(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
27 March 2008 (27.03.2008)

PCT

(10) International Publication Number
WO 2008/035149 A2

(51) International Patent Classification: Not classified

(21) International Application Number: PCT/IB2007/001458

(22) International Filing Date: 26 February 2007 (26.02.2007)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
1031223 23 February 2006 (23.02.2006) NL

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(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LV, LY, MA, MD, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
- *without international search report and to be republished upon receipt of that report*
- *the filing date of the international application is within two months from the date of expiration of the priority period*

WO 2008/035149 A2

(54) Title: ROTOR BLADE FOR A WIND TURBINE

(57) Abstract: A connector holder has a U-shaped frame and supports an internal connector-receiving part within the U-shaped frame. Guide pieces are provided that grip the ends of a connector and the cable to which the connector is attached. The connector-receiving part thereby floats inside of the U-shaped frame so as to be positioned accurately for mounting to an opposing connector.

Rotor blade for a wind turbine

The invention firstly relates to a rotor blade for a wind turbine, comprising a leading edge, a trailing edge, an upper low pressure surface and a lower high pressure surface, and having an inner root end for connection to a hub and a free outer tip end defining therebetween a rotor blade span.

In the production of environment-friendly energy wind turbines play an increasingly important role. However, it often occurs that wind turbines are prevented from being erected or are not allowed to operate at full power because of restrictive requirements with respect to the production of noise. An important source of noise in modern wind turbines is noise of the rotor blades induced by the air flow. Such rotor blade noise basically is caused by pressure fluctuations on the rotor blade lower and upper surfaces, which pressure fluctuations move along with the air flow over the trailing edge of the rotor blade, at which locations they radiate as noise (trailing edge noise). Such pressure fluctuations mainly are caused by the turbulent boundary layer on the rotor blade.

It is an object of the present invention to provide an improved rotor blade for a wind turbine of the type referred to above.

Thus, in accordance with the present invention, a rotor blade for a wind turbine of the present type is characterised by brush hairs positioned at, or in the immediate vicinity of, the trailing edge of the rotor blade.

It appears, that brush hairs positioned at, or in the immediate vicinity of, the trailing edge of the rotor blade substantially reduce the trailing edge noise of rotor blades. This noise reduction primarily is based on a diminishing of the discontinuity at the trailing edge of the rotor blade. Due to the finite flow resistance of the brush hairs pressure fluctuations are gradually equalised in the flow direction, as a result of which the trailing edge less effectively radiates noise.

Based on wind tunnel measurements noise reductions up to 10 dB are expected in a wide frequency range. Of course, the actual noise reduction will depend on a number of parameters, such as properties of the brush hairs, shape and dimensions of the rotor blade, number of revolutions of the rotor blade, etcetera.

In a first preferred embodiment the brush hairs are serially arranged along the trailing edge. In this aspect, "serially" means that the brush hairs substantially are arranged along a line. This line does not necessarily have to be a straight line (for example, when the rotor blade is twisted the trailing edge generally will not define a straight line, but a curved line).

Although it is possible, that the brush hair are arranged in a single series, it is also possible that the brush hairs are arranged in multiple series extending substantially in parallel to each other. Applying multiple series means, that at least one of said series cannot be positioned exactly at the trailing edge of the rotor blade, but will have to be positioned in the immediate vicinity thereof. However, it also might be possible that all series are positioned in the immediate vicinity without anyone being positioned exactly at the trailing edge of the rotor blade.

According to another embodiment of the rotor blade, the brush hairs are arranged in a number of separate bundles. Each bundle comprises a defined amount of brush hairs. It is not necessary that each bundle comprises the same amount of brush hairs. The bundles themselves again may be arranged serially along the trailing edge as defined above.

In a basic embodiment of the rotor blade according to the present invention the brush hairs are provided along substantially the entire extension of the trailing edge. This means, that brush hairs are provided along substantially the entire rotor blade span.

However, in accordance with another embodiment, the brush hairs are provided only over part of the rotor blade span, for example only over substantially the outer 30% of the rotor blade span.

From experiments it appeared that such outer 30% of the rotor blade span contributes the larger part of the noise generated by the rotor blade, and that providing the brush hairs only there already eliminates a major part of such noise.

With respect to the positioning of the brush hairs a number of parameters may be varied for obtaining an optimal result. For example, the brush hairs may extend substantially perpendicularly to the trailing edge.

It should be noted, that "perpendicularly to the trailing edge" should be considered at the respective local span-wise position of the rotor blade.

However, it is possible too that the brush hairs extend inclined relative to the trailing edge. For example the brush hairs may be inclined somewhat towards the outer tip end of the rotor blade to cope with a flow direction which is not perpendicularly to the trailing edge (e.g. due to centrifugal forces acting on the rotating rotor blade).

Further it is possible, that the brush hairs extend in parallel to one of the upper and lower surfaces of the rotor blade. Again, this applies with respect to the local extension of the upper and lower surfaces of the rotor blade (which may vary span-wise when the rotor blade is twisted).

In an alternative embodiment, however, the brush hairs are inclined relative to both the upper and lower surfaces of the rotor blade.

Whereas in a simple embodiment all brush hairs substantially are of equal length, it is also possible that the length of the brush hairs varies between the inner root end and the free outer tip end of the rotor blade. For example one may adopt an embodiment in which the length of the brush hairs increases from the inner root end towards the free outer tip end. Such an increase may be linearly, but also may occur in any other desired manner (to cope with the local flow characteristics at different span-wise positions along the rotor blade).

Further it is preferred that the brush hairs are sufficient flexible to adopt, during use of the rotor blade, a shape in correspondence with local air flow conditions. Generally this means, that the brush hair will have different positions in a rest position (rotor blade not active) and a working position (rotor blade active, that means rotating).

Yet another feature for influencing the noise-reducing effect of the brush hairs constitutes the choice of the cross-section of the brush hairs, which for example may be circular or non-circular.

It should be noted, that the distance between individual brush hairs should be such, that pressure fluctuations in the flow direction are gradually equalised, but a certain flow through the brush hairs is allowed for making possible such a pressure equalisation. Thus, the brush hairs should not constitute a complete seal.

For the construction of the rotor blade the brush hairs may be attached directly to the rotor blade. However, the production and maintenance of rotor blades in accordance with the present invention may be optimized when the brush hairs are attached to at least one strip member which, on its turn, is attached to the rotor blade. Such strip members may be prepared separately and may then be attached to the rotor blade. The preparation of such strip members then may occur at a different location than the location where the rotor blade is used (the location where the wind turbine is erected).

Preferably, such a strip member is releasably attachable to the rotor blade, allowing an easy disconnection for maintenance or replacement.

The brush hairs may be of a synthetic or natural nature.

The invention further relates to a strip member provided with brush hairs for application on a rotor blade according to the present invention.

Hereinafter the invention will be elucidated while referring to the drawing, in which embodiments thereof are illustrated.

Figure 1 shows in a frontal view a rotor blade of a wind turbine;

figure 2 shows, on a larger scale, and perspectively, a cross-section according to II-II in figure 1;

figure 3 shows a top plan view of an embodiment;

figure 4 shows a top plan view of another embodiment;

figure 5 shows a cross-section according to figure 2 of an embodiment;

figure 6 shows a cross-section according to figure 2 of another embodiment;

figure 7 shows a top plan view of yet another embodiment, and

figure 8 shows, on a still larger scale, a frontal view of the trailing edge section of yet another embodiment of a rotor blade.

Firstly referring to figure 1 a rotor blade 1 for a wind turbine is illustrated, comprising (with respect to the direction of rotation) a leading edge 2, a trailing edge 3, an inner root end 4 for connection to a hub 5 of the wind turbine and a free outer tip end 6. Between the inner root end 4 and free outer tip end 6 a rotor blade span S is defined. Further, referring to figure 2, the rotor blade 1 comprises an upper low pressure surface 7 and a lower high pressure surface 8.

Specifically referring to figure 2 the rotor blade 1 comprises brush hairs 9 positioned at, or in the immediate vicinity of, the trailing edge 3 of the rotor blade (these brush hairs are not illustrated in figure 1). In the embodiment of figure 2, said brush hairs 9 are serially arranged along the training edge 3. Although only one series of brush hairs 9 has been illustrated in figure 2, there also may be multiple series extending substantially in parallel to each other.

Figures 3 and 4 substantially show a top plan view in accordance with III in figure 2; in figure 3 an embodiment of a rotor blade 1 is illustrated in which all brush hairs 9 substantially are of equal length and extend substantially perpendicularly to the trailing edge 3. In the embodiment according to figure 4, however, the brush hairs 9 extend inclined relative to the trailing edge 9. Preferably the inclination is such, that the free ends of the brush hairs 9 are somewhat directed towards the free outer tip end 6 of the rotor blade 1 (which would be located at the top of figure 4, then).

Figure 5, which basically corresponds with the cross-section according to figure 2, illustrates that the brush hairs substantially extend in parallel to the lower surface 8 of the rotor blade 1. Consequently, the brush hairs 9 are inclined relative to the upper surface 7.

In the embodiment according to figure 6 the brush hairs 9 are inclined relative to both the upper and lower surfaces 7 and 8, respectively, of the rotor blade 1.

Figure 7 shows an embodiment of the rotor blade 1 in which the length of the brush hairs 9 varies between the inner root end and free outer tip end of the rotor blade 1.

For example, the length of the brush hairs 9 may increase from the inner root end 4 (bottom) towards the free outer tip end 6 (top).

In the embodiments illustrated the brush hairs 9 basically are provided along substantially the entire extension (span S) of the trailing edge (thus basically ranging from the inner root end 4 towards the free outer tip end 6). It is possible, however, that the brush hairs 9 are provided only over part of the rotor blade span S, for example only the outer 30% thereof as indicated by the hatched section in figure 1.

Figure 8 shows, on a much larger scale, a frontal view of the trailing edge section 3 which is provided with brush hairs 9 arranged in a number of separate bundles. In this schematic illustration each bundle comprises three brush hairs 9.

The provision of the brush hairs 9 at, or in the immediate vicinity of, the trailing edge 3 of the rotor blade 1 is helpful in reducing trailing edge noise. For obtaining such a function, it may be advisable that the brush hairs 9 are sufficiently flexible to adopt, during use of the rotor blade, a shape in correspondence with local air flow conditions.

It has not been shown in detail that the brush hairs may have different cross sections, for example a circular cross section or a non-circular cross section.

Whereas, in a very simple emebodiment, the brush hairs 9 are attached directly to the rotor blade, the brush hairs 9 also may be attached to at least one strip member 10 (indicated in dotted lines in figure 2) which, on its turn, is attached to the rotor blade 1, for example releasably attached. There may be only one such strip member 10 or a number of such strip members.

The specific choice of positioning of brush hairs and shapes and dimensions of such brush hairs depend from many parameters, such as, for example, expected wind velocities, number of revolutions and angle of incidence of the rotor blade. The choice should be such, that the brush hairs 9 do not have influence on the aerodynamic characterics of the rotor blades.

The invention is not limited to the embodiments described before, which may be varied widely within the scope of the invention as defined by the appending claims.

CLAIMS

1. Rotor blade for a wind turbine, comprising a leading edge, a trailing edge, an upper low pressure surface and a lower high pressure surface, and having an inner root end for connection to a hub and a free outer tip end defining there between a rotor blade span, **characterized by** brush hairs positioned at, or in the immediate vicinity of, the trailing edge of the rotor blade.

2. Rotor blade according to claim 1, wherein the brush hairs are serially arranged along the trailing edge.

3. Rotor blade according to claim 2, wherein the brush hairs are arranged in a single series.

4. Rotor blade according to claim 2, wherein the brush hairs are arranged in multiple series extending substantially in parallel to each other.

5. Rotor blade according to claim 1, wherein the brush hairs are arranged in a number of separate bundles.

6. Rotor blade according to any of the previous claims, wherein the brush hairs are provided along substantially the entire extension of the trailing edge.

7. Rotor blade according to any of the claims 1-5, wherein the brush hairs are provided only over part of the rotor blade span.

8. Rotor blade according to claim 7, wherein the brush hairs are provided only over substantially the outer 30% of the rotor blade span.

9. Rotor blade according to any of the previous claims, wherein the brush hairs extend substantially perpendicularly to the trailing edge.

10. Rotor blade according to any of the claims 1-8, wherein the brush hairs extend inclined relative to the trailing edge.

11. Rotor blade according to any of the previous claims, wherein the brush hairs extend in parallel to one of the upper and lower surfaces of the rotor blade.

12. Rotor blade according to any of the claims 1-10, wherein the brush hairs are inclined relative to both the upper and lower surfaces of the rotor blade.

13. Rotor blade according to any of the previous claims, wherein all brush hairs substantially are of equal length.

14. Rotor blade according to any of the claims 1-12, wherein the length of the brush hairs varies between the inner root end and the free outer tip end of the rotor blade.

15. Rotor blade according to claim 14, wherein the length of the brush hairs increases from the inner root end towards the free outer tip end.

16. Rotor blade according to any of the previous claims, wherein the brush hairs are sufficiently flexible to adopt, during use of the rotor blade, a shape in correspondence with local air flow conditions.

17. Rotor blade according to any of the previous claims, wherein the brush hairs have a circular cross section.

18. Rotor blade according to any of the claims 1-16, wherein the brush hairs have a non-circular cross section.

19. Rotor blade according to any of the previous claims, wherein the brush hairs are attached directly to the rotor blade.

20. Rotor blade according to any of the claims 1-18, wherein the brush hairs are attached to at least one strip member which, on its turn, is attached to the rotor blade.

21. Rotor blade according to claim 20, wherein the strip member is releasably attachable to the rotor blade.

22. Strip member provided with brush hairs, for application on a rotor blade according to claim 20 or 21.

23. Wind turbine provided with at least two rotor blades according to any of the claims 1-21.

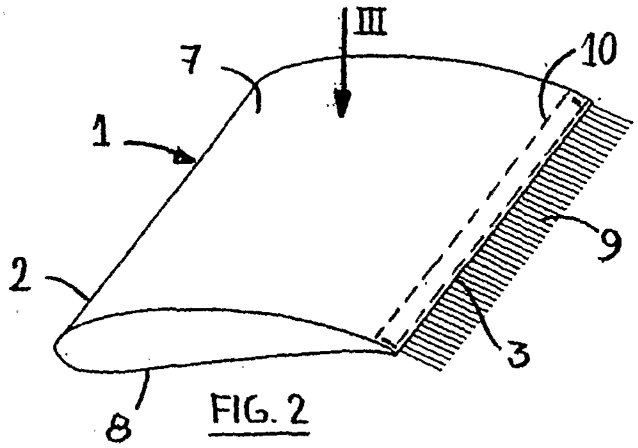

FIG. 2

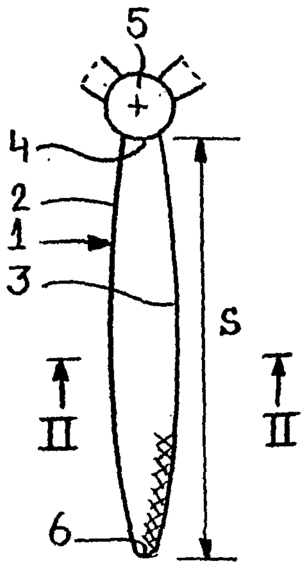

FIG. 1

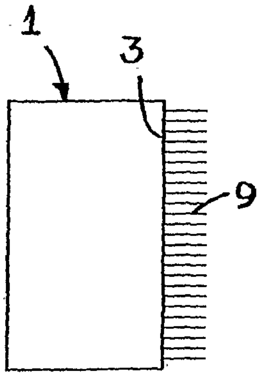

FIG. 3

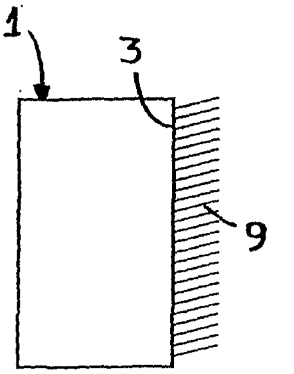

FIG. 4

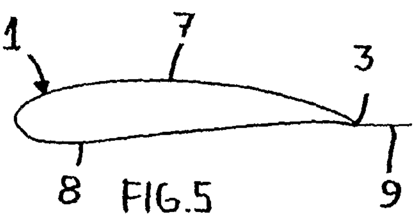

FIG. 5

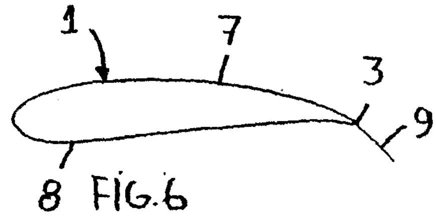

FIG. 6

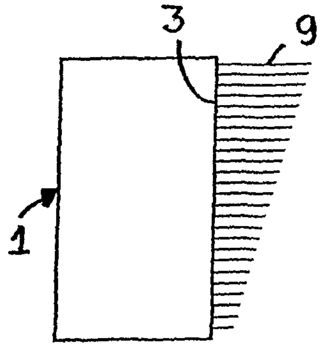

FIG. 7

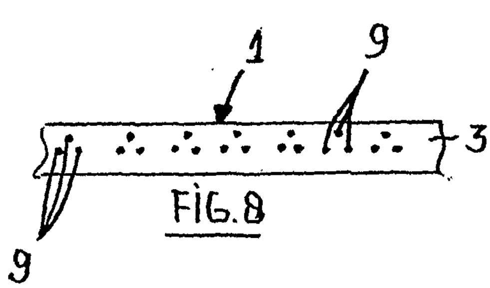

FIG. 8