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(54) **Title**: A METHOD OF MANUFACTURING A MODULAR COMPOSITE LAMINATE STRUCTURE, STRUCTURE OBTAINED BY THE METHOD AND USE THEREOF

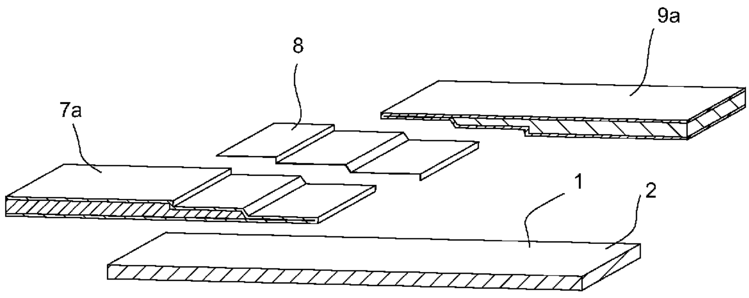

Fig. 9

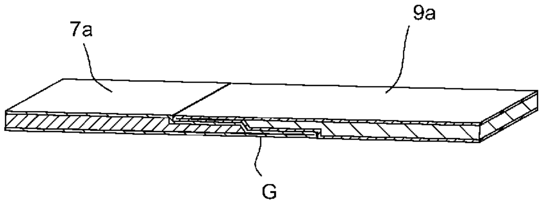

Fig. 10

(57) **Abstract**: A method of manufacturing a modular composite laminate structure, structure obtained by the method and use thereof. A method for manufacturing a modular structure comprises the steps of providing a mold (1), providing the mold (1) with a preform (7a, 9a) for the structure, and applying a resin to the preform (7a, 9a). The preform (7a, 9a) is modular, and the modules (7a, 9a) of the preform (7a, 9a) are arranged contiguously in the mold (1) with contiguous parts separated by releasable separating layers (8). The casted modules (7a, 9a) fit perfect together. They are detached from each other by removing the releasable separating layers (8), and are assembled later using a securing means such as strong glue. The modular system is inexpensive to transport and store and fast to assemble on location of use. The resulting assembled structure is strong and less vulnerable to bad weather conditions than conventional modular structures.

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A method of manufacturing a modular composite laminate structure, structure obtained by the method and use thereof.

The invention relates to a method of manufacturing a modular structure comprising the steps of

a) providing a mold,
b) providing the mold with a preform for the structure,
c) applying a resin to the preform, and
d) curing the resin.

The invention relates in particular to a method of manufacturing a modular composite laminate structure.

In the wind turbine industry e.g. the nacelle, spinner covers and the wind turbine blades are manufactured as composite structures, often as a single unit in a single mold for the whole structure, or casted as several separate mold components in each their corresponding mold part. Other industries making use of large composite structures are e.g. the locomotive, marine and automobile industry.

One conventional method, which have been used through many years for manufacturing large composite elements or structures is open molding, where a structure is made either by spraying-up or hand laying-up the layers of the laminate. In the open molding process there is only one mold surface so the element’s thickness depends on the operator’s ability to control how much resin and fibre mat or core material he/she applies to the surface of the mold. Irregularities and differences in thickness of elements of a large molded structure may constitute a problem when the elements are assembled.

The simplest of the open molding methods is the hand lay-up. A gel coat is first sprayed onto the mold cavity for a high-quality surface. When the gel coat has cured, glass reinforcing mats and/or woven rovings are placed on the mold, and the catalyzed resin is poured, brushed or sprayed on. Manual rolling then removes entrapped air, compacts the composite, and wets the reinforcement mat and/or roving with the resin. Additional layers of mat or woven roving and resin can be added on top for increased thickness. A catalyst or accelerator initiates curing in the resin system, which hardens the composite without external heat.

Spray-up also utilizes an open mold and a resin curing at room temperature. Chopped fibres are deposited in the mold from a chopper and catalyzed resin from a sprayer. Manual rolling removes entrapped air and wets the fibre reinforcement. Roving may or may not be added for thickness or strength. Gel coats can be included in same manner as for hand lay-up.

Resin transfer molding (RTM) has recently replaced the above technologies for some applications because RTM is capable of making large complex three-dimensional parts with high mechanical performance, tight dimensional tolerance, outstanding strength-to-weight characteristics and high surface finish. In the RTM technology the composite element or structure is molded using a rigid mold to provide part geometry, and a counter mold over the fibre preform, with outer atmospheric pressure compressing the fibre preform tight against the rigid mold surface using vacuum at the exit vent of the molding tool during resin infusion. Simple RTM have fixed cavity cross-section defined by opposite matching mold parts. Fibre to resin ratio can be effected by the type/amount of fibre loaded and the distribution of the fibre cross-sectionally in the laminate. A particular kind of RTM is vacuum-assisted resin transfer molding (VARTM). In VARTM there is one rigid mold surface and the opposing mold half is a film on top of the fibre to make up the fibre preform. The actual cavity is determined by the fibre thickness once the fibres are compressed, that is when, during resin injection, a vacuum is created between the rigid mold surface over the film and the fibres.

The matrix used in RTM normally are thermosetting resins because of their low viscosity that facilitates injection. Thermosetting resins include but are not limited to epoxy, phenolic, cyanate, bismaleimide polymers. They are cross-link polymers in which the motion of polymer chains is strongly limited by the high number of existing crosslinks. In the polymerisation phase thermosetting undergoes irreversible chemical change. So thermosettings are very suited to make the rigid materials needed in the wind industry. Polyurethanes are another option.

Yet another process option is e.g. Reaction Injection Molding (RIM), a process wherein two liquid polymer components are dosed in a controlled, volumetric mixing ratio in an in-line mixer unit that mixes the components into a homogenous, liquid molding material in a tank under constant recirculation, stirring, and temperature control. The liquid mass is brought into the desired geometrical shape, e.g. by pouring it into a closed, heated mold. The chemical reaction then starts and brings the material from liquid to solid form to be removed from the mold.

However high transportation costs for large composite structures, such as nacelles, blades and spinners, may need structure manufacturing close to the site of use and creates a need to continuously building facilities in proximity to the costumer.

Alternatively the composite structure can be manufactured as a modular system made-up of smaller elements or modules, such as e.g. more or less curved elements, including plate-shaped elements, which can be transported at lower costs and assembled at the place of use using mobile assembling facilities. Such a system is e.g. known from the applicant's international patent application no. PCT/IB2007/051765 in which special brackets are used in corresponding recesses in two composite elements to be joined. This method is reliable but time-consuming and may require special skills and education. Alternatives are desired.

The above technologies, processes and polymers are known to the person skilled in the art and will not be discussed further. Any of the above molding technologies are applicable in the present invention. However other molding technologies could also be used.

In a first aspect according to the present invention is provided an alternative method of the kind mentioned in the opening paragraph for manufacturing modular molded structures, such as, modular composite structures, to be assembled at the site of use.

In a second aspect according to the present invention is provided a method of manufacturing a kit of composite elements or modules mutually fitting together to create a larger composite structure.

In a third aspect according to the present invention is provided a method in which composite elements or modules can be assembled quicker, easier and tighter without custom-made mountings.

In a fourth aspect according to the present invention is provided a method for manufacturing large composite structures at low costs.

In a fifth aspect according to the invention is provided a composite structure obtained by the method.

In a sixth aspect according to the invention is provided a low-weight, high-strength composite structure of composite elements or modules of a kit.

In a seventh aspect according to the invention is provided a method for manufacturing a composite structure that are assembled of composite elements or modules of a kit, where the operator of the molding method has freedom to select the shape and size of the individual composite elements or modules.

In an eighth aspect according to the invention is provided a method for repeatingly manufacturing a composite structure that are assembled of composite elements or modules of a kit wherein the structure is assembled at the site of use and is an almost perfect match of the mold cavity.

The novel and unique features according to the invention, whereby these and other aspects are achieved, is the fact that

- the preform is modular, and
- step b) comprises step e) wherein the modules of the preform are arranged contiguously in the mold with contiguous parts of the contiguous modules separated by releasable separating layers.

Within the context of the present invention the terms "contiguous" and "contiguously" is used to describe objects immediately next to each other, or being so close to each other that they would touch each other if not for the releasable separating layers. Thus the modules of the complete preform of a casted structure is molded into modules that mate intimately together, irrespective of the preform modules have been provided on top of each other or next to each other.

While mold release films have been used for facilitating release of molded structures from its mold, it is new to make smaller composite parts, composite elements, composite modules or composite components, or resin components by dividing, by using thin releasable separating layers, the final structure up into such smaller parts, elements, modules or components already at the preform stage in the mold.

In the following the term "module" is used interchangeably with the terms part, element, or component. The term "module" should not be construed as being limiting to certain sizes of parts, elements, or components making up the larger structure.

Resin infused or otherwise applied in step b) saturates the contiguous modules of the preform but due to the presence of the releasable separating layer(s), the resin cannot cure to fuse two neighbouring modules together. Thus, neighbouring modules are advantageously casted with modules in close conjunction, thus as a common unit, but so that they can be separated. Neighbouring preform modules in intimate conjunction of each other will during casting inherently get matching and mating contiguous parts, and respective contacting surfaces and areas fit perfectly together. The method according to the present invention makes individual molds for individual modules superfluous, thus the manufacturer saves considerable costs and time, and the same mold can be used over and over again. The operator simply arranges the appropriate number and kinds of preform modules in the mold selecting the contiguous areas or parts where convenient, and separated by as many releasable separating layers as desired and needed. The operator has an hitherto not realised influence on the size and geometry of each module, due to being able to arbitrarily chose where to place the joinings of the preform modules, and thus also the joinings of the resulting modules making up the complete structure, e.g. composite modules of a composite structure. So composite structures having similar appearance to the viewer may be composed of very different kits of modules. Raw materials can be utilised at its optimum because the operator is not restricted to use certain sizes and numbers of preform modules. The operator can select, create and define the preform modules as the mold is filled, and can consider special design structures and conform the preform modules to a given mold or mold surface.

The preform modules may e.g. be a sandwich construction consisting of two opposite sheets, or opposite layers of laminate, encapsulating a distance material with the purpose of reducing material consumption as well as weight, and giving composite modules, and thus a composite structure into which they are to be assembled, the desired strength and durability.

Materials used as distance material in the production process are e.g. glass mats or foam that easily conforms to the surface of the mold, and can be cut to suitable sizes.

Instead of arranging the preform modules layer by layer in the mold, the modules of the preform can be premade sandwich modules that can be arbitrary tailored and conformed to the mold by an operator. A premade sandwich module can e.g. be a premade multi-layer laminate composed of laminate, distance material, laminate. Such preform sandwich modules are very fast to arrange separated by releasable separating layer inside the mold.

Within the context of the present invention the term “layer” is not limited to sheets, folios and films initially being in solid state. A “layer” can also be obtained by coating or spraying a liquid, cureable polymer on a subjacent support, other layer or surface.

The “preform” is not limited to materials initially being solid, but can be obtained by gradually coating and curing layer materials on top of each other. A preform may even not be needed if instead a resin is injected as a viscous substance into a mold separated by releasable separating layers arranged in the mold, to allow the resin to take shape after the mold surface and the releasable separating layers as well. The amount of resin, the injection pressure and any manipulation by the operator can be utilised to provoke thickness and shape of the modules. This modified embodiment of the method according to the present invention is particular suited for use with resins like polyurethane.

For some complex composite structures it may however be more favourable that the layers of the preform module can be laid-up in arbitrary shape, order and size of layers/laminate/cores in the mold, thus is build-up on the mold surface. Consideration can easily be taken to where holes and/or protrusions are to be created.

One way of ensuring that the molded modules, such as composite laminate modules, resulting from the molding process are suited to be joined and secured to each other later to make the final structure in a strong and reliable manner, is in step e) to arrange contiguous parts of contiguous preform modules to overlap each other on opposite sides of the releasable separating layer.

When resin is infused two neighbouring casted modules can e.g. be created so that they overlap in extension of each other along the surface curvature of the mold, e.g. by being molded with mating wedge-shaped ends of contiguous parts of the preform modules. The longer ends of contiguous parts of the preform modules the more contact area for securing between resulting casted modules that belong together. The method according to the present invention makes it possible to make a.o. two mating wedge-shaped ends that fits prefect together without any special tools. The wall thickness of the final assembled modular structure can in this way be produced to be almost the same throughout the assembled modular structure, thus also at the joined overlapping ends of two modules.

It is also possible in step e) that contiguous parts of contiguous preform modules overlap on top of each other to obtain thicker final structures when assembled, or when preparing for holes, openings and molding around cores.

In one embodiment the releasable separating layers has a surface topography so that said releasable separating layers also can be utilised to alter the surface of the cured resin of the composite module, e.g. to increase available surface area of contacting surfaces to increase joining strength, or to emboss or imprint instructions guiding the assembling and joining of contiguous modules, such as e.g. composite laminate modules.

Alternatively, in step (d) a tie layer can be applied on top of contiguous parts of contiguous modules of the preform, and the releasable separating layers be provided on top of said tie layer, thus the tie layer is inserted between preform module and releasable separating layers, and is left on the cured resin-infused preform module that becomes the casted module, to protect the subjacent surface until two contiguous casted modules are to be assembled again to obtain the final structure. A tie layer can also be of a kind that impart surface topography to the surface of the corresponding contiguous part of a casted module and for providing assembling instructions as mentioned above.

In step e) of one embodiment a first preform module can be created by a laying-up method comprising

- providing at least one first laminate layer on a surface area of the mold surface,
- providing at least one first core laminate layer on top of the at least one first laminate layer,

- providing at least one second laminate layer on top of at least the at least one first core laminate layer,
- applying the releasable separating layer at least at contiguous areas of the respective first preform module and the contiguous preform module.

This embodiment of the method according to the present invention allows the operator to make special sandwich laminate structures. Any of said layers can be selected according to a specific task and be made to meet specific customer needs and meet challenges. Additional reinforcement webs, layers, components etc. can easily be added, including incorporating metal reinforcements, distance materials and laminate layers selected in any desired kind, quality and thickness, coloured or non-coloured first and/or second laminate layers, and one or more second laminate layer, etc.

In step e) a contiguous preform module can be created by simply

- providing at least one third laminate layer in overlapping relationship with the releasable separating layer but not with the second laminate layer,
- providing at least one second core laminate layer on top of the at least one third laminate layer, and
- providing at least one fourth laminate layer on top of the at least one second core laminate layer.

In this way the overlapping parts of the contiguous composite modules can be molded to match and fit perfect together when assembled to the final structure.

In step e) of an alternative method according to the present invention the preform modules are simply premade sandwich structures conformable to the mold surface and having respective mating contiguous parts as coupling means separated by the releasable separating layer. This method can be performed fast and effective.

According to the present invention the mold is patched with preform modules separated by releasable separating layer, e.g. the above premade sandwich structures, the laid-up layers or the viscous resin itself, in any arbitrary appropriate system and/or arrangement following the curvature of the mold. Applied resin does not stick to the releasable separating layers, so when the resin cures a number of respective casted unique modules are created. Each casted module becomes a building brick in the final composite structure to be assembled.

The releasable separating layer can e.g. simply be a sheet of non-stick paper. Non-stick paper can be discarded at low costs, e.g. by incineration. Non-stick paper is also very thin so that the space it occupies between contiguous parts of contiguous casted module becomes very narrow and leaves no effect on the overall appearance of the assembled casted structure, if such effect is undesired.

Optionally the releasable separating layer has a thickness of less than 1 mm, optionally the non-stick paper is simply parchment paper.

The releasable separating layer can however have any desired thickness. This thickness can beneficially be used to create a suitable sized gap for receiving glue to create a glue joint. A releasable separating layer can e.g. be a silicone mat, including a reusable silicone mat, of up to e.g. 20 mm. The releasable separating layer, including a silicone mat, can be applied as a sheet, be sprayed on, or be brushed on the relevant area. A thin film or sheet of e.g. liquid silicone can be sprayed or painted on relevant areas of contiguous parts of preform modules not allowed to cure together when resin is applied. Other options for a releasable layer is a wax coating.

The method may comprises step e) in which the first module casted on the first preform module and the contiguous modules casted of the contiguous preform modules are detached from each other and removed from the mold as separate casted modules.

The invention also relates to a modular structure, in particular a modular composite laminate structure, obtained by the method according to the invention.

The casted modules are recombined in same order and arrangement as they had in the mold set-up, and the casted modules are secured to each other using any securing means suitable to create a strong bonding to build the strongest, high-quality casted structure with a minimum use of raw materials.

Suitable securing means include but are not limited to strong glue, double adhesive tapes, and any kind of chemical bonding able to create a strong fusion and/or bonding of two casted modules, e.g. casted composite modules. Exemplary glues are the resin itself, any one-component or any two-component glue. Specific exemplary glues include

- Ashland 7400 obtainable from Ashland Inc., 50 E. River Center Blvd., Covington, KY 41012-0391 USA,
- Scotch-weld 490 obtainable from 3M United Kingdom PLC, 3M House, 28 Great Jackson Street, Manchester, United Kingdom M15 4PA,
- Spa bond 340 obtainable from Gurit Ltd, St Cross Business Park, Newport, Isle of Wight, United Kingdom PO30 5WU.
- Sikaflex obtainable from Sika Danmark A/S, Præstemosevej 2 - 4, DK-3480 Fredensborg,

- Plexus MA560, Plexus MA425, and Plexus MA530 obtainable from ITWPLEXUS, 30 Endicott Street, Danvers, MA 01923 USA.

Which kind of glue that is appropriate for assembling a given casted modular structure depends on a.o. the size of the available contact area and of the available gap for glue application between to contiguous parts to obtain the desired and required bonding force and strength.

The chemical bond can be strengthened by mechanical means such as screws, nut and bolts, and even brackets.

The invention will be described in further details below with references to the accompanying drawing in which

Figs. 1 - 10 shows, schematically and fragmentary in perspective, a series of molding steps according to a first embodiment of the method of the present invention for producing casted composite modules that overlap end to end,

Figs. 11 - 20 shows schematically and fragmentary in perspective a series of molding steps according to a second embodiment of the method of the present invention for producing casted composite modules that overlap on top of each other,

Figs. 21 - 22 shows schematically and fragmentary in perspective a series of molding steps according to a third embodiment of the method of the present invention for producing casted composite modules that overlap end to end,

Fig. 23 is a perspective view of a structure assembled of casted modules,

Figs. 24 is an enlarged scale end view of the same, and

Figs. 25 and 26 are enlarged scale view of details of fig. 24.

In the below description of various embodiments of composite modules, preforms and methods, the releasable separating layers are as an example a releasable folio. Although only one or two preform modules or casted composite modules are shown, it is to be understood that plural preform modules are or can be laid-up in similar manner and in combined relationship before steps c) and d) are performed to cast the composite modules of the final composite structure, such as a kit of plural casted composite modules.

Since casted modules not being composite modules are manufactured along similarly steps no detailed illustrated description is believed necessary for this embodiment. This embodiment of the present invention can simply be conducted by allowing the liquid hot resin to conform and settle to mold surface curvature, applying the releasable separating layers where appropriate, and applying more resin. Alternatively resin is applied at the same time from opposite sides of the releasable separating layer already in place in the mold.

Fig. 1 shows step a) wherein a mold 1 is provided. The mold 1 has a surface 2 on which a composite structure of composite modules is to be created. The surface 2 of the mold 1 may have a non-stick coating, or be coated as occasion requires e.g. by spraying a non-stick film and/or applying a gel coat onto the surface 2.

In fig. 2 is provided a length of a first laminate layer 3 on a surface area of the mold surface 2, and as shown in fig. 3 a first core laminate layer 4 is placed on top of a part of the first laminate layer 3. The first core laminate layer 4 has a free wedge-shaped or just thinner contiguous end part 5. Then, as seen in fig. 4 a second laminate layer 6 is provided on top of the first core laminate layer 4 to enclose the first core laminate layer 6 towards the mold surface 2. In the present case the second laminate layer 6 is provided by folding the first laminate layer 3 on top of the first core laminate layer 4. Thus the first laminate layer 3 and the second laminate layer 6 are of same material, but could quite as well be separate layers of different materials. The folding step serves to surround the thinner contiguous end part 5 of the first core laminate 4. The second laminate layer 6 thus extends above and optionally beyond the first core laminate layer 4. In this way a first preform module 7 is laid-up according to step e) with a major thickness primarily defined by the material thickness of the first core laminate layer 4, and the opposite first laminate layer 3 and the second laminate layer 6.

In fig. 5 the releasable separating layer 8, the separating folio 8, is put on top of the contiguous end part 5 of the first preform module 7 in preparation to start laying-up a contiguous preform module 9, thus in the present case a second preform module 9, in a manner that makes the second preform module 9 releasable from the first preform module 7.

For creating the second preform module 9 a length of third laminate layer 10 is put on the mold surface 2 as well as on top of the releasable separating folio 8, as illustrated in fig. 6, to make sure that the first preform module 7 and the adjacent second preform module 9 are fully separately at all times, including after resin application in step c) and subsequent curing in step d). As shown in fig. 7 the next step is to put the second core laminate layer 11 on top of the third laminate layer 10 with a contiguous part 12 facing, optionally overlapping the contiguous part 5 of the first preform module 7, which contiguous part 5 of the first preform module is protected by the separating folio 8. More or less overlap between confronting contiguous parts 12,5 can be selected and preferred.

As shown in fig. 8 then the third laminate layer 10 is folded back on top of the second core laminate layer 11 to more or less enclose said second core laminate layer 11, so as to obtain the second preform module 9 with the fourth laminate layer 13.

The steps of the method are repeated until the surface 2 of the mold 1 is covered with contiguous preform modules 7,9 for a corresponding composite structure and resin application of step c) and resin curing of d) are performed. After termination of step d) the so casted contiguous preform modules have been converted into contiguous casted composite modules 7a, 9a, which are easily taken apart due to the separating folio 8, as shown in fig. 9.

As illustrated in fig. 10 contiguous composite modules 7a,9a are recombined in same pattern and arrangement as they were casted on preform modules in the mold 1. The composite modules 7a,9a are secured to each other to create the final composite structure using one or more securing means, such as glue G, bolts, rivets, etc. Tolerances between casted modules are neutralized due to the step-by-step creation of intimate casted modules. The gap between two contiguous modules due to the presence of the releasable separating layer between their respective preform modules 7,9 is inferior. The gap is e.g. expediently utilized for accommodating glue G at assembling the composite modules 7a,9a.

Figs. 11 - 20 show step by step a second embodiment of the method of the present invention for producing composite modules that overlap on top of each other. The second embodiment of the method corresponds substantially to the first embodiment and for like parts same reference numerals are used. The second embodiment differs especially from the first embodiment in that yet a contiguous preform module is casted to combine and conform to and with opposite and adjacent preform modules.

Fig. 11 corresponds to fig. 1, and fig. 12 corresponds to fig. 2, and these steps need not be discussed further.

As shown in fig. 13 a first core laminate layer 4 is placed on top of a part of the first laminate layer 3 together with and spaced apart from a second first core laminate layer 4’, so that the respective free wedge-shaped contiguous end part 5 of the first core laminate layer 5 faces the respective free wedge-shaped contiguous end part 5’ of the second first core laminate layer 4’.

Then, as seen in fig. 14 a second laminate layer 6 is provided on top of the first core laminate layer 4, the first laminate layer 3 and the second first core laminate layer 4’ to enclose and cover said layers 4,3,4’. The second laminate layer 6 can be same or different from the first laminate layer 3.

A depression or cavity 14 is obtained due to the facing wedge-shaped contiguous end part 5,5’. As seen in fig. 15 this depression or cavity 14 is then covered by the separating folio 8.

The separating folio 8 also extends a distance on top of the second laminate layer 6 at both sides of the cavity 14 to ensure reliability between the first preform modules 7,7’ and of a contiguous second preform module 15 about to be laid up. The second contiguous preform module 15 is laid-up on top of the separating folio 8 in the cavity 14 by first providing a third laminate layer 10’ on top of the releasable separating folio 8, as illustrated in fig. 16, leaving the ends of the releasable folio 8 free to make sure that the first preform module 7 and the second first preform module 7’ are fully separately at all times, including after resin application in step c) and subsequent curing in step d).

As shown in fig. 17 the next step is to put a second core laminate layer 11′ on top of the third laminate layer 10′ to fill at least the cavity 14. The second core laminate layer 11′ does not exceed the outer limits of the releasable folio 8. Finally, as shown in fig. 18, a fourth laminate layer 13′ is put on top of the second core laminate layer 11′ to enclose it. The fourth laminate layer 13′ extends beyond the second core laminate layer 11′ on top of it onto the third laminate layer 10′ still leaving the ends of the releasable folio 8 free. The contiguous parts of the second preform module 9 are in this case the opposite free end parts 9′,9′′ being contiguous to the contiguous parts 5,5′ of the respective first preform modules 7,7′, however also the centre part 9′′′ of the second preform module 9 may serve as a contiguous part, as in the present case.

As for the first embodiment the steps of the method are repeated until the surface 2 of the mold 1 is covered with contiguous preform modules for a corresponding composite structure and step c) and d) are performed. After termination of step d) the so casted contiguous laminated composite modules 7a,7a′,9a′ are taken apart due to the separating folio 8, as shown in fig. 19.

As illustrated in fig. 20 contiguous casted composite modules 7a,7a′,9a′ are recombined as they were molded as preform modules 7,7′,9 using one or more securing means G as described above for the first embodiment of the method according to the invention.

In the third embodiment of a method according to the present invention seen in fig. 21 a first preform module 15 is a premade sandwich laminate module 15 comprising a first core laminate layer 16 inserted between a first laminate layer 17 extending into a second laminate layer 18 to enclose the first core laminate layer 16 and create a contiguous end part 19 having a female engagement means 20. The contiguous second preform module 21 is also a premade sandwich laminate module 21 comprising a second core laminate layer 22 inserted between a third laminate layer 23 extending into a fourth laminate layer 24 to enclose the second core laminate layer 22 and create a contiguous end part 25 having a male engagement means 26 to be inserted in the female engagement means 20 of an opposite contiguous second preform module 15. In step b) and c) of the method premade preform modules are arranged inside the mold 1 until the mold surface 2 are covered as required to obtain the final composite structure. Releasable separating layers 8 are provided between the female and male engagement means 20,26 of contiguous premade preform modules 15,21 to keep such in close but not direct contact, and to allow subsequently casted composite modules 15a,21a to be taken apart after completion of steps c) and d).

As seen in fig. 22 the respective female engagement means 20a and male engagement means 26a of contiguous casted composite modules 15a,21a serve for securing of the casted composite modules to each other after removal of the releasable separating layer 8. In this embodiment glue G is a preferred engagement means.

Fig. 23 is a perspective view of a cylindrical modular structure 27 assembled of curved casted modules 7a,7a',9a,9a' made using the above-described method. The smooth surface is obtained because the individual casted modules fits perfect together. Fig. 24 is an enlarged scale end view of casted structure 27 illustrating two joinings 28,29 encircled by circle A and B, respectively.

Figs. 25 shows, in enlarged scale view, the joining 28 encircled by circle A, and fig. 26 the joining 29 encircled by circle B. Joining 28 corresponds to the joining seen in fig. 10, and is made by modules obtained as shown in figs. 1-9. Joining 29 corresponds to the joining seen in fig. 20, and is made by modules obtained as shown in figs. 11-19.

As is clear from figs. 23-26 a casted module have opposite free ends, and these free ends can be of very different appearance and kind. Accordingly the final casted structure may be composed of many different modules having different joinings, and the joinings be made according to different embodiments of the invention. As exemplified one end can e.g. be made according to a first embodiment but can also be part of a joining made according to the second embodiment.

Since the releasable separating layer is selected to be flexible it is able to conform to any shape and curvature of opposite contiguous parts of opposite preform modules in the mold, which contiguous parts still can make imprint on and of each other despite the presence of releasable separating layers. The operator is not restricted by any rigidity of the releasable separating layers or of any other layers. Should e.g. a core laminate layer be too rigid to conform to a very curved part of the mold, the operator can simply make this part of the composite structure of smaller preform modules.

Transport of large structures requires long vehicles for heavy loads and often such transports also require special transport permission and need to be made at period of low traffic. The invention makes it possible to use smaller transport vehicles, transport at all times, and at small costs, as well as assembling at location.

Claims

1. A method of manufacturing a modular structure (7a,9a,7a’,9a’,15a,21a) comprising the steps of
a) providing a mold (1),
b) providing the mold (1) with a preform (7,9,7’,9’,15,21) for the structure (7a,9a,7a’,9a’,15a,21a),
c) applying a resin to the preform (7,9,7’,9’,15,21), and
d) curing the resin,
characterised in that
the preform (7,9,7’,15,21) is modular, and
step b) comprises step e) wherein the modules of the preform (7,9,7’,15,21) are arranged contiguously in the mold (1) with contiguous parts (5,12,5’,19,25) of the contiguous modules of the preform (7,9,7’,15,21) separated by releasable separating layers (8).

2. A method according to claim 1, **characterised** in that the modules of the preform (7,9,7’,15,21) are premade sandwich modules (15,21), optionally premade sandwich modules arbitrary tailored and conformed to the mold (1) by an operator.

3. A method according to claims 1 or 2, **characterised** in that the layers of a preform module (7,9,7’,15,21) are laid-up in arbitrary shape, size and order of layers in the mold (1).

4. A method according to claims 1, 2 or 3, **characterised** in that in step e) contiguous parts (5,12,5’,19,25) of contiguous preform modules (7,9,7’,15,21) overlap.

5. A method according to any of the preceding claims 1 - 4, **characterised** in that in step e) contiguous parts (5, 9’,9’’,9’’’,12,19,25) of contiguous preform modules

(7,9,7’,15,21) overlap in extension of each other along the surface curvature (2) of the mold (1).

6. A method according to any of the preceding claims 1 - 5, **characterised** in that in step e) contiguous parts (5, 5’, 9’,9’’,9’’’,12,19,25) of contiguous preform modules (7,9,7’,15,21) overlap on top of each other.

7. A method according to any of the preceding claims 1 - 6, **characterised** in that the releasable separating layers (8) has a surface topography.

8. A method according to any of the preceding claims 1 - 7, **characterised** in that in step (d) a tie layer is applied on top of contiguous parts of the contiguous modules of the preform (7,9,7’,15,21), and the releasable separating layers (8) are provided on top of the tie layer, optionally the tie layer imparts a surface topography to the surface of the corresponding contiguous part.

9. A method according to any of the preceding claims 1 - 8, **characterised** in that step b) and step c) are combined so that the resin constitutes the preform (7,9,7’,15,21).

10. A method according to any of the preceding claims 1 - 9, **characterised** in that in step e)
a first preform module (7,9,7’,15,21) is created by
- providing at least one first laminate layer (3) on a surface area (2) of the mold (1),
- providing at least one first core laminate layer (4,4’) on top of the at least one first laminate layer (3),
- providing at least one second laminate layer (6) on top of at least the at least one first core laminate layer (4,4’),
- applying the releasable separating layers (8) at least at contiguous areas (5, 5’, 9’,9’’,9’’’,12,19,25) of

the respective first preform module (7,9,7’,15,21) and the contiguous preform module (7,9,7’,15,21).

11. A method according to any of the preceding claims 1 - 10, **characterised** in that in step e) a contiguous preform module (7,9,7’,15,21) is created by
 - providing at least one third laminate (10,10’) layer in overlapping relationship with the releasable separating layers (8) but not with the second laminate layer (6),
 - providing at least one second core laminate layer (11,11’) on top of the at least one third laminate layer (10,10’),
 - providing at least one fourth laminate layer (13,13’) on top of the at least one second core laminate layer (11).

12. A method according to any of the preceding claims 1 - 8, **characterised** in that in step e) the preform modules (7,9,7’,15,21) are premade sandwich structures (15,21) conformable to the mold surface (2) and having respective mating coupling means (20,26) separated by the releasable separating layers (8).

13. A method according to any of the preceding claims 1 - 12, **characterised** in that the releasable separating layers (8) is a sheet of non-stick paper, optionally the releasable separating layers (8) has a thickness of less than 1 mm, optionally the non-stick paper is parchment paper.

14. A method according to any of the preceding claims 1 - 12, **characterised** in that the releasable separating layers (8) is a wax coating or a silicone mat, optionally having a thickness of up to 20 mm.

15. A method according to any of the preceding claims 1 - 14, **characterised** in that the method comprises step e) in which the first composite laminate module (7a,7a’) casted on the first preform module (7,7’) and the contiguous composite laminate modules (9a) casted on the contiguous preform modules (9’) are detached from each other and removed from the mold (2) as separate composite laminate modules (7a,7a’,9a).

16. A casted module (7a,7a’,9a,15a,21a) manufactured by the method according to any of the preceding claims 1 - 15, **characterised** in that the casted module (7a,7a’,9a,15a,21a) is a composite laminate including a resin.

17. A casted module (7a,7a’,9a,15a,21a) manufactured by the method according to any of the preceding claims 1 - 15, **characterised** in that the casted module is a cured solid resin.

18. A modular structure (27) obtained by the method according to any of the preceding claims 1 - 15, by
    - in any convenient order recombining the casted modules (7a,7a’,9a,15a,21a), and
    - securing the casted modules (7a,7a’,9a,15a,21a) to each other.

19. A modular structure (27) according to claim 18, **characterised** in that the modular structure (27) is a composite laminate structure (27).

20. Use of the method and the casted modules (7a,7a’,9a,15a,21a) according to any of the preceding claims for wind industry components.

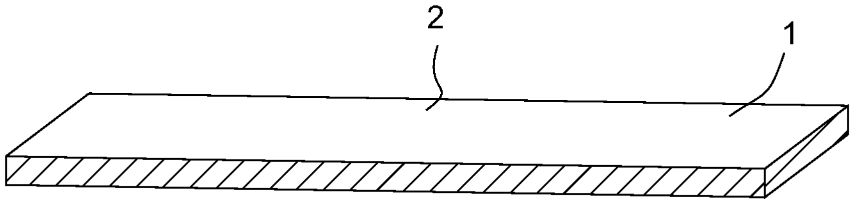

Fig. 1

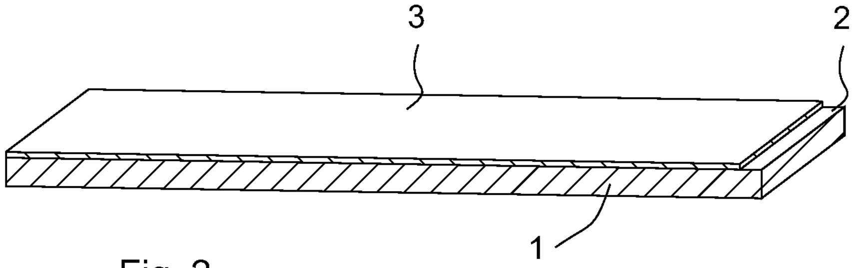

Fig. 2

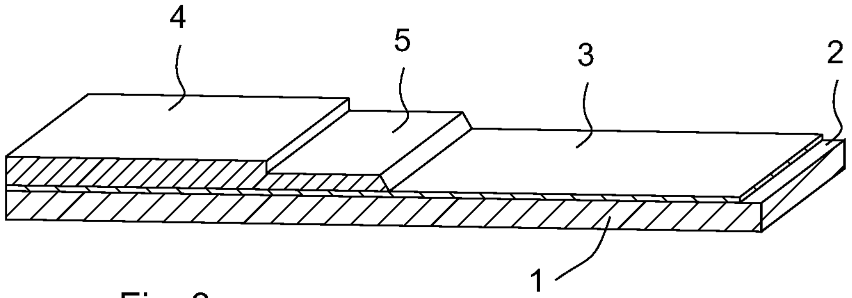

Fig. 3

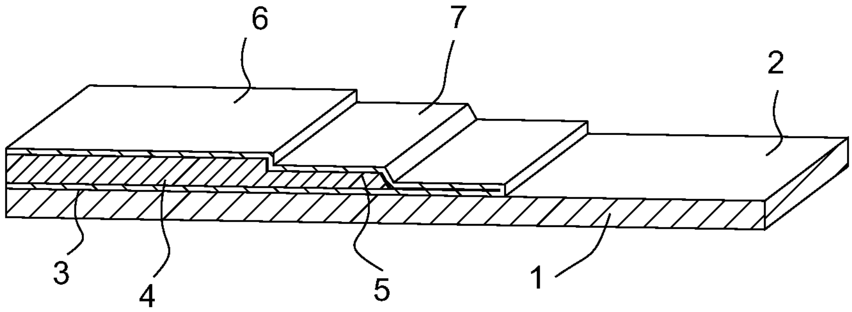

Fig. 4

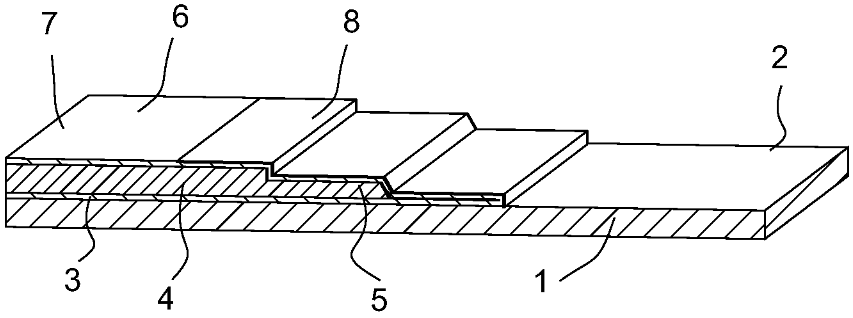

Fig. 5

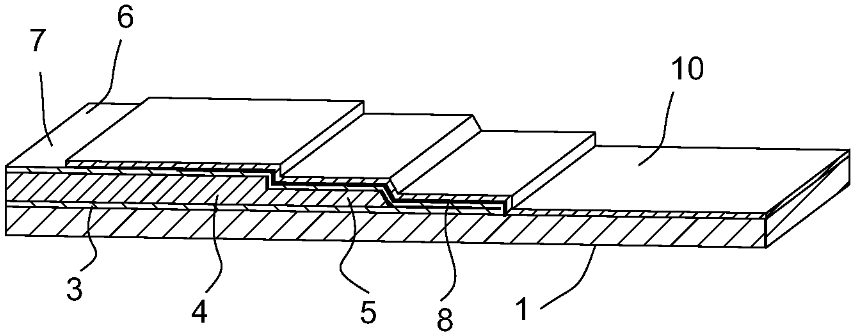

Fig. 6

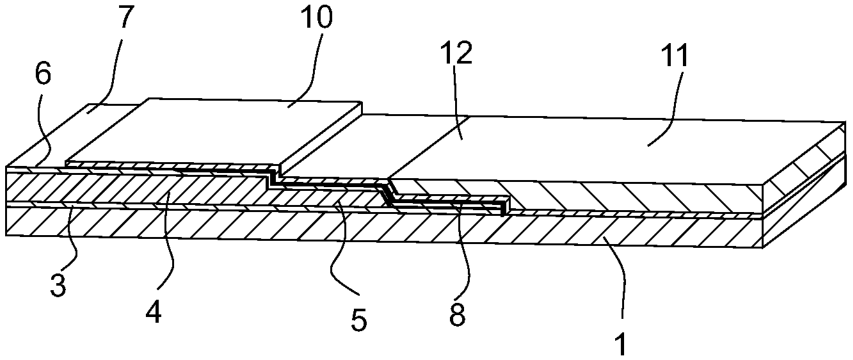

Fig. 7

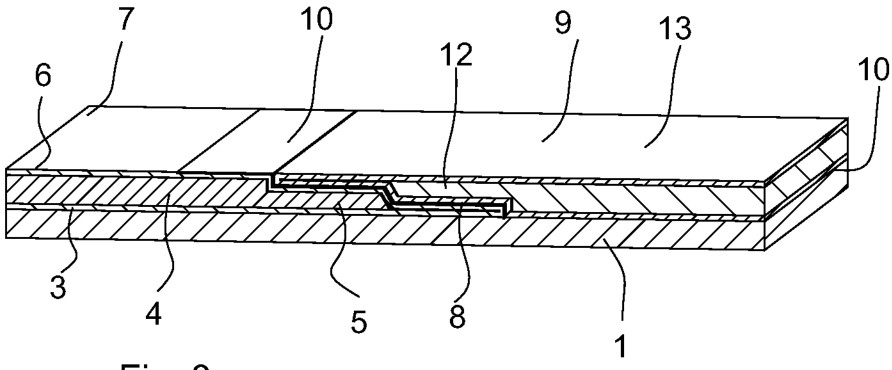

Fig. 8

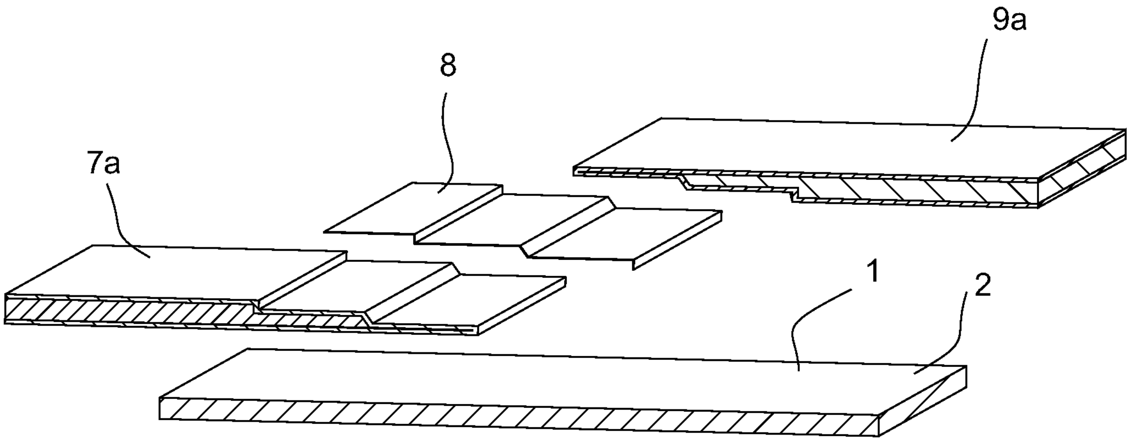

Fig. 9

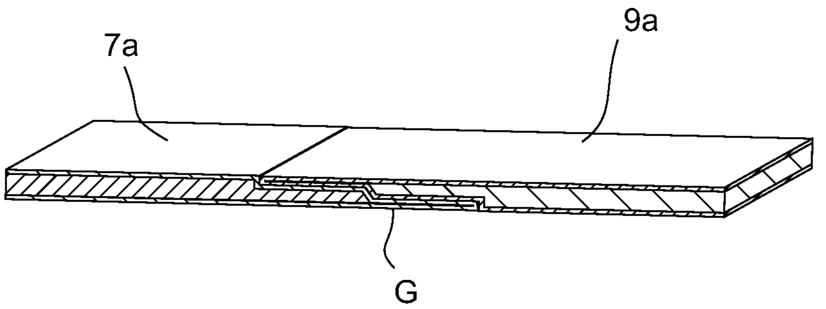

Fig. 10

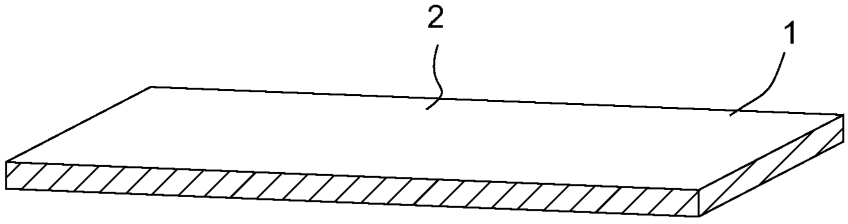

Fig. 11

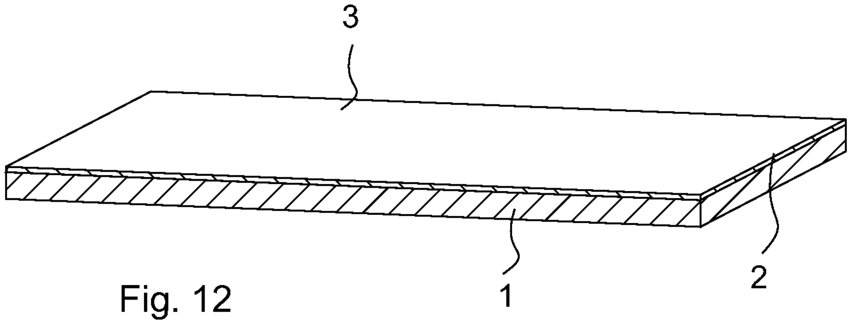

Fig. 12

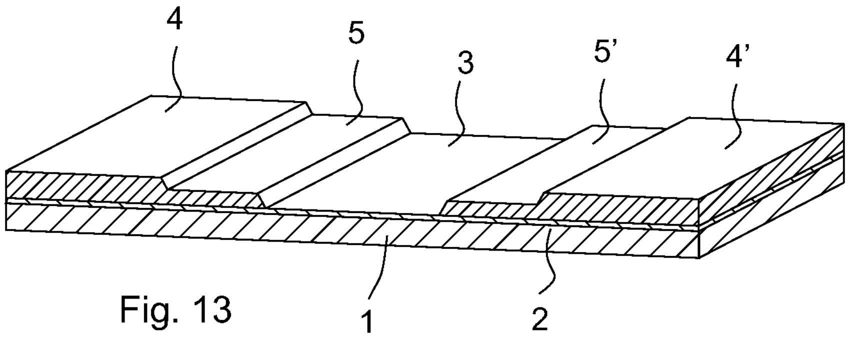

Fig. 13

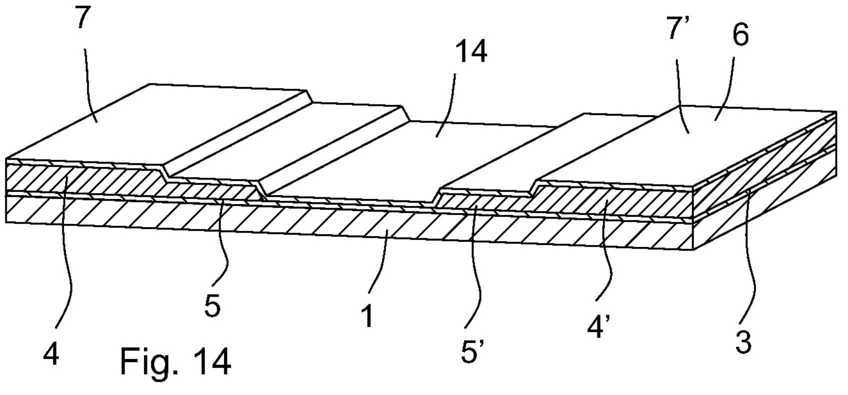

Fig. 14

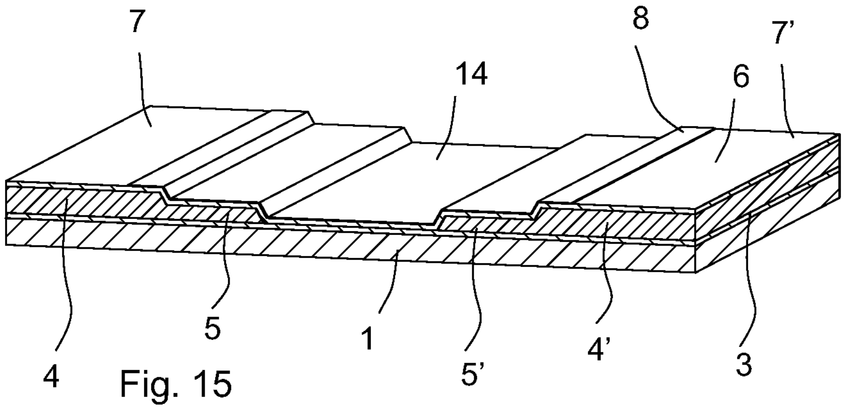

Fig. 15

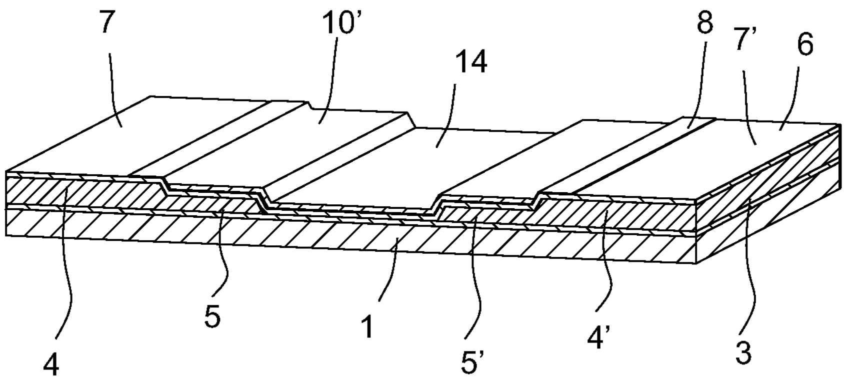

Fig. 16

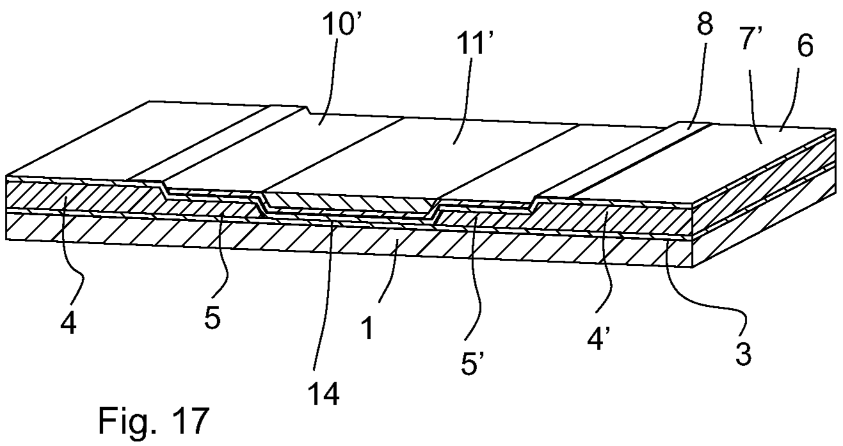

Fig. 17

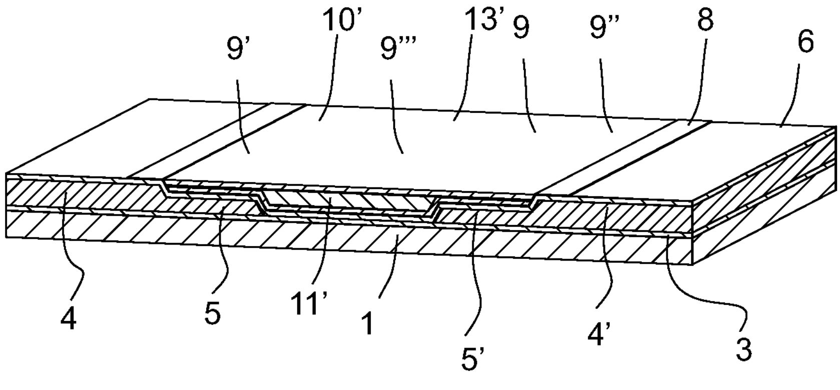

Fig. 18

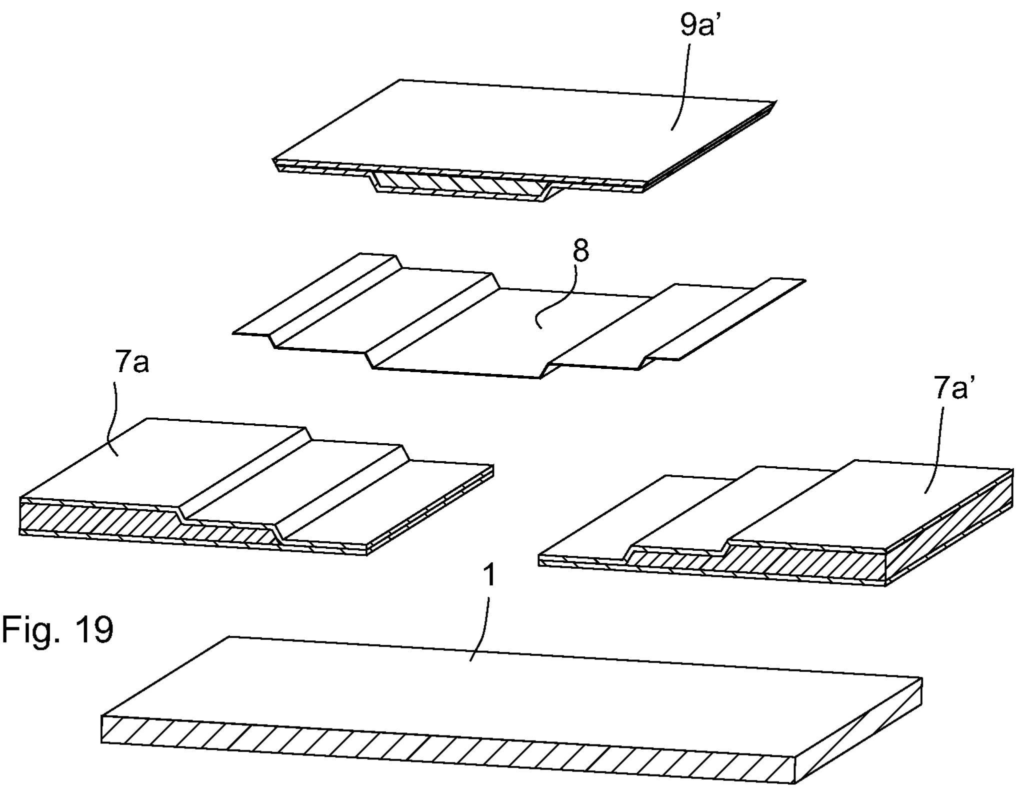

Fig. 19

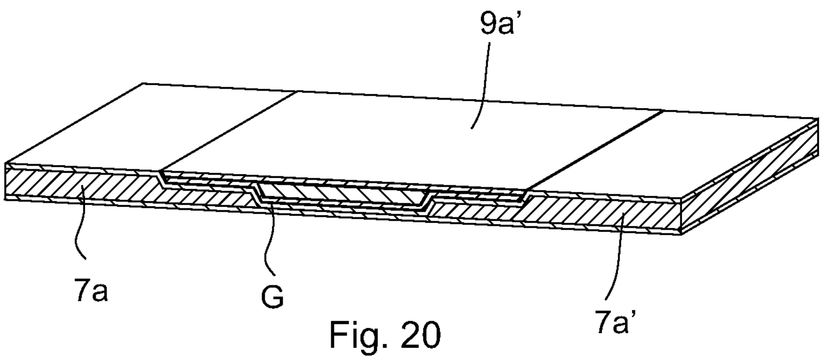

Fig. 20

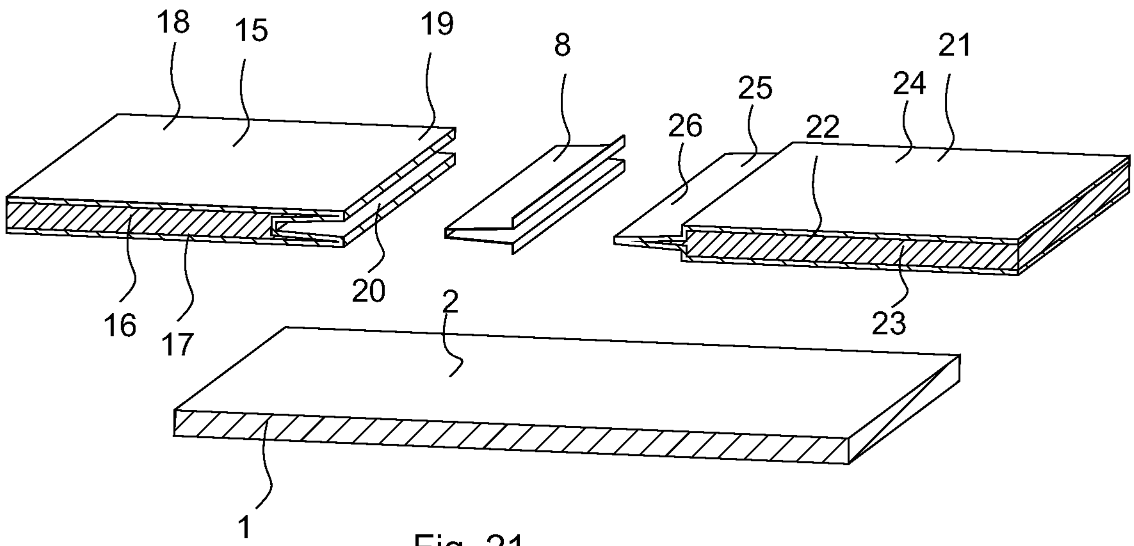

Fig. 21

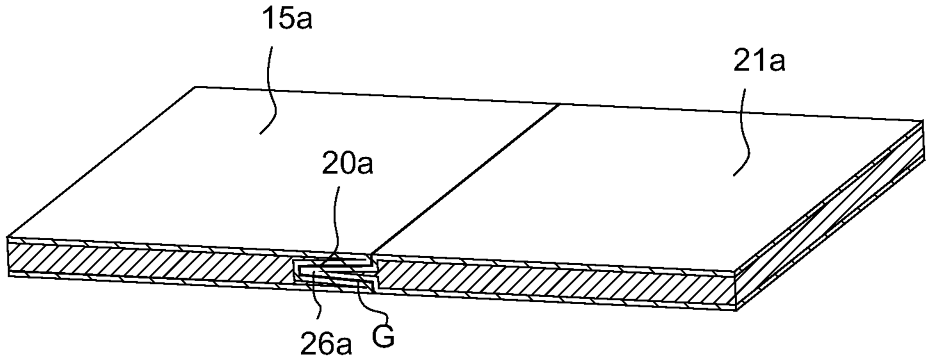

Fig. 22

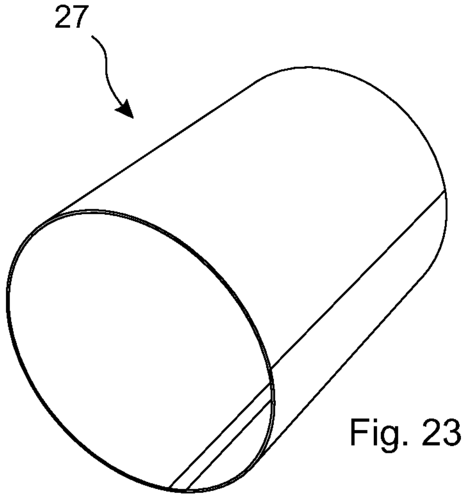

Fig. 23

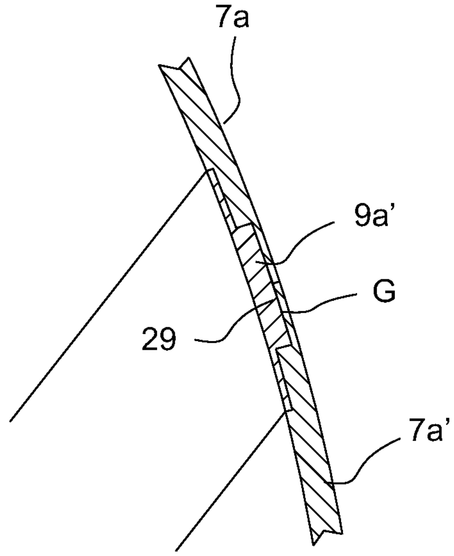

Fig. 26

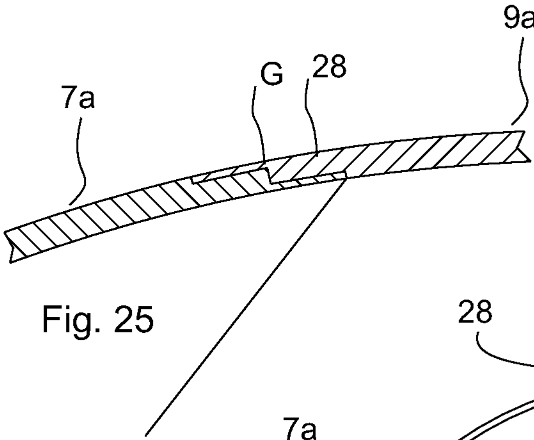

Fig. 25

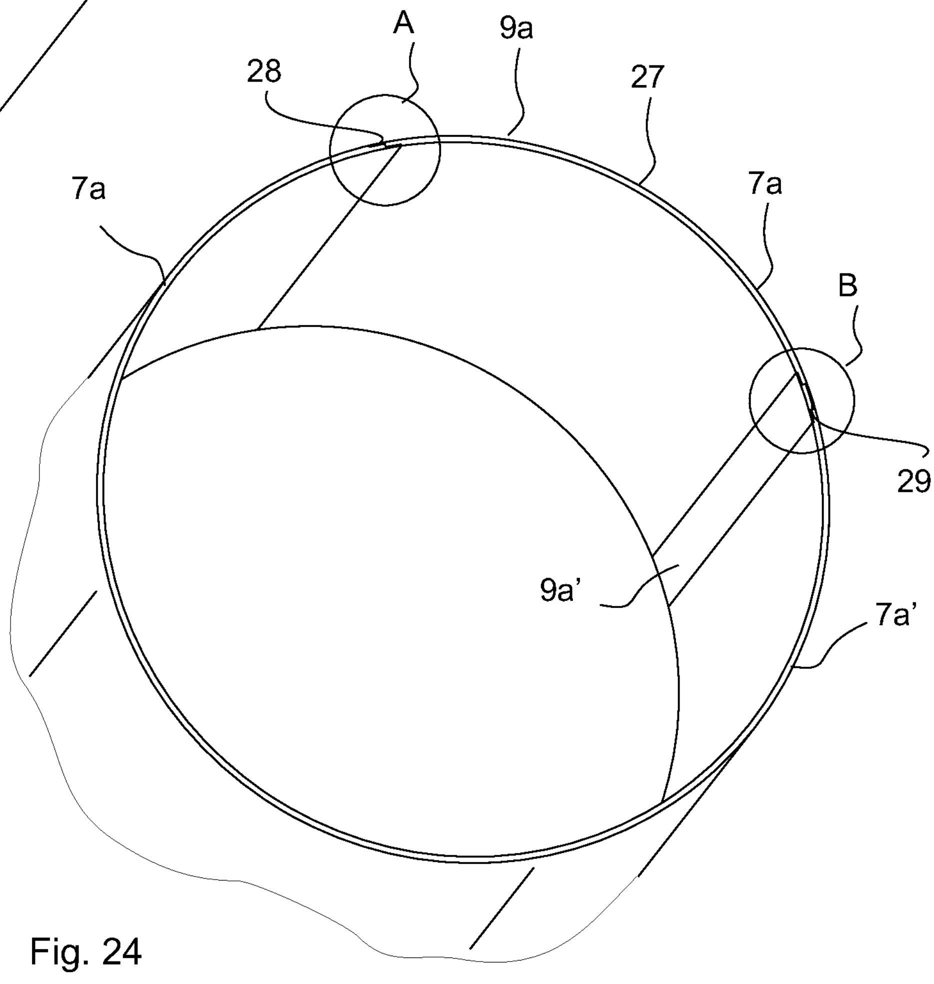

Fig. 24

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2013/071004

A. CLASSIFICATION OF SUBJECT MATTER
INV. B29C70/46 B29D99/00 B29C69/00
ADD. B29C65/48

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)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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X	WO 2009/095619 A2 (AIRBUS FRANCE [FR]; BOYELDIEU AURELIEN [FR] AIRBUS OPERATIONS SAS [FR]) 6 August 2009 (2009-08-06) abstract figures 1-4 pages 4-6 -----	1,20
A	US 6 048 488 A (FINK BRUCE K [US] ET AL) 11 April 2000 (2000-04-11) abstract figure 1 column 4, lines 1-8 ----- -/--	1-20

[X] Further documents are listed in the continuation of Box C.

[X] 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

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
4 June 2014	18/06/2014

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	Taillandier, Sylvain

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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Information on patent family members

International application No
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