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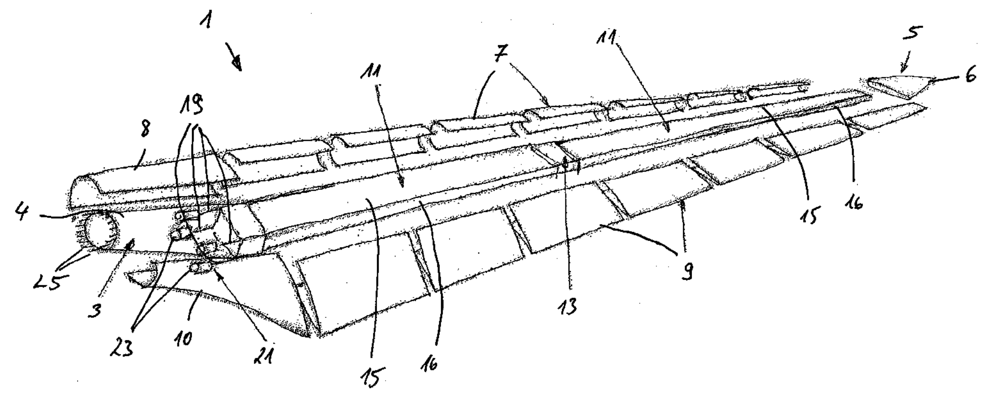

(57) **Abstract:** The present invention relates to a wind rotor blade (1) for a wind turbine which is attachable to a hub (2) of the wind turbine at a preliminary adjusted blade pitch such that when a load is applied to the blade by the wind, the blade translates the load into thrust and torque that apply a rotational force to the hub about a rotational axis of the hub, the blade comprising a proximal end (3) configured to be attached to the hub, a distal end (5) opposite the proximal end, a windward side that extends from the proximal end to the distal end and faces a direction from which the load is applied and comprising at least one section of a leading edge fairing (7), a leeward side that extends from the proximal end to the distal end and which is opposite from the windward side and comprising at least one section of a trailing edge fairing (9), a central load bearing part or spar (11) extending essentially from the proximal end to the distal end of the blade and being capable to twist around a central axis of the spar, said at least one leading edge fairing and said at least one trailing edge fairing being attached to the central spar, wherein the blade responds to increases of the load applied by flexing to continuously change the blade pitch of said at least one leading and trailing edge fairing from the proximal end to the distal end of the blade, wherein the blade pitch is subject to a change from a positive lift to a negative lift along the blade from the proximal to the distal end thereof, so that the negative lift counteracts some of the positive lift in order to reduce the thrust and torque experienced by the blade as a result of the load.

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WIND ROTOR BLADE AND WIND TURBINE COMPRISING SUCH BLADE

FIELD OF THE INVENTION

The present invention relates to wind rotor blades which are able to face loads from small winds to heavy winds, i.e. the blades are low wind optimized and need not shut down during high winds but keeping powering at full nominal power as per drive train specs during the full spectrum of winds experienced starting at very low winds and never shutting down at high winds.

Furthermore, the present invention relates to wind turbines comprising such blades.

BACKGROUND OF THE INVENTION

Wind turbines are of increasing interest for producing electric energy from attacking wind. There is a tendency of building up wind parks onshore or offshore with an arrangement of multiple wind turbines.

Wind turbines of the prior art, however, suffer from several major drawbacks. Firstly, wind turbines of the prior art are not able to start rotating under the presences of attacking wind. These turbines need an initial driving force to start turning and, after reaching a certain rotation speed, they continue turning under the force of the attacking wind.

On the other hand, when the blowing wind is too heavy, the wind turbine has to be stopped to avoid damages. In particular the wind flexes the distal end of the blades to such an extend that the blades risk to hit the pylon. Accordingly, under the presence of heavy winds these wind turbines have to be stopped leading to the next disadvantage, that under high load of the wind acting on the blades, the bearings of the turbine risk to be damaged. Such bearings, like ball-bearings or roller-bearings, are not configured to experience heave load in a stopped position.

It is, therefore, an object of the present invention to provide a wind rotor blade which is able to provide torque already under small or little wind on the one hand, and is also able to experience very heavy winds and to continue working by avoiding damage of the wind turbine under these heavy conditions.

It is furthermore an object of the present invention to provide wind turbines to overcome the above identified drawbacks of the prior art.

SUMMARY OF THE INVENTION

According to the present invention, there is provided a wind rotor blade for a wind turbine which is attachable to a hub of the wind turbine at a preliminary adjusted blade pitch such that when a load is applied to the blade by the wind, the blade translates the load into thrust and torque that apply a rotational force to the hub about a rotational axis of the hub. The blade comprising a proximal end configured to be attached to the hub, a distal end opposite the proximal end, a windward side that extends from the proximal end to the distal end and faces a direction from which the load is applied and comprising at least one section of a leading edge fairing, a leeward side that extends from the proximal end to the distal end and which is opposite from the windward side and comprising at least one section of a trailing edge fairing. A central load bearing part or central spar extends essentially from the proximal end to the distal end of the blade and is capable to twist around a central axis of the spar, said at least one leading edge fairing and said at least one trailing edge fairing being attached to this central spar, wherein the blade responses to increases of the load applied by flexing to continuously change the blade pitch of said at least one leading and trailing edge fairing from the proximal end to the distal end of the blade, wherein the blade pitch is able to change from a positive to a negative lift along the blade from the proximal to the distal end thereof, so that the negative lift counteracts at least some of the positive lift in order to reduce the thrust and torque experienced by the blade as a result of the load.

With other words, the blade is able to directly translate the central load from the real wind acting on the root or proximal end into an optimum angle of attack from root to tip for the desired final load at the root in each direction. This means that the blade is adjusted to use additional wind to relief the forces acting on the root by employing negative lift at the tip where the apparent wind comes from the side and allows directly reducing the forces when the blade pitch is set for increasing negative lift configuration pulling the blade tip into the real wind due to apparent wind creating lift that opposes the torque and thrust at the root, minimizing these while the wind gets stronger, leaving the blade rotating with full generation torque output and low thrust and reducing the loads aerodynamically in a soft response.

Accordingly, when the force being applied to the blade of the turbine is relatively low, e. g. in low wind condition, the blade is provided with pitch that minimizes loss in the translation of the force applied to the blade into rotational force applied to the hub of the turbine by the blade, which means that already in low wind conditions the blade is able to start turning the turbine.

On the other hand, when the turbine begins to rotate at relatively high speeds due to a relatively high amount of force being applied to the blade, e. g. in high wind conditions, it is, according to the present invention, advantageous to employ a blade pitch that translates a smaller proportion of force applied to the blade into rotational force applied to the hub. The turbine, as disposed in a power generating system, advantageously is able to keep the rotational speed, acceleration, jerk, and/or other time derivatives of rotational displacement below certain limits in order to protect other components of the power generations. This may include increasing the angle of blade pitch to translate less of the force applied along the blade.

According to the present invention the amount of negative lift carried out by the respective part of the blade is a function of the magnitude of the applied load. Advantageously, said amount of negative lift is adjustable, depending on the applied load. Accordingly, the blade is able to flex to increase its blade pitch as the load increases. This compensates for increases in the load that would cause the turbine in blowing the blade to attain an undesirable rotational velocity, acceleration and/or jerk. Further, as the load dissipates, the blade is designed to resiliently flex back to its original blade pitch which is differentially from root to tip.

It should be appreciated that differential blade pitch is a variable that impacts a variety of aspects of the operation of the rotor. For example, when the force being applied by the real wind to a blade of the rotor is relatively low, e.g. in low wind conditions, providing a blade with a blade pitch that minimizes loss in the translation of force (drag) and optimizes area for maximum torque at that stage, applied to the blade into rotational force applied to a hub of the rotor by the blade is advantageous. However, as the rotor begins to rotate experiencing elevated wind speeds and/or force due to a relatively high amount of real wind and subsequent high force being applied to the blade, e.g. in high wind conditions, it is, according to the present invention advantageous to employ a differential blade pitch that tranlates a smaller proportion of the force applied to the blade into rotatrional force applied to the hub, and reduce the thrust and rotational loads applied at the hub by aerodynamic apparent wind forces resolved in optimal lift drag configuration to reduce the overall thrust and torque applied to the drive train and rest of the wind turbine generator.

For instance, as the rotor is disposed in a power generating system, it is advantageous to one aspect of the present invention to keep the rotational speed, acceleration, moments, and/or other derivates of rotational displacement below certain limits in order to protect other components of the power generating system. This is achieved by the present invention by changing the angle of the blade pitch differentially to translate less of the forces and moments felt at the hub level. These forces and moments when directly responded to by the felt apparent wind will render a soft peaking of the loads at the hub with inherently stable configuration of deflection regimes ensuring that no loads will become higher than the designed for loads in thrust and rotational plane at the hub. This, therefore, renders a stable low wind generating rotor which will not increase loads even at survival wind speeds of the rotor and/or the complete wind turbine generator while continuing to power only full load generation capacity.

The blade according to the present invention is designed to respond to an increase in the load applied thereto by warping to adjust its blade pitch. The blade will flex to change its blade pitch as the load increases. This reduces increases in the load that would cause the rotor employing the blade to attain an undesirable rotational velocity, acceleration and/or moments with increased real wind velocities. Further, as the load dissipates, the blade is designed to always resiliently flex back to its original blade pitch as manufactured. Other responses to an external load are contemplated. These responses are generated by directly opposing 0 degree tows at corners of load bearing section of the blade in a predetermined set warp that can be responding passively to the wind felt at hub level or actively by relieving the installed warp of the bearing tension/compression differential with central controlling tensioners within each corner which can act as hinge pin at the corners between the load bearing panels with compression ferrules that can also be actively augmented or passively chosen to excert the correct amount of differential tension and compression to its adjoining load bearing parts (0 degree tows).

According to a further aspect of the present invention, the wind rotor blade comprises multiple leading and trailing edge fairings. The size of the blade according to the present invention may vary in a wide range. For example, the length of the blade from the proximal end or root portion to the distal end or tip portion may vary from 1 m to 100 m or even larger. Therefore, it is advantageously that the leading and trailing edge fairings comprise a modular structure, comprising a much shorter length, e. g. 0,5 m to 2 m. Of course, the present invention is not limited to these indicated sizes.

According to the present invention, the central load bearing or spar is of a box-shaped configuration comprising at least three, preferably at least four panels which are linked together. Other shapes like a hexagon or a octahedron are also possible.

Furthermore, according to the present invention, said panels are of a composite fiber structure. Such fibers may be carbon fibers or glass fibers. Of course, any kind of composite fibers can be provided to form said panels.

According to a further aspect of the present invention, said panels can be of isotropic material structure.

According to a further aspect of the present invention, the panels each comprising a compressed edge and a tensed edge opposite and adjacent from the compressed edge, wherein a plurality of elastomeric joints is provided which join the panels together such that the tensed edge of each panel is joint to the compressed edge of the adjacent panel, wherein at least one fiber tow in a given tensed edge experiences a tensile force when the tensile edge is coupled with the compressed edge of the adjacent panel by one of the elastomeric joints, wherein at least one fiber tow in a given compressed edge experiences a compression force when the given compressed edge is joint with the tensed edge of the adjacent panel by one of the elastomeric joints, wherein the tensile and compression forces applied to the tensed and compressed edges of the panels, respectively, by the elastomeric joints warps the panels to provide the blade with a blade pitch varying from the proximal end to the distal end of the blade from a positive angle of attack to a negative angle of attack resulting in positive and negative pitch.

In other words, the blade can be actively adjusted for an optimal angle of attack by applying tension to the tension tows at the corners of the central load bearing member which cause predetermined changes in geometry from a proximal end to the distal end of the blade.

This adaptation of pitch, according to the present invention is achieved by applying a respective force to the tows and/or the elastomeric joints, so that the blade is able to respond to the loads applied thereto. The blade responds because of load elongation (shortening) of the 0° tows. The differential in length causes the panels to twist in order to reach a force equilised.

According to the present invention, the central load bearing part or spar comprises one or more leading edge notches formed in the spar at the leading edge portion that the at least one leading edge fairing includes one or more tabs that extend therefrom, and in that the at least one leading edge fairing is attached to the spar at the leading edge portion at least in part by engagement between one or more tabs that extend from the leading edge fairing with the one or more notches formed in the spar at the leading edge portion.

Furthermore, the central load bearing part or spar comprises one or more trailing edge notches formed in the spar at the trailing edge portion, and at least one trailing edge fairing includes one or more tabs which extend therefrom. The at least one trailing edge fairing is attached to the spar at the trailing edge portion at least in part by the engagement between the one or more tabs that extend from the trailing edge fairing with one or more notches formed in the spar at the trailing edge portion.

Accordingly, the leading edge fairings and the trailing edge fairings can easily be assembled with the load bearing part or spar, and the assembly can be finished by applying appropriate adhesives between the fairings and the spar.

Advantageously, the central load bearing part or spar is formed from a plurality of fiber tows such that one or more of the fiber tows at the proximal end of the spar extend from the blade and are configured to engage the turbine hub to enable the blade to be removably coupled with the turbine hub.

Advantageously, the central load bearing part or spar is warped when assembled and fixed at the elastomeric transition joint. Accordingly, the central load bearing part comprises an initial twist which can be modified by applying respective forces to the fiber tows of the tensed and compressed edges.

According to a further aspect of the present invention, when fully loaded, the twisted or warped central load bearing part or spar untwists as pretermined by the joints into the straight unwarped shape.

According to the invention, the panels are built up by shear webs comprising tuned compression tows to absorb the applied frequency loads while adding stiffness with less weight in curve linear path. Advantageously, the panels comprising a light but stiff structure and provide a light but stiff structure to the whole blade.

According to a further aspect of the present invention, the at least one trailing edge fairing comprises an inner loop for adding flexibility to the fairing during twisting.

In particular for low wind conditions, the at least one trailing edge fairing houses a rolled sailcloth extending preferably from the proximal end to the distal end, that sailcloth being unrolled to extend the area of the blade during low winds. Such a sailcloth can be incorporated into the blade of the present invention, but can also be incorporated into a blade of the prior art.

According to a further aspect of the present invention, the sailcloth is rolled up in the trailing edge bearing chamber with increasing wind by feeling the tension on a sheet which is provided to pull the sailcloth out of the trailing edge and initiated through preset maximum tension allowable before roll up of a section of sailcloth is initiated until the preset tension maximum is received to a preset stop reducing sail area point. This is repeated automatically as per wind situation rolling in and out automatically through the preset points.

According to a further aspect of the present invention, the blade is coupled to the hub by a hinge and an activator, said activator during higher wind situations is able to fold the blade behind the hub in wind direction. Accordingly, when there are wind conditions which are extremely high and would damage parts of the wind turbine, it is possible to move the blades behind the hub to avoid damages.

According to a further aspect of the present invention the wind rotor blade comprises a plurality of fairings and open ends of carbon fiber filaments that end in the expansion joints between the sectional fairings to cause plasma generation when lightning is close and in that said filaments represent a receptor of path for the lightning. Accordingly, with these features it is possible to avoid damages caused by lightning.

Furthermore, the load bearing panels have a series of connectors attached to each longitudinal side allowing hinged connection each adjacent panel.

Furthermore, the corner tensioning tows act as hinge pin at the corners.

Moreover, the panels are provided with actuators, preverably hydraulic cylinders, between each connector at the hinged joint. With these actuators and easy and appropriate adjusting of the warp of the blade is obtained and with that differential angle of attack.

Furthermore, the load bearing spar comprises at each corner attached to the central tensioning tows and the hub, an actuator, for example a hydraulic cylinder, applying force to the corners together against the elastomeric joints.

According to a further aspect of the present invention, the blade comprises mold defined edges which comprise foil hinged end joints which can be folded back onto the fiber stack.

The fairings are made with the molds having the leading edge and the trailing edge at its center as integral part of the molding.

According to the present invention, the root interface to the hub is comprised by extending the load bearing tows into the mold defined interface structure.

Furthermore, the root interface is in the form of common metal stud interfaces but comprising impregnated homogenous fiber tows going through same flange bores. With this an effective mounting of the blade to the hub is achieved.

Furthermore, the root section is made with the central corner tensioning tows defining the hub interface.

According to a further aspect of the present invention, the blade is fixed without pitch control rotating the blade at the hub.

Furthermore, the blade is fixed to the hub with a hinged joint that allows the blade to fold with an actuator behind the hub and reduce the frontal area incrementally with higher wind loads.

The present invention relates also to a wind turbine for producing electric energy due to attacking winds on at least one rotor blade being removable attached to the hub of the turbine, wherein said rotor blade is configured as set forth in one of the claims 1 to 31.

Furthermore, the proximal end or root section of said blade is configured to be removably coupled with the hub, and the blade is formed from a plurality of fiber tows such that one or more of the fiber tows extend from the root section of the blade and engage the hub to enable the blade to be removably coupled with the hub.

One further aspect of the present invention is that the hub of the wind turbine forms one or more conduits, a given conduit communicating two openings formed in the surface of the hub, the one or more conduits being formed such that the one or more fiber tows that extend from the proximal end of the blade are engaged with the hub by insertion into the one or more conduits. These provide a very effective attachment of the blade to the hub.

Furthermore, the one or more fiber tows that extend from the proximal end of the blade are retained in the one or more openings by one or more fasteners that engage the one or more fiber tows and at least one of the openings of the one or more conduits.

Moreover, the turbine comprises one or more compression fasteners which comprise one or more unthreaded fastening surfaces in one preferential case one or more taper locks. Such compression locks avoid undue stress on the threads of threaded fasteners.

The present invention will be more fully understood from the following description of an embodiment to which, however, the present invention is not restricted, with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 in perspective view shows one embodiment of the blade of the present in vention in explosive illustration;

Figs. 2a to 2d illustrate the special adaptation of the blade from the attack of low winds to heavy winds;

Fig. 3 shows a plot of blade pitch as a function of radial station on a turbine blade as a load applied to the blade is increased, in accordance with the present invention;

Fig. 4 shows in perspective view one preferred embodiment of the central load bearing part or spar in untwisted condition;

Fig. 5 shows the joint of a tensile edge of one panel coupled with the compressed edge of the adjacent panel;

Fig. 6 in perspective schematic view illustrates the central load bearing part or spar in twisted condition;

Fig. 7a shows a sectional view of the blade;

Fig. 7b shows enlargement "Z" of Fig. 7a;

Fig. 7c shows the blade of the present invention with a sailcloth extended from the trailing edge fairings;

Fig. 8 shows in schematic view an actuator being linked to a blade, the blade is shown in upright position and, in dotted lines, in folded position;

Fig. 9 shows a panel comprising a shear web and curved fiber tows;

Fig 10 in perspective view schematically shows the twisted spar after assembling of the panels;

Fig. 11 in schematic view shows the fastening means of the blade to the hub of the present invention;

Fig. 12 in perspective view shows the assembled blade according to one embodiment of the present invention being provided with fiber brushes between leading edge fairings; and

Fig. 13 in schematic view shows an enlarged part "X" of Fig. 12.

DETAILED DESCRIPTION

In the figures, the same elements are referenced by the same reference numerals.

Fig. 1 shows a preferred embodiment of a wind turbine blade 1 in a perspective non-assembled view comprising a proximal end 3 forming a root section 4, a distal end 5, forming a tip section 6, a plurality of leading edge fairings 7 and a plurality of trailing edge fairings 9.

The root section 4 is covered by a leading edge fairing 8 and a trailing edge fairing 10 of different shape as the leading edge fairings 7 and trailing edge fairings 9.

In the center of blade 1 of the present invention there is provided the central load bearing part or spar 11, which, in Fig. 1 is shown in untwisted and unwarped shape. The central load bearing part or spar 11 in the configuration according to Fig. 1 is box-shaped comprising four panels 15, 16, 17 and 18 (see Fig. 4), only two of which panels 15 and 16 are shown in Fig. 1.

At the proximal end 3 of blade 1, the root section 4 forms the proximal end section of spar 11.

As shown in Fig. 1, and what will be described in more detail below with reference to Fig. 4, at each joint between panels 15, 16, 17 and 18 there is provided a central tensioning tow 19 at each joint corner, being linked to tensioning means 21, which for example are provided by hydraulic cylinders 23.

In the embodiment according to Fig. 1. central load bearing part or spar 11 comprises several sections which are linked together via tapered joints 13 with respective length.

In order to be easily linked with a hub of a wind turbine, the root section 4 comprises stud interfaces 25, which are able to protrude or engage in respective openings or conduits of the hub of the wind turbine which will be described later.

Referring now to Figs. 2a to 2d the different conditions and adaptations of the blade according to the present invention depending on the different wind situations will be described.

Vector 27 indicates the direction of the real wind acting on the blade and the length of vector 27, which differs from Fig. 2a to 2d indicates the magnitude of the wind starting from low wind according to Fig. 2a until heavy wind according to Fig. 2d.

In Figs. 2a to 2d for reasons of simplification only schematically shown the proximal end 3 and the tip section 6 are shown. Vector 29 indicates the force of the real wind onto blade 1 and vector 31 (Figs. 2b to 2d) shows the amount of the apparent wind force in magnitude and direction. Vector 33 represents the reaction force or positive lift acting on the proximal end 3 of blade 1, whereas vector 35 represents the reaction force or lift acting on the tip section 6. Vector 36 represents the drag on tip section 6, whereas vector 37 represents the drag on root section 4.

As can be seen from Fig. 2a under low wind condition there is a small positive lift according to vector 33 and a small positive lift according to vector 35 on both sections of the blade 1 the proximal end 3 and the tip section 6.

With increasing wind according to Fig. 2b the positive lift on the tip section 6 increases up to a maximum.

As can be seen from Fig. 2c, by reducing the flexing of tip section 6 in relation to proximal end 3, the positive lift changes into a negative lift as can be seen from vector 35 in Fig. 2c so that this negative lift counteracts the positive lift represented by vector 33.

Still with increasing wind according to Fig. 2d, the tip section further deflexes from the twisted position according to Figs. 2b and 2c to obtain again the position according to Fig. 2a, however, due to the heavy wind, tip section 6 provides a negative lift according to vector 35 counteracting the positive lift according to vector 33 acting on the proximal end 3 of the blade 1.

Fig. 3 is a plot of blade pitch as a function of radial station along blade 1 as a load applied to blade 1 is increased, in accordance with the embodiment of the present invention. As can be seen in Fig. 3, blade 1 starts in a preliminary configuration 55_0, in which the blade pitch at the distal end or tip section 6 may be at or near 0 degrees (or even negative). As the load applied by the wind along vector 27 increases, blade 1 flexes in succession to flexed configurations 55_1 - 55_5. At the final flexed configuration illustrated by the plot of Fig. 3 (flexed configuration 55_5), distal end or tip section 6 of blade 1 reaches a blade pitch of about 40 degree. It may be appreciated from the plot of Fig. 3, that while flexure of blade 1 enables the blade pitch of distal end 5 or tip section 6 to vary with the applied load, the blade pitch of portions of blade 1 closer to proximal end 3 will not vary as much. Thus, these portions of blade 1 still receive a positive lift from the load, and the tip section 6 of blade 1 receives the negative load that enables blade 1 as consequently the wind turbine to take advantage of the aspects of counter lift, as discussed herein.

According to the preferred embodiment, blade 1 is so designed, to respond to a load along direction of vector 27 with a predetermined blade response. The blade response includes the amount of negative lift that will be experienced by blade 1 as a function of the load, e. g. the wind speed. The blade response includes a treshold loading amount, e. g. a treshold wind speed, at which blade 1 begins to experience negative lift on the leeward side, the manner in the amount of negative lift increases as a function of increases in load applied along direction of vector 27. The blade response is provided during the fabrication of blade 1 by controlling one or more aspects of its flexture characteristics under load. For example, the number of discrete sections, starting from tip section 6 in direction to the root section 4, which will twist in coordination in response to received loads, the manner which the blade pitch of one or more sections of blade 1 increases as a function of increases in the load applied along direction of vector 27, the shape of one or both of the windward and/or leeward side of blade 1 and/or other aspects of the fabrication of blade 1 may be controlled provide the blade response.

As is described above with reference to Fig. 2a to 2d blade 1 has flexed in accordance with the blade response. The flexure of blade 1 may increase the blade pitch of tip section 6. As blade 1 flexes to the position illustrated in Fig. 2c, the rotation of the hub of the wind turbine about the axis thereof changes the angle at which the wind applying the load becomes instant on blade 1 as blade 1 rotates with the hub. This alteration of the angle at which the wind becomes instant on blade 1 caused by the movement of blade 1 may create an "apparent load" according to vector 31 that is directionally shifted from the direction according to vector 27 in which the fluid, i. e. the wind is actually flowing. For instance, due to the rotation of blade 1, the load being applied by the wind flowing along direction of vector 27 may induce an apparent load on the distal end or tip section 6 of blade 1 along the direction illustrated by vector 31. It should be appreciated that the speed of rotation of the hub and the distance from the hub to a given point of blade 1 is influencing the directionality of the apparent load experienced by blade 1. For instance, at a point on blade 1 between the proximal end 3 and the tip section 6, an apparent load will be applied by the wind in a direction between the directions of vector 27 and vector 31. The direction difference between the apparent load applied at the distal end 5 or tip section 6, along direction of vector 31 and the apparent load applied between the proximal end 3 and the tip section 6 may be described in part as a function of the differences in distance away from the hub at these two points on blade 1.

Reference is now made to Fig. 4 in which in a schematic perspective view the box-shaped central load bearing part or spar 11 is shown. Spar 11 comprises four panels 15, 16, 17 and 18, each of them comprising a compressed edge 41 and a tensed edge 43 opposite from the compressed edge 41. The compression of panel 18 is indicated by vectors 45 whereas the tension of edge 43 of panel 15 is indicated by vectors 47.

In each corner of jointed panels is provided at least one fiber tow 49 and at least one fiber tow 49 is provided in a compressed edge. The tows 49 can be actuated by the hydraulic cylinders 23 and one possible way to create different tension at the corner tows of each panel is by employing central tension tows, which can be actively adjusted for start up tension. Carbon fibers can be elongated to one 1 % linear extension which will cause a 2 % change in length at the corner at full warp.

By applying appropriate tension and compression on the fiber tows 49, i. e. applying different length at the corners which is directly opposed to each other, will cause the box to warp as indicated by arrow 51 around the central axis 53 of the central spar element.

Fig. 5 shows enlargement "X" of Fig. 4. Differential compression ferrules 56 are provided between flanges 57 of panel 15 and flanges 59 of panel 18. The differential compression ferrules 56 in an alternate manner apply compression and tension to the adjacent flanges.

Referring now to Fig. 6, there is schematically shown the central load bearing part 11 in a twisted position. Such a position is achieved by applying corresponding tension and compression forces on the fiber tows resulting in twisting of the box-shaped spar 11. The proximal end 3 and distal end 5 are shown only schematically.

Fig. 7a shows blade 1 in a schematic sectional view. The way how the leading edge fairing7 are linked to the spar 11 is better shown in enlargement "Z" illustrated in Fig. 7b. Accordingly, that the central load bearing part or spar 11 comprises one or more leading edge notches 60 formed in the spar at the leading edge portion. The leading edge fairing 7 includes one or more tabs 62 that extend therefrom, and the leading edge fairing 7 is attached to the spar 11 at the leading edge portion at least in part by an engagement between the one or more tabs 62 that extend from the leading edge fairing 7 with the one or more notches 60 formed in the spar 11 at the leading edge portion. The same link mechanism is also applied for linking the trailing edge fairing 9 to the spar 11.

Fig. 7c shows the blade 1 in a schematic sectional view. A sailcloth 61 is wound on an axis 63 being provided in an compartment 65 seated in the trailing edge fairings 9. A cable or rope 67 is connected to the sailcloth 61 and by feeling the tension on the sheet 67 the sailcloth 61 is pulled out of the trailing edge fairings including initiating furling with a precise predetermined maximum tension.

Accordingly, depending on the attacking wind, the area of the blade 1 can be enlarged drastically, to provide a large area of blade to obtain the required torque acting on the hub of the wind turbine to drive the turbine for producing electrical energy.

Reference is now made to Fig. 8 showing schematically blade 1 being hinged to hub 2, in straight lines, being directed into an upright position for wind attack. Hinge 69 enables blade 1 to fold behind hub 2 during the presence of overload wind conditions and such folding of blade 1 is provided by actuator 71 being linked to blade 1 and to hub 2. In particular, according to the present invention the folding of blade 1 can be done incrementally in order to fully react on different wind loads acting on blade 1 according to vector 73, shown in Fig. 8.

Reference is now made to Fig. 9 in which a preferred embodiment of panel 15 is shown. This preferred embodiment also applies to panels 16, 17 and 18. Panel 15 comprises a shear web being formed of composite fibers and comprising a plurality of tuned compression tows 79 which provide higher stiffness and elasticity on the one hand and good damping effect on the other hand. As experienced in the state of the art, oscillation production of wind turbines is one of the major drawbacks of these turbines. Accordingly, with the configuration according to Fig. 9, vibration damping can be obtained. The shear web 77 at one edge thereof comprises the linear 0° corner tows 81.

The tuned compression tows can also be provided by metal wires or cables. The configuration and arrangement of the tuned compression tows 79 shown in Fig. 9 is such that the bottom edge of panel 15 is directed to the proximal end 3 and the top edge of panel 15 is directed to the distal end 5 of the blade 1.

Fig. 10 shows in schematic illustration the assembled panels 15, 16, 17 and 18 to form the central load bearing part or spar 11 in an assembled twisted configuration. Each panel of the central spar 11 which is adapted for fixing it to the other opposing side, is twisted and the joints thereof fixed in twisted configuration.

In Fig. 11 assembly of the blade 1 is shown. The 0° tows 81 are introduced into a flange interface 83 in which an opening for a compression fitting such like a taper lock 85 is provided (dotted lines). Taper lock is pressed upward for example by hydraulic pressure and moves in direction of vectors 87. According to a slit 86 the taper lock 85 is able to clamp and fix tows 81. Advantageously threaded fasteners are avoided which require higher efforts and are subjected to torque overloads of the thread leading to detrimental effects on the fastener.

As can be seen from Fig. 11, the tows 81 are connected to earth a lightning hitting blade 1.

Figs. 12 and 13 illustrade a lightning protection of blade 1. Between the leading edge bearings 7 is provided a carbon fiber filament brush 93 comprising protruding ends between the joints of the fairings 7. This carbon fiber filament 93 brush provides a plasma path 95 induced by lightning 91.

Fairings 7 are covered by a foil conductor 97 which is placed outside of the fairing 7.

The modular design of the blade 1 of the present inventionalso enhances the errection ability on site by allowing the parts to be fitted seperately to the installed hub in high wind conditions due to low lift shape of small and light to be hoisted parts. These parts fit to each other in a positive clip on joint.

CLAIMS

1. A wind rotor blade (1) for a wind turbine which is attachable to a hub (2) of the wind turbine at a preliminary adjusted blade pitch such that when a load is applied to the blade by the wind, the blade (1) translates the load into thrust and torque that apply a rotational force to the hub (2) about a rotational axis of the hub, the blade (1) comprising:

a proximal end (3) configured to be attached to the hub (2),

a distal end (5) opposite the proximal end (3),

a windward side that extends from the proximal end (3) to the distal end (5) and faces a direction (27) from which the load is applied and comprising at least one section of a leading edge fairing (7),

a leeward side that extends from the proximal end (3) to the distal end (5) and which is opposite from the windward side and comprising at least one section of a trailing edge fairing (9),

a central load bearing part or spar (11) extending essentially from the proximal end (3) to the distal end (5) of the blade and being capable to twist around a central axis 853) of the spar (11), said at least one leading edge fairing (7) and said at least one trailing edge fairing (9) being attached to the central spar (11),

wherein the blade (1) responds to increases of the load applied by flexing to continuously change the blade pitch of said at least one leading and trailing edge fairing (7, 9) from the proximal end (3) to the distal end (5) of the blade (1),

wherein the blade pitch is subject to a change from a positive lift to a negative lift along the blade (1) from the proximal to the distal end thereof, so that the negative lift counteracts at least some of the positive lift in order to reduce the thrust and torque experienced by the blade as a result of the load.

2. The wind rotor blade according to claim 1, characterized in that the amount of negative lift carried out by the respective part of the blade is a function of the magnitude of the applied load at the hub.

3. The wind rotor blade according to claim 2, characterized in that said amout of negative lift is adjustable, depending on the applied load.

4. The wind rotor blade according to one of the claims 1 to 3, characterized in that said blade (1) comprises multiple leading and trailing edge fairings (7, 8, 9, 10).

5. The wind rotor blade according to one of the claims 1 to 4, characterized in that said central load bearing or spar (11) is of a box-shaped configuration comprising at least three, preferably at least four panels (15, 16, 17, 18) which are linked together.

6. The wind rotor blade according to claim 5, characterized in that said panels (15, 16, 17, 18) are of a composite fiber structure.

7. The wind rotor blade according to claim 5, characterized in that said panels are of isotropic material structure.

8. The wind rotor blade according to one of the claims 5 to 7, characterized in that said panels (15, 16, 17, 18) each comprising a compressed edge (41) and a tensed edge (43) opposite from the compressed edge (41),

   wherein a plurality of elastomeric joints (56) is provided which join the panels (15, 16, 17, 18) together such that the tensed edge (43) of each panel is jointed to the compressed edge (41) of the adjacent panel, wherein at least one fiber tow (49) in a given tensed edge experiences a tensile force when the tensile edge is coupled with the compressed edge of the adjacent panel by one of the elastomeric joints (56),

wherein at least one fiber tow (49) in a given compressed edge experiences a compression force when the given compressed edge is joined with the tensed edge of the adjacent panel by one of the elastomeric joints,

wherein the tensile and compression forces applied to the tensed and compressed edges (43, 41) of the panels (15, 16, 17, 18), respectively, by the elastomeric joints (56) warps the panels to provide the blade (1) with a blade pitch varying from the proximal end (3) to the distal end (5) of the blade from a positive angle of attack to a negative angle of attack resulting in positive and negative pitch.

9. The wind rotor blade according to claim 8, characterized by applying a respective force to the tows and/or the elastomeric joints, the blade pitch is adjustable according to the load applied on the blade (1).

10. The wind rotor blade of one of the claims 1 to 9, characterized in that the central load bearing part or spar (11) comprises one or more leading edge notches (60) formed in the spar at the leading edge portion, that the at least one leading edge fairing (7) includes one or more tabs (62) that extend therefrom, and in that the at least one leading edge fairing (7) is attached to the spar (11) at the leading edge portion at least in part by an engagement between the one or more tabs (62) that extend from the leading edge fairing with the one or more notches (60) formed in the spar at the leading edge portion.

11. The wind rotor blade of one of the claims 1 to 10, characterized in that the spar (11) comprises one or more trailing edge notches formed in the spar at the trailing edge portion, that the at least one trailing edge fairing includes one or more tabs that extend therefrom, and in that the at least one trailing edge fairing is attached to the spar at the trailing edge portion at least in part by an engagement between the one or

more tabs that extend from the trailing edge fairing with the one or more notches formed in the spar at the trailing edge portion.

12. The wind rotor blade of one of the claims 1 to 11, characterized in that the central load bearing part or spar (11) is formed from a plurality of fiber tows such that one or more of the fiber tows at the proximal end of the spar extend from the blade and are configured to engage the turbine hub (2) to enable the blade (1) to be removably coupled with the turbine hub (2).

13. The wind rotor blade of one of the claims 1 to 12, characterized in that the central load bearing part or spar (11) is warped when assembled and fixed at the elastomeric transition joints.

14. The wind rotor blade of one of the claims 1 to 13, characterized in that when fully loaded, the twisted or warped central load bearing part or spar (11) untwists as predetermined by the joints into the straight unwarped shape.

15. The wind rotor blade of one of the claims 5 to 14, characterized in that the panels are built up by shear webs (77) comprising tuned compression tows (79) to absorb the applied frequency loads while adding stiffness with less weight in curve linear paths.

16. The wind rotor blade of one of the claims 1 to 15, characterized in that the at least one trailing edge fairing (9) comprises an inner loop (65) for adding flexibility to the fairing during twisting.

17. The wind rotor blade of one of the claims 1 to 16, characterized in that said blade (1) houses a rolled sailcloth (61) extending preferably from the proximal end to the distal end, said sailcloth (61) being unrolled to extend the area of the blade (1) during low winds.

18. The wind rotor blade of claim 17, characterized in that the sailcloth (61) is rolled up in said blade (1) with increasing wind by feeling the tension on a sheet (67) which is

provided to pull the sailcloth (61) out of trailing edge fairings (9) and initiating furling with preset maximum tension.

19. The wind rotor blade of claim 18, characterized in that the blade is coupled to the hub (2) by a hinge (69) and an activator (71), said activator (71) during higher wind situations is able to fold the blade (1) behind the hub (2) in wind direction.

20. The wind rotor blade of one of the claims 1 to 19, characterized by comprising a plurality of fairings (7) and carbon fiber filaments (93) that end in the expansion joints between the sectional fairings (7) to cause plasma generation when lightning (91) is close and in that said plasma generated at filament ends represents a receptor and path (95) for the lightning (91).

21. The wind rotor blade of one of the claims 1 to 20, characterized in that the load bearing panels (15, 16, 17, 18) have a series of connectors (57, 59) attached to each longitudinal side allowing hinged connection to each adjacent panel.

22. The wind rotor blade of one of the claims 1 to 21, characterized in that the corner tensioning tows (49) act as hinge pin at the corners.

23. The wind rotor blade of one of the claims 1 to 22, characterized in that the panels (15, 16, 17, 18) are provided with actuators, preverably hydraulic cylinders (56), between each connector (57, 59) at the hinged joint.

24. The wind rotor blade of one of the claims 1 to 23, characterized in that the load bearing spar (11) comprises, at each corner attached to the central tensioning tows and the hub, an actuator pulling the corners together against the elastomeric joints.

25. The wind rotor blade of one of the claims 1 to 24, characterized in that said blade (1) comprises mold defined edges which comprise foil hinged end joints which can be folded back onto the fiber stack.

26. The wind rotor blade of one of the claims 1 to 25, characterized in that the fairings are made with the molds having the leading edge and the trailing edge at its center as integral part of the molding.

27. The wind rotor blade of one of the claims 1 to 26, characterized in that the root interface to the hub is comprised by extending the load bearing tows into the mold defined interface structure.

28. The wind rotor blade of one of the claims 1 to 27, characterized in that the root interface is in the form of common metal stud interfaces but comprising impregnated homogenous fiber tows going through same flange bores.

29. The wind rotor blade of one of the claims 1 to 28, characterized in that the root is made with the central corner tensioning tows (81) defining the hub interface.

30. The wind rotor blade of one of the claims 1 to 29, characterized in that said blade (1) is fixed without pitch control rotating the blade (1) at the hub (2).

31. The wind rotor blade of one of the claims 19 to 30, characterized in that said blade (1) is fixed to the hub (2) with a hinged joint that allows the blade to fold with an actuator (71) behind the hub (2) and reduce the frontal area incrementally with higher wind loads.

32. A wind turbine for producing electric energy due to attacking winds on at least one rotor blade being removable attached to a hub of the turbine, characterized in that said rotor blade (1) is configured according to one of the claims 1 to 31.

33. The turbine of claim 32, characterized in that the a proximal end (3) of said blade (1) is configured to be removably coupled with the hub (2), and in that the blade (1) is formed from a plurality of fiber tows such that one or more of the fiber tows extend from the proximal end of the blade and engage the hub to enable the blade to be removably coupled with the hub.

34. The turbine of claim 33, characterized in that the hub forms one or more conduits, a given conduit communicating two openings formed in the surface of the hub, the one or more conduits being formed such that the one or more fiber tows that extend from the proximal end of the blade are engaged with the hub by insertion into the one or more conduits.

35. The turbine of claim 34, characterized in that the one or more fiber tows that extend from the proximal end of the blade are retained in the one or more openings by one or more fasteners that engage the one or more fiber tows and at least one of the openings of the one or more conduits.

36. The turbine of claim 35, characterized in that the one or more fasteners comprise one or more unthreaded fasteners.

37. The turbine of claim 35, wherein the one or more fasteners comprise one or more compression locks (85).

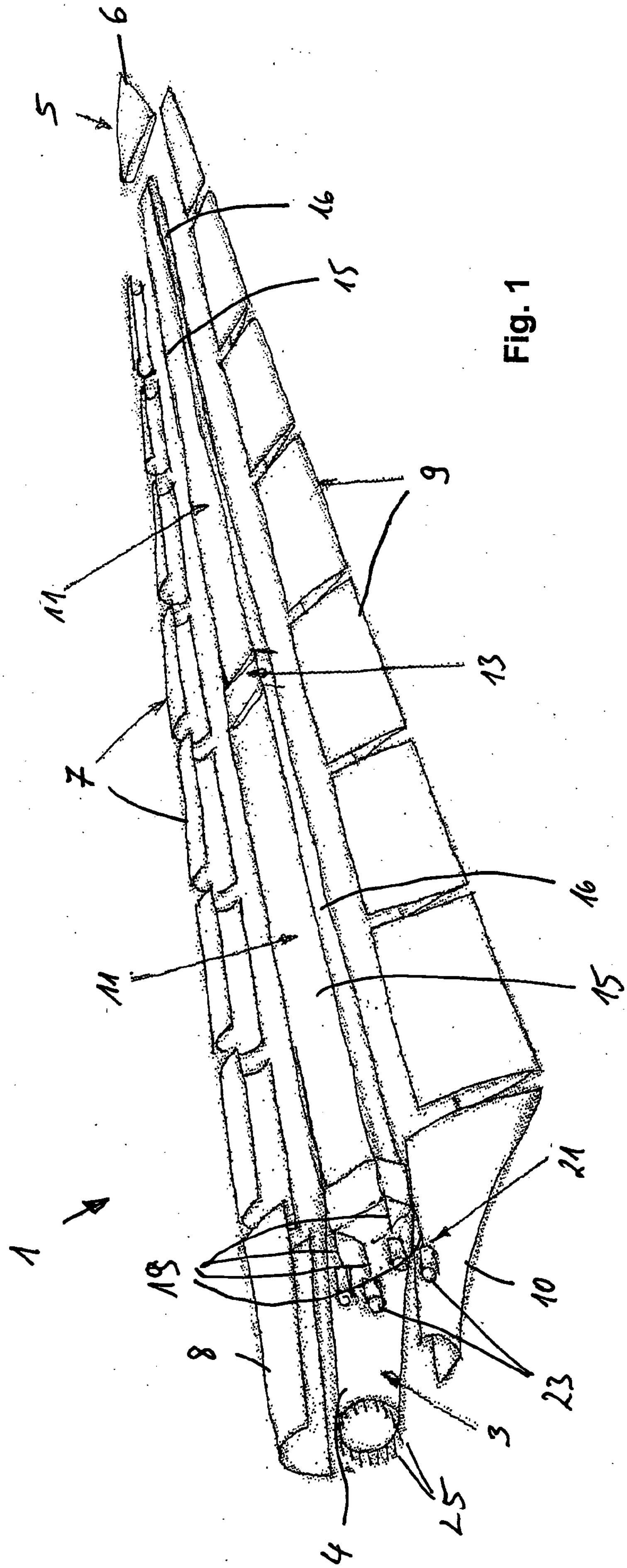

Fig. 1

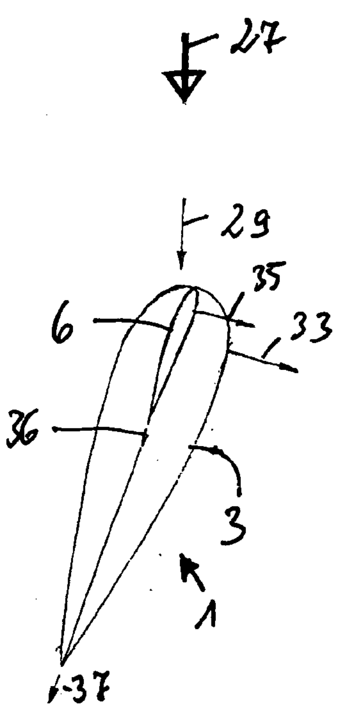

Fig. 2a

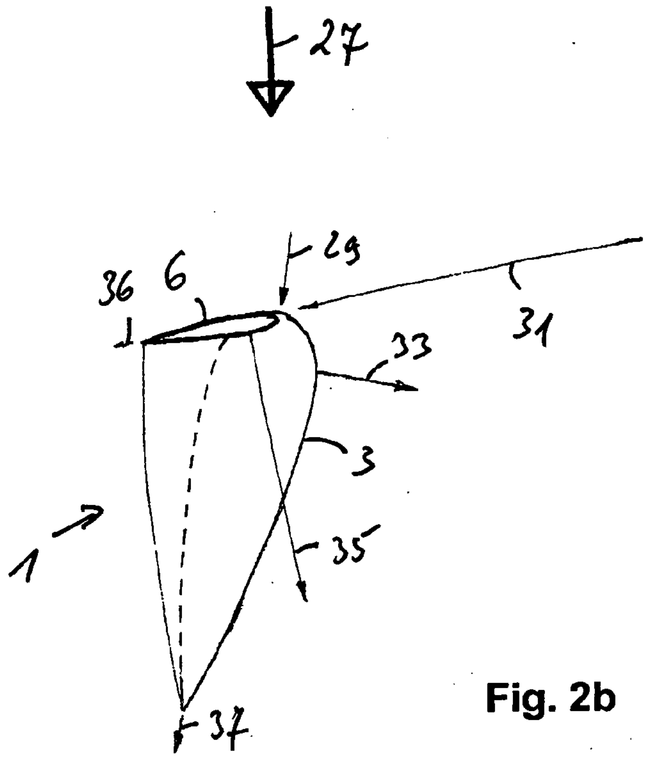

Fig. 2b

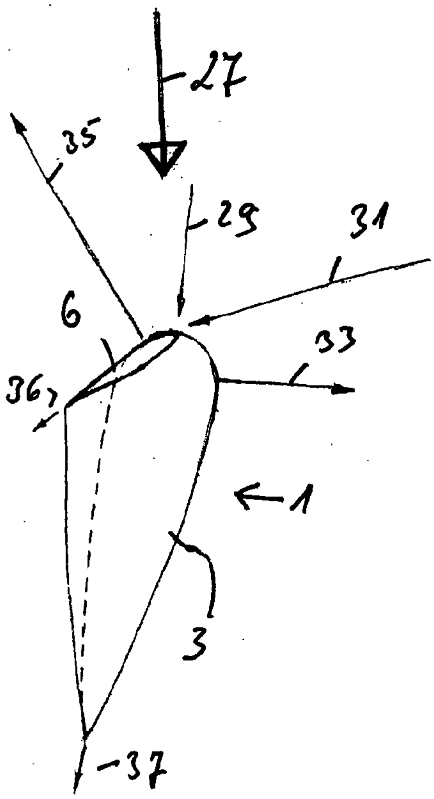

Fig. 2c

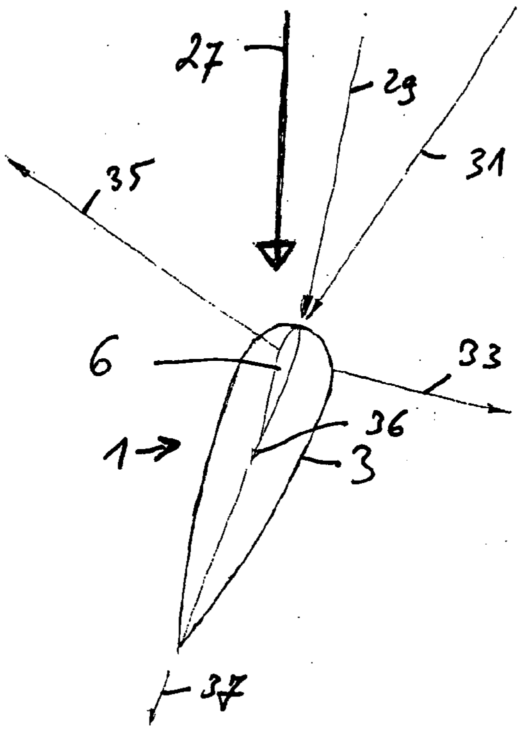

Fig. 2d

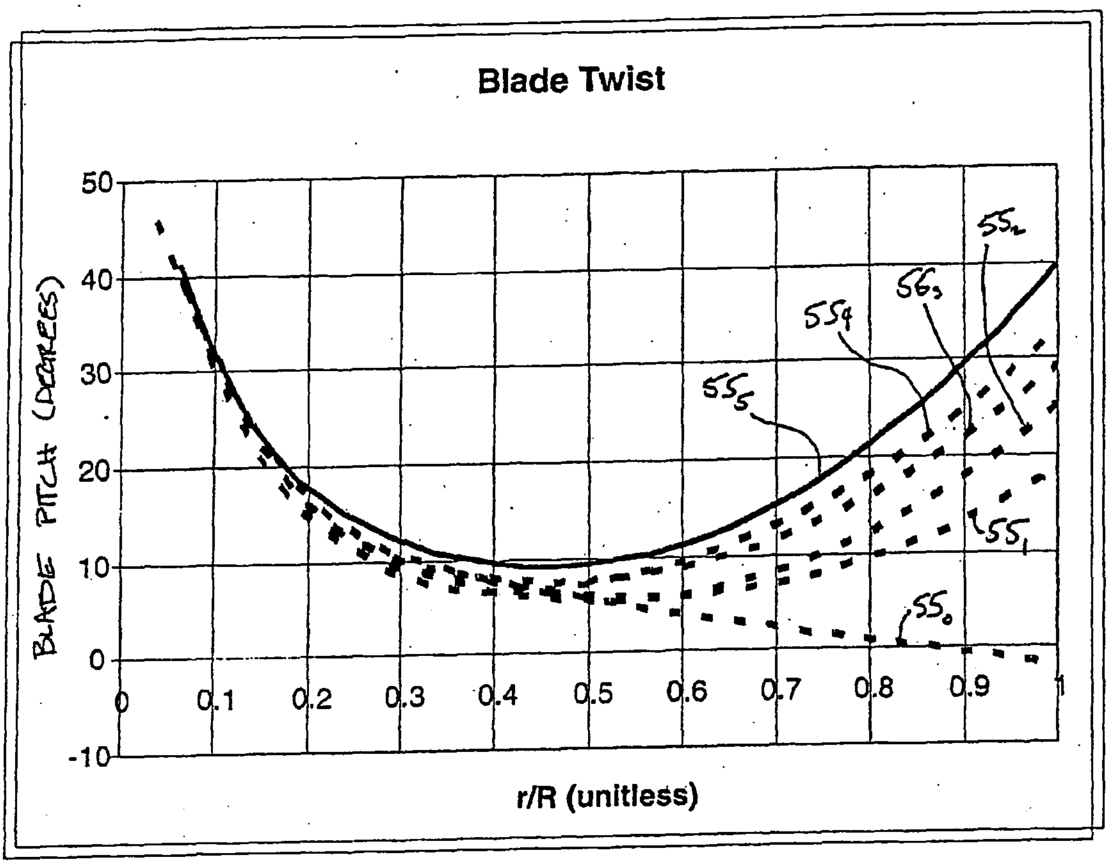
Blade Twist
50
40
30
20
10
0
-10
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
r/R (unitless)
BLADE PITCH (DEGREES)

Fig. 3

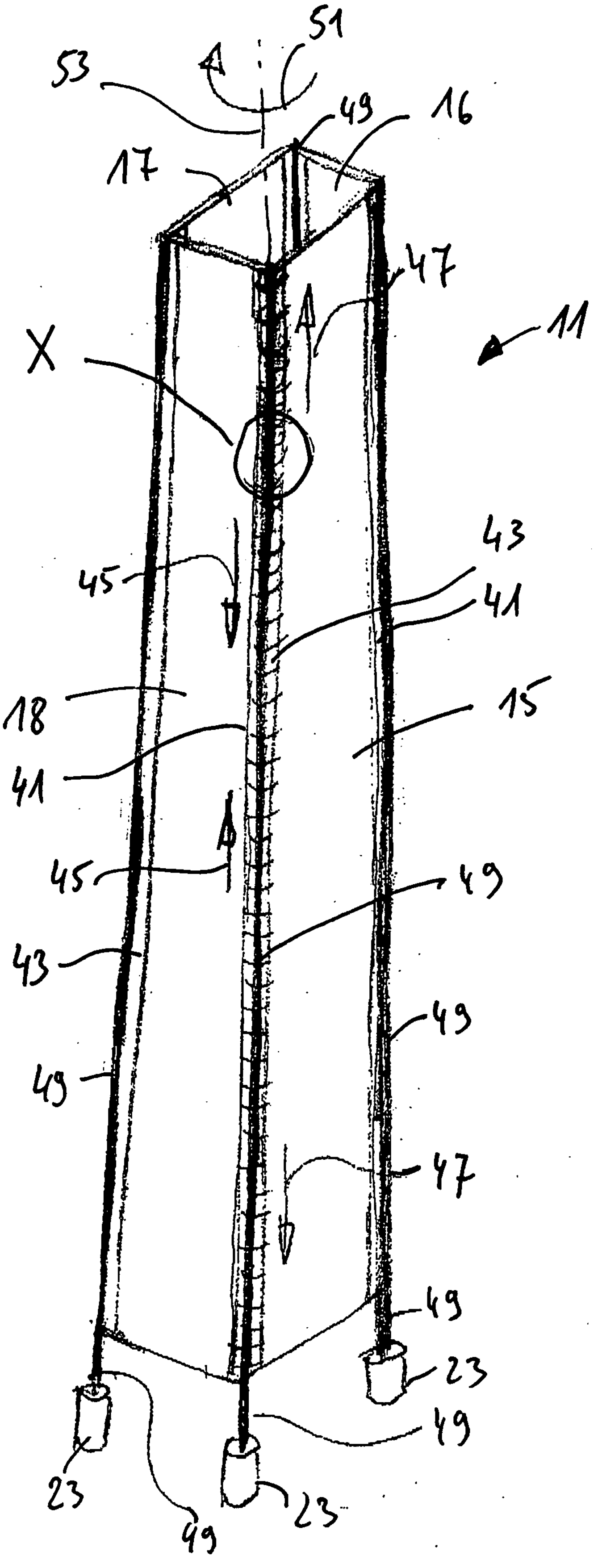
51
53
49
16
17
47
11
X
43
45
41
18
15
45
49
43
49
47
23

Fig. 4

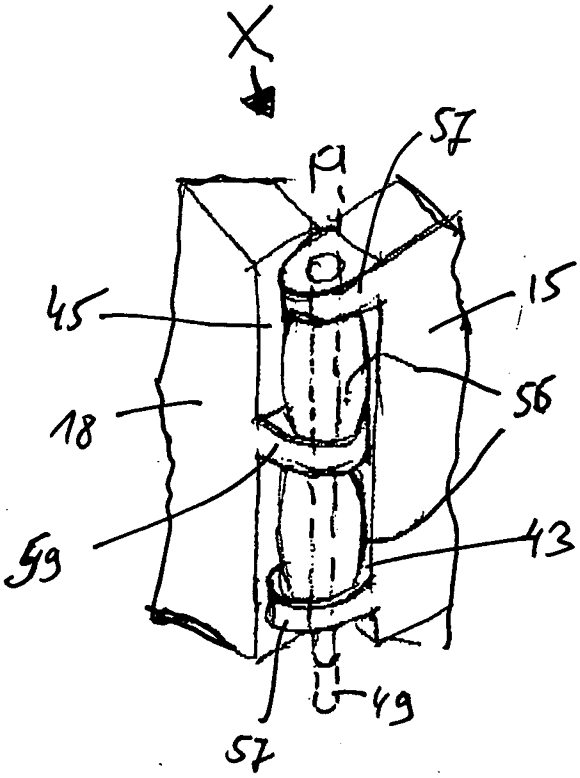
X
57
45
15
18
56
59
43
49
57

Fig. 5

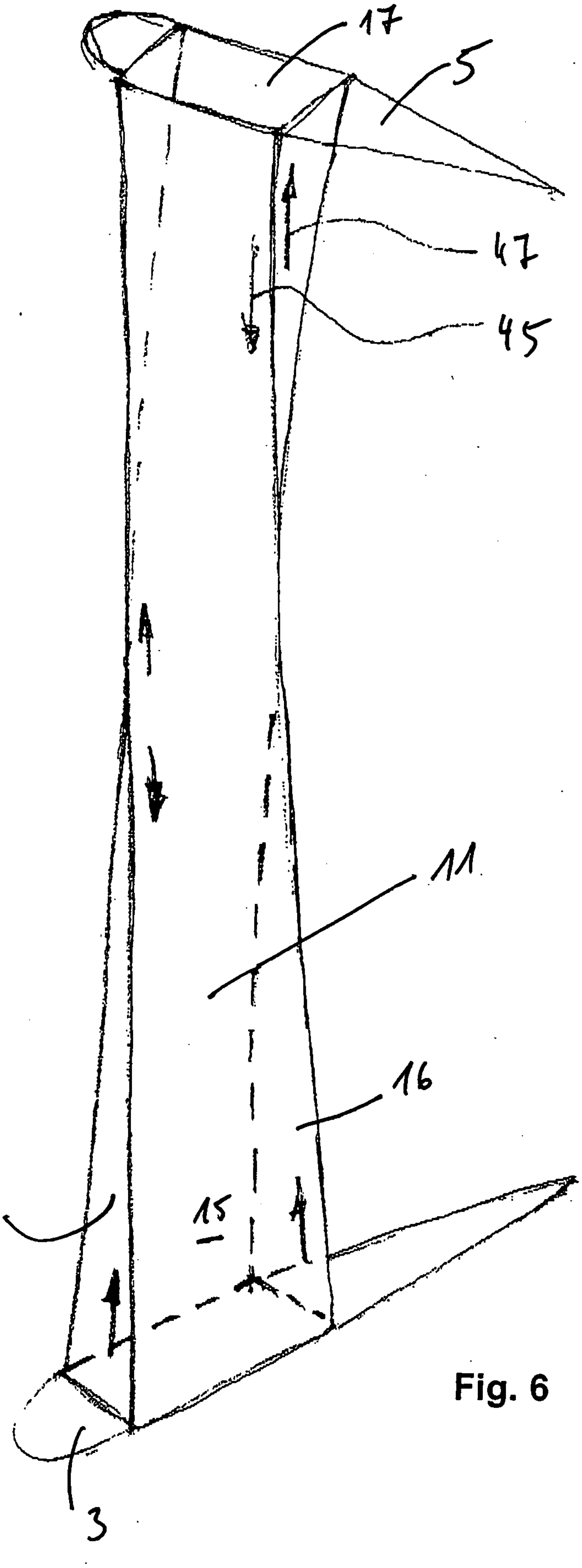

Fig. 6

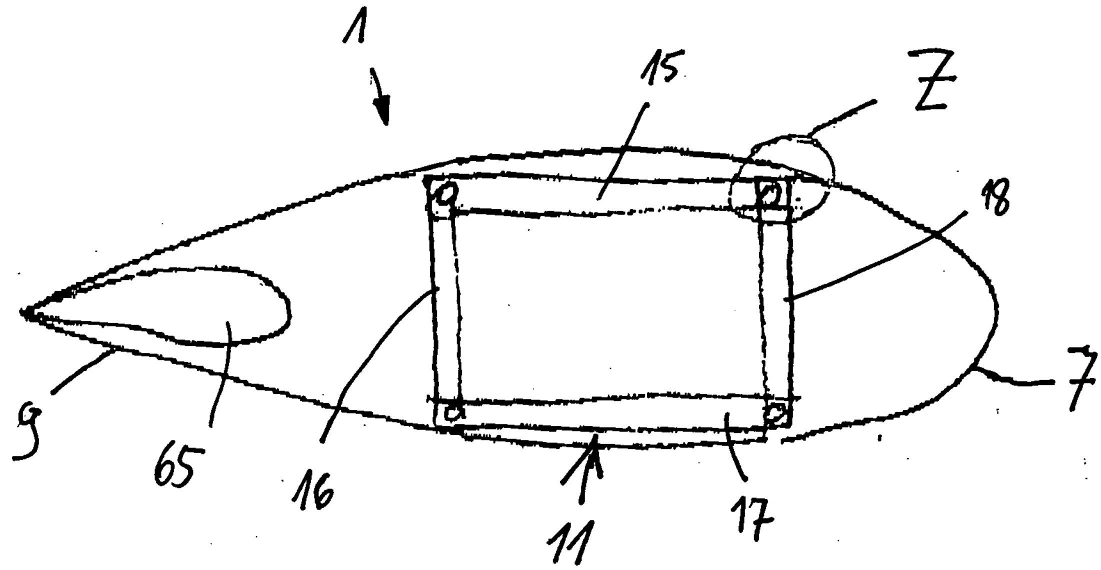

Fig. 7a

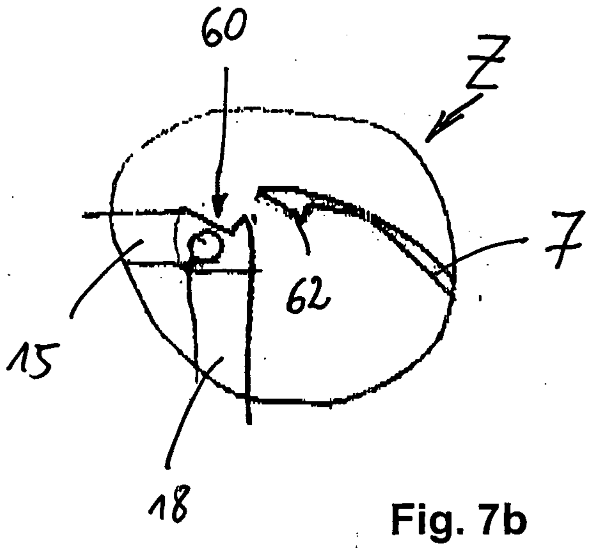

Fig. 7b

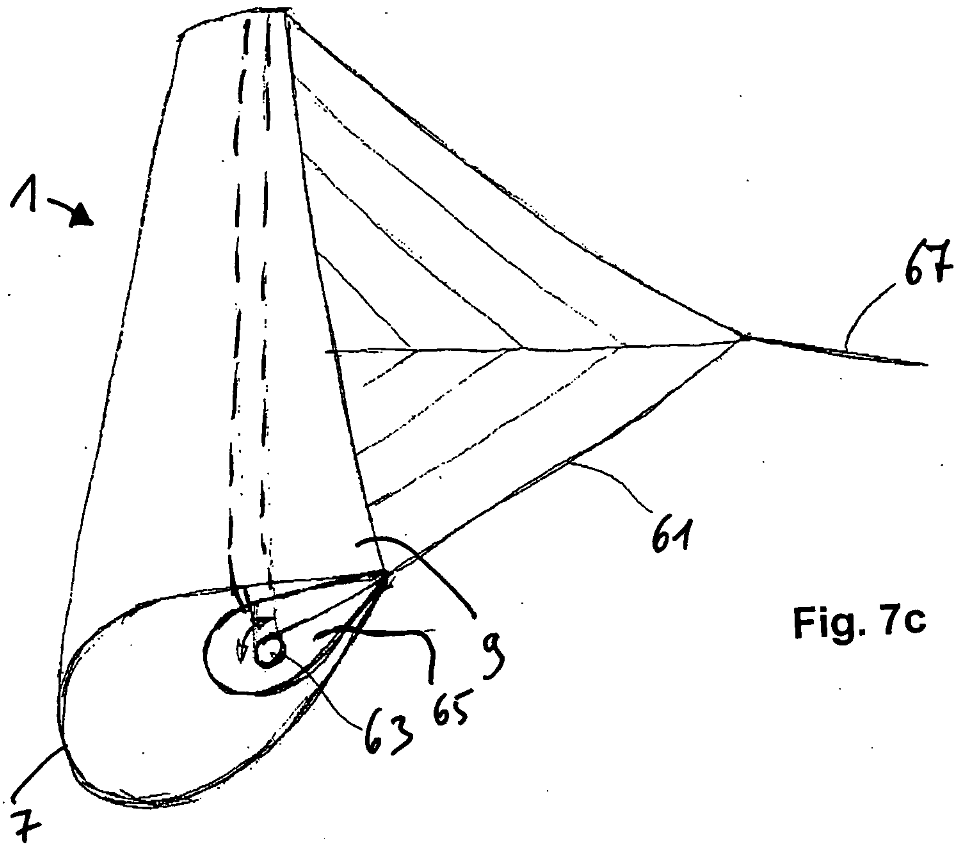

Fig. 7c

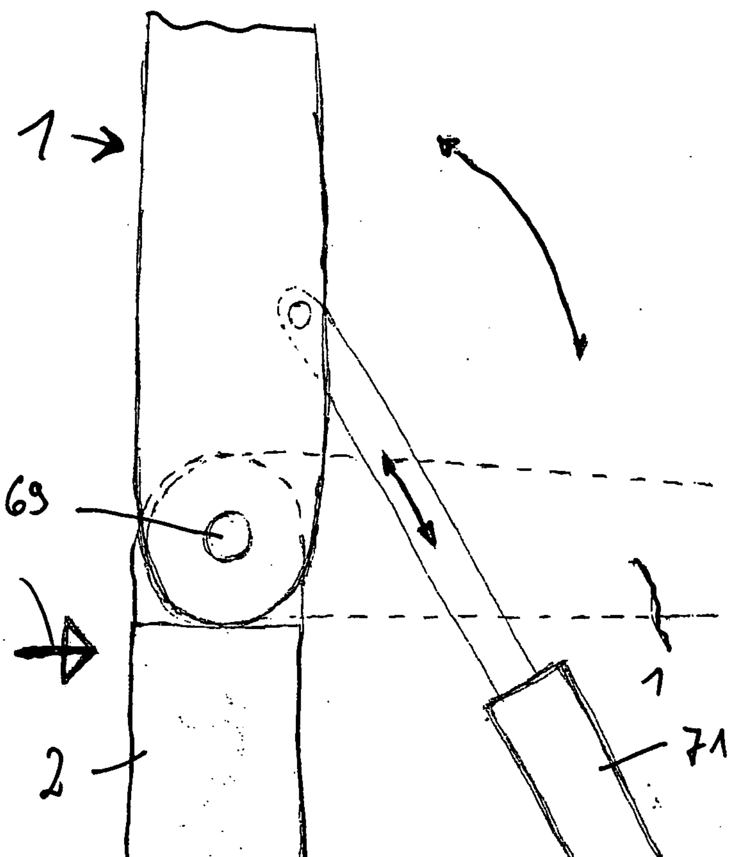

Fig. 8

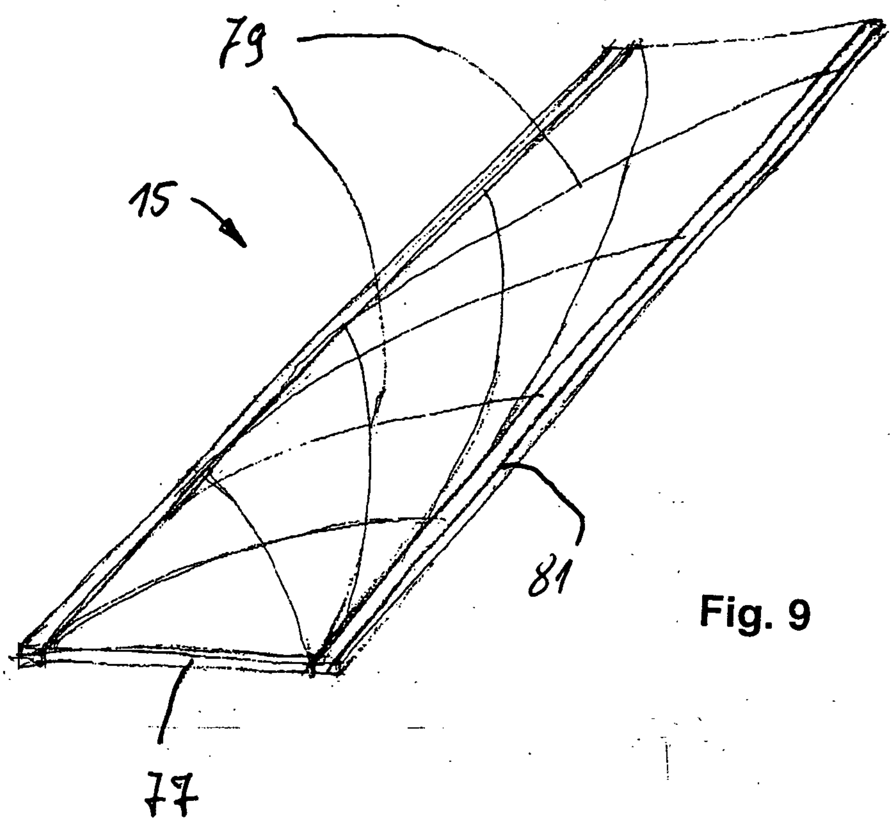

Fig. 9

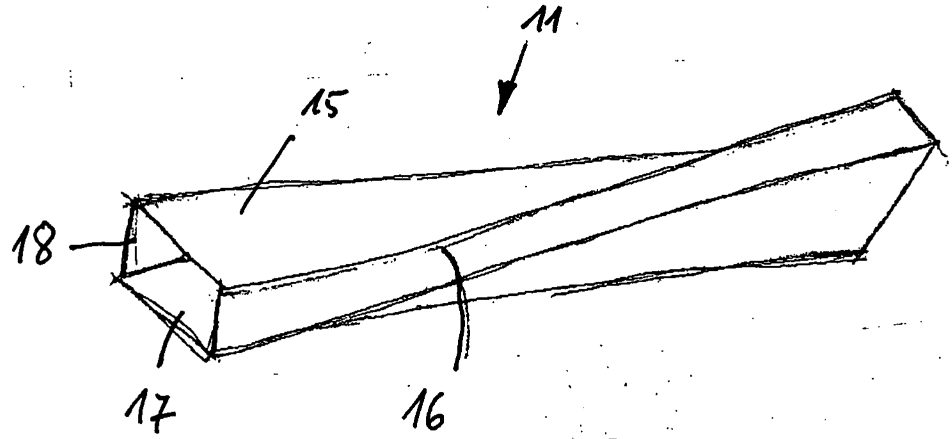

Fig. 10

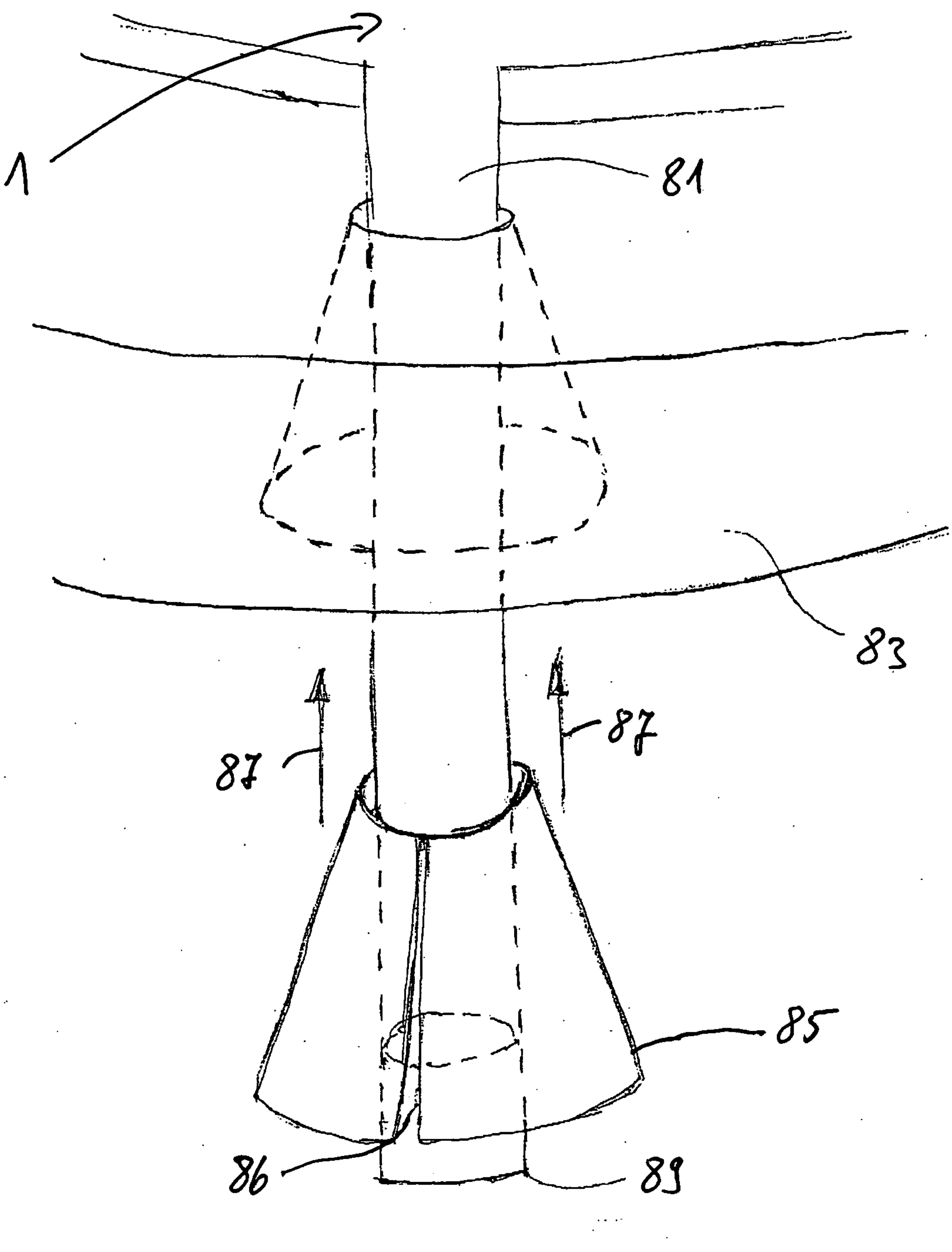

Fig. 11

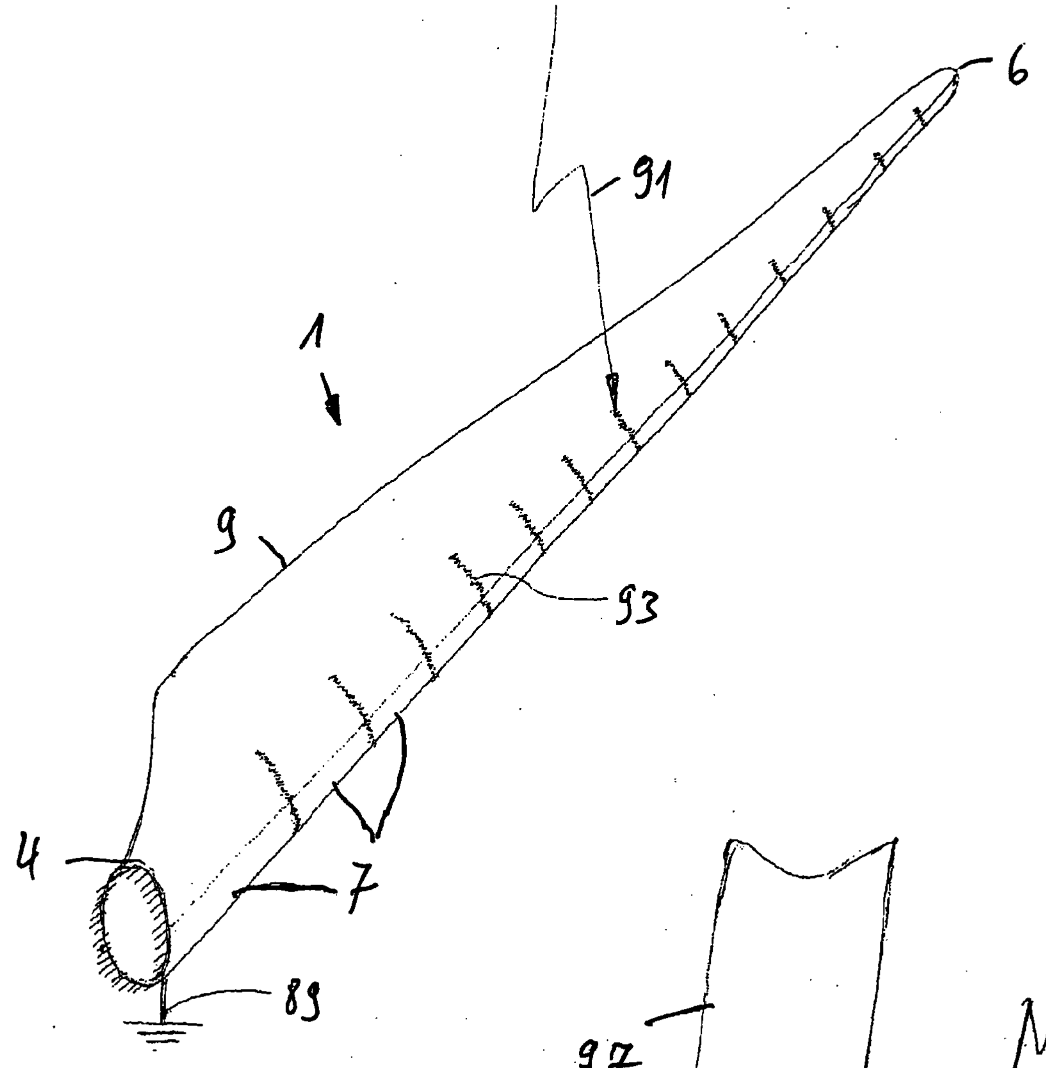

Fig. 12

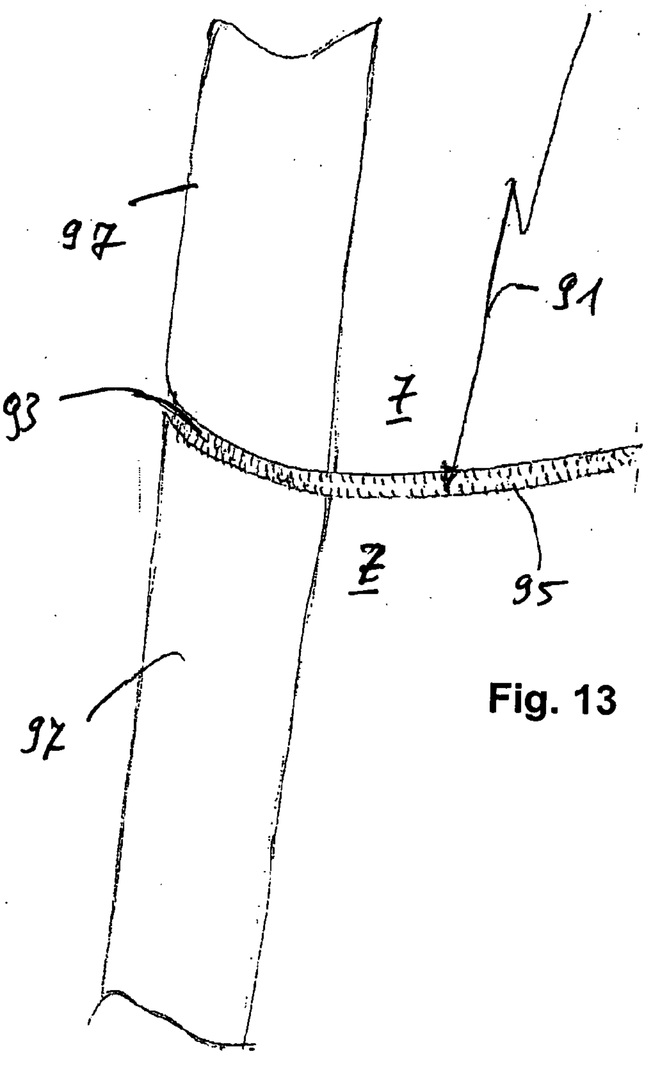

Fig. 13