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(54) Benævnelse: **ROTORBLAD OMFATTENDE EN LYDOPTIMERET PROFIL OG FREMGANGSMÅDE TIL FREMSTILLING AF ET ROTORBLAD**

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The invention relates to a rotor blade of a wind energy installation, the rotor blade having a suction side, a pressure side, a rotor blade nose and a rotor blade trailing edge, which extend between a rotor blade root and a rotor blade tip and define a profile of the rotor blade. The invention also relates to a wind energy installation comprising a rotor blade and to a method for manufacturing a rotor blade of a wind energy installation, the rotor blade having a suction side, a pressure side, a rotor blade nose and a rotor blade trailing edge, which extend between a rotor blade root and a rotor blade tip and define a profile of the rotor blade.

Rotor blades of a wind energy installation always comprise a suction side and a pressure side, which often extend on the outside of a suction-side shell and a pressure-side shell. The suction-side shell and the pressure-side shell are joined together, for example adhesively bonded, in the region of a rotor blade nose and a rotor blade trailing edge. A rotor blade is produced which extends, starting from a rotor blade root, at which said blade is connected to the hub of a wind energy installation, to the rotor blade tip. The shapes of the suction side, the pressure side, and of the rotor blade and the rotor blade trailing edge, define the profile of the rotor blade.

The output of a wind energy installation is essentially determined by the profile of its rotor blades. For this reason, rotor blades are optimized in terms of their profile with regard to an optimum power yield. However, flow noises unavoidably occur on the rotor blades during operation of a wind energy installation. For reasons of protection against noise, minimum distances, for example from residential areas or other protected areas, should be observed. This limits the possible locations at which the wind energy installation in question can be installed.

One measure for reducing the noise emission of a rotor blade is to provide said blade with trailing edge serrations. Serrations are provided in an outer portion of the rotor blade at its trailing edge. A corresponding rotor blade is known from US 2011/0142666 A1, for example.

EP 2682602, EP 2816227 and US2014/112780 are further examples of rotor blades having reduced noise emission.

An object of the invention is to provide a rotor blade of a wind energy installation and a method for manufacturing a rotor blade of a wind energy installation, it being intended for the rotor blade to have reduced noise emission.

The object is achieved by a rotor blade of a wind energy installation, the rotor blade having a suction side, a pressure side, a rotor blade nose and a rotor blade trailing edge, which extend between a rotor blade root and a rotor blade tip and define a profile of the rotor blade, the rotor blade being improved by said blade having a noise-optimized profile which, starting from an assumed power-optimized profile which is aerodynamically optimized with regard to a power yield of the rotor blade, is modified by at least one of the following measures in a rotor blade end region, which comprises the rotor blade tip, in order to reduce the noise emission of the rotor blade:

a) increasing a radius of the profile at the rotor blade nose;
b) shifting, in the direction of the rotor blade nose, a position at which a maximum thickness of the profile is to be found;
c) decreasing a maximum camber of the profile; and
d) shifting, in the direction of the rotor blade trailing edge, a position at which the maximum camber of the profile of the rotor blade is to be found.

The mentioned measures for modifying the aerodynamic profile of the rotor blade in the rotor blade end region advantageously reduce the noise power level of the wind energy installation. For a wind energy installation of this kind, lower maximum rotor noise power levels can be ensured without the noise power level having to be reduced by lowering the blade tip speed. The last measure is specifically always associated with power losses and is taken in noise-reduced operating modes. For a wind energy installation which is provided with rotor blades according to aspects of the invention, lower maximum rotor sound power levels can be ensured, meaning that said installation can also be installed at locations at which conventional installations cannot be positioned due to their noise emissions being too high, or at which they have to operate at least at times in noise-reduced operating modes. Since noise-reduced operating modes are advantageously dispensed with, the output of the wind energy installation also increases.

The power-optimized profile of the rotor blade is ascertained, for example, by means of numerical simulation or by means of practical tests, for example in the wind tunnel. Starting from this profile which is aerodynamically optimized with regard to a power yield of the rotor blade, one or more of the above-mentioned measures are taken according to aspects of the invention. It has advantageously been found that, in the outer region of the rotor blade, specifically in the rotor blade end region, a transition can be made to a noise-optimized blade tip profile which provides low noise power levels even without trailing edge serrations. The noise-optimized profile is in particular optimized and designed for turbulent flow. This is achieved by the above-mentioned measures, starting from the power-optimized profile.

The rotor blade region starts for example at 80%, 85% or 90% of the relative blade length. Relative blade length is understood to mean the quotient from the relative position in the longitudinal direction of the rotor blade divided by the rotor radius. For example, the rotor blade end region extends, viewed from the rotor blade tip, approximately 3 m to 4 m in the direction of the rotor blade root. In other words, the rotor blade thus has a profile that is noise-optimized and not power-optimized in its outermost 3 m to 4 m.

According to an advantageous embodiment, the rotor blade is improved by said blade having, in a central portion, trailing edge serrations at the rotor blade trailing edge, no trailing edge serrations being present in the rotor blade end region, and the central portion extending, starting from the rotor blade end region, in the direction of the rotor blade root.

Trailing edge serrations are known per se as means for reducing the flow noise of rotor blades. By these now being used, as proposed according to aspects of the invention, only in the central portion of the rotor blade, transporting the rotor blade is significantly easier. If trailing edge serrations are present specifically also at the outer end of the rotor blade, there is always the risk during transportation of the trailing edge serrations being damaged. By trailing edge serrations in the rotor blade end region being dispensed with, conventional transportation of the rotor blade is possible, as is known for rotor blades which have no trailing edge serrations. The rotor blade tip can be accommodated in bags without risk; the risk of damaging the trailing edge serrations during transportation is significantly decreased. Conventional devices and infrastructure for transporting the rotor blade can also be used.

The trailing edge serrations preferably extend throughout the entire central portion. According to another embodiment, the trailing edge serrations extend in the central portion of the rotor blade in some portions. Furthermore, the trailing edge serrations have in particular a length-to-width ratio of greater than two. Said serrations are therefore at least twice as long as they are wide.

According to another embodiment, the rotor blade is furthermore improved by the trailing edge serrations:

a) having a maximum length of less than 20% of a length of the chord of the profile at the associated longitudinal position of the rotor blade;

and/or

b) having a material thickness of 5 mm or less;

and/or

c) being inclined at an angle of 5° or less with respect to a direction of the chord of the profile.

The trailing edge serrations are designed to be as thin as possible. They are in particular adhesively bonded steplessly to the profile of the rotor blade. The angle between the trailing edge serrations and the chord of the profile is measured in each case in a common profile plane. By means of an angle of attack of the trailing edge serrations (angle between the direction of the chord of the profile and the plane in which the trailing edge serrations extend at this longitudinal position of the rotor blade) which has a value of 5° or less, the operating point of the profile is modified only insignificantly and the additional lift generated by the serrations is limited.

Furthermore, according to an embodiment, a ratio of the thickness of the profile to the chord length is less than 0.24 in the central portion of the rotor blade. Furthermore, according to another embodiment, the rotor blade is improved by the central portion extending, starting from a first profile plane, in the direction of the rotor blade tip, the rotor blade being, at the rated power of the wind energy installation, exposed to a flow in the first profile plane at a relative speed of 55 m/s.

Since the rotor blade tip is exposed to a flow at the greatest relative speed, said tip contributes significantly to the noise emission of the rotor blade. A modification in the profile of the rotor blade in the rotor blade region from a power-optimum profile to a noise-optimum profile is particularly efficient. It has been found that particularly good results are achieved when these changes are made starting from a region in which the rotor blade is exposed to a flow at relative speeds of 55 m/s or more.

Furthermore, according to another embodiment, in a blade root region, the rotor blade has vortex generators on the suction side, the blade root region extending, starting from the rotor blade root, to a second profile plane, and the rotor blade being, at the rated power of the wind energy installation, exposed to a flow in the second profile plane at a relative speed of 30 m/s.

An aerodynamic and structurally highly efficient blade root which is provided with vortex generators extends, according to the mentioned embodiments, up to a profile plane in which the rotor blade is exposed to a flow at a relative speed of 30 m/s. It has been found that the use of vertex generators in regions of the rotor blade which are located further in the direction of the rotor blade tip does not bring any notable further improvement with regard to noise emission of the rotor blade.

The rotor blade is furthermore improved by the rotor blade having an erosion protection means on the rotor blade nose, the erosion protection means being integrated into a surface of the rotor blade so as to have a step height of less than 0.2 mm.

Finally, the rotor blade is improved according to another embodiment by said blade having a tangential blow-out slot on the suction side, the blow-out slot extending, starting from a third profile plane, in the direction of the rotor blade tip and the third profile plane being arranged at a relative blade length of at least approximately 80%.

Both the stepless or approximately stepless integration of an erosion protection means into the surface of the rotor blade and the integration of a blow-out slot, in particular at the mentioned position, lead to a further decrease in the noise power level of the rotor blade.

The object is also achieved by a wind energy installation having a rotor blade according to one or more of the above-mentioned aspects according to the invention. The advantages already mentioned above with regard to the rotor blade apply equally or similarly to a wind energy installation of this kind, and therefore repetitions are dispensed with.

The object is furthermore achieved by a method for producing a rotor blade of a wind energy installation, the rotor blade having a suction side, a pressure side, a rotor blade nose and a rotor blade trailing edge, which extend between a rotor blade root and a rotor blade tip and define a profile of the rotor blade, the method being improved by the following steps:

I) providing a power-optimized profile of the rotor blade, the power-optimized profile being aerodynamically optimized with regard to a power yield of the rotor blade;

II) modifying the power-optimized profile in order to obtain a noise-optimized profile in a rotor blade end region in order to reduce noise emission of the rotor blade, at least one of the following measures being carried out, starting from the power-optimized profile in the rotor blade end region, which comprises the rotor blade tip:
   a) increasing a radius of the profile at the rotor blade nose;
   b) shifting, in the direction of the rotor blade nose, a position at which a maximum thickness of the profile is to be found;
   c) decreasing a maximum camber of the profile; and
   d) shifting, in the direction of the rotor blade trailing edge, a position at which the maximum camber of the profile of the rotor blade is to be found;

III) manufacturing the rotor blade so as to have the noise-optimized profile in the rotor blade end region.

Advantages and aspects already mentioned with regard to the rotor blade apply equally or similarly to the method for manufacturing a rotor blade. The method can also be carried out with little effort since, starting from a power-optimized profile which is provided for manufacturing the rotor blade, only small profile changes have to be made. These changes can be integrated into the existing manufacturing process with little effort.

The method is furthermore improved by the rotor blade being provided, in a central portion, with trailing edge serrations at the rotor blade trailing edge, no trailing edge serrations being provided in the rotor blade end region, and the central portion extending, starting from the rotor blade end region, in the direction of the rotor blade root.

Furthermore, according to another embodiment, the method is improved by the trailing edge serrations being provided so as to:

a) have a maximum length of less than 20% of a length of the chord of the profile at the associated longitudinal position of the rotor blade;

and/or

b) have a material thickness of 5 mm or less;

and/or

c) be inclined at an angle of 5° or less with respect to a direction of the chord of the profile.

According to another embodiment, a central portion is provided which extends, starting from a first profile plane, in the direction of the rotor blade tip, the rotor blade being, at the rated power of the wind energy installation, exposed to a flow in the first profile plane at a relative speed of 55 m/s. In particular, the method is improved by the rotor blade being provided, in a blade root region, with vortex generators on the suction side, the blade root region extending, starting from the rotor blade root, to a second profile plane, and the rotor blade being, at the rated power of the wind energy installation, exposed to a flow in the second profile plane at a relative speed of 30 m/s.

Furthermore, according to an embodiment, the rotor blade is provided with a tangential blow-out slot on the suction side, the blow-out slot extending, starting from a third profile plane, in the direction of the rotor blade tip and the third profile plane being arranged at a relative blade length of at least approximately 80%.

According to further embodiments, in the central portion of the rotor blade, a ratio of the thickness of the profile to the chord length of less than 0.24 is provided. Furthermore, in particular, the rotor blade is provided with an erosion protection means on the rotor blade nose, the erosion protection means being integrated into a surface of the rotor blade so as to have a step height of less than 0.2 mm.

Further features of the invention can be found in the description of embodiments according to the invention, together with the claims and the accompanying drawings. Embodiments according to the invention can be fulfilled by individual features or a combination of a plurality of features.

The invention is defined by the accompanying claims.

The invention is described below on the basis of embodiments and with reference to the drawings, without limiting the general concept of the invention, reference being made to the drawings with respect to all details according to the invention that are not explained in more detail in the text. In the drawings:

Fig. 1 is a schematically simplified view of a wind energy installation;

Fig. 2 is a schematically simplified plan view of a suction side of a rotor blade;

Fig. 3 is a schematically simplified cross-sectional view along the plane III-III in Fig. 2;

Fig. 4 is a schematically simplified cross-sectional view along the plane IV-IV in Fig. 2;

Fig. 5 is a schematically simplified cross-sectional view in the region of the rotor blade trailing edge;

Fig. 6 is a schematically simplified plan view of a portion of trailing edge serrations;

Fig. 7 and 7a are schematically simplified views of the rotor blade profile in the rotor blade end region;

Fig. 8 shows a relative radius of a noise-optimized rotor blade at the leading edge, plotted against a relative blade length;

Fig. 9 shows a relative thickness of the rotor blade profile, plotted against the relative length of the rotor blade;

Fig. 10 shows a maximum distance of the camber line of the rotor blade from the chord of the rotor blade, plotted against the relative length;

Fig. 11 shows a maximum camber of the rotor blade profile, plotted against the relative length of the rotor blade; and

Fig. 12 shows a schematically simplified profile of the rotor blade in the plane indicated in Fig. 2 by XII-XII.

In the drawings, identical or similar elements and/or parts are provided with the same reference signs, and therefore these elements do not need to be reintroduced each time.

Fig. 1 is a schematically simplified view of a wind energy installation 2, the rotor blades 4 of which extend between a rotor blade root 6 and a rotor blade tip 8. The rotor blades 4 are connected at their rotor blade roots 6 to a hub 10 which drives the main shaft of the wind energy installation 2. The rotor of the wind energy installation 2, including the power house, which holds the additional components, is fastened to a support structure 12, for example a tower.

The rotor blades 4 each comprise a suction side 14 (not visible in Fig. 1), a pressure side 26, a rotor blade nose 16 and a rotor blade trailing edge 18 (only shown with reference signs on one of the rotor blades). The suction side and the pressure side 14, 26 and the rotor blade nose 16 and the rotor blade trailing edge 18 extend between the rotor blade root 6 and the rotor blade tip 8 and define an aerodynamically active profile of the rotor blade 4. The rotor blades 4 of the shown wind energy installation 2 are optimized with regard to their noise emission. In order to obtain such a noise-optimized rotor blade profile, a power-optimized profile of the rotor blade 4 is first determined. This is done by means of numerical simulations or by means of practical tests, for example. The power-optimized profile of the rotor blade 4 is aerodynamically optimized with regard to a power yield of the rotor blade 4.

Fig. 2 is a schematically simplified plan view of a suction side 14 of a noise-optimized rotor blade 4. In order to reduce the noise emission, in a rotor blade end region 20, which comprises the rotor blade tip 8, the power-optimized profile is modified into a noise-optimized profile. The measures taken, in detail, are explained in connection with Fig. 7 to 11.

In addition to this modification of the rotor blade profile, additional optional measures are taken in the rotor blade end region 20 in order to lower the noise power level of the rotor blade 4.

For example, in a blade root region 22, the rotor blade 4 is provided on its suction side 14 with vortex generators 24.

Fig. 3 is a schematically simplified view of a cross section through the rotor blade 4 in the blade root region 22, along the plane indicated by III-III in Fig. 2. On the suction side 14, a vortex generator 24 is shown by way of example. A trailing edge tab 2 is optionally provided on the pressure side 26 at the transition between the pressure side 26 to the rotor blade trailing edge 18.

As Fig. 2 shows, the blade root region 22 extends, starting from the rotor blade root 6, to a second profile plane 30 (shown by a dashed line). At rated powers of the wind energy installation 2, the rotor blade 4 is exposed to a flow in the second profile plane 30 at a relative speed of 30 m/s.

In the direction of the rotor blade tip 8, a power region 32 follows the blade root region 22. Said power region extends, starting from the second profile plane 30, in the direction of the rotor blade tip 8, to a first profile plane 34, to which reference will be made later. In the power region 32, the rotor blade 4 has a power-optimized profile. Moreover, in this region, no measures are taken for noise-optimizing the rotor blade 4.

A central portion 36 follows the power region 32 in the direction of the rotor blade tip 8. The central portion 36 extends, starting from the rotor blade end region 20, in the direction of the rotor blade root 6, to the first profile plane 34. In the first profile plane 34, at the rated power of the wind energy installation 2, the rotor blade 4 is exposed to a flow at a relative speed of 55 m/s.

In the central portion 36 of the rotor blade 4, said blade is provided with trailing edge serrations 38 at the rotor blade trailing edge 18. Both in the rotor blade end region 20 and in the power region 32, which is located further in the direction of the blade root 6, the rotor blade 4 does not have any trailing edge serrations 38. The trailing edge serrations 38 decrease the noise emission of the rotor blade 4.

Fig. 4 shows, in a schematically simplified cross section, the profile of the rotor blade 4 in the plane indicated by IV-IV in Fig. 2. The trailing edge serrations 38 are designed, for example, such that they have a maximum length L1 that is less than 20% of a length L2 of the chord of the profile 40. The maximum length L1 of the trailing edge serrations 38 and the length L2 of the chord of the profile 40 are viewed at the particular identical longitudinal position of the rotor blade 4, i.e. at an identical distance from the rotor blade 6 or from the rotor blade tip 8. The maximum length L1 of the trailing edge serrations 38 is measured starting from the rotor blade trailing edge 18. The trailing edge serrations 38 are inclined by an angle α with respect to a direction 42 of the chord of the profile 40. The maximum length of the trailing edge serrations 38 is determined; when the angle α is 0°, the trailing edge serrations 38 thus extend in the direction 42 of the chord of the profile 40.

In the central portion 36 of the rotor blade 4, the profile is also selected, for example, such that a ratio of the thickness of the profile PD to the chord length L2 is less than 0.24. Furthermore, the rotor blade 4 is provided with an erosion protection means 44 on the rotor blade nose 16. The erosion protection means 44 is, for example, integrated into a surface of the rotor blade 4 so as to have a step height of less than 0.2 mm.

Fig. 5 is a detailed view of the cross-section shown in Fig. 4 in the region of the rotor blade trailing edge 18. A material thickness d of the trailing edge serrations 38 is less than 5 mm, for example. Furthermore, the trailing edge serrations 38 are adhesively bonded, for example steplessly, to the profile of the rotor blade 4.

Fig. 6 is a schematically simplified plan view of a portion of the trailing edge serrations 38. The serrations are designed, for example, such that their maximum length L1 is at least twice as great as their width b.

As an additional measure for decreasing the noise emission, the rotor blade 4 is provided, for example, with a tangential blow-out slot 46 (cf. Fig. 2). On the suction side 14 of the rotor blade 4, the blow-out slot 46 extends, starting from a third profile plane 48, in the direction of the rotor blade tip 8. The third profile plane 48 is arranged at a relative blade length of at least approximately 80%, for example. Furthermore, the blow-out slot 46 extends both in the central portion 36 and in the rotor blade end region 20, for example. The relative blade length r/R is understood to mean the quotient from the radial position r (the distance from the center of the rotor) and the rotor radius R.

In the following, the modification of the profile in the rotor blade end region 20 is explained with reference to Fig. 7 to 11. The noise-optimized profile provided in said region is described starting from an assumed power-optimized profile.

Fig. 7 is a schematically simplified illustration of a comparison between a power-optimized profile 50 and a noise-optimized profile 52. The rotor blade profile shown lies in a plane indicated by VII-VII in Fig. 2. The relative height d/D is plotted against the relative profile depth l/L of the rotor blade 4. Fig. 7a is an illustration that is at least approximately identical to Fig. 7 and is only used to clarify Fig. 7. The power-optimized profile 50 is shown as a solid line and the noise-optimized profile 52 is shown as a dashed line. The noise-optimized profile 52 is modified compared with the power-optimized profile by the following measures:

a) the radius of the profile at the rotor blade nose 16 is increased;
b) a position at which a maximum thickness of the profile is to be found is shifted in the direction of the rotor blade nose 16;
c) a maximum camber of the profile is decreased; and
d) a position at which the maximum camber of the profile of the rotor blade 4 is to be found is shifted in the direction of the rotor blade trailing edge 18.

The above-mentioned measures can be taken individually or in combination in order to lower the noise emission of the rotor blade 4.

The individual measures are explained again in detail on the basis of the illustrations in Fig. 8 to 11, which show different variables, each plotted against relative blade lengths r/R. The shape of the relevant variable for a power-optimized profile 50 is shown as a solid line in each case. In contrast, the differing shape of the relevant variable as is to be found for a noise-optimized profile 52 is shown as a dashed line.

Fig. 8 shows a relative nose radius of the rotor blade 4. As indicated by an arrow, the relative nose radius is increased for the noise-optimized profile 52. The modifications are made starting from a relative blade length r/R of approximately 0.9.

Fig. 9 shows a relative maximum thickness of the rotor blade 4. The arrow indicates that the maximum thickness of the rotor blade 4 is decreased in the rotor blade end region 20. A position of the maximum thickness of the profile moves in the direction of the rotor blade nose 16. This position lies, for example, on the edge shown by a double arrow, for a relative blade length of approximately 0.9, starting from which a modification for the noise-optimized rotor blade profile 52 is made.

Fig. 10 shows a maximum camber of the rotor blade 4. As indicated by an arrow, in the rotor blade end region 20, the maximum camber of the profile is decreased. This modification is made starting from a relative blade length r/R of approximately 0.92.

Furthermore, the maximum camber drops to zero at the rotor blade tip 8, i.e. a relative length of 1.

Fig. 11 shows a maximum camber of the rotor blade 4. As indicated by an arrow, in the rotor blade end region 20, the maximum camber is increased and moves in the direction of the rotor blade trailing edge 18. The maximum camber drops to zero, for example, at the rotor blade tip 8.

At the rotor blade tip 8, in a plane indicated by XII-XII in Fig. 2, the rotor blade 4 has approximately the rotor blade profile shown in Fig. 12. At the rotor blade tip 8, an at least approximately symmetrical profile is to be found, the maximum thickness of which is approximately 0.28 of the relative blade length r/R.

According to a method for manufacturing a rotor blade 4 of a wind energy installation 2, a power-optimized profile 50 of the rotor blade 4 is first provided. This is done, for example, by means of numerical simulation or by means of tests. This power-optimized profile 50 is modified by at least one of the following measures in order to obtain a noise-optimized profile 52 and to reduce the noise emission of the rotor blade 4:

increasing a radius of the profile at the rotor blade nose 16; shifting, in the direction of the rotor blade nose 16, a position at which a maximum thickness of the profile is to be found; decreasing a maximum camber of the profile; and/or shifting, in the direction of the rotor blade trailing edge 18, a position at which the maximum camber of the profile of the rotor blade 4 is to be found. The rotor blade 4 is then manufactured so as to have the noise-optimized profile.

All of the mentioned features, those to be taken from the drawings alone as well as individual features which are disclosed in combination with other features, are considered in isolation and in combination to be essential to the invention. Embodiments according to the invention can be fulfilled by individual features or a combination of a plurality of features. In the context of the invention, features qualified by “in particular” or “preferably” are to be understood to be optional features.

<u>List of reference signs</u>

2	wind energy installation
4	rotor blade
6	rotor blade root
8	rotor blade tip
10	hub
12	support structure
14	suction side
16	rotor blade nose
18	rotor blade trailing edge
20	rotor blade end region
22	blade root region
24	vortex generators
26	pressure side
28	trailing edge tab
30	second profile plane
32	power region
34	first profile plane
36	central portion
38	trailing edge serrations
40	chord of the profile
44	erosion protection means
46	blow-out slot
48	third profile plane
50	power-optimized profile
52	noise-optimized profile
L1	length of the trailing edge serrations
L2	length of the chord of the profile
α	angle
d	material thickness
b	width
PD	profile thickness
r	radial position
R	rotor radius

PATENTKRAV

1. Rotorblad (4) på et vindkraftanlæg (2), hvor rotorbladet (4) har en sugeside (14), en trykside (26), en rotorbladsnæse (16) og en rotorbladsbagkant (18), som strækker sig mellem en rotorbladsrod (6) og en rotorbladsspids (8) og definerer en profil for rotorbladet (4), **kendetegnet ved, at** rotorbladet (4) i et rotorbladsendeområde (20) har en lydoptimeret profil (52), som startende fra en antaget effektoptimeret profil (50), der er aerodynamisk optimeret med henblik på et effektudbytte af rotorbladet (4), til reducering af rotorbladets (4) lydemission i rotorbladsendeområdet (20) omfattende rotorbladsspidsen (8), er ændret ved hjælp af følgende foranstaltning: øgning af en maksimal krumning af rotorbladets (4) profil i rotorbladsendeområdet (20) fra en relativ bladlængde (r/R) på 0,92 og forskydning af en position, ved hvilken den maksimale krumning af rotorbladets (4) profil foreligger, i retning mod rotorbladsbagkanten (18).

2. Rotorblad (4) ifølge krav 1, **kendetegnet ved, at** rotorbladet (4) i et midterafsnit (36) har bagkanthak (38) (serrations) på rotorbladsbagkanten (18), hvor der i rotorbladsendeområdet (20) ingen bagkanthak (18) er, og hvor midterafsnittet (36) strækker sig fra rotorbladsendeområdet (20) i retning mod rotorbladsroden (6).

3. Rotorblad (4) ifølge krav 2, **kendetegnet ved, at** bagkanthakkene (38)

a) har en maksimal længde L1 på under 20% af en længde L2 af profilkorden (40) ved rotorbladets (4) tilhørende længdeposition,

og/eller

b) har en materialetykkelse d på 5 mm eller mindre,

og/eller

c) hælder med en vinkel α på 5° eller mindre i forhold til en retning (42) af profilkorden (40).

4. Rotorblad (4) ifølge krav 2 eller 3, **kendetegnet ved, at** i midterafsnittet (36) af rotorbladet (4) et forhold mellem profiltykkelse (PD) og kordelængde L2 er mindre end 0,24.

5. Rotorblad (4) ifølge et af kravene 2 til 4, **kendetegnet ved, at** midterafsnittet (36) strækker sig fra et første profilniveau (34) i retning mod rotorbladsspidsen (8), hvor rotorbladet (4) i det første profilniveau (34) ved vindkraftanlæggets (2) mærkeeffekt udsættes for en strøm med en relativ hastighed på 55 m/s.

6. Rotorblad (4) ifølge et af kravene 1 til 5, **kendetegnet ved, at** rotorbladet (4) i et bladrodsområde (22) på sugesiden (14) har vortex-generatorer (24), hvor bladrodsområdet (22) strækker sig fra rotorbladsroden til et andet profilniveau (30), og hvor rotorbladet (4) i det andet profilniveau (30) ved vindkraftanlæggets (2) mærkeeffekt udsættes for en strøm med en relativ hastighed på 30 m/s.

7. Rotorblad (4) ifølge et af kravene 1 til 6, **kendetegnet ved, at** rotorbladet (4) på rotorbladsnæsen (16) har en erosionsbeskyttelse (44), hvor erosionsbeskyttelsen (44) med en trinhøjde på mindre end 0,2 mm er integreret i en overflade af rotorbladet (4).

8. Rotorblad (4) ifølge et af kravene 1 til 7, **kendetegnet ved, at** rotorbladet (4) på sugesiden har en tangentiel udblæsningsspalte (46), hvor udblæsningsspalten (46) strækker sig fra et tredje profilniveau (48) i retning mod rotorbladsspidsen (8), og det tredje profilniveau (48) er anbragt ved en bladlængde på i det mindste tilnærmelsesvis 80%.

9. Vindkraftanlæg (2) med et rotorblad (4) ifølge et af kravene 1 til 8.

10. Fremgangsmåde til fremstilling af et rotorblad (4) til et vindkraftanlæg (2), hvor rotorbladet (4) har en sugeside (14), en trykside (26), en rotorbladsnæse (16) og en rotorbladsbagkant (18), som strækker sig mellem en rotorbladsrod (6) og en rotorbladsspids (8) og definerer en profil af rotorbladet (4), **kendetegnet ved** følgende trin:

I) Tilvejebringelse af en effektoptimeret profil (50) af rotorbladet (4), hvor den effektoptimerede profil med henblik på et effektudbytte af rotorbladet er aerodynamisk optimeret,

II) Ændring af den effektoptimerede profil (50) for at opnå en lydoptimeret profil (52) i et rotorbladsendeområde (20), til reducering af en lydemission fra rotorbladet (4), hvor der startende fra den effektoptimerede profil af rotorbladsendeområdet (20) omfattende rotorbladsspidsen (8), gennemføres følgende foranstaltning: øgning af en maksimal krumning af rotorbladets (4) profil i rotorbladsendeområdet (20) fra en relativ bladlængde (r/R) på 0,92 og forskydning af en position, ved hvilken den maksimale krumning af profilen foreligger, i retning mod rotorbladsbagkanten (18),

III) Fremstilling af rotorbladet (4) med den lydoptimerede profil i rotorbladsendeområdet (20).

11. Fremgangsmåde ifølge krav 10, **kendetegnet ved, at** rotorbladet (4) i et midterafsnit (36) forsynes med bagkanthak (38) (serrations) på rotorbladsbagkanten (18), hvor der i rotorbladsendeområdet (20) ikke tilvejebringes bagkanthak (18), og hvor midterafsnittet (36) strækker sig fra rotorbladsendeområdet (20) i retning mod rotorbladsroden (6).

12. Fremgangsmåde ifølge krav 11, **kendetegnet ved, at** der tilvejebringes bagkanthak (38), som

a) har en maksimal længde L1 på under 20% af en længde L2 af profilkorden (40) ved rotorbladets (4) tilhørende længdeposition,
og/eller
b) har en materialetykkelse d på 5 mm eller mindre,
og/eller
c) hælder med en vinkel α på 5° eller mindre i forhold til en retning (42) af profilkorden (40).

13. Fremgangsmåde ifølge krav 11 eller 12, **kendetegnet ved, at** der tilvejebringes et midterafsnit (36), som strækker sig fra et første profilniveau (34) i retning mod rotorbladsspidsen (8), hvor rotorbladet (4) i det første profilniveau (34) ved vindkraftanlæggets mærkeeffekt udsættes for en strøm med en relativ hastighed på 55 m/s.

14. Fremgangsmåde ifølge et af kravene 10 til 13, **kendetegnet ved, at** rotorbladet i et bladrodsområde (22) på sugesiden (14) forsynes med vortex-generatorer (24), hvor bladrodsområdet (22) strækker sig fra rotorbladsroden (6) til et andet profilniveau (30), og hvor rotorbladet (4) i det andet profilniveau (30) ved vindkraftanlæggets (2) mærkeeffekt udsættes for en strøm med en relativ hastighed på 30 m/s.

15. Fremgangsmåde ifølge et af kravene 10 til 14, **kendetegnet ved, at** rotorbladet (4) på sugesiden (14) forsynes med en tangentiel udblæsningsspalte (46), hvor udblæsningsspalten (46) strækker sig fra et tredje profilniveau (48) i retning mod rotorbladsspidsen (8), og det tredje profilniveau (48) er anbragt ved en bladlængde på i det mindste tilnærmelsesvis 80%.

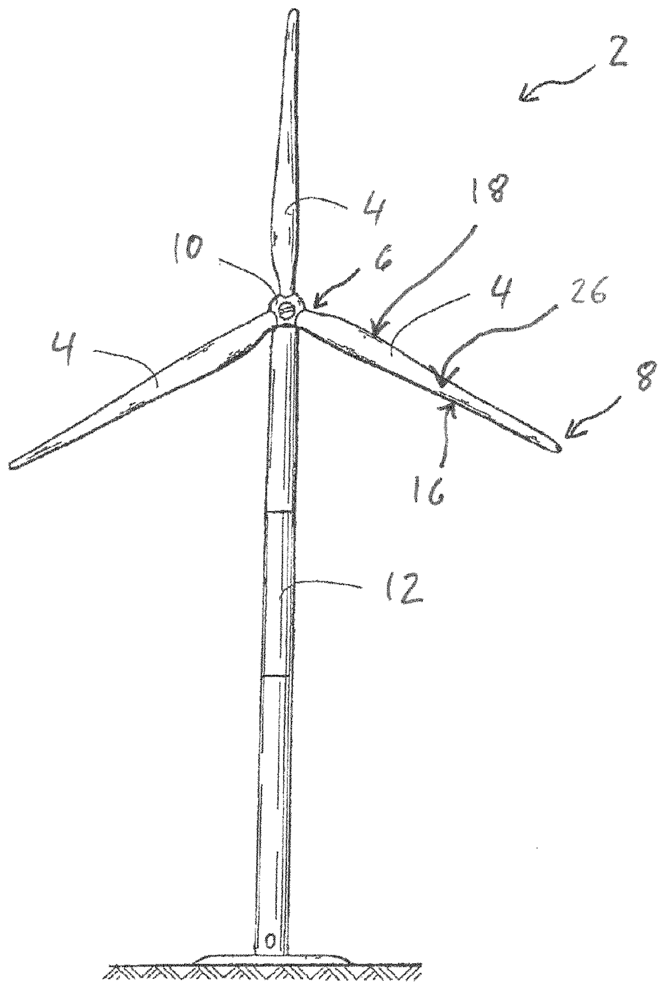


FIG. 1

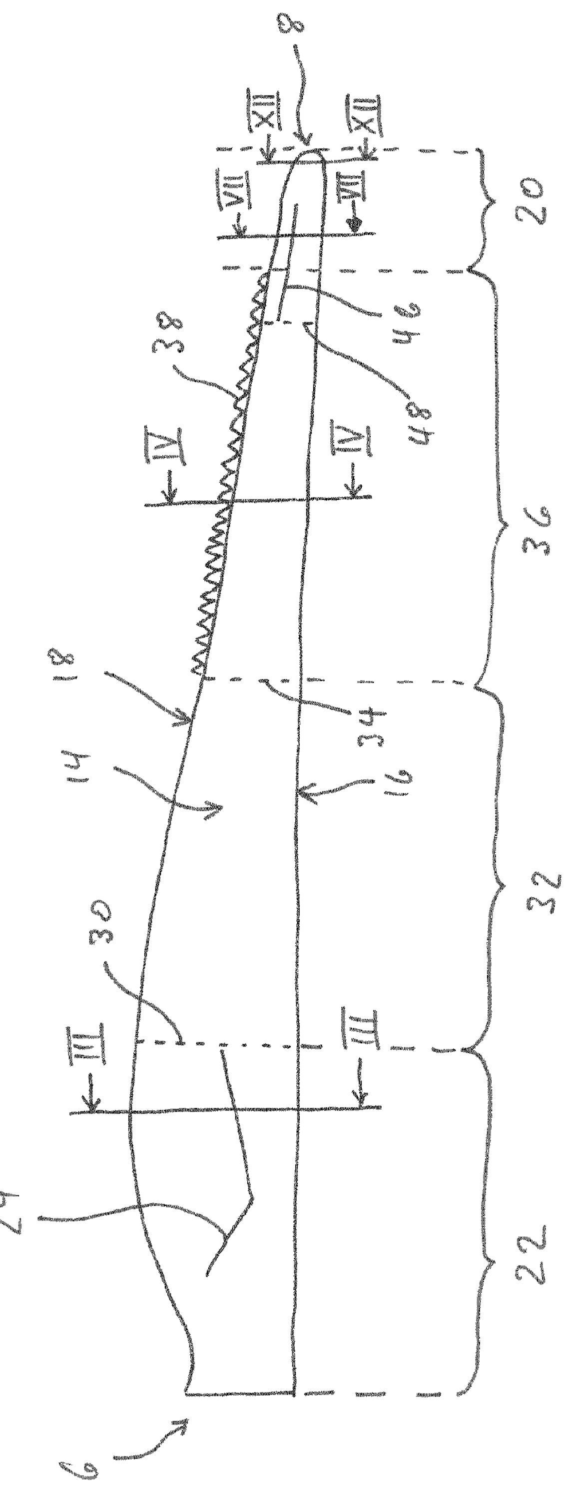


Fig. 2

Fig. 3

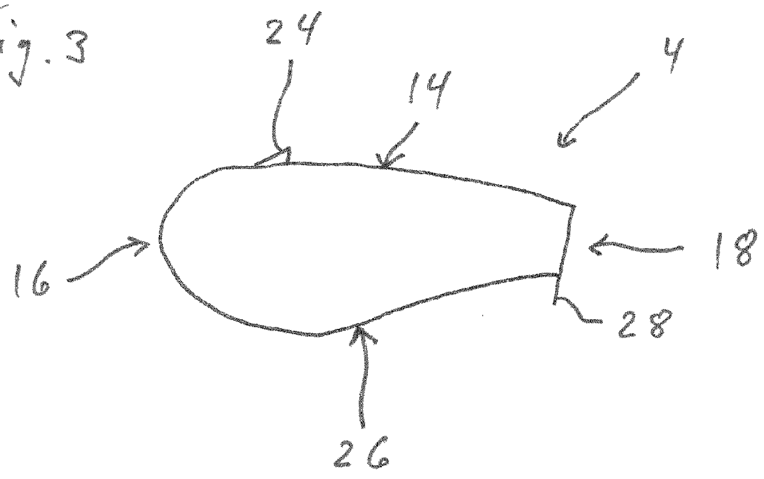


Fig. 4

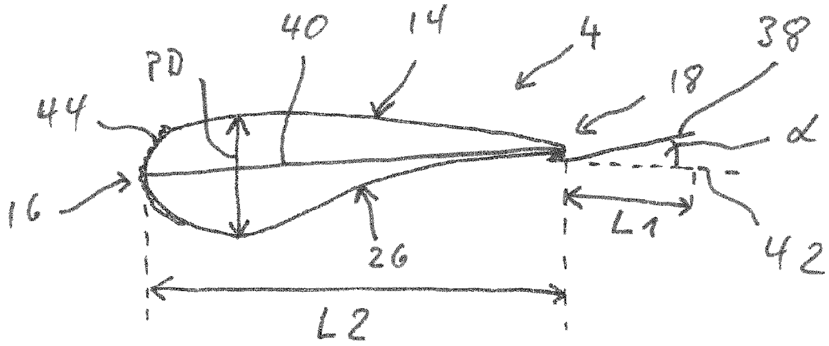


Fig. 5

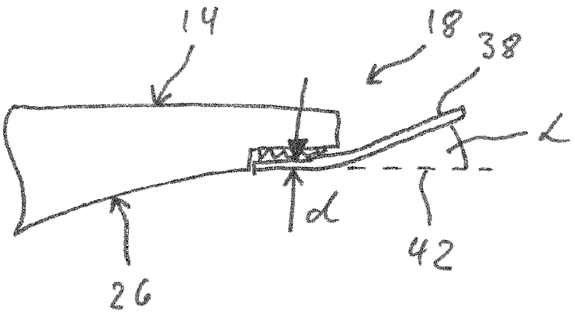


Fig. 6

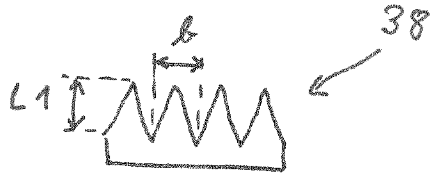
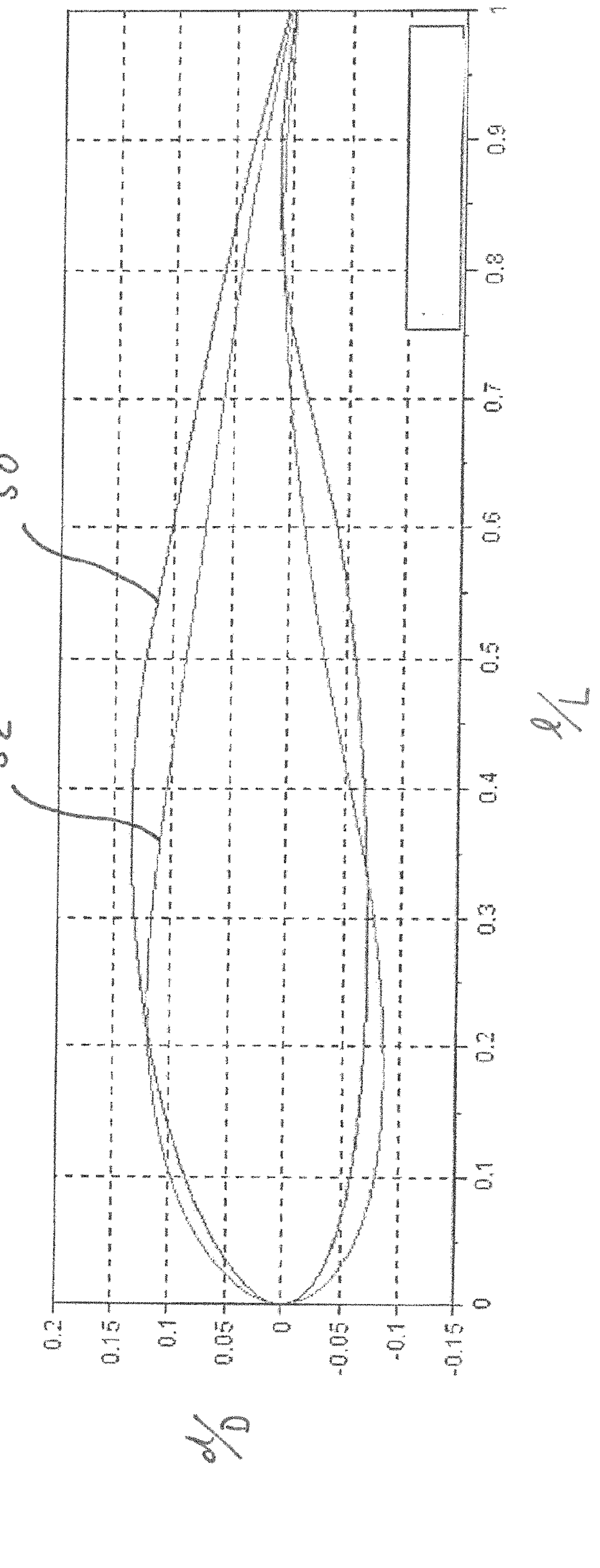


Fig. 7



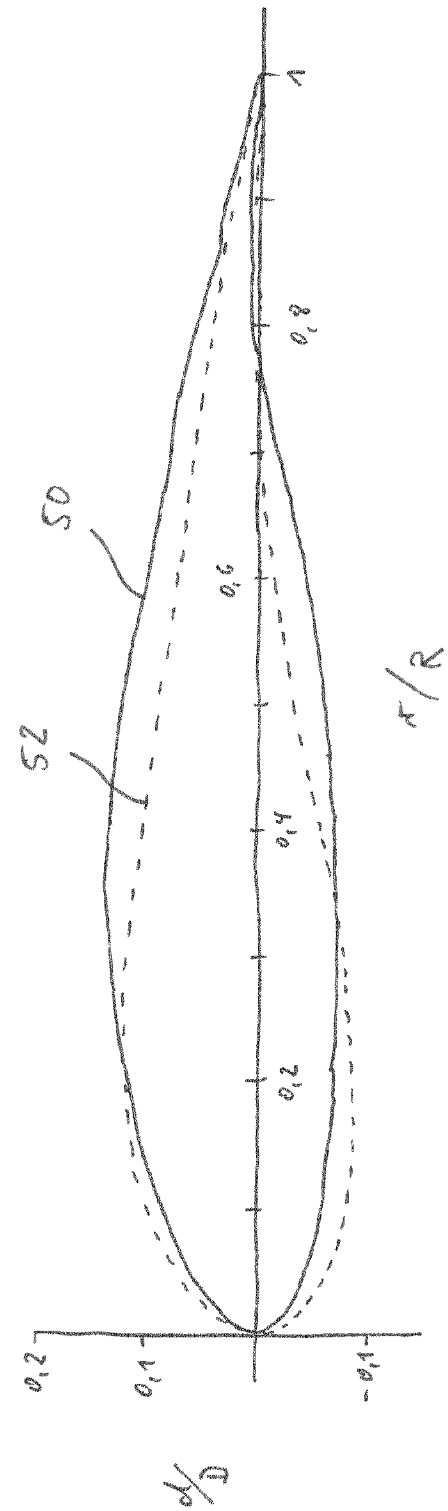


Fig. 7a

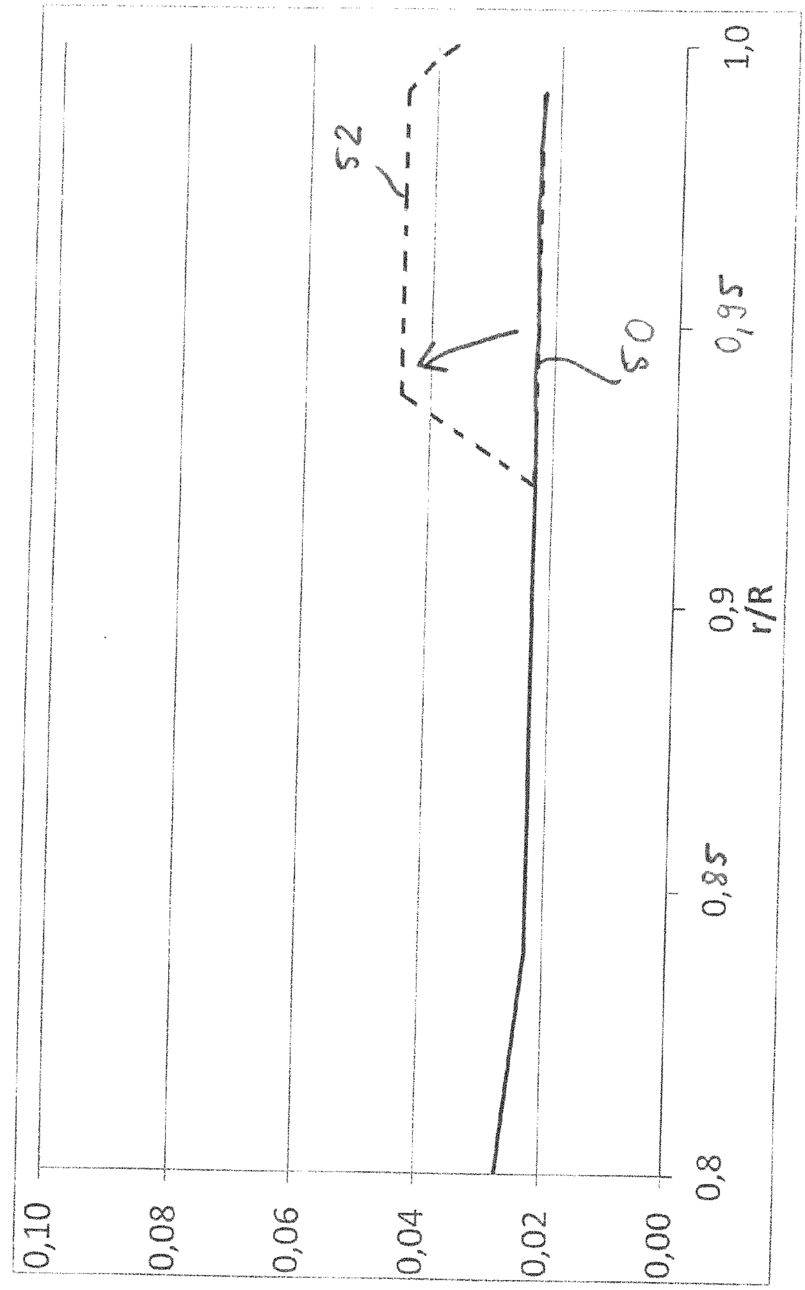
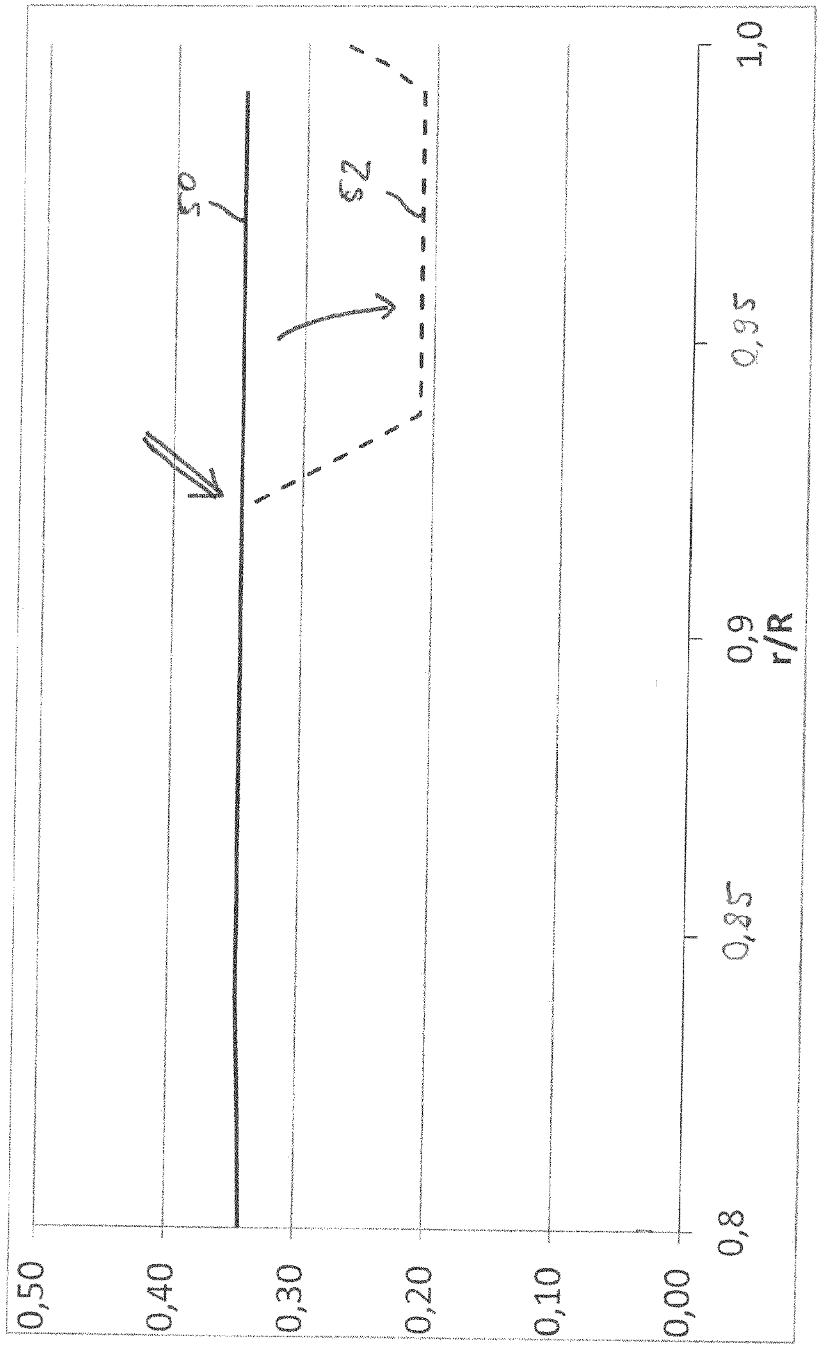
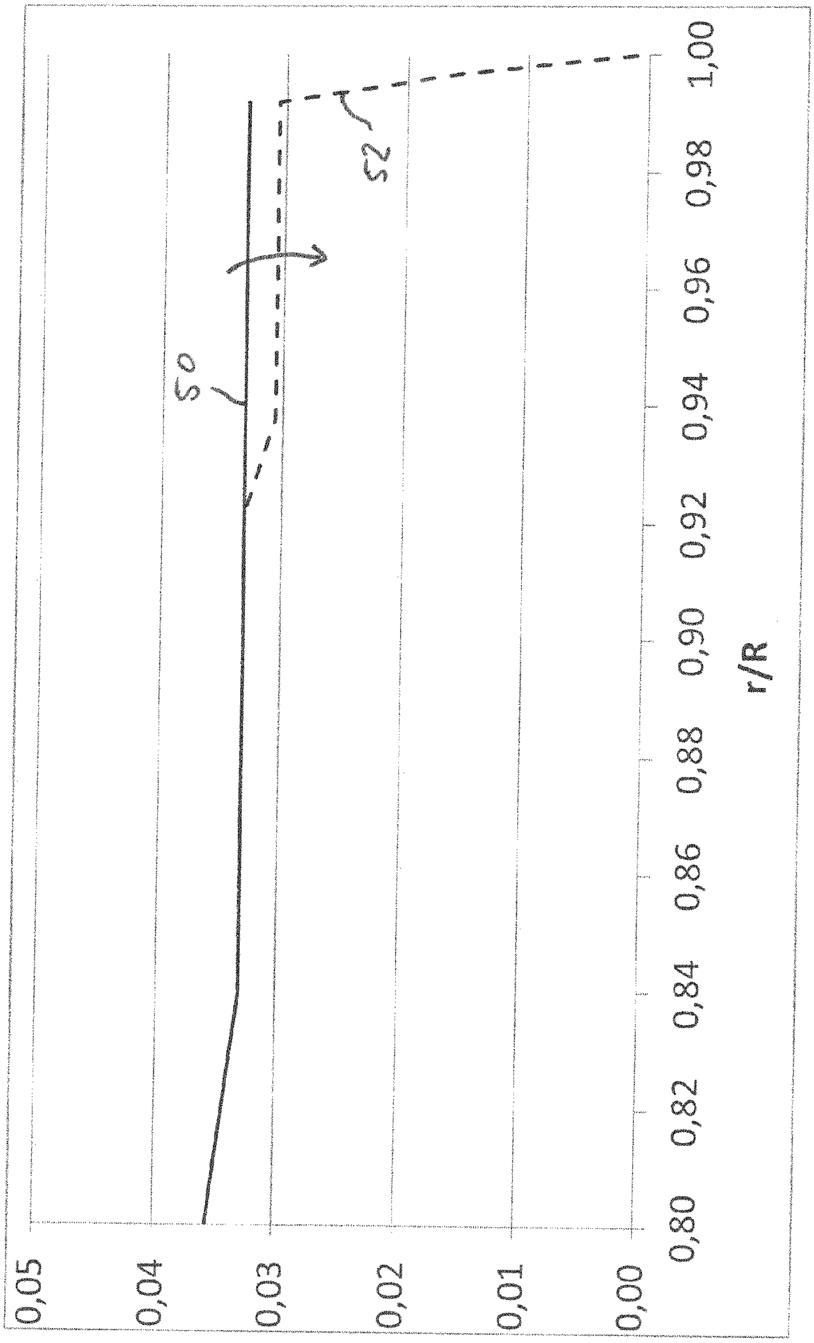


Fig. 8

Fig. 9

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0,84
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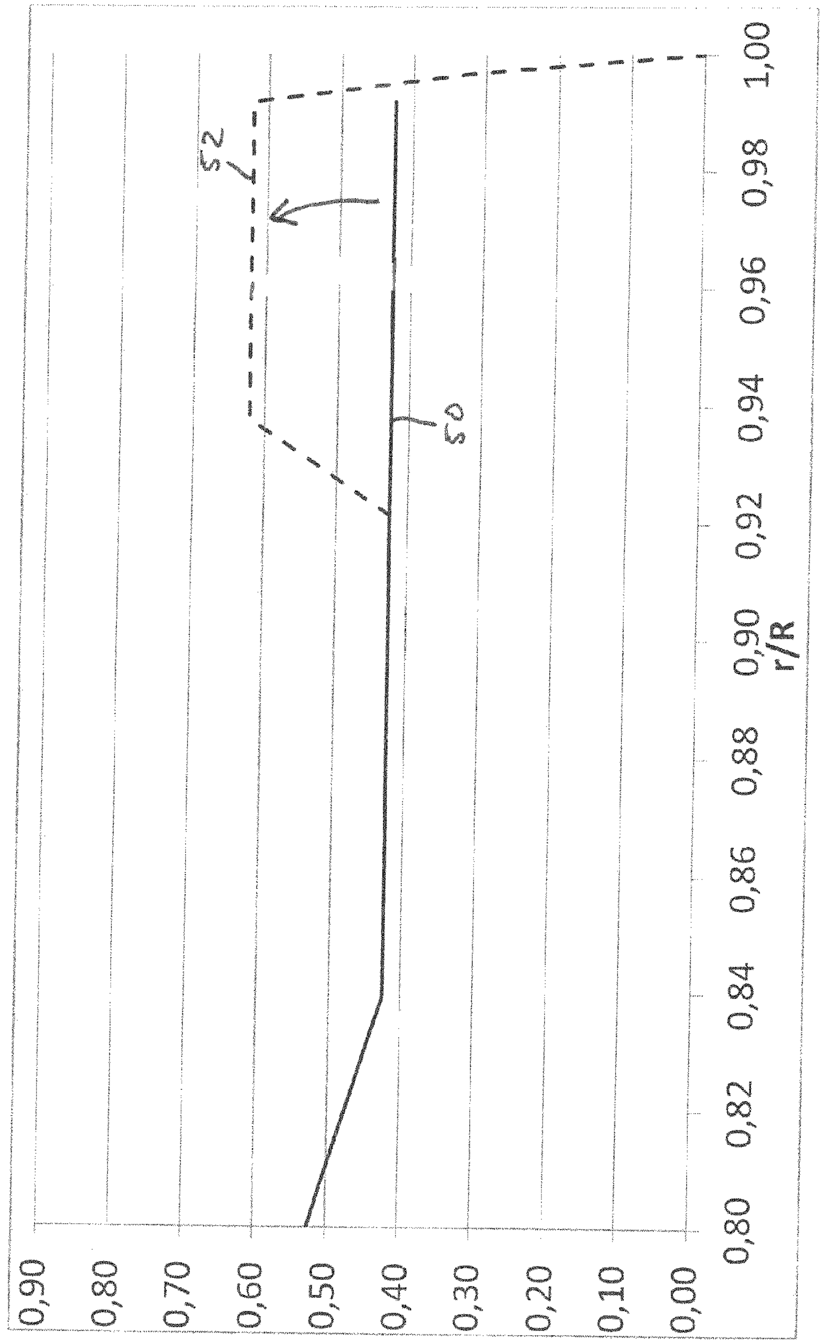
0,92
0,94
0,96
0,98
1,00
r/R
50
52

Fig. 10

Fig. 11



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r/R
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52

Fig. 12