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(54) **Title**: BLADE FOR A ROTOR OF A WIND TURBINE AND A WIND TURBINE

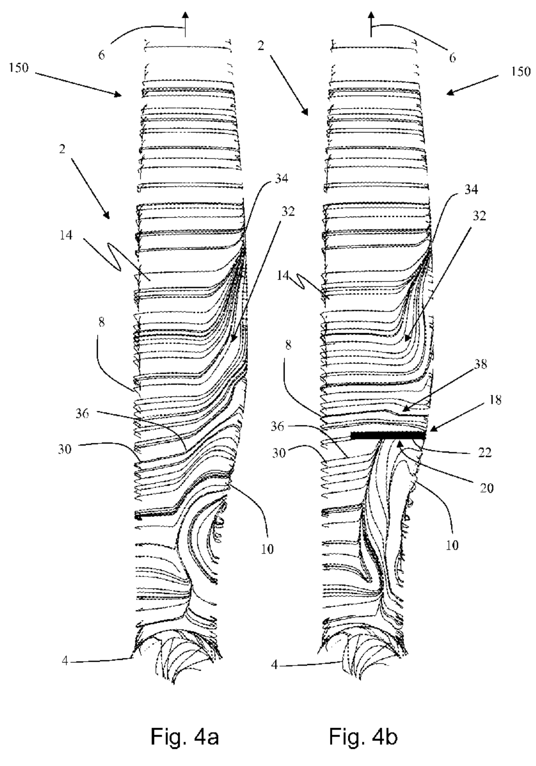

Fig. 4a Fig. 4b

(57) **Abstract**: Blade (2) for a rotor of a wind turbine, the blade (2) having a root end (4), a tip end (6), a leading edge (8), a trailing edge (10), a suction side (14) and a pressure side (16), the blade (2) being configured for generating lift upon application of an incident flow, wherein during lift generation a separated flow region (32) with radial flow extends on the suction side (14) from the root end (4) towards an end point (34) on the trailing edge (10) at a distance from the root end (4), wherein the blade (2) comprise a flow filter (18), wherein the flow filter (18) is located in the separated flow region (32), wherein the flow filter (18) is configured with a flow opening (22) for permitting boundary layer radial flow through the flow filter (18), and wherein the flow filter (18) is configured with a restrictor portion (22) for suppressing outside boundary layer radial flow through the flow filter (18).

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Blade for a rotor of a wind turbine and a wind turbine

The present invention relates to a blade for a rotor of a wind turbine, the blade having a root end, a tip end, a leading edge, a trailing edge, a suction side and a pressure side, the blade being configured for generating lift upon application of an incident flow, wherein during lift generation a separated flow region with radial flow extends on the suction side from the root end towards an end point on the trailing edge at a distance from the root end.

Furthermore the invention relates to a wind turbine comprising a rotor.

On a horizontal axis wind turbine the rotor comprise a plurality of blades. The blades are attached to a hub at their root end and evenly distributed around the hub. Each blade is an elongated body extending from the hub in a radial direction in relation to the rotation axis of the rotor towards an end point, which is defined as the tip end of the blade.

The blade is provided with profiles in planes that are orthogonal to the radial direction between the root end and the tip end. At the root end the blade has a substantially circular profile and towards the tip end the profile gradually changes into an airfoil profile.

The term lift (or lift force) is defined as; the component of the aerodynamic force generated by a surface within a fluid which is directed in the direction perpendicular to the incoming non-disturbed flow.

The term drag (or drag force) is defined as; the component of the aerodynamic force generated by a surface within a fluid which is directed in the direction parallel to the incoming non-disturbed flow.

The airfoil profile has a suction side and a pressure side, thus the blade is configured for generating lift upon application of an incident flow. The blade may therefore be divided into three regions; a root region, a transition region and a lift generating region.

The transition region tends to be rather thick due to structural and geometric constraints. During operation the blade will be subjected to high angles of attack of the incoming flow in the transition region. Therefore the flow is prone to separate on the suction side of the blade. This creates a region of highly unsteady flow which is being dragged with the blade. Due to the inability of the flow to sustain the rotation imposed by the blade, the flow begins to move radially outwards. This radial flow moves substantially perpendicular to the main incident flow, following a line pointing from the root end to the tip end of the blade. The region of radial flow is known by the person skilled in the art as the “separated flow region” or, as an alternative, “region of detached flow”. The separated flow region extends on the suction side from the root end towards an end point on the trailing edge at a distance from the root end, where the flow past the blade is directed transversal to the radial direction of the blade between the root end and the tip end.

The separated flow region is not limited to any one of the aforementioned three regions.

Although the transition region and the separated flow region may provide lift it does not work as efficiently as the lift generating region. Furthermore the drag is also high.

In US 2006/0280614 A1 an attempt to increase the efficiency of the transition region has been made. US 2006/0280614 A1 discloses a blade for a wind turbine, wherein the blade is equipped with a device for optimizing the flow in the transition region. The device is a planar element that extends substantially in the direction of the incident flow, protrudes from the suction side and is arranged in the separated flow region.

The device is configured for reducing, suppressing or precluding the radial flow from encroaching into regions of non separated flow.

Another device for optimizing the flow across a wind turbine blade has been disclosed in EP 2383465 A1. EP 2383465 A1 discloses a slat device for a wind turbine blade having a profiled contour. The slat device is being supported by at least two support devices positioning the slat device at a distance from the surface of the profiled contour. The purpose of the slat device is to control the flow in a chordwise direction of the blade. In this way the chordwise flow may remain attached and laminar further down the chord of the wing as compared to a blade without the slat. The slat is located near the leading edge area of the blade in order to influence the airflow before the flow becomes separated from the blade surface. This is because the slat is not able to operate when located in a region where the airflow is already detached and turbulent. Orienting the slat device as the device in US 2006/0280614 A1 may only improve the efficiency of the blade if the slat is located in the radial airflow upstream of the separated flow region and not arranged inside the separated flow region.

One of the objects of the present invention is to improve the efficiency of the rotor blade and the wind turbine.

According to the present invention, this is achieved by a blade of the type specified in the introduction and which is peculiar in that, the blade comprise a flow filter, wherein the flow filter is located in the separated flow region, wherein the flow filter is configured with a flow opening for permitting boundary layer radial flow through the flow filter, and wherein the flow filter is configured with a restrictor portion for suppressing outside boundary layer radial flow through the flow filter.

Furthermore according to the present invention, this is achieved by a wind turbine of the type specified in the introduction and which is peculiar in that, the rotor comprise a blade according to any of the claims 1 to 12.

In the present application the term “boundary layer radial flow” is defined as the radial flow in the region close to the surface (boundary layer of the radial flow) of the blade where the velocity of the radial flow decreases rapidly from the main outer-flow velocity towards zero relative to the blade at the surface of the blade. In this case the outer-flow velocity is the velocity with which the radial flow moves from the root and radially outwards. The termination of a boundary layer is commonly defined in the literature as the point at which the flow velocity in the boundary layer has reached 99% of the free stream flow velocity. The boundary layer of the radial flow therefore extends from the surface of the blade up to the 99% outer-flow velocity point. This is defined as the boundary layer thickness.

The boundary layer thickness of the radial flow boundary layer may vary along the chord of the blade.

In the present application the term “outside boundary layer radial flow” is defined as the flow which extends outside the aforementioned boundary layer of the radial flow and which terminates at the boundary between the separated flow region and the incident flow around the blade. The outside boundary layer radial flow may be highly unsteady and induce drag.

The airfoil used for the blade is of the trailing edge separating kind. This means that when the flow begins to separate from the surface, this happens first at the trailing edge, and as the angle of attack is increased, the separation point moves forward towards the leading edge.

In the case of separation on a rotating blade, a radial flow appears as already described. The velocity of the radial flow is not negligible.

The flow filter separates the radial flow such that the boundary layer radial flow is allowed to continue through the flow filter, and such that the outside boundary layer radial flow through the flow filter is suppressed.

Far from the surface of the blade on the suction side, where the separated flow region terminates, the radial velocity will be close to zero. Approaching the blade surface the velocity of the radial flow will first increase, giving the core of the radial flow velocity component, and approaching the blade even further until very close to the surface of the blade, the velocity of the radial flow will again approach zero because of the so-called no-slip condition. This condition assures that at the surface, all flow has a velocity equal to zero relative to the blade, i.e. the flow does not "slip" on the surface itself.

The velocity and direction of the radial flow will vary inside the separated flow region. The size and shape of the separated flow region will vary with the distance from the surface of the blade.

The radial flow is related to an increase in the speed of the flow in the boundary layer. Following an increase in speed the pressure decreases in the boundary layer. The aforementioned decrease in pressure caused by the radial flow close to the surface will stabilise the boundary layer and delay the separation of the incident flow. In all, this has the effect of delaying stall.

By introducing the flow filter a boundary layer radial flow is maintained through the flow filter and the unsteady outside boundary radial flow is suppressed or even partly blocked on the root end side of the flow filter, such that the delay in separation may be achieved on the tip end side of the flow filter. This will reduce the drag of the blade and increase the lift in the transition region. Thus, the efficiency of the blade in the transition zone is increased.

The flow filter is located in the separated flow region. The extend of the separated flow region is affected by the introduction of the flow filter. Therefore the skilled person will base the initial positioning of the flow filter on the extend of the separated flow region on a blade without the flow filter.

The positioning and specific geometry of the flow filter on a particular blade will be based on either computational fluid dynamics (CFD) analysis, wind tunnel testing on scale blades, tuft testing on full scale blades or a combination. Optimization as an iterative process may also be performed using the tools mentioned above.

The separated flow region is not stationary and it's extend and shape for a given blade is dependent on the operational parameters of the wind turbine, for example the velocity of the incident airflow, the direction of the incident airflow and/or the pitch of the blade.

The position and geometry of the flow filter is therefore preferably established based on the nominal operational condition and possibly a trade-off between that and a other operational points to achieve the most efficient compromise throughout the operational regime for a particular wind turbine.

The flow filter may be attached directly to the surface of the blade or integrated with the blade structure.

The flow filter may be an add-on feature that can be installed after the blade has been put into service.

According to a further embodiment, the blade according to the invention is peculiar in that, the starting point of the flow filter is at a distance from the leading edge of the blade of between 0 to 0.8 times the chord of the blade, preferably between the point of maximum thickness of the profile of the blade to 0.6 times the chord of the blade.

The separated flow region is usually extending between the above stated values. It has been found that especially the point of maximum thickness of the profile is related to the separation.

According to a further embodiment, the blade according to the invention is peculiar in that, the starting point of the flow filter is at a distance from the leading edge of the blade of between the point of maximum thickness of the profile of the blade to 0.6 times the chord of the blade.

It has been found that especially the point of maximum thickness of the profile is related to the separation.

According to a further embodiment, the blade according to the invention is peculiar in that, the thickness of the flow opening is between 0.001 to 0.1 times the chord of the blade, preferably between 0.005 to 0.05 times the chord of the blade.

The term thickness in relation to the flow opening refers to the distance between the surface of the blade in a direction perpendicular to the surface of the blade and the boundary of the flow opening.

The boundary layer thickness may vary along the chord of the blade and along the span. It has been found that by configuring the flow filter within the ranges stated above an optimum thickness of the flow opening.

According to a further embodiment, the blade according to the invention is peculiar in that, the flow opening extends from the blade surface.

It is herewith achieved that the boundary layer radial flow may flow smoothly through the flow opening as the boundary layer extends from the surface as explained previously.

According to a further embodiment, the blade according to the invention is peculiar in that, the thickness of the flow opening is substantially equal to the boundary layer thickness.

It is herewith achieved that the full advantage of the boundary layer radial flow is utilised.

The boundary layer thickness is variable dependent on the flow conditions. Therefore the thickness of the flow opening above the blade surface is based on a best estimate of the boundary layer thickness of the radial flow boundary layer in a preferred operating condition of the blade.

According to a further embodiment, the blade according to the invention is peculiar in that, the flow filter is a planar element, wherein said planar element is mounted by its narrow side on the suction side of the blade and oriented substantially perpendicular to the radial flow, wherein the restrictor portion is constituted by the planar element outside the flow opening.

This is a solution to providing the flow filter in a simple manner, which is easy to manufacture and design.

The planar element may be a plate that is cut into shape and attached directly to the blade.

The profile of the planar element is established based on the aforementioned design tools. It should be designed such that it blocks the majority of the outside boundary layer radial flow. However, the size and shape of the planar element is a compromise between the loss of efficiency imposed by the drag of the element and the efficiency improving effect by separating the boundary layer radial flow from the outside boundary layer radial flow.

According to a further embodiment, the blade according to the invention is peculiar in that, the restrictor portion extends in the chord-wise direction beyond the trailing edge of the blade.

As the separated flow region extend as a wake above and behind the trailing edge of the wing it has a beneficial effect to suppress the outside boundary layer radial flow as far as beyond the trailing edge of the blade.

According to a further embodiment, the blade according to the invention is peculiar in that, the flow opening is a slot or a plurality of slots or through holes in the flow filter.

It is herewith achieved that the flow filter may be securely attached to the surface of the blade as the abutment area between the flow filter and the blade is larger. Furthermore the flow filter may benefit structurally from having more attachment points to the blade.

According to a further embodiment, the blade according to the invention is peculiar in that, the flow opening extends from the chord-wise position where the separated flow region begins to the chord-wise position where the separated flow region ends.

It is herewith achieved that the full extend of the boundary layer radial flow across the chord-wise extend of the separated flow region may be utilised.

According to a further embodiment, the blade according to the invention is peculiar in that, the blade comprises a plurality of flow filters disposed side-by-side.

It is herewith achieved that an even further improvement of the efficiency of the transition region is achieved. The flow conditions in the transition region may be optimized such that as much of the flow in the transition region produces lift.

The individual flow filters may have identical or different profiles and geometries both of the flow opening and of the restrictor portion. This depends on the flow conditions at the location of each flow filter.

The flow filters may be evenly distributed within the transition zone or distributed with varying distances according to the flow conditions at the location of each flow filter.

According to a further embodiment, the blade according to the invention is peculiar in that, the flow filter has a guide surface facing the root end of the blade, wherein the guide surface is configured for guiding outside boundary layer radial flow towards the flow opening.

In this way the velocity of the flow through the filter may increase even further, such that the pressure reduction increases further. Thus the stabilising effect of the boundary layer radial flow is enhanced and the efficiency of the blade is increased.

According to a further embodiment, the blade according to the invention is peculiar in that, the guide surface is set at an acute angle in relation to the blade surface.

The guide surface will be at an acute angle to the surface of the blade towards the root end. This will guide the outside boundary layer radial flow towards the flow opening of the flow filter and thus the boundary layer of the radial flow.

This is a simple way of achieving the guidance towards the flow opening.

According to a further embodiment, the blade according to the invention is peculiar in that, the guide surface has a funnel shaped or curved course across the blade.

This will guide the outside boundary layer radial flow towards the flow opening of the flow filter and thus the boundary layer of the radial flow.

According to a further embodiment, the blade according to the invention is peculiar in that, the flow filter comprise means for absorbing noise.

It is herewith achieved that noise caused by the presence of the separated flow region may be reduced by the presence of the flow filter.

For example the means for absorbing noise may be a foam material, a mineral wool material, a Helmholtz resonator, foam covered by a plastic film or a hybrid noise absorber.

In a first further embodiment, the blade according to the invention is peculiar in that, the span-wise width of the flow filter is between 0.0001 to 0.1 times the chord of the blade, preferably between 0.001 to 0.01 times the chord of the blade.

For manufacturing reasons and weight reasons it is preferable that the span-wise width of the flow filter is as small as possible, but to achieve a secure attachment and maintain the structural integrity of the blade filter the span-wise width should be as large as possible. By using the ranges stated above a suitable compromise is achieved.

In a second further embodiment, the blade according to the invention is peculiar in that, the length of the flow filter is up to 1.5 times the chord of the blade preferably less than 1 times the chord of the blade, more preferably between 0.5 to 0.8 times the chord of the blade.

The flow filter shall preferably extend from the chord-wise position where the separated flow region begins to the chord-wise position where the separated flow region ends. It has been found that this is achieved by configuring the flow filter within the above ranges.

In a third further embodiment, the blade according to the invention is peculiar in that, the length of the flow opening is up to 1 times the chord of the blade, preferably between 0.5 to 0.8 times the chord of the blade.

The flow opening should be as large as possible, but should allow for attachment points of a sufficient size to achieve a secure attachment. It has been found that by configuring the flow filter within the above ranges this is achieved.

In a fourth further embodiment, the blade according to the invention is peculiar in that, the height of the flow filter above the surface of the blade is between 0. 1 to 1 times the chord of the blade, preferably between 0.3 to 0.5 times the chord of the blade.

The height of the flow filter determines the extend of the restrictor. In order to achieve sufficient suppression of the outside boundary layer radial flow through the filter it is preferred that the restrictor is as large as possible. However to keep the drag as low as possible and to maintain the structural integrity of the flow filter it is preferred to keep the restrictor as small as possible. By using the ranges stated above a suitable compromise is achieved.

One or more of the first, second, third, fourth, fifth and sixth further embodiments may be combined with each other.

One or more of the first, second, third and fourth further embodiments may be combined individually or in combination with all other embodiments of this application having a flow opening that extends from the blade surface, a thickness of the flow opening that is substantially equal to the boundary layer thickness and having a flow filter configured as a planar element, wherein said planar element is mounted by its narrow side on the suction side of the blade and oriented substantially perpendicular to the radial flow, wherein the restrictor portion is constituted by the planar element outside the flow opening.

The invention will be explained in more detail below with reference to the accompanying drawing, where:

Fig. 1 shows a perspective view of a wind turbine,

Fig. 2 shows a perspective view of a first embodiment of a flow filter,

Fig. 3a shows a CFD analysis of the boundary layer flow on a blade without a flow filter according to the invention,

Fig. 3b shows a CFD analysis of the boundary layer flow on a blade with a flow filter according to the invention,

Fig. 4a shows a CFD analysis of the flow at a distance from the surface of the blade on fig. 3a,

Fig. 4b shows a CFD analysis of the flow at a distance from the surface of the blade on fig. 3b,

Fig. 5 shows a side view illustration of a blade with a flow filter,

Fig. 6 shows a perspective view of a second embodiment of a flow filter,

Fig. 7 shows a perspective view of a third embodiment of a flow filter,

Fig. 8 shows a perspective view of a fourth embodiment of a flow filter,

Fig. 9 shows a perspective view of a fifth embodiment of a flow filter,

Fig. 10 shows a plan view of an embodiment of the blade having a plurality of flow filters, and

Fig. 11 illustrates the terminology used to describe the flow filter.

In the explanation of the figures, identical or corresponding elements will be provided with the same designations in different figures. Therefore, no explanation of all details will be given in connection with each single figure/embodiment.

Fig. 1 shows a perspective view of a wind turbine 100 according to the invention. The wind turbine 100 comprises a tower 110, a nacelle 120 located on top of the tower 110, a rotor 130 suspended from the nacelle 120. The rotor 130 comprises a plurality of blades 2. In the embodiment shown on fig. 1 the rotor 130 comprises three blades 2.

Each blade 2 has a root end 4 and a tip end 6. Each blade 2 may be divided into three regions; a root region 140, a transition region 150 and a lift generating region 160 that will be explained further below.

Fig. 2 shows a perspective view of a section of a blade 2 for a rotor 130 (see fig. 1) of a wind turbine 100 (see fig. 1).

The section of the blade 2 is from the transition region 150 (see fig. 1) between the root end 4 (indicated by an arrow) and the tip end 6 (indicated by an arrow). The blade 2 has a leading edge 8 and a trailing edge 10. The blade 2 is provided with profiles 12 in planes that are orthogonal to the radial direction between the root end 4 and the tip end 6. The shape of the profiles 12 is chosen such that the blade 2 is configured for generating lift upon application of an incident flow. During lift generation one side of the blade 2, the suction side 14, will be subject to suction and the other side of the blade, the pressure side 16 will be subject to pressure.

The profile 12 at the root end 4 is substantially circular and the profiles 12 closer to the tip have an airfoil shape. Therefore the profiles 12 in the transition region 150 (see fig. 1) are gradually changing from a circular shape to an airfoil shape.

The blade 2 comprises a flow filter 18. The flow filter 18 is configured with a flow opening 20 and a restrictor portion 22.

The flow opening 20 is a slot extending from a leading attachment 24 to a trailing attachment 26 respectively, where the flow filter 18 is attached to the blade 2.

The flow filter 18 may be integrated with the blade structure.

In the embodiment shown in fig. 2 the flow filter 18 is a planar element 28. The planar element 28 is mounted by it narrow side on the suction side 14 of the blade 2 and oriented substantially perpendicular to the radial flow. The restrictor portion 22 is constituted by the portion of the planar element 28 outside the flow opening 20.

In the embodiment shown in fig. 2 the restrictor portion 22 extends in the chord-wise direction beyond the trailing edge 10 of the blade 2.

The flow filter 18 may have means for absorbing noise incorporated.

Fig. 3a-b shows a CFD analysis of the boundary layer flow on a portion of a blade 2. Fig. 3a is a blade 2 without flow filter 18 and fig. 3b is a blade with flow filter 18. The flow is illustrated for the transition region 150 of the blade 2.

The flow lines 30 on fig. 3a-b illustrates the simulated boundary layer flow on the suction side 14 of the blade 2. The separated flow region 32 is clearly visible as a region of unstable flow with a generally radial direction from the root end 4 towards the tip end 6.

The separated flow region 32 extend radially to a point 34 on the trailing edge 10 where the flow lines 30 of the separated flow region 32 converge. Radially outwards of the point 34 the direction of the flow lines is generally transversal.

The flow filter 18 is located in the transition region 150 on fig. 3b. More specifically, the flow filter 18 is located in the separated flow region 32 on fig. 3b.

In the embodiment shown on fig. 3b the flow opening 20 extend from a chord-wise position inside the separated flow region 32 to the chord-wise position where the separated flow region 32 ends.

In an alternative embodiment, the flow opening 20 extends from the chord-wise position where the separated flow region 32 begins to the chord-wise position where the separated flow region 32 ends.

The chord-wise begin of the separated flow region 32 is visible on fig. 3a-b as the point 36 where a flow line 30 changes direction from a transversal direction to a radial or substantially radial direction.

The chord-wise end of the separated flow region is at the trailing edge 10 of the blade 2.

Fig. 3b illustrates the influence on the boundary layer flow of the introduction of the flow filter 18. In comparison with the blade 2 without flow filter 18 fig. 3b illustrates that the flow filter 18 does not block the boundary layer radial flow. The boundary layer radial flow passes through the flow filter through the flow opening 20.

Fig. 4a-b shows a CFD analysis of the outside boundary layer flow on the blade of fig. 3a-b respectively. Fig. 4a is the blade 2 without flow filter 18 and fig. 4b is the blade with flow filter 18. The flow is illustrated for the transition region 150 of the blade 2.

The flow lines 30 on fig. 3a-b illustrates the simulated flow on the suction side 14 of the blade 2. The separated flow region 32 is clearly visible as a region of unstable flow. The flow illustrated in fig. 4a-b is at a distance further away from the blade surface as the flow illustrated in fig. 4a-b. As the distance to the blade surface is increasing, the flow will gradually tend to converge to the flow of the incident flow. Therefore the extend of the separated flow region 32 on fig. 4a is smaller than the extend of the separated flow region on fig. 3a.

On fig. 4b it is seen that the introduction of the flow filter 18 has had a positive effect on the outside boundary layer radial flow as the flow in the region close to the flow filter on its tip side is now generally transversal.

By configuring the flow opening 20 opening for permitting boundary layer radial flow through the flow filter and configuring the restrictor portion 22 for suppressing outside boundary layer radial flow through the flow filter a more efficient lift producing region 38 is achieved within the separated flow region 32. The flow in the lift producing region 38 is not separated as the flow filter 18 delays the separation.

Fig. 5 shows a side view illustration of a blade 2 with a flow filter 18.

The blade 2 has a leading edge 8 and a trailing edge 10. The blade 2 has a profile 12. The shape of the profiles 12 is chosen such that the blade 2 is configured for generating lift upon application of an incident flow. During lift generation one side of the blade 2, the suction side 14, will be subject to suction and the other side of the blade, the pressure side 16 will be subject to pressure.

The profile 12 at the root end 4 is substantially circular and the profile 12 closer to the tip has an airfoil shape. Therefore the profiles 12 in the transition region 150 (see fig. 1) are gradually changing from a circular shape to an airfoil shape. The profile 12 shown in fig. 5 is at a position close to the end of the transition region 150 (see fig. 1). The blade 2 in fig. 5 has a close to an airfoil shape profile 12.

The blade 2 comprises a flow filter 18. The flow filter 18 is configured with a flow opening 20 and a restrictor portion 22.

The flow opening 20 is a slot extending from a leading attachment 24 to a trailing attachment 26 respectively, where the flow filter 18 is attached to the blade 2.

The flow opening 20 has a shape with a varying thickness in the chord-wise direction. The chord-wise thickness is established based on analysis or testing to optimize the efficiency of the blade 2.

The flow filter 18 extends beyond the trailing edge 10.

Fig. 6 shows a perspective view of a second embodiment of a flow filter 18. The flow opening 22 is a plurality of slots. The flow filter 18 has two intermediate attachments 38. The attachment to the blade is more secure than the first embodiment.

In alternative embodiments the flow filter has one or more two intermediate attachments 38.

Fig. 7 shows a perspective view of a third embodiment of a flow filter 18. The flow opening 22 is a plurality of through holes. The flow filter 18 has two intermediate attachments 38. The attachment to the blade is more secure than the first embodiment and second embodiment.

The through holes are extending to the surface of the blade 2; such the boundary layer radial flow is permitted through the flow filter 18.

In alternative embodiments the flow filter has one or more two intermediate attachments 38.

Fig. 8 shows a perspective view of a fourth embodiment of a flow filter 18. The flow opening 22 is a slot extending between the leading attachment 24 and the trailing attachment 26.

The flow filter 18 is having a guide surface 40 facing the root end 4 of the blade 2. The guide surface 40 is configured for guiding outside boundary layer radial flow towards the flow opening 22. The guide surface 40 has a curved course across the blade 2. The dotted line designated 42 on fig. 8 indicate a straight line across the blade 2 and the dotted line designated 44 on fig. 8 indicate the curved course of the guide surface 40.

The outside boundary layer radial flow is herewith guided towards the flow opening 22.

In an alternative embodiment the guide surface 40 may have a funnel shaped course across the blade 2. The funnel shape may comprise two or more straight lines leading towards the flow opening 20.

The alternative embodiment described above may be combined with the embodiment of fig. 8, such that the course of the flow filter 18 across the blade comprises both straight lines and curves.

Fig. 9 shows a perspective view of a fifth embodiment of a flow filter 18. The flow opening 22 is a slot extending between the leading attachment 24 and the trailing attachment 26.

The flow filter 18 is having a guide surface 40 facing the root end 4 of the blade 2. The guide surface 40 is configured for guiding outside boundary layer radial flow towards the flow opening 22. The guide surface 40 is set at an oblique angle in relation to the blade surface. The dotted line designated 46 on fig. 9 indicate a line orthogonal to the radial direction of the blade 2 and the dotted line designated 48 on fig. 9 indicate the oblique angle of the guide surface 40.

The outside boundary layer radial flow is herewith guided towards the flow opening 22.

The embodiments of fig. 8 and 9 may be combined to enhance the funnelling effect of the guide surface 40.

Fig. 10 shows a plan view of an embodiment of the blade 2 having a plurality of flow filters 18.

The flow filters 18 are positioned to optimize the efficiency of the blade 2 in the separated flow region 32 (see fig. 3-4). The flow filters 18 may be evenly distributed inside the transition region 150 (see fig. 1) or they may be distributed with different distances to each other. The flow filters 18 may be of an identical size and shape or of different sizes and shapes.

As the flow in the separated flow region 32 is highly dependent on the position and shape of the flow filters 18, the position and shape is based on CFD analysis, wind tunnel testing on scale blades and/or tuft testing on full scale blades.

The position and shape of the flow filter(s) of all embodiments of the blade 2 is preferably optimised for the nominal operation point of the wind turbine or a trade-off optimised for a range of operation points.

Fig. 11 illustrates the terminology used to describe the flow filter 18.

On fig. 11 the following letter designations are defined as:
c = Chord of the blade 2.
d = Position of maximum thickness of the blade profile 12.
e = Starting point of the flow filter 18.
f = Length of the flow filter 18.
g = Length of the flow opening 20.
t = Thickness of the opening 20.
h = Height of the flow filter 18.

CLAIMS

1. Blade (2) for a rotor of a wind turbine, the blade (2) having a root end (4), a tip end (6), a leading edge (8), a trailing edge (10), a suction side (14) and a pressure side (16), the blade (2) being configured for generating lift upon application of an incident flow, wherein during lift generation a separated flow region (32) with radial flow extends on the suction side (14) from the root end (4) towards an end point (34) on the trailing edge (10) at a distance from the root end (4), **characterised in that** the blade (2) comprise a flow filter (18), wherein the flow filter (18) is located in the separated flow region (32), wherein the flow filter (18) is configured with a flow opening (22) for permitting boundary layer radial flow through the flow filter (18), and wherein the flow filter (18) is configured with a restrictor portion (22) for suppressing outside boundary layer radial flow through the flow filter (18).

2. Blade (2) according to claim 1, **characterized in that** the starting point of the flow filter is at a distance from the leading edge of the blade of between 0 to 0.8 times the chord of the blade, preferably between the point of maximum thickness of the profile of the blade to 0.6 times the chord of the blade.

3. Blade (2) according to claim 1 or 2, **characterized in that** the thickness of the flow opening is between 0.001 to 0.1 times the chord of the blade, preferably between 0.005 to 0.05 times the chord of the blade.

4. Blade (2) according to claim 1, 2 or 3, **characterised in that** the flow opening (22) extends from the blade surface.

5. Blade (2) according to claim 4, **characterised in that** the thickness of the flow opening (22) is substantially equal to the boundary layer thickness.

6. Blade (2) according to claim 4 or 5, **characterised in that** the flow filter (18) is a planar element (28), wherein said planar element (28) is mounted by its narrow side on

the suction side (14) of the blade (2) and oriented substantially perpendicular to the radial flow, wherein the restrictor portion (22) is constituted by the planar element (28) outside the flow opening (20).

7. Blade (2) according to any of the previous claims, **characterised in that** the restrictor portion (22) extends in the chord-wise direction beyond the trailing edge (10) of the blade.

8. Blade (2) according to any of the previous claims, **characterised in that** the flow opening (20) is a slot or a plurality of slots or through holes in the flow filter (18).

9. Blade (2) according to any of the previous claims, **characterised in that** the flow opening (20) extends from the chord-wise position where the separated flow region begins to the chord-wise position where the separated flow region ends.

10. Blade (2) according to any of the previous claims, **characterised in that** the blade (2) comprises a plurality of flow filters (18) disposed side-by-side.

11. Blade (2) according to any of the previous claims, **characterised in that** the flow filter (18) has a guide surface (40) facing the root end (4) of the blade (2), wherein the guide surface (40) is configured for guiding outside boundary layer radial flow towards the flow opening (20).

12. Blade (2) according to claim 10, **characterised in that** the guide surface (40) is set at an acute angle (48) in relation to the blade surface towards the root end (4).

13. Blade (2) according to claim 10 or 11, **characterised in that** the guide surface (40) has a funnel shaped or curved course across the blade (2).

14. Blade (2) according to any of the previous claims, **characterised in that** the flow filter (18) comprise means for absorbing noise.

15. Wind turbine comprising a rotor, **characterised in that** the rotor comprise a blade according to one or more of the claims 1 to 14.

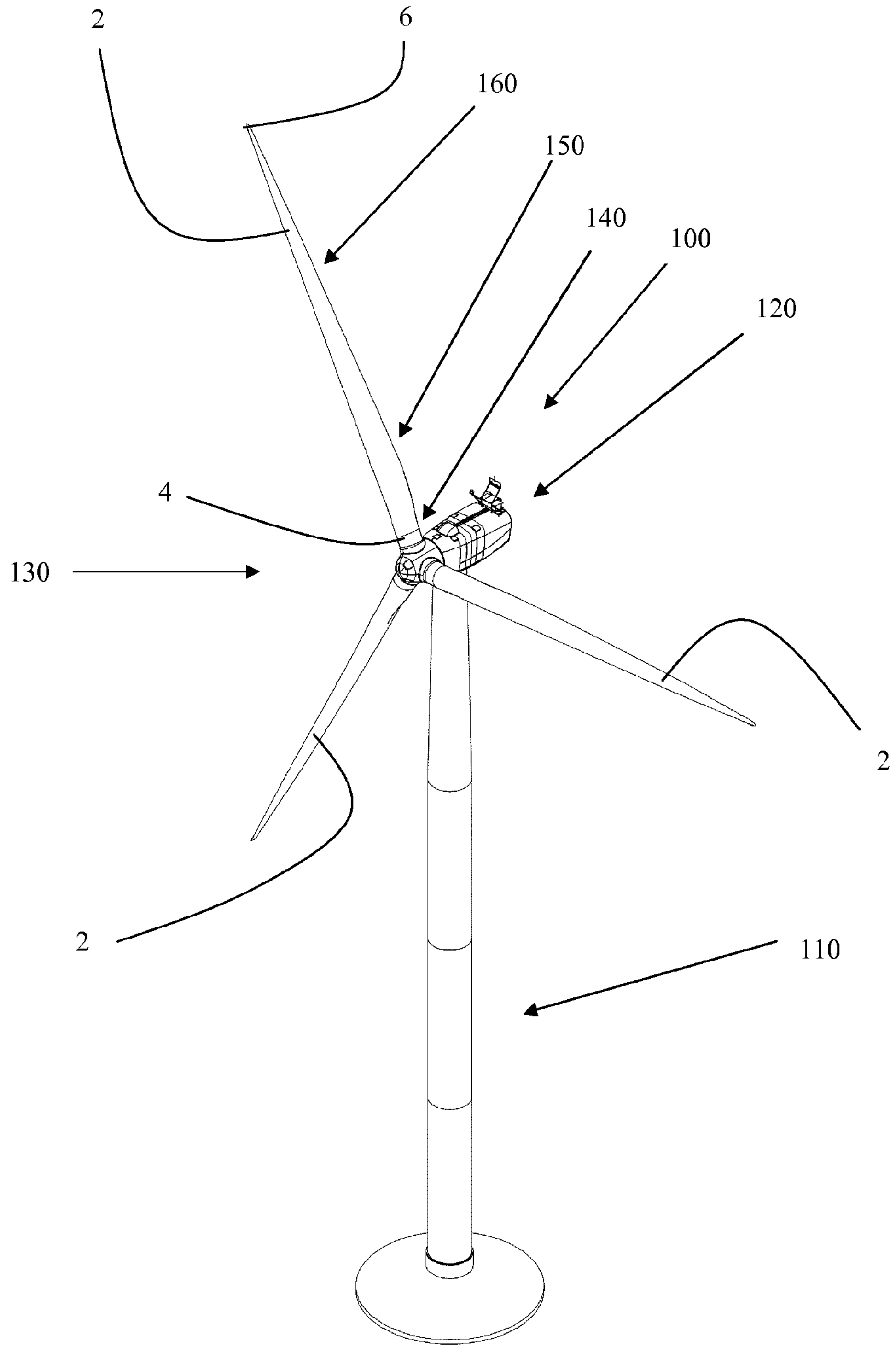

Fig. 1

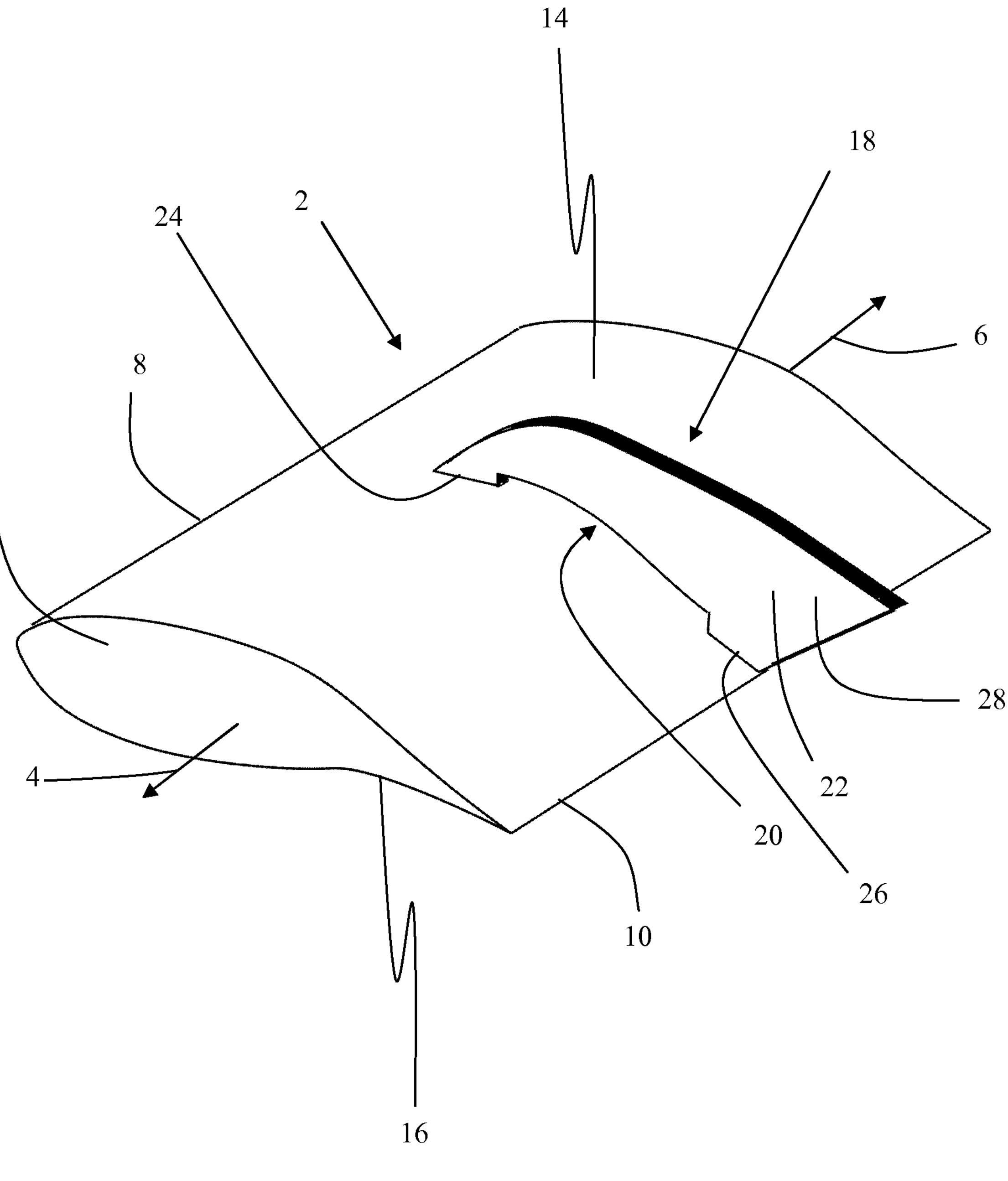

Fig. 2

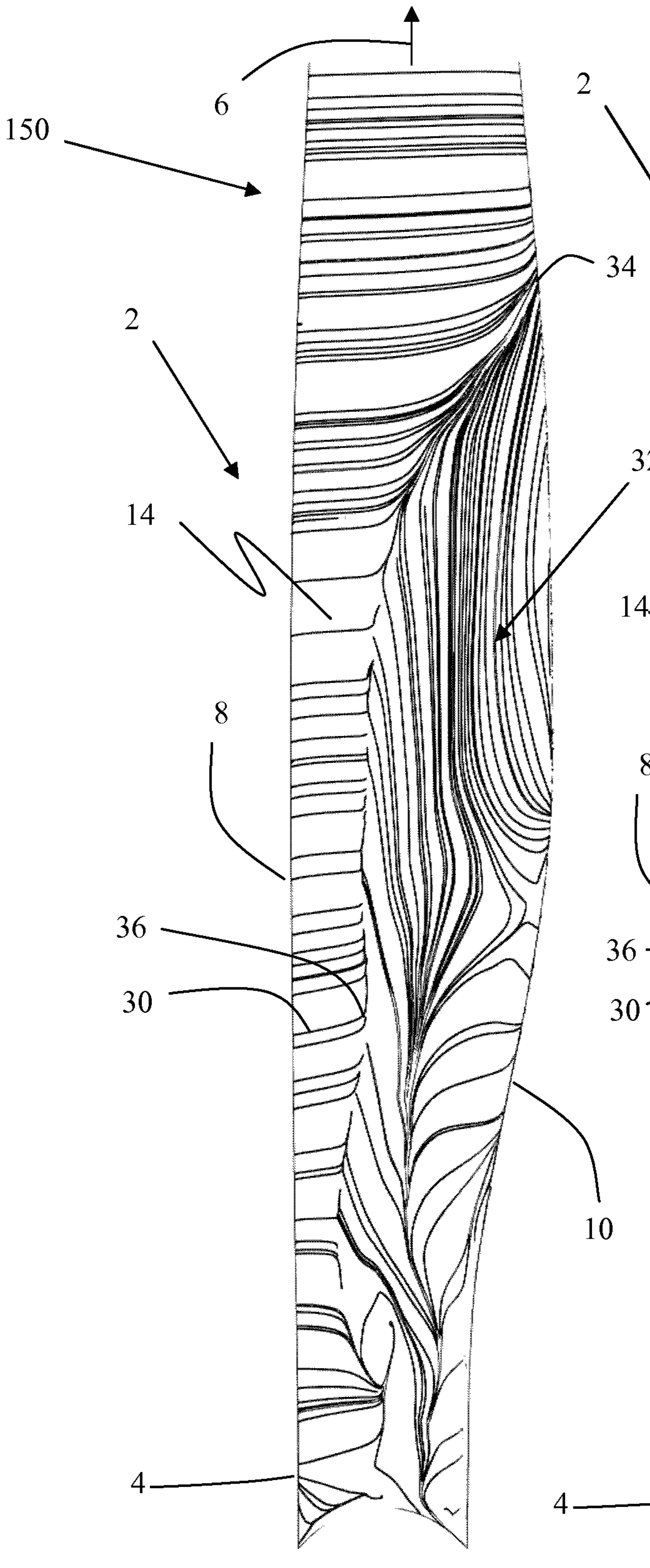

Fig. 3a

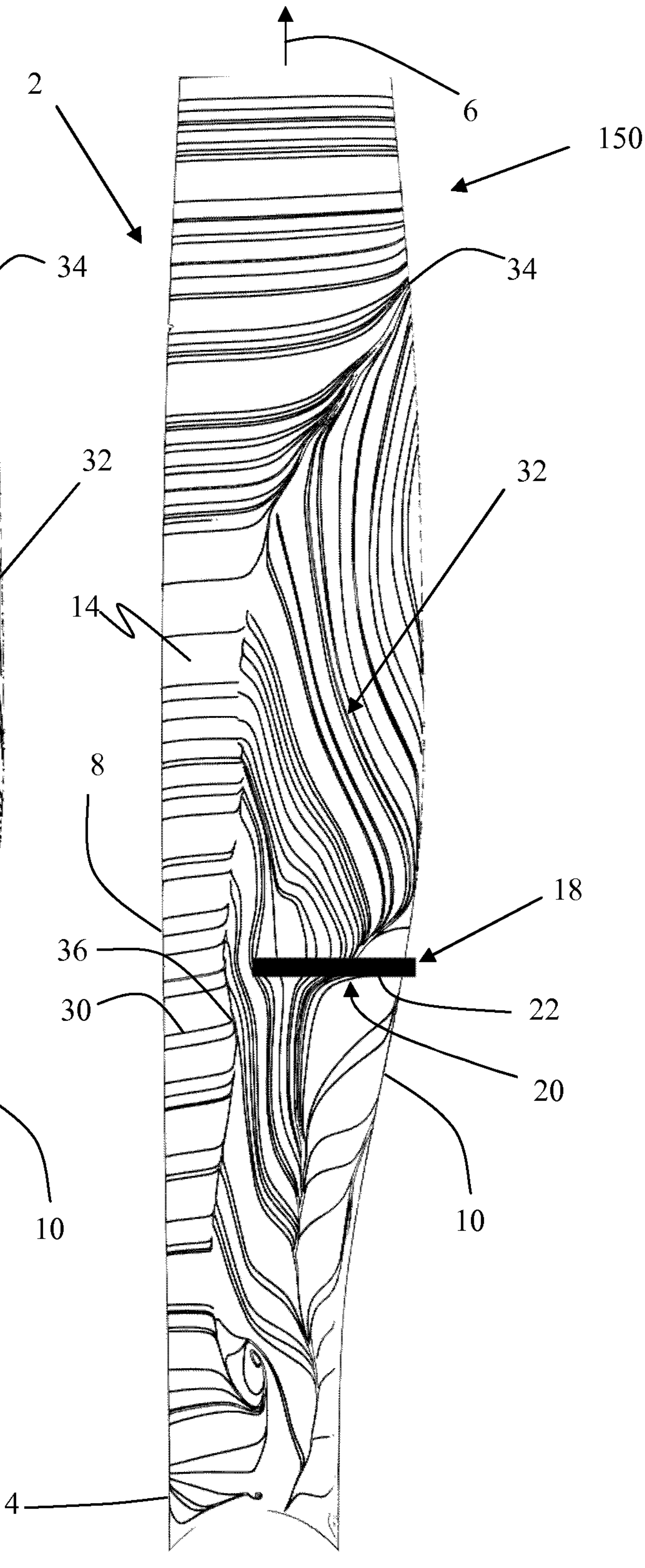

Fig. 3b

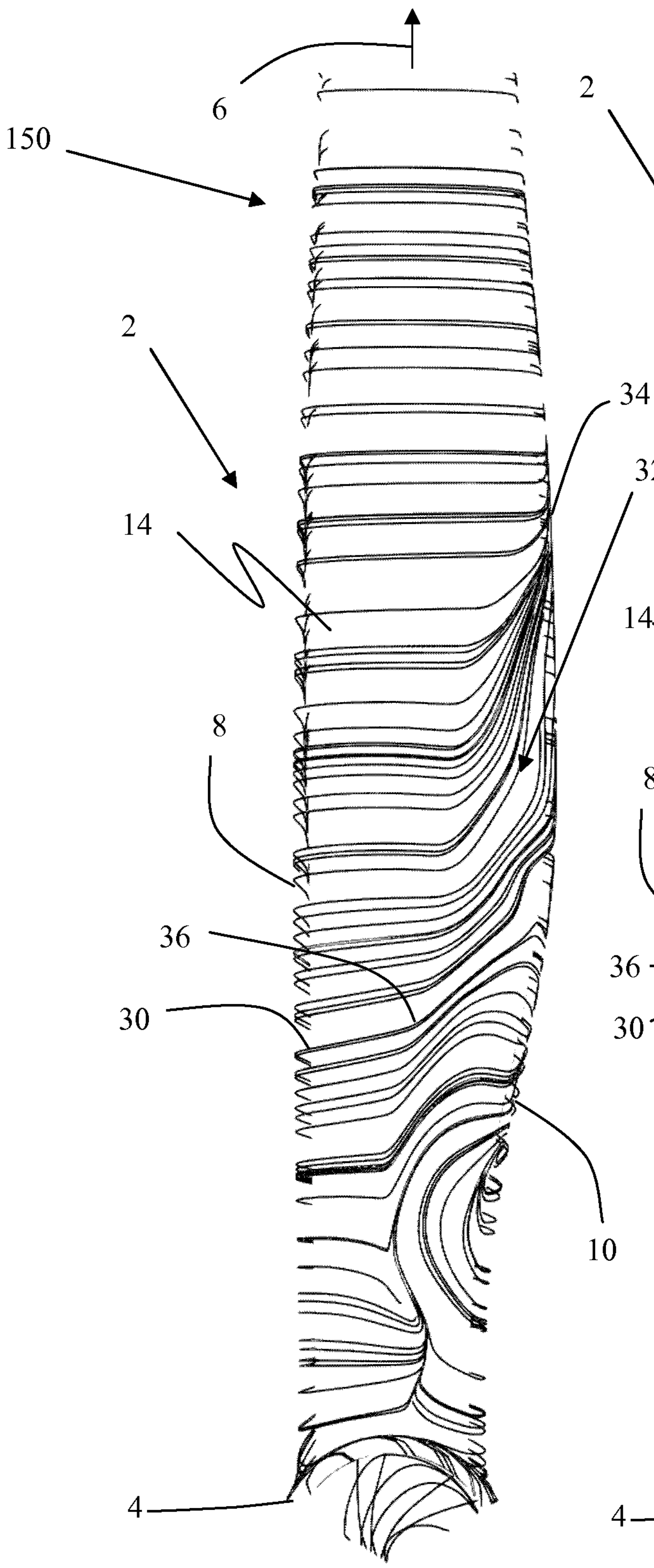

Fig. 4a

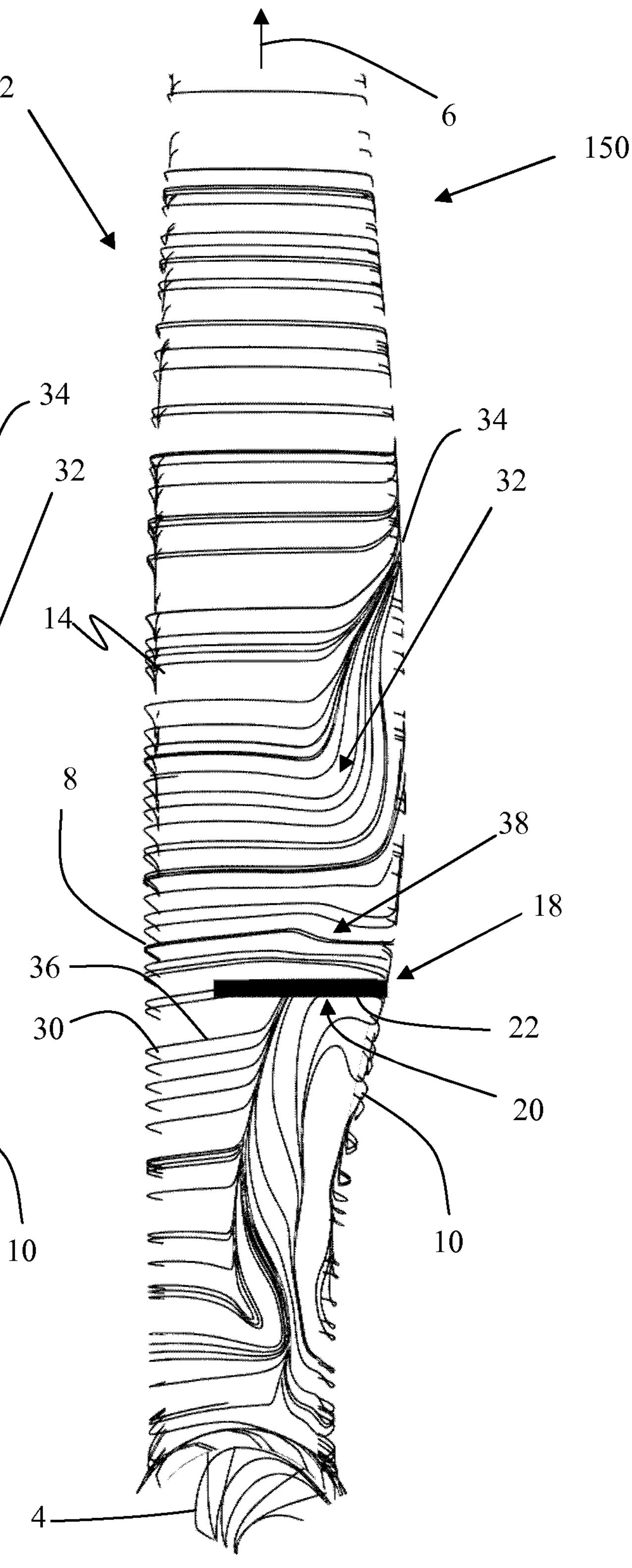

Fig. 4b

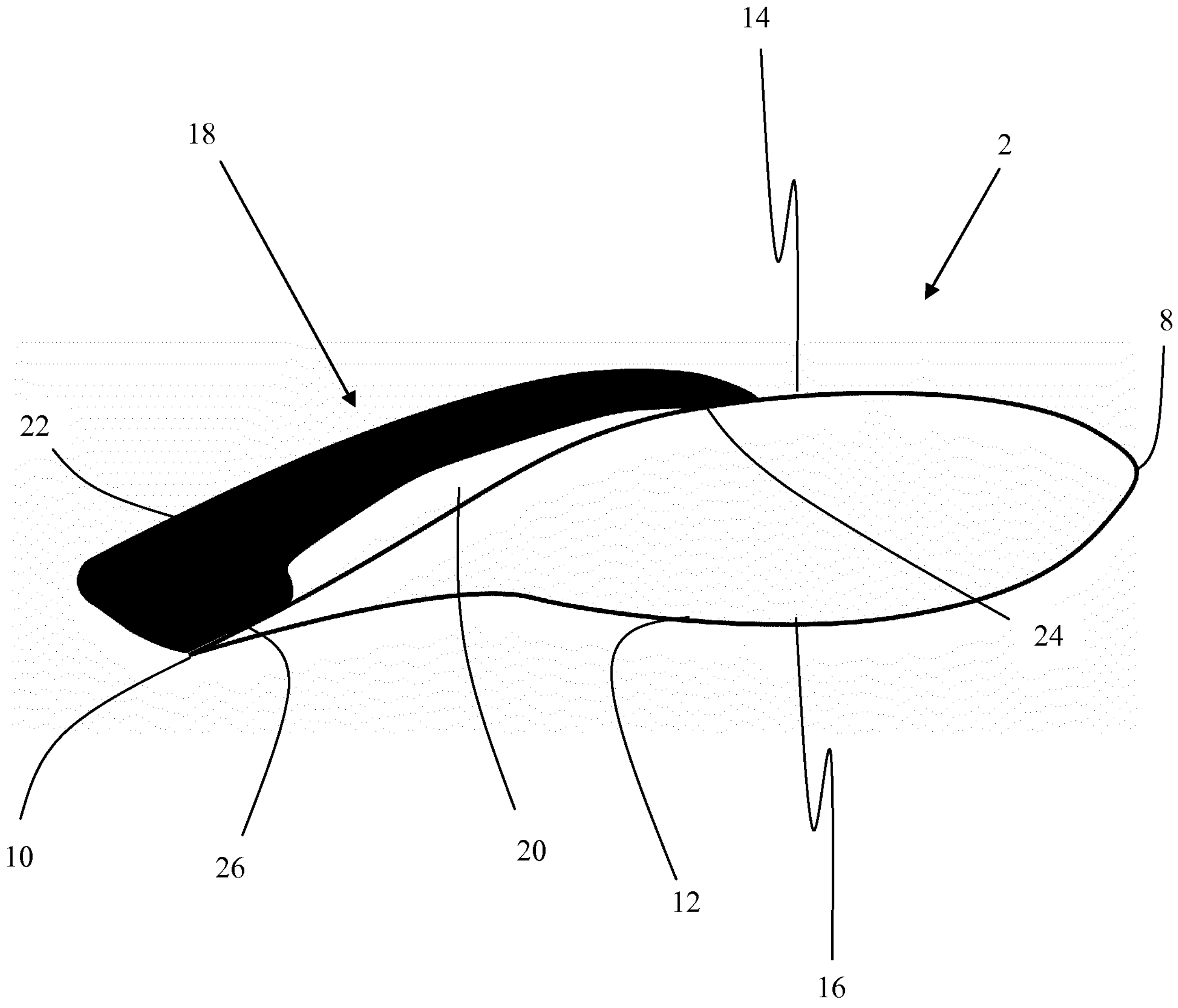

Fig. 5

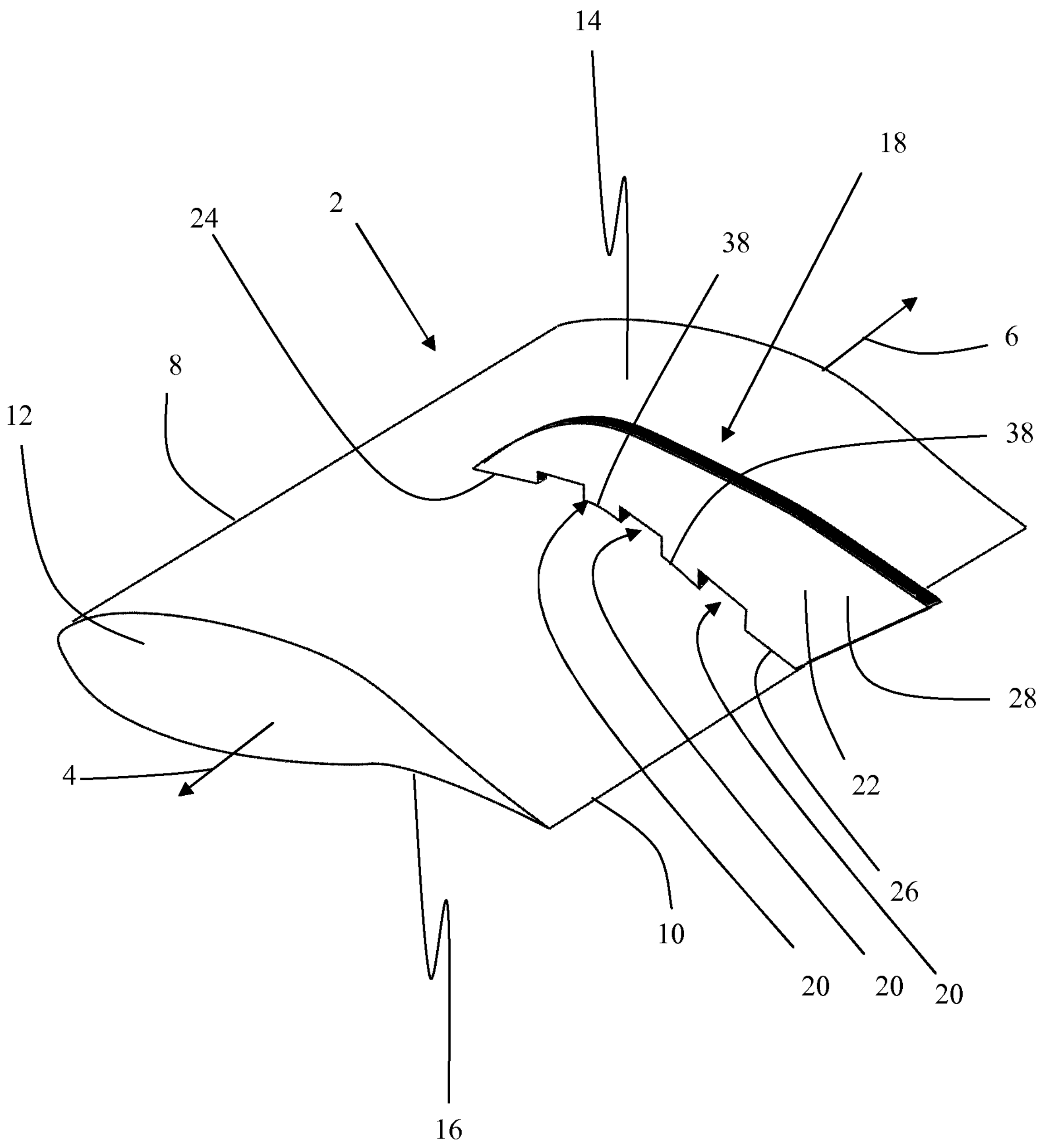

Fig. 6

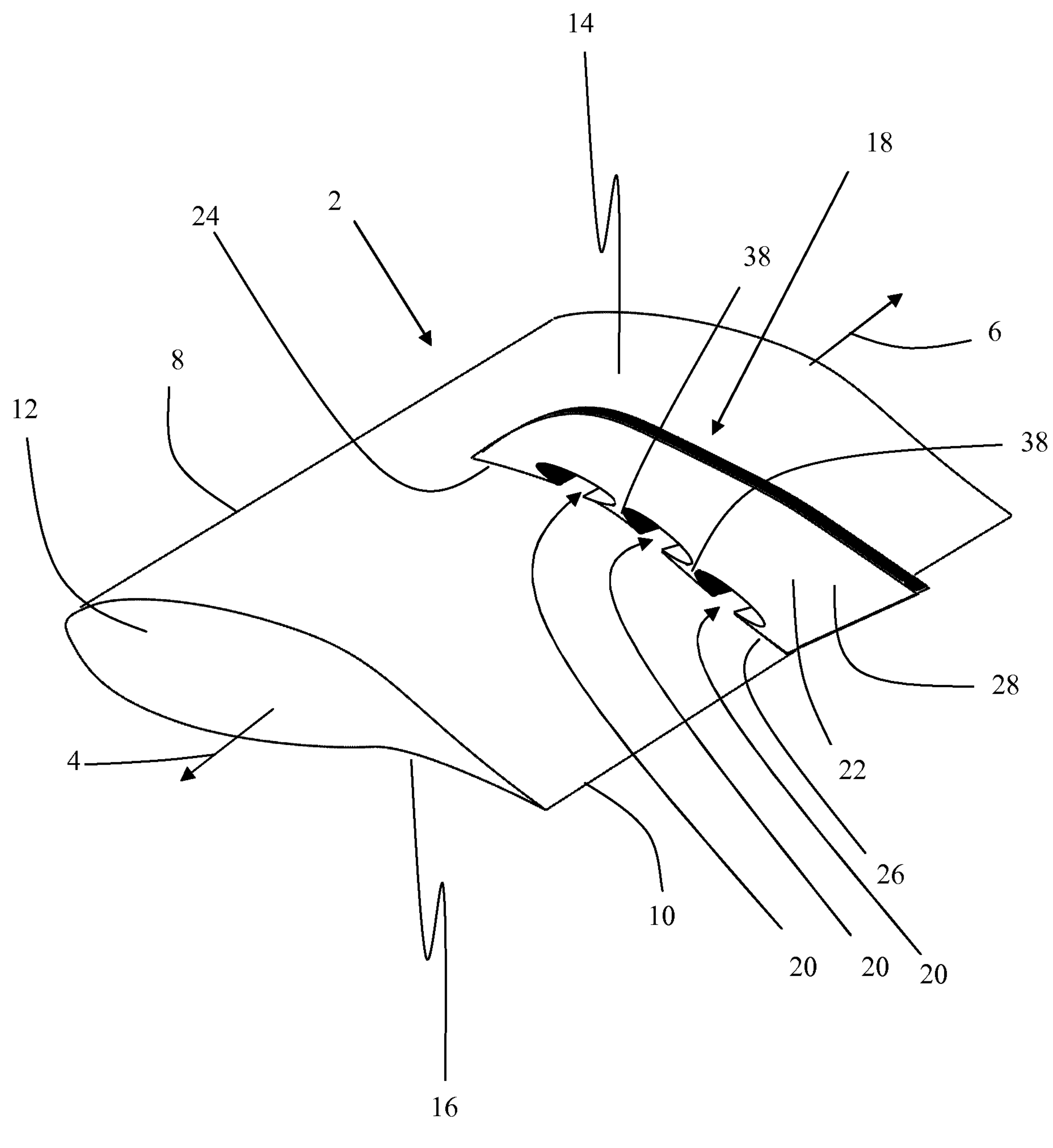

Fig. 7

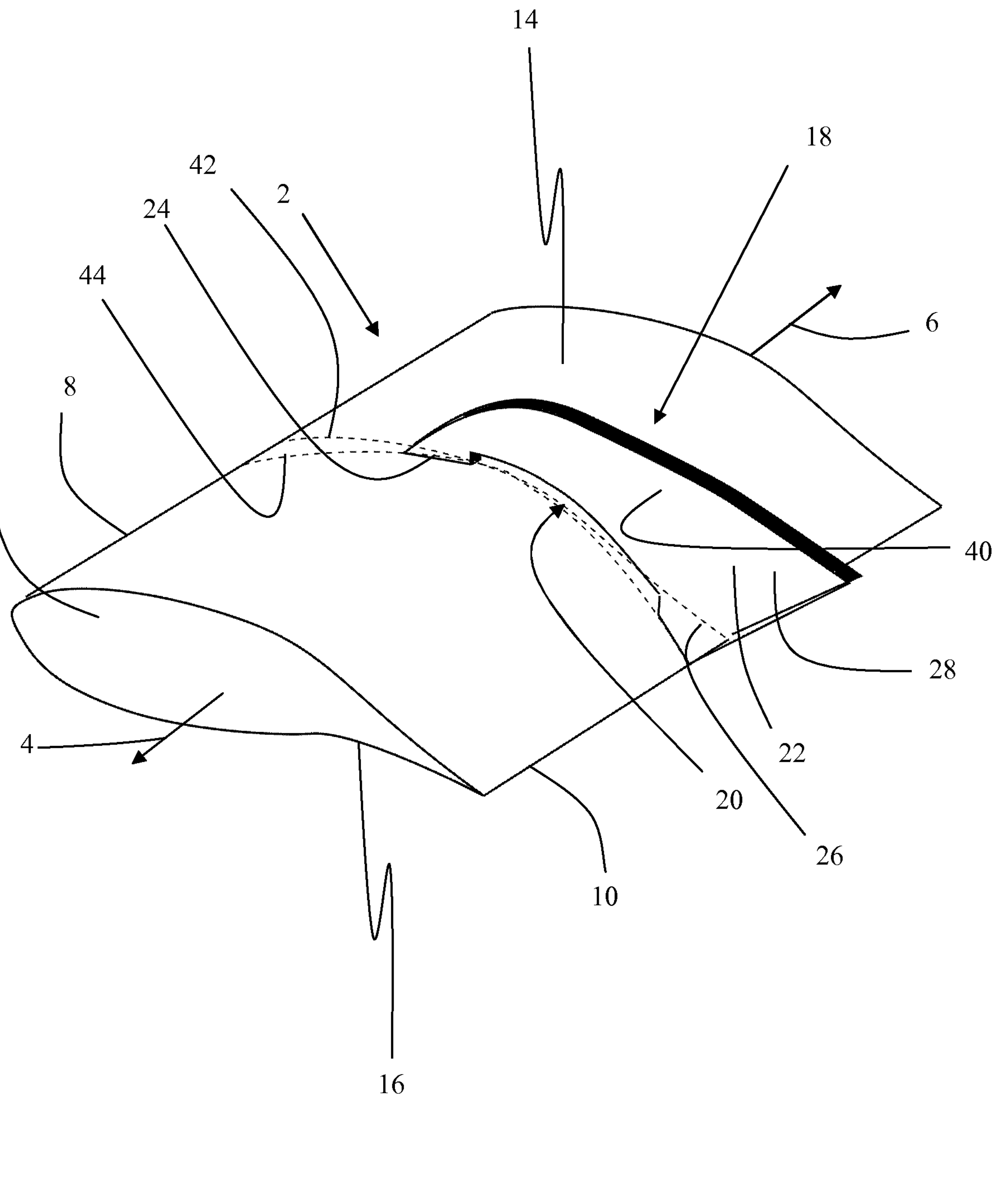

Fig. 8

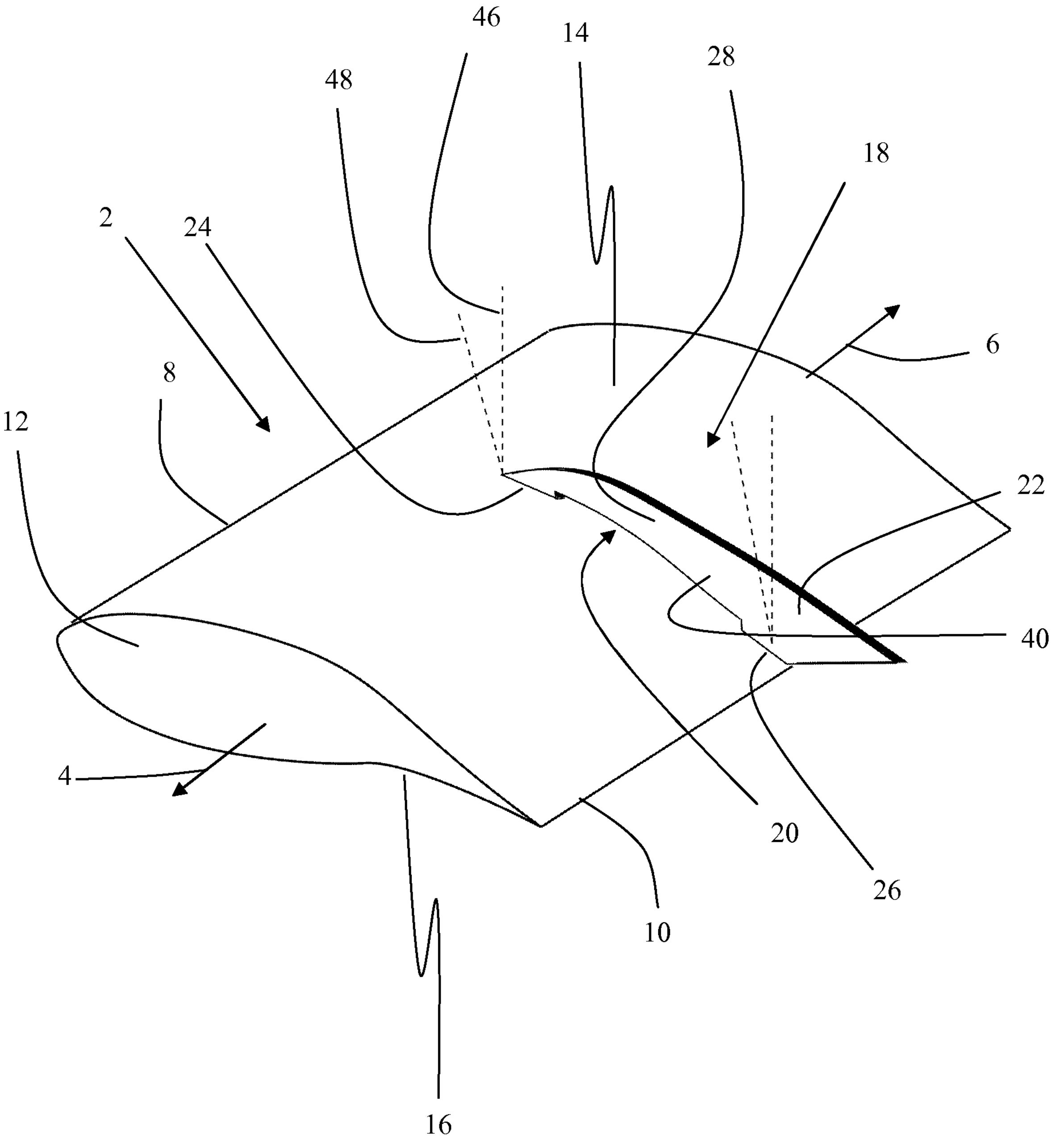

Fig. 9

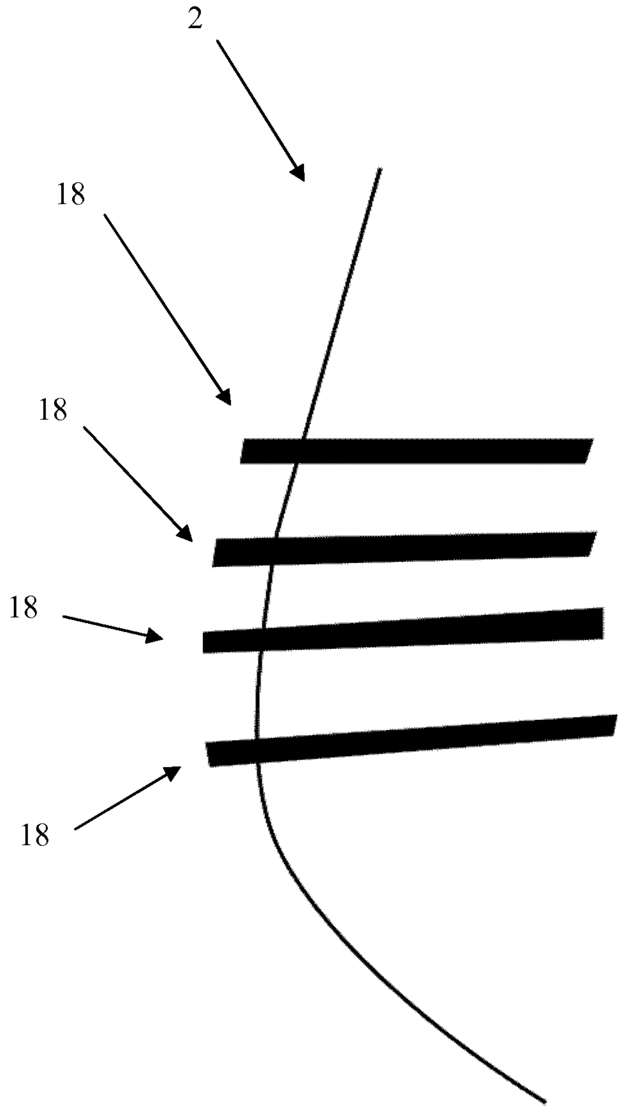

Fig. 10

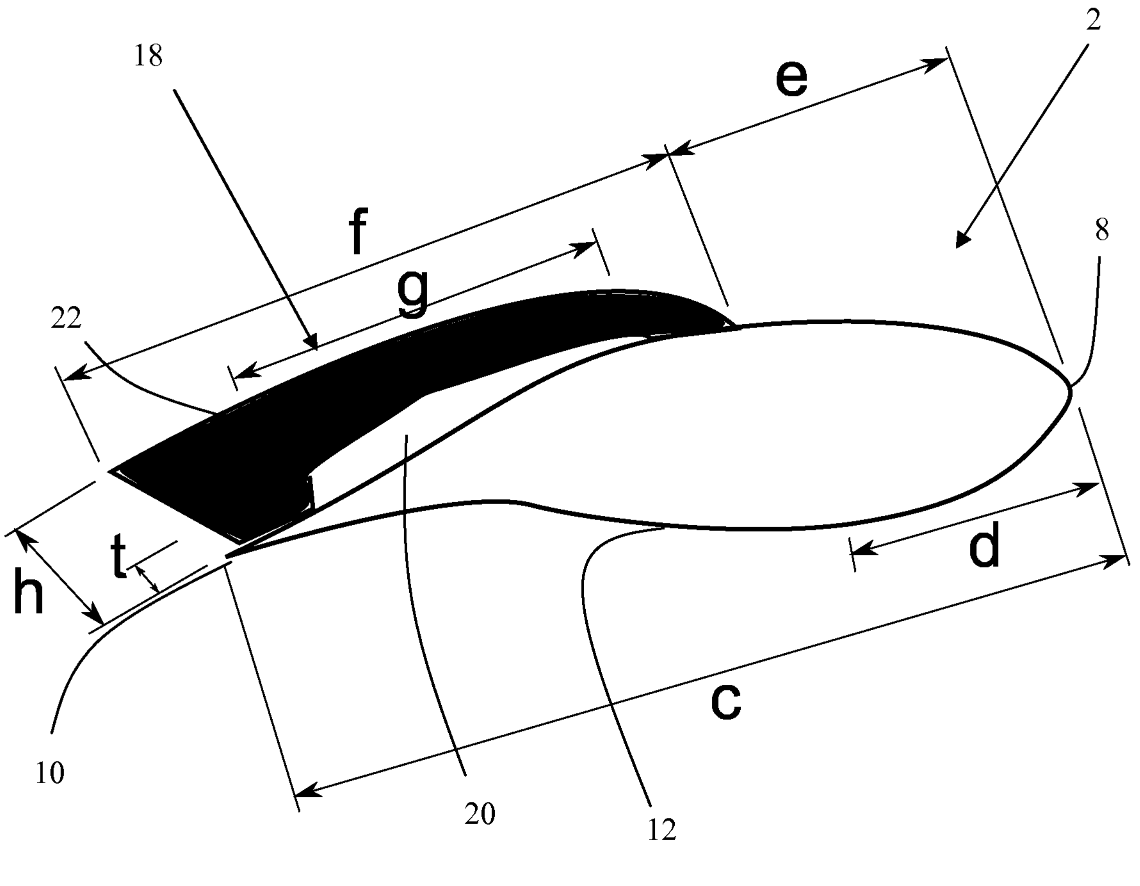

Fig. 11

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2012/065377

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.
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X	JP 61 167175 A (MITSUBISHI HEAVY IND LTD) 28 July 1986 (1986-07-28) abstract -----	1-15
A	FR 1 187 166 A (LETESSIER-SELVON MICHEL-YVES) 8 September 1959 (1959-09-08) page 2, column 2, lines 16-27; figure 1 -----	1,15
A	FR 1 070 262 A (CHANTIERS DE FRANCE ATEL) 21 July 1954 (1954-07-21) figure 1 -----	1,15
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[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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"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
8 November 2012	19/11/2012

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2012/065377

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2012/065377

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