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(54) **WIND TURBINE COMPRISING ELASTICALLY FLEXIBLE ROTOR BLADES**

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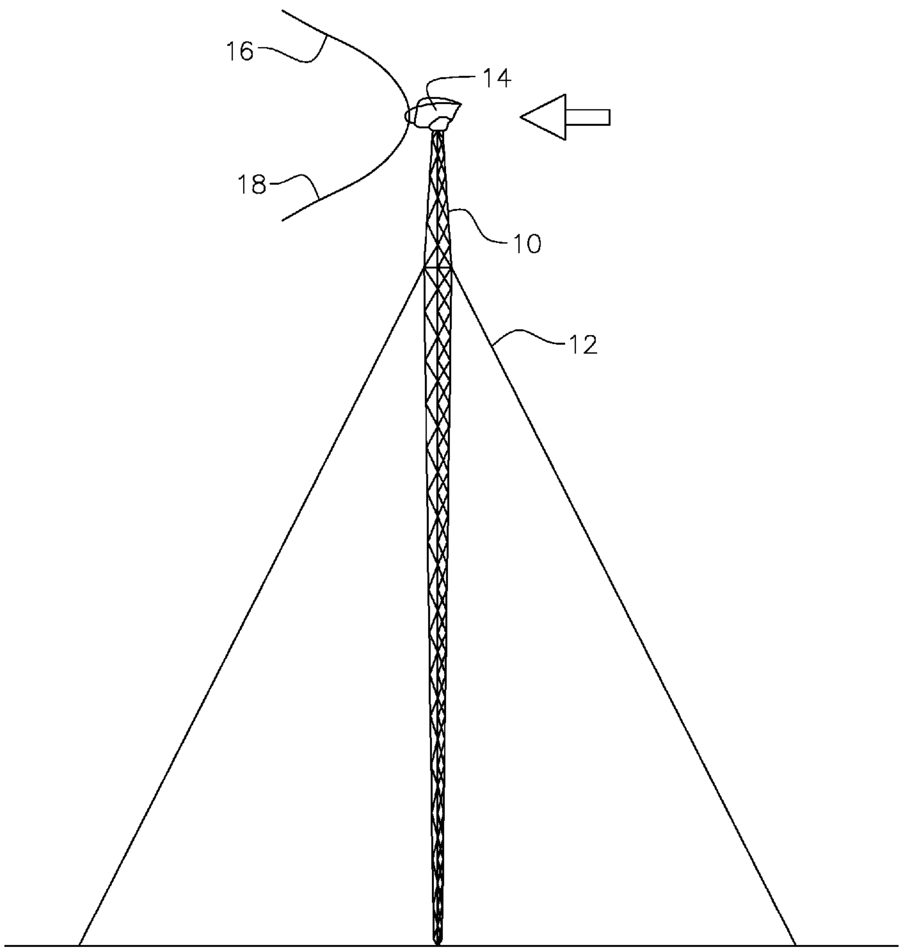
(57) **ABSTRACT**

The invention relates to a wind turbine having a tower, a nacelle that is mounted on the tower and can be rotated about the axis of the tower, and a rotor which is carried by the nacelle on the lee side and having at least one rotor blade. The flexural strength of the at least one rotor blade permitting the elastic flexure of said blade by more than half of its extension and allowing deflection by more than two thirds of its total length.



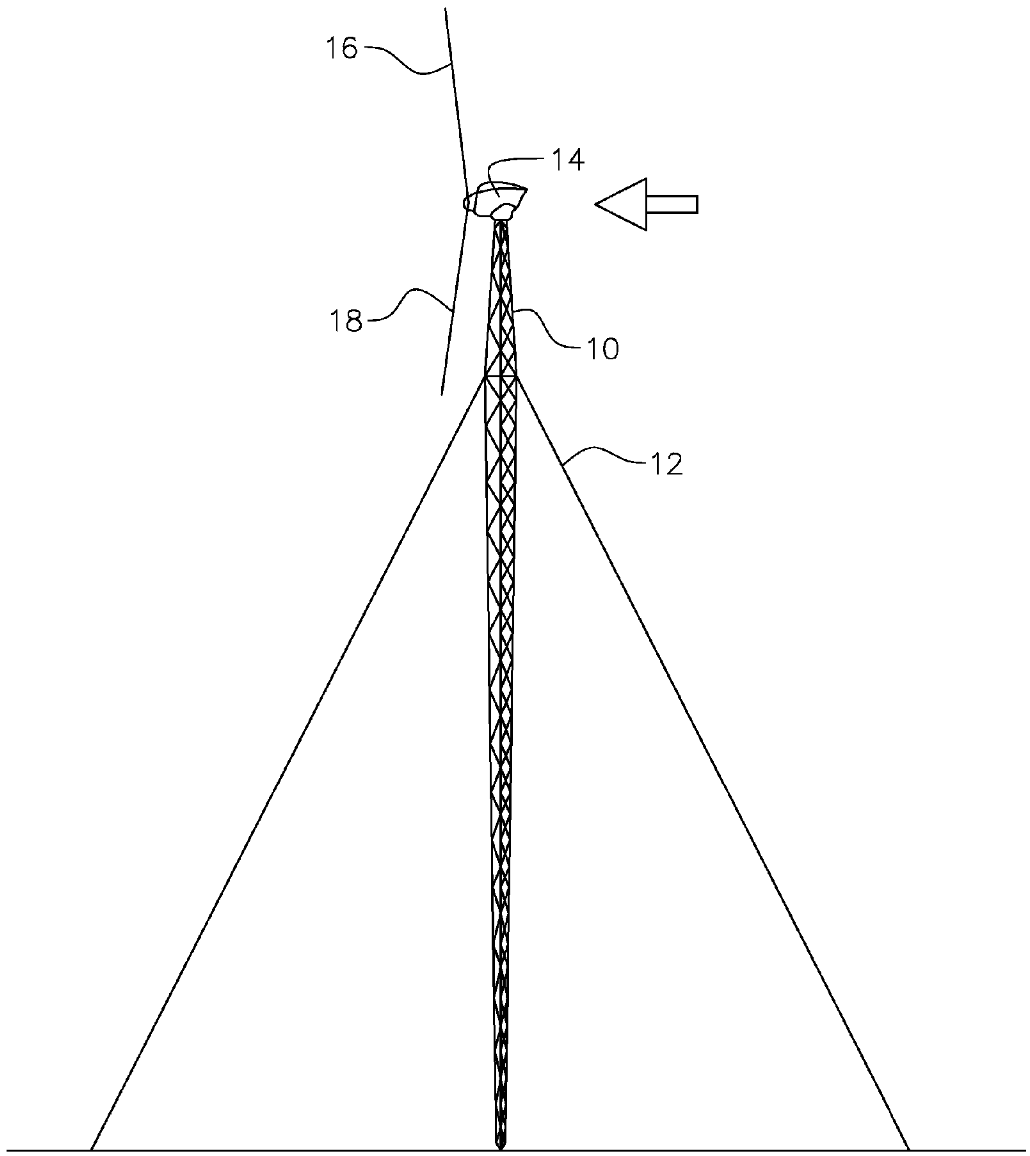


FIG. 1

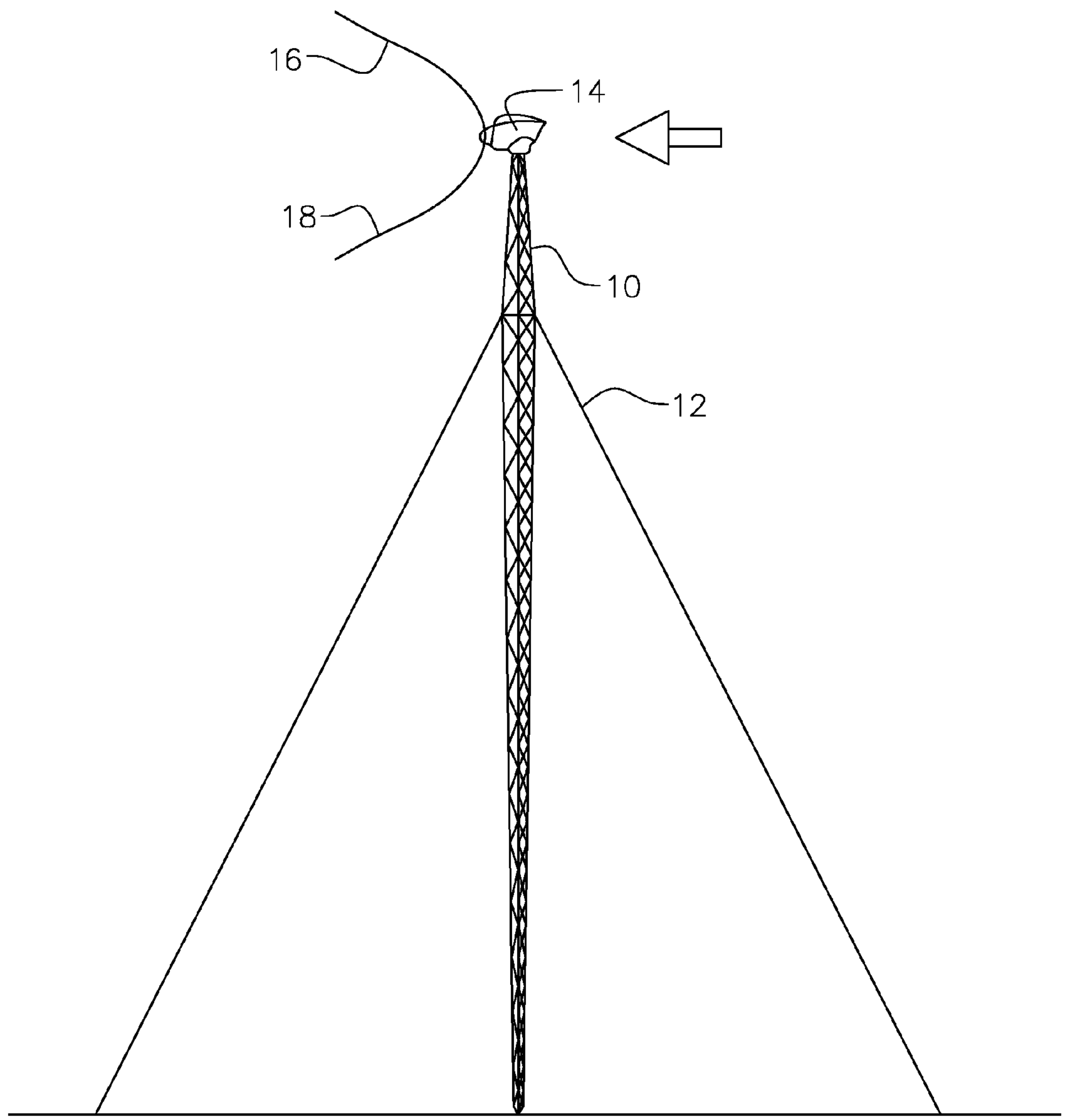


FIG. 2

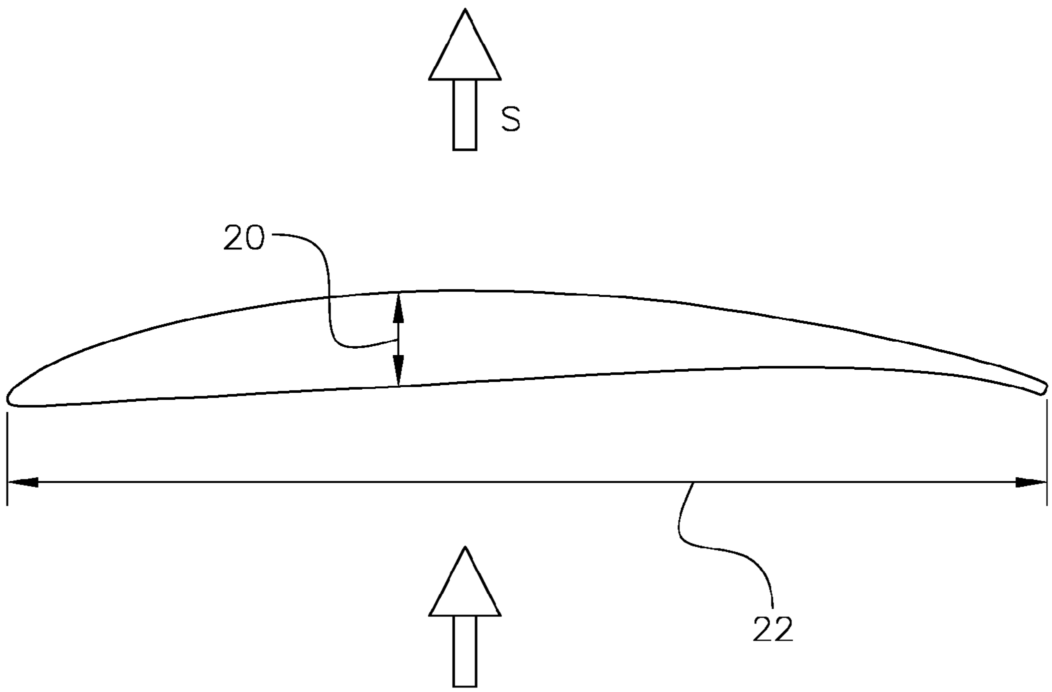
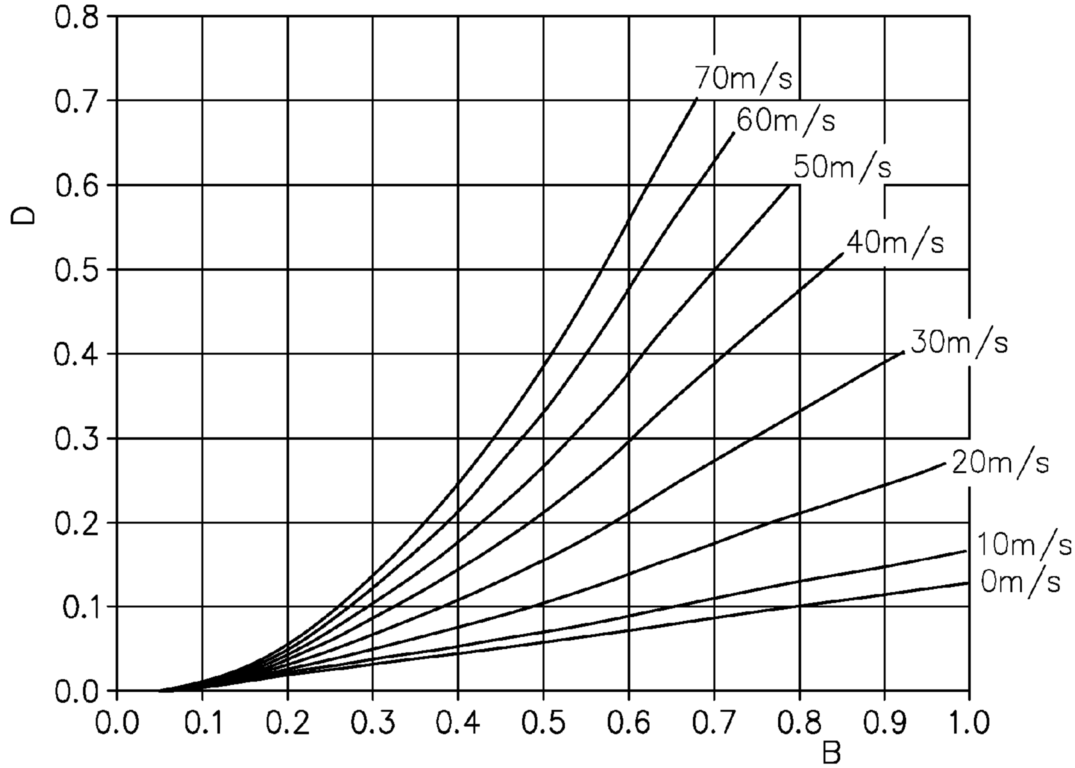


FIG. 3



D
B
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
70m/s
60m/s
50m/s
40m/s
30m/s
20m/s
10m/s
0m/s

Fig. 4

WIND TURBINE COMPRISING ELASTICALLY FLEXIBLE ROTOR BLADES

PRIOR APPLICATIONS

[0001] This application is a continuation-in-part of International Application No. PCT/DE2005/001547, filed on Sep. 5, 2005, which in turn bases priority on German Application No. 10 2004 045 401.9, filed on Sep. 18, 2004.

BACKGROUND OF THE INVENTION

[0002] 1. Field of Invention

[0003] The invention relates to a wind turbine having a tower, a nacelle mounted on the tower and rotatable about its axis, and a rotor having at least one rotor blade mounted in a rotary manner in the nacelle, and rotating on the lee side relative to the tower.

[0004] 2. Description of the Prior Art

[0005] Over the last few decades, wind power technology has developed very dynamically, relating only from average size to very large turbines for main parallel operation. However, there have been no advances in the last twenty years in the development of small power systems in the kilowatt range. Therefore, the turbines are still very expensive and have, consequently, not entered the market. Wind power use could play an important part in supplying two billion people without access to electricity. For such cases, there is a great need for turbines with a power level of 1 to 10 kW, but these must be extremely robust, inexpensive, easy to erect and largely maintenance-free.

[0006] However, existing small turbines are unable to fulfill these requirements because they are too expensive and/or too fault-prone. A particular problem arises in that the turbines must be designed in such a way as to withstand extremely high wind forces (typhoons, hurricanes, etc.). The designed wind speeds are up to 70 meters per second. With such wind speeds, the turbine is decelerated and is at a standstill.

[0007] In order to achieve this, solutions are known in which the rotor blades are rotated about their longitudinal axis so as to reduce shear. In other turbine types the entire nacelle is rotated out of the wind with the aid of a wind vane or by a pivoting device in which the complete rotor is brought into helicopter mode. It is a common feature of all these solutions that they are expensive, and also fault-prone, so that they are unsuitable for more widespread use. The same applies with regards to turbines which have to absorb high, extreme loads using very rigid blades, and transfer the same to the overall turbine and into the foundation.

[0008] DE 298 80 145 U1 discloses a wind turbine with an elastically flexible rotor blade.

[0009] The problem of the invention is to provide a wind turbine of the aforementioned type, where limited loads are applied to the overall wind turbine structure due to wind pressure under extreme wind conditions.

SUMMARY OF THE INVENTION

[0010] According to the invention, this problem is solved by the construction of the at least one rotor blade with a flexural strength of the blade profile in the force application direction, allowing the elastic deflection of the rotor blade by more than half its total length. In a preferred embodiment, the flexural strength of the rotor blade permits the deflection by more than twice its length.

[0011] It is particularly advantageous to have a fixed attachment of the rotor blade to the hub without any adjustability by means of bearings or joints, so that fault-proneness is minimized.

[0012] As a result of this pronounced deflection there is, firstly, a considerable decrease in the projected wind application surface, and secondly, the resistance coefficient is significantly reduced as a result of the pronounced outward curvature of the blades associated with the flexure or deflection. As a result of these two effects, under extreme wind conditions the wind shear on the entire turbine can be reduced by half compared with those turbines using rigid blades. This economized materials for the load-transferring components, such as the rotor shaft, machine casing, vertical bearing, tower, anchoring and foundation, so that the total turbine production costs are significantly decreased.

[0013] The considerable deflection is made possible by the use of thin aerodynamic profiles in conjunction with the use of high strength materials, and at the same time a low modulus of elasticity. Thus, even in the case of pronounced deflections, the permitted material stresses and strains are not exceeded. The preferably used relative profile thickness, i.e. the ratio of the absolute profile thickness to the absolute profile depth, is between 0.05 and 0.15.

[0014] In a preferred embodiment, the profile thickness and profile depth are constant over the entire blade length. This development makes it possible for the at least one rotor blade to be an extruded fiber composite profile. If the fiber composite material is a glass fiber plastic composite, the requirement for high strength and, at the same time, relatively low modulus of elasticity is fulfilled.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] Further features and advantages of the present invention can be gathered from the following descriptions of the preferred embodiment with reference to the attached drawings, wherein:

[0016] FIG. **1** shows a side view of the wind turbine comprising elastically flexible rotor blades with the rotor in a non-bent position and the wind direction indicated by an arrow.

[0017] FIG. **2** shows a side view of the embodiment of FIG. **1** with the wind turbine in a decelerated state and the rotor blades in a bent position from extreme winds.

[0018] FIG. **3** shows an exploded view of the rotor blade in an extruded position directed by the wind force indicated by the letter S.

[0019] FIG. **4** shows a diagrammatic representation of the deflection rate of the rotor blade at different wind speeds.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0020] FIG. **1** illustrates the wind power turbine with tower **10** and tower anchor **12**. The nacelle **14** is mounted so as to rotate about the axis of tower **10**. In nacelle **14** is mounted the rotor **16**, which rotates on the lee side, i.e. on the side of tower **10** that is remote from the wind. When the rotor **16** is stationary because of limited wind conditions, and with the turbine operating, the blades are not or only slightly deflected. The blades are fitted to the hub with a cone angle, i.e. a tilted arrangement in the wind direction, so that when the turbine is operating the centrifugal forces and wind shear forces are such that there are roughly no bending movements on the blade root. For wind speeds above the cut-out speed, the turbine is decelerated and brought to a standstill.

[0021] As illustrated in FIG. **2**, the wind power turbine of FIG. **1** is shown in the decelerated state under extreme wind speeds. As a result of the wind shear, the blades are deflected by more than two thirds of their total length. As a result of this pronounced deflection, the wind load is significantly reduced because the wind application surface is reduced. In addition, the resistance coefficient of the profile is decreased compared with the flow direction due to the marked inclination of the blade.

[0022] FIG. **3** illustrates a thin aerodynamic profile of the rotor blade with a relative profile thickness of approximately 8%, i.e. the value of the greatest profile thickness **20** relative to the profile depth **22** is 0.08. As a result, the profile cross-section has a limited rigidity in the force application direction, and the wind loading can significantly bend the blade in the force application direction.

[0023] As illustrated in FIG. **4**, the deflection of the flexible rotor blade is determined by the prevailing wind speed. The flexural strength is chosen in such a way that at wind speeds of 70 meters per second, it allows an elastic deflection of the blades of 70% of the total blade length.

Having thus described the present invention in the detailed description of the preferred embodiment, what is desired to be obtained in Letters Patent is:

1-7. (canceled)

8. A wind turbine having a tower, a nacelle located on the tower and rotatable about its axis, and a rotor having at least one rotor blade rotating on the lee side and carried by the nacelle by a hub, the wind turbine comprising:

a) the at least one rotor blade firmly connected to the hub and fabricated from a high strength material having a low modulus of elasticity thereby giving the at least one rotor blade a flexural strength for allowing their elastic flexure by more than half a total length of said at least one rotor blade and a constant profile thickness and profile depth over said total blade length.

9. The wind turbine of claim 8, wherein the flexural strength of the at least one rotor blade allows for deflection thereof by more than two-thirds of the total length of said at least one rotor blade.

10. The wind turbine of claim 8, wherein the constant profile thickness of said total blade length of said at least one rotor blade has a relative profile thickness between 5% and 15%.

11. The wind turbine of claim 8, wherein the at least one rotor blade is made from an extruded composite fiber profile.

12. The wind turbine of claim 11, wherein the at least one rotor blade is an extruded profile of fiber glass-reinforced plastic.

13. The wind turbine of claim 8, wherein the at least one rotor blade comprises two rotor blades disposed in outwardly opposed directions from said hub.

14. The wind turbine of claim 8, wherein the at least one rotor blade comprises more than two rotor blades disposed in outwardly directions from said hub.

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