METHOD FOR MANUFACTURING A COMPOSITE ELEMENT AND SUPPORT ELEMENT PROVIDED THEREBY

Fig. 5

Abstract: Method for manufacturing a composite and/or support element and to an element provided thereby and a support. Method for manufacturing a composite element, comprising the steps of: - providing a series of curled or twisted fibers (2); - forming a preform (3) with said fibers (2); - preferably connecting at least a number of the fibers to each other locally, providing a network of said fibers; - injecting a flowable compound with a foaming agent into said preform or network of fibers; - allowing the foaming agent to form a foam at least partly enclosing said fibers.
The invention relates to a method for forming an element such as a support element. The invention relates to a method for forming a composite element.

Support elements are known in the art, such as foam blocks, which can for example be made of plastic, such as polystyrene or polyurethane. The outer surface of the block can be formed by a closed skin. The blocks can be made in a mould by foaming. The flexibility and rigidity of such blocks can be controlled by the density of the foam. However, such blocks are prone to breakage, such as tearing of the skin or disintegration of the foam due to stress or pressure.

Furthermore, glass fiber reinforced foam blocks and panels are known, in which glass fibers are distributed through a foam, such as a urethane foam. Such blocks can be manufactured by placing a foaming material mixed with relatively short glass fibers in a mould and allowing the mixture to foam, for example due to a chemical reaction of a foaming agent. In such method only relatively short, thin glass fibers can be used for reinforcement.

An aim of the present disclosure is to provide a novel method for forming a composite element, especially a support block. An aim of the present disclosure is to provide a method for forming support elements. An aim of the present disclosure is to provide for a method for forming a composite, fiber reinforced element.

In a first aspect a method according to this disclosure can comprise the steps of:

- providing a series of curled or twisted fibers;
- forming a preform with said fibers;
injecting a foaming agent between and around said fibers;
allowing the foaming agent to form a foam at least partly enclosing said fibers.

At least a number of the fibers can be connected to each other locally, providing a network of said fibers.

By injecting the foaming agent, which can for example be a self foaming plastic or a mixture of a plastic and a foaming element or mixture, it can flow or be forced into the preform, between and around the fibers, before and/or during foaming, such that the fibers are at least partly and preferably substantially entirely enclosed with a foam body. The perform can have substantially the shape of the element to be formed, or a different shape and will consist at least substantially of fibers forming an open network, such that the foaming agent can pass through said network.

The fibers can be interconnected by any known method, such as but not limited to adhering by glue, heat treatment, mechanical connections or other means.

In embodiments the fibers are placed in a mould in which the foaming agent is injected, such that at least the outer shape of the element is defined by the mould. In embodiments of the method also the perform can be formed by the mould, for example by compressing the perform in the mould, such that the fibers are brought closer to each other. This can be done prior to, during and/or after injecting the foaming agent into the perform and/or the mould.

In embodiments at least one connecting element can be provided which is partly enclosed within the element and at least partly extends from the element, such that the element can be mounted to a support by said at least one connecting element.

In embodiments the fibers can be curled or twisted in a bundle and be cured, such that they maintain at least partly the curled or twisted form, wherein the bundle of fibers can be divided into a series of smaller bundles
and/or individual fibers having a curled or twisted shape. In this description twisted or curled has to be understood at least as meaning non-straight, and can be regular shaped, like spiraled, or irregular shaped.

In an aspect a method for forming a support element can comprising the steps of providing a preform made of non-straight fibers in a mould, closing the mould around the network and part of at least one connecting element and inducing the production of a foam in said mould, through and at least partly around said preform and part of said at least one connecting element, such that a fiber reinforced, foamed support element is provided.

In order to further elucidate the present invention, embodiments of methods and elements formed therewith according to the present disclosure shall be described hereafter, with reference to the drawings. Therein:

Fig. 1 schematically shows an element formed with a method according to the invention, in see through configuration, without the fibers;

Fig. 2 schematically shows in top and two cross sectional side views an element of fig. 1, showing fibers inside the element;

Fig. 3 schematically shows a number of elements carried on different carriers;

Fig. 4 schematically shows a bundle of fibers, twisted and treated to retain the twisted configuration when separated into individual fibers and/or smaller bundles of fibers;

Fig. 5 schematically shows a network of fibers in a mould;

Fig. 6 schematically shows the network of fibers in a mould, slightly compressed by closure of the mould;

Fig. 7 schematically shows a rotor blade of a wind turbine supported by elements according to the present disclosure.

In this description the same or similar elements have the same or similar reference signs. In this description support elements will be described that can be used for supporting or cushioning products during for example storage and transport or other handling. In this description support elements
will be described specifically for supporting blades for wind powered generators, such as wind turbines. Obviously the same or similar support elements can be used for supporting other products or loads.

In the present disclosure support elements are disclosed as examples of composite elements only. Composite elements according to the present disclosure could however also be used for other purposes, such as cushioning elements for impact damage prevention, filling elements, seating elements or the like. In the present disclosure preforms are described, formed from fibers which are interconnected at different positions, such that the fibers form a network of interconnected fibers. In the disclosure fibers are described which are curled or twisted, i.e. brought into or formed in a non-straight configuration before interconnecting them into said preform. However, alternatively the fibers can be interconnected into a network forming a preform, wherein during or after said forming of a network the fibers are twisted or curled.

In this description elements are described that can have synthetic fibers forming a 3-D structure, also referred to preform, which provide for a strong yet flexible structure. The fiber structure is at least partly enclosed within a foam, which can be for example a PU-foam. Foam in this disclosure has to be understood as including open cell and closed cell foams known in the art, including but not limited to high, medium and low density foams. Such foams are preferably flexible and/or elastic, such that they can be deformed elastically to a high degree without breaking. Closed cell foams can be preferable, especially when used for elements that can be subjected to environmental challenges, such as different weather conditions, chemicals, submerging in for example water, saltwater environments or the like. The fibers increase the tearing and shearing strength of the element significantly, without losing a desirable soft and flexible character of the element. Obviously the flexibility and softness can be amended by for example the type of fibers used, for example material, length, diameter, shape and ratio of
interconnection between the fibers, the type of foam used, the foam density, the fiber density, the shape of the fibers and the element, the fiber/foam ratio and total density resulting there from.

In this disclosure foaming agent has to be understood as including but not limited to any substance or compound or combination of substances or compounds that is or are at least partly flowable or injectable into a fiber network, which substance, compound or combination of substances and/or compounds form an open and/or closed cell foam structure by foaming. The forming of the foam structure can for example be induced chemically, for example by a chemical reaction between compounds, or physically, for example by heat, gas injection or pressure change.

In this disclosure a method is described for manufacturing a composite element 1, comprising the steps of providing a series of curled or twisted fibers 2 and forming a preform 3 with at least said fibers 2. Preferably at least a number of the fibers 2 is connected to each other locally, providing a network of said fibers 2. A foaming agent 4 is then injected into said preform or network 3 of fibers, where after the foaming agent 4 is allowed to form a foam 5 at least partly enclosing said fibers 2. The foaming is preferably performed mainly in a mould 6, as is schematically shown in fig. 5 and 6, in order to distinctly define an outer configuration of the element 1. The preform 3 can be compressed inside the mould 6, for example by closing the mould 6, in order to increase the density of the preform, prior to, during or after injecting the foaming agent 4 into the mould 6.

Fig. 1 and 2 show, by way of example only, an element 1, forming a support element 1, which can be mounted on for example a carrier 7, as shown schematically in fig. 3. In the embodiment shown the element 1 has a substantially block shaped outer configuration, with a top face 8, a bottom face 9, and four side faces 10. As will be discussed in more detail, a preform 3 formed by fibers 2 forming a network is provided inside the element 1, which further is substantially made of foam 5, especially by foaming of a foaming
agent 4. If desired one, or in the embodiment shown two connecting elements 11 are provided for the element 1 which at least one connecting element is formed and positioned such that a part thereof extends outside the element. In the embodiment shown each connecting element 11 comprises a plate 12 extending within the element 1, at least partly in said network of fibers 2, and two legs 13 extending from the plate 12 through the bottom face 9 of the element, such that the legs can be engaged from outside the element. The plate and legs can be made of any suitable material, such as but not limited to metal, wood or plastic, and can have any suitable configuration. The element 1 can be mounted to a mount, such as for example the carrier 7, by at least one such connecting element 11.

In the embodiment shown the side surfaces 10 of the element slope towards the top face 8. In the top face 8 a groove 14 has been formed, extending in this embodiment across the width of the top face 8 and having a substantially V-shaped cross section. Such groove 14 can be used for securing a position of a product or part to be supported by the element 1, for example by resting a part of said product or part in said groove 14. As can be seen in fig. 3 one or more of these elements 1, which can be made in basically any desired form, shape or dimension, can be mounted in a fixed or adaptable position. In fig. 3 the elements 1 are provided with a mounting plate 15 at the bottom face 9, which can be fixed to the element in any suitable way, from example using the element or elements 11 as described here above or similar elements, or by simply adhering the plate 15 to the bottom face 9, for example by an appropriate adhesive, by heat bonding, by sealing, by welding or any other suitable technique. In or on the carrier 7 the elements 1 are preferably at least in part mounted such that they can self adjust there positions in at least one plane, for example by pivoting around an axis 16 on which they are mounted. As can be seen in fig. 3 the top face 8 of an element 1 can also be free of said groove 14, whereas also other surface elements can be provided, such as cross grooves 17, for example for increasing flexibility. Self adjusting obviously has
the advantage that a product or part to be supported can be easily placed, without the necessity to manually adjust the elements positions or highly accurate placement thereof prior to placing the product or part thereof.

As can be seen in fig. 3 the carrier 7 can comprise a frame 30, having for example a number of posts 31 extending from a bottom frame part 32. The frame can be provided with appropriate mounting provisions 33 for mounting the carrier 7 on a surface, such as on a loading deck of a boat or truck. These provisions can for example comprise openings compatible with container quick lock provisions as known in the art. Between for example the posts 31 and the bottom frame part 32 support elements 34 can be provided, carrying the elements 1. In the embodiment shown a first element 1A is mounted on first a shore 35, a second element 1B on a second shore 36 and a third element 1 on a third shore 37, the second and third shore 36, 37 being positioned opposite the first shore 35. The second element 1B is according to fig. 1 and 2, having the groove 14, and is position lowest of the three elements 1. The second shore 36 can be provided with an adjustment system 38 for adjusting the position of the second element 1B relative to the other elements 1A, C.

In the present invention fibers 2 are used which can for example be made of metal, plastic, natural material such as plant fibers, or combinations thereof. The fibers 2 can have any desired cross section, such as but not limited to round, oval, rectangular, square, multi-angular or irregular shaped. Preferably the fibers 2 have an initial length, that is in a straight configuration, which is relatively long compared to the outer sizes of the element 1 to be formed. In embodiments the fibers 2 can for example be synthetic fibers, extruded or pulled in large lengths, which can then be cut into fibers lengths, for example lengths of between 25 and 500 mm, for example between 50 and 200 mm. The fibers can for example have a cross section C comparable to or formed by a circle having a diameter of less than 1 mm, for example between 0.05 and 0.5 mm, more specifically between 0.1 and 0.3 mm. The fibers can be curled or twisted such that they fit, without further
deformation, inside a cylinder $T$ having a diameter $D$ of between 10 and 100 mm, for example between 15 and 50 mm, more specifically between 15 and 30 mm, lying at least in part along part of the inside wall of said cylinder $T$ as schematically drawn in fig. 4. Other sizes could be used. For example, when the fibers 2 are spiraled, the spiral can have said diameter of between 10 and 100 mm, for example between 15 and 50 mm, more specifically between 15 and 30 mm.

The fibers 2 can be curled or twisted in a known manner, and can be cut into said lengths before, during or after said curling or twisting. The curling or twisting is preferably done in such a manner that the fibers 2 maintain at least to a degree the twisted or curled, that is deformed state. The curling or twisting can provide for regular or irregular shaped, non-straight fibers 2.

In for example JP5106153 and EP1270787 methods and apparatus are described for curling or twisting fibers, especially synthetic fibers, by extruding them in a specific manner and cooling them in water directly after cooling. Herein use is made of for example different drawing speeds for the fibers at different sides of the fiber, and of water cooling the fibers, in order to make them curl or spiral, which has to be understood in the broadest sense as assuming a non-straight configuration, which configuration is mainly maintained after removal of the fibers 2 from the apparatus. The fibers can adhere partly to each other or maintain separate positions. Fibers 2 made with such or similar methods and apparatus can be used in the present invention and are considered to have been disclosed herein as such.

Fig. 4 shows a bundle 18 of fibers 2, which have been twisted into a curled or twisted state as a bundle 18. This can for example be done manually or by using a machine in which a first end 19 of the bundle 18 is held, whereas an opposite second end 20 of the bundle 18 is rotated relative to the first end along a longitudinal axis $L$ of the bundle, parallel to the initial length of the fibers 2. The bundle 18 is brought into a spiraling shape, for example like a
screw, after which the bundle of fibers can be treated, especially heat treated such that the bundle or at least the individual fibers 2 maintain there deformed, non-straight state even without external forces. As can be seen at the second end 20 of the bundle in fig. 4, the individual fibers 2 or bundles of a smaller number of fibers 2 can then be separated out from the bundle 18. These fibers 2 will retain at least substantially their non-straight configuration as for example shown in fig. 4 right hand side.

The non-straight, i.e. twisted or curled fibers 2 can then be brought together to form the preform 3, for example by placing the fibers 2 in a mould 6 and adhering or otherwise bonding the fibers in for example discrete positions X to each other, if or as far as they are not already interconnected as a result of the manufacturing method used for bringing the fibers in the non-straight state. The bonding or adhering can for example be achieved by applying heat to the fibers 2 locally in said positions X by applying an adhesive or by mechanical interconnection, for example by tying or clamping. Alternatively the fibers can be placed in the mould or otherwise formed into a pre-form without said interconnection, though this may result in a less strong pre-form. The fibers 2 can for example be intertwined.

In embodiments the preform 3 can have an outer shape and/or dimensions similar to or even identical to the outer shape and/or dimensions of the element 1 to be formed. In alternative embodiments the preform 3 can have a different outer shape and/or dimensions. The preform 3 can be made such that it directly obtains the desired shape and dimensions. In other embodiments the preform can for example be shaped differently and be brought into a desired shape by amending said shape, for example by forcing it into said shape by external force, for example by compression, and/or by removing part of the fibers, for example by cutting, trimming, sawing or other machining techniques. The preform 3 can be made with a substantially evenly distributed density, for example by a substantially even distribution of fibers and/or interconnections between fibers throughout, or can have different parts.
having different densities, for example by different amounts of fibers, different fibers, different compression of the fibers, different distribution of connections between fibers, differently formed fibers or combinations thereof.

In fig. 5 a preform 3 is shown schematically in a mould 6 for forming an element 1. The mould 6 can be of a known design having mold parts 6A, B that are movable relative to each other for opening and closing the mould 6, especially the mould cavity 6C formed therein. An injector 21 is provided for injecting a foaming agent 4 into the mould cavity 6C and into the preform 3, in between the fibers 2. The foaming agent 4 is allowed to foam or brought to foaming, such that a foam 5 is formed, filling the mould cavity 6C and enclosing at least part of and preferably all of the preform 3, which thus reinforces the foam 5. As can be seen schematically in fig. 2, the foam 5 close to the cavity wall 22 can form a skin 23, having a density relatively high compared to the density of the foam 5 in the further element, enclosing the fibers 2. Such skin 23 can further protect the element 1, for example against impact, environmental influences or the like. In embodiments the preform 3 can be placed inside the mould cavity 6C such that it is substantially free from part of or all of the internal cavity wall 22, such that the outer surface 24 of the element as for example formed by the skin 23 can be partly or entirely free of fibers 2.

In fig. 6 a mould is shown, schematically, including a cavity 6C in which a preform 3 is placed or formed. In this embodiment the preform 3 has outer dimensions such that it does not fit properly inside the mould cavity 6C without at least some compression. In this embodiment the preform 3 is compressed into the desired shape by closing the mould, such that the mould parts push against the preform 3. This can lead to a higher density of the preform in some parts of or all of the preform 3 and of the element 1. As is shown in fig. 6 when the mould 6 is brought from the partly open position shown at the left hand side to the closed position at the right hand side, the preform 3 is compressed, increasing its density. In embodiments the foaming
agent 4 can be injected into the mould cavity only after full closure of the mould and thus compression of the preform 3. In alternative embodiments the injection of the foaming agent can be performed at least partly during compression of the perform 3 or before compression of the perform 3. In embodiments the foaming agent 4 can be allowed to form a foam 5 in the mould, which can thereafter be at least partly compressed in order to amend the density thereof.

After the foam 5 has been formed, the foam can be cured, if necessary, for example by appropriate heat or cold or chemical treatment, by radiation or any other known suitable method of curing. Such methods are well known in the art and can be chosen depending on at least the type of foam formed and the curing desired or necessary.

Before, during or after forming and, if desired, curing of the foam 5 the element 1 can be taken out of the mould 6 and can, if necessary or desired, be further treated, for example trimmed, cut into smaller elements, painted, upholstered, covered by a cover such as a fabric or skin, impregnated with chemicals such as but not limited to anti fungal, fire retardant, water resistant or anti bacterial coatings.

Fig. 7 shows schematically, and by way of example only, a blade 25 of a wind turbine supported by a number of elements 1 supported on a carrier 7. A rotor blade 25 can have a length LB of for example up to 75 m, is normally substantially hollow and needs to retain its form and shape during transport, for example over a road or over water. A rotor blade 25 can for example be supported in a known manner or by elements 1 according to the invention at a foot or base portion 26 where the rotor blade 25 will be mounted to a turbine (not shown) Such base or foot portion 26 will have proper mounting means (not shown) which can be engaged, such as an axel, bolts or nuts or other fittings. Spaced apart from said base 26, for example at or near an opposite end of the blade 25, commonly referred to as tip 27, the blade 25 has to be supported on the outer surface 28. The blade 25 and especially the tip 27 is normally not
provided with any elements to be engaged for such purpose. Therefore supporting elements have to be used. As can be seen elements 1 according to the invention, supported by a carrier 7, as for example disclosed in fig. 3, can be used to support the blade 25 properly, wherein the self-adjusting support aids at easy positioning and adaptability of the support. Since the elements 1 are made using fiber 2 reinforced foam 5, they can be very light and sufficiently flexible and soft, and nevertheless sufficiently strong and tear and shear resistant to withstand the forces exerted thereupon by the rotor blade 25 during transport, whereas they are also sufficiently resistant to for example environmental influences.

In fig. 7 a system can be used according to fig. 3. Herein the adjustment system 38 can for example comprise a jacking system operable by a handle or for example mechanically, hydraulically, electrically or pneumatically. Thus the blade 25 can be clamped between the elements 1, preferably by the elements 1. The third element 1C and third shore 37 are preferably pivotably or removable mounted to the carrier frame 30, such that the third element 1C can be moved out of the way when placing a blade on or removing the blade 25 from the carrier 7. The frame 30 can furthermore be provided with hoisting elements such as hooks or eyelets 39, for example at the free ends of one or more of the posts 31. Preferably the posts 31 are positioned such that the blade 25 extends at least partly between the posts, for further protection. It will be clear that different configurations of carriers 7 and elements 1 can be used, depending on for example the product or part thereof to be supported, the position of the carrier and element(s) 1 relative to said product or part thereof and the such factors. It shall be clear that the blade 25 is only shown as an example of a product part that can be supported using one or more elements 1 according to the present invention.

In embodiments in an element 1 of this disclosure metal fibers 2 can be used, which will make it even more difficult to break or cut the element 1.

In embodiments in an element 1 of this disclosure natural fibers 2 can be used,
which will increase the amount of renewable resources used in such elements 1, especially in foamed products, without loss of strength. In general fibers 2 used according to this disclosure can provide for foamed products having increased strength.

The invention is by no means limited to the embodiments shown and specifically discussed here above. Many variations are possible within the scope of the disclosure as defined by the claims.

For example different foams and foaming agents can be used, whereas elements formed by or according to the invention can comprise parts that are made differently. For example an element 1 can be formed in a part made of a different, for example less flexible material, such as a plastic or metal shell or a part made of a natural product such as wood, or in a woven or non woven part. Elements 1 can have different shapes and sizes, and can for example be made without or with different mounting elements 11. Elements according to or made with a method of the disclosure can be used as products or product parts for different purposes, such as for example but not limited to bumpers, fenders, buffers, fillers, cushions, padding, sports equipment, floor or wall elements, insulation and the like. In this description all combinations of features as disclosed, as well as individual aspects thereof are also considered to have been explicitly disclosed.
Claims

1. Method for manufacturing a composite element, comprising the steps of:
   - providing a series of curled or twisted fibers;
   - forming a preform with said fibers;
   - preferably connecting at least a number of the fibers to each other locally, providing a network of said fibers;
   - injecting a foaming agent into said preform or network of fibers;
   - allowing the foaming agent to form a foam at least partly enclosing said fibers.

2. Method according to claim 1, wherein the preform is placed inside a mould, preferably prior to injecting the foaming agent into said network, such that the mould substantially defines an outer configuration of the element.

3. Method according to claim 1 or 2, wherein the network of fibers is compressed in a mould, preferably prior to or during injecting the foaming agent into the network of fibers.

4. Method according to any one of the previous claims, wherein the fibers are made using at least one of a synthetic material, a natural fiber material and metal.

5. Method according to any one of the previous claims, wherein a foaming agent is used which is curable.

6. Method according to any one of the previous claims, wherein a foaming agent is used forming a synthetic foam such as a PU-foam.

7. Method according to any one of the previous claims, wherein the element is formed in a mould, such that a skin is formed having a density which is higher than the density of a core of the element.

8. Method according to any one of the previous claims, wherein at least one connecting element is provided, at least partly in said network of fibers,
which at least one connecting element is formed and positioned such that a part thereof extends outside the element.

9. Method according to any one of the previous claims, wherein the fibers are brought into said curled or twisted form from straight fibers, whereby the fibers are treated, preferable heat treated, in order to maintain the said curled or twisted shape.

10. Method according to any one of the previous claims, wherein a bundle of fibers is curled or twisted and cured in order to maintain the cured or twisted form, where after the bundle of fibers is divided into bundles of smaller number of fibers and/or individual fibers, for forming the fibers to form the network, wherein the bundle of fibers can have a relatively large length cut into the fibers used for forming the network.

11. Method according to any one of the previous claims, wherein the fibers are connected to each other by bonding, especially mechanical or chemical bonding and/or heat bonding.

12. Method for forming a support element, preferably using a method according to any one of claims 1 - 11, comprising the steps of providing a preform made of non-straight fibers in a mould, closing the mould around the network and part of at least one connecting element and inducing the production of a foam in said mould, through and at least partly around said preform and part of said at least one connecting element, such that a fiber reinforced, foamed support element is provided.

13. Method according to claim 12, further comprising providing at least connecting element extending from within said mould to outside said mould, such that the support element is mountable by said at least one connecting element.

14. Element, formed with a method according to any one of the previous claims.

15. Support, comprising a number of elements according to claim 14, wherein at least a number of said elements is connected to a mounting frame.
by pivots, such that at least said number of elements can pivot relative to said frame and/or each other.
## INTERNATIONAL SEARCH REPORT

**A. CLASSIFICATION OF SUBJECT MATTER**

INV. B29C44/12

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 practical, search terms used)

EPO-Internal, WPI Data

### C. DOCUMENTS CONSIDERED TO BE RELEVANT

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<td>29 August 1990 (1990-08-29) page 8, last paragraph - page 11, paragraph 1; figures</td>
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- **X** Further documents are listed in the continuation of Box C.
- **[X]** See patent family annex.

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