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(54) **FIBER COMPOSITE MATERIAL AND METHOD FOR PRODUCTION THEREOF**

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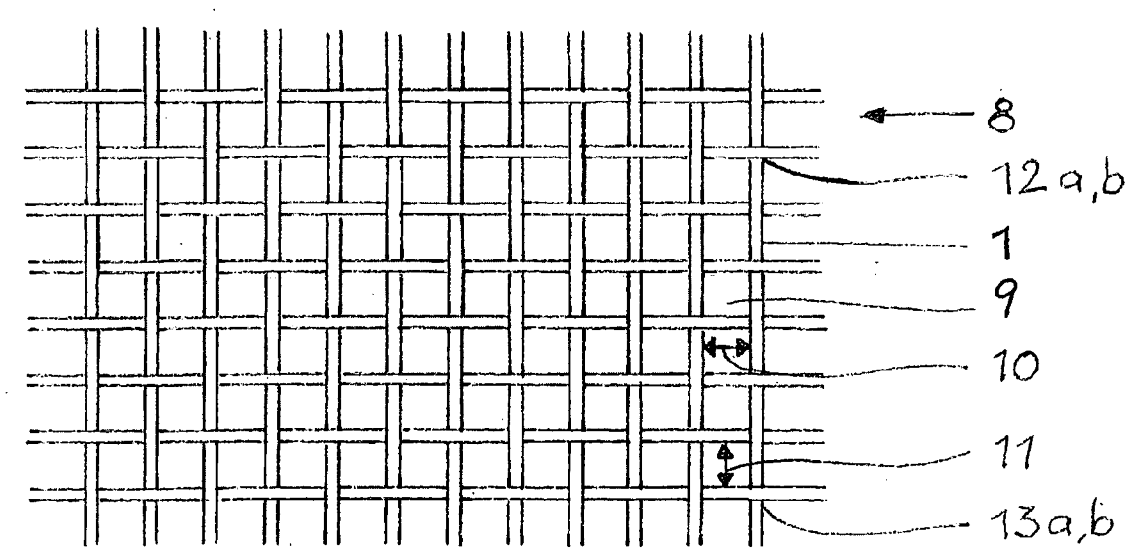
(57) **ABSTRACT**

A fiber composite material includes fibers and a resin connecting the fibers. The composite material has a high strength while reducing resin consumption and has great flexibility with respect to subsequent deformation. To achieve this, threads are used that include a plurality of individual filaments and a resin which can be crosslinked under an impact of at least one physical variable and/or one chemical substance. The resin is provided in non-crosslinked condition, but is essentially solvent-free, and holds the individual filaments in the threads together, wherein the individual filaments are arranged unidirectional to each other, and the threads form a composite by bonding together at contact surfaces of their respective external enveloping surfaces through resin bridges. The invention further relates to a fiber composite material including resin in a crosslinked state as well as a method for producing the fiber composite material.



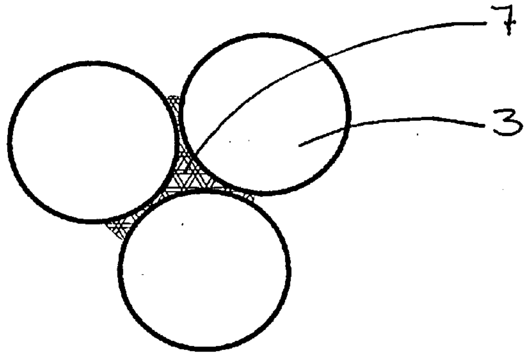



FIG. 2

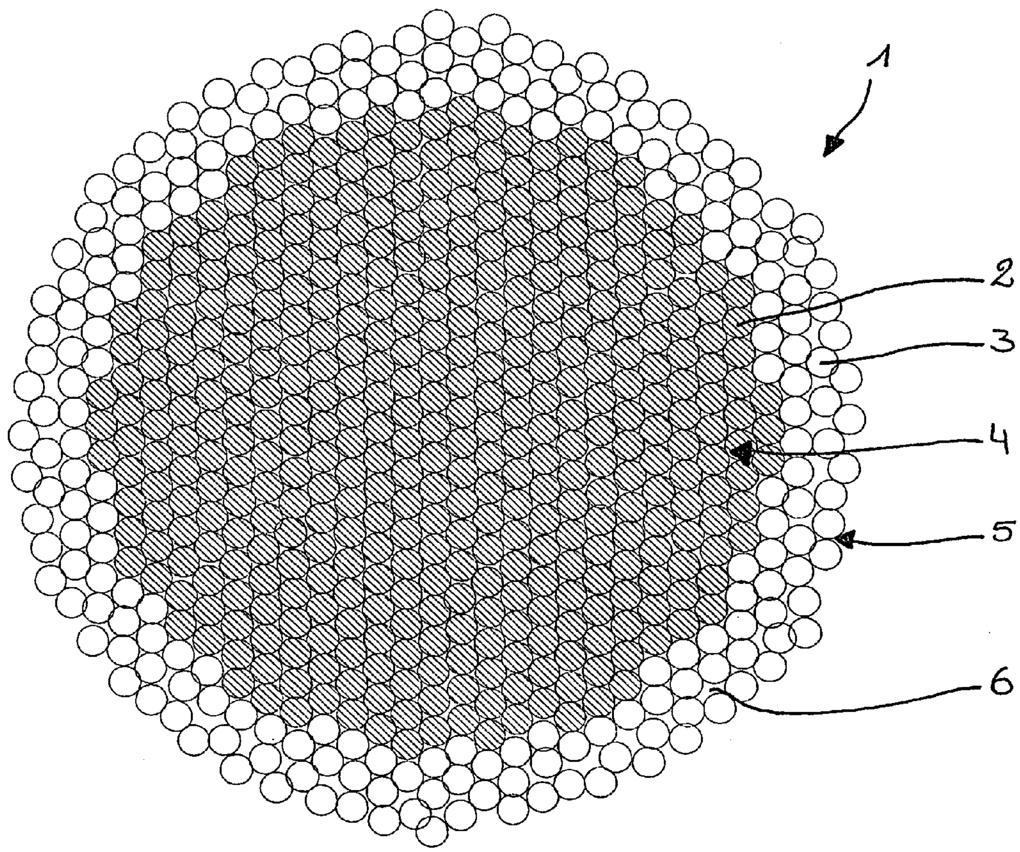



FIG. 1

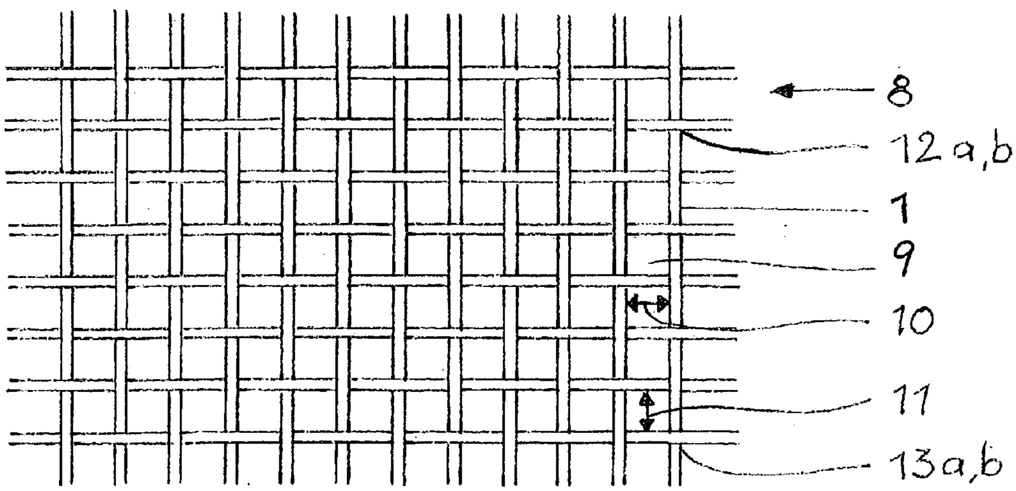



FIG. 3

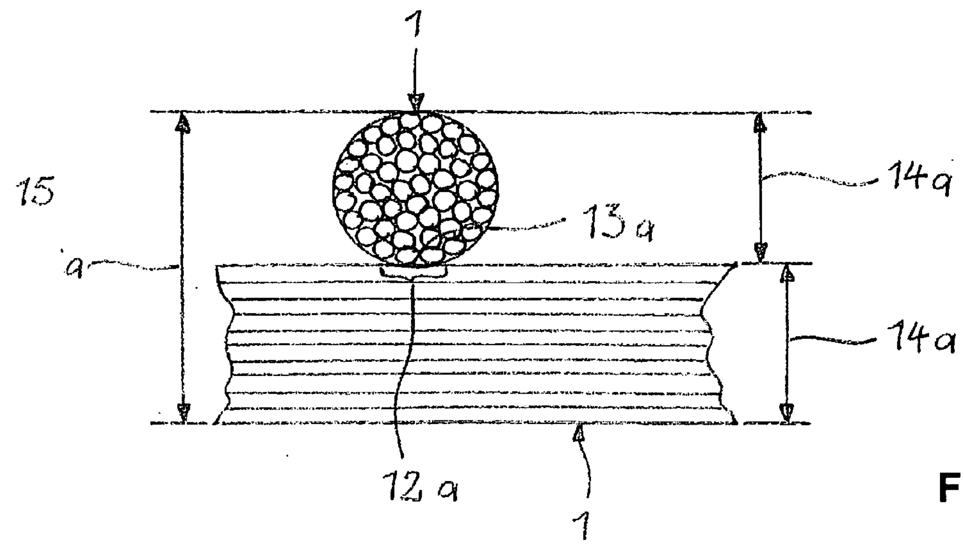



FIG. 4a

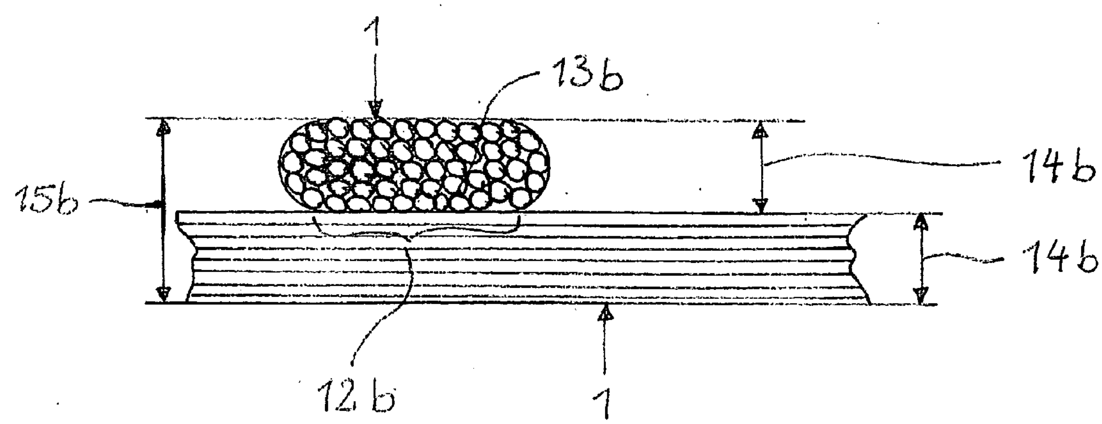



FIG. 4b

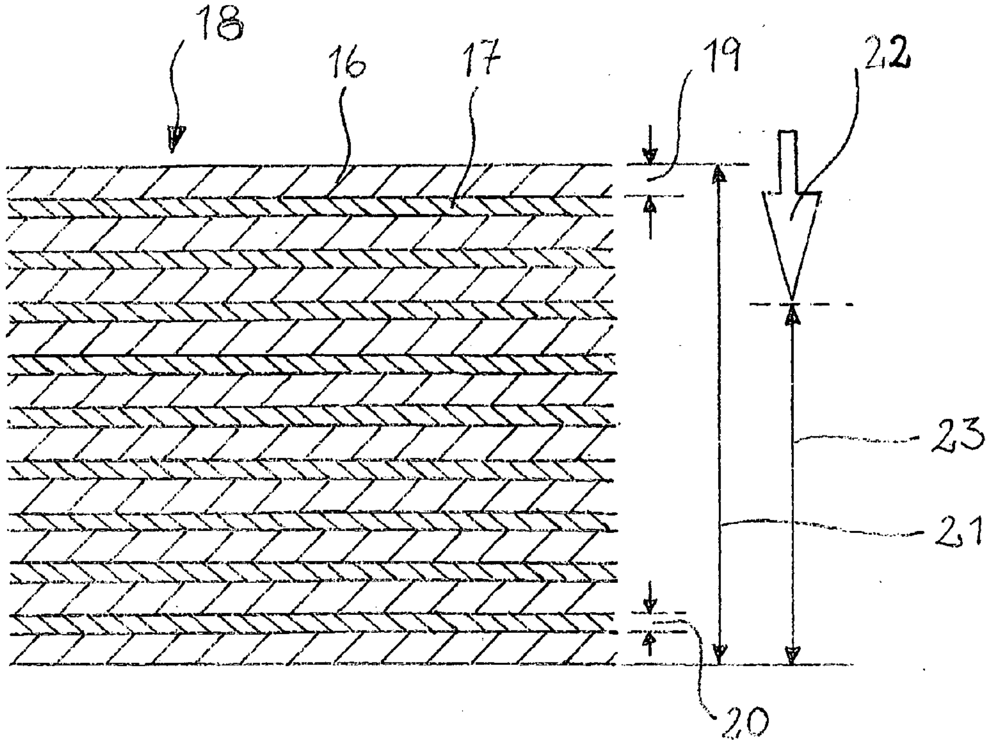



FIG. 5

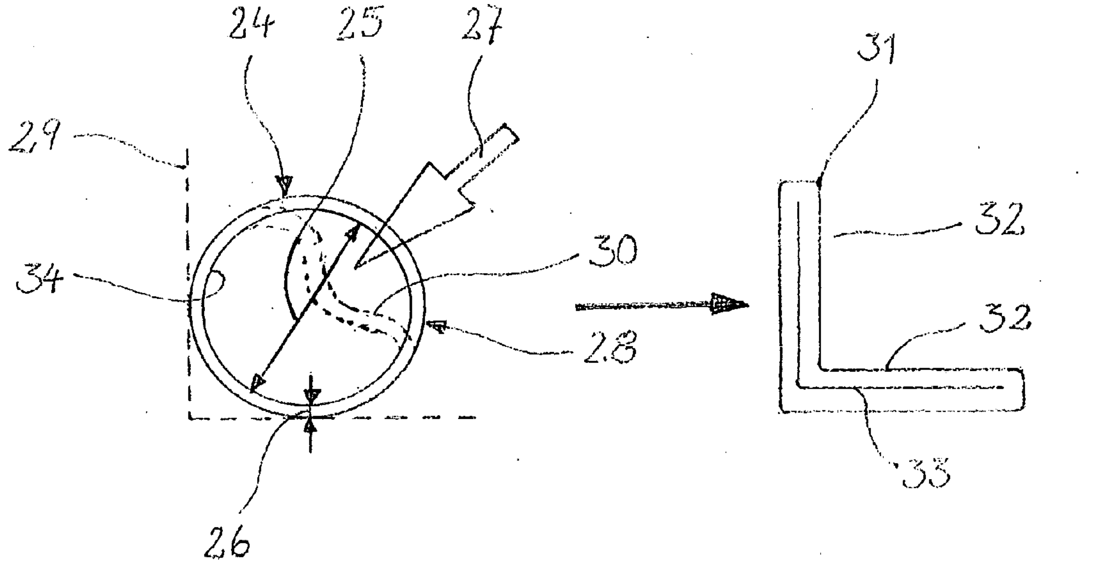



FIG. 6

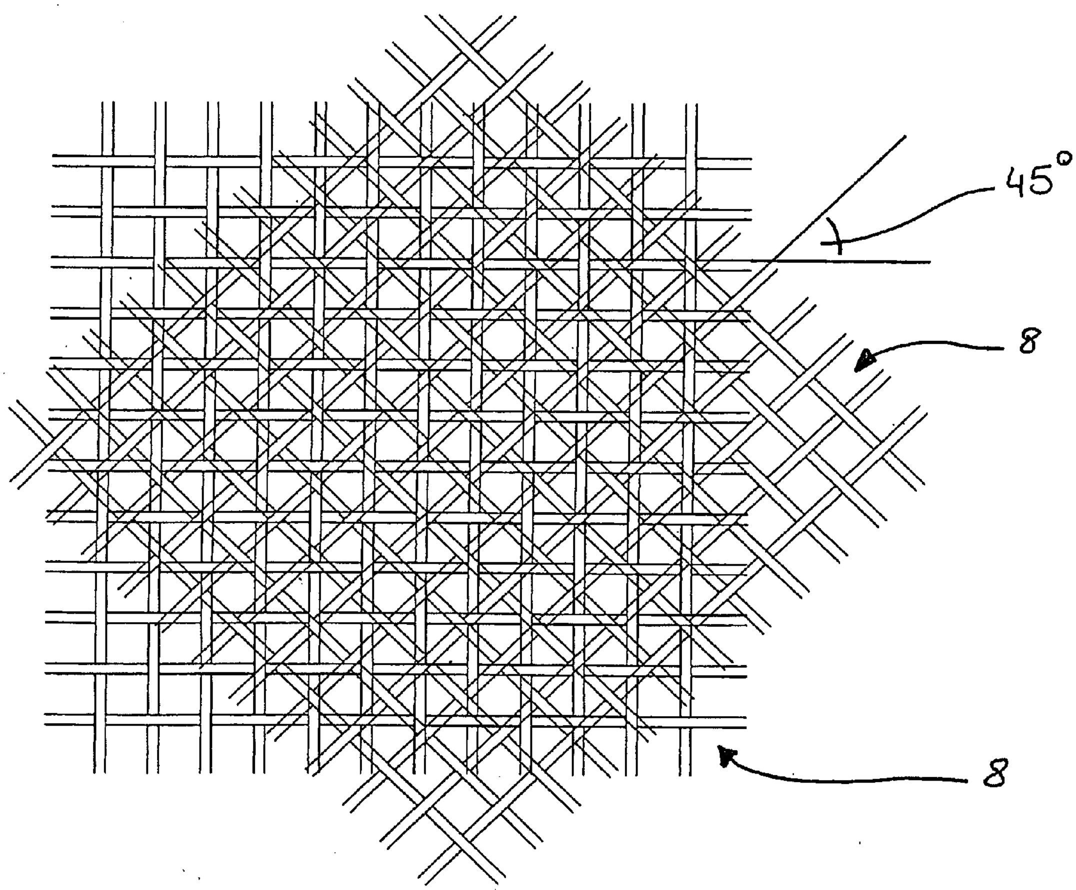



FIG. 7

# FIBER COMPOSITE MATERIAL AND METHOD FOR PRODUCTION THEREOF

## RELATED APPLICATIONS

[0001] This application is a continuation of International application PCT/EP2010/056040 filed on May 4, 2010 claiming priority from German application DE 10 2009 019 500.9 filed on May 4, 2009 and German application DE 10 2009 061 031.6 filed on July 29, 2009. All the above applications are incorporated in their entirety by this reference.

## FIELD OF THE INVENTION

[0002] The invention relates to a fiber composite material including fibers and a resin connecting the fibers. Additionally, the invention relates to a method for producing a fiber composite material including fibers and a resin connecting the fibers.

## BACKGROUND OF THE INVENTION

[0003] Fiber composite materials are multi-phase or mix materials which include a bedding matrix made from resin and reinforcing fibers. Through interaction of the two components a fiber composite material has better properties than the fibers or the resin respectively by themselves. In particular when using extremely thin fibers with a diameter of only a few micro-meters, the so-called effect of specific strength influences the fiber composite material in a positive manner. A reason for this effect is the increasing alignment of the molecule chains of the fibers for a reduced diameter in the decreasing cross-sectional surface that is provided. The plurality of extremely thin fibers also leads to a distribution of the fracture inducing voids in the material to very large distances. A material void in a fiber this way cannot cause a failure of the entire component produced from the fiber but initially only a fracture of an individual fiber in the composite. Therefore fiber composite materials are characterized by excellent properties which are achieved through optimum interaction of both components. In particular fiber composite materials have a very good ratio of strength to weight.

[0004] As fibers for fiber composite materials, typically glass fiber, carbon fibers, ceramic fibers (aluminum oxide, silicon dioxide, etc.), aramide fibers, metal fibers, in particular steel fibers and natural fibers (from flax, hemp, jute, sisal, etc.) are being used. The resin matrix of the known fiber composite materials is typically formed by duromeres (synonyms: duroplast, synthetic resin) elastomeres or thermoplasts.

[0005] Typical embodiments of fiber composite materials are so-called laminates in which the advantages of an individual fiber orientation are being used. Laminates often include a plurality of fiber mats that are placed on top of one another with different main fiber orientations. For laminate production, typically methods like manual placement, manual placement with vacuum pressing, prepreg technology, vacuum infusion, fiber winding and fiber spraying are being used, wherein the latter strictly speaking is not a laminating method since there are no defined layers, whereas the result however has comparable properties like classic laminates.

[0006] Besides laminates, fiber composite materials are often also implemented in the form of injection molded components, injection pressed components and extruded components, wherein the unidirectional orientation of the fibers can be practiced with different degrees of success depending on the method.

[0007] Last but not least, so-called "sheet molding compounds" (SMC) are known in which resin mats (with additives like hardeners, optional fillers or additives) and cut glass fibers are pre-fabricated and finished after a maturing time in which the viscosity significantly increases, wherein typically a pressing and curing is performed in heated tools after reliquefaction.

[0008] A frequent disadvantage of fiber composite material is the incomplete embedding of fibers into the resin matrix. This occurs typically when subsequently infusing composite structures made from fibers (woven materials, laid tapes, knitted material, fleeces, etc.) and applies in particular for a processing of the fiber monofilaments into threads when using a twisting or threading of monofilaments. The intermediary cavities between the individual filaments can hardly be completely reached or filled considering the viscosity of the resin so that the strength of the materials obtained remains significantly below the theoretically possible amount. Furthermore, the portion of the resin relative to the mass or the volume of the entire fiber composite material from a cost point of view and from energy and environmental points of view is too high.

## BRIEF SUMMARY OF THE INVENTION

[0009] It is the object of the invention to provide a fiber composite material and a method for a production thereof which is characterized by high strength and minimum resin use.

[0010] The object is achieved by a fiber composite material which includes threads which include a plurality of individual filaments and resin that is crosslinkable through the effect of at least one physical variable and/or at least one chemical material, wherein the resin in a non-crosslinked condition is provided essentially free from solvents and the plurality of individual filaments in the thread is cohesive, wherein the individual filaments in the threads are arranged unidirectionally and wherein the threads thus form a composite material in that they adhere to one another at contact surfaces of their respective outer enveloping surfaces through bridges made from resin.

[0011] The fiber composite material according to the invention described supra is a semi-finished product since the resin is provided in non-crosslinked condition in which it only has a minor portion of its final strength or hardness and in this intermediary state of the composite material is only used to keep the composite material formed from threads together in order to make it fit to handle at all. The fiber composite material according to the invention is thus characterized by good deformability and flexibility, so that it still can be formed before crosslinking, this means that it can be brought into its final form before the actual crosslinking, this means hardening of the resin occurs in order to produce a finished product from the semi-finishes product, wherein the finished product can certainly be processed further in additional process steps.

[0012] An important component is formed by the monofilament threads used for producing composite materials according to the invention, wherein the monofilament threads include a plurality of individual filaments and resin enveloping the individual filaments. The unidirectionally aligned individual filaments in the threads thus constructed are preferably completely embedded by the resin, wherein no air enclosures shall be in the resin anymore. Though the individual filaments are joined by the resin to form a thread that can be handled as a monofilament, the individual fibers, however, are movable relative to one another with respect to their positions. This is important in particular when adjacent threads of the composite material formed from threads can flatten their cross-sections at their contact locations, thus forming greater contact surfaces than this is the case for threads Which include twisted individual filaments. The size of the contact surfaces substantially determines the subsequent strength of the fiber composite material after curing the resin.

**[0013]** Another important characteristic of the material according to the invention is the fact that no additional resin has to be used when forming the composite material. Thus, the process of infusing, submerging, spraying, pouring, etc. of a support structure formed from fibers as required for conventional production methods is omitted. Thus, the resin portion for the fiber composite material according to the invention is very small, since the resin is only used where it adheres to the threads or their individual filaments. In spite of the small amount of resin required which renders the material according to the invention producible very environmentally friendly, light but also cost effective, the resin portion, in case this is desired, can be increased through adding more resin that is independent from the threads, for example, to fill the cavities that typically otherwise remain between the threads. It shall be emphasized that also independently from a filling that is rather untypical for the material according to the invention, good cohesion of the threads is assured, since all contact locations of the threads provide good adhesion for gluing together through the "resin bridges", since the threads that are being used according to the invention are also completely encased by a resin layer at their outer enveloping surfaces. The threads used according to the invention, which are made from individual filaments and their production are described in detail in the international patent application PCT/EP 2010/056 038 filed on May 4, 2010, which is incorporated herein by reference in its entirety.

**[0014]** The important advantages of the fiber composite material provided through the invention thus are large contact surfaces at the contact points of the threads due to their capability to still deform also after production of the intermediate product "fiber composite material with non-crosslinked resin" while maintaining the sub-composite "thread", wherein typically the cross-section of the thread is theoretically deformable from a circular flattened shape to a rectangular shape. Instead of the line shaped contact portions for geometrically exactly circular threads and parallel alignment of adjacent threads, rectangular contact strips are formed for the material according to the invention, whose surface is accordingly larger which yields better cohesion, this means higher strength of the finished product in crosslinked condition. When adjacent threads extend at an angle of 90° relative to one another, in particular in a case where they cross over at an angle of approximately 90°, instead of a single contact point for geometrically exact cylindrical threads a square contact surface is provided for rectangular flattened threads. Also in this case, a substantial enlargement of the contact surface and thus an increase of the strength are provided. The possible omission of separately adding resin in addition to the threads used renders the processing, this means the production, of the fiber composite material according to the invention particularly simple and clean.

**[0015]** It is furthermore important for the invention that fiber composite material is provided in non-linked condition in order to retain many degrees of freedom for the subsequent use and to let only the subsequent user decide which particular geometric shape the fiber composite material shall assume. The resin is only crosslinked when the material is brought into the desired shape, for example, through bending, pressing, rolling, winding, stretching, laminating, etc.

**[0016]** In order to increase the cohesion of the composite material that is being used as intermediary product and thus to simplify handling and to reduce the risk of undesired dissolving of the composite before curing of the resin, threads adhering to one another can be pressed against one another, wherein preferably the composite material as such is being pressed. Thus, the applied pressure should be moderate and only serve the purpose to couple the threads to one another at their surfaces through bridges of the non-crosslinked resin. The actual curing process of the resin (and if required, another pressing process) is then typically performed at another location at another point in time after the fiber composite material with the non-cured resin is brought into its final shape through additional processing, in particular forming.

**[0017]** In another embodiment of the invention it is provided that the fiber composite material is a knitted material, a laid material, a fleece or a woven material, preferably with linen binding which includes warp threads and/or filling threads which form a monofilament composite, including a plurality of individual filaments and the non-crosslinked resin, wherein the individual filaments of all recited threads are aligned unidirectionally relative to one another. Based on the large contact surfaces between the threads, a material with excellent strength properties can be provided this way.

**[0018]** It is further provided that the fiber composite material is a sandwich material including at least one layer including a woven material, preferably with linen binding and at least one layer including a fleece, wherein the woven material includes threads, preferably only includes threads which include a plurality of individual filaments and the non-crosslinked resin and the fleece is provided with a non-crosslinked resin, in particular infused therewith or sprayed therewith, and the layers are connected with one another through bridges from resin between adjacent threads of adjacent layers in order to form the fiber composite material.

**[0019]** The object is furthermore achieved through a composite material which includes threads which include a plurality of individual filaments and which include the crosslinked resin which connects the individual filaments with one another, wherein the individual filaments are arranged unidirectional relative to one another, so that the threads form an interconnection, wherein the contact surfaces of the outer enveloping surfaces of the threads are connected with one another through bridges of the crosslinked resin.

**[0020]** The material described supra compared to the other material described supra is also a fiber composite material according to the invention, thus a finished product since the resin is provided in crosslinked condition, this means in cured condition. Thus, the composite material has reached its final hardness and can be handled with considerably less care than the material described supra with the non-crosslinked resin. Through crosslinking the resin, the strength is high and the flexibility compared to the non-crosslinked condition of the resin is significantly reduced. Therefore, subsequent shape changes of the material are only possible within very tight limits. The fiber composite material according to the invention with crosslinked resin is therefore particularly suitable for standard products like plates or profiles with various cross-sections, tubes, etc. which are produced in standardized dimensions and are traded and stocked like standard semi-finished products. Also a use as support woven material or laid support material or other types of textile fabrics or also grids is possible. With respect to the strength and the manufacturing method, the same applies as stated supra regarding the composite material with non-crosslinked resin.

**[0021]** Particularly high strength of the fiber composite material is provided when the cross sections of the threads are oval, ellipsoid or rectangular with rounded corners at least in the portion of their contact surfaces, wherein the contact surfaces in the cross-section are at the flattened sides of the oval or of the ellipse or at the long sides of the rectangle. Through the contact surface enlargement an improvement of the coherence is provided through the glue forces caused by the cured resin.

**[0022]** Also for the crosslinked resin, the composite material according to the invention can be a sandwich material, preferably including at least one layer including a woven material, a laid material, a knitted material, etc. and at least one layer including a fleece, wherein the woven material, the laid material or the knitted material includes threads according to the invention with individual filaments in unidirectional orientation with embedded resin. The provided sandwich material can be formed through pressing into a formed component or a profile, in particular a I-, L-, T-, U-, V-, H- or Y-profile and can be crosslinked during pressing or subsequently, in particular through heat impact.

**[0023]** The solution according to the invention furthermore includes a method for producing a fiber composite material including fibers and a resin crosslinking the fibers comprising the following steps:

**[0024]** a) threads are being used for the fiber composite material which respectively include a monofilament composite including a plurality of individual filaments which are kept together through a resin that is crosslinkable under an impact of at least one physical variable and/or a chemical substance, wherein the individual filaments of a thread are respectively aligned unidirectional;

**[0025]** b) a composite material is formed from the threads in that adjacent threads are connected with one another at contact surfaces of their outer enveloping surfaces through bridges of a resin provided in non-crosslinked condition, wherein the connecting resin previously formed a portion of the threads.

**[0026]** The method according to the invention thus uses particular monofilament threads whose individual filaments are movable relative to one another due to the resin not yet being crosslinked, so that the cross-sectional shape of the threads can still be changed under impact of external forces.

**[0027]** Due to the presence of a sufficient amount of non-crosslinked resin in the monofilament threads, in particular also at their entire outer enveloping surface they can be arranged into a composite fleece (textile fabric=woven material, laid material, knitted material, fleece, etc.) through different connection or coupling types without having to use additional resin for achieving reliable cohesion. The non-crosslinked resin is provided in a condition due to storing capabilities and further processing capabilities in which it essentially does not include any more solvent. However, it has a “residual tackiness” which facilitates coupling resin encased threads through contacting them so that the composite thus formed can be handled, this means can be stored, wound, stacked, packaged, etc. without the resin previously already having to be transformed into the crosslinked condition.

**[0028]** Until the crosslinking of the resin is eventually caused the shape of the fiber composite material produced according to the invention can still be changed, which indicates versatile usability.

**[0029]** In order to increase strength for the provided material, the adjacent threads that are respectively connected with one another through a resin bridge can be pressed into one another in the portion of the contact surface. Imparting pressure thus causes a change of the shape of the thread cross-section in the sense of a flattening and thus an increase of the surfaces that are in contact with one another.

**[0030]** Forming the interconnection from threads with non-crosslinked resin according to the method according to the invention is thus provided independently from the crosslinking of the resin and thus from achieving the final strength of the fiber composite material.

**[0031]** Advantageously, pressing the threads together in the interconnection previously formed and crosslinking in particular under the impact of temperature is at least partially performed simultaneously. Thus the manufacturing method is particularly efficient.

**[0032]** Eventually it is proposed according to the invention, that a tubular hollow profile with circular, oval, elliptical or polygonal cross-section is produced from the threads including the non-crosslinked resin embedding their monofilaments and the hollow profile is subsequently formed through longitudinally progressing contraction in a direction perpendicular to the longitudinal axis of the hollow profile to form a profile with reduced cross-sectional surface, preferably using pressure orthogonal to the longitudinal axis of the hollow profile and wherein the resin is crosslinked during forming or subsequent thereto in particular through heat application.

**[0033]** This way, profiles with various cross-sectional shapes can be produced in a very elegant manner from the hollow elements produced prior thereto, wherein a high quality corner or edge formation can be provided through folding.

## BRIEF DESCRPTION OF THE DRAWINGS

**[0034]** The invention is subsequently described in more detail based on plural embodiments of fiber composite materials with reference to figures, wherein:

**[0035]** FIG. **1**: illustrates a cross-section of a thread, including a plurality of individual filaments with an inner zone and an outer zone;

**[0036]** FIG. **2**: illustrates three exemplary individual filaments from the thread cross-section according to FIG. **1**;

**[0037]** FIG. **3**: illustrates a composite material configured as a woven linen material;

**[0038]** FIG. **4***a* and FIG. **4***b*: respectively illustrate an enlarged depiction of two flattened threads in the portion of their contact surface;

**[0039]** FIG. **5**: illustrates a sectional view of a fiber composite material in the form of a sandwich material, including nineteen individual layers;

**[0040]** FIG. **6**: illustrates a schematic view of the forming process from a circular hollow profile to an L-profile; and

**[0041]** FIG. **7**: illustrates a top view of the fiber composite material according to FIG. **5**.

DETAILED DESCRIPTION OF THE INVENTION

**[0042]** A thread **1** illustrated in cross-section in FIG. **1** includes a plurality of individual filaments **2**, **3** which respectively are "endless" monofilaments. The individual filaments **2** of a first type which are arranged in a substantially circular inner zone **4** of the cross-section of the thread **1** include, for example, para-aramide, however the individual filaments **3** of the second type which are arranged in an annular outer zone **5** about the inner zone **4** and form a type of "jacket" are made from glass fibers about the "core" formed by the inner zone **4**. All known fibers are suitable as individual filaments for the fiber composite material according to the invention, in particular the fibers already recited supra. Certainly also only one single type of individual filaments can be arranged in a thread. All intermediary cavities **6** between adjacent threads are filled with a non-crosslinked resin, in the present case a silicon resin made by Wacker Corporation. In the entire cross-section of the thread, there are no air cavities but all individual filaments **2**, **3** are completely embedded in the material of the resin. Furthermore, also the outer enveloping surfaces of the individual filaments **3** of the outer zone **5** that form an outer layer are coated with a thin resin layer at their outward oriented sides, wherein the resin layer is not illustrated in FIG. **1** for simplification purposes.

**[0043]** FIG. **2** illustrates three individual filaments **3** taken out of the individual filament compound thus made from glass fiber. A spandrel portion **7** between the three adjacent individual filaments **3** is completely filled with the resin and provides safe and stable cohesion for the three individual filaments. As stated supra, the resin filling is also provided for all other spandrel portions towards the individual filaments **3** or **2** that are not illustrated in the boundary portion between the inner zone **4** and the outer zone **5**.

**[0044]** FIG. **3** illustrates a top view of a first embodiment of a fiber composite material **8**, configured as a woven material with linen binding. The particular threads **1**, for example, have a configuration according to FIGS. **1** and **2**, but can also be configured differently. In the present case, it is relevant that the resin which keeps the individual filaments **2**, **3** of the threads **1** together is provided in non-crosslinked condition, so that the cohesion of the thread **1** which is considered as a monofilament is provided, however relative movability of the individual filaments **2**, **3** is still provided as long as the resin is not cured, this means not crosslinked.

**[0045]** The individual filaments **2**, **3** of the threads **1** are all oriented unidirectionally, this means they extend parallel to one another and parallel to a longitudinal axis of the thread **1**. This alignment of the individual filaments **2**, **3** has to be maintained during windup of the threads **1** after their production, but also during the entire subsequent production process of the linen woven material of the fiber composite material **8** (weaving process). For this reason, it is not possible to use the so-called "overhead pull off" for threads from spools that is otherwise widely used in the production of woven materials. Thus it is important that the individual filaments **2**, **3** of the threads **1** are also all still unidirectionally aligned in the linen woven material according to FIG. **3**.

**[0046]** The woven material of the fiber composite material **8** according to FIG. **3** has very low density of warp threads and filling threads, so that a grid structure is being formed. Loops **9** defined by two respective adjacent warp threads and also two adjacent filling threads are open, this means in particular not filled with resin. The loops **9** typically have a width **10** measured in horizontal direction of approximately 5 mm to 10 mm and a width **11** measured in vertical direction of 5 to 10 mm as well, so that loops **9** with a square cross-section are provided.

**[0047]** After the weaving process for the fiber composite material **8**, including threads **1** with non-crosslinked resin, the fiber composite material can be pressed together lightly without using high temperatures (in particular not above 100° C.). This only improves the interconnection in the portion of the contact surfaces of intersecting threads **1** in order to be able to maintain the integrity of the woven material in non-crosslinked condition of the resin without having to perform the handling processes with extreme caution. Through the moderate pressure perpendicular to the plane formed by the woven material, the threads are only lightly changed in any cross-sectional shape, this means flattened, so that the contact surfaces **12***a* in the portion of the intersecting threads **1** are comparatively small, namely the width of a strip shaped contact surface **12***a* is much smaller than the diameter of the thread **1**. In the portion of the contact surface **12***a*, a bridge **13***a* is configured from non-crosslinked resin which connects the threads **1** that are crossing over, this means in particular the individual filaments **3** of the respective outer zone **5** provided in the threads **1**, with one another.

**[0048]** After the woven material of the fiber composite material **8** was stored and transported in non-crosslinked condition of the resin in wound up form, it can be transformed into its end condition using pressure (e.g., 150 to 300 $N/cm^2$) and temperature (above approximately 140° C.) in that the resin is crosslinked and thus cured.

**[0049]** As can be derived in particular from FIG. **4***b*, the threads **1** significantly change their cross-sectional shapes through applying the increased pressure recited supra in that they are substantially flattened now and have an oval shape, theoretically they can even be deformed into an only slightly rounded rectangular shape. A height **14***b* of the threads **1**, **2** is significantly reduced over the height **14***a* according to FIG. **4***a*. The approximate thickness **15***a* of the woven material in only slightly pre-pressed condition can only be reduced through the deformation of the threads **1** also significantly to the thickness **15***b* according to FIG. **4***b* provided after the crosslinking.

**[0050]** In practical applications, the reduced thickness **15***b* of the tissue is approximately 20 to 70% of the original thickness after the weaving process which almost corresponds to twice the diameter of an individual thread **1**. It can be furthermore derived from FIG. **4***b* that the contact surface **12***b* after applying the pressure and associated flattening, that means broadening of the threads **1** has significantly increased which then makes the developing resin bridge **13***b* significantly greater than in case of the only light pressure according to FIG. **4***a*.

**[0051]** The increased contact surface **12***b* or the increased bridge **13***b* causes a substantial strength increase of the fiber composite material **8** after the pressing process and crosslinking the resin.

**[0052]** After the pressing process and after resin crosslinking, the woven material can be provided with a carrier material (e.g., paper or foil) with a one-sided silicon coating in order to subsequently cut the formed sandwich material into webs and to use it as an adhesive film which glues on one side or on both sides.

**[0053]** The fiber composite material **18** according to FIG. **5** is a sandwich material which includes a plurality of layers **16** respectively including a woven material and a plurality of layers **17** respectively including a fleece. In the present embodiment, the fiber composite material **18** includes ten layers **16** of woven material which can be configured, for example, according to the fiber composite material **8** illustrated in FIG. **3**. Other types of tissues which respectively include threads **1** including a plurality of individual filaments and non-crosslinked resin embedding the individual filaments but also other binding types are also feasible.

**[0054]** The layers **16**, including woven material and **17** including fleece are respectively arranged on top of one another (stacked), wherein the upper and the lower layer **16** are respectively formed by a woven material in order to increase abrasion resistance of the fiber composite material **18** at its surface. The layers **16** including the woven material as illustrated in FIG. **7** are respectively arranged rotated by 45° in an alternating manner within the plane of the woven material in order to obtain higher tensile strength also in a diagonal direction of a layer **16** through the adjacent layer **16** being rotated relative thereto by 45°. Through the additional connection points between the threads twisted relative to one another with a fleece layer connected there between, the strength and dimensional stability is significantly increased and the applicability of finite element computation methods is significantly improved.

**[0055]** The layer **17** including the fleece includes an aramide fleece with an area weight of approximately 25 g/m$^2$ and 40 g/m$^2$. In order to provide a safe connection with the layers **16** of the woven material in non-crosslinked condition and also subsequently in crosslinked condition of the resin, the layers **17** from the fleece are preferably provided with the same resin which is used for embedding the individual filaments in the threads **1** of the woven material of the layers **16**. The resin can be applied through infusing the fleece of the layers **17** in a resin bath or through spraying the fleece with the resin. Thus, it is helpful to place the dry fleece onto the woven material, for example, according to FIG. **3** in dry condition in order to compensate for the high strength loss caused by infusing the resin and to subsequently handle the stabilizing woven material and the infused fleece as a pair during production of the sandwich material. Nine of the pairs of this type can be arranged on top of one another, wherein eventually, for example, on the top side another layer **16** made from woven material is applied. In spite of a possible resin excess in the fleeces of the layer **17** infused or sprayed with resin, the loops **9** in the woven material of the layers **16** are not completely filled.

**[0056]** The aramide fiber elements which are initially loosened from the fleece interconnection in the course of infusing or spraying with resin are used as mechanical connection of the individual filaments of the threads **1** among one another and with the adjacent fleece layers and freely movable.

**[0057]** In particular to increase mechanical strength in several directions, the layers **16** of the woven material are arranged rotated in an alternating manner by 45° with reference to the longitudinal direction, for example, of a group of threads (filling threads).

**[0058]** While the thickness **19** of a single layer **16** of woven material is between 0.35 mm and 1.5 mm, the thickness of a layer **17** made from fleece with approximately 0.15 and 0.25 mm is much smaller than the recited material .thickness. The nineteen individual layers of fiber composite material **18** illustrated in FIG. **5** in non-pressed condition have a thickness **21** of 0.45 to 1.7 mm.

**[0059]** Before applying heat for crosslinking the resin, the fiber composite material **18** is pressed together, for example, with a plate press and thus in a direction of the arrow **22** which yields a reduction of the thickness **23** provided after the pressing and curing process.

**[0060]** FIG. **6** illustrates in a schematic depiction how the production process of an additional alternative embodiment of a fiber composite material **28** configured as an L-profile in cross-section can be provided. A starting point for the eventually L-shaped profile as illustrated in FIG. **6** in the right half of the figure is a profile **24** with a cross-section shaped like a circular ring drawn in the left half of the figure in solid lines. The latter profile is produced using a mandrel, whose outer diameter corresponds to an inner diameter **25** of the profile cross-section in that the threads **1** are applied to an outer enveloping surface of the mandrel e.g. in cross-binding. The threads **1** used for this purpose in turn include a plurality of individual filaments of the same type or of various types of individual filaments in mixed or spatially separate arrangement and a non-crosslinked resin enclosing the threads which provides monofilament properties to the thread. It is furthermore important for the winding process that it does not introduce any twist into the thread, this means also in wound form all individual filaments of all threads have unidirectional orientation. A cohesion of the particular threads in the wound composite is provided through selecting a suitable winding tension which provides a sufficiently strong contact for threads crossing over one another in the portions of their contact surfaces (c.f. illustration of threads crossing over one another according to FIG. **4***a*). The contact surfaces at which bridges with non-crosslinked resin are formed, however are still comparatively small, so that the winding compound provided in tubular form has sufficient cohesion for handling, but no strength which would be required for a use as a finished material.

**[0061]** A wall thickness **26** of the wound tube is approximately between 0.45 mm and 2.4 mm. Depending on the diameter of the used threads, approximately 2 to 60 thread layers are required for achieving a wall thickness in this range. It is also important in this case that when producing the wound composite contrary to classic procedure when producing fiber composite material, no additional resin is used to close the gaps remaining between the particular threads.

**[0062]** In analogy to the sandwich material according to FIG. **5**, also layers made from a resin infused fleece including different fibers can also be arranged between adjacent thread layers during winding in order to create a denser material with a larger surface area so that e.g. the damping and insulating properties are improved.

**[0063]** After completing the winding process and an optional laminating process performed there between (intermediary layers made from fleece) the semi-finished product configured as a tubular profile **24** can be pulled off from the support mandrel. Since the resin in this instant is not crosslinked, the profile **24** has comparatively large flexibility and deformability, so that its shape can be changed within wide ranges under the impact of internal forces. Thus, for example, a pressure can be imparted upon the profile **24**, for example, in the direction of the arrow **27** through a suitable tool, e.g. a plurality of press rollers in order to provide multi-stage shape change, wherein this in turn shall be performed by a suitable tool which is schematically illustrated by a dashed line **29** extending at a 90° angle and is supported opposite to the force acting in the direction of the arrow. Thus, the profile **24** in its intermediary condition can have the shape with an indented cross-section according to the dashed lines **30** in the left half of FIG. **6**.

**[0064]** After a possibly multi-stage forming process, the L-profile **31** is provided as a result, which is depicted in FIG. **6** on the right. This is an L-profile with arms with identical lengths, wherein both L-arms have a contact surface **33** in their centers, at which sections of the prior inner enveloping surface **34** of the profile **24** join due to the pressing process. The inner contact surface **33** is not visible in the finished profile **31**. The inner contact surface is not relevant with respect to the material and strength properties since due to the high pressure also in this portion of the contact surfaces **33**, a flattening of the threads coming in contact with one another occurs, so that the contact surfaces between the threads and the bridges formed by the resin are accordingly large which as a result creates a component with very homogeneous properties over the entire profile cross-section. The length of the profiles thus produced can be up to 10 m or more.

**[0065]** As a matter of principle, it can be stated with reference to the fiber composite materials **8**, **18**, **28** according to the invention and the method for their production that the material properties are significantly influenced by the amount of the pressure which is applied after producing a thread composite, wherein the pressure is still applied using the resin in non-crosslinked condition. With increasing pressure, the flattening of the threads and thus the size of the contact surfaces and also of the resin bridges increases which yields higher strength and density of the material but also reduced elasticity. However, with a comparatively small pressure, materials can also be produced with a higher elasticity in cured resin condition and also with greater porosity, this means with greater surface area, which is important in particular for insulation and absorption properties. Also the specific weight of the fiber composite material according to the invention can be varied through selecting a suitable pressure within a rather large range.

**[0066]** Another aspect of the invention is using a pulp, for example, an aramide pulp in order to be able to obtain a filling or reduction of the cavities of the loops **9** of a woven material with a grid structure according to FIG. **3** without using a fleece. Thus a comparatively open woven material as illustrated in FIG. **3** can be pulled through a bath, for example, at an angle between 15° and 45° relative to one of the thread systems, wherein the bath includes a mix of water, resin and high fiber content pulp (surface approximately 13 $m^2$ per gram of fibers). When required, additives in the form of micro-balloons made from glass or porous balls made from ceramic or solid balls made from ceramic or spherical particles made from molten aluminum silicate or kaolin can be added. As a function of the orientation of the woven material when it is moved through the mix of water, resin, pulp and possibly additives, the woven material or its threads absorb different amounts of pulp. The pulp which is preferably highly loaded with fibers causes mechanical interlocking of the threads of the grid shaped woven material.

**[0067]** Producing a fiber composite material of this type is similar to producing paper, wherein the grid shaped woven material is used as a component that remains in the finished fiber composite material as a solid component later on. The resin provided in the threads of the tissue (c.f. FIG. **3**) is not crosslinked at the point in time of immersion in the pulp bath and is dissolved again through the solvent included in the pulp bath and is thus very receptive for high fiber content pulp so that the adhesion effect is very good.

**[0068]** After removing the woven material from the pulp bath, a slight compression of the composite thus provided and a drying preferably through an air flow dryer can be performed at temperatures below 120° C. in order to prevent crosslinking the resin also in this case. After drying a second press process can occur in which in turn the temperature has to be kept at a low level (30° C. at the most). Subsequently, a woven material made from the same fibers or from other fibers can be applied in order to subsequently cause an application of the fibers forming the pulp through a movement through the pulp bath.

**[0069]** Optionally, a Teflon coated grid can be used as tool when applying the pulp fibers, wherein the grid is removed again after the drying process. The process of producing a fiber composite material of this type can also be performed as a flow process like paper production. In analogy to a forming portion of a paper machine the grid woven material is moved through the pulp bath in order to achieve fiber adhesion. Removing the solvent of the pulp bath from the fiber composite material being created can be performed through vacuum suction boxes. Subsequently, the solvent content can be reduced through pressing between rollers analogous to the pressing portion of a paper machine. Eventually additional drying of the material can be achieved through running the fiber composite material web over steam heated cylinders in order to be able to wind the web material in non-heated condition of the resin onto a roller without gluing. Also this material can be used for producing sandwich arrangements in combination with identical web material in a 45° titled configuration.

REFERENCE NUMERALS AND DESIGNATIONS

**[0070]** **1**. Thread
**[0071]** **2**. Individual filament
**[0072]** **3**. Individual filament
**[0073]** **4**. Inner zone
**[0074]** **5**. Outer zone
**[0075]** **6**. Intermediary space
**[0076]** **7**. Spandrel portion
**[0077]** **8**. Fiber composite material
**[0078]** **9**. Loop
**[0079]** **10**. Width
**[0080]** **11**. Width
**[0081]** **12***a*. Contact surface
**[0082]** **12***b*. Contact surface
**[0083]** **13***a*. Bridge
**[0084]** **13***b*. Bridge
**[0085]** **14***a*. Height
**[0086]** **14***b*. Height
**[0087]** **15***a*. Thickness
**[0088]** **15***b*. Thickness
**[0089]** **16**. Layer
**[0090]** **17**. Layer
**[0091]** **18**. Fiber composite material
**[0092]** **19**. Thickness
**[0093]** **20**. Thickness
**[0094]** **21**. Thickness
**[0095]** **22**. Arrow
**[0096]** **23**. Thickness
**[0097]** **24**. Profile

[0098] **25**. Inner diameter
[0099] **26**. Wall thickness
[0100] **27**. Arrow
[0101] **28**. Fiber composite material
[0102] **29**. Line
[0103] **30**. Line
[0104] **31**. Profile
[0105] **32**. Arm
[0106] **33**. Contact surface
[0107] **34**. Inner enveloping surface

What is claimed is:

**1**. A fiber composite material, comprising:
fibers;
a resin connecting the fibers; and
threads including a plurality of individual filaments,
wherein the resin is crosslinkable through an impact of at least one physical variable or at least one chemical substance,
wherein the resin is provided in a non-crosslinked condition substantially free from solvent and holds the plurality of individual filaments in the threads together,
wherein the individual filaments are arranged unidirectionally, and
wherein the threads form the fiber composite material in that they adhere to one another at contact surfaces of their respective outer enveloping surfaces through bridges made from the resin.

**2**. The fiber composite material according to claim **1**,
wherein the threads adhering to one another are pressed against one another, and
wherein the fiber composite material is pressed in its entirety or only in portions.

**3**. The fiber composite material according to claim **1**, wherein the fiber composite material is a knitted material, a laid material, a fleece or a woven material, with linen binding including warp threads or filling threads configured as threads which form a monofilament composite including the plurality of individual filaments and the non-crosslinked resin, and
wherein the individual filaments of all the threads are aligned unidirectionally.

**4**. The fiber composite material according to claim **1**,
wherein the fiber composite material is a sandwich material including at least one layer including a knitted material, a laid material and at least one layer including a fleece,
wherein the knitted material, the laid material or the woven material only includes the threads which include a plurality of individual filaments and the non-crosslinked resin and the fleece is provided with a non-crosslinked resin, and
wherein the layers are connected through bridges including the resin between adjacent threads or fibers of adjacent layers to form the fiber composite material.

**5**. A fiber composite material, comprising:
fibers;
a resin connecting the fibers; and
threads including a plurality of individual filaments,
wherein the resin in a crosslinked condition connecting the individual filaments with one another,
wherein the individual filaments are arranged unidirectionally in the threads forming a composite, and
wherein the threads are connected with one another at contact surfaces of their respective outer enveloping surfaces through bridges made from the resin in the crosslinked condition.

**6**. The fiber composite material according to claim **5**,
wherein cross-sections of the threads are shaped oval, elliptical or rounded rectangular in a portion of their contact surfaces, and
wherein the contact surfaces are arranged in a cross-section at flattened sides of the oval or the ellipse or at long sides of the rectangle.

**7**. The fiber composite material according to claim **5**,
wherein the fiber composite material is a sandwich material including at least one layer including a knitted material, a laid material or a woven material and at least one layer includes a fleece,
wherein the knitted material, the laid material or the woven material includes the the threads which include the plurality of individual filaments and the crosslinked resin, and the fleece includes the resin in the crosslinked condition,
wherein the layers are connected with one another through bridges between adjacent threads or fibers of adjacent layers including the resin in the crosslinked condition to form the fiber composite material, and
wherein the sandwich material is formed into a formed component or a profile through pressing and the resin is in the crosslinked condition in a pressed condition of the sandwich material.

**8**. A method for producing a fiber composite material including fibers and a resin connecting the fibers, comprising the steps:
using threads which respectively include a monofilament composite including a plurality of individual filaments which are held together through a resin that is crosslinkable under an impact of at least one physical variable or a chemical substance, wherein the individual filaments of a thread are respectively aligned unidirectionally; and
forming the fiber composite material from the threads in that adjacent threads are connected with one another at contact surfaces of their outer enveloping surfaces through bridges of the resin provided in non-crosslinked condition, wherein the resin forming the bridges previously formed a portion of the threads.

**9**. The method according to claim **8**, wherein the adjacent threads respectively connected through bridges made from the resin are pressed into one another at their contact surfaces.

**10**. The method according to claim **8**, wherein the resin is crosslinked after forming the fiber composite material from the threads which provides the fiber composite material with its final strength.

**11**. The method according to claim **9**,
wherein the resin is crosslinked after forming the fiber composite material from the threads, which provides the fiber composite material with its final strength, and
wherein pressing the threads into one another in the fiber composite material and crosslinking through applying heat are at least partially performed simultaneously.

**12**. The method according to claim **8**,
wherein a tubular hollow profile with circular, oval, elliptical or polygonal cross-section is produced from the threads including the non-crosslinked resin embedding their monofilaments,

wherein the hollow profile is subsequently formed through longitudinally progressing contraction of its cross section in a direction perpendicular to a longitudinal axis of the hollow profile to provide a profile with reduced cross-sectional surface using pressure orthogonal to the longitudinal axis of the hollow profile, and

wherein the resin is crosslinked during forming or subsequent thereto, in particular through heat application.

**13**. A method for producing a fiber composite material including fibers and a resin connecting the fibers, comprising the steps:

using threads which respectively include a monofilament composite including a plurality of individual filaments which are held together through a resin that is crosslinkable under an impact of at least one physical variable and a chemical substance, wherein the individual filaments of a thread are respectively aligned unidirectionally; and

forming the fiber composite material from the threads in that adjacent threads are connected with one another at contact surfaces of their outer enveloping surfaces through bridges of the resin provided in non-crosslinked condition, wherein the resin forming the bridges previously formed a portion of the threads.

**14**. A fiber composite material, comprising:

fibers;

a resin connecting the fibers; and

threads including a plurality of individual filaments,

wherein the resin is crosslinkable through an impact of at least one physical variable and at least one chemical substance,

wherein the resin is provided in a non-crosslinked condition substantially free from solvent and holds the plurality of individual filaments in the threads together,

wherein the individual filaments are arranged unidirectionally, and

wherein the threads form the fiber composite material in that they adhere to one another at contact surfaces of their respective outer enveloping surfaces through bridges made from the resin.

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