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(54) Titre : FABRICATION D'UNE STRUCTURE TEXTILE EN 3 DIMENSIONS ET SEMI-PRODUIT FIBREUX A BASE DE MATERIAU COMPOSITES RENFORCE DE FIBRES.
(54) Title: PRODUCTION OF A 3D TEXTILE STRUCTURE AND SEMI-FINISHED FIBRE PRODUCT MADE OF FIBRE COMPOSITES

(57) Abrégé/Abstract:
The invention relates to a method for producing a 3D textile structure having contours that are matched to the 3D textile structure by means of folding a 2D textile structure.
Abstract

The invention relates to a method for producing a 3D textile structure having contours that are matched to the 3D textile structure by means of folding a 2D textile structure.
The present invention relates to a method for producing a 3D textile structure and a semi-finished fibre product made of fibre composites and the use thereof.

In order to produce composite materials, fibres can be used in the form of woven or non-woven textile structures and in the form of individual, loose fibres. Use of woven fabrics has the advantages that fibres can be introduced in large quantities and with a comparatively uniform distribution in the composite material. In addition, the use of a woven fabric has the advantage that the fibres are present in bound form in the woven fabric and usually do not require any further fastening to one another. It is a disadvantage however that the production of a woven fabric is associated with high costs, in particular if sensitive or difficult-to-weave fibres are used.

Compared to woven fabrics, fibre scrims have the advantage that these can usually be manufactured far more cost-effectively. At the same time, however, fibre scrims have only a very poor cohesion which makes any processing of fibre scrims, particularly on an industrial scale, very difficult. In order to improve the cohesion of fibre scrims, for example, fibre layers can be adhesively bonded, linked or woven by hot-melting binding threads or interconnected by needling.

However, joining fibre layers by needling only results in fibre scrims capable of withstanding comparatively low loading whilst joining by adhesive bonding or by using hot-melting binding threads brings with it the risk that at higher temperatures cohesion of the fibre scrim is no longer given in sufficient strength since
the adhesive or the hot-melting binding threads melt or decompose.

In the present field of technology, there is therefore a need for the development of another method that makes it easier to produce three-dimensional semi-finished fibre products made of fibre composites and in which the individual starting material components of the composite material, i.e. the fibre material component, the matrix material component and the fastener components are matched to one another.

Appended figures show in an explanatory and non-restrictive manner a fibre-scrim reinforced composite material according to the invention and a plurality of fibre scrims produced as intermediate products during the method according to the invention:

Fig. 1 shows the folding of scrims in 2D structures.

Fig. 2 shows the folding of scrims in 3D structures.

It is therefore the object of the invention to provide a method for producing a 3D textile structure (three-dimensional semi-finished fibre product, preform) having contours matched to the 3D textile structure by folding a 2D textile structure.

A 2D structure comes about in a woven fabric by the crossing of warp and weft threads at right angles. In a scrim a 2D structure is achieved by one or more fibre layers being arranged one above the other with different fibre orientation and interconnected by means of a warp thread system.

The folding is particularly preferably accomplished in a concertina manner as a result of which the textile
semi-finished product is achieved. In so doing, the 2D structure is in each case folded into itself by means of the inserted fold contours so that the same side of the product always meets. A zigzag fold is thus produced similar to a concertina.

It is further particularly preferred that the 2D textile structure has fold-assisting gaps which make it easier to construct the semi-finished fibre product to the shape close to the final contour.

The textile structure preferably consists of the group of scrim, woven fabric, networks, knitwear, felts, nonwovens, combinations of the same and other two-dimensional structures (e.g. films).

The scrim is optionally coated with a binder so that after the folding process, a stabilised preform such as a leaf spring, for example, is obtained by a thermal forming process.

The textile structure preferably consists of glass fibres, carbon fibres, aramid fibres, ceramic fibres, other polymer fibres (e.g. polyester, HD polyethylene or polyamides), metal fibres or mixtures of the aforesaid fibres.

The term "carbon fibre" as used within the framework of the present application comprises any carbon fibre which was manufactured starting from a carbon-containing starting material fibre, for example, a polyacrylonitrile-based fibre, a polyacrylonitrile-based fibre, a polyacrylonitrile-based fibre, a polyphenylene-based fibre, a pitch-based fibre or a cellulose-based fibre, where this term can in particular comprise fibres having a carbon content of more than 75 wt.%, preferably more than 85 wt.%. 
preferably more than 92 wt.%, in each case relative to the total weight of the fibre.


Methods for manufacturing phenol resin fibres and the manufacture of binding threads from these threads are known to the person skilled in the art. In addition, such methods are described, for example, in the documents DE 2 308 827 and DE 2 328 313.

For example, oxide and/or non-oxide fibres based on one or more compounds comprising at least one, preferably at least two, of the elements carbon, silicon, boron, titanium, zirconium, tungsten, aluminium and nitrogen, can be used as ceramic fibres, for example, for fibre layers.

The term "fibre layer" as used in the present application comprises any layer or ply of fibres of any materials or material mixtures. A fibre layer can in particular comprise a unidirectional layer or setting layer, that is a fibre layer which, for example, comprises a plurality of filaments or yarns which usually extend parallel or substantially parallel in one direction. This can be accomplished, for example, by spreading out a cable or an arbitrary parallel arrangement of filaments or yarns. In addition, the term fibre layer also comprises fibre layers having an arbitrary arrangement or arbitrary profile of filaments.
or fibre sections of shorter length, for example, a nonwoven layer. In particular, the fibre layers can also have different length and/or width dimensions or a different shape.

Preferably the ceramic fibres consist completely or of at least 90 wt.% relative to the total weight of the ceramic fibres of compounds comprising at least two of the elements carbon (C), silicon (Si), boron (B), titanium (Ti), zirconium (Zr), tungsten (W), aluminium (Al) and nitrogen (N).

In particular, ceramic fibres can be used in which the sum of the content of C, Si, B, N, Al, Zr, Ti, W is more than 50 wt.%, preferably more than 83 wt.%, preferably more than 85 wt.%, in particular more than 95 wt.% of the total weight of the ceramic fibres, where the content of one or more of C, Si, B, N, Al, Zr, Ti, W can be 0 wt.%.

For example, fibres, in particular fibres highly resistant to elevated temperatures, based on Si, C, B, N, Al or compounds thereof (where these fibres are designated, for example, in the document DE 197 11 829 C1 as "Si/C/B/N fibres") and in particular ceramic fibres based on compounds comprising at least two of these elements are used. Such fibres are described, for example in the document DE 197 11 829 C1.

Ceramic fibres can comprise, for example, at least one compound selected from aluminium oxide, zirconium oxide, SiNC, SiBNc, SiC, B₄C, BN, Si₃N₄, TiC, WC and mixtures thereof, or can consist completely of this or of at least 90 wt.%, preferably of at least 93 wt.% in relation to the total weight of fibres. In particular, ceramic fibres can comprise basalt fibres and/or glass fibres or a mixture hereof with other ceramic fibres.
The contours are particularly preferably tracks and/or knitting patterns which allow the intended folding. This is accomplished by omitting one or more fibre yarns in each case in the 0° direction or by splitting the textile by modifying the connecting knitting threads.

As a result of the scrim according to the invention having tracks introduced in the longitudinal and/or transverse direction, the folding is in particular made possible in the case of heavy scrim.

A single fibre layer or unidirectional layer can have an area-related weight in the range of, for example, 50 g/m² to 500 g/m², preferably in a range of 150 g/m² to 2000 g/m². Depending on the desired end product, it can be particularly preferred to select one or more fibre layers or unidirectional layers having an area-related weight of at least 305 g/m².

When using carbon fibres and/or precursor fibres, both fibres which were obtained starting from polyacrylonitrile but also starting from pitch or phenol resin fibres yielded a fibre layer having a very good mechanical loading capacity.

The diameter of the filaments of at least one fibre layer or unidirectional layer, preferably of all fibre layers or unidirectional layers, can lie in a range of, for example, from 6 to 8 μm.

At least one fibre layer preferably consists of more than 70 wt.%, further preferably more than 87 wt.%, particularly preferably more than 98 wt.% of fibres, selected from carbon fibres, precursor fibres of carbon fibres, ceramic fibres and mixtures thereof, relative to the total weight of the particular fibre layer.
In addition to carbon fibres, their precursor fibres and ceramic fibres, the fibre layers can comprise any fibres which a person skilled in the art can select on the basis of his general technical knowledge and the teaching of the present invention.

The textile structure preferably consists of at least 50% of fibres in the principal direction of loading of the three-dimensional semi-finished fibre product to be produced.

The two-dimensional textile structure is preferably coated and/or impregnated with a matrix system or with several matrix systems (liquid/solid) after knitting.

The content of the matrix system for coating and/or impregnating the two-dimensional textile structure is preferably at least 0% to 70%. The textile structure preferably contains soluble polymers (e.g. PVA, polyphenoxy).

The textile structure can be transformed into a three-dimensional semi-finished fibre product (preform) by applying chemical, physical (chemical reaction, pressure and/or temperature) and/or mechanical strengthening methods (sewing, needling).

The two-dimensional (quasi two-dimensional) textile structure having a weight per unit area of 100-5000 g/m², preferably 500-2300 g/m², can be obtained by a method according to one or more of the preceding claims.

The weight per unit area is preferably locally adapted by reducing or increasing the amount of fibre in the two-dimensional (quasi-two-dimensional) fibre structure or by a separate process step.
The three-dimensional semi-finished fibre product can be infiltrated and cured with thermosetting and/or thermoplastic resins.

Fibre scrims having very advantageous properties can be obtained, for example, if at least one fibre layer, in particular a unidirectional layer, preferably all the fibre layers, have a number of filaments which lies in the range of 0.5 K (500 filaments) to 500 K (500 000 filaments). Preferably, the number of filaments of a fibre layer or unidirectional layer lies in a range of 1 K (1000 filaments) to 400 K (400 000 filaments), preferably in a range of 12 K (12 000 filaments) to 60 K (60 000 filaments).

Fibre scrims having advantageous material properties and comparatively low manufacturing costs can further be obtained if one or more fibre layers, in particular unidirectional layers are used, which comprises polymer fibres, in particular organic polymer fibres, or mixtures thereof. In some applications, it can also prove advantageous to use polyacrylonitrile-based fibres, viscose-based fibres, to produce at least one fibre layer. One, two, three or more of the fibre layers can, for example, consist completely or of at least 80 wt.% of polyacrylonitrile fibres and/or viscose fibres relative to the total weight of fibres in the fibre layer.

Fibre scrims having different material properties can be obtained by producing fibre scrims comprising two, three, four, five, six, seven, eight or arbitrarily more fibre layers and/or unidirectional layers. In order to achieve highly loadable material it can be advantageous if one unidirectional layer extends in a different longitudinal direction from the unidirectional layer located in each case above and/or
below this unidirectional layer. Preferably all the unidirectional layers in a fibre scrim extend in a respectively different longitudinal direction. It can be advantageous here if at least the longitudinal direction of one unidirectional layer forms an angle of at least 30°, preferably at least 45°, preferably at least 60°, in particular 85-90° to the longitudinal direction of at least one following unidirectional layer.

If the unidirectional layers each have different longitudinal directions from one another, biaxial fibre scrims are obtained when using two unidirectional layers, triaxial fibre scrims are obtained when using three unidirectional layers, quadraxial fibre scrims are obtained when using four unidirectional layers.

Preferably when using two or more unidirectional layers, the two or more other unidirectional layers are arranged in such a manner that their respective longitudinal directions form angles having opposite signs to the 0° direction, where the magnitude of the angles can be the same (and the angles can, for example, be +60°/-60° or +45°/-45°) or different or their respective longitudinal directions to the 0° direction are at angles of 0° and 90°.

Preferably a 0/90 scrim is produced on a scrim machine, in which at least 90% of the fibres, particularly preferably 95% of the fibres are disposed in the 0° direction. The width and the fibre weight per unit area of the scrim according to the invention is determined by the fibre titre used, the layer structure provided, the resulting number of layers and their width.

It is a surprising advantage of the method according to the invention that the total width of a, for example,
fast-running scrim machine can be used. This is, for example also a particular advantage compared with ribbon looms.

Resins which are particularly suitable for impregnating fibre scrim are, for example, phenol resins, epoxide resins, benzoxyline resins, cyanate ester resins, polyester/vinyl ester resins, furan resins, polyamide resins, polyimide resins, polyacrylate resins, derivatives therefrom and mixtures thereof.

In addition, inorganic impregnating agents can be used for impregnating the fibre scrim, where, for example, liquid silicon, SiC precursor polymers, in particular silazanes, SiC precursor oligomers and mixtures thereof are particularly suitable for impregnating the fibre scrim.

The term "SiC precursor polymer" as used within the framework of the present invention describes any compound having a molecular mass of more than about 300 g/mol which comprises silicon, as well as carbon and/or nitrogen and for example, can have a content of 10 to 99 wt.% of Si, relative to the total weight of the compound. The term "SiC precursor oligomer" as used within the framework of the present invention describes any compound which comprises silicon, as well as carbon and/or nitrogen, which has at least two silicon atoms and has a molecular mass of up to and including about 300 g/mol, and for example, can have a content of 10 to 99 wt.% of Si, relative to the total weight of the compound. Preferably a SiC precursor polymer or a SiC precursor polymer is at least partially converted into SiC when heated to a temperature of more than 150°C in an inert atmosphere.
When impregnating fibre scrims, for example, very good results can be obtained by using at least one compound selected from the group consisting of oligosilazanes, polysilazanes, oligocarbosilazanes, polycarbosilazanes, oligosilanes, polysilanes, oligoborocarbosilazanes, polyborocarbosilazanes, methyl-oligosiloxanes, methyl-polysiloxanes, oligocarbosilanes, polycarbosilanes, oligoborosilazanes, polyborosilazanes, oligo(dialkyl)silicones, poly(dialkyl)silicones, oligosiloxanes, polysiloxanes, for example poly(dialkyl)siloxanes, such as poly(dimethyl)siloxanes, for example, poly(dialkyl)siloxanes, such as poly(diphenyl)siloxanes, for example, poly(monoalkyl-monoarylsiloxanes, such as poly(monomethyl-monophenyl)siloxanes, derivatives thereof and mixtures thereof. The terms oligosilazanes, oligocarbosilazanes, oligosilanes, oligoborocarbosilazanes, methyl-oligosiloxanes, oligocarbosilanes, oligoborosilazanes, oligo(dialkyl)silicones, oligosiloxanes, etc. comprise any oligomer coming under the term, which is constructed from at least two monomer units, that is, any oligomer beginning with one dimer as far as compounds having a molecular weight up to an including about 300 g/mol.

The terms polysilazanes, polycarbosilazanes, polysilanes, polyborocarbosilazanes, methyl-polysiloxanes, polycarbosilanes, polyborosilazanes, poly(dialkyl)silicones, polysiloxanes, etc. comprise any polymer coming under the term that has a molecular weight of more than about 300 g/mol.

A fibre scrim can additionally be impregnated with inorganic impregnating agents and also with resins, preferably synthetic resins. For example, neighbouring sections of a fibre scrim can be impregnated with one
or more inorganic impregnating agents and/or with one of more resins. For example, an impregnation can additionally be accomplished in several layers or in a sequence of impregnating processes using one or more inorganic impregnating agents and/or using one or more resins and/or an impregnation can be made using mixtures of one or more inorganic impregnating agents and resins. The choice of curing conditions takes into account the requirements of the selected impregnating agent.

The curing of the impregnated fibre scrim can take place in a curing temperature range of at least 40°C, at a curing temperature in the range of 50 to 260°C, preferably 80 to 200°C. The curing can preferably take place before commencement of and/or at least during a subperiod of the curing time under pressure, for example, by pressing at least one surface section of at least one surface of the impregnated fibre scrim with a pressing tool. The curing time can, for example, be at least 1 minute, preferably between 10 minutes and 8 hours, preferably between 15 minutes and 3 hours. The curing time under pressure can, for example, be in a range of at least 1 minute, preferably between 10 minutes and 8 hours, preferably between 15 minutes and 3 hours. The pressing pressure can, for example, be at least 0.01 MPa, preferably 0.01 MPa to 100 MPa.

The content of resin and/or inorganic impregnating agents, relative to the total weight of the non-impregnated fibre scrim, can lie in a range of 5 to 85 wt.%, preferably of 25 to 65 wt.%, particularly preferably of 30 to 45 wt.%.

The fibre scrim can, for example, be impregnated as far as saturation of the fibre scrim. In particular, liquid
resins or molten resins ("hot melt resin") can be used, which can for example comprise phenol resins.

The curing and impregnation can be carried out using any method known for this to the person skilled in the art. Very advantageous results can be obtained if the impregnation is carried out by dipping in a dipping bath or by means of a film transfer method. For example, these process steps can be carried out continuously, that is, the woven fabric can, for example, be unrolled from a roll, passed through one or more furnaces having a suitable temperature and atmosphere such as, for example, 400°C or more in an inert atmosphere and then passed further through a resin bath and/or a bath containing inorganic impregnating agent, and/or roll calendars and/or another impregnating device. A curing can then take place, where a composite material is obtained whose matrix is reinforced by a fibre scrim, for example, a carbon fibre scrim. The curing process step can be carried out both continuously and discontinuously. The cured resin and/or the cured inorganic impregnating agent fulfils several functions in the composite material obtained after the curing. Firstly, the resin makes connections between the cables and threads of the fibre scrim and fixes their position in the woven fabric. Depending on the application of the composite material, the fibre scrim can be embedded in a matrix comprising cured resin and/or inorganic impregnating agent, completely or in sections and/or it can be covered with a film of resin and/or inorganic impregnating agent merely covering individual fibres, completely or in sections and/or it can be free of resin in sections. The cured binder additionally effects a mechanical reinforcement of the fibre scrim.
After the curing and/or pressing, a fibre scrim-reinforced composite material or a fibre scrim-reinforced composite material product can be obtained.

A fibre scrim-reinforced composite material product within the framework of the present application designates a partially or preferably completely cured fibre scrim-reinforced composite material which has optionally been subject to further processing steps, for example, cutting to size, shape cutting etc. Within the framework of the present application a cured fibre scrim-reinforced composite material is also designated as green body.

Optionally, the partially or completely cured fibre scrim-reinforced composite material, even without an interposed step of obtaining, or the partially or completely cured fibre scrim-reinforced composite material product can undergo further process steps such as, inter alia, a thermal treatment, for example, for carbonising or graphitising or an extensive heating and/or pressing.

A thermal treatment can be carried out in a first temperature range (frequently also designated as "carbonisation") and can, for example, be carried out by heating with the exclusion of oxidizing substances, i.e. either in an inert atmosphere, in protective gas or by enveloping the material to be combusted with a substance acting as a getter, which binds oxidising media, especially oxygen, at a temperature or in a temperature range from about 800°C to about 1250°C, preferably from 850°C to 950°C, in particular from 880°C to 920°C. The thermal treatment in the first temperature range can take place during a time interval of, for example, at least 30 minutes, preferably of at least 8 hours, in particular from 30 minutes to 96
hours. Any method known to the person skilled in the art can be used for the thermal treatment in a first temperature range ("carbonisation") within the framework of the teaching of the present invention, for example, a solid phase pyrolysis. In order to achieve a good coke yield, a heating-up phase can be executed first, for example, with a comparatively small temperature gradient in the range from 300 to 600°C at a maximum of 4°C per hour or coking is carried out under pressure. The final temperature in this process step cannot exceed, for example, 1250°C.

Both a completely and also an only partially cured fibre-scrim-reinforced composite material can be subjected to the thermal treatment in a first temperature range.

After the thermal treatment in the first temperature range, a composite material is obtained whose matrix comprises carbon and is reinforced with a carbon fibre woven fabric ("carbon fibre reinforced carbon", CFC).

Alternatively to the thermal treatment in a first temperature range or additionally to this, in particular after this, a thermal treatment can be carried out in a second temperature range (frequently also designated as "graphitisation"). The thermal treatment in a second temperature range ("graphitisation") can be carried out by any method known for this to the person skilled in the art. In particular, heating can be carried out in an inert atmosphere at a temperature in the range from about 1251°C to 3000°C, preferably from 1800°C to 2200°C during a time interval of, for example, at least about 30 minutes, preferably of at least 8 hours, in particular from 30 minutes to 96 hours.
During a thermal treatment in the first and/or second temperature range, the resin layer shrinks as a result of the weight loss due to the cleaving of volatile components. The composite material obtained after the thermal treatment is characterised by a high temperature resistance.

After the thermal treatment of the fibre-scrim-reinforced composite material or composite material product, a thermally treatment fibre-scrim-reinforced composite material or composite material product can be obtained. Optionally the composite material obtained after one or more thermal treatments in a first and/or second temperature range, in particular a composite material comprising fibre-scrim-reinforced carbon can be additionally subjected once or several times to an after-treatment, in particular an after-treatment in which the composite material is impregnated at least once, in particular is impregnated with a carbonisable agent, and/or is subjected at least one again to a thermal treatment in a first and/or second temperature range (which is usually designated as after burn). The post-compaction, in particular the steps of impregnation and thermal treatment, can fundamentally be carried out by any method known for this to the person skilled in the art within the framework of the teaching of the present invention. The term post-compaction as used within the framework of the present invention designates any treatment of a material or workpiece which results in a maintaining of or increase in the density of the treated material or workpiece. Advantageously an increase in the density can be accomplished by such after-treatment. The impregnation and the thermal treatment can particularly advantageously be carried out under the conditions explained hereinbefore and hereinafter. The so-called
vacuum pressure method can be used, for example, for the impregnation.

All substances known for an impregnation of parts comprising carbon or consisting thereof, can be used as impregnating agents, for example, substances having a coke yield of more than 30 weight percent, for example, synthetic resins, in particular thermosetting resins or pitches and derivatives derived therefrom as well as mixtures or resins and pitches and/or pitch derivatives. In particular, phenol resins of the novolak or resol type, furan resins or impregnating pitches can be used. A thermal treatment in a first and/or second temperature range as defined previously following the impregnation, so-called after-burning, is carried out with the exclusion of oxidising substances, in particular in an inert atmosphere.

Prior to and/or after the thermal treatment in a first and/or second temperature range, a heating or cooling of, for example, 8 to 10 hours, for example to room temperature (20°C) can be carried out. Example and preferred time intervals and temperature ranges for a thermal treatment in a first and/or second temperature range are explained in detail hereinbefore. In this process step one or several carbon shells should be applied to the already existing shell and after the first carbonisation step, cracks and pores still present in the first shell should be closed. Depending on the intended protective effect for the fibres, this impregnation and after-burning process can take place several times, preferably once to three times.

It can be advantageous for optimisation of the composite material in specific applications if a first thermal treatment in a first temperature range in which carbonisation can take place is followed by a thermal
treatment in a second temperature range in an inert atmosphere in which graphitisation takes place. However, the execution of such a measure is merely optional. Usually the end temperature of 3000°C, in particular 2400°C, is not exceeded during graphitisation. It is preferable to work at temperatures from 1800 to 2200°C. All known graphitisation processes can be used for this step.

The post-compaction described hereinbefore which comprises firstly an impregnation and then a burning process can be repeated once or several times.

The number of post-compactions to be carried out is dependent on the desired target density of the carbon fibre-reinforced carbon ceramic and can be carried out once or several times, for example, twice, three times or four times or more, preferably in a directly successive manner. Preferably the steps of impregnation and subsequent burning are each carried out three times. After post-compaction, densities for example of 1.30-1.60 g/cm³, preferably of 1.30-1.55 g/cm³ can be achieved.

Furthermore, the composite material comprising fibre-scrim-reinforced carbon obtained after one or more thermal treatments and/or post-compacted as explained hereinbefore can optionally be provided with a gas phase coating by the CVD method (CVD = chemical vapour deposition) or by the CVI method (CVI = chemical vapour infiltration) with protective layers of high-melting substances such as pyrocarbon, TiC, TiN or SiC. Any CVD/CVI method known to a person skilled in the art can be used within the framework of the preceding invention. CVD/CVI methods are, for example, taught in the document DE 39 33 039 A1 or in the publication E.
Fitzer et. al., Chemie-Ingenieur-Technik 57, No. 9, p. 737-746 (1985).

In addition, the composite material comprising fibre scrim-reinforced carbon obtained after a thermal treatment in a first and/or second temperature range and/or post-compacted as explained hereinbefore and/or additionally coated by the CVD method or by the CVI method can be subjected to siliconizing. Such a process is described for example in the publication E. Fitzer et. al., Chemie-Ingenieur-Technik 57, No. 9, p. 737-746 (1985).

Siliconization can be carried out within the framework of the present invention by any method known to a person skilled in the art. Composite materials of particularly high quality can be obtained, for example, if the siliconization is carried out in the temperature range from 1450°C to 2200°C, preferably in the temperature range from 1650°C to 1750°C in an inert atmosphere. In particular it is possible to work in the temperature range from 1650°C to 1750°C in vacuum. After reaching the siliconization temperature, the time interval for infiltration and reacting to give SiC can be at least 10 minutes, for example, 10 minutes to 1 hour.

In the case of siliconization without using vacuum, siliconization can be carried out in particular at temperatures from 2100°C to 2200°C in an inert atmosphere. The total of infiltration and reaction time also during a siliconization without using vacuum can be at least 10 minutes, for example, between 10 minutes and one hour.

Advantageously the previously described siliconizations can be carried out using the so-called wick technique.
In this case, the bodies to be siliconized lie on porous highly absorbent carbon bodies in relation to the silicon, whose lower part stands in liquid silicon. The silicon then rises through this wick body into the bodies to be siliconized without the latter having a direct connection with the silicon bath.

The previously explained steps of post-compaction, in particular by impregnation and optional, subsequent thermal treatment in a first and/or second temperature range, siliconization and gas-phase coating can each be repeated once or several times and combined with one another in any sequence.

Composite materials having particularly high quality can be obtained, for example, if, following the step of curing and optionally pressing the impregnated fibre scrim and a thermal treatment in a first temperature range in which carbonisation can take place, the previously described steps of impregnation and thermal treatment in a first and/or second temperature range through which post-compaction can be achieved, are executed at least once, preferably once to three times, preferably three times.

Optionally a siliconization or a gas-phase coating or a siliconization followed by a gas-phase coating can then additionally be carried out. The gas-phase coating can in particular be carried out with carbon or carbon-comprising mixtures, by means of a CVD or CVI process, as described hereinbefore.

The three-dimensional semi-finished fibre product is preferably used for leaf springs or profiles (e.g. T profiles or stringers) for the aerospace field, for the automobile field, for wind energy and sports articles.
as a result of the low weight, the high flexibility and loading capacity.

The textile structure is preferably already adapted or machined (e.g. contour machining or cutouts) in the two-dimensional (quasi two-dimensional) textile structure to the shape of the three-dimensional semi-finished fibre product close to the final contour.
CLAIMS

1. Method for producing a 3D textile structure having contours matched to the 3D textile structure by folding a 2D textile structure.

2. The method according to claim 1, characterised in that the contours are tracks and/or knitting patterns.

3. The method according to one or more of the preceding claims, characterised in that the folding is accomplished in a concertina manner.

4. The method according to one or more of the preceding claims, characterised in that the 2D textile structure has fold-assisting gaps which make it easier to construct the semi-finished fibre product to the shape close to the final contour.

5. The method according to one or more of the preceding claims, characterised in that the 2D textile structure consists of the group of scrim, woven fabric, networks, knitwear, felts, nonwovens, combinations of the same and other two-dimensional structures.

6. The method according to one or more of the preceding claims, characterised in that the 2D textile structures consists of glass fibres, carbon fibres, aramid fibres, ceramic fibres, other polymer fibres, metal fibres or mixtures of the aforesaid fibres.

7. The method according to one or more of the preceding claims, wherein at least one fibre layer
consists of more than 70 wt.%, preferably more than 87 wt.%, particularly preferably more than 98 wt.% of fibres, selected from carbon fibres, precursor fibres of carbon fibres, ceramic fibres and mixtures thereof, relative to the total weight of the particular fibre layer.

8. The method according to one or more of the preceding claims, wherein the textile structure consists of at least 50% of fibres in the principal direction of loading of the three-dimensional semi-finished fibre product to be produced.

9. The method according to one or more of the preceding claims, wherein the textile structure is coated and/or impregnated with a matrix system or with several matrix systems.

10. The method according to claim 9, wherein the content of the matrix system for coating and/or impregnating the two-dimensional textile structure is at least 0% to 70%.

11. The method according to one or more of the preceding claims, wherein the textile structure contains soluble polymers.

12. The method according to one or more of the preceding claims, wherein the textile structure can be transformed into a three-dimensional semi-finished fibre products by applying of chemical, physical and/or mechanical strengthening methods.

13. Three-dimensional textile structure having a weight per unit area of 100-5000 g/m², preferably
500-2300 g/m², which can be obtained by a method according to one or more of the preceding claims.

14. Three-dimensional textile structure according to claim 13, wherein the weight per unit area is locally adapted by reducing or increasing the amount of fibre in the two-dimensional fibre structure or by a separate process step.

15. Three-dimensional semi-finished fibre product that is infiltrated and cured with thermosetting and/or thermoplastic resins, manufactured by a method according to one or more of claims 1 to 12.

16. Three-dimensional semi-finished fibre products according to claim 15 for producing leaf springs or profiles for the aerospace field, for the automobile field, for wind energy and sports articles.

17. Three-dimensional textile structure according to one or more of claims 13 or 14, wherein this is already adapted in the two-dimensional textile structure to the shape of the three-dimensional semi-finished fibre product close to the final contour.
Application number / Numéro de demande: EP2010061975

Figures: 1

Pages: 

Unscannable items received with this application
(Request original documents in File Prep. Section on the 10th floor)

Documents reçu avec cette demande ne pouvant être balayés
(Commander les documents originaux dans la section de la préparation des dossiers au 10ième étage)