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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
2 May 2013 (02.05.2013)

WIPO | PCT

(10) International Publication Number
WO 2013/060722 Al

(51) International Patent Classification:
F03D 1/06 (2006.01)

(21) International Application Number:
PCT/EP20 12/07 105 1

(22) International Filing Date:
24 October 2012 (24.10.2012)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
11186497. 1 25 October 201 1 (25. 10.201 1) EP

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, 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, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, 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, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.1 7(in))*

— *of inventorship (Rule 4.17(iv))*

Published:

— *with international search report (Art. 21(3))*

(54) Title: WIND TURBINE BLADE PROVIDED WITH SLAT

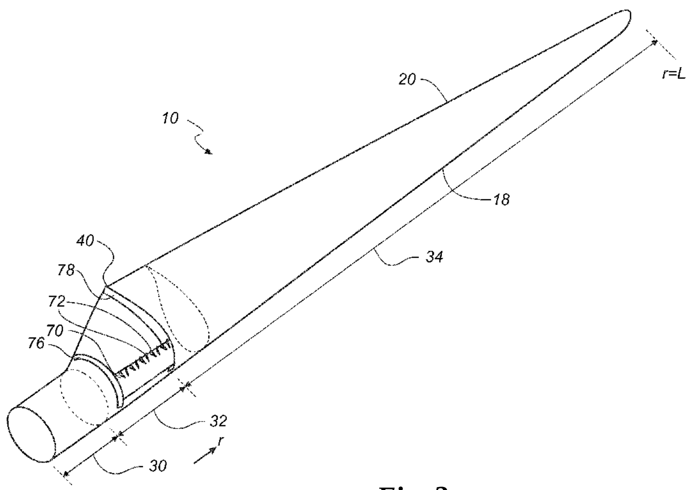

Fig. 2

(57) Abstract: A wind turbine blade (10) for a wind turbine (2) having a substantially horizontal rotor shaft is described. The blade comprises: a main blade having a surface comprising a pressure side and a suction side as well as a leading edge (18) and a trailing edge (20) with a chord extending between the leading edge (18) and the trailing edge (20), the main blade surface generating a lift when being impacted by an incident airflow, and a slat (70, 170, 270, 370, 470, 570, 670) which extends along a longitudinal extent of the blade and which creates a slot between the slat (70, 170, 270, 370, 470, 570, 670) and the main blade surface. The slat(70, 170, 270, 370, 470, 570, 670) is provided with vortex generators (72, 172, 272, 372, 472, 572, 672). The slat (70, 170, 270, 370, 470, 70, 670) and vortex generators (72, 172, 272, 372, 472, 572, 672) are arranged so as to generate turbulent air vortices along at least a part of the suction side of the main blade.

WO 2013/060722 A1

Title: Wind turbine blade provided with slat

Technical Field

The present invention relates to a wind turbine blade for a wind turbine having a substantially horizontal rotor shaft, wherein the blade comprises: a main blade having a surface comprising a pressure side and a suction side as well as a leading edge and a trailing edge with a chord extending between the leading edge and the trailing edge, the main blade surface generating a lift when being impacted by an incident airflow, and a slat which extends along a longitudinal extent of the blade and which creates a slot between the slat and the main blade surface. The invention further relates to a wind turbine comprising a rotor including such blades.

Background Art

Horizontal axis wind turbines comprise a rotor provided with a number of blades - often two or three - which extend radially from a hub. The blades have a profile transversely to the longitudinal or radial direction of the blade. The blade comprises a root region with a substantially circular profile closest to the hub, an airfoil region with a lift generating profile furthest away from the hub, and a transition region between the root region and the airfoil region, the profile of the transition region gradually changing in the radial direction from the circular profile of the root region to the lift generating profile of the airfoil region. The lift generating profile is provided with a suction side and a pressure side as well as a leading edge and a trailing edge, so that the blade during normal use, i.e. wind-powered rotation of the rotor, is impacted by an incident airflow flowing from the leading edge towards the trailing edge, thereby generating a reduced pressure at the suction side (at a leeward side) relative to the pressure side (at a windward side) so that a pressure differential is created between the suction side and the pressure side, thus generating a lift.

Ideally, the airflow remains attached to the surface of the blade over the entire longitudinal length of the blade. However, in practice the airflows may detach at the suction side of the blade, which may cause increased drag, reduced lift, or both, and thereby lead to a decrease in energy production. This airflow detachment usually occurs in the transverse direction between a position of maximum thickness and the trailing edge of the profile and typically occurs at the root region or transition region, where the profile is non-ideal and has the largest relative blade thickness.

The flow detachment may entail substantially stagnant vortices of airflow, which due to the rotational forces of the rotor may propagate towards the tip end of the blade. These cross-flows of detached airflow can seriously impair the functionality of the blade by reducing the lift over a larger longitudinal extent of the blade.

WO 2005/035978 discloses a blade which is provided with a planar element protruding from the suction side of the blade and extending from the leading edge to the trailing edge of the blade. The planar element is arranged in a zone of transversal flow in order to prevent the transversal flow from propagating towards the tip end of the blade.

WO 2009/026927 discloses a blade which is provided with barrier generating means on the suction side of the blade, and where the barrier generating means are arranged in or near the transition zone of the blade so as to generate a barrier of airflow along a strip, which extends in a transverse direction of the blade on the suction side of the blade. The barrier generating means may for instance be a slat or vortex generators arranged on the suction side of the blade.

WO 2010/100237 discloses a wind turbine blade which is provided with a slat along a part of the blade having a relative thickness of at least 36%. The flap may be provided with vortex generators in order to improve flow attachment at the flap, which in turn will improve the lift of the blade.

WO 2010/133649 discloses a wind turbine with a rotor mounted on a hub section and comprising a plurality of blades. The blades comprise a main blade section as well as auxiliary blade sections for increasing the planform area of the blade and increase aerodynamic lift. The main blade section as well and the auxiliary blade sections are all mounted to the hub. It is mentioned that the main blade section or the auxiliary blade sections may be provided with vortex generators.

Disclosure of the Invention

It is an object of the invention to obtain a new blade for a rotor of a wind turbine, which overcomes or ameliorates at least one of the disadvantages of the prior art or which provides a useful alternative.

According to a first aspect of the invention, the object is obtained by the slat being provided with vortex generators, and wherein the slat and vortex generators are arranged so as to generate turbulent air vortices along at least a part of the suction side of the main blade.

This provides for a particular simple solution, where the combination of slat sections and vortex generators can be used for improving the aerodynamic properties along a longitudinal section of the blade. Thus, the vortex generators can be utilised for changing e.g. the lift, drag, or noise generated from said longitudinal section without actually arranging the vortex generators on the surface of the blade. This also makes it possible to use vortex generators in embodiments, where the slat is arranged near the main blade surface and which could make proper arrangement of the vortex generators difficult.

Since the slat creates a slot between the main blade surface and the slat, this in other words means that the slat is arranged with a spacing between the main blade surface and the slat.

According to a first advantageous embodiment, the slat extends along the leading edge of the main blade surface. This embodiment provide for simple solutions, where the slat can be used for changing the inflow conditions for the particular blade section, and where the vortex generators may be utilised for delaying separation of airflow towards the trailing edge of the main blade surface or preventing it entirely.

The vortex generator may advantageously be vane vortex generators. The vortex generators advantageously protrude from the surface of the slat. The vortex generators may advantageously have a maximum height corresponding to 0.5-2% of the local chord of the main blade. Such heights have shown to provide appropriately sized vortices along the main blade section in order to delay the separation of airflow towards the trailing edge of the main blade section. The vortex generators may be arranged on the slat in a position that is between the position of maximum thickness and the leading edge of the main blade section, alternatively in a position between the position of maximum thickness and the trailing edge of the main blade section.

According to yet another advantageous embodiment, a centre point or axis of the slat is arranged closer to the suction side of the main blade surface than the pressure side of the main blade section, thereby preventing or delaying separation of airflow from the suction side of the main blade surface. Overall, according to an advantageous embodiment, the slat and vortex generators are arranged so as to generate turbulent air vortices along at least a part of the suction side of the main blade surface.

Advantageously, the slat is arranged so as to at least partly project over the leading edge and/or the suction side of the blade, advantageously so that a part of the slat extends parallel to on the suction side of the main blade section.

In one embodiment, the main blade surface is divided into: a root region having a substantially circular or elliptical profile closest to the hub, an airfoil region having a lift-generating profile farthest away from the hub, and a transition region between the root region and the airfoil region, the transition region having a profile gradually changing in the radial direction from the circular or elliptical profile of the root region to the lift-generating profile of the airfoil region, and wherein the slat is arranged along at least a part of the root region and/or the transition region. Thus, it is seen that the blade comprises a main blade part, which corresponds to conventional, modern wind turbine blades, and where the slat is arranged along a blade section, where the aerodynamic properties are sub-optimum. Accordingly, the main blade may be provided with a shoulder having a shoulder width and located at the boundary between the transition region and the airfoil region. The slat may of course also extend into the airfoil region of the main blade as well.

According to an advantageous embodiment, the slat is fastened to the main blade surface via at least a first support device. The support device (or equivalently fastening means) ensures that the slat is fastened to the main blade and assures that the slot is formed between the slat and the main blade surface.

In one particular advantageous embodiment, the support device is formed as a plate-shaped element or a wall preventing air from propagating in a direction substantially perpendicular to the first support device. The plate-shaped element or wall is preferably arranged substantially in direction of the inflow, i.e. in a substantially transverse direction of the blade, and preferably protruding from the suction side of the main blade surface. Thus, the plate-shaped element or wall may function as a stall fence, and the setup combines the use of slat for changing the inflow and vortex generators and stall fences for delaying and preventing expansion of a separated airflow.

The first support device may extend along at least 20% of a local chord of the main blade surface, advantageously along at least 30%, 40%, 50%, 60%, 70%, or 80% of the local chord. The first support device may even extend along 90% of the chord or even along the entire chord.

Advantageously, the slat is further fastened to the main blade surface via a second support device, which may make the arrangement more stable. The second support device may comprise any of the characteristics of the first support device, i.e. be a plate-shaped or wall-shaped element that may function as a stall fence.

According to one advantageous embodiment, the first support device is supporting the slat near or at a first end thereof, and the second support device is supporting the slat near or at a second end thereof. The first and the second support device may be designed so that only one or both of the devices function as a stall fence.

According to another advantageous embodiment, the slat, the first support device and the second support device together form the slot. Thus, the first support device forms a first sidewall of the slot, and the second support device forms a second sidewall of the slot.

The cross-sectional area may be substantially constant from a first end of the slot (e.g. the leading edge of the slot) to a second end of the slot (e.g. the trailing edge of the slot). The cross-sectional area may alternatively be varying from the first end towards the second end of the slot. According to a first embodiment, the area is decreasing from the first end towards the second end, thereby accelerating the flow. According to a second embodiment, the area is increasing from the first end towards the second end, thereby decelerating the flow. In a third embodiment, the area is first decreasing and then increasing from the first end towards the second end. Thereby, the flow is first accelerated and then decelerated, which may form additional turbulent vortices that may reenergise the boundary layer. This type of slot may for instance be formed by letting the first sidewall and the second sidewall converge and then diverge from the first end towards the second end of the slot. This may also make the flow detach from the side-walls in the intermediate region, where the sidewalls change from converging to diverg-ing, creating even further turbulent vortices.

According to one embodiment, the height of the slot, i.e. the spacing between the slat and the main blade surface, is 10-200% of the height of the local boundary layer, ad-vantageously, between 10% and 150%, more advantageously between 10% and 100%, and even more advantageously between 10% and 50%. The boundary layer height may be the height of the boundary layer at the design point of the blade. Alterna-tively or in addition hereto, it may be the height of the boundary layer at a range of an-gle of attack of between 0 and 50 degrees, advantageously between 0 and 35 degrees, and more advantageously between 0 and 25 degrees. In particular the inboard part of the blade may experience high angle of attacks depending on the wind speed.

In yet another embodiment, the slat may be provided with a first winglet arranged at a first end thereof and/or a second winglet arranged at a second end thereof. Such wing-lets may limit vortices generated at said ends. The winglets may extend away from the main blade surface. In such an embodiment, the winglets may be part of the support devices. In another embodiment, where the support devices support a surface of the slat facing towards the main blade surface, the ends of the slat may be provided with winglets that are not attached to the main blade surfaces. Such winglets may extend towards the main blade surface or away from the main blade surface. Further, the winglet could be designed to function as vortex generators, the winglets thus being the vortex generators provided on the slat.

In one embodiment, the slat has a chord length which is between 5-50% of a local chord length of the main blade surface, advantageously between 5-35%, and more ad-vantageously between 5-25%, and even more advantageously between 5-20%. Since the support device(s) may extend along a larger extent of the local chord, it is seen that the slat need only extend along a part of the support device(s), or in other words that the stall fences may extend beyond the chordal extent of the slat. Further, the slat need only be supported along a part of the chordal extent of the slat, and the slat may extend beyond a leading edge of the first support device and/or the second support de-vice.

According to one advantageous embodiment, the vortex generators are vane vortex generators. The vortex generators may also be vanes for accelerating and/or decelerating the flows or arranged so as to create a Venturi effect. It is also possible to use surface indentations and/or projections, surface roughness and/or non-homogenous materials for creating the vortices.

The slat may advantageously have a rectangular or trapezoidal shape in plan view.

The slat may be arranged parallel to the leading edge of the main blade surface, alternatively non-parallel.

The slat may be flat, bent, or arcuately curved in cross-section. The slat may also be airfoil shaped in cross-section.

According to an advantageous embodiment, the blade has a length of at least 40 metres.

The slat may be translationally and/or rotatably mounted relative to the main blade.

Advantageously, the first support device and/or second support device are arranged on the suction side of the blade in the transition region or in the airfoil region in a part nearest the transition region.

According to a first embodiment, the slat comprises a first surface facing towards the main blade surface, and a second surface facing away from the main blade surface, and wherein the vortex generators are arranged on the second surface. Alternatively, the vortex generators are arranged on the first surface, thereby arranged closer to the main blade surface, which may more efficiently provide turbulent vortices near the main blade surface.

According to a second aspect, the invention provides a wind turbine having a substantially horizontal rotor shaft and comprising a rotor including a hub from which a number, advantageously two or three, of blades according to any of the preceding claims extends substantially in a radial direction from the hub.

Brief Description of the Drawings

The invention is explained in detail below with reference to the drawings, in which

Fig. 1 shows a wind turbine,

Fig. 2 shows a wind turbine blade according to the invention,

Fig. 3 shows a schematic view of an airfoil profile,

Figs. 4a-c show a schematic view of various cross sections of slats according to the invention,

Fig. 5 shows a schematic view of a blade section provided with two stall fences and a slat provided with vortex generators,

Fig. 6 shows a schematic view of a blade provided with one stall fence and a slat provided with vortex generators,

Fig. 7 shows a schematic view of a blade provided with an intermediate stall fence and a slat provided with vortex generators,

Fig. 8 shows a schematic view of a blade provided with a slat having vortex generators and winglets, and

Figs. 9a-d show various possible shapes of the slot.

Detailed Description of the Invention

Fig. 1 illustrates a conventional modern upwind wind turbine according to the so-called "Danish concept" with a tower 4, a nacelle 6 and a rotor with a substantially horizontal rotor shaft. The rotor includes a hub 8 and three blades 10 extending radially from the hub 8, each having a blade root 16 nearest the hub and a blade tip 14 farthest from the hub 8. The rotor has a radius denoted R.

Fig. 2 shows a schematic view of a first embodiment of a wind turbine blade 10 according to the invention. The wind turbine blade 10 comprises a main blade part that has the shape of a conventional wind turbine blade and comprises a root region 30 closest to the hub, a profiled or an airfoil region 34 farthest away from the hub and a transition region 32 between the root region 30 and the airfoil region 34. The blade 10 comprises a leading edge 18 facing the direction of rotation of the blade 10, when the blade is mounted on the hub, and a trailing edge 20 facing the opposite direction of the leading edge 18.

The airfoil region 34 (also called the profiled region) has an ideal or almost ideal blade shape with respect to generating lift, whereas the root region 30 due to structural considerations has a substantially circular or elliptical cross-section, which for instance makes it easier and safer to mount the blade 10 to the hub. The diameter (or the chord) of the root region 30 may be constant along the entire root area 30. The transition region 32 has a transitional profile gradually changing from the circular or elliptical shape of the root region 30 to the airfoil profile of the airfoil region 34. The chord length of the transition region 32 typically increases with increasing distance rfrom the hub. The airfoil region 34 has an airfoil profile with a chord extending between the leading edge 18 and the trailing edge 20 of the blade 10. The width of the chord decreases with increasing distance rfrom the hub.

A shoulder 40 of the blade 10 is defined as the position, where the blade 10 has its largest chord length. The shoulder 40 is typically provided at the boundary between the transition region 32 and the airfoil region 34.

It should be noted that the chords of different sections of the blade normally do not lie in a common plane, since the blade may be twisted and/or curved (i.e. pre-bent), thus providing the chord plane with a correspondingly twisted and/or curved course, this being most often the case in order to compensate for the local velocity of the blade being dependent on the radius from the hub.

The blade is provided with an element 70 in form of a slat, which is positioned above the suction side of the blade 10 and which forms a slot, i.e. a gap, between the slat 70 and the surface of the blade 10. The slat 70 extends along the leading edge 18 of the blade 10 along a blade section and is supported at a first end by a first support device 76 and at a second end by a second support device 78. In the shown embodiment, the first support device 76 and the second support device are formed as stall fences that may prevent cross-flows and separated airflows to propagate beyond the stall fences in the spanwise direction of the blade. The slat 70 is provided with vortex generators 72 on a surface facing away from the main blade surface. It is seen that the vortex generators 72 are arranged near a trailing edge of the slat 70. Thus, the vortex generators are arranged so as to generate turbulent vortices along at least a part of the suction side of the main blade surface, thereby delaying separation of airflow towards the trailing edge 20 of the blade 10 or preventing it entirely.

Fig. 3 shows a schematic view of an airfoil profile 50 of a typical blade of a wind turbine depicted with the various parameters, which are typically used to define the geometrical shape of an airfoil. The airfoil profile 50 has a pressure side 52 and a suction side 54, which during use - i.e. during rotation of the rotor - normally face towards the windward (or upwind) side and the leeward (or downwind) side, respectively. The airfoil 50 has a chord 60 with a chord length c extending between a leading edge 56 and a trailing edge 58 of the blade. The airfoil 50 has a thickness f, which is defined as the distance between the pressure side 52 and the suction side 54. The thickness f of the airfoil varies along the chord 60. The deviation from a symmetrical profile is given by a camber line 62, which is a median line through the airfoil profile 50. The median line can be found by drawing inscribed circles from the leading edge 56 to the trailing edge 58. The median line follows the centres of these inscribed circles and the deviation or distance from the chord 60 is called the camber *f*. The asymmetry can also be defined by use of parameters called the upper camber (or suction side camber) and lower camber (or pressure side camber), which are defined as the distances from the chord 60 and the suction side 54 and pressure side 52, respectively.

Airfoil profiles are often characterised by the following parameters: the chord length c, the maximum camber *f*, the position d_f of the maximum camber *f*, the maximum airfoil thickness f, which is the largest diameter of the inscribed circles along the median camber line 62, the position d_t of the maximum thickness f, and a nose radius (not shown). These parameters are typically defined as ratios to the chord length c. Thus, a local relative blade thickness *t/c* is given as the ratio between the local maximum thickness f and the local chord length c. Further, the position d_p of the maximum pressure side camber may be used as a design parameter, and of course also the position of the maximum suction side camber.

Fig. 4a shows a schematic, cross-sectional view of a blade section 150. It is seen that the blade section is provided with a slat 170, which is mounted to the surface of the blade section 150 via at least first support devices 176 and which assures that a slot is formed between the slat 170 and the surface of the blade section 150. The slat is provided with vortex generators 172 that are arranged near a trailing edge of the slat 170. The vortex generators 172 generate turbulent vortices 174 that propagate along the suction side of the blade section 150 and which pull the boundary layer towards the blade surface, thereby delaying or preventing separation of the airflow. In the shown embodiment, the cross-sectional profile of the slat 170 is shaped as an airfoil.

Figs. 4b and 4c show schematic, cross sectional views of a second and third embodiment, respectively, where like numerals refer to like parts of the embodiment shown in Fig. 4a. The only difference is that in the second embodiment, the slat 270 is formed as a flat, arcuate element, which may ensure a fixed spacing to the main blade surface, and in the third embodiment, the slat 370 is formed as a flat, non-curved element.

In the embodiments shown in Figs. 4a-c, the vortex generators 172, 272, 372 are arranged near a leading edge of the slat 170, 270, 370 on a surface facing away from the main blade surface. However, the vortex generators 172, 272, 372 may also be positioned further forward on the slat 170, 270, 370 and/or on a surface facing towards the main blade surface, which may ensure that the vortices are generated closer to the main blade surface.

Figs. 5-8 shows four different embodiments of blade sections provided with a slat having vortex generators.

Fig. 5 shows a first embodiment of a blade section 450 according to the invention. The blade section 450 is provided with a slat 470. The slat 470 extends along the leading edge the blade section and is mounted to the blade section 150 via a first support device 476 and a second support device 478 so as to form a slot between the blade section 450 and the slat 470. The first support device 476 and the second support device both form stall fences that may prevent cross-flows and separated airflows to propagate beyond the stall fences in the spanwise direction of the blade. The slat 470 is provided with vortex generators 472 on a surface facing away from the main blade surface of the blade section 450. It is seen that the vortex generators 472 are arranged near a trailing edge of the slat 70. Thus, the vortex generators are arranged so as to generate turbulent vortices along at least a part of the suction side of the blade section 450, thereby delaying separation of airflow towards the trailing edge of the blade section or preventing it entirely. The stall fences 476, 478 may extend along at least 20%, 30%, 40%, 50%, 60%, 70%, 80%, or 90% of the local chord. The first support device may even extend along the entire chord of the blade section 450. In general, the stall fences should be arranged so as to both efficiently prevent cross-flows in the spanwise direction of the blade and supporting the slat 470.

Fig. 6 shows a second embodiment of a blade section 550 according to the invention, where like numeral refer to like parts of that of the first embodiment shown in Fig. 5. In this embodiment only the first support device 576 is formed as a stall fence, whereas the second support device 578 is used for supporting the slat 570 only. Based on the specific need the stall fence may be arranged outermost or innermost on the blade.

Fig. 7 shows a third embodiment of a blade section 650 according to the invention, where like numerals refer to like parts of that of the first embodiment shown in Fig. 5. In this embodiment, the slat 670 is supported at a first end and a second end by a first support device 676 and a second support device 678, respectively. Further, the slat 670 is supported by an intermediate support device 679 supporting the slat 670 in a position between the first end and the second end thereof. The intermediate support device 679 is shaped as a stall fence preventing cross-flows to propagate in the spanwise direction of the blade. The vortex generators 672 that are arranged outboard of the stall fence 679 prevent the build up of possible detached airflows outboard of the stall fence 679.

Fig. 8 shows a third embodiment of a blade section 650 according to the invention, where like numerals refer to like parts of that of the first embodiment shown in Fig. 5. In this embodiment, the slat 770 is supported by a first support device 776 and a second support device 778 that supports the slat on a surface facing towards the surface of the blade section 750. The slat is further provided with a first winglet 782 at the first end, and a second winglet 784 at the second end. The winglets may be used for reducing the creation of vortices near the ends of the slat 782. Alternatively, they may be shaped so as to function as vortex generators, thereby contributing to delaying the separation of airflow towards the trailing edge of the main blade section 750. The winglets may be designed so as to have a part extending beyond the slat outline and projecting towards or away from the main blade surface 750. They may also as shown in Fig. 8 have a first part projecting away from the main blade surface and a second part projecting towards the main blade surface.

Although, from the schematic drawings of Figs. 5-8, it appears that the slat is arranged along a part of the airfoil section, the slats are advantageously arranged along at least a part of the transition region and/or the root region as shown in Fig. 2. The slat may of course also extend into the airfoil region.

Figs. 9a-d show various embodiments of the slot, where the slot is formed by the slat 70', 70", 70"', 70"", the first support device 76', 76", 76"', 76"", and the second support device 78', 78", 78"', 78"". In these embodiments, the first support device and the support device function as sidewalls of the slot. As in the previously shown embodiments, the support devices may be designed as stall fences and may extend beyond the extent of the slat. The cross-sectional area may be substantially constant from a first end of the slot at a leading edge of the slot to a second end of the slot at a trailing edge of the slot. The cross-sectional area may alternatively be varying from the first end towards the second end of the slat.

According to a first embodiment shown in Fig. 9b, the area is decreasing from the first end towards the second end, thereby accelerating the flow.

According to a second embodiment shown in Fig. 9a, the area is increasing from the first end towards the second end, thereby decelerating the flow.

In a third and fourth embodiment shown in Figs. 9c and 9d, respectively, the area is first decreasing and then increasing from the first end towards the second end. Thereby, the flow is first accelerated and then decelerated, which may form additional turbulent vortices that may reenergise the boundary layer. This type of slot may, as shown in the figures, for instance be formed by letting the first sidewall and the second sidewall converge and then diverge from the first end towards the second end of the slot, e.g. by having a sharp intermediate point as shown in Fig. 9c or by having a smooth transition as shown in Fig. 9d. This may also make the flow detach from the sidewalls in the intermediate region, where the sidewalls change from converging to diverging, creating even further turbulent vortices. Alternatively or in addition thereto, the height of the slot may first be decreased and then increased from the first end of the slot towards the second end of the slot.

List of reference numerals

2	wind turbine
4	tower
6	nacelle
8	hub
10	blade
14	blade tip
16	blade root
18	leading edge
20	trailing edge
30	root region
32	transition region
34	airfoil region
40	shoulder
50, 150, 250, 350, 450, 550, 650, 750	profile / blade section
52	pressure side
54	suction side
56	leading edge
58	trailing edge
60	chord
62	camber line / median line
70, 170, 270, 370, 470, 570, 670, 770	element / slat
72, 172, 272, 372, 472, 572, 672, 772	vortex generators
174, 274, 374	vortices
76, 176, 276, 376, 476, 576, 676, 776	first support device / stall fence
78, 178, 278, 378, 478, 578, 678, 778	second support device / stall fence
679	intermediate support device / stall fence
782	first winglet
784	second winglet

Claims

1. A wind turbine blade (10) for a wind turbine (2) having a substantially horizontal rotor shaft, where the blade comprises:

- a main blade having a surface comprising a pressure side and a suction side as well as a leading edge (18) and a trailing edge (20) with a chord extending between the leading edge (18) and the trailing edge (20), the main blade surface generating a lift when being impacted by an incident airflow, and

- a slat (70, 170, 270, 370, 470, 570, 670) which extends along a longitudinal extent of the blade and which creates a slot between the slat (70, 170, 270, 370, 470, 570, 670) and the main blade surface, **characterised in that**

- the slat (70, 170, 270, 370, 470, 570, 670) is provided with vortex generators (72, 172, 272, 372, 472, 572, 672), and wherein the slat (70, 170, 270, 370, 470, 570, 670) and vortex generators (72, 172, 272, 372, 472, 572, 672) are arranged so as to generate turbulent air vortices along at least a part of the suction side of the main blade.

2. A wind turbine blade according to claim 1, wherein the vortex generators (72, 172, 272, 372, 472, 572, 672) protrude from the surface of the slat (70, 170, 270, 370, 470, 570, 670) and have a height of 0.5-2% of a local chord length of the main blade.

3. A wind turbine blade according to claim 1 or 2, wherein the slat is extending along the leading edge of the main blade surface.

4. A wind turbine blade according to any of the preceding claims, wherein a centre point or centre axis of the slat is arranged closer to the suction side of the main blade surface than the pressure side of the main blade section.

5. A wind turbine blade according to any of the preceding claims, wherein the main blade surface is divided into:

- a root region (30) having a substantially circular or elliptical profile closest to the hub,

- an airfoil region (34) having a lift-generating profile furthest away from the hub, and

- a transition region (32) between the root region (30) and the airfoil region (34), the transition region (32) having a profile gradually changing in the radial direction from the circular or elliptical profile of the root region to the lift-generating profile of the airfoil region, and wherein the slat (70, 170, 270, 370, 470, 570, 670) is arranged along at least a part of the root region (30) and/or the transition region (32).

6. A wind turbine blade according to any of the preceding claims, wherein the slat is fastened to the main blade surface via at least a first support device (76, 176, 276, 376, 476, 576, 676, 776).

7. A wind turbine blade according to claim 6, wherein the support device is formed as a plate-shaped element or a wall preventing air from propagating in a direction substantially perpendicular to the first support device.

8. A wind turbine blade according to claim 7, wherein the first support device extends along at least 20% of a local chord of the main blade surface, advantageously along at least 30%, 40%, 50%, 60%, 70%, or 80% of the local chord.

9. A wind turbine blade according to any of claims 6-8, wherein the slat is further fastened to the main blade surface via a second support device (78, 178, 278, 378, 478, 578, 678, 778).

10. A wind turbine blade according to claim 9, wherein the first support device supports the slat near or at a first end thereof, and the second support device supports the slat near or at a second end thereof.

11. A wind turbine blade according to any of claims 6-10, wherein the slat has a chord length which is between 5-50% of a local chord length of the main blade surface, advantageously between 5-35%, and more advantageously between 5-25%, and even more advantageously between 5-20%.

12. A wind turbine blade according to any of claims 6-11, wherein the first support device and/or second support device are arranged on the suction side of the blade (10) in the transition region (32) or in the airfoil region (34) in a part nearest the transition region (32).

13. A wind turbine blade according to any of the preceding claims, wherein the slat comprises a first surface facing towards the main blade surface, and a second surface

facing away from the main blade surface, and wherein the vortex generators are arranged on the second surface.

14. A wind turbine blade according to any of the preceding claims, wherein the slat comprises a first surface facing towards the main blade surface, and a second surface facing away from the main blade surface, and wherein the vortex generators are arranged on the first surface.

15. A wind turbine having a substantially horizontal rotor shaft and comprising a rotor (8) including a hub (8) from which a number, advantageously two or three, of blades (10) according to any of the preceding claims extends substantially in a radial direction from the hub (8).

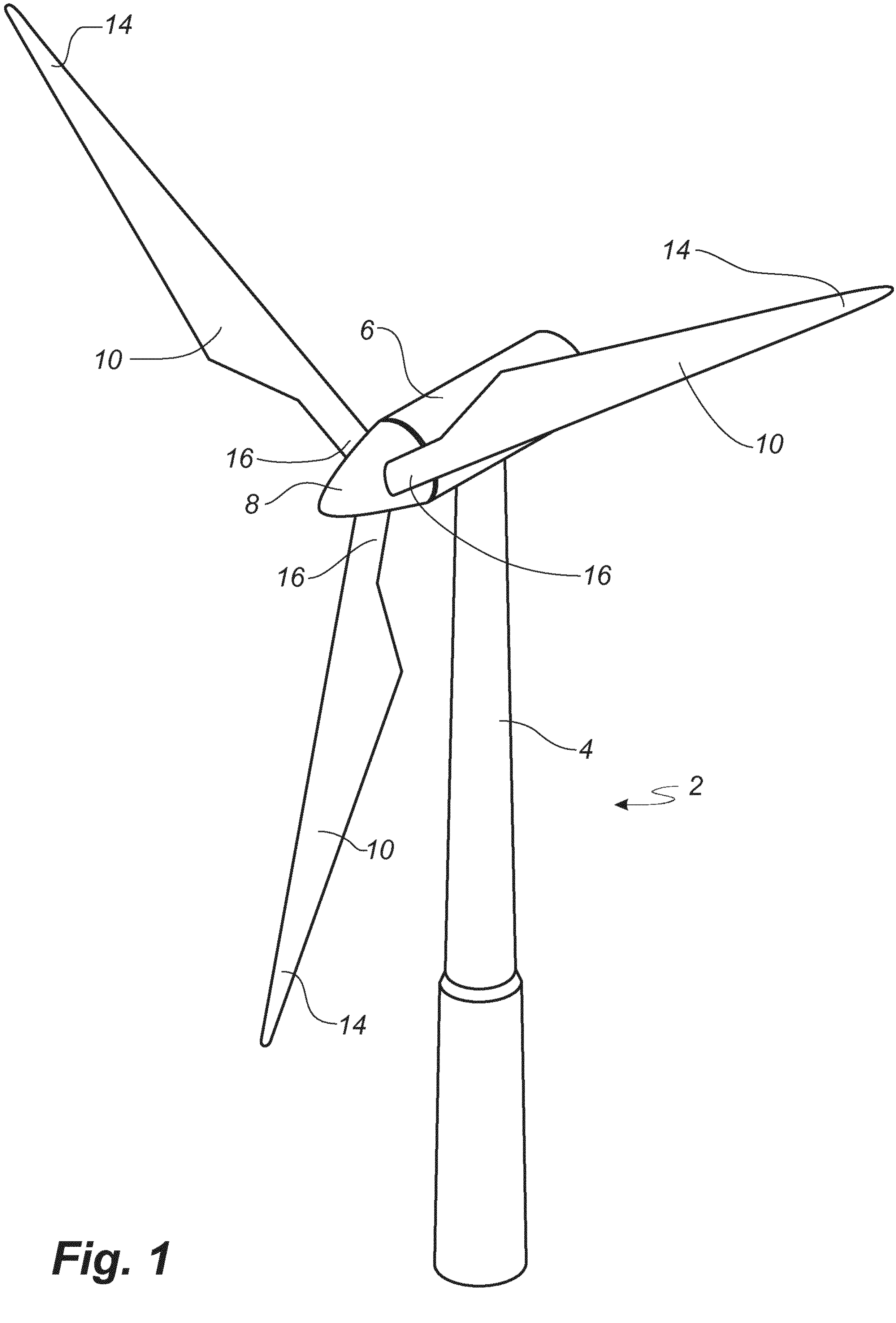

Fig. 1

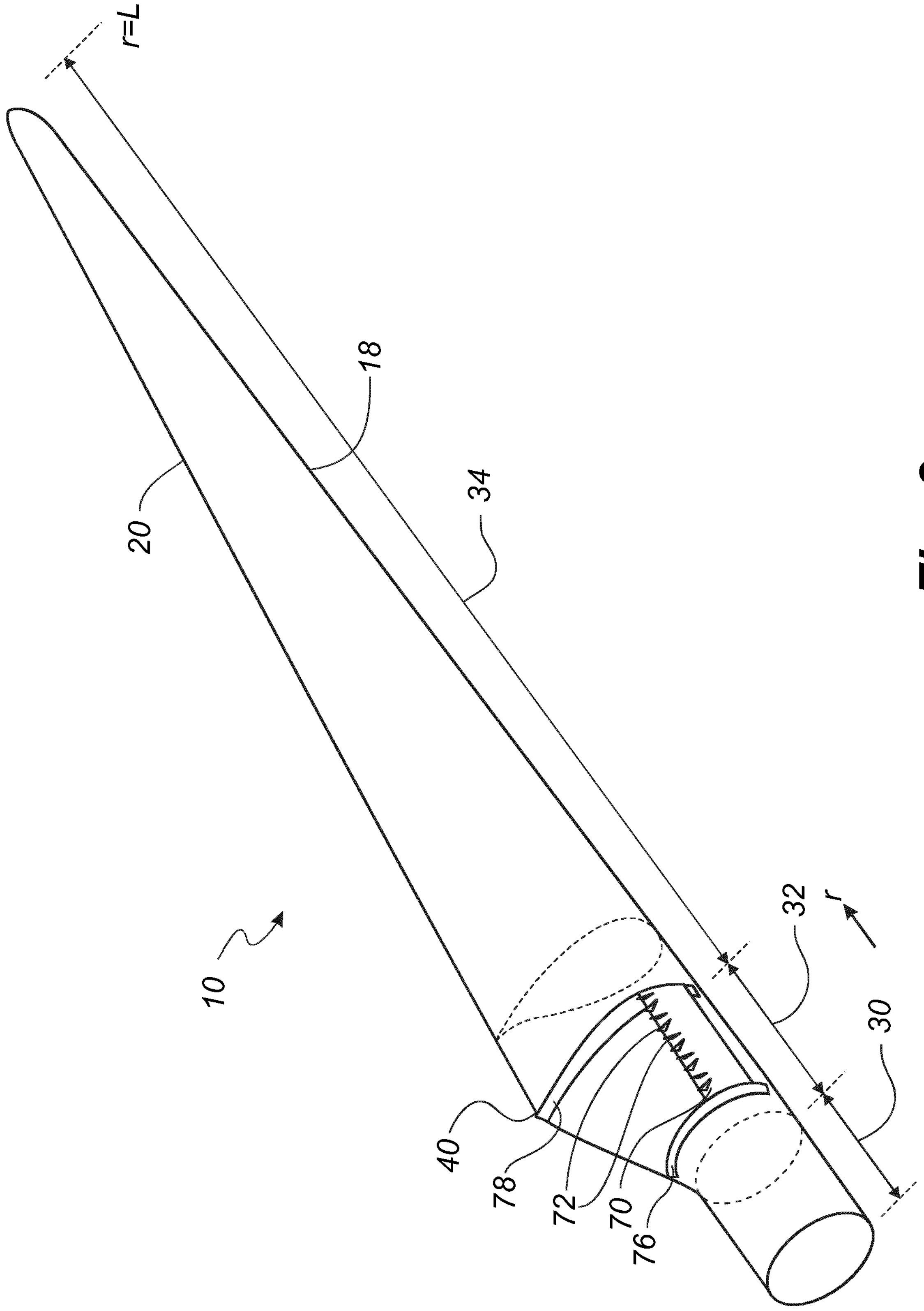

Fig. 2

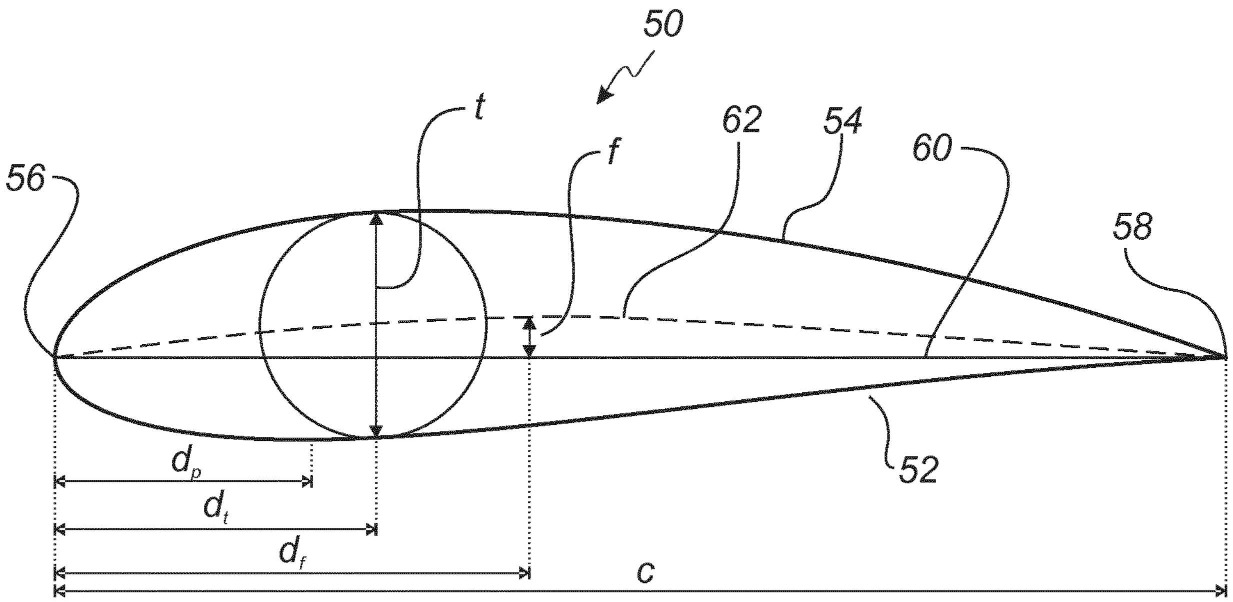

Fig. 3

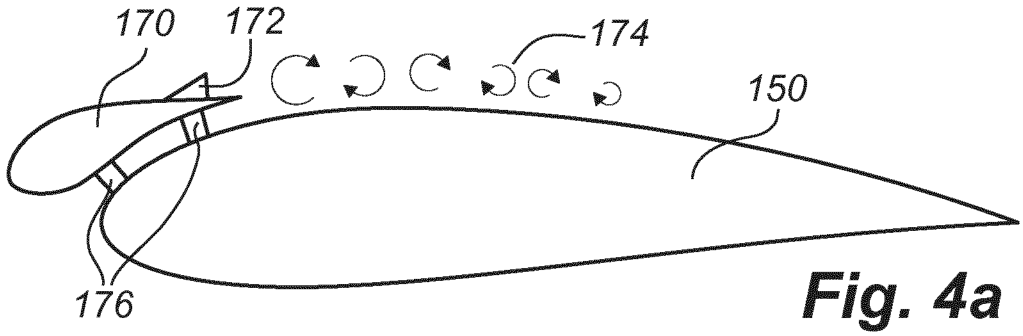

Fig. 4a

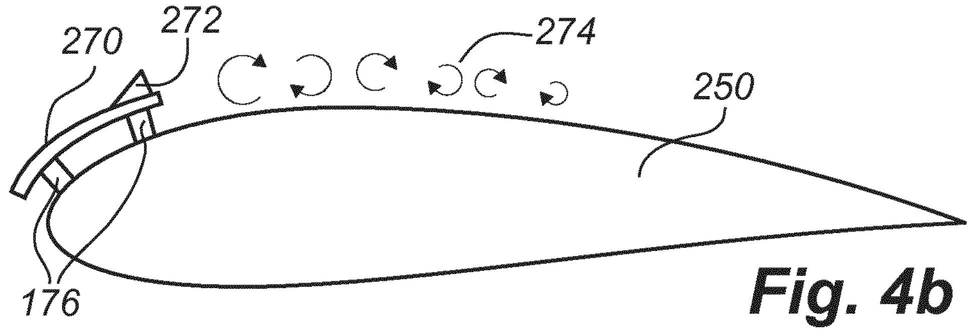

Fig. 4b

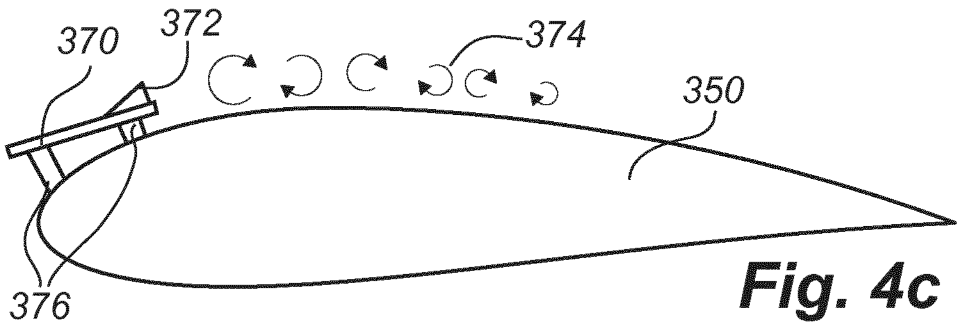

Fig. 4c

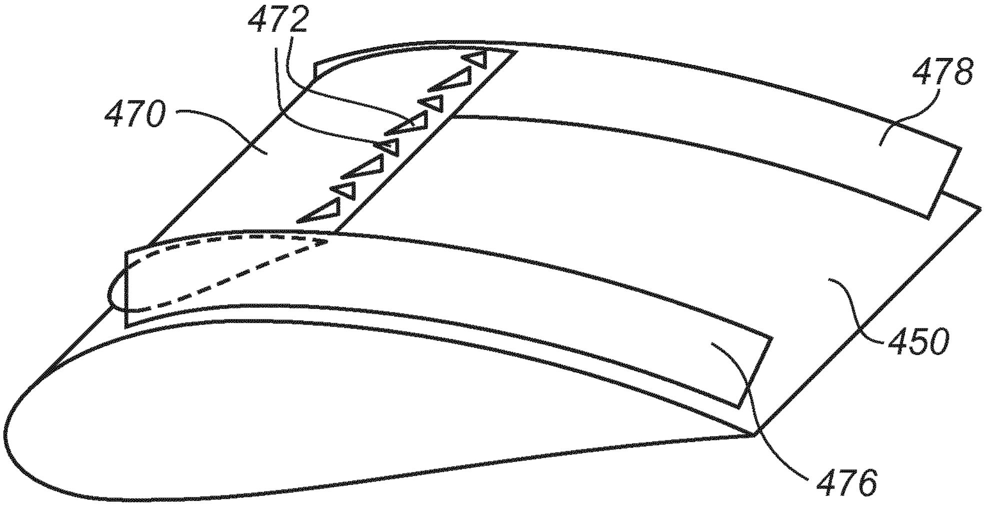

Fig. 5

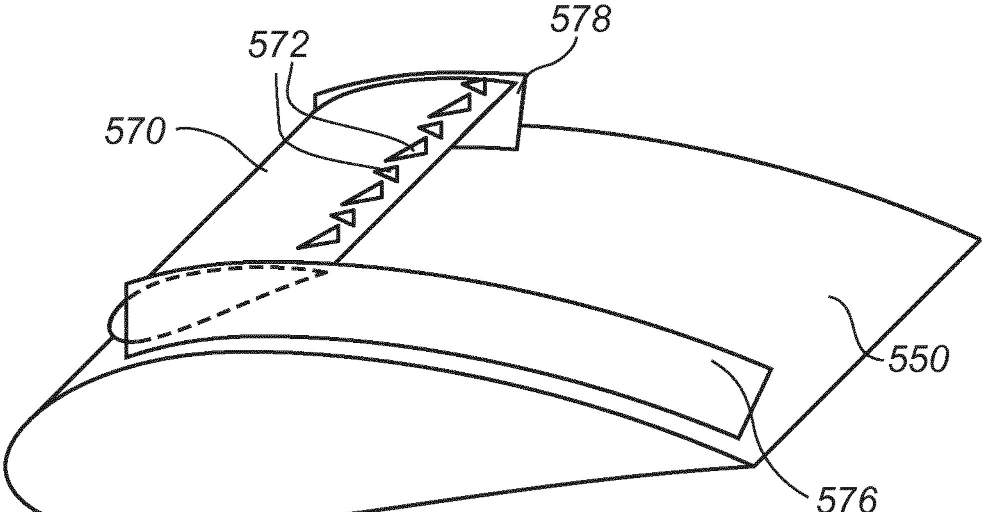

Fig. 6

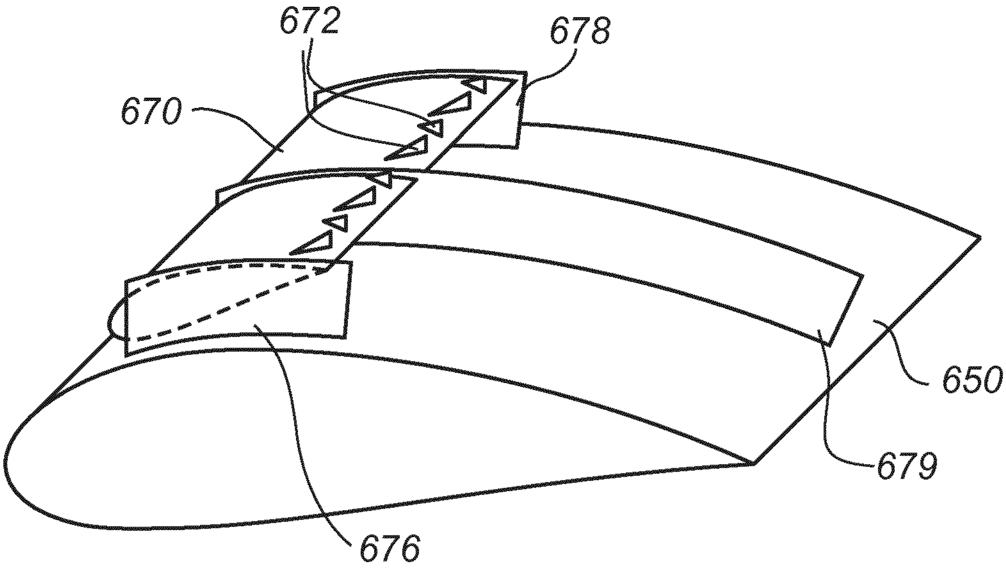

Fig. 7

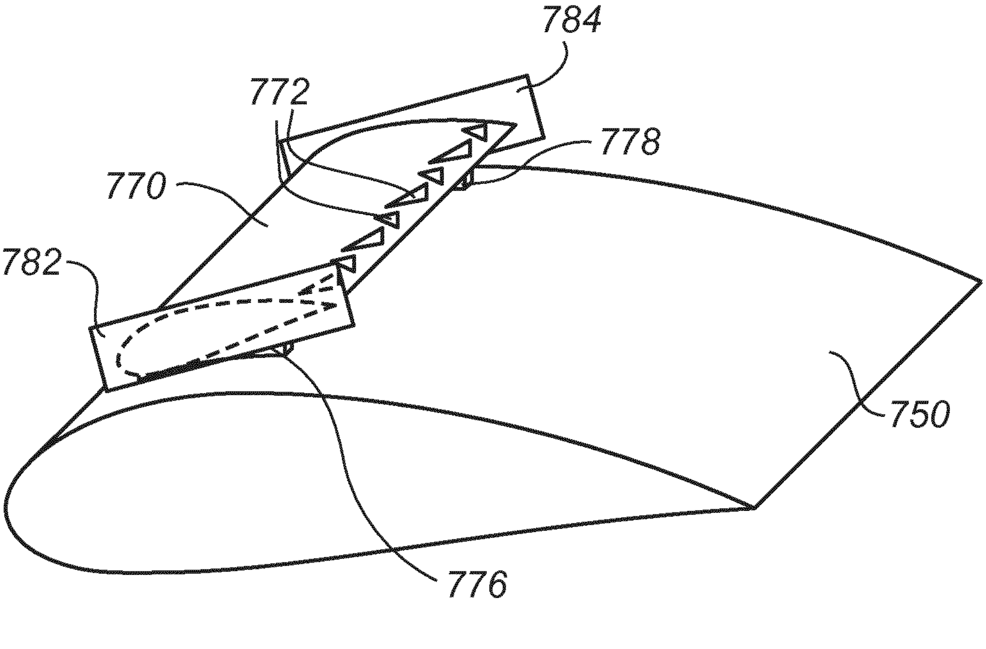

Fig. 8

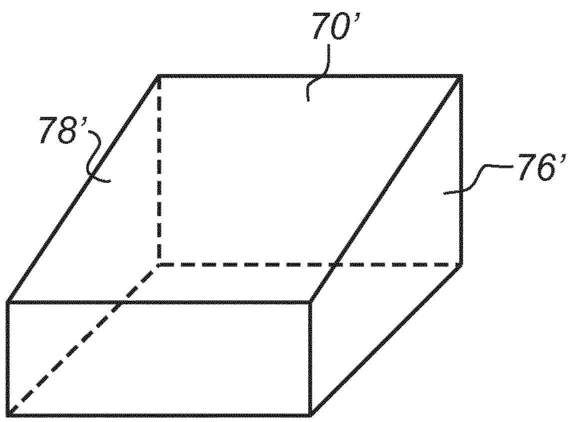

Fig. 9a

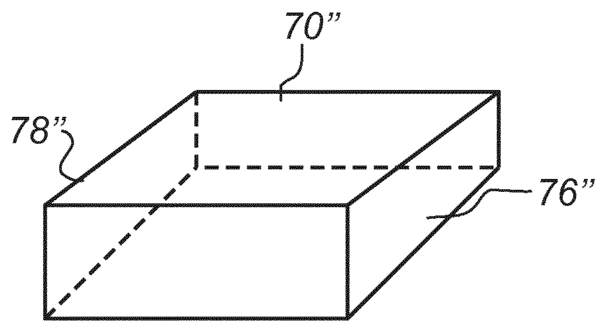

Fig. 9b

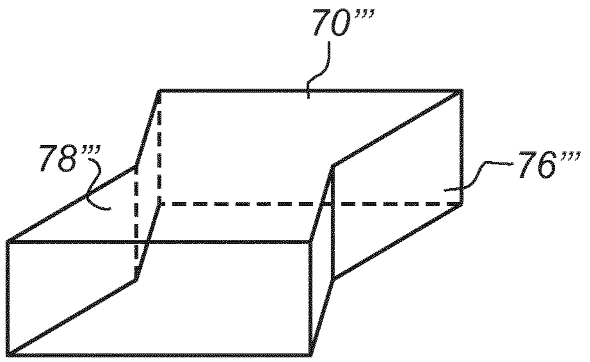

Fig. 9c

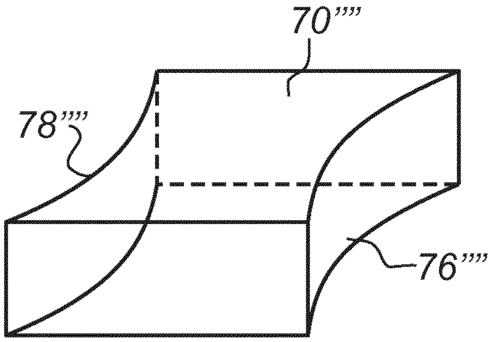

Fig. 9d

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2012/071051

A. CLASSIFICATION OF SUBJECT MATTER
INV. F03D1/06
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F03D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2010/133649 A2 (VESTAS WIND SYS AS [DK]; GODSK KRISTIAN BALSCHMIDT [DK]) 25 November 2010 (2010-11-25)	1-15
Y	figures 1, 2 page 9, line 18 - line 26 page 8, line 4 - line 6 -----	6-12
Y	WO 2009/146810 A2 (MICKELER SIEGFRIED [DE]) 10 December 2009 (2009-12-10) figures 2a, 6-16, 19, 20 page 11, line 17 - line 30 -----	6-12
A	WO 01/16482 A1 (STICHTING ENERGIE [NL]; CORTEN G C [NL]) 8 March 2001 (2001-03-08) figure 2 page 2, line 11 - line 14 page 2, line 29 - line 31 -----	2,14
	-/-	

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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"E" earlier application or patent but published on or after the international filing date

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"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	Date of mailing of the international search report
3 January 2013	11/01/2013

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Altmann, Thomas

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2011/142681 AI (FISHER MURRAY [US] ET AL) 16 June 2011 (2011-06-16) figure 5 paragraph [0039] -----	6-12
A	WO 2010/100237 A2 (VESTAS WIND SYS AS [DK]; R0MBLAD JONAS [DK]; G0DSK KRISTIAN BALSCHMIDT) 10 September 2010 (2010-09-10) figure 1 page 7, line 1 - line 10 -----	1-15

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2012/071051

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2010133649 A2	25-11-2010	CN 102459874 A	16-05-2012
		EP 2432993 A2	28-03-2012
		US 2012107117 A1	03-05-2012
		WO 2010133649 A2	25-11-2010
WO 2009146810 A2	10-12-2009	DE 102008026474 A1	10-12-2009
		EP 2297455 A2	23-03-2011
		WO 2009146810 A2	10-12-2009
WO 0116482 A1	08-03-2001	AU 7324300 A	26-03-2001
		NL 1012949 C2	06-03-2001
		WO 0116482 A1	08-03-2001
US 2011142681 A1	16-06-2011	CN 102345570 A	08-02-2012
		DE 102011051985 A1	26-01-2012
		US 2011142681 A1	16-06-2011
WO 2010100237 A2	10-09-2010	CN 102414440 A	11-04-2012
		EP 2404055 A2	11-01-2012
		WO 2010100237 A2	10-09-2010