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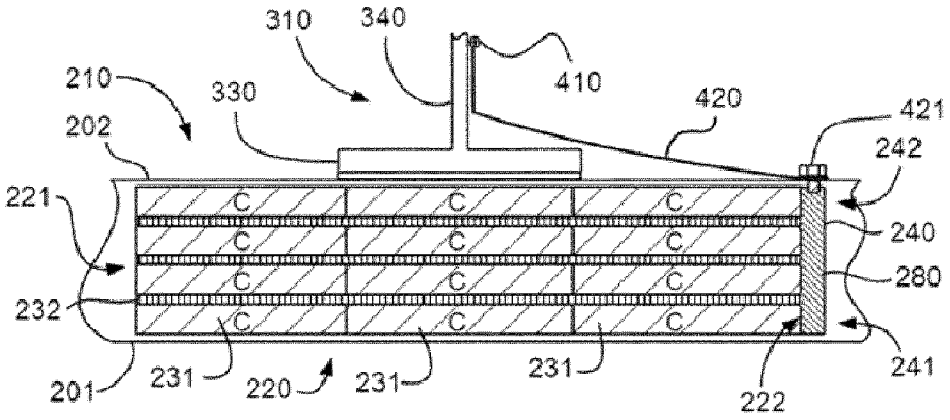


Figure 4A

(57) Abstract: There is provided a spar cap structure for a wind turbine blade. The spar cap structure comprises a main body and a lightning conductor assembly. The main body comprises a first side and a second side. The main body comprises a plurality of layers of one or more carbon fiber components, each of these layers being arranged one on top of the other between the first and the second sides, whereby the main body spans a thickness. The lightning connector assembly is arranged at one of the sides of the main body. The lightning connector assembly comprises a conductive block electrically connected to the main body. The conductive block spans a height from an outer end to an inner end of the lightning conductor assembly in a direction substantially parallel to the thickness of the main body. The inner end is connectable to a down conductor of a lightning protection system of a wind turbine blade.

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Spar cap structures comprising a conductive block

The present disclosure relates to a spar cap structure comprising a conductive block, a wind turbine blade comprising the spar cap structure and a method for manufacturing the spar cap structure.

BACKGROUND

Modern wind turbines are commonly used to supply electricity to the electrical grid. Wind turbines of this kind generally comprise a rotor with a rotor hub and a plurality of wind turbine blades. The rotor is set into rotation under the influence of the wind on the blades. The rotation of the rotor shaft drives the generator rotor either directly ("directly driven") or through the use of a gearbox. The gearbox (if present), the generator and other systems are usually mounted in a nacelle on top of a wind turbine tower.

Wind turbine blades are generally made from fiber-reinforced polymers or plastics (FRPs), which are composite materials consisting of a polymer matrix and reinforced with fibers. The fibers are usually glass or carbon and provide longitudinal stiffness and strength.

Wind turbine blades are commonly manufactured by joining two blade shell parts made from fiber-reinforced polymers (e.g., glass or carbon fiber reinforced polymers). These blade shell parts may be molded using resin infusion technology or prepreg technology. In resin infusion technology, fibers are placed in a mold, and the resin is injected into the mold cavity under pressure. This resin fills the volume between the cavity, then the resin is cured or hardened. Examples of resin infusion technology may be Resin Transfer Molding (RTM) or Vacuum Assisted Resin Transfer Molding (VARTM). In VARTM, the resin is injected under a vacuum or pressure lower than atmospheric pressure.

A load-carrying structure may be arranged between the pressure side blade shell part and the suction side blade shell part. The load-carrying structure may comprise a reinforcing structure joined to opposing spar caps of the respective blade shell part. The spar caps may be embedded within the composite laminate materials of the blade shell parts or laminated to an inner surface of the blade shell. The spar caps are used to receive the reinforcing structure (e.g., a pair of opposing flanges) and to

structurally reinforce the wind turbine blade. The spar caps provided in the blade shell parts typically increase the stiffness, buckling resistance and strength of the wind turbine blade. The spar caps extend along a longitudinal length of the wind turbine blade.

Spar caps may be constructed of various materials, including glass fiber laminate composites and carbon fiber laminate composites. For example, glass fiber fabrics or carbon fiber fabrics may be employed for manufacturing spar caps. In order to increase the mechanical properties, pultruded composites may alternatively be used.

Pultruded composites or pultrusions are fiber reinforcement materials that are impregnated with resin and pulled through a heated stationary die such that the resin cures and undergoes polymerization. Pultruded composites may comprise carbon fiber pultrusions and/or glass fiber pultrusions. As such, the pultrusion process is typically characterized by a continuous process that produces composite parts having a constant cross-section. Thus, a plurality of pultrusions can be vacuum infused together in a mold to form the spar caps. The pultrusions are prefabricated, which allows for a high level of quality and better fiber configuration and homogeneity.

In recent times, there has been a trend to increase the size of wind turbine blades to capture more wind. Larger blades typically involve higher mechanical requirements. Furthermore, manufacturing complexity also increases with larger blades. Carbon fibers (e.g., carbon fiber pultrusions) offer a better stiffness/weight ratio and fatigue properties than glass fibers (e.g., glass fiber pultrusions). Accordingly, carbon fibers (e.g., carbon fiber pultrusions) may be used to achieve these high mechanical requirements. To this end, carbon fiber pultrusions may be employed for manufacturing spar cap structures.

Furthermore, as wind turbine blades increase in size, the risk of lightning striking the wind turbine blades increases. Wind turbine blades may be provided with lightning receptors to capture the lightning strike. These lightning receptors are electrically connected to a down conductor arranged within the wind turbine blade to conduct the lightning current to the ground. These lightning receptors are arranged outside spar cap structures made from carbon fiber components. The lightning receptors are generally arranged in the glass fiber of the blade shell part (e.g., in core structures outside the spar cap structures).

The electrical conductivity of carbon fibers is greater than that of glass fibers. Lightning striking carbon fibers may cause the carbon fiber to conduct the lightning current. However, the resin that bonds carbon fiber layers (e.g., several carbon fiber pultrusions) comprises a lower electrical conductivity. Accordingly, the resin and any gaps between the carbon fiber layers may hinder the lightning current from flowing between carbon fiber layers (e.g., carbon fiber pultrusions). This hindering may cause a risk of internal flashover between carbon fiber layers, which may potentially damage the material. To this end, thin conductive interlayers or veils may be provided between layers of carbon fiber components (e.g., between carbon fiber pultrusions). These thin interlayers have an electrical conductivity greater than that of the resin. These conductive interlayers may be electrically connected to the down conductor.

Mounting the lightning receptors in the core structures and connecting them to the conductive interlayers arranged between the carbon fiber components (e.g., carbon fiber pultrusions) of the spar cap is complex and requires several elements. Copper elements are generally at least partially arranged on the inner side of the core structures (i.e., sticking out from the spar cap). Some of these copper elements may be used for connecting the conductive interlayers to the down conductor. These copper elements are generally arranged on the inner side of the blade shell and apart from the spar cap.

For example, structures known as lightning protection ears may be made from copper meshes. These lightning protection ears may stick out from the spar cap and may be arranged on the inner side of the core structure. Using these lightning protection ears may involve the use of interconnecting cables connected to the lightning protection ears through copper discs bonded to the lightning protection ears. These interconnecting cables may connect the lightning protection ears to the down conductor.

As the lightning protection ears are difficult to infuse together with the fibers of the spar cap, the spar cap is typically manufactured and then the copper meshes forming the lightning protection ears are bonded to the spar cap. These copper meshes may get damaged or disconnected from the spar cap when the spar cap is transferred from the spar cap mold to the blade shell mold. Furthermore, aligning these copper meshes with the shell (e.g., core structure) is difficult. In addition, since the copper meshes or lightning protection ears are on the inner side of the core structure, damage and misalignment of the copper mesh or of the lightning protection ears is

difficult to detect by inspecting from outside the wind turbine blade (e.g., through an ultrasonic inspection). Furthermore, the adhesion between the lightning protection ears or the copper meshes with the blade shell is generally poor. The adhesion of the copper disc and the copper mesh is also generally poor.

In other examples, the copper components are arranged inside the core structure. Mounting these components, on the core structure, requires precise machining. These operations are thus complex and time-consuming. Furthermore, machining the core structure for placing the copper components and the lightning receptor of the lightning protection system may weaken the core structure. The structural integrity of the wind turbine blade may thus be negatively affected. In these examples, the connection between the conductive interlayers and the copper components is also complex. The adhesion of the copper components and the core structure may also be poor.

The present disclosure provides examples of systems and methods that at least partially resolve some of the aforementioned disadvantages.

SUMMARY

In a first aspect, a spar cap structure for a wind a turbine blade is provided. The spar cap structure comprises a main body and a lightning connector assembly, which comprises a conductive block.

The main body comprises a first side and a second side. Furthermore, the main body comprises a plurality of layers of one or more carbon fiber components. Each of these layers is arranged one on top of the other between the first and the second sides, whereby the main body spans a thickness. The lightning connector assembly is bonded to one of the sides of the main body. The lightning conductor assembly comprises the conductive block, which is electrically connected to the main body and spans a height from an outer end to an inner end of the lightning conductor assembly in a direction substantially parallel to the thickness of the main body. The inner end is connectable to a down conductor of a lightning protection system of a wind turbine blade.

According to the first aspect, elements of the lightning receptors may be integrated within the spar cap structure. Consequently, the accuracy and precision of the

manufacturing operations may be increased. The use of some lightning protection elements, in particular lightning protection ears or copper discs, is eliminated in this aspect. As a result, problems related to the arrangement and the adhesion of these lightning protection elements in the blade shell are overcome. Furthermore, as the lightning connector assembly is arranged within the spar cap structure (and not in the core structures adjacent to the spar cap), the lightning connector assembly may be inspected from outside the wind turbine blade. Ultrasonic methods may thus be used, which may increase the reliability of blade manufacturing.

As the lightning connector assembly is within the spar cap structure, the electrical connections between the main body having carbon fibers and the lightning connector assembly are simplified. The electrical connection between the main body and the lightning connector assembly may thus be performed before forming the whole wind turbine blade, allowing the number of elements to be reduced and reducing the need to perform some post-operation tasks, such as machining the blade shell to mount the typical copper disc and soldering operations to connect the main body to the lighting receptors. Electrical current may thus flow from the main body having the carbon fibers to the conductive block of the lightning connector assembly. The electrical current may then be conducted towards the down conductor.

Furthermore, mounting the lightning receptors is simplified, since the lightning receptors may be attached to the outer end of the lightning connector assembly. Accordingly, it is not required to insert the lightning receptors through the whole thickness of the core structure from outside the spar cap structure. The lightning system protection may thus be assembled in an easier manner.

Furthermore, handling operations for placing the spar cap in the blade shell mold may be simplified. De-attaching the lightning elements such as lightning protection ears from the blade shell (e.g., from the spar cap or from the core structure) may be further prevented. The safety of these operations may be further improved.

In a second aspect, a wind turbine blade extending in a lengthwise direction is provided. The wind turbine blade comprises an upper blade shell part and a lower blade shell part joined to the upper blade shell part. The wind turbine blade further comprises a reinforcing structure between the upper blade shell part and the lower blade shell. In addition, the upper blade shell part and/or the lower blade shell part comprises a receiving part configured to engage the spar cap structure according to

any of the examples herein disclosed.

In a third aspect, a method for manufacturing a spar cap structure is provided. The method comprises forming a main body by stacking a plurality of layers of one or more carbon fiber components between a first side and a second side of the main body, whereby the main body spans a thickness. The method also comprises arranging a lightning connector assembly at one side of the sides of the main body, wherein the lightning connector assembly comprises a conductive block, the conductive block spanning a height from an outer end to an inner end in a direction substantially parallel to the thickness of the main body. The inner end is connectable to a down conductor of a lightning protection system of a wind turbine blade. The method further comprises electrically connecting the conductive block to the main body and bonding the lightning connector assembly to the main body.

In a fourth aspect, a method for manufacturing a wind turbine blade according to any of the examples herein disclosed is provided. The method for manufacturing a wind turbine blade comprises forming the upper blade shell part and the lower blade shell. Forming the upper blade shell part and/or the lower blade shell part comprises arranging the spar cap structure on an outer layer laid in a blade shell part mold and bonding the spar cap structure to the outer layer. The method for manufacturing the wind turbine blade further comprises joining the reinforcing structure to the upper blade shell part and to the lower blade shell part such that the reinforcing structure is arranged between the upper blade shell part and the lower blade shell part and joining the upper blade shell part to the lower blade shell part.

Advantages derived from the second, third and fourth aspects may be the same or similar to those mentioned regarding the first aspect.

BRIEF DESCRIPTION OF THE DRAWINGS

Non-limiting examples of the present disclosure will be described in the following, with reference to the appended drawings, in which:

Figure 1 illustrates a perspective view of a wind turbine according to one example;

Figure 2 shows a perspective view of a wind turbine blade according to one example;

Figure 3 shows a cross-sectional view of a wind turbine blade according to one example of the present disclosure;

Figure 4A schematically represents a cross-sectional view of a spar cap structure arranged in a wind turbine blade according to an example of the present disclosure;

Figure 4B schematically represents a cross-sectional view of a spar cap structure arranged in a wind turbine blade according to another example of the present disclosure;

Figure 4C schematically represents a cross-sectional view of a spar cap structure arranged in a wind turbine blade according to another example of the present disclosure;

Figure 4D schematically represents a cross-sectional view of a spar cap structure arranged in a wind turbine blade according to another example of the present disclosure;

Figure 4E schematically represents a cross-sectional view of a spar cap structure arranged in a wind turbine blade according to another example of the present disclosure;

Figure 5A schematically represents an isometric view of a part of a spar cap structure according to an example of the present disclosure;

Figure 5B schematically represents an isometric view of a part of a spar cap structure according to another example of the present disclosure;

Figure 5C schematically represents an isometric view of a part of a spar cap structure according to another example of the present disclosure;

Figure 6 is a block diagram of a method for manufacturing a spar cap structure according to one example of the present disclosure; and

Figure 7 is a block diagram of a method for manufacturing a wind turbine blade according to one example of the present disclosure.

DETAILED DESCRIPTION OF EXAMPLES

Figure 1 illustrates a perspective view of one example of a wind turbine 1. As shown, the wind turbine 1 includes a tower 2 extending from a support surface 3, a nacelle 4 mounted on the tower 2 and a rotor 5 coupled to the nacelle 4. The rotor 5 includes a rotatable hub 6 and at least one wind turbine blade 7 coupled to and extending outwardly from the rotor hub 6. In the illustrated example, the rotor 5 includes three wind turbine blades 7. However, in an alternative example, the rotor 5 may include more or less than three wind turbine blades 7. Each wind turbine blade 7 may be spaced from the rotor hub 6 to facilitate rotating the rotor 5 to enable kinetic energy to be transferred from the wind into usable mechanical energy and, subsequently, electrical energy. For instance, the rotor hub 6 may be rotatably coupled to an electric generator positioned within the nacelle 4 or forming part of the nacelle to permit electrical energy to be produced.

Figure 2 illustrates an example of a wind turbine blade 7. The wind turbine blade 7 extends in a longitudinal direction or lengthwise direction 37 from a blade root end 71 to a blade tip end 72. The wind turbine blade 7 comprises a blade root region or portion 50 closest to the rotor hub, a profiled or an airfoil portion 52 furthest away from the rotor hub and a transition portion 51 between the blade root portion 50 and the airfoil portion 52. The wind turbine blade 7 comprises a leading edge 53 facing the direction of rotation of the wind turbine blade 7 when mounted on the rotor hub and a trailing edge 54 facing the opposite direction of the leading edge 53.

The airfoil portion 52 has a shape designed to generate lift, whereas the blade root portion 50 has a circular or elliptical cross-section for structural considerations and easy mounting of the blade to the rotor hub. The diameter or the chord of the blade root portion 50 may be constant along the entire blade root portion 50. At the transition portion 51, the profile gradually changes from the circular or elliptical cross-section of the blade root portion 50 to the airfoil profile of the airfoil portion 52. The wind turbine blade 7 may be connected to the rotor hub through a blade root attachment portion 55.

The wind turbine blade 7 comprises a blade shell 73. The blade shell 73 comprises an outer side or surface that defines the external shape of the blade (e.g., the outer shape at the blade root portion and the outer shape at the airfoil portion). The blade shell 73 also comprises an inner side or surface that defines the internal volume of

the blade and faces a load-carrying structure (not shown). The blade shell 73 may be made of fiber-reinforced polymer or plastics (e.g., glass fiber and/or carbon fiber).

The blade shell may be formed by a plurality of blade shell parts. The plurality of blade shell parts may be joined together to form the blade shell. The blade shell parts may be formed and then joined according to any of the examples herein disclosed. Resin infusion technology (e.g., RTM or VARTM) or prepreg technology may be used for manufacturing the blade shell parts.

In some examples, the blade shell comprises a lower side blade shell part and an upper blade shell part. The lower side blade shell may be a pressure side blade shell part. The upper blade shell part may be a suction side blade shell part. The lower side blade shell part may be joined to the upper side blade shell part along joining lines along the leading edge 53 and the trailing edge 54. Each of these blade shell parts may be manufactured in a mold and then joined together to define the entire blade shell of the wind turbine blade 7. A reinforcing structure is arranged between the lower side blade shell part and the upper side blade shell part.

Figure 3 shows a cross-sectional view of a wind turbine blade 7 according to one example of the present disclosure. A suction side blade shell part or upper blade shell part 100, and a pressure side blade shell part or lower blade shell part 200 extend from the leading edge 53 to the trailing edge 54. The wind turbine blade 7 further comprises a chord line 38 between the leading edge 53 and the trailing edge 54. The chord line 38 extends in an edgewise direction or chordwise direction. A flapwise direction 39 is substantially perpendicular to the chord line 38. The upper blade shell part 100 and the lower blade shell part 200 are joined (e.g., bonded) together along the leading edge 53 and the trailing edge 54.

The upper blade shell part 100 comprises an upper outer layer 101 and an upper inner layer 102. The upper outer layer 101 defines an outer shape of the upper blade shell part 100 and the upper inner layer 102 defines an inner shape of the upper blade shell part 100. The upper outer layer 101 and the upper inner layer 102 may comprise glass fiber laminates. For example, one or more glass fiber laminates may be arranged to form the upper outer layer 101 and/or the upper inner layer 102. The fibers (e.g., glass fibers) may be oriented bidirectionally to enhance the torsional stiffness of the wind turbine blade 7. In other examples, the fibers may be arranged unidirectionally. In further examples, the upper layers 101 and/or 102 comprise

laminates with unidirectional fibers and laminates with bidirectional fibers.

The upper blade shell part 100 of this example comprises an upper spar cap structure 110 embedded between the upper outer layer 101 and the upper inner layer 102. The upper spar cap structure 110 is thus arranged between the upper outer layer 101 and the upper inner layer 102. The upper spar cap structure 110 structurally reinforces the upper blade shell part 100.

A core structure may be arranged between the upper outer layer 101 and the upper inner layer 102 in some parts of the upper blade shell part 100. For example, a core structure may extend a portion between the upper spar cap structure 110 and the leading edge. Additionally, or alternatively, a core structure may extend a portion between the upper spar cap structure 110 and the trailing edge 54. The core structure generally increases the thickness of the blade shell part so as to improve the stiffness without an excessive weight increase. The core structure may be made from a lightweight material such as balsa wood or polymer foam.

The lower blade shell part 200 may be manufactured like the upper blade shell part 100. As described with respect to the upper blade shell part 100, the lower blade shell part 200 comprises a lower outer layer 201 and a lower inner layer 202. The lower outer layer 201 and/or the lower inner layer 202 may comprise bidirectional glass fibers. A lower spar cap structure 210 is embedded between the lower outer layer 201 and the lower inner layer 202.

The upper spar cap structure 110 and the lower spar cap structure 210 of this example cross the flapwise direction 39. The spar cap structures 110 and 210 face each other. The spar cap structures 110 and 210 may extend a length along the spanwise direction 37 of the wind turbine blade 7. The length of the spar cap structures 110, 210 may be greater than 90% of the entire length of the wind turbine blade 7.

The spar cap structures 110, 210 may be according to any of the examples herein. The spar cap structures 110, 210 of this example comprise a main body comprising carbon fibers. The carbon fibers are arranged to form layers of carbon fiber components.

The wind turbine blade 7 may comprise a receiving part configured to engage the

spar cap structure 110, 210. The receiving part may be foam. The receiving part may be intermediate with respect to the spar cap structure 110, 210 and the core structure.

In some examples, the main body of the spar cap structures 110, 210 may comprise carbon fiber fabric layers. Layers formed from carbon fiber fabrics may thus be arranged one on top of the other to, at least in part (i.e., there may be layers of other materials which also contribute), define the thickness of the main body. In these examples, the carbon fiber components are carbon fiber fabrics. In other examples, the main body may comprise a plurality of carbon fiber pultrusions. The carbon fiber pultrusions may be arranged forming several rows of carbon fiber pultrusions. A plurality of pultrusions may be arranged side by side to form the row of carbon fiber pultrusions. In these examples, the carbon fiber components are carbon fiber pultrusions.

The spar cap structures 110 and 210 of this figure comprise a lightning connector assembly arranged at one side of the main body. The lightning connector assembly is bonded at one side of the main body. For instance, the lightning connector assembly may extend from the one side (e.g., may extend from the layers of carbon fiber components). The electrical connection of the spar cap to the down conductor may thus be easily performed. As detailed below, the lightning connector assembly comprises a conductive block to facilitate this conduction without the need for lightning protection ears, for instance.

The spar cap structures 110, 210 may be prefabricated. The main body and the lightning connector assembly may be bonded together (e.g., infused together) before being placed on the blade shell mold for manufacturing the corresponding blade shell part. Prefabricating the spar cap structures 110, 210 simplifies the electrical connection between the main body having carbon fibers and the lightning conductor assembly.

The wind turbine blade 7 comprises a reinforcing structure 300 arranged between the upper blade shell part 100 and the lower blade shell part 200. The reinforcing structure 300 provides stiffness to the wind turbine blade 7. The reinforcing structure 300 comprises a first reinforcing beam 310 arranged between the upper spar cap structure 110 and the lower spar cap structure 210. In further examples, the reinforcing structure comprises a first reinforcing beam and a second reinforcing

beam.

The first reinforcing beam 310 of this example extends a length along the spanwise direction 37. The first reinforcing beam 310 may substantially extend between the root portion and the tip portion. The length of the first reinforcing beam 310 may correspond to the length of the spar cap structures 110, 210.

The first reinforcing beam 310 comprises a web 340 extending between an upper flange 320 and a lower flange 330. The upper flange 320 of the first reinforcing beam 310 is joined to the upper blade shell part 100. The upper flange 320 is joined (e.g., bonded) to the upper inner layer 102 at the region of the upper spar cap structure 110. Similarly, the lower flange 330 is joined to the lower inner layer 202 at the region of the lower spar cap structure 210. In this example, the first reinforcing beam 310 and the spar cap structures 110, 210 form the load-carrying structure of the wind turbine blade 7 that serves to withstand loads applied to the wind turbine blade 7.

In this example, the first reinforcing beam 310 comprises a single web. However, in other examples, the first reinforcing beam 310 may comprise two webs extending between the flanges 320 and 330. This configuration may be generally known as a spar box configuration.

An adhesive layer may be arranged between the flanges 320 and 330 and the corresponding inner layer 102 and 202. The adhesive layers join the flanges 320 and 330 to the blade shell parts 100 and 200. The first reinforcing beam 310 may thus be bonded to the upper blade shell part 100 and to the lower blade shell part 200. The spar cap structures 110, 210 are arranged between the corresponding flanges 320, 330 and the outer layer 101, 201.

Figure 4A schematically represents a cross-sectional view of a spar cap structure 210 arranged in a wind turbine blade 7 according to an example of the present disclosure. Figure 4A shows a spar cap structure 210 arranged in the lower blade shell part (a lower spar cap). However, the spar cap arranged within the upper blade shell part (an upper spar cap) may be according to any example of lower spar caps herein disclosed.

The spar cap structure 210 is arranged between the lower outer layer 201 and the lower inner layer 202. The spar cap structure 210 comprises a main body 220

extending between a first side 221 and a second side 222. In this example, the first side 221 is a leading edge side and the second side 222 is a trailing edge side; other examples may be the opposite. The main body 220 comprises a thickness extending in a direction substantially perpendicular to the flapwise direction 39 (i.e., extending between the lower outer layer 201 and the lower inner layer 202).

The main body 220 is formed by a plurality of layers of carbon fiber components arranged one on top of the other. In this example, the carbon fiber components are carbon fiber pultrusions 231 arranged in a unidirectional configuration. The main body 220 comprises rows of carbon fiber pultrusions 231. The main body 220 of this example comprises four rows of carbon fiber pultrusions 231, each row comprising three carbon fiber pultrusions 231. In some examples, the number of carbon fiber pultrusions 231 may vary along the spanwise direction 37 of the blade. The main body 220 may comprise any suitable number of carbon fiber pultrusions 231. In other examples, the layers may be formed by directly placing fibers (e.g., in the form of fabrics).

The carbon fiber pultrusions 231 of this example are plates. The width of the pultrusion plates is several times its thickness, for example, greater than ten times. In some examples, the pultrusion plates comprise a width between 20 mm and 300 mm and a thickness between 1 mm and 6 mm (e.g., 5 mm). In other examples, the pultrusions comprise other suitable cross-sectional shapes (e.g., a rectangular cross-section).

The main body 220 may extend a body length in a direction parallel to the spanwise or lengthwise direction 37 of the wind turbine blade 7 along a length of the corresponding spar cap structure 210. In some examples, the length of the pultrusions of each row or layer varies along the spanwise direction so as to form a stepwise configuration. In further examples, some pultrusions of one row or layer may extend the entire length of the spar cap structure 210.

In other examples, the main body 220 may have a hybrid configuration: carbon fiber pultrusions and other types of fiber pultrusions (e.g., glass fiber pultrusions and/or aramid fiber pultrusions). In some examples, the carbon fiber pultrusions may comprise copper portions. For example, the copper portions may be arranged at each side of the carbon fiber pultrusions. These copper portions may enhance the electrical connectivity of the carbon fiber pultrusions.

The main body 220 of this example comprises a conductive foil or interlayer 232 arranged between two consecutive rows of pultrusions. The conductive interlayer 232 (e.g., a foil or veil) may extend at least the width of the layers or rows of carbon fiber pultrusions 231. In this example, the conductive interlayers 232 extend from the first side 221 to the second side 222. In some examples, the conductive interlayer 232 comprises a thickness of less than 0.5 mm (e.g., 0.05 mm and 0.45 mm).

In some examples, the conductive interlayer 232 comprises carbon fibers. The interlayer 232 may also comprise metal (e.g., copper and/or steel). In some examples, the conductive interlayer 232 comprises carbon fibers in the form of carbon fiber fabric and/or metal conductive wires. The carbon fibers may be arranged in a biaxial configuration. Additionally, or alternatively, the conductive interlayer 232 may comprise copper filaments. In further examples, the conductive interlayer 232 may comprise a hybrid fiber configuration, such as glass/carbon fiber fabric or woven material.

A resin material may be arranged between two consecutive layers or rows of carbon fiber pultrusions 231. Advantageously, the application of the resin between rows of the carbon fiber pultrusions is facilitated by the pattern of the interlayer 232. The electrical conductivity of the conductive interlayer 232 is greater than the electrical conductivity of the resin material.

In this example, each conductive interlayer 232 is sandwiched between two consecutive carbon fiber pultrusions. Alternatively, or additionally, an electrically conductive exterior layer may be arranged on top and/or on the bottom of the main body 220. The electrically conductive exterior layer may be a mesh comprising a metal (e.g., copper). For clarity, the conductive exterior layer is not shown in Figure 4A. The conductive exterior layer 233 is shown in Figures 5A and 5B.

The spar cap structure 210 further comprises a lightning connector assembly 240. In this example, the lightning connector assembly 240 is arranged at the second side 222 of the main body (i.e., at the trailing edge 54 side of the main body 220). The lightning connector assembly 240 is bonded to the second side 222 of the main body. In other examples, the lightning connector assembly 240 may be arranged and bonded to the leading edge 53 side.

The lightning connector assembly comprises a conductive block 280. The conductive block is electrically connected to the main body 220. The conductive block 280 extends a height from an outer end 241 to an inner end 242 in a direction substantially parallel to the thickness of the main body 220. In other words, the conductive block 280 spans a height from the outer end 241 to the inner end of the lightning conductor assembly 240 in a direction substantially parallel to the thickness of the main body 220. The outer end 241 is arranged adjacent to the lower outer layer 201 and the inner end 242 is adjacent to the lower inner layer 202. In this example, the height of the lightning connector assembly 240 substantially corresponds to the thickness of the main body 220. In other examples, the height of the lightning connector assembly 240 may be greater or smaller than the thickness of the main body 220.

The conductive block 280 comprises carbon fibers. The carbon fibers may be in a biaxial arrangement. In some examples, the conductive block 280 comprises copper, aluminium and/or glass fibers in addition to or instead of the carbon fibers.

The conductive block 280 may not have rectangular faces. In other words, the conductive block may have faces with vertices that deviate from 90 degrees. For instance, the conductive block may be trapezoidal. For example, the conductive block 280 may comprise no more than one pair of parallel faces. A first face of the pair of parallel faces may have a greater area than the second face of the pair of parallel faces. The conductive block 280 may be arranged such that the first face faces (e.g., abuts) the main body 220 and the second face faces away from the main body 220. In this example, the first face of the conductive block 280 may be bonded to the second side 222 of the main body. In other examples, the first face of the conductive block 280 may be bonded to the first side of the main body. Resin may be used for bonding the conductive block 280 to the main body. The first face and the second face may thus be the parallel faces of a trapezoidal conductive block. Advantageously, this arrangement may facilitate electrical connection of the conductive block 280 to the main body 220. For instance, this arrangement may facilitate attachment of the conductive block 280 to the main body, such as infusion of the conductive block 280 with the main body, thereby increasing the stability of the spar cap structure 110, 210. More generally, advantageously, this geometry reduces local stresses and enables easier cleaning and maintenance of molds used in the manufacture of the conductive block 280.

In the case that the conductive block 280 comprises carbon fibers in a biaxial arrangement or carbon and glass, the conductive block 280 typically has a width of 30 – 70 mm and a length of 200 – 600 mmm. For example, the conductive block may have a width of 50 mm and a length of 400 mm.

In the example shown in Figure 4A, the conductive block 280 is uninterrupted from the outer end 241 to the inner end 242. In other words, the conductive block 280 is a continuous, integral structure. Advantageously, manufacturing an uninterrupted conductive block is straightforward and low cost.

Advantageously, the inclusion of the block enables the conductive interlayers 232 to be electrically connected to the down conductor of the wind turbine blade 7 in a simple manner. The electrical connection between the conductive interlayers 232 and the lightning protection system may thus be performed before forming the whole wind turbine blade 7. As a result, the number of elements is reduced and some post-operation tasks, such as machining the blade shell to mount the typical copper disc, are rendered unnecessary, thereby increasing the structural integrity of the blade 7 and reducing manufacturing and maintenance costs.

The wind turbine blade 7 of this example further comprises a down conductor 410 extending in a direction substantially parallel to the lengthwise direction 37. The down conductor 410 may substantially extend to the entire length of the wind turbine blade 7. The down conductor 410 is configured to be electrically coupled to the ground so as to conduct lightning currents to the ground.

In this example, the down conductor 410 is supported by the web 340 of the first reinforcing beam 310. In other examples, the down conductor 410 may be coupled to the lower flange 330 or the upper flange of the first reinforcing beam 310.

In this example, a cable 420 electrically connects the lightning connector assembly 240 to the down conductor 410. One end of this cable 420 is attached to the inner end 242 of the lightning connector assembly 240 (e.g., coiled around a fastener 421 screwed on the inner end 242 of the lightning connector assembly 240). The opposite end of the cable 420 is attached to the down conductor 410.

In some examples, the spar cap structure 210 may additionally comprise a conductive assembly extending from the main body 220 to the lightning connector

assembly 240. The metal conductive assembly may comprise conductive elements having an end connected to the lightning connector assembly 240 and another end connected to the layers of carbon fiber components. The conductive elements may comprise metal conductive elements (e.g., a thread of copper wires and/or carbon fibers). These conductive elements may be used for connecting the interlayers 232 to the conductive elements. The conductive elements may be at least partially arranged between two consecutive layers of carbon fiber components (e.g., embedded in the interlayers 232).

The main body 220, the conductive block and the lightning connector assembly 240 may be assembled before being placed on the blade shell mold. For example, these components may be infused together. In other examples, some of these components may be separately infused and then connected to each other to form the spar cap structure 210. At least some of these elements may be infused together with the blade shell in the blade shell mold.

Figure 4B schematically represents a cross-sectional view of a spar cap structure 210 arranged in a wind turbine blade 7 according to an example of the present disclosure. The spar cap structure 210 of this example corresponds to the spar cap structure 210 of Figure 4A apart from the configuration of the conductive block 280 and the interlayer 232.

In the alternative example shown in Figure 4B, the interlayer 232 continues through the conductive block. By extending through the conductive block 280, the interlayer 232 divides the conductive block 280 into discrete portions. The difference between the spar cap structure 210 of Figure 4B compared with the spar cap structure of Figure 4A can be better understood by comparing Figure 5A with Figure 5B, both of which are discussed below.

Figure 4C schematically represents a cross-sectional view of a spar cap structure 210 arranged in a wind turbine blade 7 according to another example of the present disclosure. The main body 220 of this example comprises a plurality of layers of carbon fiber components. The layers of this figure are carbon fiber fabric layers 235. The carbon fiber fabric layers 235 are arranged one on top of the other. Each of the carbon fiber fabric layers 235 of this example extends from the first side 221 to the second side 222 of the main body 220. The example shown in Figure 4C does not include the interlayer 232. Other features in Figure 4C correspond to those in Figures

4A and 4B.

Figures 4D and 4E schematically represent a cross-sectional view of a spar cap structure 210 arranged in a wind turbine blade according to another example of the present disclosure in which the conductive block 280 comprises a lightning receptor 400 and an electrical pin 430. The spar cap structure 210 shown in Figures 4D and 4C corresponds to that shown in Figures 4A and 4B, respectively, part from the addition of the lightning receptor 400 and the electrical pin 430.

In the examples shown in Figures 4D and 4E, the lightning receptor 400 is connected to the outer end 241 of the lightning connector assembly 240. The lightning receptor 400 passes through the outer layer 201 and is inserted into a hole arranged at the outer end 241 of the lightning receptor 400. The lightning receptor 400 is thus electrically coupled to the lightning connector assembly 240. The hole may be a threaded hole to thread an upper end of the lightning receptor 400. The lightning receptor 400 of this example comprises an outer portion arranged outside the wind turbine blade 7 to capture lightning strikes. The lightning receptor 400 of this figure comprises a substantial T-shape. As can be seen in Figures 4D and 4E, the lightning receptor 400 contacts the lightning connector assembly 240. A current path may thus be created towards the down conductor 410.

In some examples, the wind turbine blade 7 comprises a plurality of lightning receptors 400 connected to the outer end 241 of the lightning connector assembly 240. A plurality of cables 420 may connect the inner end 242 of the lightning connector assembly 240 to the down conductor 410. Each of the cables 420 may be associated with a lightning receptor 400.

The electrical pin 430 is connectable to the down conductor 410, typically at the inner end. The electrical 430 pin passes through the conductive block 280 substantially parallel to the second side 22, meeting the lightning receptor at the outer layer 201. The electrical pin connects the conductive block 280 (Figure 4D) or the interlayer 232 and the conductive block 280 (Figure 4E), by direct contact therewith, to the lightning receptor, facilitating the current path towards the down conductor 410.

Figure 5A schematically represents an isometric view of a part of a spar cap structure 210 according to one example of the present disclosure, and Figure 5B represents an isometric view of a spar cap structure 210 according to another example of the

present disclosure. Figures 5A and 5B substantively correspond to Figures 4A and 4B, respectively. Figures 5A and 5B do not show the down conductor 410, web 340, first reinforcing beam 310, lower flange 330 or cable 420 merely for clarity. Figures 5A and 5B show three layers of carbon fiber components (i.e., carbon fiber pultrusions 231) compared with the four layers of carbon fiber components (i.e., carbon fiber pultrusions 231) shown in Figures 4A and 4B; as alluded to earlier, the main body 220 is not restricted to comprising a particular number of layers of carbon fiber components (i.e., carbon fiber pultrusions 231).

Unlike Figure 5A, which, as in for the example of Figure 4A, shows an uninterrupted conductive body 280, Figure 5B shows the interlayer 232 dividing the conductive block into discrete portions, resulting in the conductive block 280 comprising a first portion 281, a second portion 282 and a third portion 283. Each of this plurality of portions has a same thickness as a corresponding one of the plurality of layers (e.g., the first portion 281 has the same thickness as the layer of carbon fiber components closest to the outer end). Advantageously, this arrangement of the conductive block 280 (Figure 5B) increases the efficiency of lightning conduction compared with an uninterrupted conductive block 280 (Figure 5A).

As mentioned above in relation to Figure 4A, Figures 5A and 5B show the electrically conductive exterior layer 233. The electrically conductive exterior layer 233 may be electrically connected to the conductive block 280 to further improve the efficiency of lighting conduction provided by the lightning connector assembly 240. For instance, the electrically conductive exterior layer 233 may be in contact with the conductive block 280.

In Figures 5A and 5B, two conductive blocks 280 are shown. However, it should be appreciated that a single conductive block 280 or more than two conductive blocks 280 may be distributed along the lengthwise direction 37. In some examples, a foam material may be arranged between two consecutive conductive blocks 280 along the lengthwise direction 37. This foam material may thus fill the gap between two conductive blocks 280.

The wind turbine blade 7 may comprise a receiving part configured to engage the spar cap structure 110, 210. Such a receiving part 285 is shown in Figure 5C, which is based on Figure 5B. The receiving part 285 may be intermediate with respect to the spar cap structure 110, 210 and the core structure. The receiving part 285 may

conform to a surface defined by the main body 220 and the conductive block(s) 280. In other words, a surface of the receiving part 285 in contact with the spar cap structure 210 may have a geometry that is complementary thereto. The receiving part 285 may be foam.

Figure 6 is a block diagram of a method for manufacturing the spar cap structure 110, 210 according to any example of the present disclosure.

The method 500 comprises forming 510 the main body 220, as described in relation to Figures 4A – 5C, by stacking a plurality of layers of one or more carbon fiber components between a first side 221 and a second side 222 of the main body 220. The plurality of layers of one or more carbon fibers, resultingly, at least in part, defines a thickness of the main body 220.

In some examples, carbon fiber fabrics may be laid on the spar cap mold to form the main body 220. In other examples, a plurality of carbon fiber pultrusions 231 may be arranged on the spar cap mold to form rows of carbon fiber pultrusions 231. A conductive interlayer 232 may be arranged between two consecutive rows of carbon fiber pultrusions 231.

The method 500 further comprises arranging 520 a lightning connector assembly 240, which includes the conductive block 280, as described in relation to Figures 4A, 4B, 5A and 5B.

The method further comprises electrically connecting 530 conductive block 280 to the main body 220. Electrically connecting 530 conductive block 280 to the main body 220 may comprise attaching the conductive block 280 to the main body 220.

The method further comprises bonding 540 the lightning connector assembly 240 to the main body 220. The main body 220 and the lightning connector assembly 240 may be infused together. The conductive assembly 280 may also be infused together with the main body 220 and the lightning connector assembly 240. Resin may thus be injected into the spar cap mold to fill the gaps between the layers forming the main body 220 and the lightning connector assembly 240. Then, this resin is cured to form a prefabricated spar cap structure 110, 210. This method may help to automatize the manufacturing process and arranging the stacks on the outer layer may be simplified. Accordingly, the spar cap structure 110, 210 may be prefabricated before being

arranged on top of the outer layer 101, 201 placed on the blade mold. Furthermore, the electrical connections may be simplified. In other examples, the lightning connector assembly 240 may be attached to an infused main body 220 to form a prefabricated spar cap 110, 210.

In further examples, the main body 220 and the lightning connector assembly 240 may be placed in a blade shell mold to be infused together with the blade shell.

Figure 7 is a block diagram of a method for manufacturing a wind turbine blade 7 according to one example of the present disclosure. The method may be used for manufacturing a wind turbine blade 7 according to any of the examples herein. These wind turbine blades 7 include the spar cap structure 110, 210 according to any of the examples herein.

The method comprises forming 610 the upper blade shell part 100 and the lower blade shell part 200. Forming 610 the upper blade shell part 100 and the lower blade shell part 200 comprises arranging the spar cap structure 110, 210 on an outer layer laid in a blade shell part mold and bonding the spar cap structure 110, 210 to the outer layer 201.

The method may comprise laying the outer layer 101, 201 in a blade shell mold (e.g., laying one or more glass fiber laminates). These glass fiber laminates may comprise bidirectional glass fibers. The spar cap structure 110, 210 may then be laid on the outer layer 101, 201.

As previously explained, the spar cap structure 110, 210 may be pre-bonded or prefabricated before being arranged on top of the outer layer 101, 201. Alternatively, spar cap structure 110, 210 may be formed on the outer layer 101, 201. The spar cap structure 110, 210 may be manufactured according to any of the examples herein.

Then, the inner layer 102, 202 may be laid on top of the spar cap structure 110, 210. The inner layer 102, 202 may comprise one or more glass fiber laminates (e.g., have bidirectional glass fibers).

In some examples, a core structure or a plurality of core structures may be placed adjacent to the spar cap structure 110, 210. The inner layer may be placed on top of these core structures.

The spar cap structure 110, 210 (prefabricated or directly arranged on top of the outer layer) may be bonded to the outer layer 101, 201 and to the inner layer 102, 202 to form the blade shell part 100, 200. In some examples, bonding the spar cap structure 110, 210 to the outer layer 101, 201 and to the inner layer 102, 202 comprises molding the inner layer, the spar cap structure and the outer layer together with a resin infusion technology. Once the inner layer covers the spar cap structure and the outer layer, resin is injected into the mold cavity under pressure. This resin fills the volume between the stacks and the layers. Then, the resin is cured or hardened. Accordingly, the spar cap structure 110, 210 may be bonded to the inner layers and to the outer layers by using a resin infusion process. After curing, a blade shell part may be obtained.

The method further comprises joining (620) the reinforcing structure 300 to the upper blade shell part 100 and to the lower blade shell part 200 such that the reinforcing structure 300 is arranged between the upper blade shell part 100 and the lower blade shell part 200. The first reinforcing beam 310 may thus be joined to the upper and to the lower blade shell parts. The lower flange 330 of the first reinforcing beam 310 may be joined to the lower blade shell part 200 and the upper flange 320 of the first reinforcing beam 310 to the upper blade shell part 100.

Joining the flanges 320, 330 with the corresponding blade shell part 100, 200 may comprise adhering or bonding the flanges 320, 330 to the corresponding inner layers 102, 202 of the blade shell parts 100, 200. An adhesive layer may thus be formed between the flanges 320, 330 and the inner layers 102, 202.

At block 630, joining the upper blade shell part 100 to the lower blade shell part 200 is represented. The blade shell parts may be bonded together through bonding lines formed at the leading edge 53 and at the trailing edge 54.

In some examples, the method further comprises inserting a plurality of lightning receptors into the lightning connector assembly 240 (e.g., into the outer end 241 of the lightning connector assembly 240). The lightning receptors 400 may be positioned at different locations of the wind turbine blade along the spanwise direction 37. In some examples, the lightning receptors 400 may be arranged at both the upper blade shell part 100 and the lower blade shell part 200.

In some examples, inner end 242 of the lightning connector assembly 240 may be connected to the down conductor (e.g., through a cable).

For reasons of completeness, various aspects of the present disclosure are set out in the following numbered clauses:

Clause 1: A spar cap structure for a wind turbine blade, the spar cap structure comprising:

a main body comprising a first side and a second side, wherein the main body comprises a plurality of layers of one or more carbon fiber components, each of these layers being arranged one on top of the other between the first and the second sides, whereby the main body spans a thickness; and

a lightning connector assembly bonded to one of the sides of the main body, wherein the lightning connector assembly comprises a conductive block electrically connected to the main body, wherein the conductive block spans a height from an outer end to an inner end of the lightning conductor assembly in a direction substantially parallel to the thickness of the main body, and wherein the inner end is connectable to a down conductor of a lightning protection system of a wind turbine blade.

Clause 2: The spar cap structure according to clause 1, wherein the conductive block comprises an electrical pin connectable to the down conductor.

Clause 3: The spar cap structure according to clause 1 or 2, wherein the layers of one or more carbon fiber components comprise carbon fiber fabric layers.

Clause 4. The spar cap structure according to clause 1 or 2, wherein the layers of one or more carbon fiber components comprise carbon fiber pultrusions.

Clause 5: The spar cap structure according to clause 4, wherein the main body comprises an interlayer material arranged between two consecutive layers of carbon fiber pultrusions.

Clause 6: The spar cap structure according to clause 5, wherein the interlayer material comprises carbon fibers in a biaxial arrangement.

Clause 7: The spar cap structure according to any preceding clause, comprising an

electrically conductive exterior layer, wherein the electrically conductive exterior layer is arranged on top and/or on the bottom of the main body and is electrically connected to the conductive block.

Clause 8: The spar cap structure according to clause 7, wherein the electrically conductive exterior layer is a copper mesh.

Clause 9: The spar cap structure according to any preceding clause, wherein the conductive block comprises carbon fibers in a biaxial arrangement.

Clause 10: The spar cap structure according to any preceding clause, wherein the conductive block comprises copper, aluminum and/or glass fibers.

Clause 11: The spar cap structure according to any preceding clause, wherein the conductive block has vertices that deviate from 90 degrees.

Clause 12: The spar cap structure according to any preceding clause, wherein the conductive block comprises carbon fibers in a biaxial arrangement or carbon and glass, and wherein the conductive block has a width of 30 - 70 mm and a length of 200 – 600 mm.

Clause 13: The spar cap structure according to any preceding clause, wherein the conductive block is uninterrupted from the outer end to the inner end.

Clause 14: The spar cap structure according to any of clauses 5 - 12, wherein the interlayer material continues through the conductive block.

Clause 15: The spar cap structure according to clause 14, wherein the conductive block comprises a plurality of portions, wherein each portion has a same thickness as a corresponding one of the plurality of layers.

Clause 16. The spar cap structure according to any preceding clause, comprising a plurality of the conductive blocks.

Clause 17: The spar cap structure according to any preceding clause, wherein the outer end is connectable to a lightning receptor.

Clause 18: The spar cap structure according to any preceding clause, wherein the conductive block comprises a first side facing the one of the sides (221, 222) of the main body and a second side facing away the one of the sides (221, 222), wherein the first side of the conductive block is bonded to the one of the sides (221, 222) of the main body..

Clause 19: A wind turbine blade extending in a lengthwise direction, the wind turbine blade comprising:

an upper blade shell part;

a lower blade shell part joined to the upper blade shell part;

a reinforcing structure between the upper blade shell part and the lower blade shell; and

wherein the upper blade shell part and/or the lower blade shell part comprises a receiving part configured to engage the spar cap structure according to any of clauses 1 – 18.

Clause 20: A method for manufacturing a spar cap structure comprising:

forming a main body by stacking a plurality of layers of one or more carbon fiber components between a first side and a second side of the main body, whereby the main body spans a thickness;

arranging a lightning connector assembly at one side of the sides of the main body, wherein the lightning connector assembly comprises a conductive block, wherein the conductive block spans a height from an outer end to an inner end of the lightning conductor assembly in a direction substantially parallel to the thickness of the main body, and wherein the inner end is connectable to a down conductor of a lightning protection system of a wind turbine blade;

electrically connecting the conductive block to the main body; and

bonding the lightning connector assembly to the main body.

Clause 21: A method for manufacturing a wind turbine blade according to clause 17, comprising:

forming the upper blade shell part and the lower blade shell part, wherein forming the upper blade shell part and/or the lower blade shell part comprises:

arranging the spar cap structure on an outer layer laid in a blade shell part mold; and

bonding the spar cap structure to the outer layer;

joining the reinforcing structure to the upper blade shell part and to the lower

blade shell part such that the reinforcing structure is arranged between the upper blade shell part and the lower blade shell part; and

joining the upper blade shell part to the lower blade shell part.

This written description uses examples to disclose the invention, including the preferred embodiments, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims. Aspects from the various embodiments described, as well as other known equivalents for each such aspects, can be mixed and matched by one of ordinary skill in the art to construct additional embodiments and techniques in accordance with principles of this application. If reference signs related to drawings are placed in parentheses in a claim, they are solely for attempting to increase the intelligibility of the claim and shall not be construed as limiting the scope of the claim.

CLAIMS

1. A spar cap structure (110, 210) for a wind turbine blade (7), the spar cap structure (110, 210) comprising:

a main body (220) comprising a first side (221) and a second side (222), wherein the main body (220) comprises a plurality of layers of one or more carbon fiber components, each of these layers being arranged one on top of the other between the first (221) and the second sides (222), whereby the main body (220) spans a thickness; and

a lightning connector assembly (240) bonded to one of the sides (221, 222) of the main body (220), wherein the lightning connector assembly (240) comprises a conductive block (280) electrically connected to the main body (220), wherein the conductive block (280) spans a height from an outer end (241) to an inner end (242) of the lightning conductor assembly (240) in a direction substantially parallel to the thickness of the main body (220), and wherein the inner end (242) is connectable to a down conductor of a lightning protection system of a wind turbine blade (7).

2. The spar cap structure (110, 210) according to claim 1, wherein the conductive block (280) comprises an electrical pin connectable to the down conductor.

3. The spar cap structure (110, 210) according to claim 1 or 2, wherein the layers of one or more carbon fiber components comprise carbon fiber fabric layers (235).

4. The spar cap structure (110, 210) according to claims 1 or 2, wherein the layers of one or more carbon fiber components comprise carbon fiber pultrusions (231).

5. The spar cap structure (110, 210) according to claim 4, wherein the main body (220) comprises an interlayer material (232) arranged between two consecutive layers of carbon fiber pultrusions (231).

6. The spar cap structure (110, 210) according to any preceding claim, wherein the conductive block (280) comprises carbon fibers in a biaxial arrangement.

7. The spar cap structure (110, 210) according to any preceding claim, wherein the conductive block (280) comprises copper, aluminum and/or glass fibers.

8. The spar cap structure (110, 210) according to any preceding claim, wherein the conductive block (280) has vertices that deviate from 90 degrees.

9. The spar cap structure (110, 210) according to any preceding claim, wherein the conductive block (280) is uninterrupted from the outer end (241) to the inner end (242).

10. The spar cap structure (110, 210) according to any of claims 5 - 8, wherein the interlayer material (232) continues through the conductive block (280).

11. The spar cap structure (110, 210) according to claim 10, wherein the conductive block (280) comprises a plurality of portions (281, 282, 283, 284), wherein each portion has a same thickness as a corresponding one of the plurality of layers.

12. The spar cap structure (110, 210) according to any preceding claim, comprising a plurality of the conductive blocks (280).

13. The spar cap structure (110, 210) according to any preceding claim, wherein the conductive block (280) comprises a first side facing the one of the sides (221, 222) of the main body and a second side facing away the one of the sides (221, 222), wherein the first side of the conductive block is bonded to the one of the sides (221, 222) of the main body.

14. A wind turbine blade (7) extending in a lengthwise direction (37), the wind turbine blade (7) comprising:

an upper blade shell part (100);

a lower blade shell part (200) joined to the upper blade shell part (100);

a reinforcing structure (300) between the upper blade shell part (100) and the lower blade shell (200); and

wherein the upper blade shell part (100) and/or the lower blade shell part (200) comprises a receiving part configured to engage the spar cap structure (110, 210) according to any of claims 1 – 13.

15. A method (500) for manufacturing a spar cap structure (110, 210) comprising:

forming (510) a main body (220) by stacking a plurality of layers of one or more carbon fiber components between a first side (221) and a second side (222) of the main body (220), whereby the main body (220) spans a thickness;

arranging (520) a lightning connector assembly (240) at one side of the sides (221, 222) of the main body (220), wherein the lightning connector assembly (240) comprises a conductive block (280), wherein the conductive block (280) spans a height from an outer end (241) to an inner end (242) of the lightning conductor assembly (240) in a direction substantially parallel to the thickness of the main body (220), and wherein the inner end (242) is connectable to a down conductor of a lightning protection system of a wind turbine blade (7);

electrically connecting (530) the conductive block (280) to the main body (220); and

bonding (540) the lightning connector assembly (240) to the main body (220).

FIGURES

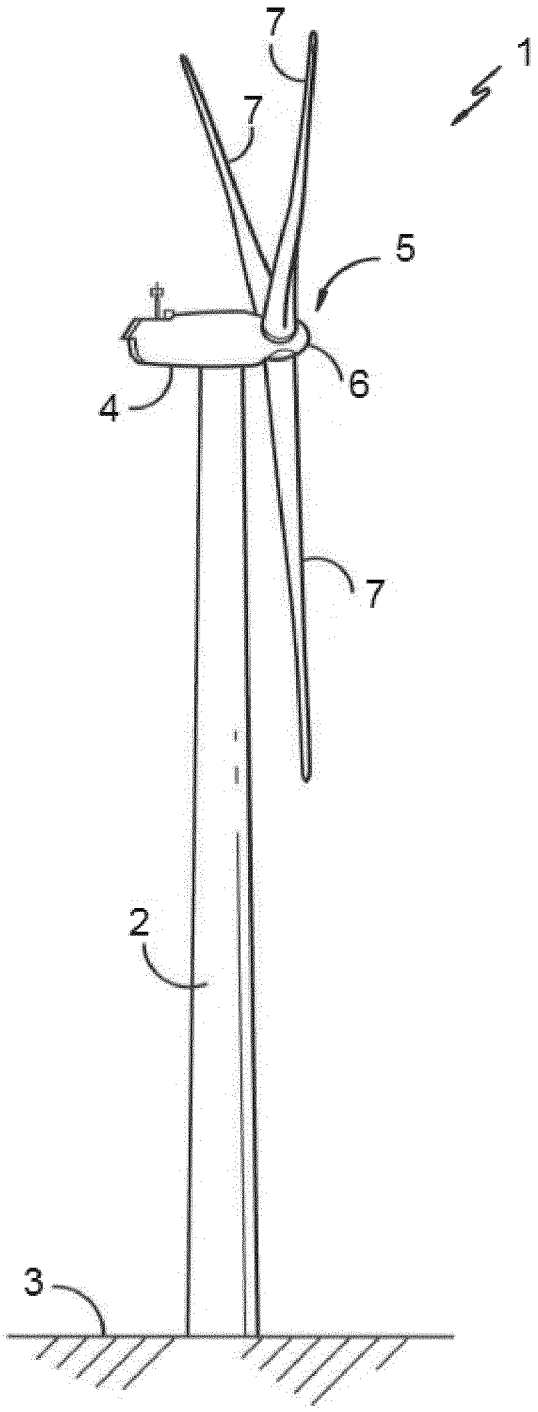


Figure 1

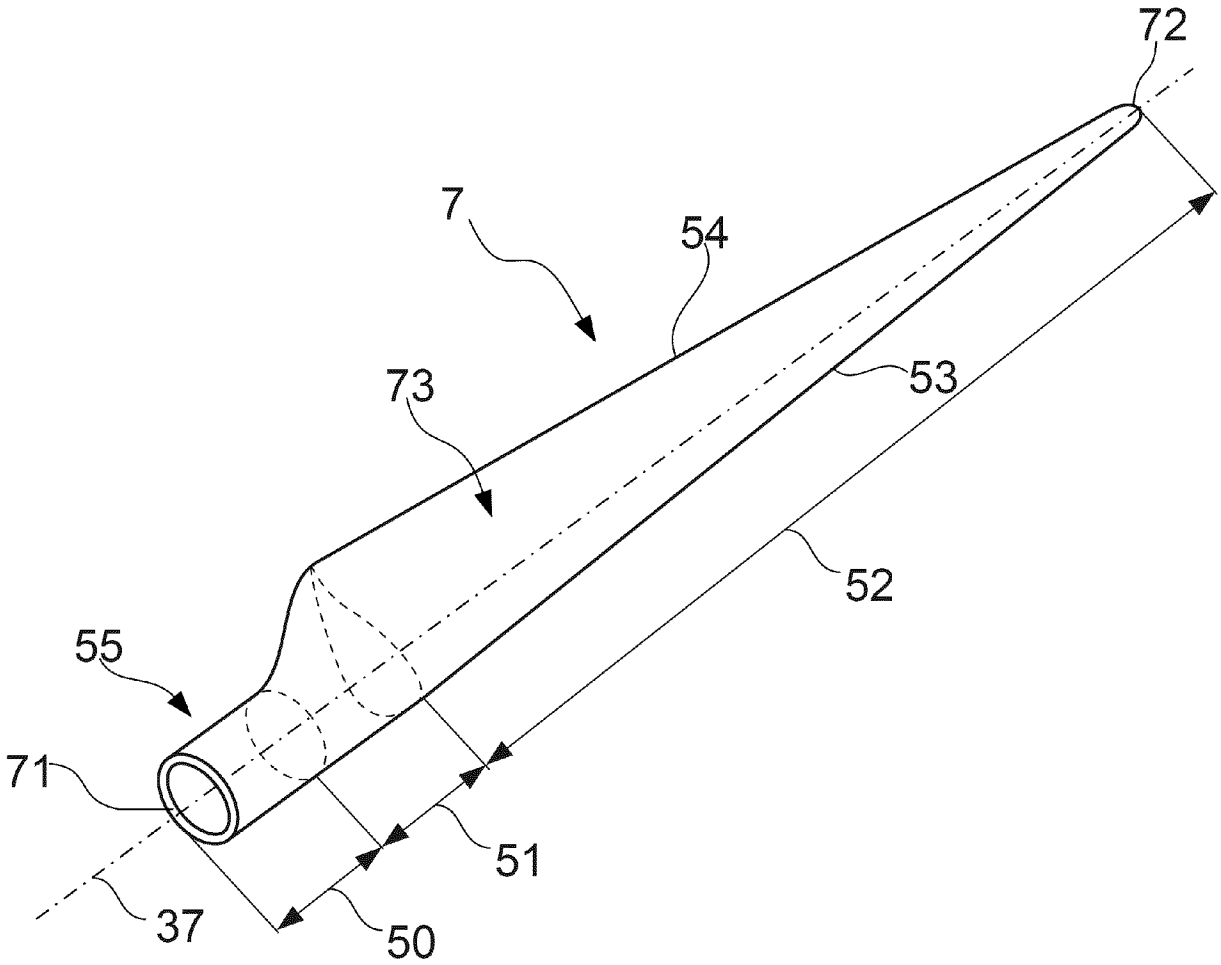


Figure 2

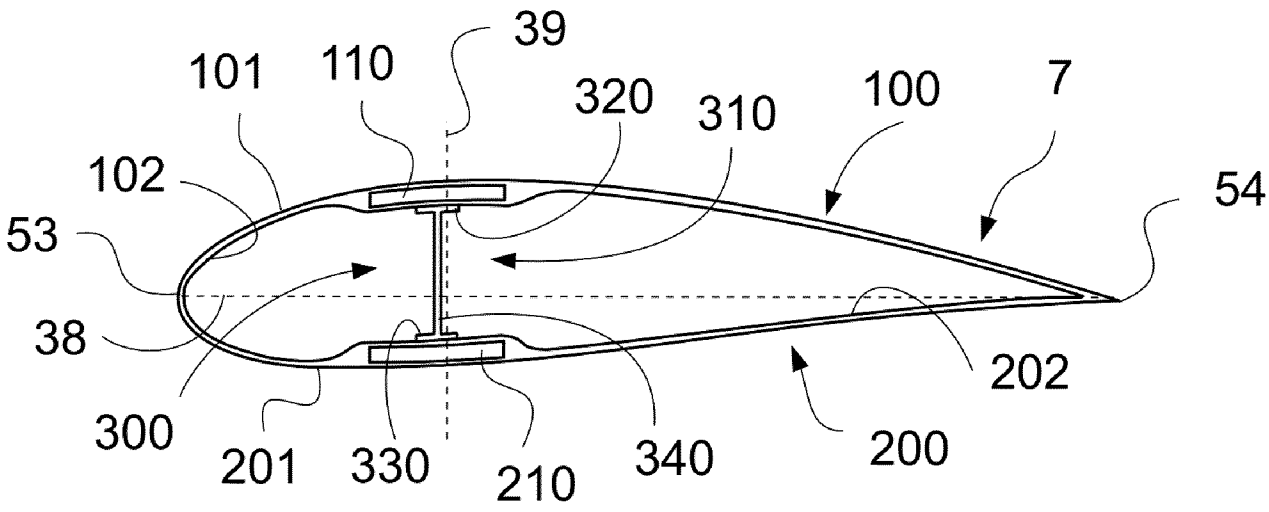


Figure 3

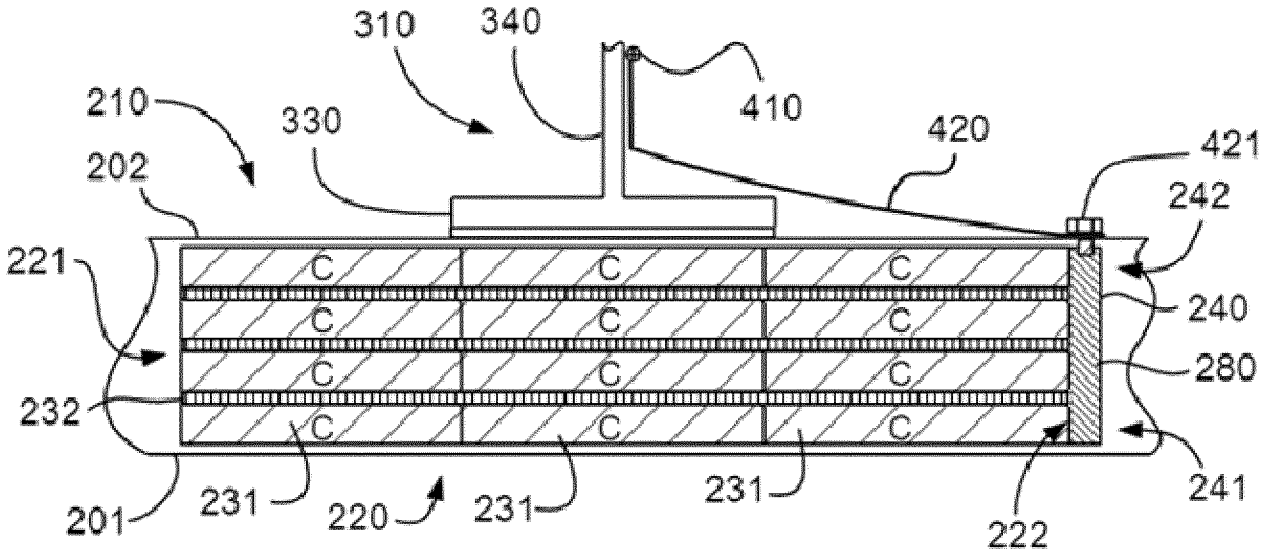


Figure 4A

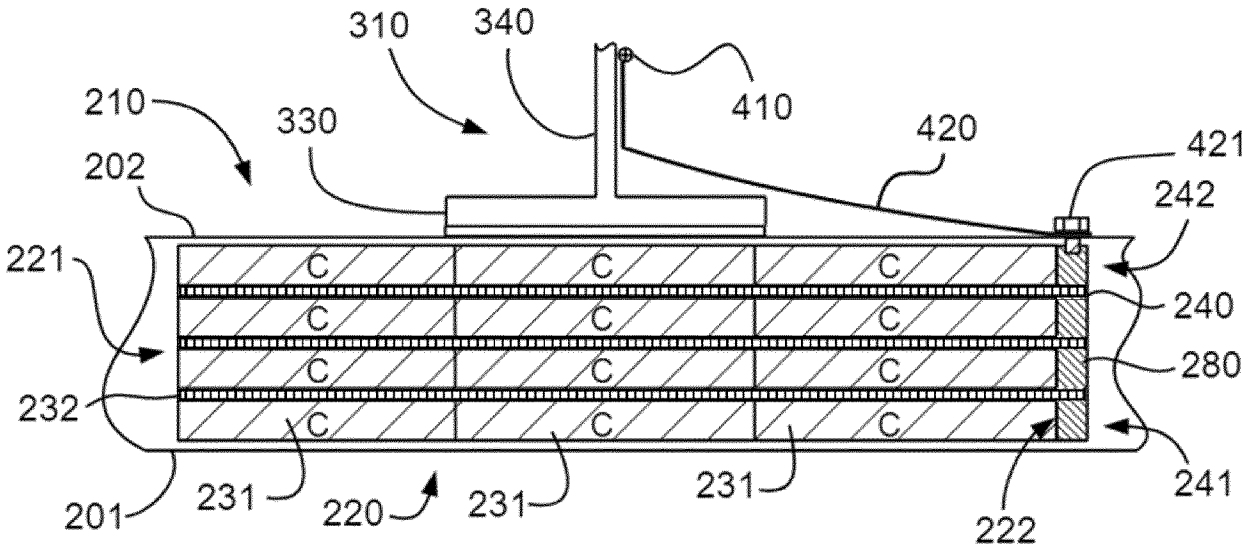


Figure 4B

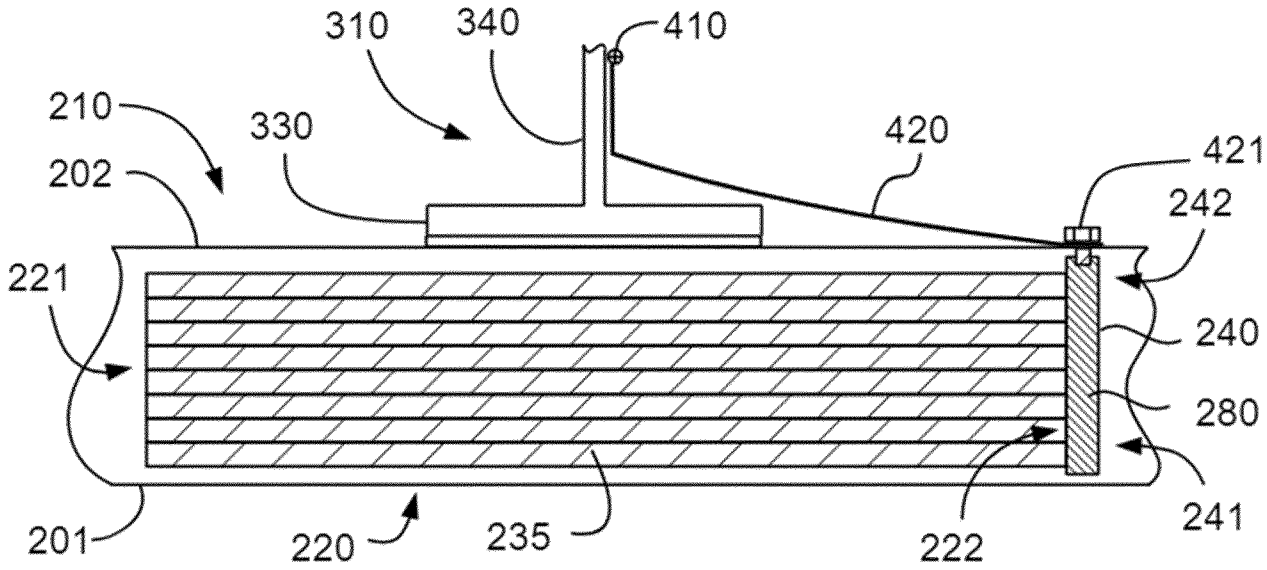


Figure 4C

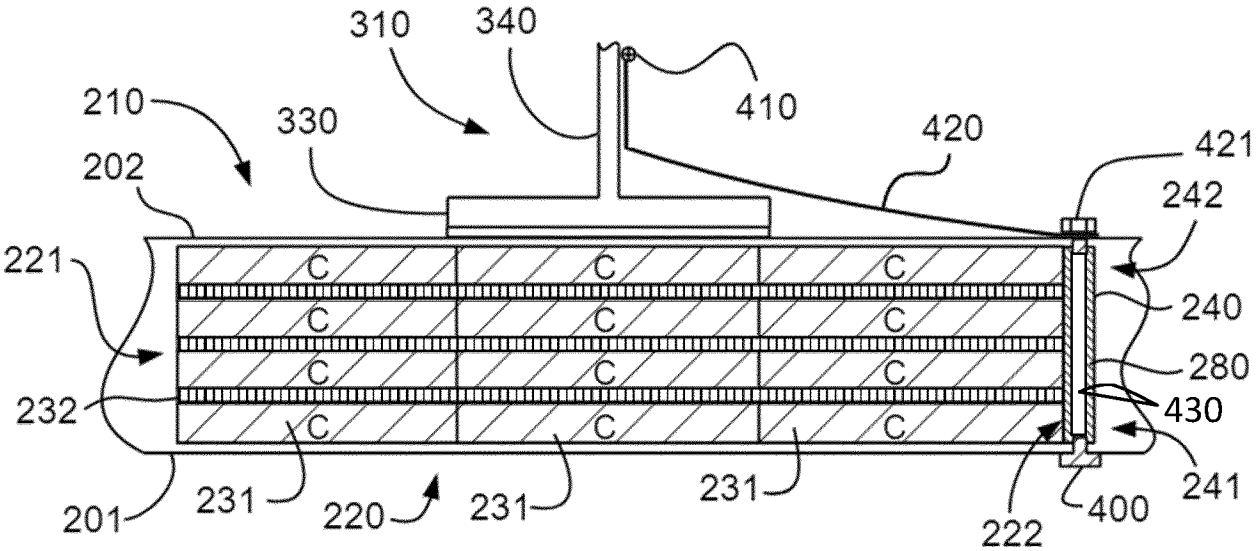


Figure 4D

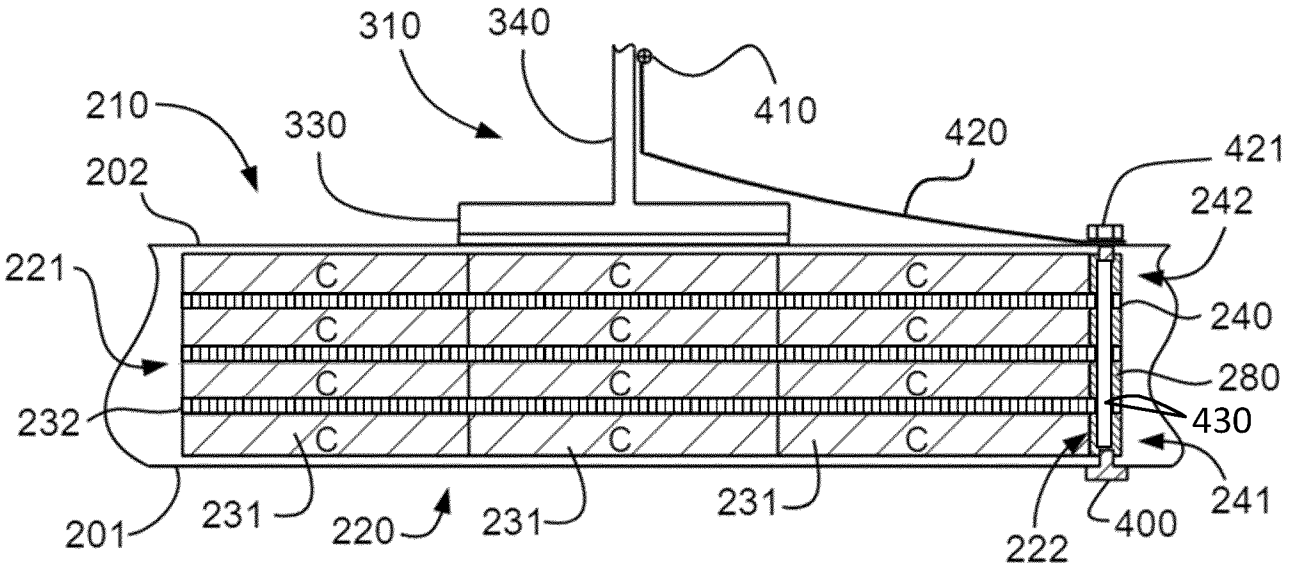


Figure 4E

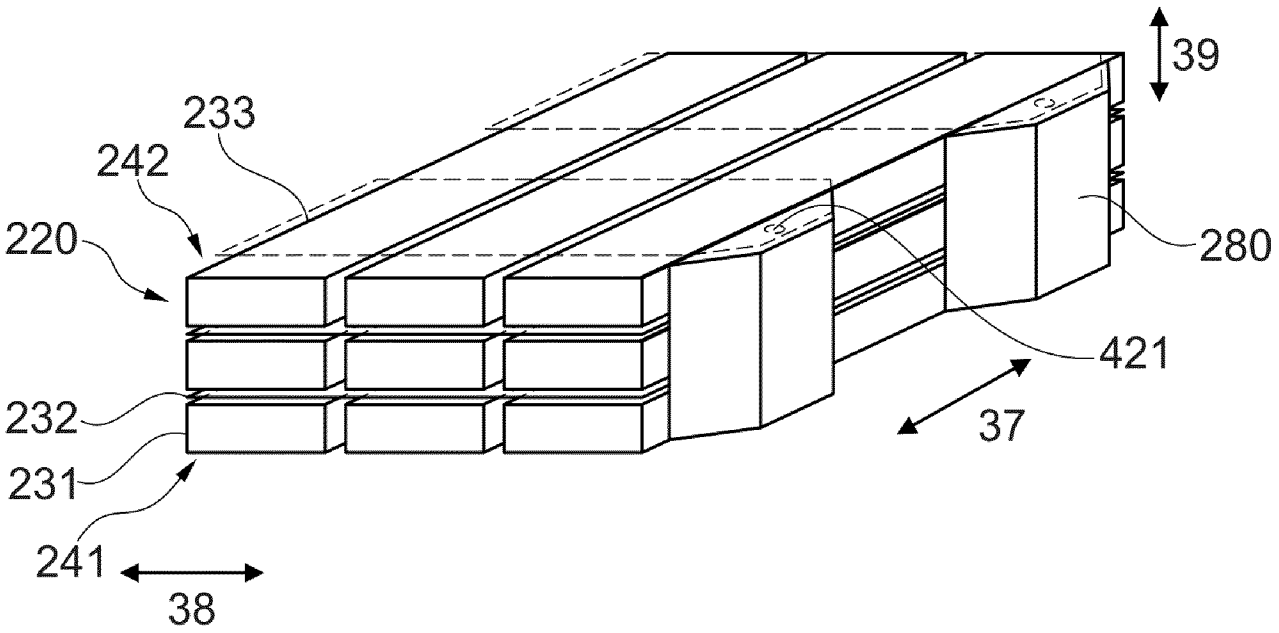


Figure 5A

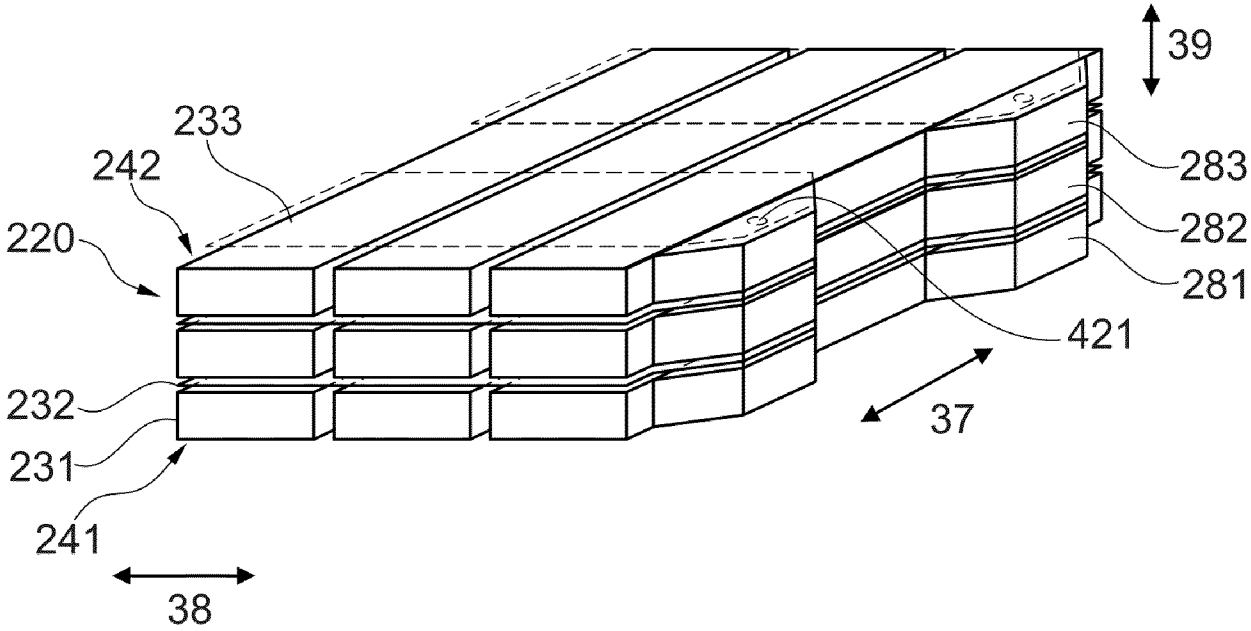


Figure 5B

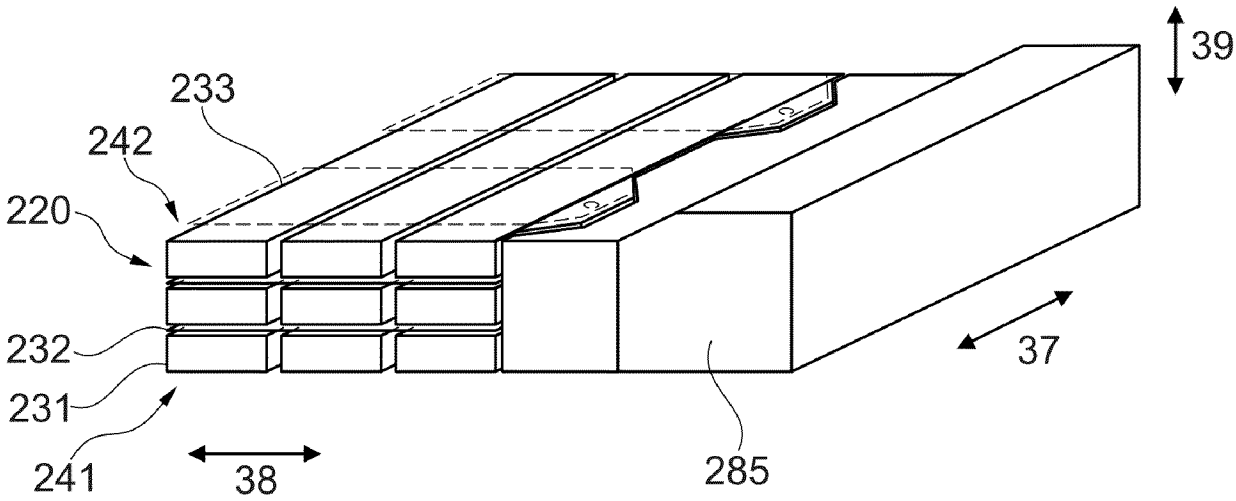


Figure 5C

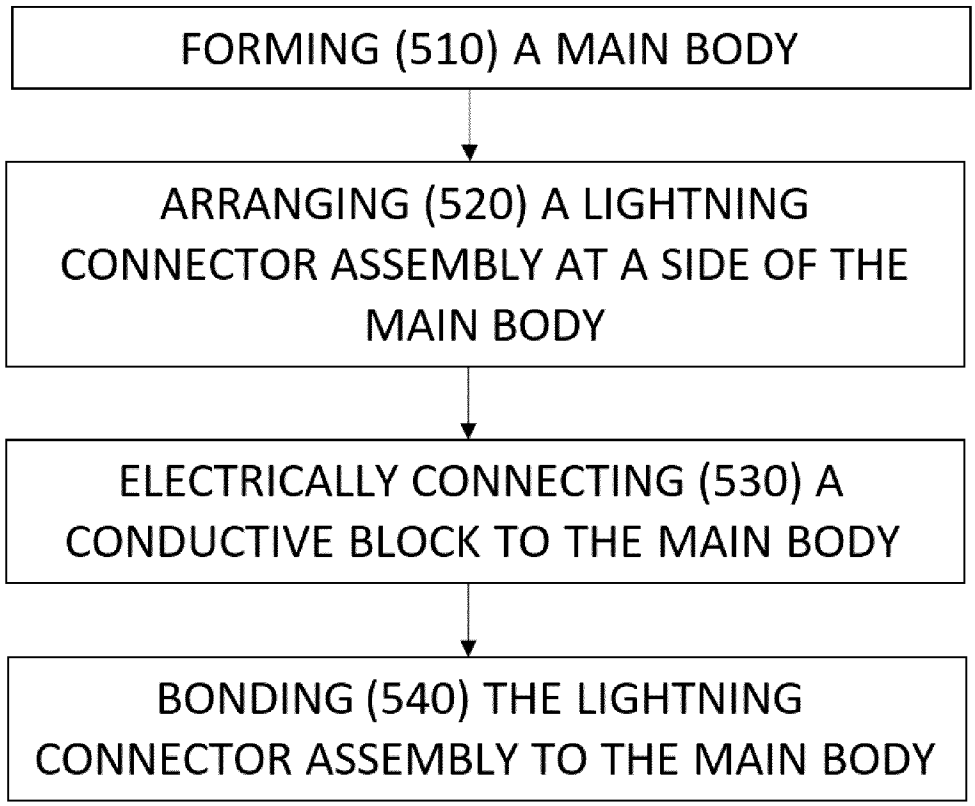


Figure 6

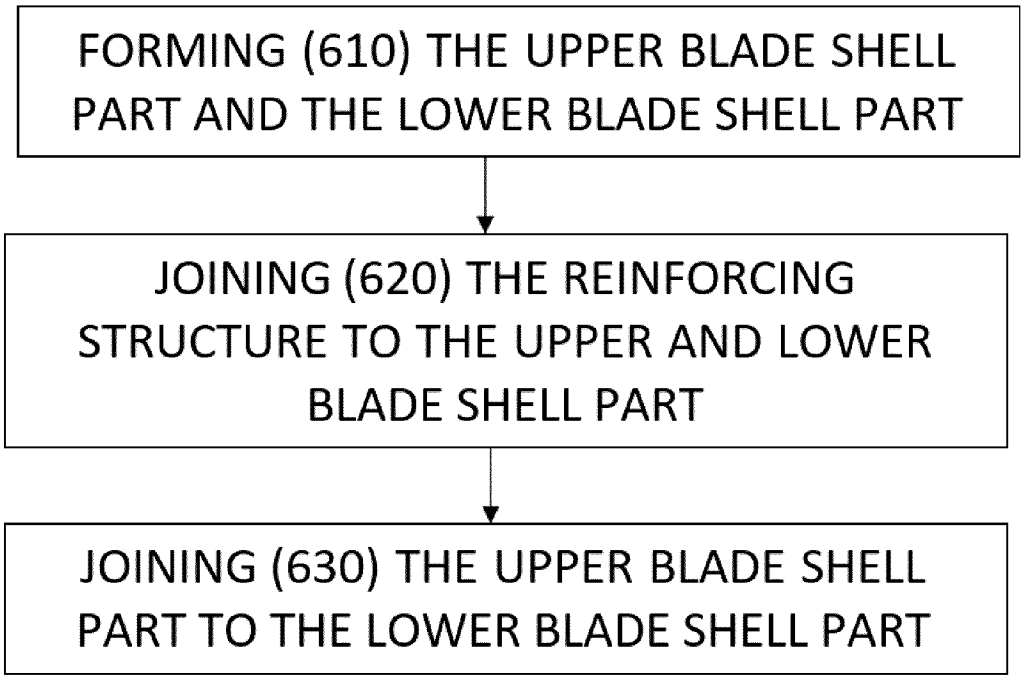


Figure 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2024/070121

A. CLASSIFICATION OF SUBJECT MATTER
INV. F03D1/06 F03D80/30
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F03D B29D B29L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2020/300214 A1 (BURCHARDT CLAUS [DK] ET AL) 24 September 2020 (2020-09-24) paragraph [0009]; figures 1-4 paragraph [0030] - paragraph [0032] -----	1-15
X	EP 4 086 449 A1 (LM WIND POWER AS [DK]) 9 November 2022 (2022-11-09) paragraph [0001] paragraph [0008] - paragraph [0023] paragraph [0026] - paragraph [0045] paragraph [0053] - paragraph [0068]; figures 1-6,8,9a,9b paragraph [0070] - paragraph [0085]; figures 11A-11E ----- -/--	1-15

[x] Further documents are listed in the continuation of Box C. [x] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
9 September 2024	24/09/2024

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Herdemann, Claire

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INTERNATIONAL SEARCH REPORT

International application No
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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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X	WO 2020/104585 A1 (SENVION GMBH [DE]) 28 May 2020 (2020-05-28) page 2, line 22 - page 4, line 2; figures 1-3	1-15

X	WO 2022/106351 A1 (LM WIND POWER AS [DK]) 27 May 2022 (2022-05-27) page 13, line 29 - page 15, line 17; figures 3,4,10-12	1-15

A	WO 2022/023586 A1 (NABRAWIND TECH SL [ES]) 3 February 2022 (2022-02-03) the whole document	1-15

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International application No
PCT/EP2024/070121

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