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(54) **WIND TURBINE BLADE WITH A LIGHTNING RECEPTOR**

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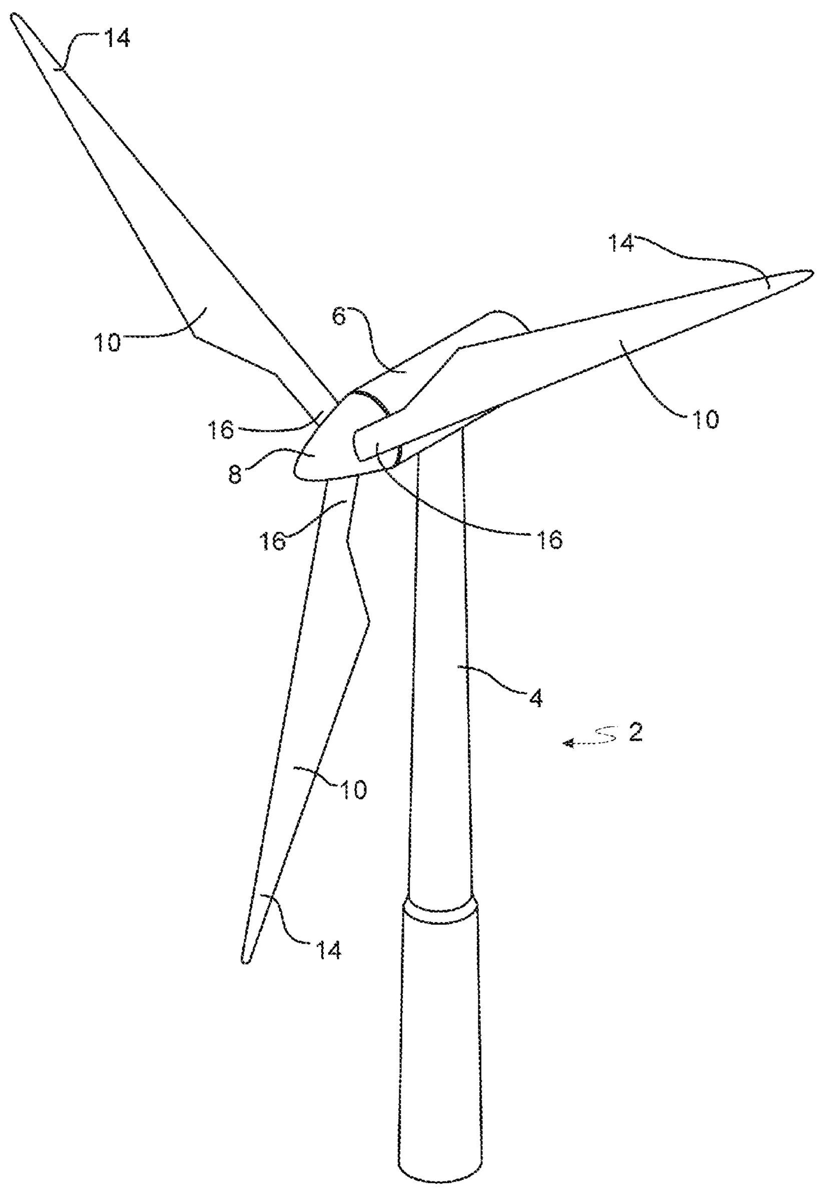
(57) **ABSTRACT**

The present invention provides a wind turbine blade shell part for a wind turbine blade, the blade shell part comprising: a structural element providing structural strength to the blade shell part and comprising carbon fibres embedded in a polymer matrix; a lightning receptor exposed at an outer surface of the blade shell part and extending towards the structural element; and an electrically conductive adhesive attaching the lightning receptor to the structural element. A method for manufacturing such a blade shell part is also provided.
(FIG. **8**C)



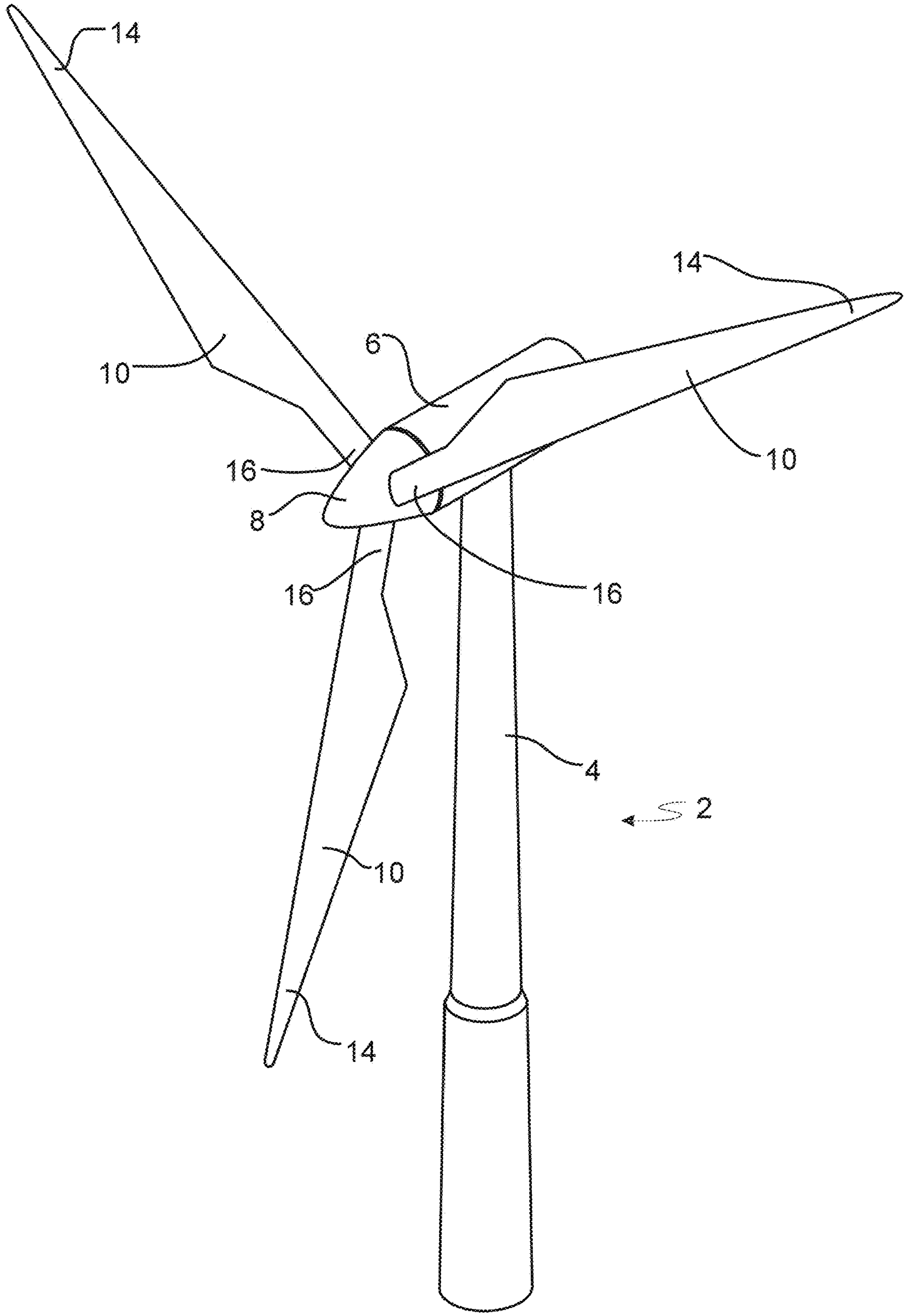


Fig. 1

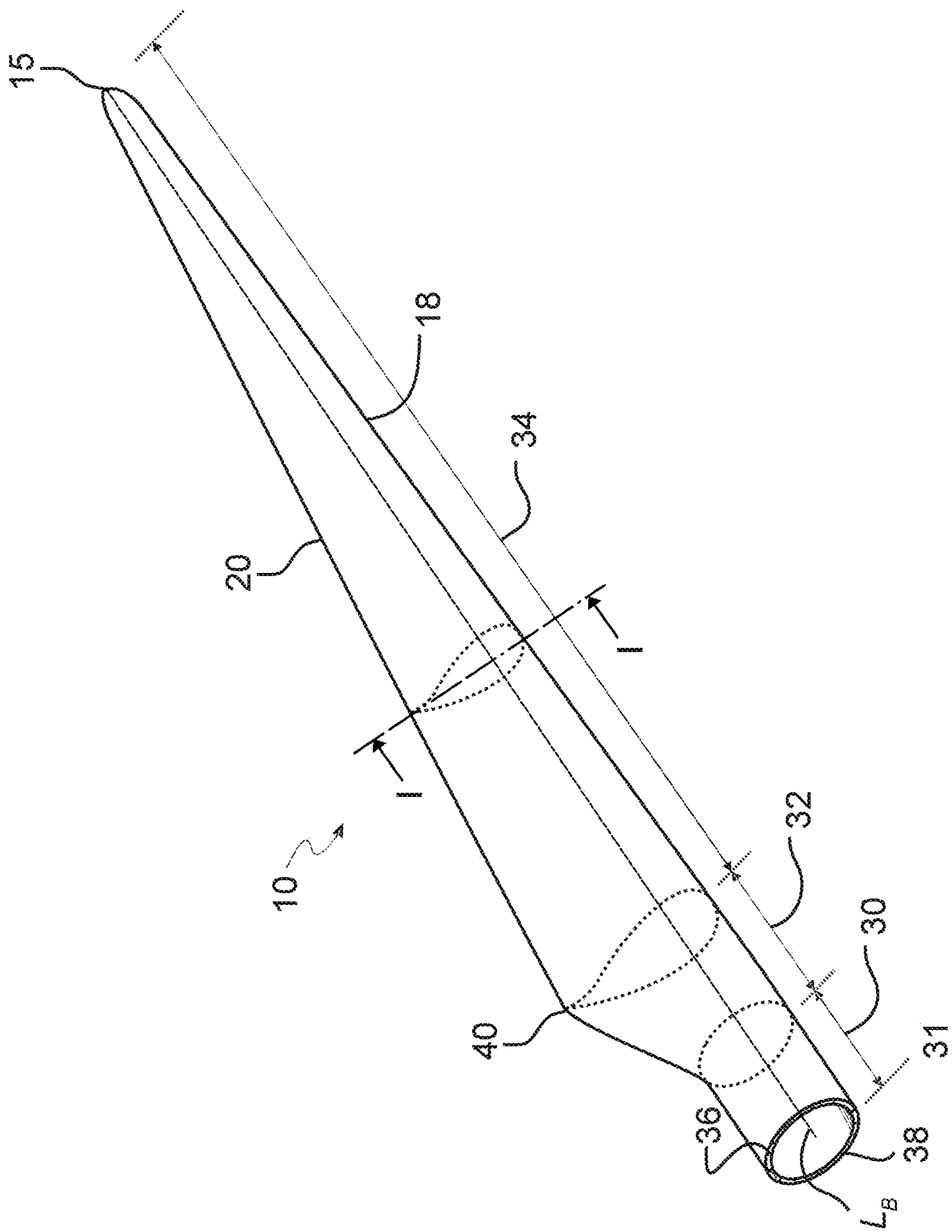


Fig. 2

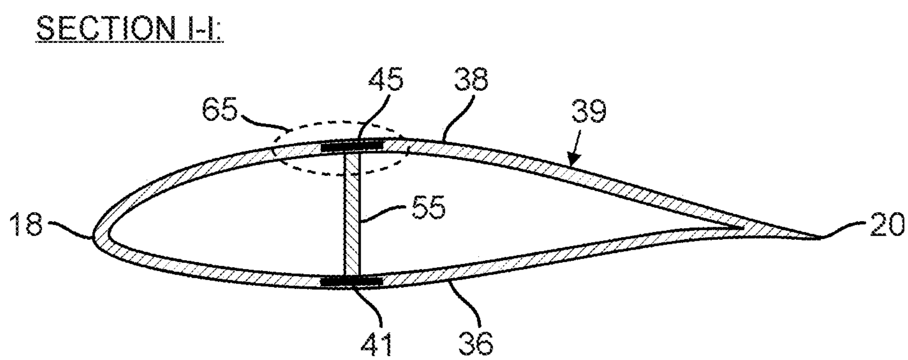


Fig. 3

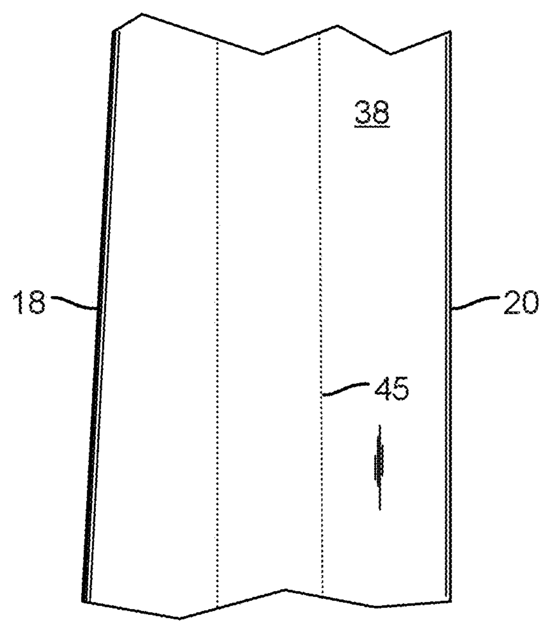


Fig. 4

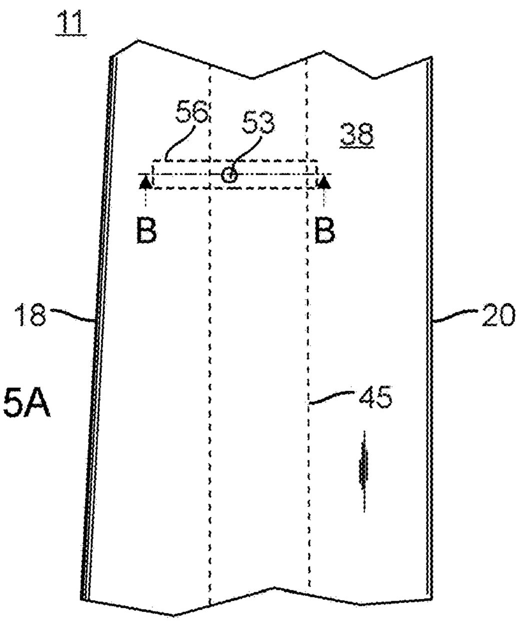


Fig. 5A

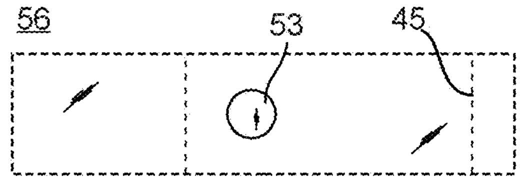


Fig. 5B

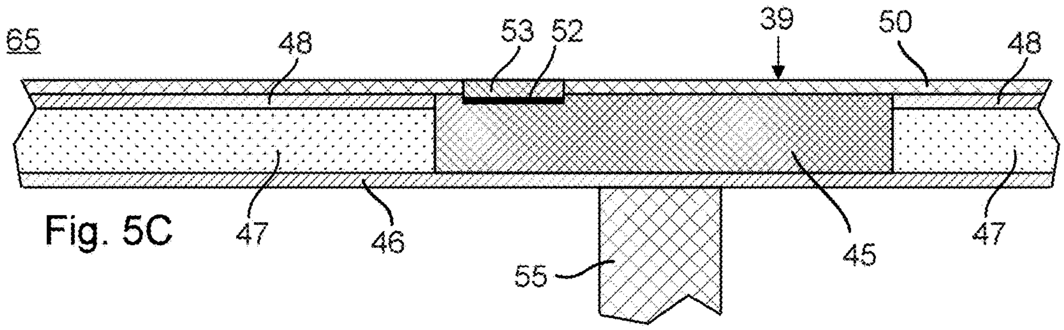


Fig. 5C

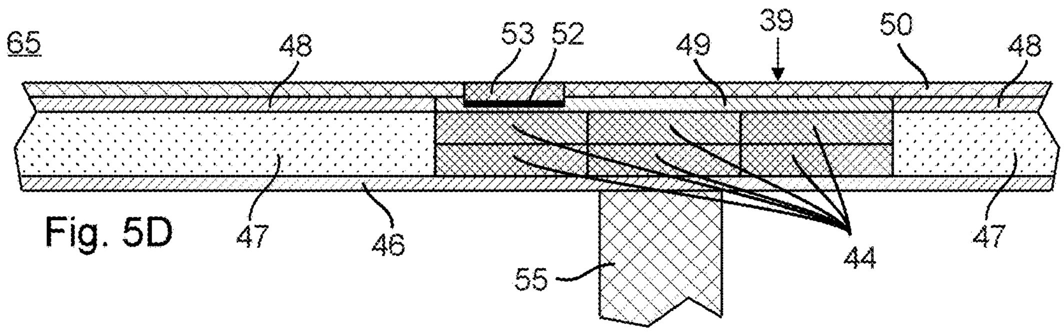


Fig. 5D

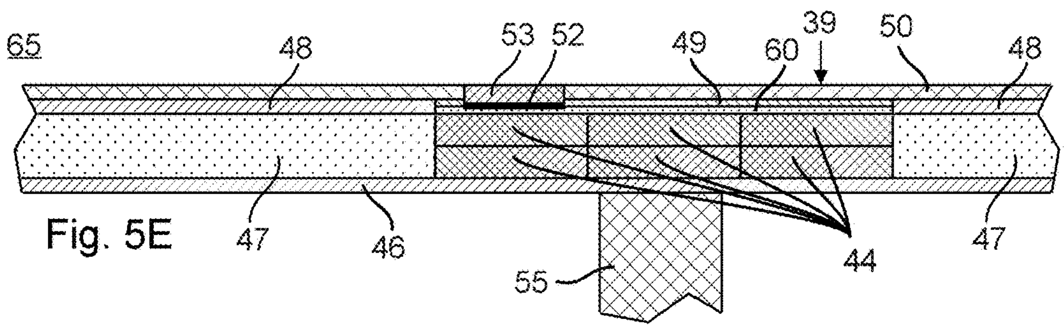


Fig. 5E

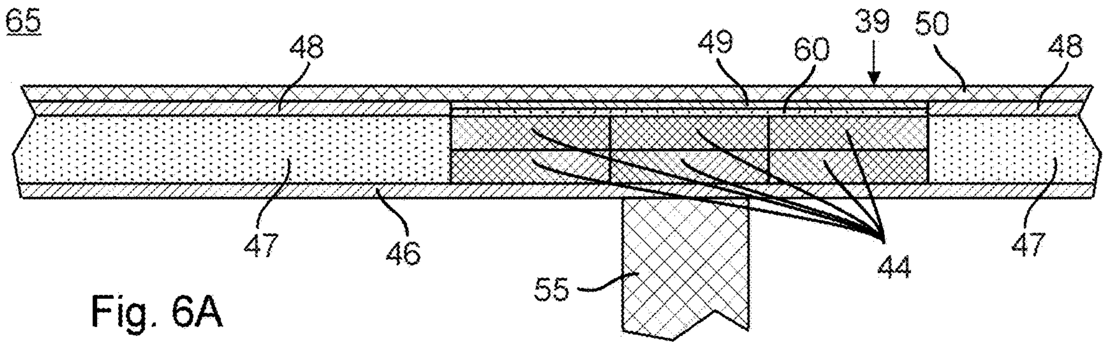


Fig. 6A

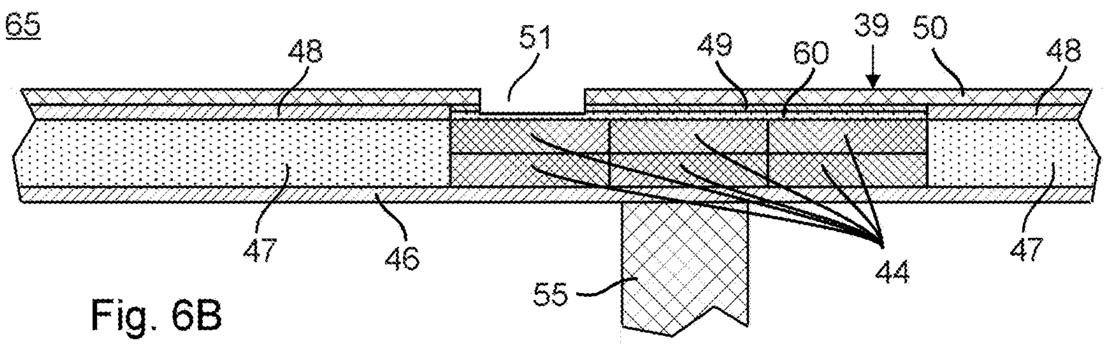


Fig. 6B

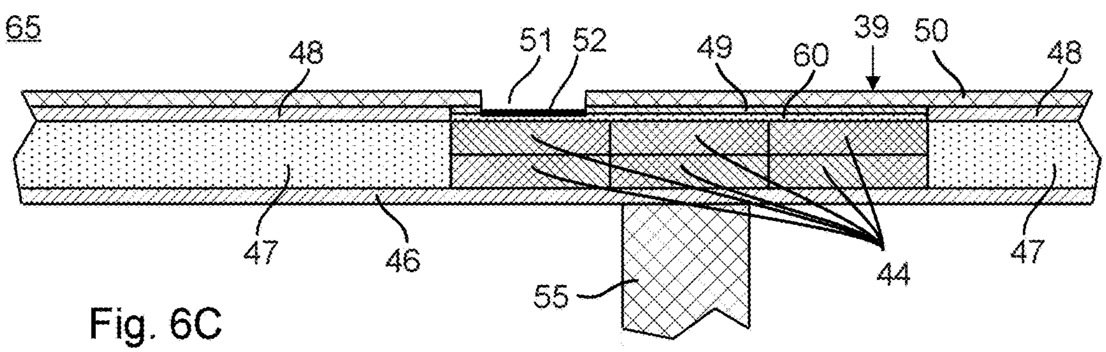


Fig. 6C

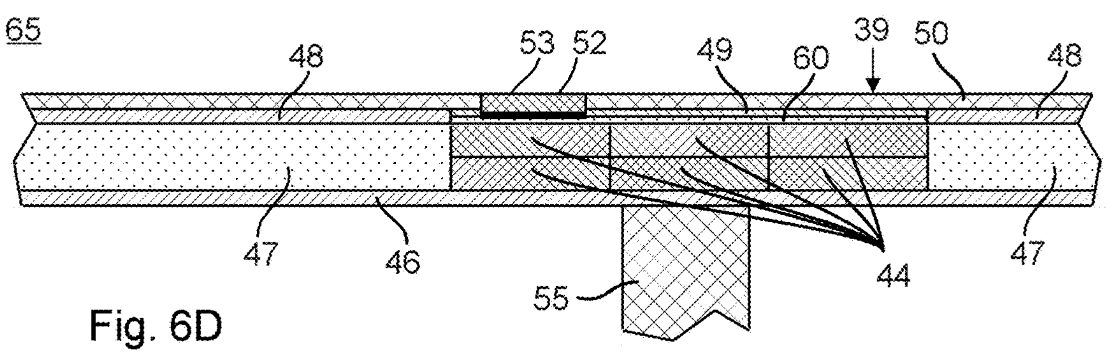


Fig. 6D

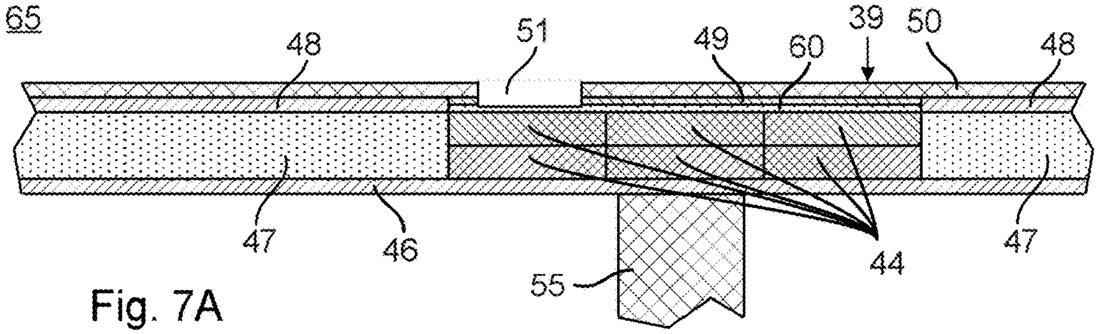


Fig. 7A

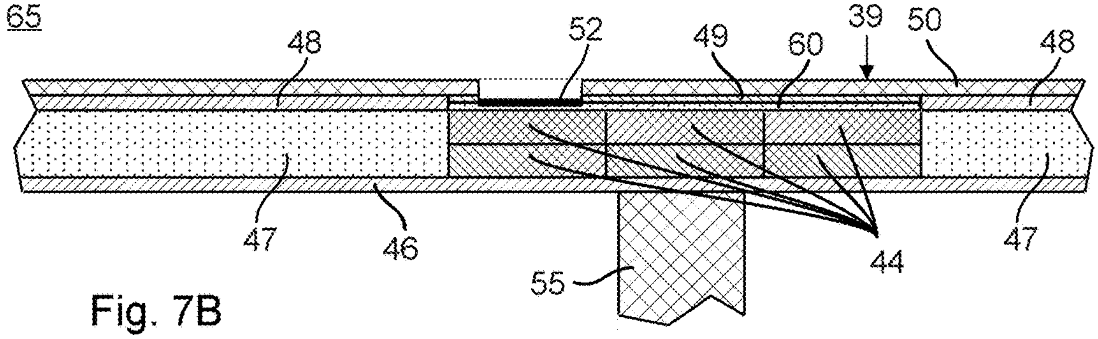


Fig. 7B

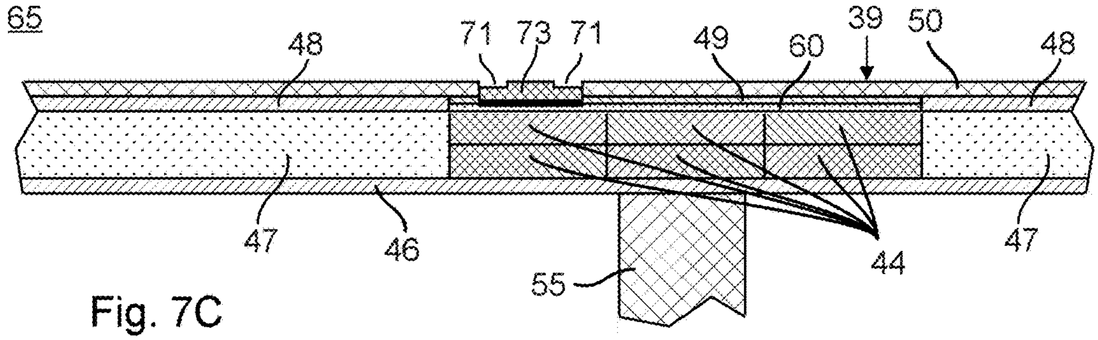


Fig. 7C

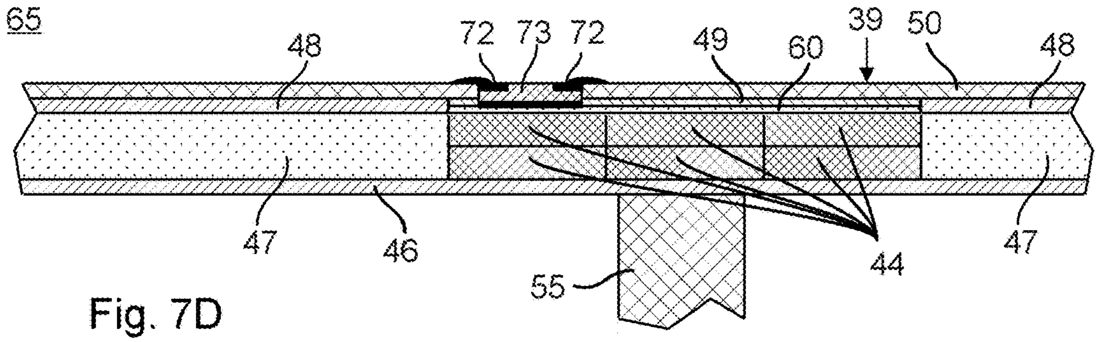


Fig. 7D

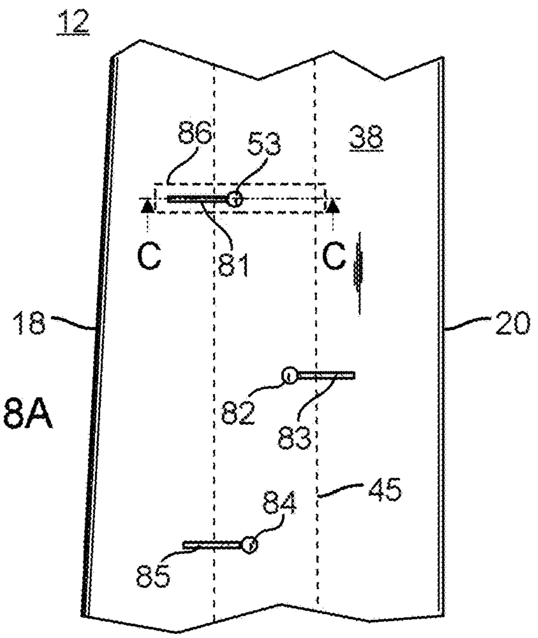


Fig. 8A

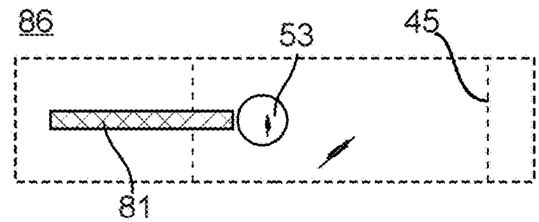


Fig. 8B

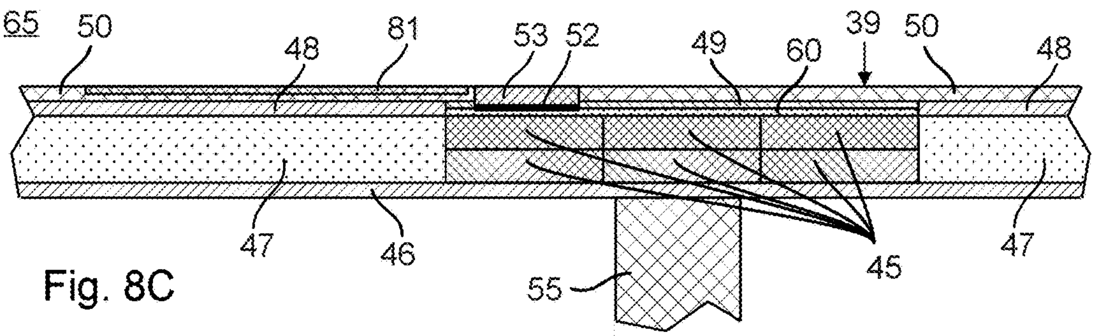


Fig. 8C

WIND TURBINE BLADE WITH A LIGHTNING RECEPTOR

BACKGROUND OF THE INVENTION

[0001] As wind turbines and wind turbine blades increase in size, the risk of lighting striking the wind turbine increases. It is therefore of increasing interest to provide wind turbines and in particular wind turbine blades with lightning protection measures.

[0002] Lightning protection measures in a wind turbine blade typically include metallic lightning receptors exposed at the outer surface of the blades to attract lightning in case of a lightning strike. The lightning receptors are typically connected to ground through metallic conductors in order to prevent lightning current from flashing over between less conductive parts, causing heating and potentially damage the parts. Typically, blades include a downconductor cable extending substantially the entire length of the blades. The downconductor cable is typically coupled to several lightning receptors arranged along the length of the blade to reduce the risk of flashovers during a lightning strike.

[0003] As blade sizes increase, a need also arises for manufacture of blades having increased rigidity and a comparatively low increase in weight. One way of achieving these properties is to combine various kinds of fibres in the laminate of the blades. For instance, it is an option to combine glass fibres and carbon fibres or make certain components merely of carbon fibre composite. However, a high amount of carbon fibre in composite structural elements, such as spar caps, increases the risk of flashover because carbon fibres are conductive enough that lightning current will flow in the carbon spar caps during a lightning strike, which can cause substantial heating and result in structural damage to the carbon fibre composite as well as surrounding parts. It may also cause delamination between different types of composites, such as interfaces between carbon fibre composites and glass fibre composites, in part due to the difference in their mechanical, thermal, and electrical properties.

[0004] Thus, it is of increasing importance to provide lightning protection measures that reduce the risk of flashover of lightning current into electrically conductive materials such as carbon fibres composites within a wind turbine blade. Further, it is desirable that these measures are relatively easy to implement.

SUMMARY OF THE INVENTION

[0005] It is an object of the present invention to mitigate one or more of the issues described above.

[0006] In a first aspect, the invention provides a wind turbine blade shell part for a wind turbine blade, the blade shell part comprising:

[0007] a structural element providing structural strength to the blade shell part and comprising carbon fibres embedded in a polymer matrix,

[0008] a lightning receptor exposed at an outer surface of the blade shell part and extending towards the structural element, and

[0009] an electrically conductive adhesive attaching the lightning receptor to the structural element.

[0010] The present invention reduces the risk of flashover of lightning current into electrically conductive materials such as carbon fibres composites within a wind turbine blade in case of a lightning strike to the blade.

[0011] In some embodiments, the electrically conductive adhesive adhesively attaches the lightning receptor to the structural element, as opposed to the electrically conductive adhesive holding the lightning receptor for instance by use of a threading. This can provide a strong bond between the lightning receptor and the structural element.

[0012] In some embodiments, the structural element is a spar cap. In some embodiments, the spar cap is in contact with a shear web, such as a shear web extending between the spar cap and another spar cap located in another part of the blade shell part.

[0013] In some embodiments, the structural element comprises one or more pultrusions comprising carbon fibres embedded in a polymer matrix and the electrically conductive adhesive attaches the lightning receptor to carbon fibres in one or more of the pultrusions. This provides electrical contact from the outer surface of the blade and the pultrusions, reducing the risk of flashover into the pultrusions.

[0014] In some embodiments, the structural element comprises:

[0015] one or more pultrusions comprising carbon fibres embedded in a polymer matrix, and

[0016] one or more fibre layers comprising carbon fibres, the one or more fibre layers being positioned between the outer surface of the blade shell part and one or more of the pultrusions and being adhesively attached to and in electrical contact with at least one of the one or more pultrusions,

[0017] the electrically conductive adhesive attaching the lightning receptor to carbon fibres in one or more of the fibre layers.

[0018] In such embodiments, electrical contact between the outer surface of the blade and the pultrusions is provided via the one or more fibre layers. The one or more fibre layers partly act as a sacrificial layer that introduces tolerance when then recess is being formed, as described in relation to the second aspect further below.

[0019] In some embodiments, the structural element comprises two or more pultrusions and the one or more fibre layers provide potential equalization between at least two of the pultrusions. When the one or more fibre layers extend across several pultrusions, the potential is equalized between the pultrusions, which reduces the risk of flashover between pultrusions and also reduces the resistance by ensuring that current is distributed across several pultrusions.

[0020] In some embodiments, the structural element comprises:

[0021] one or more pultrusions comprising carbon fibres embedded in a polymer matrix, and

[0022] a metallic element, such as a metallic mesh, positioned between the outer surface of the blade shell part and one or more of the pultrusions and being in electrical contact with at least one of the one or more pultrusions,

[0023] the electrically conductive adhesive attaching the lightning receptor to a part of the metallic element.

[0024] In such embodiments, electrical contact between the outer surface of the blade and the pultrusions is provided by the metallic element, such as a metal mesh, such as a copper mesh. Like the one or more fibre layers above, the metallic element may partly act as a sacrificial layer that introduces tolerance when then recess is being formed.

[0025] In some embodiments, the metallic element further extends to one or more other sides of the pultrusions. In some embodiments, the metallic element also surrounds all sides of the pultrusions. In all cases, the contact area between the pultrusions and the metallic element is increased, providing electrical coupling between more pultrusions, which provides further potential equalization between pultrusions. This further reduces the risk that the pultrusions are damaged by lightning current in case of a lightning strike.

[0026] In some embodiments, the structural element comprises two or more pultrusions and the metallic element provides potential equalization between at least two of the pultrusions. When the metallic element extends across several pultrusions, the potential is equalized between the pultrusions, which reduces the risk of flashover between pultrusions and also reduces the resistance by ensuring that current is distributed across several pultrusions.

[0027] In some embodiments, the lightning receptor abuts a lightning diverter forming part of the outer surface of the blade shell part. The connection between the lightning diverter and the lightning receptor and the connection between the lightning receptor and the structural element reduce the risk of a flashover from the lightning diverter and the structural element.

[0028] In some embodiments, the lightning receptor is located a first distance from the lightning diverter. This ensures the lightning diverter is not damaged when the lightning receptor is inserted. This is described in more detail in relation to the second aspect of the invention.

[0029] In some embodiments, the first distance is at most 20 mm, such as at most 10 mm, such as at most 5 mm. In some embodiments, the first distance is in the range 2-20 mm, such as in the range 2-15 mm, such as in the range 3-12 mm, such as in the range 3-10 mm. The distances provide a good compromise between ease of insertion of the lightning receptor and the ease with which lightning current from the lightning diverter may jump from the lightning diverter to the lightning receptor connecting the outer surface to the structural element.

[0030] In some embodiments, the lightning diverter is a segmented lightning diverter.

[0031] In some embodiments, the electrically conductive adhesive material has an electrical resistivity which is less than 1.0 10^{-5} Ohm-meter, such as less than 7.0 10^{-6} Ohm-meter, such as less than 5.0 10^{-6} Ohm-meter, such as less than 3.0 10^{-6} Ohm-meter.

[0032] In some embodiments, the electrically conductive adhesive material has an electrical resistivity which is at least 0.5 10^{-6} Ohm-meter, measured at 25° C.

[0033] In some embodiments, the electrically conductive adhesive material has an electrical resistivity in the range 1.0 10^{-6} Ohm-meter to 1.0 10^{-5} Ohm-meter, such as in the range 2.0 10^{-6} Ohm-meter to 6.0 10^{-6}, measured at 25° C. Such values have been found to provide a good compromise between resistivity of the electrically conductive adhesive and its adhesive strength.

[0034] Adhesives such as Loctite Ablestik 57C or Loctite Ablestik 8200C provide a good balance between adhesiveness and electrical conductivity.

[0035] In some embodiments, a perimeter of the lightning receptor is surrounded by a sealant at the outer surface. This protects the structural element from water.

[0036] In some embodiments, an area of the lightning receptor at the outer surface of the blade shell part is at least 5 cm^2.

[0037] In some embodiments, an area of the lightning receptor at the outer surface of the blade shell part is at most 50 cm^2.

[0038] In some embodiments, an area of the lightning receptor at the outer surface of the blade shell part is in the range 10-30 cm^2.

[0039] The area of the lightning receptor at the outer surface defines a cross-sectional area of the lightning receptor. In some embodiments, the lightning receptor has a smaller cross-sectional area at the outer surface than a cross-sectional area of the first recess in which the lightning receptor is placed. This embodiment deliberately provides room for an adhesive for sealing the outer surface around the lightning receptor. In some embodiments, a ratio between the cross-sectional area of the receptor at the outer surface and the cross-sectional area of the first recess is less than 0.95, such as less than 0.9, such as less than 0.8. In some embodiments, the ratio between the cross-sectional area of the receptor at the outer surface and the cross-sectional area of the first recess is in the range 0.8-0.95.

[0040] In some embodiments, the structural element is a spar cap.

[0041] In some embodiments, the fibres in the pultrusions are substantially carbon fibres only. In some embodiments, pultrusions comprise both carbon fibres and other types of fibres, such as glass fibres and/or steel fibres.

[0042] In some embodiments, the blade shell part comprises a wind turbine blade pressure side shell half and/or a wind turbine blade suction side shell half. In some embodiments, the blade shell part is a complete wind turbine blade shell, including a pressure side and a suction side.

[0043] A second aspect of the invention provides a method for attaching a lightning receptor to a wind turbine blade shell part of a wind turbine blade to provide electrical contact between an outer surface of the blade shell part and a structural element in the blade shell part. The method comprises:

[0044] providing a blade shell part comprising a structural element, the structural element comprising carbon fibres embedded in a polymer matrix,

[0045] providing a first recess extending from an outer surface of the blade shell part towards the structural element,

[0046] applying an electrically conductive adhesive into the recess,

[0047] inserting a lightning receptor into the recess such that the electrically conductive adhesive attaches the lightning receptor to the structural element, and

[0048] curing the adhesive.

[0049] This method makes it relatively easy to provide electrical connection from an outer surface of the blade shell part and the structural element.

[0050] In some embodiments, the structural element comprises one or more pultrusions comprising carbon fibres embedded in a polymer matrix, and providing the recess exposes a part of one or more of the pultrusions without extending into any of the pultrusions.

[0051] In some embodiments, the structural element comprises:

[0052] one or more pultrusions comprising carbon fibres embedded in a polymer matrix, and

[0053] one or more fibre layers comprising carbon fibres, the one or more fibre layers being positioned between the outer surface of the blade shell part and one or more of the pultrusions and being adhesively attached to and in electrical contact with at least one of the one or more pultrusions,

[0054] the recess extending into one or more of the fibre layers, but not into any of the one or more pultrusions, the electrically conductive adhesive attaching the lightning receptor to carbon fibres in one or more of the fibre layers.

[0055] In some embodiments, the structural element comprises:

[0056] one or more pultrusions comprising carbon fibres embedded in a polymer matrix, and

[0057] a metallic element, such as a metallic mesh, positioned between the outer surface of the blade shell part and one or more of the pultrusions and being in electrical contact with at least one of the one or more pultrusions,

[0058] the recess exposing a part of the metallic element without extending into any of the one or more pultrusions, the electrically conductive adhesive attaching the lightning receptor to a part of the exposed metallic element.

[0059] In some embodiments, the lightning receptor, after insertion, abuts a lightning diverter forming part of the outer surface of the blade shell part.

[0060] In some embodiments, the blade shell part complies with the IEC 61400-24 standard (2019 version).

[0061] In some embodiments, the lightning receptor and the electrically conductive adhesive, when they are attached to the structural element, can withstand a lightning current of at least 10 kA, such as a rating in the range 10-300 kA, such as in the range 10-200 kA, such as in the range 10-100 kA. In some embodiments, the blade shell part complies with the IEC 61400-24 standard (2019 version).

[0062] In some embodiments, the lightning receptor and the electrically conductive adhesive, when attached to the structural element, can withstand a lightning strike with a charge of at least 50 Coulomb, such as a charge in the range 50-1000 Coulomb, such as in the range 50-300 Coulomb, such as in the range 100-200 Coulomb. In some embodiments, the blade shell part complies with the IEC 61400-24 standard (2019).

[0063] In some embodiments, the lightning receptor, after insertion, is located a first distance from a lightning diverter, wherein the first distance is at most 20 mm, such as in the range 2-20 mm, such as in the range 3-10 mm.

[0064] In some embodiments, a second recess is present around the lightning receptor at the outer surface after insertion of the lightning receptor into the first recess, and the method further comprises filling the second recess around the lightning receptor with a sealant.

[0065] In some embodiments, the electrically conductive adhesive material has an electrical resistivity which is less than 1.0 10^{-5} Ohm-meter, such as less than 7.0 10^{-6} Ohm-meter, such as less than 5.0 10^{-6} Ohm-meter, such as less than 3.0 10^{-6} Ohm-meter, such as less than 2.0 10^{-6} Ohm-meter, such as less than 1.0 10^{-6} Ohm-meter, measured at 25° C.

[0066] In some embodiments, the structural element is a spar cap.

[0067] In some embodiments, the fibres in the pultrusions are substantially carbon fibres only. In some embodiments, pultrusions comprise both carbon fibres and other types of fibres, such as glass fibres and/or steel fibres.

[0068] In some embodiments, the blade shell part comprises a wind turbine blade pressure side shell half and/or a wind turbine blade suction side shell half. In some embodiments, the blade shell part is a complete wind turbine blade shell, including a pressure side and a suction side.

[0069] Advantages of the various features of embodiments of the second aspect are described in relation to the first aspect. Other features from embodiments of the first aspect of the invention may be included in embodiments of the second aspect.

BRIEF DESCRIPTION OF THE DRAWINGS

[0070] The invention is explained in detail below with reference to the embodiments shown in the drawings.

[0071] FIG. **1** illustrates a wind turbine.

[0072] FIG. **2** illustrates a wind turbine blade.

[0073] FIG. **3** illustrates a cross-section of a wind turbine blade containing structural elements.

[0074] FIG. **4** illustrates a top view of a blade shell section of a wind turbine blade comprising a structural element.

[0075] FIG. **5**A illustrates a top view of a blade shell part with a lightning receptor in accordance with the invention.

[0076] FIG. **5**B illustrates a detail of the top view shown in FIG. **5**A.

[0077] FIG. **5**C-**5**E illustrate a cross-section of a blade shell part in accordance with the invention.

[0078] FIGS. **6**A-**6**D illustrate a method in accordance with the invention.

[0079] FIGS. **7**A-**7**D illustrate a method in accordance with the invention.

[0080] FIG. **8**A illustrates a top view of a blade shell part with a lightning receptor in accordance with the invention.

[0081] FIG. **8**B illustrates a detail of the top view shown in FIG. **5**A.

[0082] FIG. **8**C illustrates a cross-section of a blade shell part in accordance with the invention.

DETAIL DESCRIPTION OF SELECTED EMBODIMENTS

[0083] Embodiments of the invention will be described in more detail in the following with reference to the accompanying drawings. Like reference numerals may refer to like elements throughout. The drawings show selected ways of implementing the present invention and are not to be construed as limiting the scope of the claims. The drawings are not necessarily drawn to scale.

[0084] FIG. **1** illustrates a conventional modern upwind wind turbine **2** according to the so-called "Danish concept" with a tower **4**, a nacelle **6** and a rotor with a substantially horizontal rotor shaft. The rotor includes a hub **8** and three blades **10** extending radially from the hub **8**, each having a blade root **16** nearest the hub and a blade tip **14** farthest from the hub **8**.

[0085] FIG. **2** shows a schematic view of a wind turbine blade **10**. The wind turbine blade **10** has the shape of a conventional wind turbine blade and comprises a root region **30** closest to the hub, a profiled or an airfoil region **34** farthest away from the hub and a transition region **32** between the root region **30** and the airfoil region **34**. The blade **10** comprises a leading edge **18** facing the direction of rotation of the blade **10**, when the blade is mounted on the hub, and a trailing edge **20** facing the opposite direction of the leading edge **18**. The outermost point of the blade **10** is the tip end **15**, located opposite the root end **31** that attaches to the wind turbine hub **8**.

[0086] The airfoil region **34**, also called the profiled region, of the wind turbine blade has an ideal or almost ideal blade shape with respect to generating lift, whereas the root region **30** due to structural considerations has a substantially circular or elliptical cross-section, which for instance makes it easier and safer to mount the blade **10** to the hub. The diameter (or the chord) of the root region **30** may be constant or may vary along the root region **30**. The transition region **32** has a transitional profile gradually changing from the circular or elliptical shape of the root region **30** to the airfoil profile of the airfoil region **34**. The chord length of the transition region **32** typically increases with increasing distance from the hub. The airfoil region **34** has an airfoil profile with a chord that extends between the leading edge **18** and the trailing edge **20** of the blade **10**. The chord usually decreases with increasing distance from the hub.

[0087] A shoulder **40** of the blade **10** is defined as the position where the blade **10** has its largest chord length. The shoulder **40** is typically located at the boundary between the transition region **32** and the airfoil region **34**. FIG. **2** also illustrates the longitudinal extent L_B of the blade **10**. L_B also represents a longitudinal axis of the blade **10**.

[0088] The blade is typically made from a pressure side shell part **36** and a suction side shell part **38** that are glued to each other along bond lines at the leading edge **18** and the trailing edge **20** of the blade **10**.

[0089] FIG. **3** schematically illustrates the cross-section I-I (see FIG. **2**) of the wind turbine blade **10**. The cross-section I-I illustrates the suction side shell part **38**, the pressure side shell part **36**, the leading edge **18** and the trailing edge **20** of the wind turbine blade **10** shown in FIG. **2**. Further, the wind turbine blade **10** comprises a structural element **45**, such as a spar cap, in the suction side part **38** of the shell and a spar cap **41** in the pressure side part **36** of the blade **10**. A shear web **55** extends between the two spar caps **41**, **45** and provides resistance to shear forces. The portion **65** indicated in FIG. **3** is described in further detail below in relation to different embodiments of the invention. FIG. **3** also indicates an outer surface **39** of the suction side part **38**.

[0090] Carbon fibre composites are used in wind turbine blades in part because they are lighter and stiffer by volume than glass fibre composites. Structural elements, such as spar caps, often comprise carbon fibre composite material, which improves the overall mechanical properties of blades. However, carbon fibre composites can conduct current during a lightning strike, although poorly, and thus carbon fibre composites are more susceptible to flashover than for instance glass fibre composites. Flashovers cause heating that can damage the carbon fibre composite and other parts, such as glass fibre composite material, in the vicinity.

[0091] FIG. **4** schematically illustrates a portion of the suction side blade shell **38** of a wind turbine blade. FIG. **4** is a view towards the outer surface **39** (see FIG. **3**) of the suction side blade shell **38**. The structural element **45**, such as a spar cap, is located below the outer surface **39** of the suction side shell part **38**. In some embodiments, the structural element **45** is separated from the outer surface **39** by a gelcoat and in some embodiments by composite material and/or one or more metallic elements. The present invention provides electrical contact between the outer surface **39** and the structural element **45**, thereby reducing the risk that a lightning strike causes a flashover to the structural element **45** and damages the wind turbine blade.

[0092] FIG. **5**A illustrates a portion of a blade shell part **11** in accordance with the invention, in this example a portion of a suction side blade shell **38**. A lightning receptor **53** is exposed at the outer surface of the blade. In the present example, the lightning receptor **53** is located over the spar cap **45**, which is situated under the outer surface **39** (see FIG. **3**) of the suction side blade shell **38**. The lightning receptor **53** attracts lightning in case of a lightning strike, thereby reducing the risk that lightning causes a flashover at least in the vicinity of the lightning receptor **53**. The region **56** indicated in FIG. **5**A is shown enlarged in FIG. **5**B, showing the lightning receptor **53** arranged over the spar cap **45** located in the suction side blade shell **38**.

[0093] FIG. **5**C illustrates the portion **65** (defined in FIG. **3**) of a cross-section of the blade shell part **11** shown in FIG. **5**A. The portion **65** includes the structural element **45**, part of the shear web **55**, an outermost gelcoat layer **50**, outer glass fibre composite layers **48**, core material **47**, such as foam, and inner glass fibre composite layers **46**. As seen from FIG. **5**C, the lightning receptor **53** extends from the outer surface **39** towards the structural element **45** and is in contact with the structural element **45**. In accordance with the invention, the lightning receptor **53** is adhesively attached to the structural element **45** using an electrically conductive adhesive **52**, as shown in FIG. **5**C.

[0094] A method of manufacturing such a blade shell part **11** is described in more detail further below. The different structures shown in the figures shall not be construed as limiting the scope of the claims.

[0095] FIG. **5**D illustrates another embodiment of the invention. In this example, the structural element **45** comprises (six) pultrusions **44** providing strength and stiffness to the blade. The embodiment also includes a material portion **49** positioned between the pultrusions **44** and the outer surface **39**, in this example a gelcoat layer **50**. The additional material **49** in part acts as a buffer in the sense that it is easier to provide electrical contact to the pultrusions without damaging the pultrusions **44**. The buffer may be provided as adhesively attached to the pultrusions before layup of the blade shell part **11**, or it may be laid up separately in the blade shell part mould before the pultrusions **44** are added to the layup. Subsequent resin infusion will then bond the buffer **49** to the one or more pultrusions **44**. The buffer may for instance comprise one or more fibre layers, such as fibre layers comprising carbon fibre, such as fibre layers in which the fibres are exclusively made of carbon.

[0096] FIG. **5**E illustrates another embodiment of the invention. In this example, the buffer **49** positioned between the outer surface **39** and the pultrusions **44** comprises one or more carbon fibre layers **49** and a metallic element **60**, made for instance from copper, or aluminium brass or tungsten or titanium or stainless steel or gold, or an alloy of one or more of these. In some embodiments, the metallic element is a mesh. Like the one or more fibre layers **49** in the embodiment in FIG. **5**D, the copper mesh is in electrical connection with the carbon pultrusions **44** and thereby equalize the potential across the pultrusions. This allows lightning current to be distributed across the different pultrusions, reducing the resistance and in turn reducing heating caused by a lightning strike. The metallic element **60** may be provided adhesively attached to one or more of the pultrusions **44** before layup of the blade shell part (optionally together with the fibre layers **49** or other material positioned between the metallic mesh **60** and the pultrusions **44**), or it may be laid up separately before pultrusions **44** are added to the blade shell part layup.

[0097] FIGS. **6**A-**6**D illustrate a method in accordance with the invention. The steps provide electrical contact between an outer surface of the blade shell part **11** and the structural element **45** in the blade shell part **11**.

[0098] FIG. **6**A is similar to FIG. **5**E above but shows the blade shell part before the lightning receptor is added.

[0099] After providing the blade shell part **11** comprising pultrusions **44** and the buffer, which in this example comprises carbon fibre layers **49** and a copper mesh **60**, a first recess **51** is formed into the blade shell part **11** as shown in FIG. **6**B. In the example, the first recess **51** extends from the outer surface **39** blade shell part through the one or more fibre layers **49**, and finally exposes a part of the metallic element **60**. The first recess **51** does not extend into any of the one or more pultrusions since this will weaken the strength of the pultrusion. The buffer makes it easier to form the recess **51** while not damaging the pultrusions **44**. In a sense, it partly acts as a sacrificial layer and provides some tolerance when then recess **51** is being formed.

[0100] FIG. **6**C illustrates a step of applying an electrically conductive adhesive **52** in the first recess **51** in such a way that the electrically conductive adhesive **52** can subsequently adhesively attach the exposed part of the metallic element **60** to the lightning receptor **53** when the lightning receptor **53** is inserted. The electrically conductive adhesive **52** may for instance have an electrical resistivity of at most $1.0\ 10^{-5}$ Ohm-meter, measured at 25° C. This ensures a sufficiently high conductivity between the lightning receptor **53** and the metallic element **60**. Loctite provides adhesive materials that have an electrical resistivity below $1.0\ 10^{-5}$ Ohm-meter.

[0101] Next, as illustrated in FIG. **6**D, the lightning receptor **53** is inserted into the first recess **51** such that it becomes adhesively attached to the metallic element **60** via the electrically conductive adhesive **52**, thereby being in electrical connection with the copper mesh **60** with low resistance.

[0102] Preferably, the electrically conductive adhesive effectively seals off the layers below the gelcoat **50** from any water outside the blade shell part **11**. If needed, a sealant may be applied to completely seal the outer surface **39** from any water outside the blade shell part **11**.

[0103] Finally, the adhesive **52** and any sealant are cured. This results in the blade shell part shown in FIG. **5**E.

[0104] FIGS. **7**A-**7**D illustrate another method in accordance with the invention. The method is similar to the method described above in relation to FIGS. **6**A-**6**D. However, the method described below provides an improved seal around the lightning receptor.

[0105] FIG. **7**A corresponds to FIG. **6**B, showing the blade shell part with the first recess **51** having been formed to expose the metallic element **60**. FIG. **7**B corresponds to FIG. **6**C, illustrating application of the electrically conductive adhesive **52** in the first recess **51**.

[0106] The method differs from the method described above in that a different lightning receptor **73** is used. The lightning receptor **73** is formed such that, when inserted in the first recess **51**, a significant second recess **71** is present around the lightning receptor **73** at the outer surface of the blade shell part **11**. This is illustrated in FIG. **7**C. The lightning receptor **73** has a smaller cross-sectional area at the outer surface than the cross-sectional area of the first recess **51**. For instance, a ratio between the cross-sectional area of the receptor **73** at the outer surface and the cross-sectional area of the first recess **51** may be less than 0.95, such as less than 0.9, such as less than 0.8.

[0107] FIG. **7**D illustrates sealing the second recess **71** by filling the second recess **71** around the lightning receptor **73** with a sealant **72**. This more effectively seals the outer surface from any water outside the blade shell part compared to the lightning receptor **53** shown in FIG. **6**D, which fits snugly but for that reason is more difficult to seal. In the example, the sealant **72** extends onto the outer surface **39** where it is preferably rounded and thin so as to not impact the aerodynamic properties of the blade. By extending the sealant **72** onto the outer surface **39**, the seal becomes very strong. If moist gets to the electrically conductive adhesive, such as a silver Loctite, an oxidation process will start that will adversely affect the electrically conductive adhesive, both its mechanical properties and its electrical properties.

[0108] Alternatively, the sealant **72** may be flush with the outer surface **39**, but this may result in a less efficient seal having a shorter service life. If the seal breaks, oxidation of the electrically conductive adhesive will occur, as described above, and the mechanical and electrical properties of the electrically conductive adhesive will deteriorate.

[0109] Finally, the adhesive and the sealant are cured.

[0110] FIGS. **8**A-**8**C illustrate another embodiment of the invention. It is similar to the embodiment shown in FIG. **5**E. However, as shown in FIG. **8**A, the outer surface **39** includes a lightning diverter **81**, such as a segmented lightning diverter. In the present example, the segment lightning diverter is located close to, but not abutting the lightning receptor **53**. The region **86** indicated in FIG. **8**A is shown in more detail in FIG. **8**B, which also illustrates a distance between the lightning diverter **81** and the receptor **53**. The segmented diverter may for instance be provided when manufacturing the blade shell part, or it may be added after embedding fibre layers, pultrusions, and one or more metallic elements in resin.

[0111] The blade shell part may include a plurality of lightning receptors **53**, **82**, and **84**, as shown in FIG. **8**A. In the embodiment in FIG. **8**A, there are corresponding lightning diverters **81**, **83**, and **85** in combination with respective lightning receptors **53**, **82**, and **84**.

[0112] An advantage of placing the lightning receptor **53** a distance from the lightning diverter **81** is that the lightning diverter **81** is not damaged when providing the recess **51**, which could happen if the recess **51** is provided abutting the lightning diverter **81** or even formed overlapping part of the lightning diverter **81**.

LIST OF REFERENCES

[0113] **2** wind turbine
[0114] **4** tower
[0115] **6** nacelle
[0116] **8** hub
[0117] **10** blade
[0118] **11**,**12** blade shell part
[0119] **14** blade tip
[0120] **15** tip end

[0121] **16** blade root
[0122] **18** leading edge
[0123] **20** trailing edge
[0124] **30** root region
[0125] **31** root end
[0126] **32** transition region
[0127] **34** airfoil region
[0128] **36** pressure side shell part
[0129] **38** suction side shell part
[0130] **39** outer surface of blade shell part
[0131] **40** shoulder
[0132] **41**,**45** structural element/load-carrying structure/spar cap
[0133] **44** pultrusions comprising carbon fibre material
[0134] **46** fibre composite layers
[0135] **47** core material
[0136] **48** fibre composite layers
[0137] **49** additional material, buffer
[0138] **50** gelcoat
[0139] **51** recess
[0140] **52** electrically conductive adhesive
[0141] **53** lightning receptor
[0142] **55** shear web
[0143] **56** region of blade shell part
[0144] **60** metallic element, copper mesh
[0145] **65** portion of blade shell part
[0146] **71** recess surrounding lightning receptor
[0147] **72** adhesive surrounding lightning receptor at outer surface
[0148] **73** lightning receptor
[0149] **81**, **83**, **85** lightning diverter, segmented lightning diverter
[0150] **82**, **84** lightning receptor
[0151] **86** region of blade shell part
[0152] L_B length/longitudinal axis of blade

1-27. (canceled)

28. A blade shell part for a wind turbine blade, the blade shell part comprising:

a structural element providing structural strength to the blade shell part and comprising one or more pultrusions comprising carbon fibers embedded in a polymer matrix;

a lightning receptor exposed at an outer surface of the blade shell part and extending towards the structural element; and

an electrically conductive adhesive attaching the lightning receptor to the carbon fibers in the one or more pultrusions of the structural element.

29. The blade shell part of claim **28**, further comprising one or more fiber layers comprising carbon fibers, the one or more fiber layers being positioned between the outer surface of the blade shell part and one or more of the pultrusions and being adhesively attached to and in electrical contact with at least one of the one or more pultrusions, the electrically conductive adhesive attaching the lightning receptor to the carbon fibers in one or more of the fiber layers.

30. The blade shell part of claim **28**, wherein the structural element further comprises a metallic element positioned between the outer surface of the blade shell part and the one or more pultrusions and being in electrical contact with at least one of the one or more pultrusions, the electrically conductive adhesive attaching the lightning receptor to a part of the metallic element.

31. The blade shell part of claim **30**, wherein the one or more fiber layers or the metallic element provides potential equalization between at least two of the one or more pultrusions.

32. The blade shell part of claim **28**, wherein the lightning receptor abuts a lightning diverter forming part of the outer surface of the blade shell part, and wherein the lightning receptor is located a first distance from the lightning diverter forming part of the outer surface of the blade shell part.

33. The blade shell part of claim **32**, wherein the lightning diverter is a segmented lightning diverter.

34. The blade shell part of claim **32**, wherein the first distance is in the range of 2 millimeters (mm) to 20 mm.

35. The blade shell part of claim **28**, wherein the electrically conductive adhesive material has an electrical resistivity in the range 1.0 10^{-6} Ohm-meter to 1.0 10^{-5} Ohm-meter measured at 25° C.

36. The blade shell part of claim **28**, wherein a perimeter of the lightning receptor is surrounded by a sealant at the outer surface.

37. The blade shell part of claim **28**, wherein the structural element is a spar cap.

38. The blade shell part of claim **28**, wherein the blade shell part comprises at least one of a pressure side shell or a suction side shell. **39** The blade shell part of claim **28**, wherein the lightning receptor and the electrically conductive adhesive, when attached to the structural element, can withstand a lightning current of at least 10 kA.

40. The blade shell part of claim **28**, wherein the lightning receptor and the electrically conductive adhesive, when attached to the structural element, can withstand a lightning charge during a lightning strike of at least 50 Coulomb.

41. A method for attaching a lightning receptor to a wind turbine blade shell part of a wind turbine blade to provide electrical contact between an outer surface of the blade shell part and a structural element in the blade shell part, the method comprising:

providing a blade shell part comprising a structural element, the structural element comprising one or more pultrusions comprising carbon fibers embedded in a polymer matrix;

providing a first recess extending from an outer surface of the blade shell part towards the structural element, the recess exposing a part of one or more of the pultrusions without extending into any of the pultrusions;

applying an electrically conductive adhesive into the recess;

inserting a lightning receptor into the recess such that the electrically conductive adhesive attaches the lightning receptor to the carbon fibers in the one or more pultrusions of the structural element; and

curing the electrically conductive adhesive.

42. The method of claim **41**, further comprising one or more fiber layers comprising carbon fibers, the one or more fiber layers being positioned between the outer surface of the blade shell part and one or more of the pultrusions and being adhesively attached to and in electrical contact with at least one of the one or more pultrusions, the electrically conductive adhesive attaching the lightning receptor to the carbon fibers in one or more of the fiber layers.

43. The method of claim **41**, wherein the structural element further comprises a metallic element positioned between the outer surface of the blade shell part and the one or more pultrusions and being in electrical contact with at least one of the one or more pultrusions, the electrically conductive adhesive attaching the lightning receptor to a part of the metallic element.

44. The method of claim **41**, wherein the lightning receptor, after insertion, abuts a lightning diverter forming part of the outer surface of the blade shell part.

45. The method of claim **41**, wherein the lightning receptor, after insertion, is located a first distance from a lightning diverter.

46. The method of claim **41**, wherein a second recess is present around the lightning receptor at the outer surface after insertion of the lightning receptor into the first recess, and wherein the method further comprises filling the second recess around the lightning receptor with a sealant.

47. The method of claim **41**, wherein the electrically conductive adhesive material has an electrical resistivity which is less than $1.0\ 10^{-5}$ Ohm-meter measured at 25° C.

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