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(54) Title: WIND TURBINE WITH HUB INTERCONNECTION MEANS

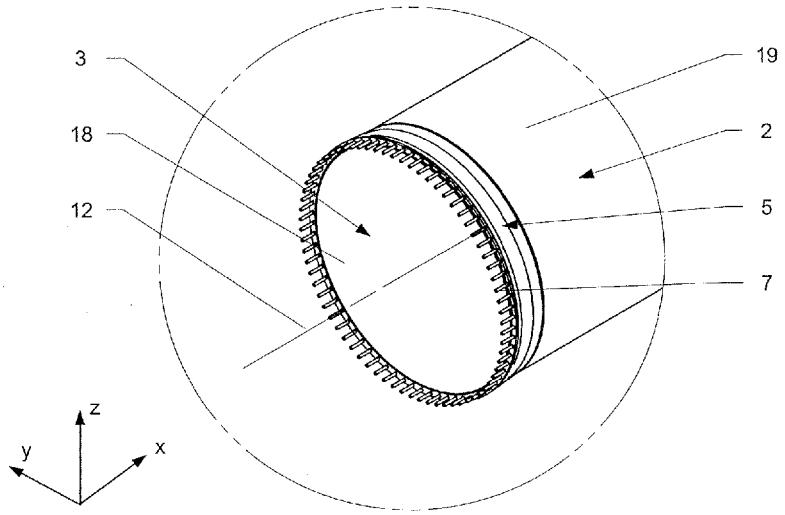

Fig. 2

(57) Abstract: The invention relates to a wind turbine blade (1) comprising a blade shell (2) extending in a longitudinal direction (x) from a blade root (3) to a blade tip (4). The blade shell (2) further comprises at the blade root (3) at least one first load application surface (10), and an interconnection member (5) extending at the blade root (3) in a circumferential direction along the blade shell (2). The interconnection member is comprising a core (6) with several interconnection means (7) spaced apart from each other in the circumferential direction to interconnect the wind turbine blade (1) to a hub of a wind turbine. Hereby, the core (6) comprises a front face (8) extending between at least two interconnection means (7) and which in the assembled position is at least partially encompassed by at least one layer of fiber reinforced material (9). The at least one layer of fiber reinforced material (9) forms at least one second load application surface (11) by which the interconnection member (5) is interconnected to the at least one first load application surface (10) of the blade shell (2).

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WIND TURBINE WITH HUB INTERCONNECTION MEANS

FIELD OF THE INVENTION

The present invention relates to a wind turbine blade comprising an interconnection means for the interconnection of the wind turbine blade to a wind turbine hub.

BACKGROUND OF THE INVENTION

In recent years, the size of wind turbines increased drastically to meet the growing demand of renewable energy. The larger rotor sizes and longer blades yield however massive fluctuating loads which strain among others the blade structure, the blade-hub interconnection and the drive train.

The wind turbine blades, build from fibre-reinforced material, require being joined to the wind turbine hub. This is e.g. realized by incorporating threaded inserts into the blade shell into which fixing bolts or screws are inserted to establish a connection from the wind turbine blade to the turbine hub. In most applications the inserts are hereby either incorporated into holes that are drilled into the fibre-reinforced material or elaborately incorporated during the blade manufacturing. In the following, some examples are given from several alternative blade-hub interconnection mechanism known from prior art:

DE102015212906A1, published on the 12.01.2017 by RWE Innogy GmbH, relates to a rotor blade mounting with a rotor blade mounting flange with mounting bolts being inserted in the rotor blade. A rotor hub flange with through holes are interspersed in the mounting position of the rotor blade of the fastening bolt. The bolts are preloaded with at least a nut.

WO14155293A1, published on the 02.10.2014 by Wilic S.AR.L, relates to wind turbine blade root having an annular structure extending about a main axis and made of a composite material including a matrix and reinforcing fibres. The root further comprises first longitudinal reinforcing elements as well as an annular reinforcing element. The first longitudinal reinforcing elements are incorporated in the annular structure, extend in the direction of the main axis, and are spaced apart in a circle about the main axis. The annular reinforcing element connects the first longitudinal reinforcing elements and has first coupling portions for the connection to the first longitudinal reinforcing elements.

WO15124568A1, published 27.08.2015 by the LM WO Patent Holding, discloses a wind turbine blade bushing system for the arrangement in a root end of a wind turbine blade. The wind turbine blade bushing system comprises a threaded element for retaining a mounting bolt for a wind turbine blade and an anchor element for the arrangement at the root end of the wind turbine, wherein the anchor element acts to retain the threaded element in the wind turbine blade. Hereby, the threaded element is formed from a first material and the anchor element is formed

from a second material with the first material having a higher strength and higher fracture toughness than the second material.

WO12111518, published by Mitsubishi Heavy Industries on the 23.08.2012, relates to a blade-root forming piece with an embedded metal including a nut part having a hole with an internal thread formed therein. Furthermore, a protrusion protrudes from the nut part in a circumferential direction of the blade root and a core member is disposed adjacent to the protrusion. A FRP-wound layer formed by a unidirectional fiber prepreg is layered around the protrusion and the core member.

Blade-hub interconnection mechanisms known from the prior art often suffer from severe fatigue due to large aerodynamical as well as gravitational forces acting on the wind turbine blade. This results in a decrease of the overall lifetime of the blade structure, wherein the blade structure at the blade root and around the blade-hub interconnection mechanisms is particularly affected.

SUMMARY OF THE INVENTION

It is an object of the invention to provide a wind turbine blade with an improved force transmission from the wind turbine blade to the wind turbine hub. A further object of the invention is to provide a wind turbine blade which allows a non-destructive structural integration of the interconnection means to the wind turbine blade.

A wind turbine blade according to the invention comprises a blade shell extending in a longitudinal direction from a blade root to a blade tip. The blade shell further comprises at the blade root at least one first load application surface.

An interconnection member for the interconnection of the wind turbine blade to the wind turbine hub extends at the blade root in a circumferential direction along the blade shell. Preferably, the interconnection member is ring-shaped such that the ring is orientated along the blade shell in in the region of the blade root. A cross-section of the blade shell in the region of the blade root is normally circular, however the interconnection member may also follow an individual, non-circular shape of the blade root.

The interconnection member comprises several interconnection means spaced apart from each other in the circumferential direction to interconnect the wind turbine blade to a hub of a wind turbine. Preferably, the interconnection member further comprises a core to which the interconnection means are interconnected. The core comprises a front face extending between at least two interconnection means. In an assembled position the core is preferably at least partially encompassed by at least one layer of fiber reinforced material.

The interconnection member is interconnected to at least one first load application surface of the blade shell via at least one second load application surface of the interconnection member. Depending on the embodiment, the interconnection

member may comprise at least two second load application surfaces which are arranged at an angle with respect to each other. If multiple second load application surfaces are present, they are preferably arranged evenly spaced apart over the circumference of the blade shell for an evenly balanced force transmission.

In a variation of the invention, an inner face of the interconnection member and/or an outer face of the interconnection member may be tapered in a direction away from the interconnection means. The inner face of the interconnection member is thereby defined as facing towards a middle axis of the interconnection member and the outer face as facing away from said middle axis. However, in a preferred variation of the invention, the inner and the outer face are both tapered in the direction away from the interconnection means and the interconnection member has a drop-shaped cross-section. The drop-shaped cross-section of the interconnection member is preferably present at least between two interconnection means, where the at least one layer of fiber reinforced material encompasses the core, such that front face of the core between the interconnection means is rounded to facilitate said encompassing of fibers. A cross-section in the area of the interconnection means may alternatively also have a different cross-section since in this area the core does not necessarily be fully encompassed by fiber reinforced material. This facilitates the integration and assembly of the interconnection means.

The interconnection member (interconnected to the blade shell via the first and second load application surfaces) may be arranged along an outer shell face and/or an inner shell face of the blade shell. Consequently, the second load application

surface may be arranged on the inner and/or on the outer face of the interconnection member with respect to the middle axis of the interconnection member. Respectively, the first load application surface may be arranged on said outer shell face and/or said inner shell face of the blade shell. Hereby, the first load application surface is advantageously also tapered towards the blade root in such a way, that the interconnection member in the assembled position cannot slip further over the said first load application surface in the longitudinal direction and is thus fixated in said longitudinal direction. For a good force transmission, the first and the second load application surfaces are advantageously tapered in such a way that they extend long each other and engage form fittingly.

If the interconnection member is slit into the blade shell such that the first load application surface is located at the inner shell face of the blade shell and the second load application surface is located at the outer face of the interconnection member, the interconnection of the interconnection member and the blade shell may be further stabilized by a rib. Therefore, the rib may be integrated perpendicular to the blade shell into the blade shell such that a circumferential outer side of the rib is braced at least partly over the circumference against the interconnection member. Hence, the rib presses the interconnection member against the blade shell and thereby improves the force transmission between the interconnection member and the blade shell.

For an advantageous and overall lighter built-up of the interconnection member, the core of said interconnection member may comprise a first section made from a

first material and a second section made from a second material, wherein the second material preferably has a lower density than the first material. While the first section is foreseen to receive and transfer the occurring forces, the second section is foreseen to maintain the cross-section and prevent unwanted buckling of the thereto adjacent composite material. Advantageously, the first section comprises the at least one interconnection means such that the interconnection means is anchored in the more dense and firm material. This set-up allows for an overall longer interconnection member with larger first and second load application surfaces which improves the load transmittal between the blade and the hub. Depending on the application, the second material may e.g. be a duroplast or plastic foam, meanwhile the first section may be made at least partially of metal. Alternatively or in addition to that the second section may also have honeycomb structure resulting in said lower density. In one variation of the invention, the core may also be dividable in multiple sections in the circumferential direction by e.g. attaching several ring sections of the core to form the ring-shaped interconnection member.

For the interconnection of the wind turbine blade to a wind turbine hub the core may comprise multiple openings extending in the longitudinal direction from the front face towards the blade tip, each receiving an interconnection means. The interconnection means may be e.g. a screw or a bolt. The interconnection means and the interconnection member may comprise an additional anchoring for the fixation of the interconnection means into said opening of the interconnection member. The anchoring may e.g. be a thread or a different fastening mechanism. In the above described case, that the core comprises a first and a second section, the

openings may be arranged in the first and/or the second section, however the anchoring of the interconnection means is preferably realized in the more dense first section.

Depending on the individual case, the interconnection member may comprise a positioning means to position the wind turbine blade on the wind turbine hub. The positioning means is preferably arranged in the core and, if present, in the first section of the core. The positioning means may also be received in an opening of the core, as described above. Since the positioning means is not meant to carry or transmit loads but is rather a tool to align the wind turbine blade to the hub during interconnection, the positioning means may be e.g. be a pin pressed into said opening. Thus, for an easy alignment using said positioning means, the extension of the positioning means from the front face towards a wind turbine hub may be greater than an extension of the interconnection means.

To improve the support of the wind turbine blade on the hub, an outer fiber layer can be arranged at the blade root in front of the interconnection member to level out possible shape disparities between e.g. a rounded front of the interconnection member and a hub interface and/or to reinforce locally the fiber structure. The outer fiber layer thus may form a support surface foreseen to abut against the hub interface.

For an easy assembly of the wind turbine blade, the interconnection member may be a pre-manufactured subassembly which is assembled before being slit as a

whole on or in the blade shell of the wind turbine. Hence, the core (or the multiple core sections, if present) are wrapped by at least one fiber reinforced material, preferably, when the interconnection means are already in place. This subassembly may then be slit on as a whole on the first load application surface of the blade shell and attached by means of an adhesive such as e.g. an epoxy. Depending on the application, the outer fiber layer may be attached before or after the assembly of the interconnection member on the blade shell.

In a variation of the invention, the wind turbine blade shell may also feature two interconnection members arranged on the inner and the outer shell face via two thereon arranged first load application surfaces. The resulting sandwich structure, comprising two interconnection members with the blade shell arranged in-between, offers a particular strong and durable interconnection if required.

It is to be understood that both the foregoing general description and the following detailed description present embodiments, and are intended to provide an overview or framework for understanding the nature and character of the disclosure. The accompanying drawings are included to provide a further understanding, and are incorporated into and constitute a part of this specification. The drawings illustrate various embodiments, and together with the description serve to explain the principles and operation of the concepts disclosed.

BRIEF DESCRIPTION OF THE DRAWINGS

The herein described invention will be more fully understood from the detailed description given herein below and the accompanying drawings which should not be considered limiting to the invention described in the appended claims. The drawings are showing:

Fig. 1 A first variation of the wind turbine blade (1) according to the invention in a perspective view,

Fig. 2 a detail of the blade root (4) of the wind turbine blade (1) according to Figure 1 in a perspective view,

Fig. 3 the wind turbine blade (1) according to Figure 1 in a side view,

Fig. 4 the wind turbine blade (1) in a sectionized view (G) as depicted in Figure 3,

Fig. 5 a detail of the wind turbine blade (1) according to Figure 4,

Fig. 6 the wind turbine blade (1) according to Figure 1 in a perspective disassembled view,

Fig. 7 a second variation of the wind turbine blade (1) according to the invention in a side view,

Fig. 8 the wind turbine blade (1) in a sectionized view (E) as depicted in Figure 7,

Fig. 9 a detail of the wind turbine blade (1) according to Figure 8.

DESCRIPTION OF THE EMBODIMENTS

Reference will now be made in detail to certain embodiments, examples of which are illustrated in the accompanying drawings, in which some, but not all features are shown. Indeed, embodiments disclosed herein may be embodied in many different forms and should not be understood as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will satisfy applicable legal requirements. Whenever possible, like reference numbers will be used to refer to like components or parts.

Figure 1 to **Figure 6** show a first variation of a wind turbine blade 1 according to the invention, meanwhile **Figure 7** to **Figure 9** illustrate a second variation of the wind turbine blade 1 according to the invention. In **Figure 1** the wind turbine blade 1 can be seen as a whole (in Figure 2 – Figure 9 the blade shell is only illustrated in the root region in a schematic way): the wind turbine blade 1 comprises a blade shell 2 which is extending in a longitudinal direction (x) from a blade root 3 to a blade tip 4. At the blade root 3 the blade shell 2 comprises a first load application surface 10 on which an interconnection member 5 is interconnected via a second

load application surface 11 of said interconnection member 5 (compare also **Figure 6**). The details of the interconnection member 5 can be seen in **Figure 5**, which is an enlarged detail of the wind turbine blade 1 in a sectionized view as illustrated in **Figure 4**. **Figure 5** depicts the built-up and interconnection of the interconnection member 5 to the blade shell 2 at the blade root 3. The interconnection member 5 is in the illustrated variation ring-shaped and extending at the blade root 3 in a circumferential direction along an outer side 14 of the blade shell 2. The interconnection member comprises a core 6 which is in the assembled position at least partially encompassed by at least one layer of fiber reinforced material 9. Therefore the core 6 comprises a rounded front face 8 extending between at least two interconnection means 7 of the interconnection member 5. The interconnection means 7 interconnects the wind turbine blade 1 to a hub of a wind turbine (not shown) and are spaced apart from each other in the circumferential direction. The at least one layer of fiber reinforced material 9 forms at least one second load application surface 11 by which the interconnection member 5 is interconnected to the at least one first load application surface 10 of the blade shell 2.

The interconnection member preferably has a drop shaped cross-section that is tapered in a direction away from the interconnection means 7. Hereby, the interconnection member 5 and/or the core 6 may have at least a drop-shaped cross-section between two interconnection means 7, where the core is encompassed by the at least one fiber reinforced material 9. The drop-shape, respectively a rounded front face 8 of the core 5, is advantageous since it facilitates the encompassing of the fiber reinforced material 9 in this area.

In the shown sectionized view of **Figure 5**, it can further be seen that the core 6 comprises a first and a second section 16 which are arranged behind one another (in the longitudinal direction). The cross-section of the assembled core, including the first and second section has thus also a drop-shape, as described above. Hereby, the first section, arranged at the front, respectively in direction closer to the wind turbine hub, comprises multiple openings 17 around the circumference of the interconnection member 5. The openings 17 are extending from the front face 8 of the core 6 in a direction away from the interconnection means 5 (in the longitudinal direction towards the blade tip 4), each receiving an interconnection means 7 for the interconnection of the wind turbine blade 1 to a wind turbine hub. The first section 15 may be made from a first material different from a second material of the second section 16. Preferably, the second material has hereby a lower density than the first material. Thus, the core 6 may e.g. be made from a second material such as duroplast or plastic foam and a first material such as metal. In longitudinal direction (x) in front of the interconnection member 5 an outer fiber layer 21 may be arranged at the blade root 3 forming a support surface 20 for the wind turbine blade 1 on the wind turbine hub (not shown).

Figure 6 illustrates a disassembled state of the wind turbine blade 1 (only root region shown) in a perspective view. Here, the first load application surface 10 on the outer shell face 19 located at the blade root 3 can be seen. On the interconnection member 5 the inner face 13 and the outer face 14 can be distinguished. In the shown variation, the second load application surface, interacting in the assembled

position with the first load application surface, is located at the inner face 13 of the interconnection member 5.

The second variation of the invention as illustrated in **Figure 7** to **Figure 9**, differs from the above described first variation in that the interconnection member 5 is orientated at the inner shell face 18 of the blade shell 2. Thus, the first load application surface 10 is located at said inner shell face 18 at the blade root 3 and the second load application surface 11 is located at the outer face 14 of the interconnection member 5. The transmittal of the forces during operation through the first and second load application surfaces 10, 11 may be further improved by an additional rib 22 placed in the inside of the blade shell 2 and being defined in its contour (seen from the longitudinal direction) by the inner face 13 of the (ring-shaped) interconnection member 5. The rib has hereby preferably a passage opening 23 such that the inside of the blade shell 2 may be reached for later installation purposes.

The words used in the specification are words of description rather than limitation, and it is understood that various changes may be made without departing from the spirit and scope of the invention.

LIST OF DESIGNATIONS

1	Wind turbine blade
2	Blade shell
3	Blade root
4	Blade tip
5	Interconnection member
6	Core
7	Interconnection means
8	Front face
9	Fiber layer
10	First load application surface
11	Second load application surface
12	Middle axis
13	Inner face (interconnection member)
14	Outer face (interconnection member)
15	First section
16	Second section
17	Opening
18	Inner shell face
19	Outer shell face
20	Support surface
21	Outer fiber layer
22	Rib
23	Passage opening

PATENT CLAIMS

1. Wind turbine blade (1) comprising

   a. a blade shell (2) extending in a longitudinal direction (x) from a blade root (3) to a blade tip (4), said blade shell (2) comprising at the blade root (3) at least one first load application surface (10), and

   b. an interconnection member (5) extending at the blade root (3) in a circumferential direction along the blade shell (2) comprising

      i. a core (6) with several interconnection means (7) spaced apart from each other in the circumferential direction to interconnect the wind turbine blade (1) to a hub of a wind turbine, wherein

      ii. the core (6) comprises a front face (8) extending between at least two interconnection means (7) and which in the assembled position is at least partially encompassed by at least one layer of fiber reinforced material (9), wherein

      iii. the at least one layer of fiber reinforced material (9) forms at least one second load application surface (11) by which the interconnection member (5) is interconnected to the at least one first load application surface (10) of the blade shell (2).

2. Wind turbine blade (1) according to one of the preceding claims, **characterized in that** the interconnection member (5) is ring-shaped.

3. Wind turbine blade (1) according to one of the preceding claims, **characterized in that** the interconnection member (5) has a drop-shaped cross-section (12) which is tapered in a direction away from the interconnection means (7).

4. Wind turbine blade (1) according to claim 3, **wherein** the cross-section of the interconnection member (5) is drop shaped at least between two interconnection means (7).

5. Wind turbine blade (1) according to one of the preceding claims, **characterized in that** the front face (8) of the core (6) between the interconnection means is rounded to facilitate the encompassing of the at least one layer of fiber reinforced material (9).

6. Wind turbine blade (1) according to one of the preceding claims, **characterized in that** the second load application surface (11) is arranged on an inner face (13) and/or on an outer face (14) of the interconnection member (5).

7. Wind turbine blade (1) according to one of the preceding claims, **characterized in that** the core (6) comprises a first section (15) made from a first material and a second section (16) made from a second material having a lower

density than the first material, wherein the first section (15) is comprising at least one interconnection means (7).

8. Wind turbine blade (1) according to claim 7, **characterized in that** the second material is a duroplast or plastic foam.

9. Wind turbine blade (1) according to claim 7, **characterized in that** the first section (6) is at least partially made of metal.

10. Wind turbine blade (1) according to one of the preceding claims, **characterized in that** the interconnection member (5) comprises two second load application surfaces (11) which are arranged at an angle with respect to each other.

11. Wind turbine blade (1) according to one of the preceding claims, **characterized in that** an outer fiber layer (21) is arranged at the blade root (3) in front of the interconnection member (5) forming a support surface (20) for the wind turbine blade (1) on the wind turbine hub.

12. Wind turbine blade (1) according to one of the preceding claims, **characterized in that** the core (6) comprises multiple openings (17) extending in the longitudinal direction from the front face (8) towards the blade tip (4), each receiving an interconnection means (7) for the interconnection of the wind turbine blade (1) to a wind turbine hub.

13. Wind turbine blade (1) according to one of the preceding claims **characterized in that** the core (6) comprises a positioning means to position the wind turbine blade (1) on the wind turbine hub.

14. Wind turbine blade (1) according to one of the preceding claims, **characterized in that** the core (6) is dividable in multiple sections in the circumferential direction.

15. Wind turbine blade (1) according to one of the preceding claims, **characterized in that** the interconnection member is a pre-manufactured subassembly.

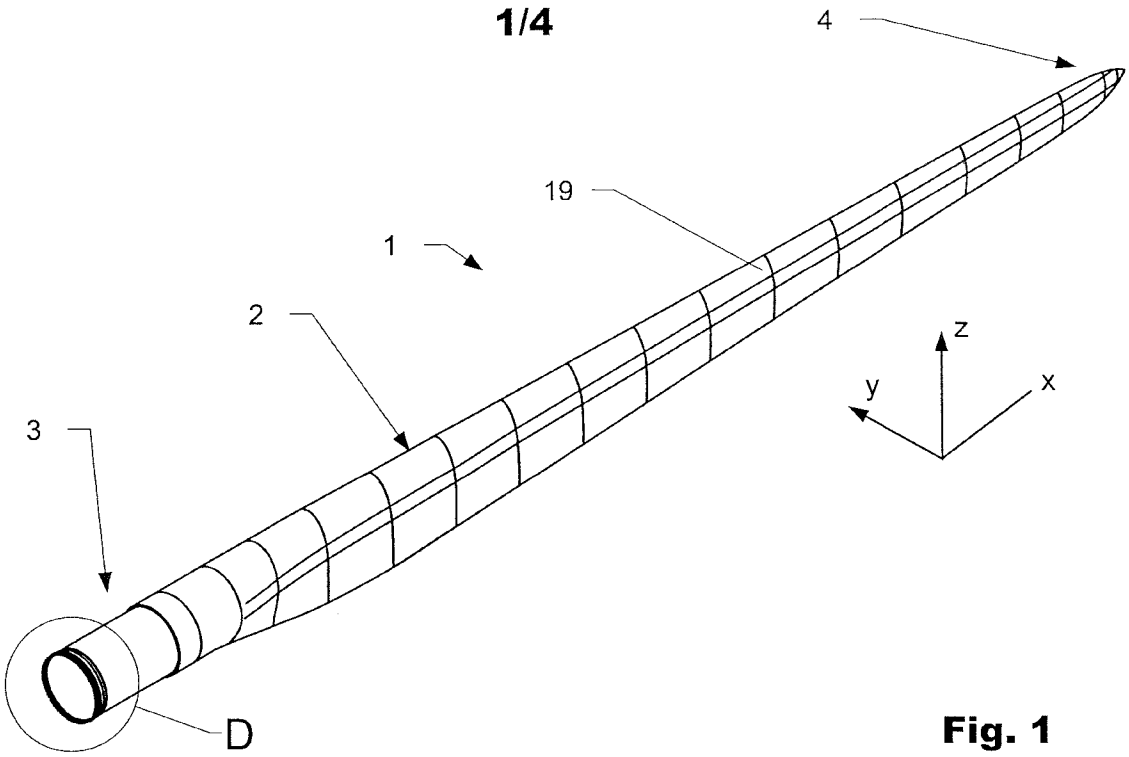

Fig. 1

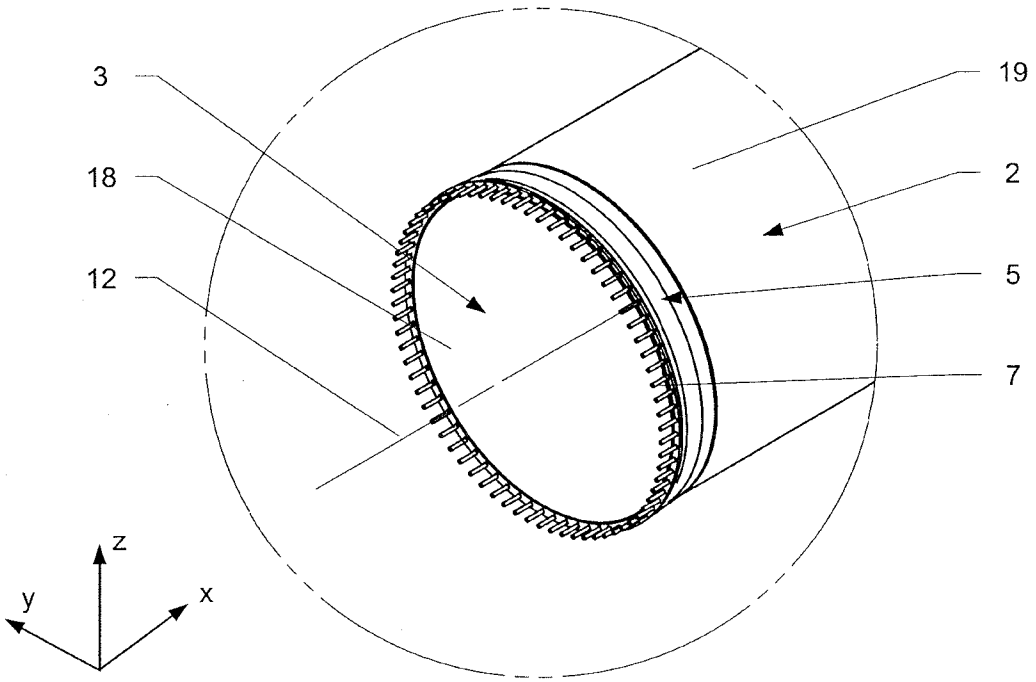

Fig. 2

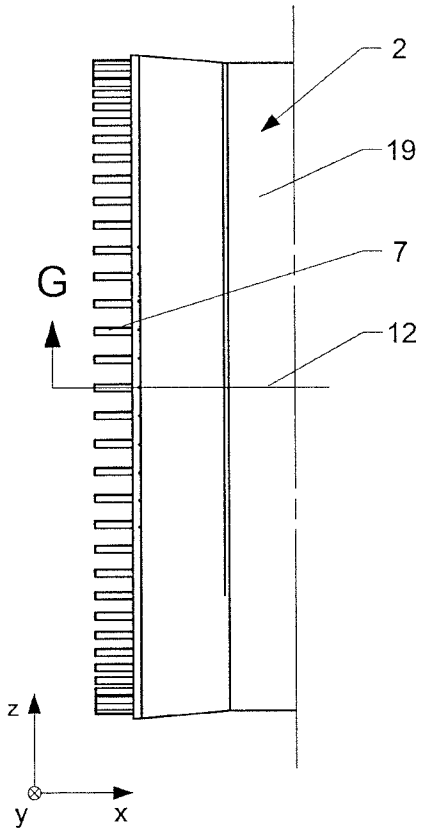

Fig. 3

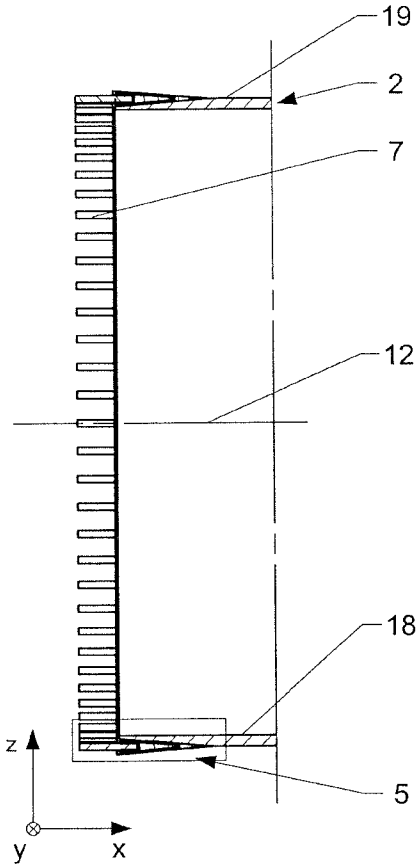

Fig. 4

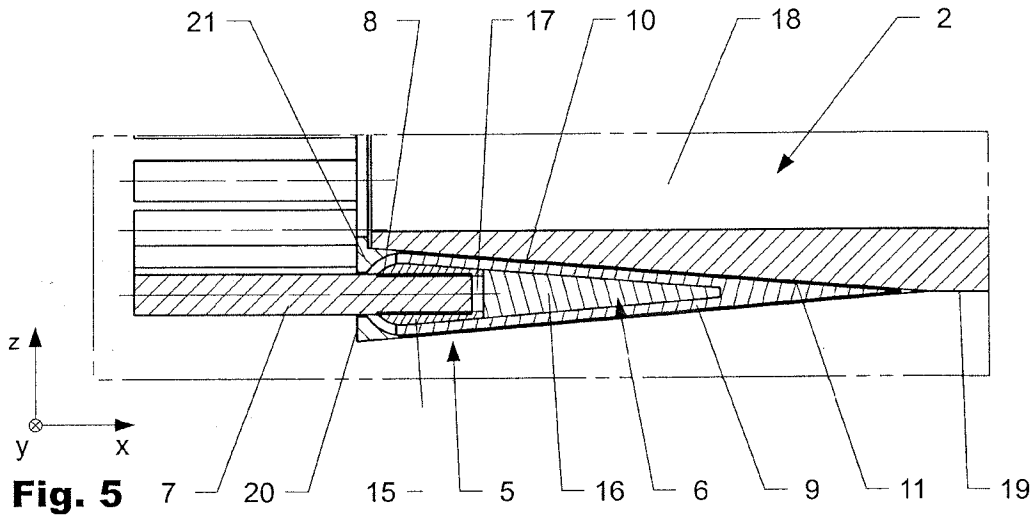

Fig. 5

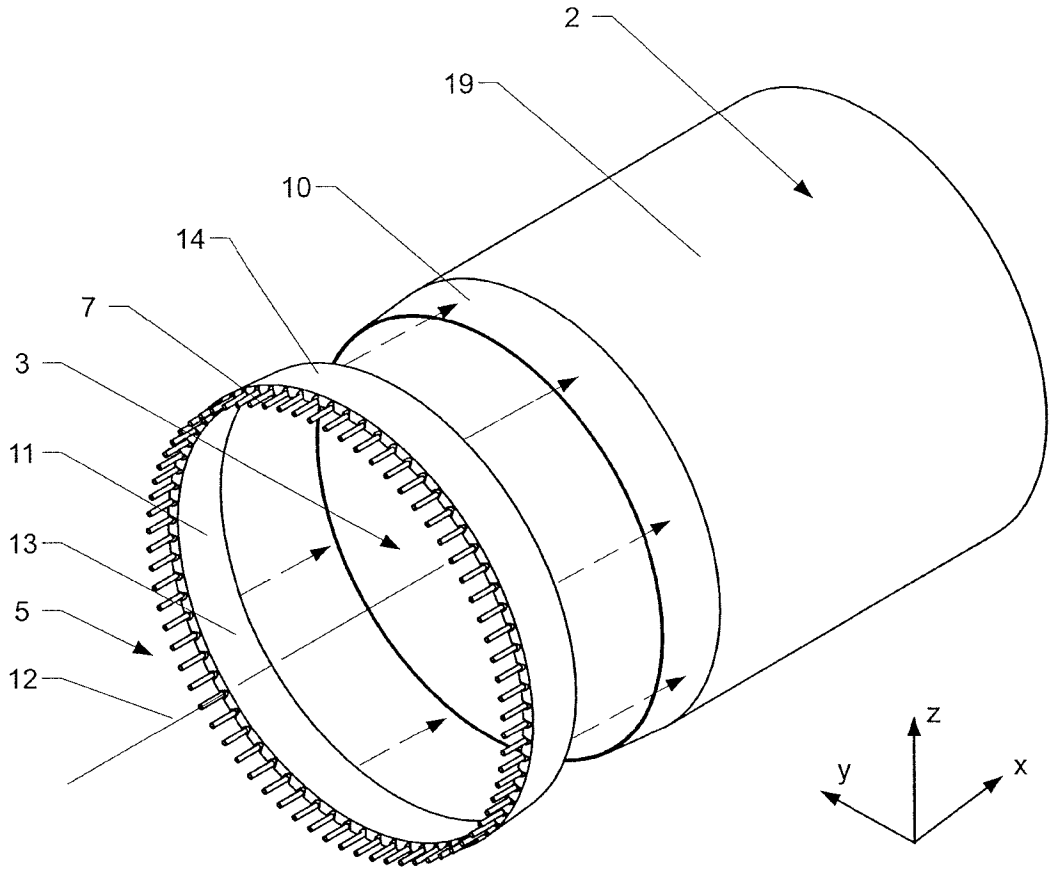

Fig. 6

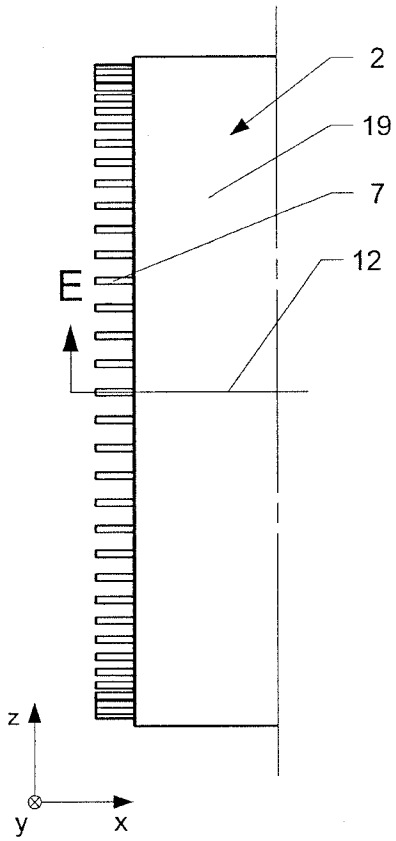

Fig. 7

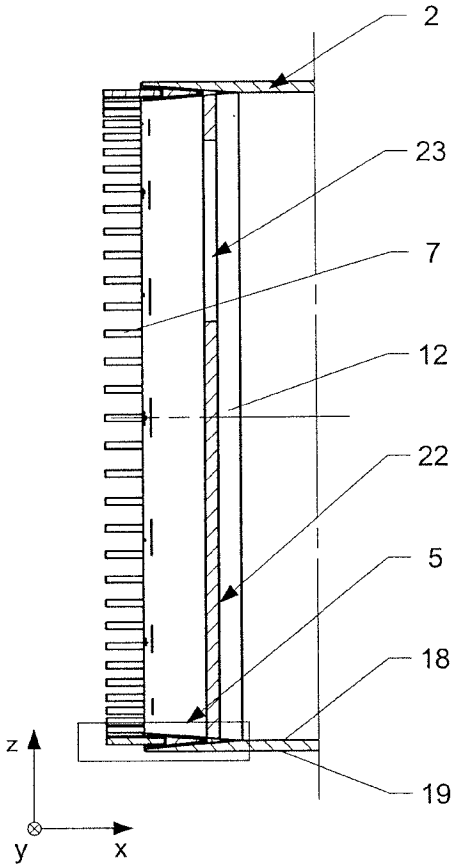

Fig. 8

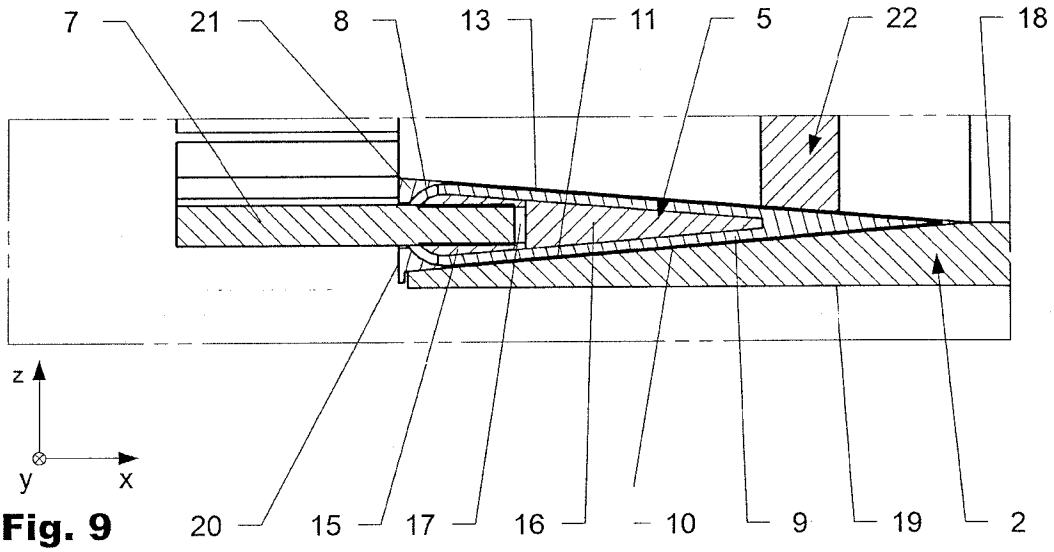

Fig. 9

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2018/078790

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, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2013/108464 A1 (MCEWEN LUKE NEIL [GB] ET AL) 2 May 2013 (2013-05-02) paragraphs [0001], [0074], [0075], [0077], [0080], [0082], [0114] figures 3-8,11,14	1-15
X	US 2017/002660 A1 (SAMUDRALA SRIKANTH [IN] ET AL) 5 January 2017 (2017-01-05) paragraphs [0001], [0041], [0043], [0045], [0047], [0048] figures 4-6	1,2,6-15
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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
25 January 2019	06/02/2019

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

International application No
PCT/EP2018/078790

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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Information on patent family members

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