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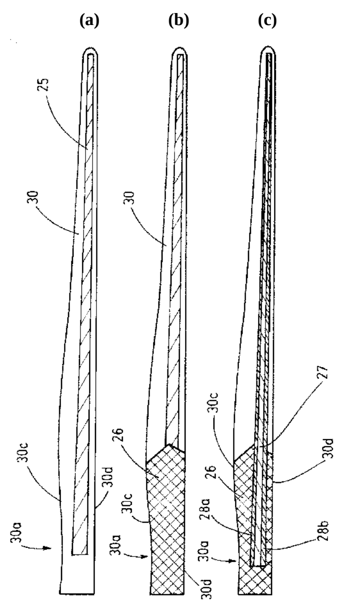
[Continued on next page]

(54) **Title:** METHOD OF MANUFACTURING A WIND TURBINE BLADE AND A WIND TURBINE BLADE

[Fig. 3]



(57) Abstract: The disclosure relates to a method for manufacturing a wind turbine blade, comprising the steps of pre-manufacturing a first blade member, wherein pre-manufacturing the first blade member comprises bonding at least two structural members of the wind turbine blade, positioning said pre-manufactured first blade member in a joining mold and bonding said first blade member with a second blade member using a vacuum assisted infusion process so as to form an integrated blade part wherein said integrated blade part comprises a root reinforcement member. In another aspect the disclosure relates to a wind turbine blade manufactured by a method comprising the steps of pre-manufacturing a first blade member, wherein pre-manufacturing the first blade member comprises bonding at least two structural members of the wind turbine blade, positioning said pre-manufactured first blade member in a joining mold, positioning a trailing edge member or a leading edge member in the joining mold, and using a vacuum-assisted infusion process to form an entire blade half shell of a suction side and a pressure side respectively, wherein the blade half shells comprise a root reinforcement member respectively, and optionally, bonding the blade half shell of the suction side and the blade half shell of the pressure side to form an entire blade.

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Description

Title of Invention: METHOD OF MANUFACTURING A WIND TURBINE BLADE AND A WIND TURBINE BLADE

Technical Field

[0001] The disclosure relates to a method of manufacturing a wind turbine blade. In a further aspect, the disclosure relates to a wind turbine blade produced by using a certain manufacturing method.

Background Art

[0002] Since the trend in wind turbine development has evolved towards an enlarged size of wind turbines, also the size of the wind turbine blades has increased to a large extent, especially concerning the blades of offshore wind turbines. As a consequence of this development, manufacturing wind turbine blades is an extremely difficult task whose importance has risen significantly during the recent years.

[0003] Due to their enormous size, wind turbine blades are not manufactured in one piece. Usually, two blade half shells are manufactured separately and subsequently bonded. It is also common to produce each blade half shell in several production steps out of several blade half shell parts. These parts are bonded in a joining mold to form an entire blade half shell. For bonding the different blade half shell parts, usually adhesives such as gluing paste are used. A disadvantage of applying adhesives is the fact that its distribution and bonding strength can hardly be controlled, resulting in a varying quality of the connection.

[0004] US 2009/0155084 A1 discloses a manufacturing method for a wind turbine blade which tries to overcome the above mentioned problem. The described method includes the assembly of a plurality of wind turbine blade segments in the longitudinal direction of the blade. Bonding the different wind turbine blade segments using an adhesive is done by providing a bonding grid which enhances the distribution of the adhesive. A disadvantage of this solution is the arrangement of the blade into several segments in the longitudinal direction as this restricts the use of strengthening elements extending in the longitudinal direction of the blade such as spar caps. Another disadvantage is that the above method is very cumbersome and therefore does not decrease the effort related to bonding blade segments by adhesives.

[0005] In US 2007/025 1090 A1 a method for fabricating a blade using a mold having the shape of at least a portion of the blade is disclosed wherein the method comprises stacking pre-fabricated components.

[0006] EP 2338 669 A1 relates to a method of producing a composite shell structure comprising a reinforced fiber material embedded in a cured resin, i.e. a cured polymer material.

Summary of Invention

[0007] It is an object of at least some embodiments of the present invention to provide an improved manufacturing method for wind turbine blades. It is a further object of at least some embodiments to provide a wind turbine blade which is produced by the enhanced manufacturing method.

[0008] According to embodiments of the present invention, the method of manufacturing a wind turbine blade comprises the steps of pre-manufacturing a first blade member in a mold. The term "pre-manufacturing" signifies in the context of the present application that the first blade member is at least partly pre-fabricated so that the first blade member is at least partly manufactured in advance before it is bonded to a second blade member. In some embodiments, pre-manufacturing refers to pre-fabricating the entire first blade member. Pre-manufacturing the first blade member comprises the step of bonding at least two structural members of the wind turbine blade with each other. Generally, the term "structural member" does not refer to insignificant small components of the blade, such as single fibers. The term rather relates to members having a considerable contribution to the structure and/or functions of the wind turbine blade. The structural members can, for example, comprise a spar cap, a core member, a root reinforcement member and/or a metal mesh member or a metal foil member. The structural members can be pre-manufactured before bonding them to each other in order to form the first pre-manufactured blade member. Alternatively, the structural members comprise blade building material and are formed during the bonding process. Bonding refers to any method of connecting the at least two structural members. In some embodiments, a vacuum-assisted infusion process is applied for bonding the at least two structural members.

[0009] The pre-manufactured first blade member is placed in a joining mold and bonded to a second blade member using a vacuum assisted infusion process to form an integrated part of the blade. The joining mold can either be the same mold in which the first blade member was pre-manufactured or a different mold. The integrated part of the blade comprises a root reinforcement member. This root reinforcement member can either be already incorporated in the first pre-manufactured blade member or be comprised in the second blade member. The root reinforcement member reinforces the blade to be manufactured in its root portion by providing structural strength. This is important since the blade is mounted to the hub in this region, which is thus exposed to high loads. In some embodiments, the root reinforcement member extends continuously from one transverse end of the blade to be manufactured to the other transverse end, i.e. from the trailing edge of the blade to be manufactured to the leading edge along the entire width of the blade, so that it covers the entire root portion of the blade to be manufactured.

[0010] In an embodiment, the pre-manufactured first blade member is positioned in the center of the joining mold and extends along substantially the entire length of the blade to be manufactured. According to an embodiment, the pre-manufactured first blade member comprises a spar cap. A spar cap is the main structural member of the blade carrying its weight and the loads acting on it. In some embodiments, the spar cap comprises composite material wherein at least the substantial part of the fibers run in the longitudinal direction of the blade, in other embodiments all of its fibers run along the longitudinal direction of the blade. Furthermore, the spar cap extends along substantially the entire length of the blade in some embodiments of the invention. The spar cap is integrated in the shell of the blade and is not disposed outside of the blade shell. In a further embodiment of the invention, the pre-manufactured first blade member comprises two spar caps. In an embodiment of the invention, the spar cap is pre-manufactured. Alternatively, the spar cap comprises blade building material which refers to any "dry" material, meaning material which has not been infiltrated with bonding means before. In some embodiments, the spar cap comprises composite material in which the substantial part of the fibers runs in the longitudinal direction of the blade. Such material could comprise unidirectional composite material or roving composite material.

[0011] Pre-manufacturing the first blade member can be done in one step by use of an infusion process or in several steps including pre-manufacturing the spar caps by infusion and connecting the spar caps and the shell structure by direct roving.

[0012] The bonding between the first and the second blade member is done using a vacuum assisted infusion process. The term "infusion process" relates to any bonding process including the step of infusing a bonding means for bonding. In some embodiments, the infusion process comprises only one single infusion step, i.e. one step at which an infusion is applied. The term "vacuum assisted" means that a vacuum is applied to the area in which the bonding means is infused. According to an embodiment, the vacuum is applied using a foil as a vacuum bag which is laid over the area to be infused allowing the creation of a vacuum. Once a vacuum is established, it ensures a uniform and controllable flow of the bonding means. Consequently, a good bonding quality can be achieved.

[0013] In some embodiments, the method comprises the steps of curing the pre-manufactured first blade member, demolding it and transporting it to the joining mold in which it is bonded to a second blade member to form an integrated part of the blade member. In an embodiment of the invention, the integrated part of the blade is cured and bonded to other blade members, again using a vacuum assisted infusion process.

These steps are repeated, until a half shell of the blade or the entire blade is completed. In this context, curing can refer to pre-curing, after which a certain extent of rigidity has been achieved but the full strength has not been established yet, or post-curing, after which the full strength of the member has developed.

[0014] According to a further embodiment of the invention, pre-manufacturing the first blade member comprises positioning a first root reinforcement member in a root portion of a mold. The mold can either be the joining mold in which the first blade member is bonded to the second blade member or a separate mold for pre-manufacturing the first pre-manufactured blade member. If the pre-manufactured blade member is pre-manufactured in a separate mold, the time in which the joining mold is occupied is reduced significantly resulting in a higher output of the manufacturing method.

[0015] The first root reinforcement member can be pre-manufactured or can comprise blade building material. The blade building material can, for example, comprise fibers, balsa, woven or stitched fabrics, monolithic structured composites, sandwich-type structured composites or sandwich cores. The term "sandwich-type structured composite" signifies a composite material which comprises two thin but stiff outer skins and a lightweight thick sandwich core being disposed between the skins. Even though the sandwich core normally exhibits low strength, its thickness provides the sandwich type structure with high bending stiffness and low overall weight.

[0016] According to some embodiments, the first root reinforcement member reinforces the root portion of the blade to be manufactured. For this purpose, the first root reinforcement member comprises composite material comprising fibers in embodiments of the invention, wherein the substantial part of the fibers further run in the longitudinal direction of the blade in some of these embodiments. The term "root portion" of the mold refers to a region of the mold in which the root portion of the blade is manufactured.

[0017] Pre-manufacturing the first blade member further comprises the step of positioning at least one core member in the mold. The core member can be pre-manufactured or can be composed of blade building material. In embodiments of the invention, the core member comprises composite material, in some embodiments a monolithic structured composite or a sandwich-type structured composite.

[0018] Furthermore, pre-manufacturing the first blade member comprises positioning at least one spar cap in the mold and using a vacuum assisted infusion process to form the first pre-manufactured blade member. According to an embodiment of the invention, the above steps are conducted consecutively in the above order. In some embodiments, pre-manufacturing the first pre-manufactured blade member comprises only one vacuum assisted infusion process which makes the pre-manufacturing process very time and cost efficient.

[0019] In a further embodiment of the invention, pre-manufacturing the first blade member additionally comprises positioning at least one metal foil member or metal mesh member in the mold. The term "metal foil member of metal mesh member" refers to any metal foil or metal mesh being disposed in the blade, said metal foil or metal mesh members further being components of a blade lightning protection system in some embodiments. In an embodiment, the metal foil member or metal mesh member are positioned in the mold before the first root reinforcement member is positioned in it so that the metal foil member or metal mesh member is disposed radially behind the first root reinforcement member in the root portion of the mold. In some embodiments, the metal foil is located in close proximity to the outer surface of the blade so that it can directly function as a lightning receptor. In some embodiments the metal foil is only separated from the outer surface of the blade by a thin protection layer. In a further embodiment, the metal foil extends from the tip end area to the root end area of the blade so that it can function as a down conductor along the entire length of the blade. As the metal foil extends along the longitudinal direction of the blade, it can conduct the current of a lightning strike to the root end area of the blade independently of the position of the lightning strike. Incorporating the metal foil member or metal mesh member already while manufacturing the blade ensures an optimal integration of at least parts of a blade lightning protection system into the blade to be manufactured.

[0020] According to a further embodiment of the invention, the second blade member comprises a trailing edge member or a leading edge member. The trailing edge member or the leading edge member can be pre-manufactured or they can comprise blade building material. The leading edge member is positioned next to the leading edge side of the first pre-manufactured blade member in some embodiments, while the trailing edge member is disposed next to the trailing edge side of first pre-manufactured blade member in some embodiments. In an embodiment, the leading edge member or the trailing edge member extend from the leading edge side or the trailing edge side of the first pre-manufactured blade member continuously until the end of the mold in transverse direction of the blade respectively.

[0021] According to some embodiments, the trailing edge member or the leading edge member comprise a trailing edge reinforcement member and a leading edge reinforcement member respectively. The function of these reinforcement members is to increase the structural strength of the trailing edge member or the leading edge member, in some embodiments in the region in which a manufactured blade half shell is connected to another manufactured blade half shell. For this purpose, the leading edge reinforcement member is disposed in a region proximate to the leading edge side of the leading edge member in some embodiments, whereas the trailing edge reinforcement member is disposed in a region proximate to the trailing edge side of the trailing edge member in some embodiments. In an embodiment of the invention, the leading edge reinforcement member and the trailing edge reinforcement member form the leading edge side or the trailing edge side of the leading edge member or the trailing edge member respectively.

[0022] The leading edge reinforcement member and the trailing edge reinforcement member comprise composite material in some embodiments in which the substantial part of the fibers extends along the longitudinal direction of the trailing edge reinforcement member or the leading edge reinforcement member. According to a further embodiment, the leading edge reinforcement member and the trailing edge reinforcement member comprise unidirectional composite material or roving composite material.

[0023] In an embodiment of the invention, the second blade member comprises a second root reinforcement member. This second root reinforcement member can be pre-manufactured or can comprise blade building material. For supporting the root region of the blade to be produced the second root reinforcement member comprises composite material in an aspect of the invention. The fibers extend substantially along the longitudinal direction of the blade in some embodiments. In a further embodiment of the invention, the length of the second root reinforcement member in longitudinal direction of the blade corresponds to the length of the first root reinforcement member in the same direction.

[0024] In an aspect of the invention, the second root reinforcement member and the first root reinforcement member are arranged at a distance to each other for at least a part of the length of the root reinforcement members in longitudinal direction of the blade in which the first root reinforcement member and the second root reinforcement member consequently do not have contact to each other. In some embodiments, the first root reinforcement member and the second root reinforcement member are arranged at a distance to each other for at least 30 percent, in other embodiments for at least 50 percent, in even other embodiments for at least 75 percent, of the length of the root reinforcement members.

[0025] According to an embodiment, the manufacturing method further comprises positioning a trailing edge member or a leading edge member in the joining mold. The leading edge member is positioned next to the leading edge side of the first pre-manufactured blade member in some embodiments, while the trailing edge member is positioned next to the trailing edge side of the first pre-manufactured blade member in some embodiments.

[0026] The manufacturing method further comprises the steps of positioning a second root reinforcement member in a root portion of the joining mold and using a vacuum-assisted infusion process to form an entire blade half shell of a blade suction side or a blade pressure side respectively. In an embodiment, bonding the first pre-manufactured blade member with the other blade members necessitates only one vacuum assisted infusion process in order to manufacture a complete blade half shell of a suction side or a pressure side of the blade. Applying only one infusion process, i.e. only one single infusion step in which an infusion is applied, in the joining mold for manufacturing the entire blade half shell reduces the time in which the joining mold is occupied significantly and thus ensures a more cost and time efficient manufacturing process. Optionally, the blade half shell of the suction side and the blade half shell of the pressure side are bonded to form an entire blade. Bonding the blade half shells is achieved by means of bonding paste in some embodiments.

[0027] According to an embodiment of the invention, the second root reinforcement member, the trailing edge member or the leading edge member comprises a composite material having a first section with fibers. In a further embodiment, the fibers of the first section are substantially arranged in at least two preferred directions. Due to the arrangement along the preferred directions, the first section exhibits a great strength along these preferred directions. In some embodiments, the second root reinforcement member, the trailing edge member or the leading edge member comprises two sections with fibers, namely a first section and a second section, of which the first section comprises fibers running in two preferred directions while the second section comprises fibers running in three preferred directions.

[0028] According to an embodiment of the invention, a protection layer is positioned in the joining mold. In some embodiments, this protection layer is positioned in the joining mold before positioning any other member so that the protection layer is arranged in direct contact with the joining mold. In an embodiment, the protection layer is positioned in the entire joining mold so that the inner surface of the joining mold is completely covered by the protection layer. After manufacturing the blade, the protection layer thus forms the entire outer surface of the blade to be manufactured and protects it from outer influences. In some embodiments, the protection layer comprises a thin glass fleece layer or a gel coat layer.

[0029] In an embodiment of the invention, at least one shear web is pre-manufactured and bonded to the pre-manufactured first blade member. In some embodiments, bonding the at least one shear web with the manufactured first blade member is achieved by using bonding paste.

[0030] In some embodiments, the pre-manufactured first blade member comprises an integrated bonding flange for the connection to other blade members. In an alternative embodiment, the second blade member comprises at least one bonding flange for the connection to the pre-manufactured first blade member. In some embodiment, the first blade member can comprise one bonding flange on each of its longitudinal sides, the trailing edge side and the leading edge side, respectively. According to an embodiment, the bonding flanges extend along the whole length of the leading edge side and trailing edge side of the first blade member. In some embodiments, the end faces of the pre-manufactured first blade member also comprise bonding flanges. In an embodiment, the bonding flange comprises a peel ply as a thin protective layer which is removed before the infusion process in order to ensure a good surface quality for the connection to another blade member.

[0031] In a further embodiment of the invention, the second blade member comprises blade building material which is positioned in the joining mold overlapping the first blade member, in some embodiments its bonding flange. A vacuum is applied to the blade building material which is infused by bonding means, therefore infiltrating the blade building material with the bonding means. The second blade member is therefore formed during the bonding process to the first blade member. In an embodiment of the invention, bonding means comprise epoxy resin. In a further embodiment, heat is applied to the integrated part for curing the bonding means. This can be achieved by use of an integrated heating system.

[0032] In an embodiment of the invention, a complete half shell of the blade is manufactured by applying the above method to each one of the bonding flanges on the trailing edge side and the leading edge side of the pre-manufactured first blade member, respectively. This is done by filling the joining mold along its transverse direction and bonding the blade material to the pre-manufactured first blade member until an entire blade half shell is produced.

[0033] In an alternative embodiment, the second blade member is also pre-manufactured. The pre-manufactured second blade member is placed next to the pre-manufactured first blade member in such a way that an interspace, a bonding gap, between the two blade members exists. The second blade member can be placed next to the pre-manufactured first blade member in cross direction or in longitudinal direction of the blade to be manufactured. The second blade member can also be positioned on top of the pre-manufactured first blade member. A vacuum is applied to the bonding gap, in some embodiments by using a vacuum bag such as a plastic foil which enables an air tight seal so that a vacuum can be applied. Subsequently, the bonding gap is infused with bonding means, in some embodiments epoxy resin, which after curing will establish the connection. Compared to using gluing paste, the use of epoxy resin in combination with a vacuum assisted infusion process is advantageous as it allows a better control of bonding gap thickness and bonding quality. According to an embodiment of the invention, a flow medium is inserted in the bonding gap for allowing an even more improved flow of the bonding means. The flow medium can be a distribution means and is structured, such as e.g. a mat, in some embodiments which provides passageways for the bonding means for a continuous and controllable flow. In an embodiment, the bonding gap is filled with some suitable sort of "dry" material, this "dry" material comprising fabric or textile material in some embodiments, which will act as a flow medium for the bonding means. In a further embodiment, heat is applied to the integrated part for curing the bonding means, in some embodiments by means of an integrated heating system.

[0034] In an embodiment, the above process is repeated until a half shell of a blade or an entire blade is manufactured. In some embodiments, the above method comprises the steps of curing the second pre-manufactured blade member, demolding it and transporting it to the joining mold. These steps can be repeated, until all remanufactured blade members are completed.

[0035] According to an embodiment of the invention, the first pre-manufactured blade member is enveloped with a covering member comprising composite material. Enveloping signifies completely enclosing the first pre-manufactured blade member. The covering member can either consist of only one part enclosing the first pre-manufactured blade member entirely or it can be composed of several parts which together envelope the first pre-manufactured blade member. In some embodiments, the fibers of the composite material of the covering member substantially run in at least two preferred directions, in some embodiments in two preferred directions or in other embodiments in three preferred directions. In an embodiment, a first part of the covering member is positioned in the mold. On top of this first part of the covering member, the first pre-manufactured blade member is positioned. After this, a second part of the covering member is positioned next to and on top of the first pre-manufactured blade member in such a way that together with the first part of the covering member it envelops the first pre-manufactured blade member completely.

[0036] In another aspect of the invention, a wind turbine blade manufactured by using a method comprising the following steps is provided: First, a blade member is pre-manufactured in a mold wherein pre-manufacturing the first blade member comprises bonding at least two structural members of the wind turbine blade. In some embodiments, pre-manufacturing the first blade member comprises the steps of positioning a first root reinforcement member in a root portion of the mold, positioning at least one core member in the mold, positioning at least one spar cap in the mold and using a vacuum-assisted infusion process to form the first pre-manufactured blade member. Pre-manufacturing the first blade member additionally comprises the step of positioning at least one metal foil member or metal mesh member in the mold in an embodiment.

[0037] The pre-manufactured first blade member is positioned in a joining mold. The joining mold can be the same mold in which the first blade member was pre-manufactured or a different mold. A trailing edge member or a leading edge member is positioned in the joining mold and a vacuum-assisted infusion process is used to form an entire blade half shell of a suction side or a pressure side respectively wherein the blade half shells each comprise a root reinforcement member. Consecutively, the blade half shell of the suction side and the blade half shell of the pressure side can optionally be bonded to form an entire blade. In some embodiments, the method further comprises positioning a second root reinforcement member in a root portion of the joining mold.

Brief Description of Drawings

[0038] Embodiments of the present invention will be described below with reference to the following figures which show in schematic representation

[fig. 1]Figure 1 is a cross sectional view of a pre-manufactured first blade member and blade building material in a joining mold in the area of the middle portion of a blade;

[fig.2]Figure 2 is a cross sectional view of a pre-manufactured first blade member, second blade members in a joining mold in the area of the middle portion of a blade;

[fig.3]Figures 3(a) to 3(c) are front views of a mold at different first blade member pre-manufacturing stages;

[fig.4]Figure 4 is a longitudinal sectional view of a part of a blade half shell; and

[fig.5]Figures 5(a) to 5(c) are cross sectional views of a joining mold and a blade half shell along the lines A-A, B-B and C-C of figure 4.

Description of Embodiments

[0039] Figure 1 shows a cross sectional view of a pre-manufactured first blade member 11, second blade members 21a and 21b and of a section of a joining mold 12. The joining mold 12 comprises a shaped cavity which is utilized to give an intended form to a blade member or blade half shell to be manufactured. The pre-manufactured first blade member 11 comprises two spar caps 28a, 28b which are connected to each other via a sandwich structure 15 consisting of a light weighted core surrounded by fiber re-inforced material. Furthermore, the pre-manufactured first blade member 11 comprises two bonding flanges, namely one bonding flange 16 at the trailing edge side and one bonding flange 17 at the leading edge side of the pre-manufactured first blade member 11. The bonding flanges 16, 17 extend continuously along the longitudinal direction of the pre-manufactured first blade member 11. The bonding flanges 16, 17 comprise a first part 16a, 17a which is arranged adjoining the joining mold 12 and one spar cap 28a, 28b, respectively. Furthermore, the bonding flanges 16, 17 comprise a second part 16b, 17b which is formed integrally with the first part 16a, 17a. The second parts 16b, 17b are formed as a flat extension adjoining the joining mold 12. The bonding flanges 16, 17 together amount to about 30 to 50 percent of the width of the pre-manufactured first blade member 11 in cross direction. After positioning the pre-manufactured first blade member, it is bonded with two shear webs 18, 19 which form second blade members using bonding paste. For this purpose, one shear web 18, 19 is positioned on the inner side of one spar cap 28a, 28b of the pre-manufactured first blade member 11, respectively.

[0040] The second blade members 21a, 21b are comprised of blade building material placed next to the pre-manufactured first blade member 11 on each of its longitudinal sides respectively. The blade building material 21a, 21b is positioned along the longitudinal sides of the pre-manufactured first blade member 11 in such a way that it overlaps with the second parts 16b, 17b of the bonding flanges 16, 17 of the pre-manufactured first blade member 11. The pre-manufactured first blade member 11 and the blade building material 21a, 21b are bonded using a vacuum assisted infusion process respectively by applying a vacuum to the blade building material 21a, 21b and infusing it with bonding means. As a result, two other blade members are formed during the two bonding processes. By means of the bonding processes, an entire blade half shell 22 is produced.

[0041] Figure 2 shows a cross sectional view of a pre-manufactured first blade member 11 comprising two spar caps 28a, 28b in a joining mold 12 in the area of the middle portion of the blade half shell to be manufactured. The pre-manufactured first blade member 11 comprises a bonding flange 16 at the trailing edge side and a bonding flange 17 at its leading edge side. Next to the bonding flange 16 at the trailing edge side a pre-manufactured trailing edge member 23 is placed which comprises a mating flange 23a which corresponds to the bonding flange 16 of the pre-manufactured first blade member 11. At the bonding flange 17 at the leading edge side of the pre-manufactured first blade member 11 a pre-manufactured leading edge member 24 is positioned which also comprises a mating flange 24a corresponding to the bonding flange 17 of the pre-manufactured first blade member 11. The leading edge member 24 comprises a leading edge reinforcement member 24b at its trailing edge side, while the trailing edge member 23 has a trailing edge reinforcement member 23b at its trailing edge side. The trailing edge reinforcement member 23b and the leading edge reinforcement member 24b are formed as unidirectional layers of composite material which form the surface of the trailing edge member 23 or leading edge member 24 at its trailing edge side or leading edge side respectively.

[0042] The pre-manufactured trailing edge member 23 and the pre-manufactured leading edge member 24 are bonded to the pre-manufactured first blade member 11 by means of using a vacuum assisted infusion process. After the bonding processes, an entire half shell 22 of a blade is produced.

[0043] In figures 3(a) to 3(c) front views of a mold 30 at different first blade member pre-manufacturing stages are shown. In figure 3(a) a metal foil member 25 is positioned in the center of the mold 30 along its longitudinal direction. The metal foil member 25 extends along substantially the entire length of the blade half shell to be manufactured. Only in a part of the root portion 30a of the mold 30 the metal foil member 25 is not arranged. In figure 3(b) a first root reinforcement member 26 is positioned on top of the metal foil member 25 in a root portion 30a of the mold 30. The first root reinforcement member 26 extends continuously from one transverse end 30c of the mold 30 to the other transverse end 30d of the mold 30 so that it covers the entire root portion 30a of the mold 30. Figure 3(c) shows one core member 27 and two spar caps 28a, 28b being disposed on top of the first root reinforcement member 26 and the metal foil member 25 which run almost along the entire length of the mold except for a part at the root portion 30a of the mold 30. After using a vacuum assisted infusion process, the first pre-manufactured blade member is manufactured.

[0044] In figure 4 a longitudinal sectional view of a part of a blade half shell 22 at its root end 22a is shown. A protection layer extends continuously from the first root end 22a of the blade half shell 22 towards the tip end of the blade half shell 22 which is not depicted in this figure. A metal foil member 25 extends from a first end 25c which is placed in a distance 41 from the root end 22a of the blade half shell 22 towards the tip end of the blade half shell 22. A first root reinforcement member 26 is disposed at the root end 22a of the blade half shell 22 extending from a first end 26a beyond the first end 25c of the metal foil member 25 to a second end 26b. The distance 40 from the second end 26b of the first root reinforcement member 26 to the root end 22a of the blade half shell 22 is larger than the distance 41 of the first end 25c of the metal foil member 25 to the root end 22a.

[0045] A spar cap 28 is disposed on top of the metal foil member 25 and the first root reinforcement member 26 extending from a first end 28c towards the tip end of the blade. The distance 42 of the first end 28c of the spar cap 28 to the root end 22a of the blade half shell 22 is smaller than the distance 41 of the first end 25c of the metal foil member 25 and smaller than the distance 40 of the second end 26b of the first root reinforcement member 26.

[0046] At last, a second root reinforcement member 29 is positioned on top of the first root reinforcement member 26 and the spar cap 28 extending from a first end 29a at the root end 22a of the blade half shell 22 to a second end 29b. The distance 43 of the second end 29b of the second root reinforcement member 29 to the root end 22a of the blade half shell 22 is as large as the distance 40 of the second end 26b of the first root reinforcement member 26 to the root end 22a of the blade half shell 22. The first root reinforcement member 26 and the second root reinforcement member 29 taper from their first ends 26a, 29a towards their second ends 26b, 29b. The spar cap 28 tapers in opposite direction towards its first end 28c. The metal foil member 25, the first root reinforcement member 26, the second root reinforcement member 29 and the spar cap 28 are arranged in such a way that they pile up in an interweaving way.

[0047] Figures 5(a) to 5(c) show cross sectional views of a joining mold 12 and a blade half shell 22 at the different positions along the length of the blade half shell 22, namely along the lines A-A, B-B and C-C which can be seen in figure 4. While figures 5(a) and 5(b) show cross sections of the joining mold 12 as well as the blade half shell 22 at two different positions in the root portion 12a of the joining mold 12, namely along the lines A-A and B-B, figure 5(c) displays the cross section of the blade half shell 22 and the joining mold 12 at a position in the middle portion of the joining mold 12 along the line C-C. In figures 5(a) to 5(c) a protection layer 31 is shown which covers the inner surface 12e of the joining mold 12 completely. On top of this protection layer 31 two metal foil members 25a, 25b are arranged which extend along substantially the entire length of the joining mold 12. A first root reinforcement member 26 is disposed on top of the metal foil members 25a, 25b extending along the entire root portion 12a of the joining mold 12. Three core members 27a, 27b, 27c and two spar caps 28a, 28b are disposed on top of the protection layer 31 and the first root reinforcement member 26 in the root portion 12a of the joining mold 12. The spar caps 28a, 28b are disposed directly on top of the metal foil members 25a, 26b in the root portion 12a or on top of the first root reinforcement member 26 in such a way that the metal foil members 25a, 25b are disposed radially behind the spar caps 28a, 28b.

[0048] The metal foil members 25a, 25b, the first root reinforcement member 26, the core members 27a, 27b, 27c and the spar caps 28a, 28b together form the first pre-manufactured blade member 11. A trailing edge member 23 and a leading edge member 24 are placed next to the first pre-manufactured blade member 11. A second root reinforcement member 29 is placed in a root portion 12a of the joining mold 12 on top of the first pre-manufactured blade member 11. The trailing edge member 23, the leading edge member 24 and the second root reinforcement member 29 are bonded to the first pre-manufactured blade member 11 by means of a vacuum assisted infusion process.

Claims

[Claim 1] A method for manufacturing a wind turbine blade, comprising the steps of:
pre-manufacturing a first blade member,
wherein pre-manufacturing the first blade member comprises bonding at least two structural members of the wind turbine blade,
positioning said pre-manufactured first blade member in a joining mold, and bonding said first blade member with a second blade member using a vacuum assisted infusion process so as to form an integrated blade part,
said integrated blade part comprising a root reinforcement member.

[Claim 2] The method according to claim 1, wherein pre-manufacturing the first blade member comprises the steps of:
positioning a first root reinforcement member in a root portion of a mold,
positioning at least one core member in the mold,
positioning at least one spar cap in the mold, and
using a vacuum-assisted infusion process to form the first pre-manufactured blade member.

[Claim 3] The method according to claim 2, wherein pre-manufacturing the first blade member additionally comprises the step of positioning at least one metal foil member or metal mesh member in the mold for forming the first pre-manufactured blade member.

[Claim 4] The method according to claim 1,
wherein the second blade member comprises a trailing edge member or a leading edge member.

[Claim 5] The method according to claim 1,
wherein the second blade member comprises a second root reinforcement member.

[Claim 6] The method according to claim 4,
wherein the trailing edge member and the leading edge member comprise fibers, and
wherein at least the substantial part of the fibers extends in the longitudinal direction of the blade.

[Claim 7] The method according to claim 1, comprising the steps of
positioning a trailing edge member or a leading edge member in the joining mold,

positioning a second root reinforcement member in a root portion of the joining mold, and
using a vacuum-assisted infusion process to form an entire blade half shell of a blade suction side or a blade pressure side respectively,
and optionally, bonding the blade half shell of the suction side and the blade half shell of the pressure side to form an entire blade.

[Claim 8] The method according to claim 7, wherein the second root reinforcement member, the trailing edge member or the leading edge member comprises a composite material, said composite material comprises a first section with fibers.

[Claim 9] The method according to claim 8, wherein the fibers of the first section are substantially arranged in at least two preferred directions.

[Claim 10] The method according to claim 1,
wherein a protection layer is positioned in the joining mold.

[Claim 11] The method according to claim 7, comprising the step of
pre-manufacturing at least one shear web, and
bonding the pre-manufactured first blade member with the pre-manufactured shear web.

[Claim 12] The method according to claim 1,
wherein the first blade member comprises a spar cap, and
wherein the spar cap comprises fibers and wherein at least the substantial part of the fibers extend in the longitudinal direction of the blade.

[Claim 13] The method according to claim 1,
wherein the first blade member comprises a bonding flange for bonding said first blade member to the second blade member.

[Claim 14] The method according to claim 1,
wherein the second blade member is made up of blade building material, comprising the steps of:
positioning said blade building material in the joining mold, wherein at least part of the blade building material overlaps the first blade member,
applying a vacuum to the blade building material, and
infusing the blade building material with bonding means.

[Claim 15] The method according to claim 1,
wherein the second blade member is pre-manufactured, comprising the steps of:
positioning said pre-manufactured second blade member next to the

first blade member in the joining mold such that an interspace in between them exists,
applying a vacuum to said interspace between the first blade member and the second blade member, and
infusing bonding means into the interspace.

[Claim 16] The method according to claim 1,
wherein the first pre-manufactured blade member is enveloped with a covering member, said covering member being composed of composite material.

[Claim 17] A wind turbine blade manufactured by a method comprising the steps of:
pre-manufacturing a first blade member,
wherein pre-manufacturing the first blade member comprises bonding at least two structural members of the wind turbine blade,
positioning said pre-manufactured first blade member in a joining mold,
positioning a trailing edge member or a leading edge member in the joining mold, and
using a vacuum-assisted infusion process to form an entire blade half shell of a suction side and a pressure side respectively,
said blade half shells comprising a root reinforcement member respectively,
and optionally, bonding the blade half shell of the suction side and the blade half shell of the pressure side to form an entire blade.

[Claim 18] The wind turbine blade according to claim 17 manufactured by a method further comprising the step of
positioning a second root reinforcement member in a root portion of the joining mold.

[Claim 19] The wind turbine blade according to claim 17, wherein pre-manufacturing the first blade member comprises the steps of:
positioning a first root reinforcement member in a root portion of the mold, positioning at least one core member in the mold,
positioning at least one spar cap in the mold, and
using a vacuum-assisted infusion process to form the first pre-manufactured blade member.

[Claim 20] The wind turbine blade according to claim 19, wherein pre-manufacturing the first blade member additionally comprises the step of positioning at least one metal foil member or metal mesh member in the mold for forming the first pre-manufactured blade member.

AMENDED CLAIMS

received by the International Bureau on 3 April 2013 (03.04.2013).

[Claim 1] (Currently amended) A method for manufacturing a wind turbine blade, comprising the steps of:

pre-manufacturing a first blade member,

wherein pre-manufacturing the first blade member comprises bonding at least two structural members of the wind turbine blade,

positioning said pre-manufactured first blade member in a joining mold, and bonding said first blade member with a second blade member using a vacuum assisted infusion process so as to form an integrated blade part,

said integrated blade part comprising a root reinforcement member, and

wherein pre-manufacturing the first blade member comprises the steps of:

positioning a first root reinforcement member in a root portion of a mold,

positioning at least one core member in the mold,

positioning at least one spar cap in the mold, and

using a vacuum- assisted infusion process to form the first pre-manufactured blade member.

[Claim 2] (Currently amended) The method according to claim 1, wherein:

in the step of positioning the first root reinforcement member, the first root reinforcement member is positioned to extend from a first end of the first root reinforcement member that is at a root end of the integrated blade part to a second end of the first root reinforcement member!

in the step of positioning the at least one spar cap, the at least one spar cap is positioned to extend from a first end of the at least one spar cap toward a tip end of the integrated blade part; and a distance from the root end to the first end of the at least one spar cap is smaller than a distance from the root end to the second end of the first root reinforcement member.

[Claim 3] The method according to claim 2, wherein pre-manufacturing the first blade member additionally comprises the step of positioning at least one metal foil member or metal mesh member in the mold for forming the first pre-manufactured blade member.

[Claim 4] The method according to claim 1,
wherein the second blade member comprises a trailing edge member or a leading edge member.

[Claim 5] The method according to claim 1,
wherein the second blade member comprises a second root reinforcement member.

[Claim 6] The method according to claim 4,
wherein the trailing edge member and the leading edge member comprise fibers, and
wherein at least the substantial part of the fibers extends in the longitudinal direction of the blade.

[Claim 7] The method according to claim 1, comprising the steps of
positioning a trailing edge member or a leading edge member in the joining mold,
positioning a second root reinforcement member in a root portion of the joining mold, and
using a vacuum-assisted infusion process to form an entire blade half shell of a blade suction side or a blade pressure side respectively,
and optionally, bonding the blade half shell of the suction side and the blade half shell of the pressure side to form an entire blade.

[Claim 8] The method according to claim 7, wherein the second root reinforcement member, the trailing edge member or the leading edge member comprises a composite material, said composite material comprises a first section with fibers.

[Claim 9] The method according to claim 8, wherein the fibers of the first section are substantially arranged in at least two preferred directions.

[Claim 10] The method according to claim 1,
wherein a protection layer is positioned in the joining mold.

[Claim 11] The method according to claim 7, comprising the step of
pre-manufacturing at least one shear web, and
bonding the pre-manufactured first blade member with the pre-manufactured shear web.

[Claim 12] The method according to claim 1,
wherein the first blade member comprises a spar cap, and
wherein the spar cap comprises fibers and wherein at least the substantial part of the fibers extend in the longitudinal direction of the blade.

[Claim 13] The method according to claim 1,
wherein the first blade member comprises a bonding flange for bonding said first blade member to the second blade member.

[Claim 14] The method according to claim 1,
wherein the second blade member is made up of blade building material, comprising the steps of:
positioning said blade building material in the joining mold, wherein at least part of the blade building material overlaps the first blade member,
applying a vacuum to the blade building material, and
infusing the blade building material with bonding means.

[Claim 15] The method according to claim 1,
wherein the second blade member is pre-manufactured, comprising the steps of-
positioning said pre-manufactured second blade member

next to the first blade member in the joining mold such that an interspace in between them exists,
applying a vacuum to said interspace between the first blade member and the second blade member, and
infusing bonding means into the interspace.

[Claim 16] The method according to claim 1,
wherein the first pre-manufactured blade member is enveloped with a covering member, said covering member being composed of composite material.

[Claim 17] (Currently amended) A wind turbine blade manufactured by a method comprising the steps of:
pre-manufacturing a first blade member,
wherein pre-manufacturing the first blade member comprises bonding at least two structural members of the wind turbine blade,
positioning said pre-manufactured first blade member in a joining mold,
positioning a trailing edge member or a leading edge member in the joining mold, and
using a vacuum-assisted infusion process to form an entire blade half shell of a suction side and a pressure side respectively,
said blade half shells comprising a root reinforcement member respectively,
and optionally, bonding the blade half shell of the suction side and the blade half shell of the pressure side to form an entire blade, and
wherein pre-manufacturing the first blade member comprises the steps of:
positioning a first root reinforcement member in a root portion of the mold, positioning at least one core member in the mold,

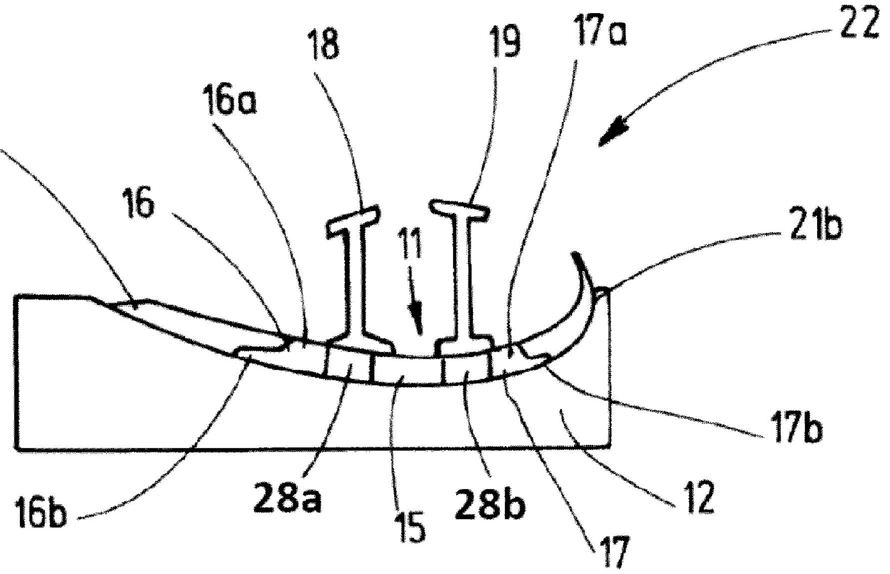
positioning at least one spar cap in the mold, and
using a vacuum-assisted infusion process to form the first pre-manufactured blade member.

[Claim 18] The wind turbine blade according to claim 17 manufactured by a method further comprising the step of
positioning a second root reinforcement member in a root portion of the joining mold.

[Claim 19] (Currently amended) The wind turbine blade according to claim 17, wherein:
the first root reinforcement member extends from a first end of the first root reinforcement member that is at a root end of the integrated blade part to a second end of the first root reinforcement member!
the at least one spar cap extends from a first end of the at least one spar cap toward a tip end of the integrated blade parti and
a distance from the root end to the first end of the at least one spar cap is smaller than a distance from the root end to the second end of the first root reinforcement member.

[Claim 20] The wind turbine blade according to claim 19, wherein pre-manufacturing the first blade member additionally comprises the step of positioning at least one metal foil member or metal mesh member in the mold for forming the first pre-manufactured blade member.

[Fig. 1]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17a
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16a
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21b
17b
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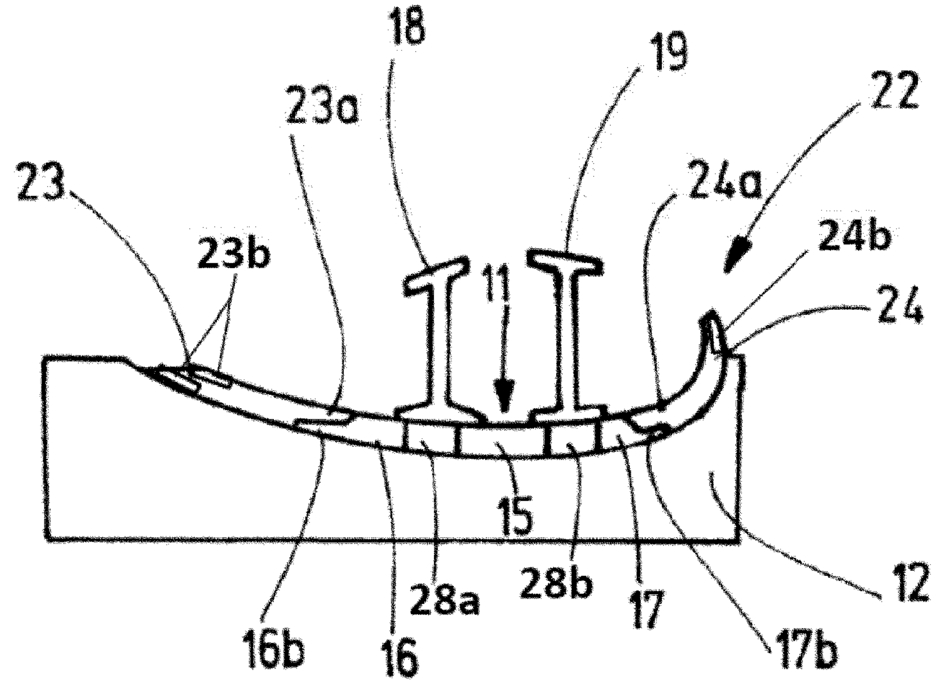
15
28b
12
17

[Fig. 2]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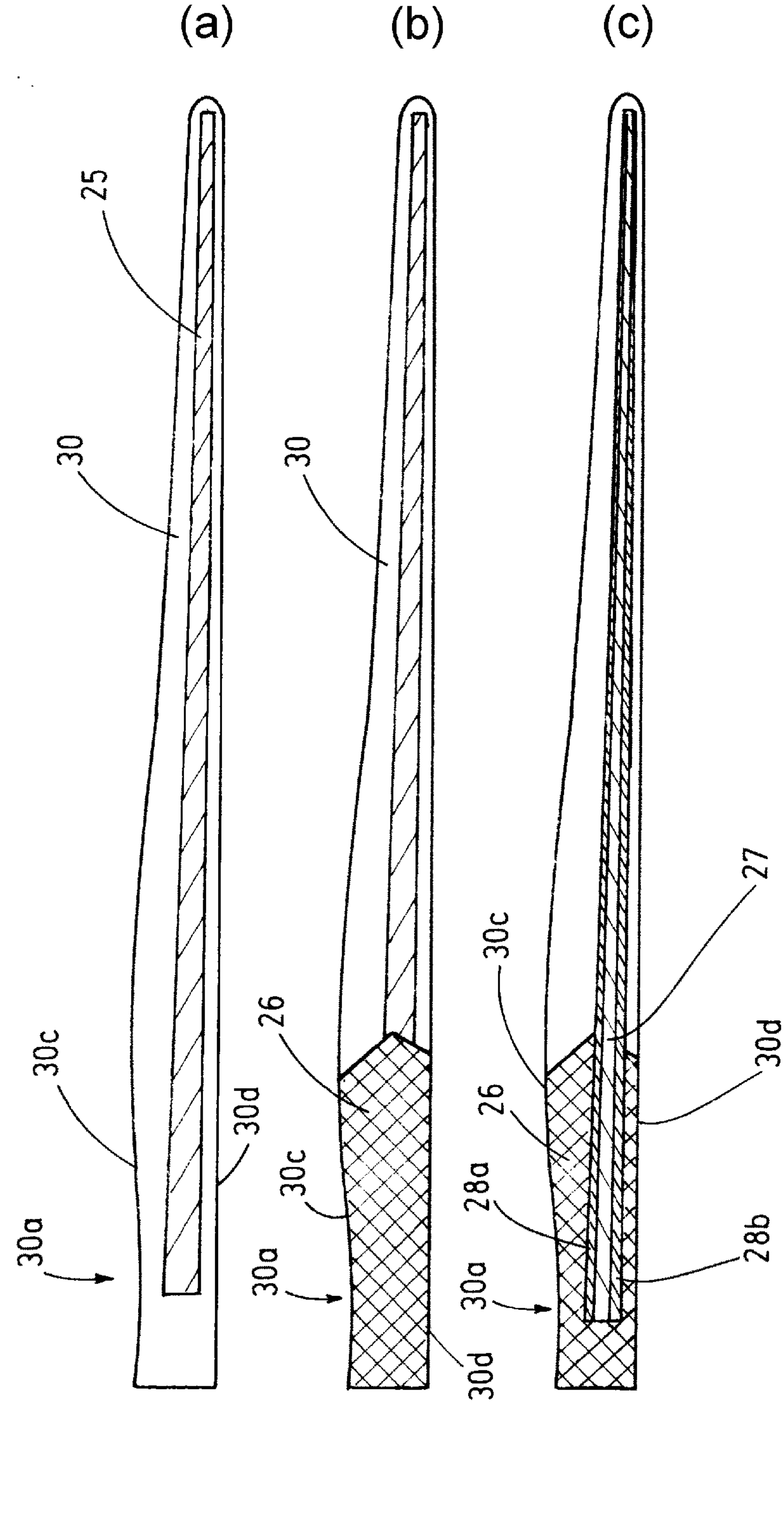
17b

[Fig. 3]


(a)
(b)
(c)
25
30
30
27
30c
26
30d
30c
30d
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30c
28a
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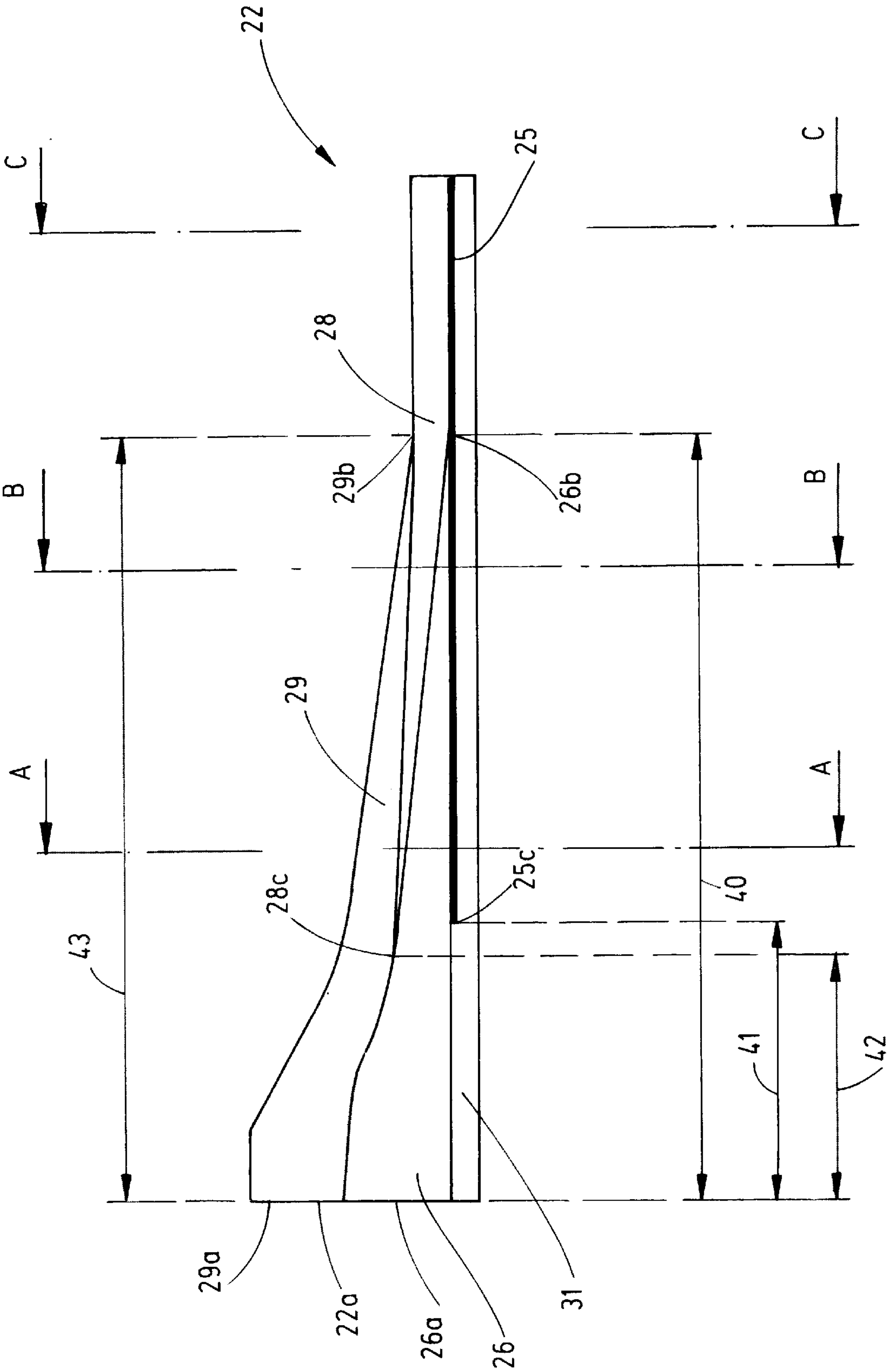
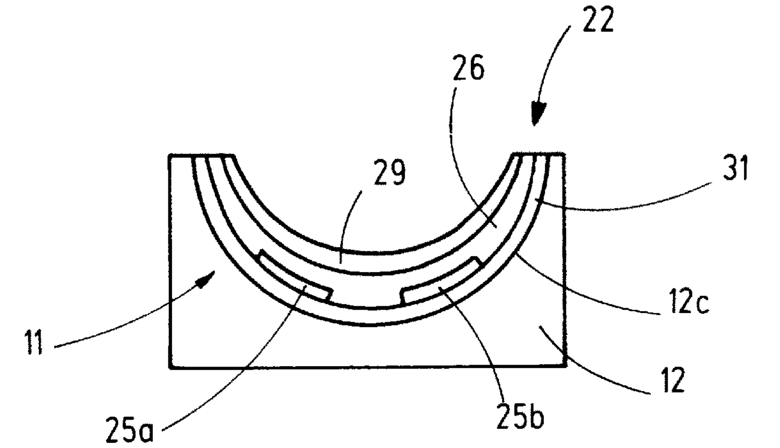
28b
30a
30a
30d

[Fig. 4]



[Fig. 5]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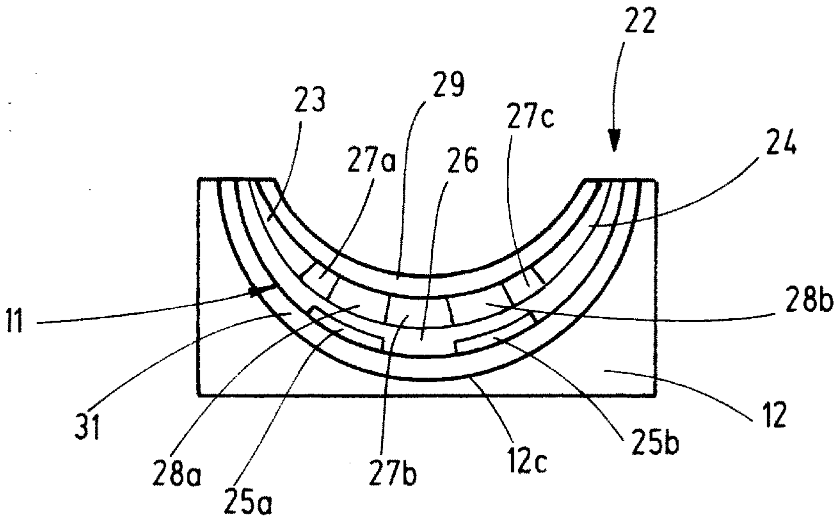
(a)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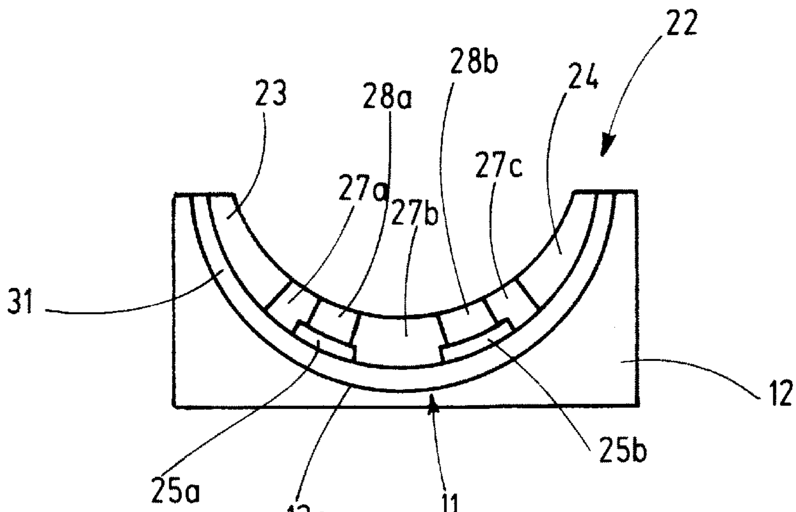
25b

(b)


22
28b
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28a
24
27c
27a
27b
31
12
25a
12c
11
25b

(c)

INTERNATIONAL SEARCH REPORT

International application No
PCT/JP2012/0O6045

A. CLASSIFICATION OF SUBJECT MATTER
INV. B29C70/44 F03D1/06 B29L31/08
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)
B29C B29L 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

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X Y	WO Q3/03538Q AI (CORIOLIS COMPOSITES [FR] ; HAMLYN ALEXANDRE [FR] ; HARDY YVAN [FR]) 1 May 2003 (2003-05-01) abstract page 6, 1ine 29 - page 9, line 6 page 10, line 18 - line 34 page 11, line 12 - page 12, line 2 page 13, line 33 - page 15, line 5 figures 1-4,9 ,10, 13, 14 -----	1,2,5 , 12-19 3,4, 6-11,20
X	US 7 364 407 B2 (GRABAU PETER [DK] ET AL) 29 April 2008 (2008-04-29) abstract figures 2,5,6 column 1, line 14 - line 25 column 6, line 24 - column 7, line 21 -----	1

-/- -

[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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"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

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"&" document member of the same patent family

Date of the actual completion of the international search

11 December 2012

Date of mailing of the international search report

17/12/2012

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Authorized officer

Lozza, Monica

INTERNATIONAL SEARCH REPORT

International application No
PCT/JP2012/0O6045

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	EP 2 255 957 Al (LM GLASFIBER AS [DK]) 1 December 2010 (2010-12-01) abstract paragraph [0047] - paragraph [0053] paragraph [0058] - paragraph [0062] figures 3-7, 10, 11 -----	3,4, 6-11,20

2

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
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			WO 03035380	Al	01-05-2003
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			CA 2479604	Al	25-09-2003
			CN 1643249	A	20-07-2005
			DK 200200425	A	20-09-2003
			EP 1485610	Al	15-12-2004
			PL 206772	Bl	30-09-2010
			US 2005180854	Al	18-08-2005
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			EP 2255957	Al	01-12-2010
			US 2012067515	Al	22-03-2012
			WO 2010136432	Al	02-12-2010