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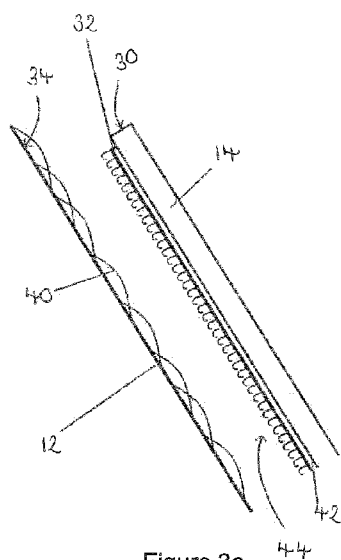


Figure 3a

(57) Abstract: A method of manufacturing a wind turbine component having a composite shell structure is described. One or more first layers of dry fibrous fabric are arranged in a mould and a further component of the shell structure is fastened on or against the first layer(s) by means of a hook fastener element. The hook fastener element comprises a multitude of hooks which are configured to grip fibres of the first layer(s) to secure the further component to the first layer(s) according to the principles of a hook-and-loop fastening mechanism.

A METHOD OF MANUFACTURING A WIND TURBINE COMPONENT,
A WIND TURBINE BLADE AND A SHELL COMPONENT

TECHNICAL FIELD

- 5 The present invention relates generally to the manufacture of wind turbine components such as wind turbine blades.

BACKGROUND

- 10 Modern wind turbine components, such as blade shells, are often formed in large moulds. This process generally involves arranging various constituent materials of the component in the mould in a 'layup process' to form a 'layup'. Typically, a number of layers of fibrous reinforcing fabric, such as glass or carbon fibre plies, are arranged in the mould first. Other structural components, such as foam panels and reinforcing spars, are then placed into the
15 mould on top of and/or between the fibre plies to form the layup.

The layup is then covered using a vacuum bag and the bag is sealed against the mould to form a sealed region encapsulating the layup. A vacuum is applied to the sealed region and liquid resin is admitted into the sealed region, infusing throughout the various materials.

- 20 Thereafter, the resin is cured by applying heat and pressure to the mould until the resin hardens. This infusion process is commonly referred to as vacuum assisted resin transfer moulding (VARTM), but the skilled person will be aware of other methods of manufacturing composite components.

- 25 During layup, it is important that the various structural components on top of the fibre reinforced fabric are arranged with precision in their correct positions relative to the mould surface and to each other. If the materials are not arranged accurately, then the structure of the resulting component may be compromised. It is particularly challenging to ensure the correct position of materials arranged against curved or otherwise inclined regions of the
30 mould surface. This is because the materials have a tendency to slide or sag relative to the mould surface in such regions. This problem is particularly acute in portions of a wind turbine blade mould corresponding to the root end and parts of the leading edge of the blade. In these regions, the curvature of the mould is highly pronounced and some components are arranged against a near vertical surface.

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A number of techniques have been proposed to prevent relative movement of the materials in the mould during lay-up, for example the use of spray adhesives. In this technique, an

adhesive substance, for example epoxy resin, is sprayed onto the surface of the fibrous fabric and the other components (for example further layers of fibrous fabric) are laid on top. The adhesive qualities of the resin mean that the materials are less likely to slide away from their correct positions in the mould. However, spraying adhesive substances such as epoxy
5 carries health and safety risks and its use is prohibited in some countries. In addition, such adhesives are sensitive to temperature and therefore their use may not always be practical. Alternatively, mechanical attachment means have been proposed, for example plastic staples. This prior art technique can be unreliable since the plastic staples have a tendency to become dislodged from the material.

10 Accordingly, there is a need for an improved technique suitable for attaching layers of materials together to maintain their relative alignment in a way that is safe, reliable and efficient.

15 SUMMARY OF INVENTION

According to an aspect of the present invention, there is provided a method of manufacturing a wind turbine component having a composite shell structure. The method comprises the following steps in any suitable order: arranging one or more first layers of dry fibrous fabric in
20 a mould; arranging a further component of the shell structure on or against the one or more first layers, the further component being provided with a hook fastener element comprising a multitude of hooks; and fastening the further component to the one or more first layers by means of the hook fastener element. The hooks of the hook fastener element are configured to grip fibres of the one or more first layers to secure the further component to the one or
25 more first layers.

In accordance with the invention, the further component is fastened to the first layer(s) according to the principles of a 'hook-and-loop' fastening mechanism. Hook and loop fasteners are two-part fasteners comprising a hook fastener element having a multitude of
30 small hooks and a loop fastener element having a multitude of small loops. Velcro® is a well-known example. When the two parts are placed in contact, the hooks engage with the loops to secure the two parts together. In the present invention, a hook fastener element such as, for example, the hook fastener element of Velcro® is provided on the further component. However, it is not required to provide a corresponding Velcro® loop fastener
35 element on the first layers. Instead, the exposed fibres of the first layers intrinsically function as the loop fastener element and the further component can be secured to the first layer simply by positioning the hook fastener element in contact with the fibres of the first layer.

This allows the further component conveniently to be arranged and secured in any position or orientation against the first layer, and repositioned easily if required. The present invention therefore provides a fast and convenient method of securing layers and components together in a composite layup process.

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Whilst Velcro® is mentioned specifically above, the present invention is not limited to the use of Velcro®. Velcro® is one well-known brand of hook-and-loop fastener and equivalent hook-and-loop fasteners are available and equally suitable for use in the present invention.

10 As will be apparent from the detailed examples discussed later, the steps of the method may be performed in any suitable order. For example, the further component may be fastened to the first layer(s) before or after the layers are arranged in the mould. Further, the first layer(s) and the further component may be arranged in the mould in any order. For example, the first layer(s) may be arranged in the mould first and the further component may be arranged on
15 top of the first layer(s). Alternatively, the further component could be arranged in the mould first and the first layer(s) may be arranged on top. As a further alternative one of the first layer(s) or the further component could be arranged in the mould first and the other of the first layer(s) or the further component could subsequently be arranged beneath. In each case, the further component is arranged on or against the first layer(s).

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The method of the invention provides the advantage that layers of material to be used in the production of a wind turbine component can be secured together without the disadvantages associated with prior art techniques. Fasteners of this type (i.e. hook-and loop fasteners) are reliable and do not pose a health and safety concern. This aspect of the invention provides a
25 quick and simple way of securing materials together in the context of wind turbine manufacturing. Therefore, the method aids the efficient production of composite wind turbine components.

The one or more first layers may comprise glass or carbon fibre fabric. The further
30 component of the shell structure may be selected from: one or more layers of fibrous fabric such as glass or carbon fibre fabric; core material; or another component to be embedded within the composite shell structure, for example a pre-cured reinforcing structure.

The hook fastener element may be attached to the further component prior to arranging the
35 one or more layers of dry fibrous fabric in the mould. This advantageously reduces the 'in-mould time' required for the layup process (i.e. the time for which the mould is monopolised

during the layup process), therefore aiding the efficient production of composite wind turbine components.

5 The hook fastener element may be bonded or stitched to the further component. The hook fastener element is thus easily attached to the further component.

The hook fastener element may comprise a backing material, and a multitude of hooks extends from a first side of the backing material and a multitude of hooks extends from a second side of the backing material.

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The further component may comprise one or more layers of fibrous fabric and the hook fastener element may be fastened to the one or more first layers by means of the hooks extending from the first side of the backing material which are configured to grip fibres of the one or more first layers to secure the hook fastener element to the one or more first layers; and the hook fastener element is fastened to the further component by the hooks on the second side of the backing material which are configured to grip fibres of the further component to secure the hook fastener element to the further component. The hook fastener element can thus be easily attached to the one or more first layers and the further component.

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The first layer and the further component may be arranged on a curved or otherwise inclined surface of the mould. In such cases, at least a portion of the first layer and the further component may be arranged on a substantially vertical surface of the mould. The hook fastener element may be arranged substantially to prevent the further component from sliding or otherwise moving with respect to the first layer in the mould. The further component is therefore fixed in its correct position within the mould.

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The hook fastener element may be provided on one or more edges of the further component. This provides a strong and reliable attachment between the first layer and the further component without requiring a large hook fastener element. For example, the hook fastener element may be provided on an uppermost edge of the further component. The further component therefore effectively hangs from its uppermost edge and drapes suitably over and against the first layer.

30

The hooks of the hook fastener element(s) may have a height, substantially perpendicular to the surface of the hook fastener element, of less than approximately 2 mm, or less than 1 mm, or less than approximately 0.5 mm or of approximately 0.3 mm. Tests have shown that

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hook sizes within these ranges provide a strong and reliable attachment between the first layer and the further component.

The further component may comprise a plurality of layers of fibrous fabric arranged in a stack with each layer in the stack being fastened to an adjacent layer in the stack by means of one or more further hook fastener elements. Thus, a stack of fibrous fabric layers may be fastened together quickly and simply, aiding the efficient production of composite wind turbine components.

In such cases, the method may comprise fastening the plurality of layers of the further component together prior to arranging the further component in the mould. This allows a large quantity of material to be deposited in the mould whilst minimising the in-mould time and therefore increasing the efficiency of the layup process.

The method may comprise arranging a plurality of first layers in the mould and fastening the first layers to each other using hook fastening elements. Thus, a number of layers of fibrous fabric may be fastened together in the mould quickly and simply, aiding the efficient production of composite wind turbine components.

The wind turbine component may be a wind turbine blade, in which case the mould is a wind turbine blade mould. The method of the invention may of course be used to attach constituent materials of other wind turbine components.

The method may comprise arranging the one or more first layers of dry fibrous fabric at a root end of the wind turbine blade mould. The surface of the mould at the root end may be circular or part circular in shape.

The inventive concept encompasses a wind turbine blade manufactured in accordance with the method of the above-described aspect, where the wind turbine blade has a composite shell structure comprising one or more embedded hook fastener elements. The inventive concept also extends to a wind turbine comprising one or more such blades.

According to another aspect of the invention, there is provided a shell component configured to form part of a composite shell structure of a wind turbine component. The shell component includes a hook fastening element comprising a multitude of hooks configured to grip fibres of a layer of dry fibrous fabric such that the shell component can be fastened to

said layer during a composite layup process during manufacture of the wind turbine component.

BRIEF DESCRIPTION OF THE DRAWINGS

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Examples of the invention will now be described in further detail with reference to the following figures, in which:

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Figure 1 is a schematic perspective view of a portion of a wind turbine blade mould showing two glass fibre fabric layers arranged one on top of the other in the mould;

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Figure 2 is a schematic perspective view of an upper edge region of the upper glass fibre fabric layer shown in Figure 1, and shows a hook fastener strip mounted on a surface of the layer near the upper edge;

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Figures 3a and 3b are schematic side views of the two glass fibre fabric layers in the region of the hook fastener strip, and show a multitude of hooks of the hook fastener strip hooking around glass fibres of the lower layer to form a hook-and-loop fastening mechanism between the two layers;

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Figure 4a is a schematic transverse cross-section of the wind turbine blade mould, taken along the line A-A in Figure 1, showing a third layer of material arranged in the mould;

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Figure 4b shows schematic side views of upper edge regions of the three layers and illustrates features of a hook and loop fastening mechanism between the second and third layers;

Figures 5a to 5d are a series of schematic cross-sectional views of a stack of layers of blade material provided with hook fastener elements, illustrating sequential steps in a method of securing a stack of layers together using a hook-and-loop fastening mechanism in accordance with the method of the invention; and

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Figure 6 is a schematic side view of the two glass fibre fabric layers in the region of the hook fastener strip, and shows a multitude of hooks on each side of the hook fastener strip.

DETAILED DESCRIPTION

Referring initially to Figure 1, this shows a perspective view of a root end portion of a wind turbine blade mould 10. The mould 10 is used to form the composite shell of a wind turbine blade. The composite shell is formed from a plurality of layers of reinforcing material, which are stacked on top of one another in the mould. Two such layers 12, 14 are shown in Figure 1, as will be discussed in further detail below. A gel coat is provided on the mould surface 16 and then the various reinforcing layers of the shell are arranged in the mould 10 in a layup process to form a layup, which is then covered with a vacuum film before resin is admitted into the mould 10. The resin infuses throughout the reinforcing layers and, once cured, binds these layers together in the composite shell structure. Other structural and functional components and layers may also be incorporated within the layup as will be appreciated by persons skilled in the art.

As mentioned above, two layers 12, 14 of reinforcing material are shown in Figure 1. In this example, both layers 12, 14 are layers of dry glass fibre fabric material, commonly referred to as plies or mats. In other embodiments of the invention, the layers 12, 14 may be made from carbon, aramid or any other suitable fibrous material. Whilst only two layers 12, 14 are shown in Figure 1, in practice the layup would comprise many more stacked layers. Also, whilst not illustrated in Figure 1, in practice further stacked plies would be arranged in the mould 10 to cover the entire mould surface 16 during the layup process.

It can be seen in Figure 1 that the surface 16 of the mould 10 has a concave-curved profile between leading and trailing edges 18, 20 of the mould surface 16. The curvature is particularly pronounced in the root region 22 of the mould 10, shown in Figure 1, where the mould surface 16 is part-circular. The curvature is also particularly pronounced near the leading edge 18 of the mould surface 16, and in these regions the mould surface 16 is near-vertical. As described by way of introduction, unless the layers 12, 14 are supported in some way, they may slide down the inclined surfaces 16 of the mould 10 under gravity. This is not such a problem for the first layer 12, which tends to be retained in the correct position by the tackiness of the gel coat; however, subsequent layers arranged on top of the first layer 12 may tend to slide relative to one another away from their assigned positions in the mould 10.

In order to prevent the layers 12, 14 from sliding relative to one another, the second (upper) layer 14 in this example is secured to the first (lower) layer 12 by means of a hook-and-loop fastening mechanism, as will now be described in further detail.

Referring to Figure 2, which is a perspective view of an upper edge 30 region of the second layer 14, it can be seen that the second layer 14 is provided with a hook fastener element 32 in the form of a narrow strip provided near the uppermost edge 30 of the second layer 14. The strip extends parallel to the uppermost edge 30 of the second layer 14, across the width of the layer 14. In this example, the hook fastener element 32 comprises the hook fastener portion of the well-known Velcro® material.

The fastening mechanism between the first and second layers 12, 14 will now be described in more detail with reference to Figures 3a and 3b, which both show the uppermost portions of the two layers 12, 14, in the region generally indicated by a dashed circle in Figure 2, as viewed from the side. The second layer 14 and the surface 34 of the first layer 12 can be seen. It will be appreciated that Figures 3a and 3b are highly schematic representations intended to illustrate the principles of the hook-and-loop fastening mechanism but are not intended to be realistic representations nor are they intended to reflect the scale or relative proportions of the various components.

Figure 3a shows the first and second layers 12, 14 before they are fastened together. The individual fibres 40 of the glass fibre fabric of the first layer 12 are shown schematically. The skilled person will be aware that, due to the manufacturing process of glass fibre fabric (which may involve weaving and/or stitching and/or fibres criss-crossing with each other), the fibres effectively form 'loops' which protrude from the surface of the material. It is these looped glass fibres 40 that realise the loop aspect of the hook-and-loop fastener. The fact that the loop fastener element is intrinsic to the first layer 12 is advantageous and particularly convenient because there is no need to attach a separate loop fastener element.

The hook fastener element 32 is shown in more detail in Figure 3a. Specifically, the hook fastener element 32 comprises a backing material 42 and a multitude of hooks 44 that project from the surface of the backing material 42. The hooks 44 of the hook fastener element 32 are suitably configured to grip (i.e. hook around) the looped fibres 40 of the glass fibre fabric. Trials have shown that hooks 44 with a height of less than 2mm are most effective. More specifically, in this example the hooks 44 have a height of approximately 0.3mm, which results in a particularly effective fastening mechanism between the two layers 12, 14.

To fasten the second layer 14 to the first layer 12, the second layer 14 is arranged over the first layer 12 and the hook fastening element 32 is pressed (if required) against the first layer 12, as shown in Figure 3b. The hooks 44 of the hook fastener element 32 catch in the

looped fibres 40 of the glass fibre fabric, gripping the material of the first layer 12. Thus, the second layer 14 is secured to the first layer 12 and is retained in position relative to the first layer 12 by the hook-and-loop fastening mechanism.

- 5 The attachment that is formed between the hooks 44 and the looped fibres 40 is reversible; that is to say that the hooks 44 can be disengaged from the loops 40 by pulling the first and second layers 12, 14 apart. The hooks 44 are somewhat flexible, so when the layers 12, 14 are pulled apart, the hooks 44 straighten and slide out of the loops 40 without damaging the hooks 44 or the fibres 40. When the straightening force is released, the hooks 44 return to
10 their normal shape and so the hook-and-loop fastening mechanism can be used again. This allows the second layer 14 to be repositioned relative to the first layer 12 simply by pulling the second layer 14 away from the first layer 12 and moving it to a new position. The second layer 14 can be secured to the first layer 12 again by pressing the second layer 14 against the first layer 12. This repositioning can, if necessary, be performed many times and over an
15 indefinite period of time without affecting the strength of the bond between the hook fastener element 32 and the looped fibres 40 of the first layer 12.

- The hook fastener element 32 may be provided in any suitable position or configuration on the second layer 14, and multiple hook fastener elements may be provided if required.
20 Generally speaking, the larger the surface area of the hook fastener element 32, the stronger the bond between the second layer 14 and the first layer 12. However, it is desirable to minimise the size of the hook fastener element 32 where possible for reasons of cost and in order to avoid having any detrimental effect on the integrity of the shell structure. One way to minimise the size of the hook fastener element is by careful selection of the
25 placement of the hook fastener element. In this example, it has already been discussed with reference to Figure 2 that the hook fastener element 32 is provided as a single strip near the upper edge 30 of the second layer 14. This arrangement has been found to work well as the upper edge 30 of the layer 14 in this example is arranged against the steepest section of the mould surface 16, and providing the hook fastener element 32 near the upper edge 30
30 means that the second layer 14 effectively hangs from its uppermost edge 30 and drapes suitably over and against the first layer 12. In some cases it may be desirable to provide further hook fastener elements also in other parts of the second layer 14, as required. It will be appreciated that, in practice, many factors contribute to the optimal configuration of the hook fastener element 32, depending on the specific circumstances of each situation. For
35 example, in a portion of the mould 10 with a more pronounced curvature, or with a more complex shape, it may be desirable to provide the hook fastener element along more than one edge of the second layer 14.

In this example, the hook fastener element 32 is bonded to the second layer 14 by means of adhesive. However, in other examples, the hook fastener element 32 may be attached to the second layer 14 by stitches or any other suitable means. The hook fastener element 32 is advantageously attached to the second layer 14 prior to arranging the first layer 12 in the mould 10. This reduces the 'in-mould time' required for the layup process (i.e. the time for which the mould 10 is monopolised during the layup process). This is a significant advantage since wind turbine blade moulds are very large and expensive and a typical blade production facility may have relatively few moulds. It is therefore important to maximise the efficiency and rate of blade production.

In this example, the second layer 14 is a layer of glass fibre fabric. However, in other embodiments of the invention, the second layer 14 may be any component to be embedded within the finished blade, for example core material such as foam panels or other structural components such as pre-cured reinforcing elements. If the second layer 14 is a layer of dry fibrous fabric, as is the case in this example, then a third layer of material may be secured on top of the second layer 14 by means of a further hook fastening element. This will now be described in more detail with reference to Figures 4a and 4b.

Figure 4a shows a cross section of the mould 10 of Figure 1 taken in the plane AAAA in Figure 1. A third layer of material 50 is arranged in the mould 10 on top of the second layer 14. The third layer 50 may be any component to be embedded within the finished blade, for example a further layer of fibrous fabric, core material or a pre-cured fibreglass component.

The fastening between the second and third layers 14, 50 will now be described in more detail with reference to Figure 4b which shows the uppermost portions of the three layers 12, 14, 50 of material as viewed from the side. As can be seen from this figure, the third layer 50 is provided with a hook fastener element 52 comprising a multitude of hooks 54, similar to the one provided to the second layer 14. It will be appreciated that these figures are also highly schematic.

The individual fibres 56 of the second layer 14 are shown schematically in Figure 4b. Similarly to the previous description, these fibres 56 form loops that realise the loop aspect of the fastening mechanism between the second and third layers 14, 50. The hooks 54 of the hook fastener element 52 grip the looped fibres 56 of the second layer 14 and thus, the third layer 50 is fastened to the second layer 14. The skilled person will appreciate that if more

layers of material are required to be arranged in the mould 10 then this process may be repeated to secure fourth, fifth and subsequent layers on top of the third layer 50.

Although it is beneficial in some situations to secure layers of material together individually within the mould 10 (as described above), in other circumstances, particularly where a larger number of layers are required to be arranged in the mould 10, this process can be excessively time consuming. In order to reduce the in-mould time of the lay-up process, a number of layers of material may be attached together outside the mould 10 to form a 'kit' that is placed into the mould 10 as one piece in a single lifting operation. This process will now be described in more detail with reference to Figures 5a to 5d, which show a series of steps in a method of forming a kit using hook fastener elements.

Referring initially to Figure 5a, this shows a single layer of dry fibrous fabric 60. In this example, the fabric is glass fibre fabric but in other embodiments, the material may be carbon or aramid fibre fabric, for example.

Figure 5b shows a second layer 62 of dry fibrous fabric arranged on top of the first layer 60. The second layer 62 is secured to the first layer 60 by means of a hook fastener element 64 in the form of three strips 64a, 64b, 64c provided across the lower face 66 of the second layer 62. In other embodiments, the hook fastener element(s) 64 may be provided in any appropriate configuration. Similarly to the description above, the hooks of the hook fastener element 64 grip the individual looped fibres of the first layer 60 and so the second layer 62 is secured to the first layer 60.

Figure 5c shows a third layer of material 68 arranged on top of the second layer 62 to form the finished kit 70. The third layer 68 is fastened to the second layer 62 in a similar way to the fastening of the second layer 62 to the first layer 60. That is to say, the third layer 68 is provided with a hook fastener element 72 in the form of three strips 72a, 72b, 72c across its lower face 74. The hooks of the hook fastener element 72 grip the looped fibres on the top face of the second layer 62 to secure the third layer 68 to the second layer 62. The skilled person will appreciate that this process may be repeated to form a kit having any number of layers.

In this example, the layers of material 60, 62, 68 are similar; that is, they are equally sized pieces of glass fibre fabric. However, in other embodiments, the layers in the stack may be dissimilar, for example having differing sizes and/or being made from differing materials or having different constructions, for example the kit may include biax and triax layers. The first

and second layers 60, 62 must be layers of dry fibrous fabric so that the hooks of the hook fastener elements 64, 72 can grip onto their looped fibres but the top layer of the stack 68 may be any component to be embedded in the finished wind turbine blade. However, in other embodiments if non-fibrous layers are to be incorporated in the bulk of the kit then these could be provided with separate loop fastening elements, such as a suitable loop fastening element of Velcro® material.

Once the kit 70 has been attached together, it is transported to the mould 10 and arranged in the mould 10 as one piece. If the kit 70 is to be arranged in the mould 10 against or on top of a layer of dry fibrous material, then it may be beneficial to secure the kit 70 to that layer by means of a hook fastener element. Figure 5d shows the kit of Figure 5c provided with a hook fastener element 76 on the bottom face 78 of the first layer 60. The hooks of the hook fastener element 76 grip the fibres of the layer of material arranged beneath the kit 70 in the mould 10 and the kit 70 can therefore be secured in its correct position.

The skilled person will appreciate that a hook fastening element could alternatively be provided on the layer of material arranged in the mould, with hooks configured to grip the fibres of the bottom face 78 of the first layer 60.

Figure 6 shows a further example of the first and second layers 12, 14 before they are fastened together. The individual fibres 40 of the fibre fabric of the first layer 12 and second layer 14 are shown schematically. As described above with respect to Figure 3, the fibres effectively form 'loops' which protrude from the surface of the material. It is these looped glass fibres 40 that realise the loop aspect of the hook-and-loop fastener.

In this example, the hook fastener element 32 comprises a backing material 42 and a multitude of hooks 44 that project from both surfaces of the backing material 42 (hooks 44a on a first side and hooks 44b on a second opposing side). The hooks 44 of the hook fastener element 32 are suitably configured to grip (i.e. hook around) the looped fibres 40 of the fibre fabric of first and second layers 12, 14. The hooks have the same form as those described with respect to Figure 3.

In this example, the first layer 12 is arranged in the mould. Then the hook fastener element 32 is attached to the first layer 12 by the hooks 44a gripping the fibres 40 of the first layer. The second layer 14 is then arranged in the mould and the fibres 40 of the second layer grip the hooks 44b of the hook fastener element 32. This example has an advantage in that the

hook fastener element 32 does not need to be stitched or adhesively bonded to one of the layers.

5 This example of the hook fastener element 32 which is attached to the first layer 12 and the second layer 14 by a multitude of hooks on each side of the backing material can be used in the examples described above with respect to Figures 2, 4 and 5.

10 Whilst the above examples relate to the manufacture of a wind turbine blade, the invention is equally suitable for use in the manufacture of other wind turbine components of composite construction.

15 It will be appreciated that many modifications may be made to the above examples without departing from the scope of the present invention as defined in the accompanying claims. For example, the layers of material may occupy any portion of the width/length of the mould as required. Further, whilst the above embodiments describe attaching constituent materials of a wind turbine blade, attachment techniques according to the present invention are equally suitable for securing consumable materials such as vacuum film or breather fabric for use in a vacuum-assisted moulding process.

CLAIMS

1. A method of manufacturing a wind turbine component having a composite shell structure, the method comprising the following steps in any suitable order:

- 5 arranging one or more first layers of dry fibrous fabric in a mould;
- arranging a further component of the shell structure on or against the one or more first layers, the further component being provided with a hook fastener element comprising a multitude of hooks; and
- 10 fastening the further component to the one or more first layers by means of the hook fastener element whereby the hooks of the hook fastener element are configured to grip fibres of the one or more first layers to secure the further component to the one or more first layers.
2. The method of Claim 1, wherein the one or more first layers comprise glass or carbon fibre fabric.
- 15 3. The method of Claim 1 or Claim 2, wherein the further component of the shell structure is selected from: one or more layers of fibrous fabric such as glass or carbon fibre fabric; core material; or other component to be embedded within the composite shell structure.
4. The method of any preceding claim, wherein the method further comprises the step of attaching the hook fastener element to the further component prior to arranging the one or more layers of dry fibrous fabric in the mould.
- 20 5. The method of any preceding claim, wherein the hook fastener element is bonded or stitched to the further component.
6. The method of any Claims 1 to 4, wherein the hook fastener element comprises a backing material, and a multitude of hooks extends from a first side of the backing material and a multitude of hooks extends from a second side of the backing material.
- 25 7. The method of claim 6, wherein the further component comprises one or more layers of fibrous fabric, wherein
- 30 the hook fastener element is fastened to the one or more first layers by means of the hooks extending from the first side of the backing material which are configured to grip fibres of the one or more first layers to secure the hook fastener element to the one or more first layers; and

the hook fastener element is fastened to the further component by the hooks on the second side of the backing material which are configured to grip fibres of the further component to secure the hook fastener element to the further component.

- 5 8. The method of any preceding claim, wherein the hook fastener element is arranged substantially to prevent the further component from sliding or otherwise moving with respect to the first layer in the mould.
9. The method of any preceding claim, wherein the method comprises arranging the first layer and the further component on a curved or otherwise inclined surface of the mould.
- 10 10. The method of any preceding claim, wherein the method comprises arranging at least a portion of the first layer and the further component on a substantially vertical surface of the mould.
11. The method of any preceding claim, wherein the method comprises providing the hook fastener element on one or more edges of the further component.
12. The method of any preceding claim, wherein the method comprises providing the hook
15 fastener element on an uppermost edge of the further component.
13. The method of any preceding claim, wherein the hooks of the hook fastener element(s) have a height of less than approximately 2 mm, or less than 1 mm, or less than approximately 0.5 mm or of approximately 0.3 mm.
14. The method of any preceding claim, wherein the further component comprises a plurality
20 of layers of fibrous fabric arranged in a stack with each layer in the stack being fastened to an adjacent layer in the stack by means of one or more further hook fastener elements.
15. The method of Claim 14, wherein the method comprises fastening the plurality of layers of the further component together prior to arranging the further component in the mould.
16. The method of any preceding claim, wherein the method comprises arranging a plurality
25 of first layers in the mould and fastening the first layers to each other using hook fastening elements
17. The method of any preceding claim, wherein the wind turbine component is a wind turbine blade and the mould is a wind turbine blade mould.
- 18 The method of any preceding claim, wherein the method comprises arranging the one or
30 more first layers of dry fibrous fabric at a root end of the wind turbine blade mould, and wherein a surface of the mould at the root end is circular or part circular in shape.

19. A wind turbine blade manufactured in accordance with the method of any preceding claim, wherein the wind turbine blade has a composite shell structure comprising one or more embedded hook fastener elements.

5 20. A shell component configured to form part of a composite shell structure of a wind turbine component, wherein the shell component includes a hook fastening element comprising a multitude of hooks configured to grip fibres of a layer of dry fibrous fabric such that the shell component can be fastened to said layer during a composite layup process during manufacture of the wind turbine component.

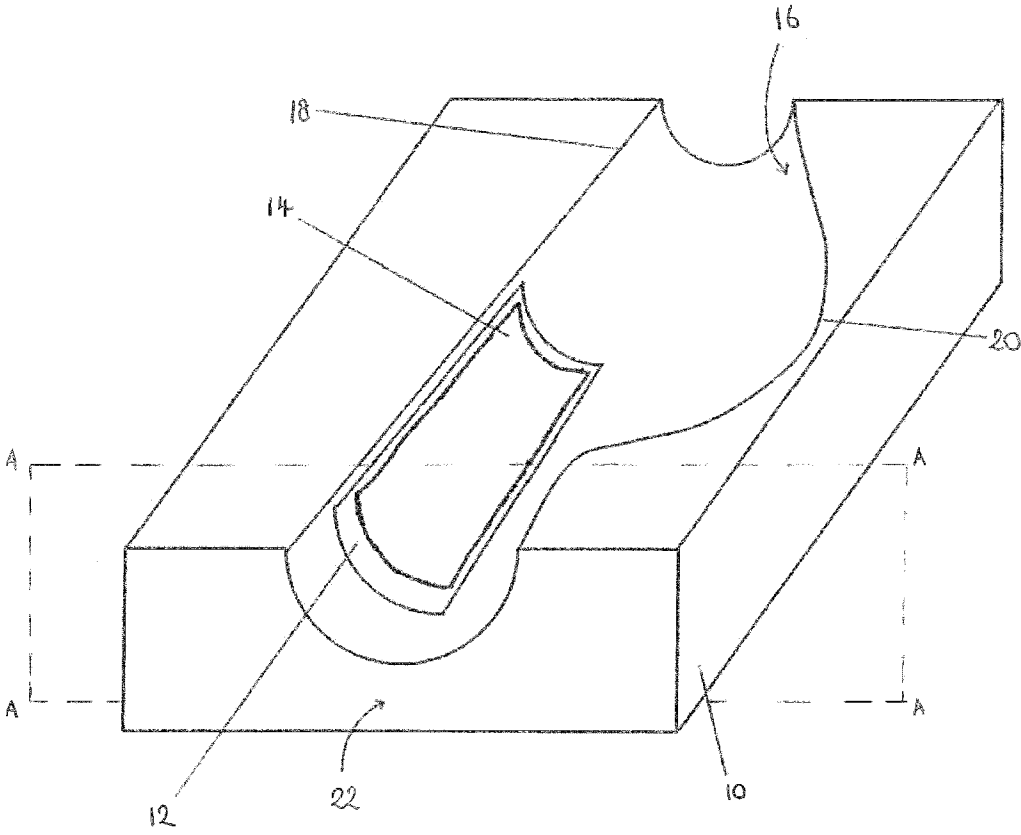


Figure 1

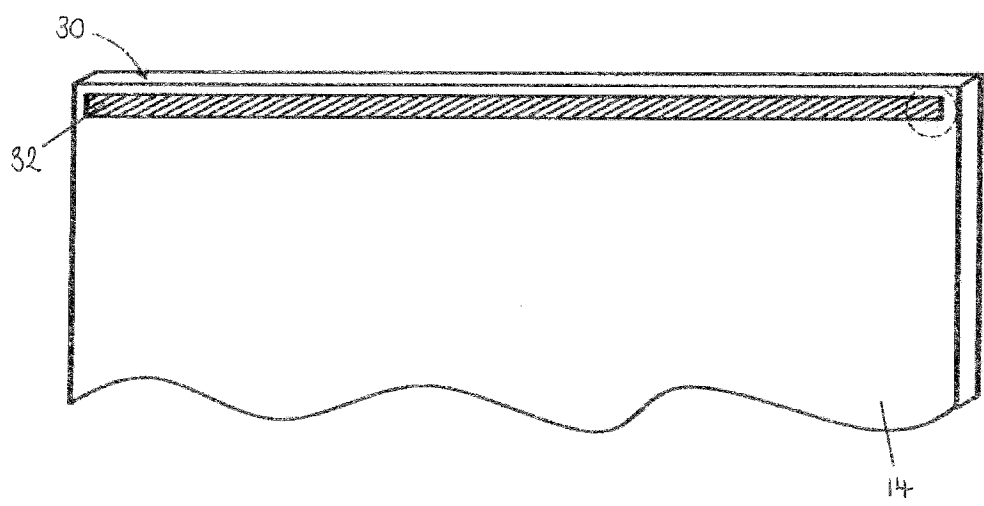


Figure 2

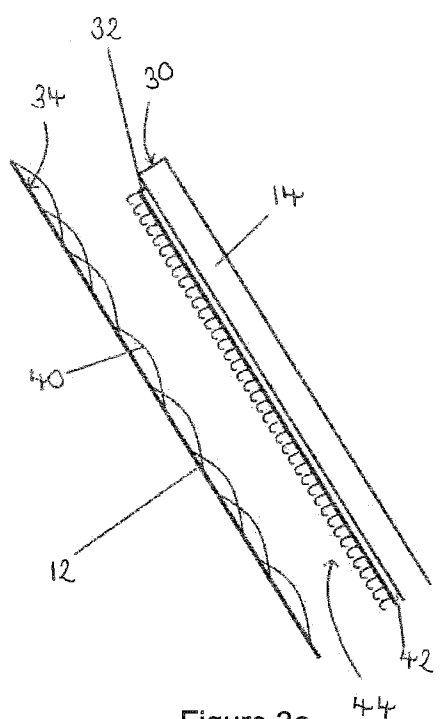


Figure 3a

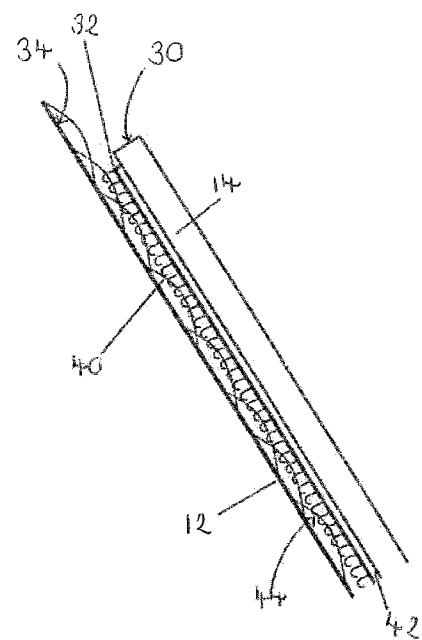


Figure 3b

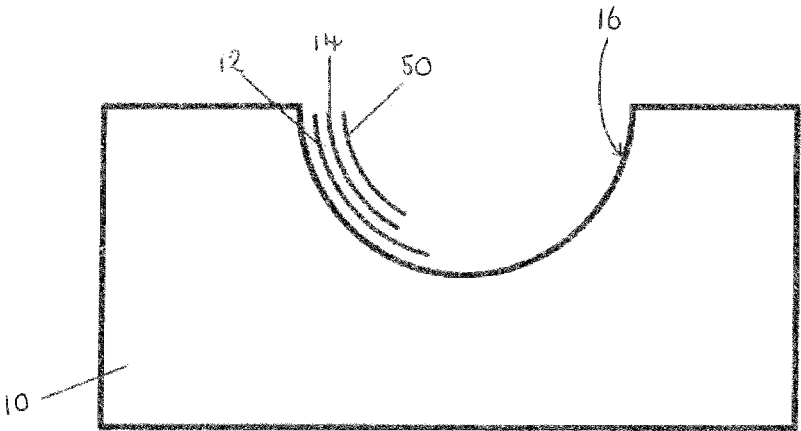


Figure 4a

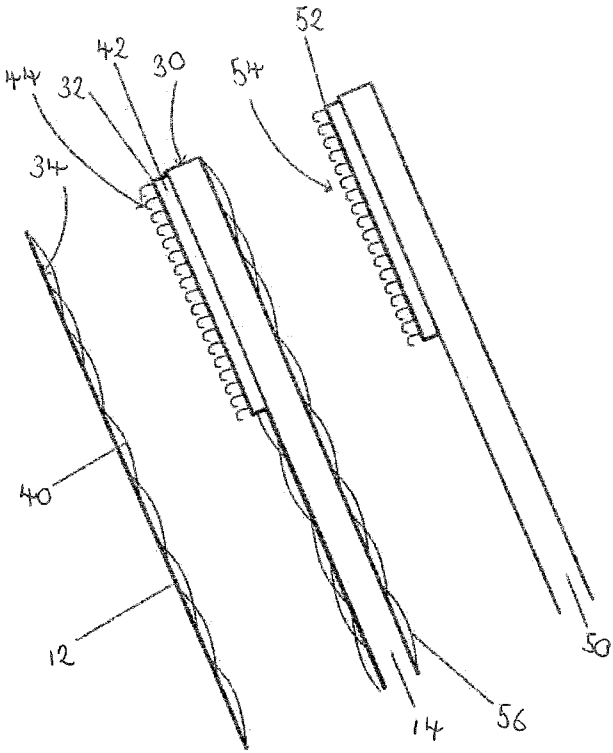


Figure 4b



Figure 5a

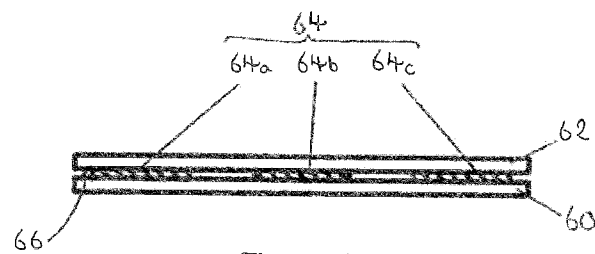


Figure 5b

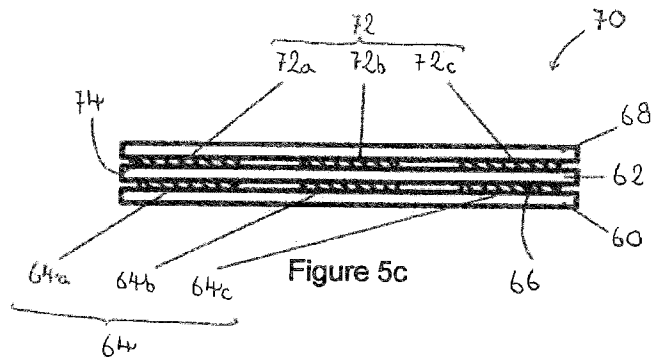


Figure 5c

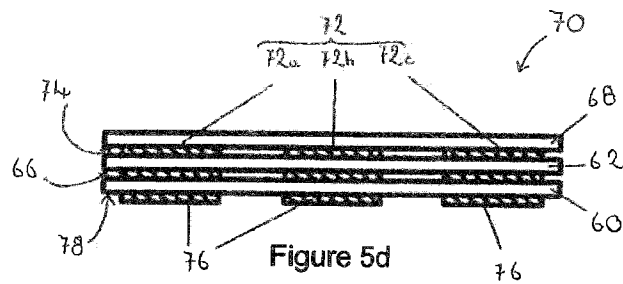


Figure 5d

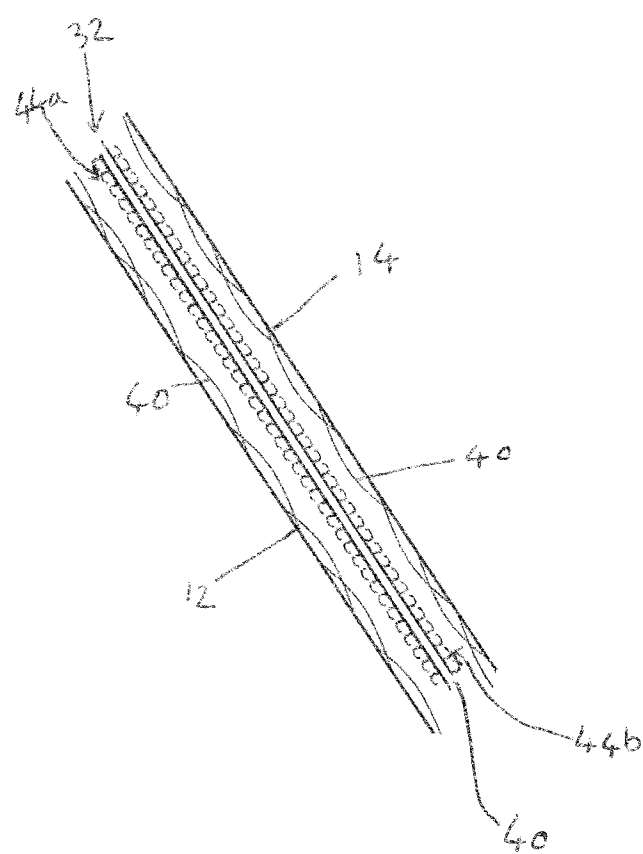


Figure 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/DK2016/050133

A. CLASSIFICATION OF SUBJECT MATTER

INV. B29C70/10 B29C70/70 B29C70/72 B29C70/54 B29C65/00
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B29C

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)

EP0-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2008/193709 A1 (HAN NANLIN [US]) 14 August 2008 (2008-08-14) paragraph [0003]; claims 26-30; figures 1,2,4,18a,48,49 -----	1-20
X	US 5 540 970 A (BANFIELD DONALD L [US] ET AL) 30 July 1996 (1996-07-30) figures 1,2a,6,7 -----	1
X	EP 2 662 202 A2 (AIRBUS OPERATIONS GMBH [DE]) 13 November 2013 (2013-11-13) claims 1,4,8,10,11; figures 1,3,4 -----	1
A	US 2010/227112 A1 (HAN NANLIN [US]) 9 September 2010 (2010-09-09) paragraph [0005]; figures 3-6 -----	1



Further documents are listed in the continuation of Box C.



See patent family annex.

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

29 July 2016

Date of mailing of the international search report

08/08/2016

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Authorized officer

Boone, John

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/DK2016/050133

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			EP 2662202 A2	13-11-2013
			US 2013302544 A1	14-11-2013

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