. In turn, the opposite distal end of the blade actuating arm 56 is fixedly coupled, through an eyelet screw 58 or the like, to a substantially circular belt 60 that links together the distal ends of each blade actuating arms 56 around the hub structure assembly 16. The circular belt 60 may be represented by a conventional stranded steel cable, a plurality of elongated solid steel stems chain-linked to one another, a suitably sized nylon cable, or the like. As shown in Fig. 11, at least one of the support sleeve 46 assembly around the hub structure assembly 16 is further provided with an additional radially extending actuating arm 62 substantially configured at a right angle relative to the blade actuating arm 56 described above. This additional actuating arm 62 is, in turn, rigidly fixed to a shaft and coupling plate 64 extending inwardly toward the center of the hub structure 16. The shaft and coupling plate 64 serves as an attachment means for coupling an actuating device, typically an electro-hydraulic control device (not shown), for pivoting or twisting the wind blades 20 about their longitudinal axes 21. Thus, by actuating the shaft and coupling plate 64 such that the corresponding support pivot pin 50 is pivoted about its longitudinal axis 21, all the wind blades 20 around the hub structure assembly 16 are

also synchronously pivoted about their longitudinal axes 21 through the circular belt 60 and their actuating arms 56.

[0040] Fig. 13A shows a wind blade 20 having a substantially rectangular shape generally defined by longitudinal leading edge 66 and trailing edge 68, a tip end 70 and a base end 52. It is to be noted that the wind blade 20 is proportionally wider between the leading and trailing edges 66, 68, and proportionally shorter between the tip and bottom ends 70, 52 respectively, as compared to a conventional wind turbine blade of the prior art. Fig. 13D further shows the wind blade 20 having a substantially tear-drop shaped cross-section that is more closely resembling the cross-section of a conventional airplane wing than a typical wind turbine blade of the prior art, with a substantially convex top side 72 and a substantially concave, bottom side 74.

[0041] Furthermore, the trailing edge 68 of the blade preferably defines a continuous longitudinal curvature corresponding to a difference of roughly between 5 and 45 degree angle from the tip end 70 to the base end 52 relatively to the leading edge 66 of the wind blade 20 taken as a reference point. Hence, as is the case with conventional airplane wings, the relatively wide area of the blade, combined with the airplane wing-like cross-section of the top side 72 and bottom side 74 of the latter create a vacuum effect above the convex top side 72, and thus an air lift effect which, in turn, induces a rotation movement to the rotatable hub assembly 15.

[0042] At this point, it is important to note that the shape of the wind blades 20 is preferably optimized to maximize its load-bearing capability at low speed in order to provide adequate power even in low wind conditions. Hence, the wind blades 20 are generally not optimized for speed. In that sense, the shape of the wind blades 20 is generally akin to the shape of firefighting airplanes (e.g. a Canadair CL-415 airplane).

[0043] In operation within the wind turbine 10, the wind blades 20 are preferably oriented at an incidence angle relative to the general horizontal axis of the turbine 10 such that the bottom side 52 of the blade is generally oriented at an angle towards the upwind or front end of the wind turbine. In other word, the tip ends 70 of the wind blades are preferably slightly more downwind than the base ends 52. The slight angle in the wind blades 20 can be obtained, for example, by making the longitudinal axes

21 thereof slightly angled with respect to the plane of rotation of the hub assembly 15, or by making the leading edge 66 slightly angled with respect to the plan of rotation of the hub assembly 15.

5 [0044] Its has been found that angles smaller than 10° , generally smaller than 5° , preferably smaller than 1° and most preferably smaller than 0.5° , are particularly useful. Still, the skilled addressee will understand that the actual angle of the wind blades 20 would typically vary according to the particular size and configuration of the wind turbine 10. Hence, wind turbines 10 made in accordance with the present
10 invention are not limited to the angles recited above.

[0045] By being slightly angled with respect to the plane of rotation of the hub assembly 15, the wind blades 20 forces the incoming wind to flow toward the tip ends 70 of the wind blades 20. The force generated by the radial flow of wind induces the
15 wind turbine 10 to pivot, via rotation of the nacelle or of the support structure 12, to align itself with the direction of the incoming wind. Accordingly, the wind turbine 10 generally automatically aligns itself without external assistance. Moreover, due to the particular shape of the wind blades 20, the substantially automatic alignment of the wind turbine 10 functions even at low wind conditions.

20 [0046] Referring now to Figs. 13A to 13D, a pair of oppositely disposed base 50 and tip 76 pivot support pins are longitudinally extending from the base 52 and tip 70 ends of the blade 20, for pivotally mounting the latter between the hub structure assembly 16 and outer rim 24 respectively.

25 [0047] Outer rim 24 has a substantially funnel-shaped annular configuration and may be represented by an assembly of a plurality of arched modular segments 80, such as the one illustrated in Figs. 12A, 12B and 12C. Each arched modular segment 80 has a substantially V-shaped cross-section (as best illustrated in Fig. 12A) that is provided
30 with a plurality of reinforcement elements 82 suitably distributed along the arched length of the segment 80, and rigidly mounted at an inner mid portion between the two distal ends of the V-shaped cross-section. The distal edge portions 84, 86 of the modular segments 80 are provided with edge fastening means in the form of compatible overlapping edge configurations with a plurality of correspondingly

aligned through holes 88 for fastening the distal ends 84, 86 to one another using any suitable means such as, for example, bolts or rivets. It is to be understood that any other suitable edge configuration and fastening means may be used. As well, outer rim 24 may be manufactured as a one piece element made out of, for example, a sheet of metal using a conventional multi-stage punch press process, or a thermoplastic resin using a conventional injection molding process.

[0048] As shown in Fig. 7, a pair of correspondingly aligned holes 88 through the overlapping distal edge portions 84, 86 of two adjacent modular segments 80, and in cooperative relation with a spacer sleeve 90, serve as a blade support sleeve for pivotally receiving therein the upper portion of the pivot support pin 76 at the tip end 70 of a blade 20. The distal end of the pivot support pin 76 is secured therethrough by means of a screw 92 and washer 94 screwed in a threaded bore 96 provided at the distal end of the pin 76.

[0049] Once the modular segments 80 are assembled into an outer rim 24, a relatively rectilinear portion 100 of the V-shaped cross-section of the modular segment 80 defines a substantially cylindrical portion 106 axially centered on the horizontal axis 33 of the wind turbine 10, while the opposite and lightly outwardly curved distal end 102 of the V-shaped cross-section generally defines the flared portion 108 of the funnel-shaped outer rim 24.

[0050] As best illustrated in Fig. 1, the funnel-shaped outer rim 24 is disposed such that the flared portion 108 is oriented towards the upwind end of the wind turbine 10, which causes the incoming wind hitting the rim 24 to converge primarily towards the tip end 70 of the wind blades 20 and, thus, further raises the efficiency of the blades 20. The outer rim 24 also inhibits the formation of vortices and, thus, the loss of load-bearing capability at the tip end 70 of the blades 20.

[0051] Figs. 14A to 14D show various aspects of a front hub cover 14 that is configured to cover the upwind end 26 of the hub structure assembly 16. Front hub cover 14 has a hemispheric portion 110 adjoined to a relatively shorter, cylindrical portion 112. Proximal the distal peripheral edge 114 of the cylindrical portion 112 there is provided a plurality of fastening through holes 116 equidistantly disposed

around the cylindrical portion 112 for fastening the front hub cover 14 to the hub cover fastening members 45 provided around the hub structure assembly 16 described above. Extending through the distal peripheral edge 114 of the cylindrical portion 112, and alternatively disposed relative to the through holes 116, there is provided a plurality of substantially half circular indentations 118 that are in register with a corresponding half diametrical portion of the pivot support pins 50 at the base of the wind blades 20.

[0052] As best illustrated in Figs. 5 and 6, a through hole 120 is provided at a suitable position through the hemispherical portion 110 of the cover for allowing a distal end of the support structure 12 to be rigidly fastened to and support an electrical power generating means (not shown) concealed within the cavity 122 of the front hub cover 14 and which, in turn, supports the rotatable hub structure assembly 16 of the wind turbine 10 through a horizontally extending power transmission shaft (not shown).

[0053] Furthermore, the hemispherical portion 110 being fixed relative to the support structure 12, the cylindrical portion 112 is rotatable relative to the hemispherical portion 110 through, for example, a thrust roller bearing element, or the like, provided at the annular junction 124 between the two portions 110 and 112 of the front hub cover 14.

[0054] It is to be noted that the substantially large front hub cover 14, relative to the size of the surrounding wind blades 20, forces the incoming wind hitting the front cover 14 to converge primarily toward the base end 52 of the blades 20 and, thus, confers a significant improvement in the overall efficiency of the wind turbine 10.

[0055] Figs. 15A to 15D show various aspects of a rear hub cover 18 that is configured to cover the downwind end 28 of the hub structure assembly 16. Rear hub cover 18 has a conically-shaped portion 130 adjoined to a relatively shorter, cylindrical portion 132. Likewise the front hub cover 14, proximal the distal peripheral edge 134 of the cylindrical portion 132 there is provided a plurality of fastening through holes 136 equidistantly disposed around the cylindrical portion 132 for fastening the rear hub cover 18 to the hub cover fastening members 45 provided around the hub structure assembly 16 described above. Extending through the distal

peripheral edge 134 of the cylindrical portion 132, and alternatively disposed relative to the through holes 136, there is provided a plurality of half circular indentations 138 that are in register with a corresponding half diametrical portion of the pivot support pins 50 at the base of the wind blades 20. Thus, with the front and rear hub covers 14 and 18 rigidly fastened to the hub cover fastening members 45 around the hub structure assembly 16, using screws, rivets or the like, the diametrically opposed half-circular indentations 118 and 138 allows the covers to provide a substantially uniform covering surface that surround each pivot support pins 50 at the base end 52 of the wind blades 20. Unlike the front hub cover 14, the conically shaped portion 130 of the rear hub cover 18 is generally fixed relative to its cylindrical portion 132.

[0056] The various components of the wind turbine 10 described above are constructed of durable corrosion resistant materials. Preferably, the wind blades 20 are advantageously manufactured as a polyester shell, using a rotational moulding process, injected with high density polyurethane. Still, depending on the actual size of the wind turbine 10, other suitable materials could be used; the present invention is not so limited.

[0057] Additionally to the adjustable pitch of the wind blades 20, it is to be noted that their number and width can be varied to maximize the efficiency of the wind turbine 10 depending on the average wind conditions of the area.

[0058] While illustrative and presently preferred embodiments of the invention have been described in detail hereinabove, it is to be understood that the inventive concepts may be otherwise variously embodied and employed and that the appended claims are intended to be construed to include such variations except insofar as limited by the prior art.

Claims

- 1) A wind turbine of a downwind type comprising at an upwind end, a nacelle mounted to a support structure, and at a downwind end, a rotatable hub assembly coupled to said nacelle, said hub assembly comprising a hub, an annular outer rim, and a plurality of wind blades radially extending between said hub and said rim, said wind blades being pivotally mounted to said hub and said rim.
- 2) A wind turbine as claimed in claim 1, wherein said wind blades are at an angle with respect to a plane of rotation of said hub assembly.
- 3) A wind turbine as claimed in claim 1, wherein each of said wind blades comprises a leading edge and wherein at least one of said leading edges of said wind blades is at an angle with respect to a plane of rotation of said hub assembly.
- 4) A wind turbine as claimed in claim 1, wherein each of said wind blades comprises a leading edge, said leading edges extending in a radial direction and in an axial direction with respect to an axis of rotation of said hub assembly such that said leading edges are at an angle with respect to a plane of rotation of said hub assembly.
- 5) A wind turbine as claimed in claim 4, wherein said leading edges extend axially in a downwind direction.
- 6) A wind turbine as claimed in claim 5, wherein said angle is smaller than 10°.
- 7) A wind turbine as claimed in claim 5, wherein said angle is smaller than 5°.
- 8) A wind turbine as claimed in claim 5, wherein said angle is smaller than 1°.
- 9) A wind turbine as claimed in claim 5, wherein said angle is smaller than 0.5°.

- 10) A wind turbine as claimed in claim 1, wherein each of said wind blades comprises a base end proximate to said hub and a tip end proximate to said outer rim, and wherein said tip ends of said wind blades are located more downwind than said base ends of said wind blades.
- 5
- 11) A wind turbine as claimed in claim 1, wherein each of said wind blades comprises a base end proximate to said hub, a tip end proximate to said outer rim, and a leading edge extending between said base end and said tip end, and wherein said leading edges is more downwind as they extend toward said tip ends of said wind blades.
- 10
- 12) A wind turbine as claimed in claim 1, wherein said outer rim comprises, at an upwind end, a first annular portion, and at a downwind end, a second annular portion, said first annular portion being substantially flared.
- 15
- 13) A wind turbine as claimed in claim 12, wherein said outer rim comprises a plurality of arcuate segments mounted together.
- 14) A wind turbine as claimed in claim 13, wherein at least one of said arcuate segments comprises at least one reinforcing element.
- 20
- 15) A wind turbine as claimed in claim 1, wherein each of said wind blades comprises a base end proximate to said hub, a tip end proximate to said outer rim, a substantially straight leading edge extending radially between said base end and said tip end, and a substantially curved trailing edge extending radially between said base end and said tip end, said base end, tip end, leading edge and trailing edge defining a first substantially convex surface and a second substantially concave surface.
- 25
- 16) A wind turbine as claimed in claim 15, wherein said convex surfaces and said concave surfaces are shaped such that when incoming wind hits said wind blades, said convex surfaces of said wind blades generate lift which induces rotation of said hub assembly.
- 30

- 17) A wind turbine as claimed in claim 1, wherein each of said wind blades is adapted to pivot about a respective longitudinal axis.
- 18) A wind turbine as claimed in claim 17, wherein said wind blades respectively
5 comprise actuating means for inducing rotation of said wind blades about said respective longitudinal axis.
- 19) A wind turbine as claimed in claim 18, wherein said actuating means are interconnected such that rotation of one of said wind blades induces rotation of
10 all the other of said wind blades.
- 20) A wind turbine as claimed in claim 1, wherein said nacelle comprises, at an upwind end, a round portion.
- 15 21) A wind turbine as claimed in claim 1, wherein said hub comprises, at a downwind end, a conical portion.
- 22) A wind turbine as claimed in claim 1, wherein at least one of said wind blades is made of a polyester shell injected with high density polyurethane.
- 20 23) A wind turbine as claimed in claim 1, wherein said support structure is pivotally mounted to a base.
- 24) A wind turbine of a downwind type comprising at its upwind end, a nacelle
25 mounted to a support structure, and at its downwind end, a rotatable hub assembly coupled to said nacelle, said hub assembly comprising a hub, an outer rim, and a plurality of wind blades radially extending between said hub and said outer rim and pivotally mounted to said hub and said outer rim, said nacelle having, at its upwind end, a round portion, and said outer rim having,
30 at its upwind end, a flared portion, whereby when incoming wind hits said round portion of said nacelle and said flared portion of said outer rim, said wind is deflected toward said wind blades.

- 25) A wind turbine as claimed in claim 24, wherein said wind blades are at an angle with respect to a plane of rotation of said hub assembly.
- 26) A wind turbine as claimed in claim 24, wherein each of said wind blades comprises a leading edge, said leading edges extending in a radial direction and in an axial direction with respect to an axis of rotation of said hub assembly such that said leading edges are at an angle with respect to a plane of rotation of said hub assembly.
- 27) A wind turbine as claimed in claim 26, wherein said leading edges extend axially in a downwind direction.
- 28) A wind turbine as claimed in claim 27, wherein said angle is smaller than 10° .
- 29) A wind turbine as claimed in claim 27, wherein said angle is smaller than 5° .
- 30) A wind turbine as claimed in claim 27, wherein said angle is smaller than 1° .
- 31) A wind turbine as claimed in claim 27, wherein said angle is smaller than 0.5° .
- 32) A wind turbine as claimed in claim 24, wherein each of said wind blades comprises a base end proximate to said hub, a tip end proximate to said outer rim, a substantially straight leading edge extending between said base end and said tip end, and a substantially curved trailing edge extending between said base end and said tip end, said base end, tip end, leading edge and trailing edge defining a first substantially convex surface and a second substantially concave surface.
- 33) A wind turbine as claimed in claim 32, wherein said convex surfaces and said concave surfaces are shaped such that when incoming wind hits said wind blades, said convex surfaces of said wind blades generate lift which induces rotation of said hub assembly.

- 34) A wind turbine as claimed in claim 24, wherein at least one of said wind blades is made of a polyester shell injected with high density polyurethane.
- 35) A wind turbine as claimed in claim 24, wherein said support structure is pivotally mounted to a base.
- 36) A wind turbine of a downwind type comprising at its upwind end, a nacelle mounted to a support structure, and at its downwind end, a rotatable hub assembly coupled to said nacelle, said hub assembly comprising a hub, an outer rim, and a plurality of wind blades radially extending between said hub and said outer rim and pivotally mounted to said hub and said outer rim, each of said wind blades comprising a base end proximate to said hub, a tip end proximate to said outer rim, a substantially straight leading edge extending between said base end and said tip end and at an angle with respect to a plane of rotation of said hub assembly, and a substantially curved trailing edge extending between said base end and said tip end, said base end, tip end, leading edge and trailing edge defining a first substantially convex surface and a second substantially concave surface,
- wherein said nacelle comprises, at its upwind end, a round portion and wherein said outer rim comprises, at its upwind end, a flared portion, whereby when incoming wind hits said round portion of said nacelle and said flared portion of said outer rim, said wind is deflected toward said wind blades.
- 37) A wind turbine as claimed in claim 36, wherein said leading edges extend in a radial direction and in an axial direction with respect to an axis of rotation of said hub assembly such that said leading edges are at said angle with respect to said plane of rotation of said hub assembly.
- 38) A wind turbine as claimed in claim 37, wherein said leading edges extend axially in a downwind direction.
- 39) A wind turbine as claimed in claim 38, wherein said angle is smaller than 10°.
- 40) A wind turbine as claimed in claim 38, wherein said angle is smaller than 5°.

41) A wind turbine as claimed in claim 38, wherein said angle is smaller than 1°.

42) A wind turbine as claimed in claim 38, wherein said angle is smaller than 0.5°.

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43) A wind turbine as claimed in claim 36, wherein at least one of said wind blades is made of a polyester shell injected with high density polyurethane.

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44) A wind turbine as claimed in claim 36, wherein said support structure is pivotally mounted to a base.

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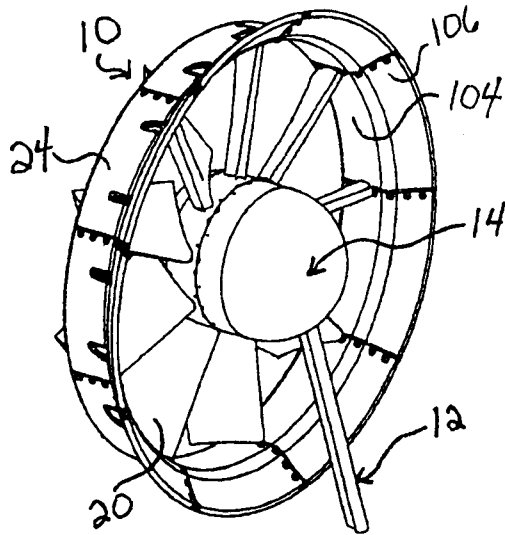


FIG. 1

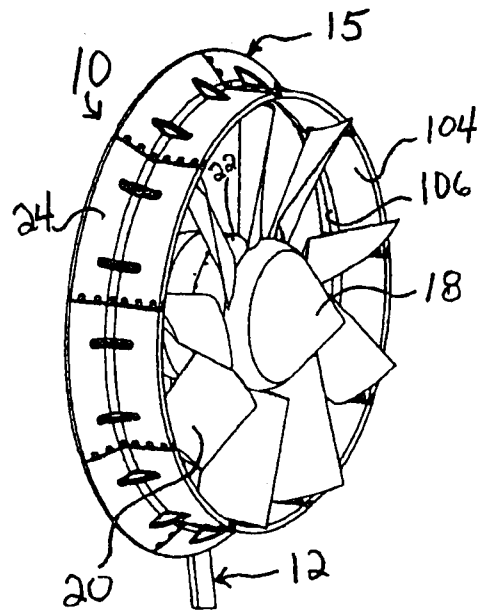


FIG. 2

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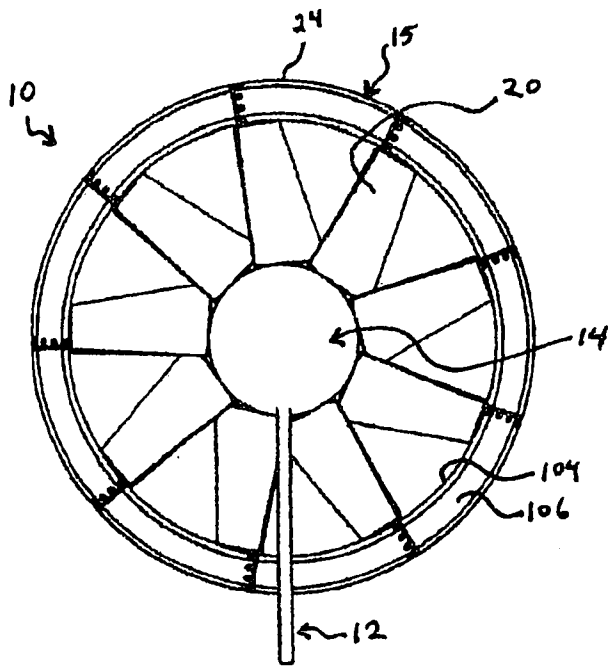


FIG. 3

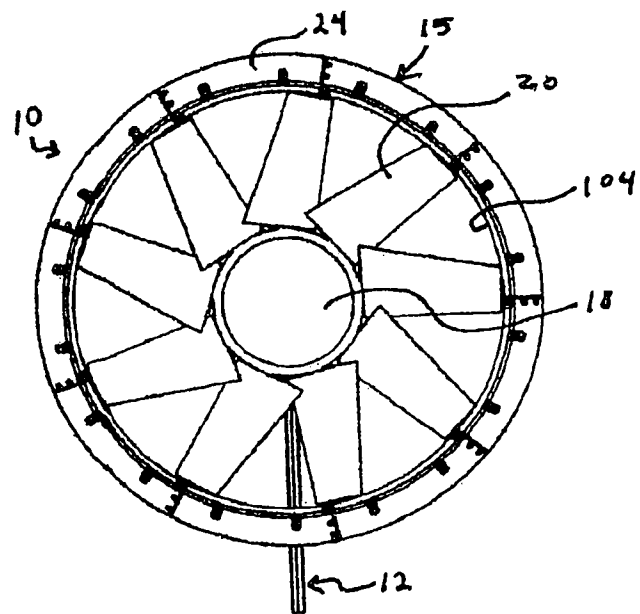


FIG. 4

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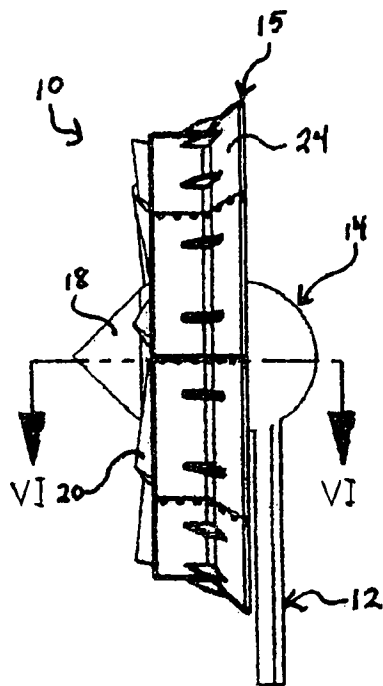


FIG. 5

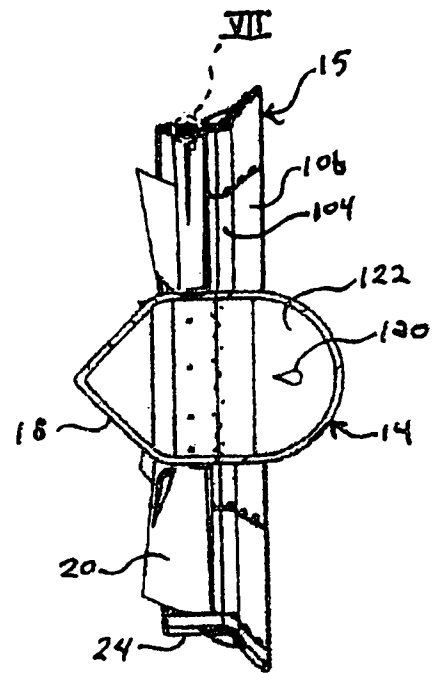


FIG. 6

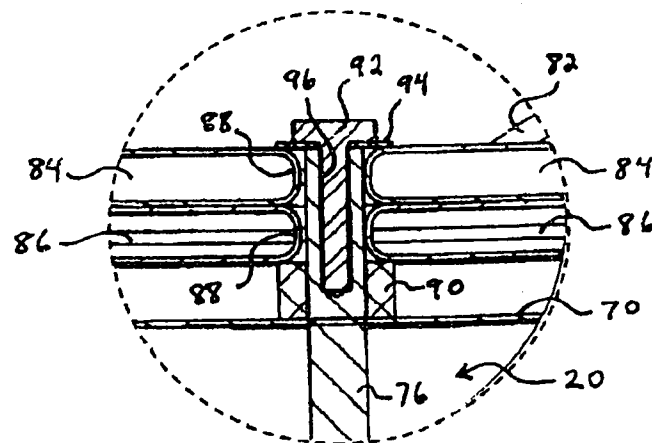


FIG. 7

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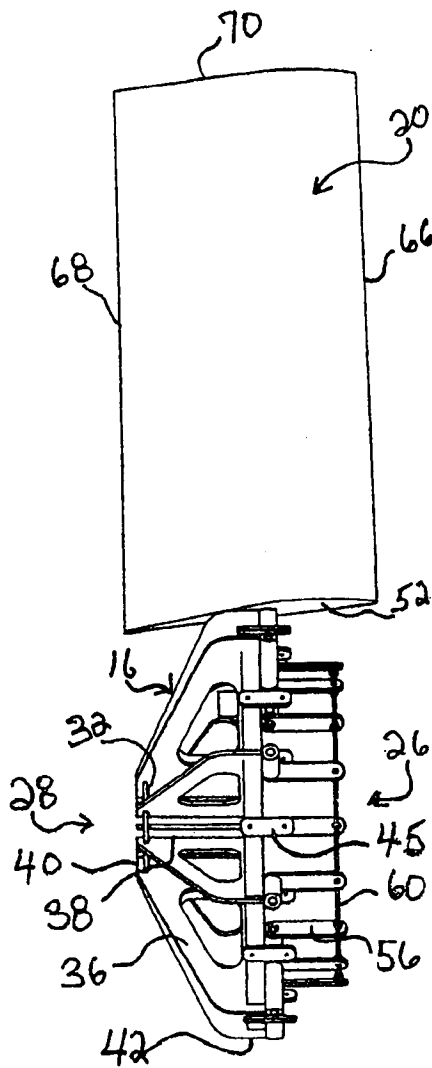


FIG. 8

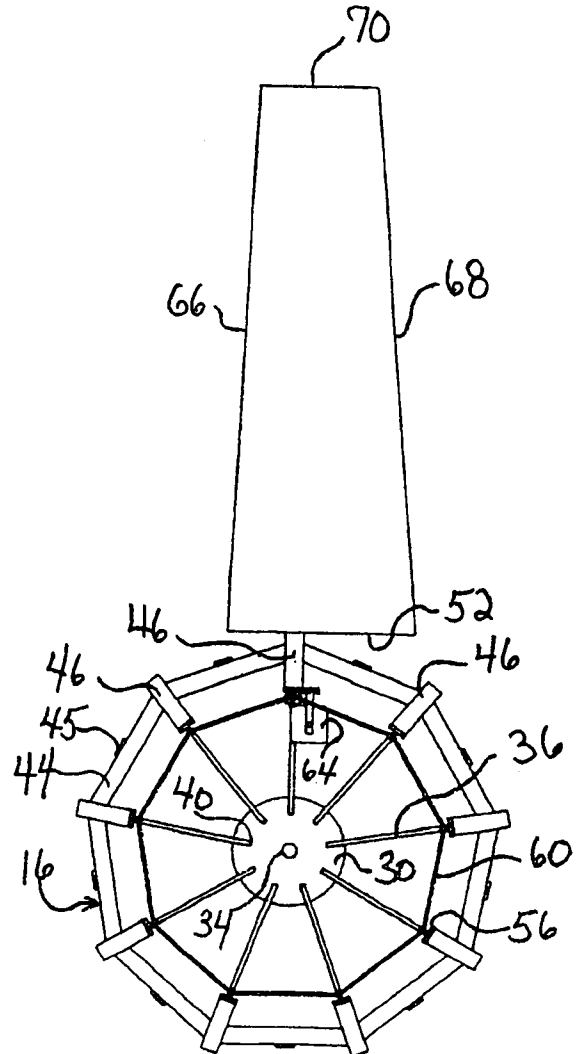
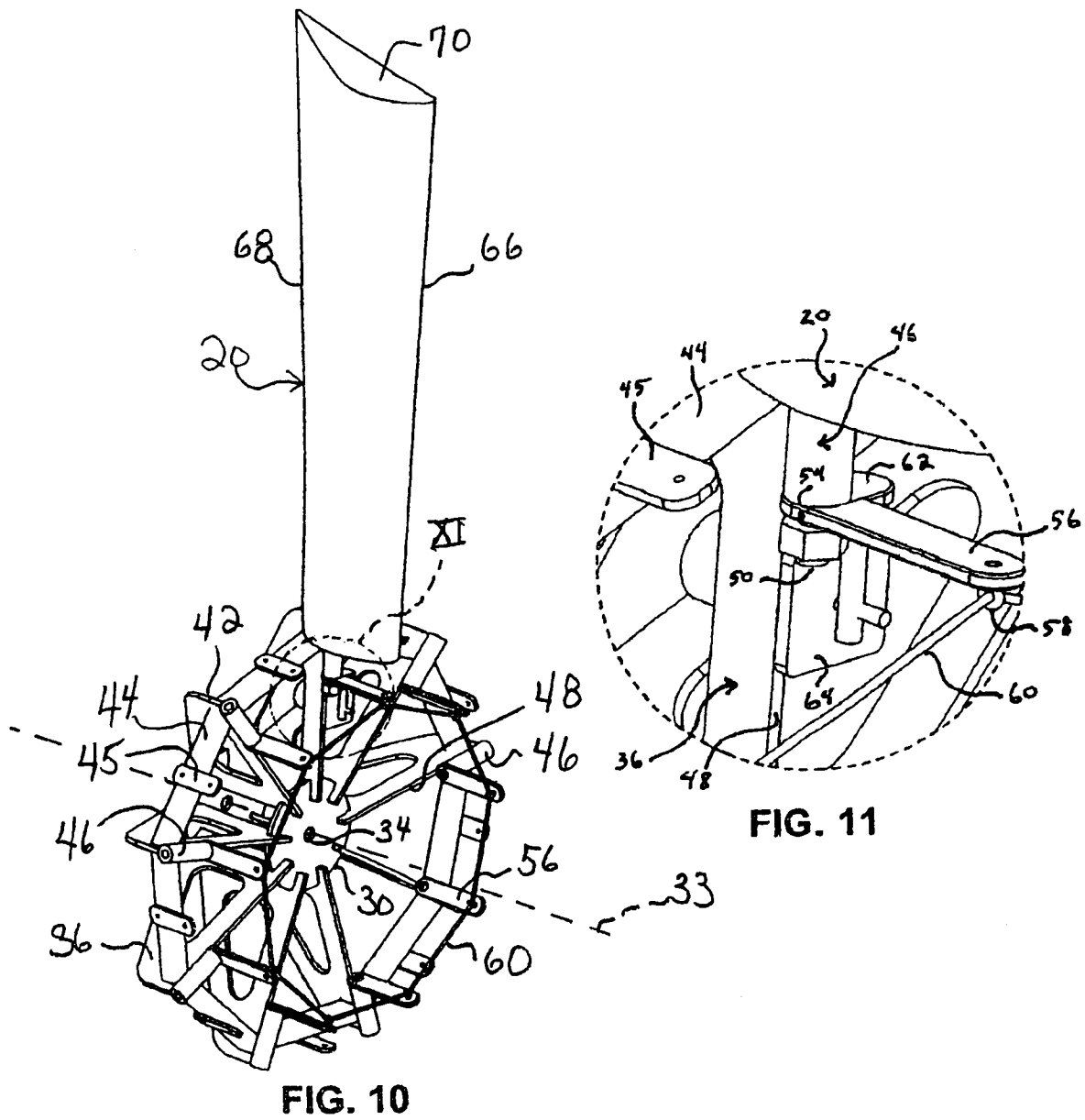


FIG. 9

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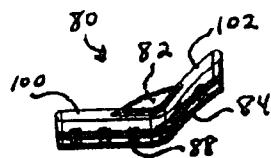


FIG. 12A

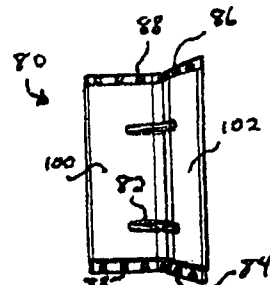


FIG. 12B

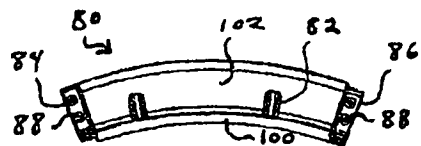


FIG. 12C

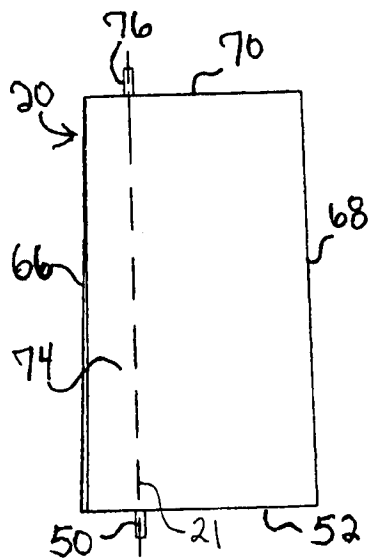


FIG. 13A

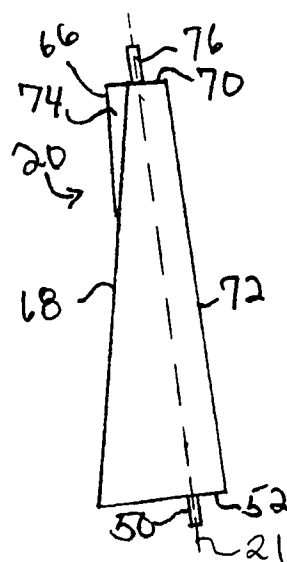


FIG. 13B



FIG. 13C

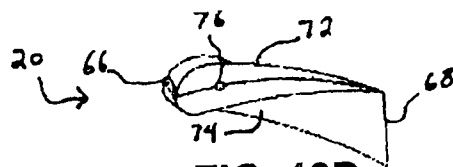


FIG. 13D

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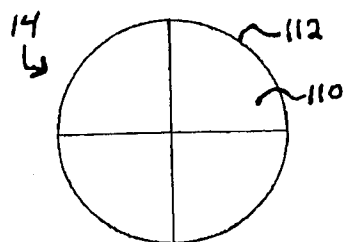


FIG. 14A

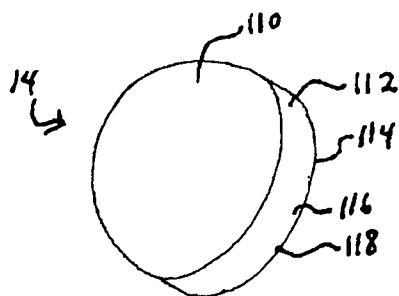


FIG. 14B

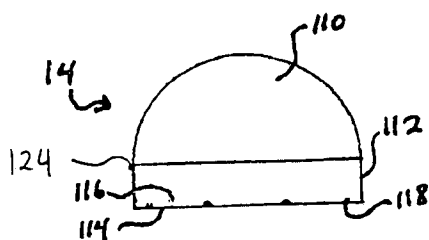


FIG. 14C

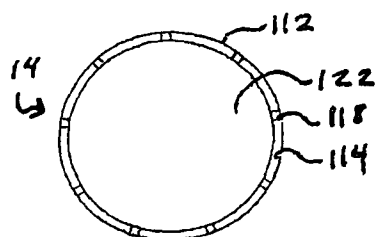


FIG. 14D

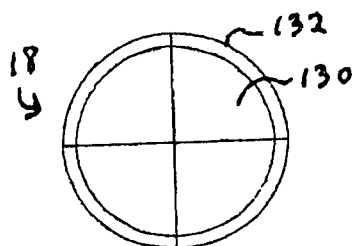


FIG. 15A

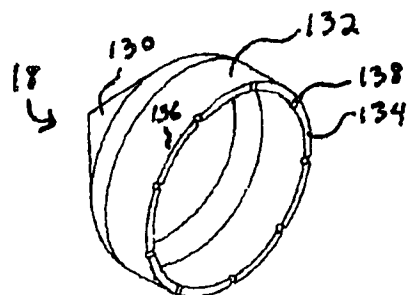


FIG. 15B

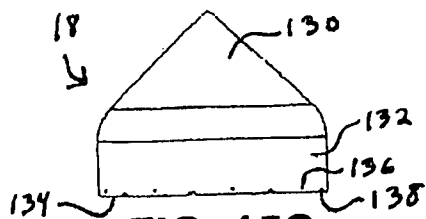


FIG. 15C

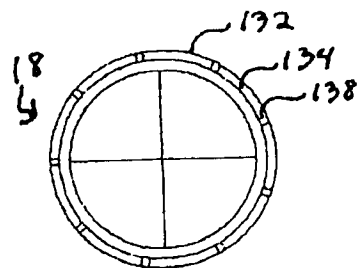


FIG. 15D

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CA2009/000769

A. CLASSIFICATION OF SUBJECT MATTER IPC: F03D 1/06 (2006.01) , F03D 1/00 (2006.01) , F04D 29/36 (2006.01) 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) IPC: F03D, F04D USCL: 415, 416, 290 CCL: 170, 230		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic database(s) consulted during the international search (name of database(s) and, where practicable, search terms used) WEST, Delphion, Espacenet, QPAT, CPD keywords: wind, turbine, horizontal, rim, shroud, wing, teardrop, convex, concave, downwind, pitch		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 821 162 A1 (McCABE, F.) 28 January 1998 (28-01-1998) * Whole document *	1-44
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☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family	
Date of the actual completion of the international search 15 September 2009 (15-09-2009)	Date of mailing of the international search report 18 September 2009 (18-09-2009)	
Name and mailing address of the ISA/CA Canadian Intellectual Property Office Place du Portage I, C114 - 1st Floor, Box PCT 50 Victoria Street Gatineau, Quebec K1A 0C9 Facsimile No.: 001-819-953-2476	Authorized officer Gilbert Plouffe (819) 997-9811	

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International application No.
PCT/CA2009/000769

C (Continuation). 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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A	US 5080553 A1 (ARMEL, L.) 14 January 1992 (14-01-1992) * Whole document *	1-44

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Information on patent family members

International application No.
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