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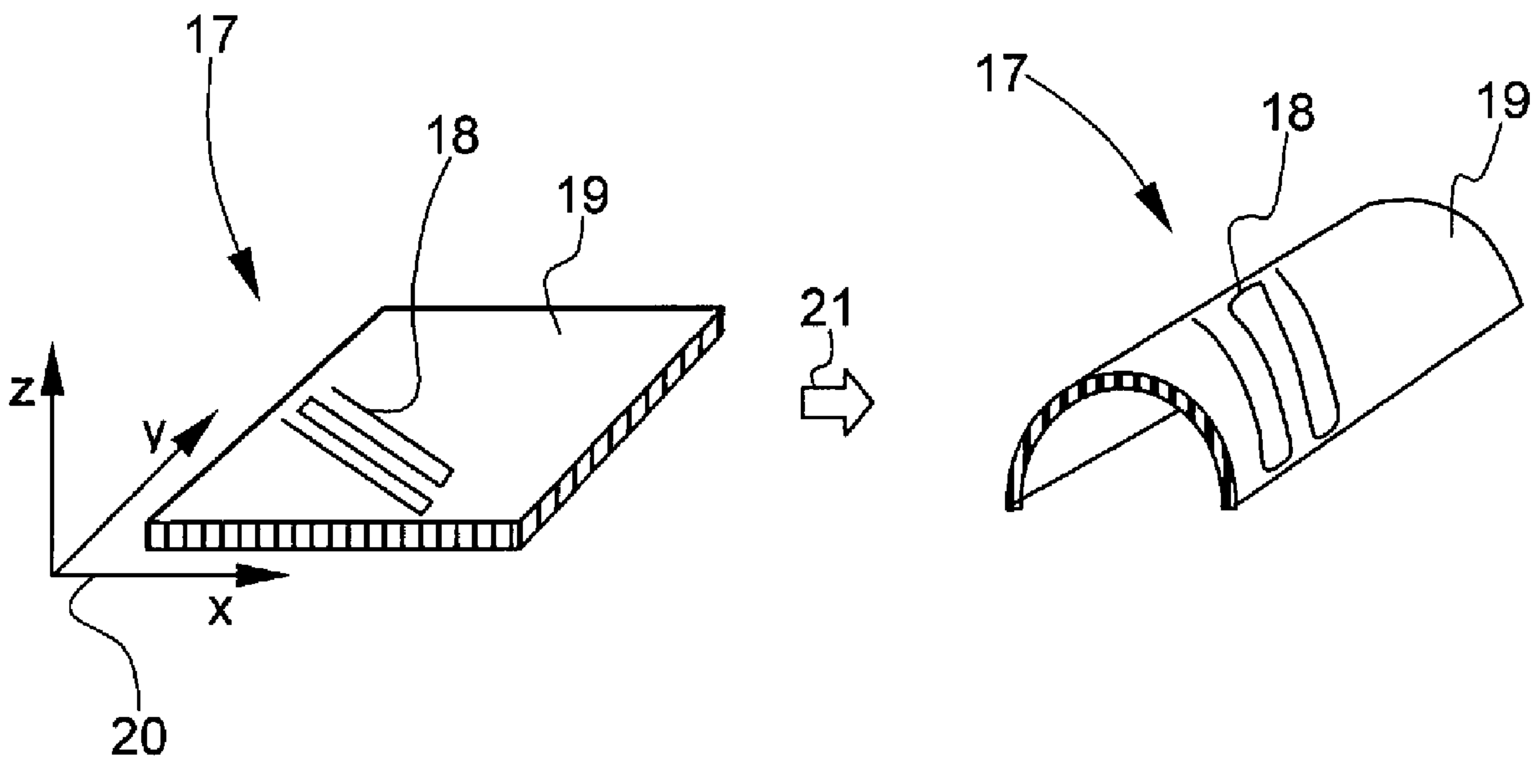
(72) **Inventeurs/Inventors:**
JOERN, PAUL, DE;
EBERTH, ULRICH, DE

(73) **Propriétaire/Owner:**
AIRBUS DEUTSCHLAND GMBH, DE

(74) **Agent:** OYEN WIGGS GREEN & MUTALA LLP

(54) Titre : PROCEDE POUR PRODUIRE DES EBAUCHES FIBREUSES MONOCOUCHES OU MULTICOUCHES AU COURS D'UN PROCEDE TFP
(54) Title: METHOD FOR PRODUCING SINGLE- OR MULTI-LAYERED FIBRE PREFORMS BY THE TFP PROCESS



(57) **Abrégé/Abstract:**
The invention relates to a method for producing single- or multi-layered fibre preforms 1,17 by the TFP process with fibre strands 2-8, 18 which are aligned in particular such that they are oriented with the flux of force, wherein the fibre preforms 1, 17 have virtually any desired material thickness without troublesome backing layers and have virtually any desired surface geometry, comprising the steps of: - laying and attaching the fibre strands 2 to 8, 18 on a flexible and elastic base 9, 19, in particular a base 9, 19 formed by an elastomer, with a fixing thread 10, 11 led through a sewing head to form the fibre preform 1, 17 and - lifting the fibre preform 1, 17 off the elastic and flexible base 9, 19. The fibre preforms 1, 17 produced by means of the method according to the invention have a virtually optimum fibre alignment, that is to say substantially oriented with the flux of force, and no appreciable flaws in the arrangement of fibres, and consequently make it possible to create composite components that can withstand extreme mechanical stress and are at the same time lightweight, for example by subsequent processing in the RTM process.

Abstract

The invention relates to a method for producing single- or multi-layered fibre preforms 1,17 by the TFP process with fibre strands 2-8, 18 which are aligned in particular such that they are oriented with the flux of force, wherein the fibre preforms 1, 17 have virtually any desired material thickness without troublesome backing layers and have virtually any desired surface geometry, comprising the steps of:

- laying and attaching the fibre strands 2 to 8, 18 on a flexible and elastic base 9, 19, in particular a base 9, 19 formed by an elastomer, with a fixing thread 10, 11 led through a sewing head to form the fibre preform 1, 17 and
- lifting the fibre preform 1, 17 off the elastic and flexible base 9, 19.

The fibre preforms 1, 17 produced by means of the method according to the invention have a virtually optimum fibre alignment, that is to say substantially oriented with the flux of force, and no appreciable flaws in the arrangement of fibres, and consequently make it possible to create composite components that can withstand extreme mechanical stress and are at the same time lightweight, for example by subsequent processing in the RTM process.

Figure 2

P21325
Airbus Deutschland GmbH
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Method for producing single- or multi-layered fibre preforms by the TFP process

The invention relates to a method for producing single- or multi-layered fibre preforms by the TFP process ("Tailored Fibre Placement") with fibre strands which are aligned in particular such that they are oriented with the flux of force, wherein the fibre preforms have virtually any desired material thickness without troublesome backing layers and have virtually any desired surface geometry.

In lightweight construction, in particular in aircraft construction, use is increasingly being made of composite components made of fibre-reinforced plastics, which can withstand extreme mechanical loads and at the same time offer a high weight-saving potential. These components are formed with reinforcing fibres which are subsequently saturated or impregnated with a curable polymer material, for example a polyester resin, an epoxy resin or the like, to form the finished component.

The alignment of the reinforcing fibres in a component of this type has a decisive influence on its rigidity and strength. To achieve optimum mechanical properties, the reinforcing fibres should, if possible, follow the direction of loading and not have any undulations. In addition, it is desirable for each individual reinforcing fibre to be subjected to uniform loading.

With conventional semifinished products, such as, for example, woven or laid fibre fabrics, for reinforcement of the polymer material, not all conceivable fibre orientations can be realized, since there the reinforcing fibres always run with a specific orientation.

One possible way of complying with a requirement for fibre alignment in accordance with loading is the TFP process ("Tailored Fibre Placement"). This involves the laying of fibre strands for mechanical reinforcement ("rovings"), which are in turn formed by a multiplicity of discrete reinforcing fibres running parallel to one another, along any desired path curve and attaching them with the aid of a fixing thread on a backing layer, whereby the alignment of the individual fibre strands can be adapted virtually optimally to the flux of force acting on the finished composite component. The optimum utilization of the mechanical load-bearing capacity of the fibre strands that is achieved in this way can minimize their number, and consequently also the weight. Moreover, the cross section of the component can be adapted in an ideal way to the respective local loads. Furthermore, reinforcements can be formed specifically in zones that are subjected to particular loading, such as, for example, regions where force is introduced or the like, by laying additional fibre strands. The discrete reinforcing fibres are, for example, glass fibres, carbon fibres, aramid fibres or the like.

The production of fibre preforms by means of the TFP process is performed on customary CNC-controlled automatic sewing and embroidering machines, which are also used, for example, in the textile industry. Once all the required layers have been laid with fibre strands, the finished fibre preform, which generally already has the desired final contour, is placed in a closable mould, and impregnated with a curable polymer material and subsequently cured to form the finished composite component. A number of TFP fibre preforms and/or layers of reinforcing fabrics may be combined with one another here. The impregnation of the fibre preforms with the curable polymer material may be performed, for example, by means of known RTM processes ("Resin Transfer Moulding") in a correspondingly designed mould. If appropriate, any backing layer material that protrudes beyond a given edge contour of the fibre preform is cut off before carrying out the RTM process.

However, with the fixing thread and the backing layer, the TFP process introduces into the fibre preform two components that no longer perform any function in the later composite component. Specifically, the backing layer causes difficulties in realizing an ideal sequence of layers and represents a not insignificant proportion of the overall weight, in particular if a number of fibre preforms are placed one on top of the other. Although the backing layer may also be formed by a woven reinforcing fabric, for example by a woven glass- or carbon-fibre fabric, even in this case at least some of the reinforcing fibres have an alignment that is not in accordance with the loading. Moreover, the woven reinforcing fabric is also impaired by the penetration with the sewing needle during the TFT process, so that the characteristic material values may be impaired.

Furthermore, it is known to use a solid foam core as a supporting structure for the forming of three-dimensional fibre preforms, the fixing threads being firmly clamped in the upper side of the foam core by means of a tufting method, so that there is no need for an additional lower fixing thread. In the case of this method, however, a special foam core must be kept in stock for each fibre preform with a different surface geometry.

The object of the invention is therefore to improve the known TFP process for producing fibre preforms to the extent that fibre preforms are produced with virtually any desired material thickness and without the disturbing influence of a backing layer that is otherwise necessary for the TFP process remaining on the fibre preform, only a universal base having to be kept in stock for the production of fibre preforms with different surface geometries. In addition, the attachment of the fixing threads in this base is to be improved.

The method described herein includes the steps of:

- laying and attaching the fibre strands on a flexible and elastic base, in particular a base formed by an elastomer, with a fixing thread led through a sewing head to form the fibre preform and
- lifting the fibre preform off the base.

As a result of the elastically and flexibly formed base, fibre preforms with different three-dimensional surface geometries can be produced on one and the same universal base.

In accordance with an advantageous refinement of the method according to the invention, a surface geometry of the base is changed before the laying and attaching of the fibre strands for adaptation to a surface geometry that is intended for the fibre preform.
This makes it possible to provide the base, and consequently also the fibre preform to be laid on it, with any desired surface geometry from the beginning, so that a fibre preform that has right away virtually any desired three-dimensional surface geometry can be laid and attached using a device that is suitable for carrying out the TFP process, for example a CNC-controlled device.
Furthermore, the variability of the surface geometry of the base allows the production of a large number of

different preforms with different surface geometries on one and the same base.

In accordance with a further advantageous refinement, the surface geometry of the base is changed before the lifting off of the fibre preform for adaptation to a surface geometry that is intended for the fibre preform.
As a result, it is possible, for example, to form the base initially in the form of a plane and to lay and attach the fibre strands on it by means of the TFP process. Subsequently, the base can be given a surface geometry that differs from the planar shape, curved three-dimensionally in virtually any way desired. Consequently, the fibre strands can first be laid and attached in the xy plane to form the fibre preform by computer-controlled standard automatic sewing and embroidering machines. Subsequently, the base is then given a different surface geometry, which, for example, corresponds to a surface shape of a half cylinder. To form the fibre preform, it is consequently possible to use a constructionally less complex standard automatic sewing and embroidering machine, which only allows positioning of the sewing head in the spatial xy direction, producing a considerable time and cost saving potential.

In accordance with a further advantageous refinement, the surface geometry of the base is predetermined by supporting elements.
This refinement makes it possible, in particular in combination with a CNC-controlled automatic sewing and embroidering machine or the like, to produce fibre preforms with different surface geometries on one and the same universal base.

In accordance with a further advantageous refinement of the method according to the invention, the supporting elements are moved by an open-loop and closed-loop

control device for adaptation to a surface geometry that is intended for the fibre preform.
The fact that the supporting elements can be individually activated by means of the open-loop and closed-loop control device allows the base to be given virtually any desired surface geometry. The supporting elements may be formed here, for example, as movable rams or supports that are arranged uniformly spaced apart, are arranged underneath the base to hold it up and the paths along which they move are monitored in at least one spatial dimension, for example by an open-loop and closed-loop control device or manually. With preference, both tensile and compressive forces can be applied to the base by means of the positionable rams, in order to achieve a variable deformation of the base. The open-loop and closed-loop control device for varying the surface geometry of the base is preferably coupled here with the CNC control or the computer control of the automatic sewing and embroidering machine that is used for carrying out the TFP process, or represent part of this control.

A further advantageous refinement provides that the fibre preform is fixed before the lifting off from the elastic and flexible base.

As a result, any undesired displacements of the fibre strands that occur within the fibre preform as a result of the lifting off from the base are largely avoided. A thermoplastic powder that melts at a low temperature, a curable adhesive or the like may be used, for example, for fixing the fibre strands in the fibre preform.

Further advantageous refinements of the method according to the invention are presented in the further patent claims.

In the drawing:

Figure 1 shows a cross-sectional representation of a fibre preform formed by the method according to the invention on an elastic and flexible base and

Figure 2 shows a perspective representation of an exemplary forming process for the elastic and flexible base with fibre strands lying on it.

The sequence of the method according to the invention is to be described on the basis of Figure 1 and Figure 2.

Figure 1 firstly shows the sequence of the method according to the invention on the basis of the formation of a planar fibre preform 1. To form the fibre preform 1, in accordance with the known TFP process ("Tailored Fibre Placement"), a multiplicity of fibre strands 2 to 8 ("rovings") are laid and attached on the elastic and flexible base 9 as the backing layer, in particular in a direction oriented with the flux of force. The base 9 may be formed, for example, by an elastic and flexible sheet of an elastomer, in particular a rubber sheet or a rubber mat or the like. The fibre strands 2 to 8 are built up by a multiplicity of discrete reinforcing fibres ("filaments"), which in Figure 1 run approximately perpendicularly to the plane of the drawing. Glass fibres, carbon fibres, aramid fibres or the like are used, for example, as reinforcing fibres. The laying of the fibre strands 2 to 8 on the base 9 is performed by an automatic sewing and embroidering machine, which is not represented any more specifically but has a correspondingly formed sewing head for guiding the fibre strands 2 to 8. The sewing head may serve at the same time for attaching the fibre strands 2 to 8 on the elastic base 9. With preference, the sewing head is monitored by means of an open-loop and closed-loop control device that is not represented, for example a CNC control or the like, to create any desired laying curves of the fibre strands 2 to 8, in particular curves appropriate for the flux of force.

The attaching of the fibre strands 2 to 8 on the base 9 takes place by the fixing threads 10, 11, which are introduced at least partially into the base 9 by means of a needle arranged on the sewing head. Fixing thread loops 12 to 14 thereby form, making it possible for the fixing threads 10, 11 to be securely fastened in the base 9 without the requirement of an additional lower fixing thread ("tufting method"). The fixing thread loops 12 to 14 are firmly held here by being clamped in as a result of suitable frictional conditions within the base 9. As a result, uncontrolled displacement of the laid fibre strands 2 to 8 on the base 9 is avoided. With preference, the fibre strands 2 to 8 are attached on the base 9 by zigzag stitches.

To ensure a secure hold of the fixing thread loops 12 to 14 within the elastic and flexible base 9 and at the same time ensure the adaptability of the latter to different surface geometries, it is formed by an elastomer or some other material that has elastic and flexible properties. For example, the elastic and flexible base 9 may be formed as a rubber sheet or silicone sheet. The base 9 performs the same function as the backing layer, generally similar to a woven fabric, along with a lower fixing thread, that is necessary in the case of conventional TFP processes, but additionally makes it possible to produce fibre preforms with a complex surface geometry without the requirement to keep in stock supporting bodies in the form of solid foam cores that are respectively adapted to the desired surface geometry of the fibre preform to be produced.

In the shown exemplary embodiment of Figure 1, the fibre preform 1 has two layers 15, 16. Here, the fibre strands 6, 7, 8 are laid in the lower layer 16, while the fibre strands 2 to 5 are arranged in the upper layer 15. By means of the method according to the invention, fibre preforms 1 with virtually any desired number of layers arranged one on top of the other can be formed. The maximum number of fibre strands 2 to 8 that can be laid one on top of the other in the TFP process is limited substantially by the length of the needle used, since the needle with the fixing thread has to pierce through all the layers, including part of the base 9.

After the completion of the fibre preform 1, it can be detached from the base 9 without adversely affecting the integrity of the fibre strands 6, 7, 8, because the fibre preform 1 is only loosely held or "tufted" on it by the fixing thread loops 12, 13, 14. After the detachment of the fibre preform 1, only the fixing threads 10, 11 remain in the fibre preform 1, so that the mechanical properties of the fibre preform 1 are not appreciably impaired by this.

Since the production of a planar fibre preform 1 should first be described, the base 9 has a planar surface geometry throughout the method sequence. If, however, fibre preforms with curved surface geometries are to be produced, it is required to use supporting elements to provide the elastic and flexible base 9 with the intended surface geometry before and/or after the completion of the laying and attaching process.

Figure 2 illustrates by way of example the forming of a fibre preform 1 (cf. Figure 1) with an initially planar surface geometry into the fibre preform 17, which has approximately the surface geometry of a half-cylinder.

Firstly, a fibre strand 18 is laid and attached on a planar, elastic and flexible base 19. Here, the fibre strand 18 is representive of a multiplicity of further fibre strands, which have not been represented for the sake of a better overview of the drawing. The procedure when laying and attaching the fibre strand 18 on the initially planar, elastic and flexible base 19 corresponds here to the statements made in the course of the description of Figure 1.

The forming of the initially planar base 19 produces in particular the advantageous effect that automatic sewing and embroidering machines of a simple construction can be used for laying and attaching the fibre strand 18, since only movement of the sewing head in the xy direction of the system of coordinates 20, i.e. parallel to the plane defined by the base 19, is necessary. An additional movement option of the sewing head parallel to the z direction of the system of coordinates 20 is not required.

Following this, as indicated by the arrow 21, the base 19 is formed in such a way that it is given, for example, the surface geometry of a half-cylinder. Following this, the fibre preform 17 can be lifted off the base 19 for further processing. Instead of the surface geometry of a half-cylinder, the base 19 may be given virtually any conceivable surface geometry, for example also a geometry that is spherically curved at least in certain portions.

The deforming of the elastic and flexible base 19 may be performed, for example, by supporting elements that are not represented. These supporting elements are arranged such that they are uniformly spaced apart in the manner of a matrix underneath the elastic and flexible base 6. The supporting elements may, for example, be formed as vertically movable rams or the like, it being possible for the paths along which they move to be monitored in the z direction of the system of coordinates 20 by means of the open-loop and closed-loop control device, so that fibre preforms 17 with virtually any desired surface geometry can be formed by means of the method according to the invention. The open-loop and closed-loop control device here allows a virtually fully automatic and highly precise sequence of the process of deforming the elastic and flexible base 19 and the process of laying and attaching the fibre strands to form the fibre preforms 17. Consequently, fibre preforms 17 with virtually any desired surface geometry and high dimensional stability can be produced in great numbers virtually fully automatically by means of the method according to the invention. Furthermore, the base 19 can be accommodated in a clamping frame, in order already to achieve a substantially planar starting surface geometry, in particular in the case of a small material thickness of the base that is used, without any adjustment or holding up by the supporting elements.

After the completion of the process of deforming the base 19, the fibre preform 17 can be easily detached from the latter and cured to form a finished fibre reinforced composite component, for example by means of the known RTM process ("Resin Transfer Moulding"). For this purpose, the fibre preform 17 is saturated or impregnated with a curable polymer material, for example a polyester resin, an epoxy resin or the like. After the detachment of the fibre preform 17 from the base 19, it may be necessary in advance to bring the edge contours of the fibre preforms 17 to predetermined required dimensions by trimming.

To ensure adequately secure fixing of the fibre strand 18, the fibre preform 17 may, if appropriate, be additionally fixed with a binder before the lifting off from the base 19 and/or before the deforming of the base 19. Thermoplastics that melt in a temperature range between 50°C and 150°C and/or suitable adhesives, for example hotmelt adhesives, come into consideration in particular as binders. These binders may be applied, for example, in powder form into and/or onto the fibre preform 17.

Apart from the fixing threads, no troublesome elements, in particular backing layers or the like, that could lead to impairment of the mechanical properties of the fibre preform 17 remain within the fibre preforms 17 after the detachment of the fibre preform 17 from the base 19. As a result, to produce fibre reinforced composite components with a greater material thickness, a number of correspondingly formed fibre preforms can be arranged one on top of the other to form multi-layered fibre preforms, before they are placed into a mould for carrying out the RTM process. The mechanical properties of the multi-layered fibre preforms formed in this way are not impaired by backing layers or other intermediate layers or the like that are required in the course of the TFP process.

It must be taken into account for the method that the presented sequence of the individual method steps is only of an exemplary character and it is possible if need be to depart from the method sequence explained.

By means of the method according to the invention, fibre preforms which have a fibre alignment that is substantially oriented with the flux of force and may also have a surface geometry that departs from a planar shape can be produced in a simple way. The fibre preforms can, moreover, be produced on computer-controlled automatic sewing and embroidering machines, the sewing head of which can only be positioned in the xy plane, so that a considerable time and cost saving is obtained. The fibre preforms formed in accordance with the method according to the invention may be used, for example, for producing composite components by the RTM process.

The composite components produced in this way have a virtually optimum fibre alignment, that is to say substantially oriented with the flux of force, and no appreciable flaws in the laminate structure, and consequently make it possible to create components that can withstand extreme mechanical stress and, moreover, have only a very low weight.

The invention accordingly relates to a method for producing single- or multi-layered fibre preforms 1, 17 by the TFP process with fibre strands 2 to 8, 18 which are aligned in particular such that they are oriented with the flux of force, the fibre preforms 1, 17 having virtually any desired material thickness without troublesome backing layers and virtually any desired surface geometry, comprising the steps of:

- laying and attaching the fibre strands 2 to 8, 18 on a flexible and elastic base 9, 19, in particular a base 9, 19 formed by an elastomer, with a fixing thread 10, 11 led through a sewing head to form the fibre preform 1, 17 and
- lifting the fibre preform 1, 17 off the base 9, 19.

The surface geometry of the base 9, 19 is preferably changed before the laying and attaching of the fibre strands 2 to 8, 18 for adaptation to a surface geometry that is intended for the fibre preform 1, 17.

The surface geometry of the base 9, 19 is changed before the lifting off of the fibre preform 1, 17, for example for adaptation to a surface geometry that is intended for the fibre preform 1, 17.

The surface geometry of the base 9, 19 is also advantageously predetermined by supporting elements.

The supporting elements are moved, for example, by an open-loop and closed-loop control device for adaptation to a surface geometry that is intended for the fibre preform 1, 17.

The fibre preform 1, 17 is fixed before the lifting off from the base 9, 19.

The fixing of the fibre preform 1, 17 is performed in particular with a binder, in particular with a thermoplastic material and/or an adhesive.

The fixing thread 10, 11 is introduced into the base 9, 19, for example, by piercing the base 9, 19 by means of a needle arranged on the sewing head, and formed fixing thread loops 12 - 14 are in this way firmly held in the base 9, 19.

The position of the sewing head with respect to the base 9, 19 is advantageously monitored in at least two spatial dimensions by the open-loop and closed-loop control device, in order to make virtually any desired laying curves of the fibre strands 2 - 8, 18 on the base 9, 19 possible, in particular curves oriented with the flux of force.

At least in certain regions, at least two fibre strands 2 - 8, 18 are, for example, laid on the base 9, 19 and fixed, in order to form a fibre preform 1, 17 with at least two layers 15, 16.

After the detachment from the base 9, 19, at least two fibre preforms 1, 17 are advantageously arranged one on top of the other to form a multi-layered fibre preform 1, 17.

List of reference numerals

1	fibre preform
2	fibre strand
3	fibre strand
4	fibre strand
5	fibre strand
6	fibre strand
7	fibre strand
8	fibre strand
9	base
10	fixing thread
11	fixing thread
12	fixing thread loop
13	fixing thread loop
14	fixing thread loop
15	layer
16	layer
17	fibre preform
18	fibre strand
19	base
20	system of coordinates
21	arrow

Patent claims

1. Method for producing single- or multi-layered fibre preforms (1, 17) by the TFP process with fibre strands (2-8, 18) which are aligned such that they are oriented with the flux of force, wherein the fibre preforms (1, 17) have virtually any desired material thickness without troublesome backing layers and have virtually any desired surface geometry, comprising the steps of:
   a) changing the surface geometry of a flexible and elastic base (9, 19) for adaptation to a surface geometry that is intended for the fibre preform (1, 17) before the laying and attaching of the fibre strands (2 to 8, 18) on the base (9, 19), the base (9, 19) being formed by a rubber sheet or a silicone sheet,
   b) laying and attaching the fibre strands (2 to 8, 18) on the base (9, 19) with a fixing thread (10, 11) led through a sewing head to form the fibre preform (1, 17),
   c) inserting the fixing thread (10, 11) into the base (9, 19) by means of a needle arranged on the sewing head, whereby the fixing thread (10, 11) is introduced into the base (9, 19) and fixing thread loops (12, 14) formed as a result are firmly held in the base (9, 19), and
   d) lifting the fibre preform (1, 17) off the base (9, 19).

2. Method according to Claim 1, **characterized in that** the surface geometry of the base (9, 19) is changed before the lifting off of the fibre preform (1, 17) for adaptation to a surface geometry that is intended for the fibre preform (1, 17).

3. Method according to Claim 1 or 2, **characterized in that** the surface geometry of the base (9, 19) is predetermined by supporting elements.

4. Method according to Claim 3, **characterized in that** the supporting elements are moved by an open-loop and closed-loop control device for adaptation to a surface geometry that is intended for the fibre preform (1, 17).

5. Method according to one of Claims 1 to 4, **characterized in that** the fibre preform (1, 17) is fixed before the lifting off from the base (9, 19).

6. Method according to one of Claims 1 to 5, **characterized in that** the fixing of the fibre preform (1, 17) is performed with a binder, in particular with a thermoplastic material and/or an adhesive.

7. Method according to Claim 4, **characterized in that** the position of the sewing head with respect to the base (9, 19) is monitored in at least two spatial dimensions by the open-loop and closed-loop control device, in order to make virtually any desired laying curves of the fibre strands (2 - 8, 18) on the base (9, 19) possible, in particular curves oriented with the flux of force.

8. Method according to one of Claims 1 to 7, **characterized in that,** at least in certain regions, at least two fibre strands (2 - 8, 18) are laid on the base (9, 19) and fixed, in order to form a fibre preform (1, 17) with at least two layers (15, 16).

9. Method according to one of Claims 1 to 8, **characterized in that,** after the detachment from the base (9, 19), at least two fibre preforms (1, 17) are arranged one on top of the other to form a multi-layered fibre preform (1, 17).

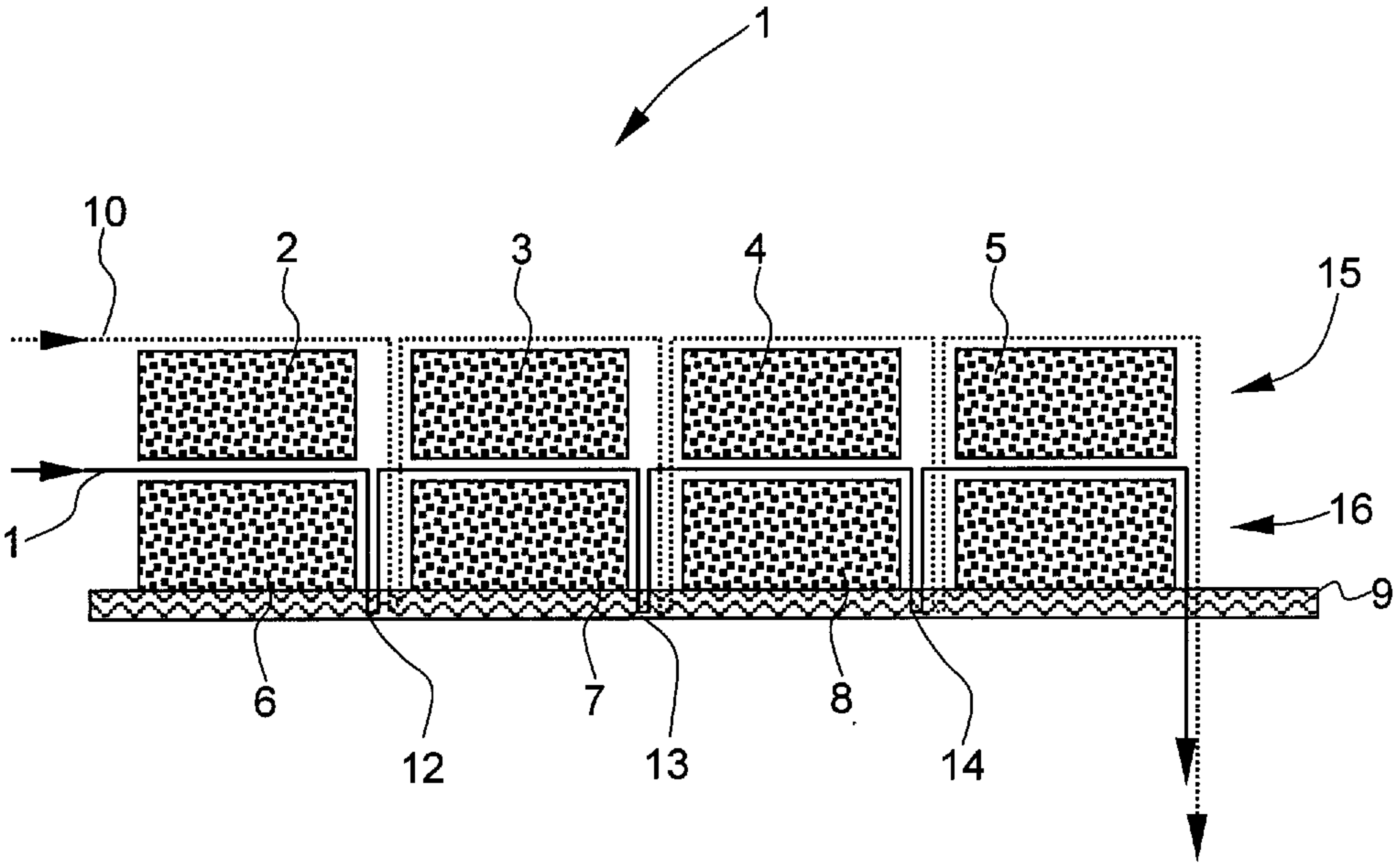


Fig. 1

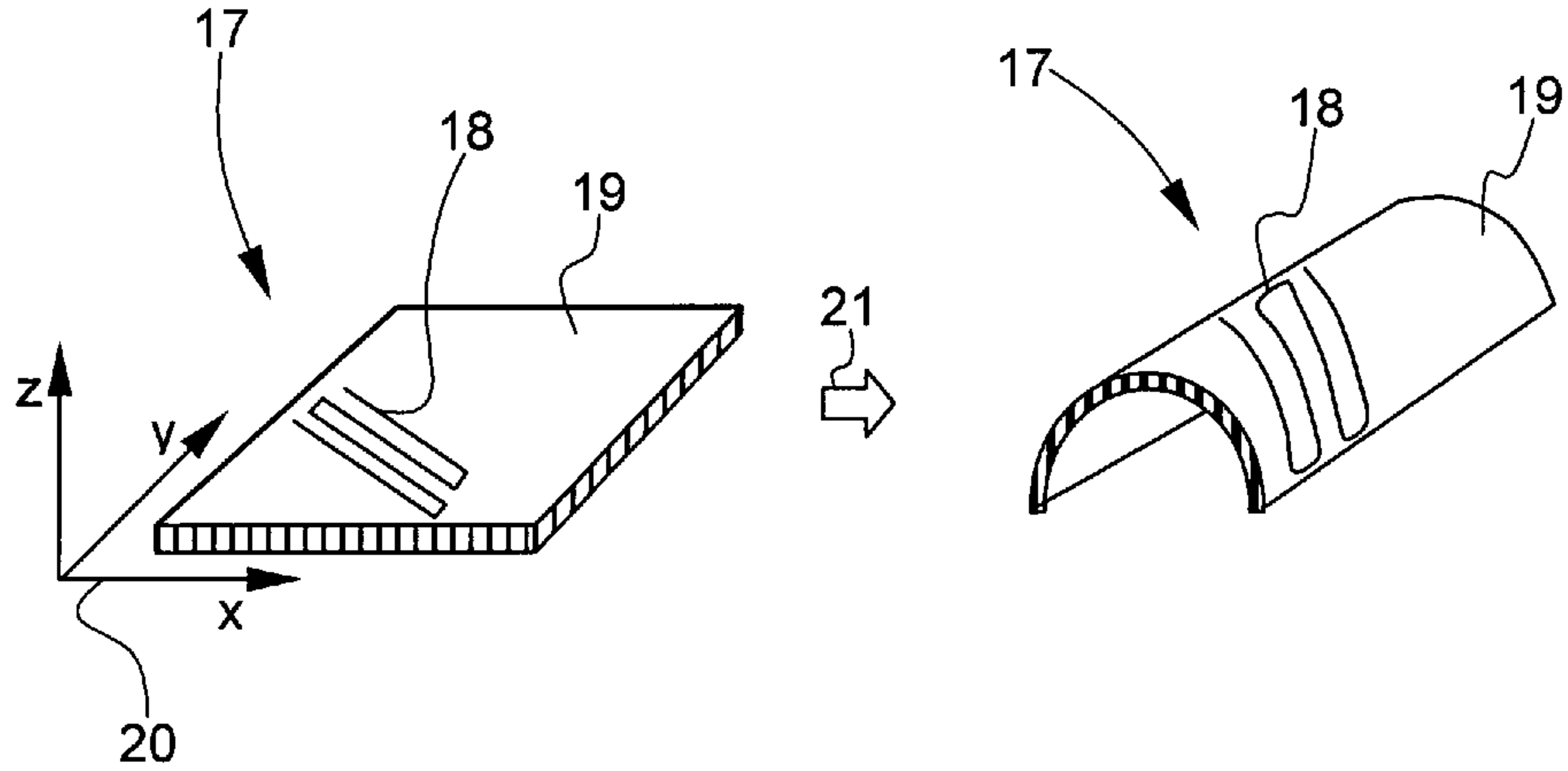
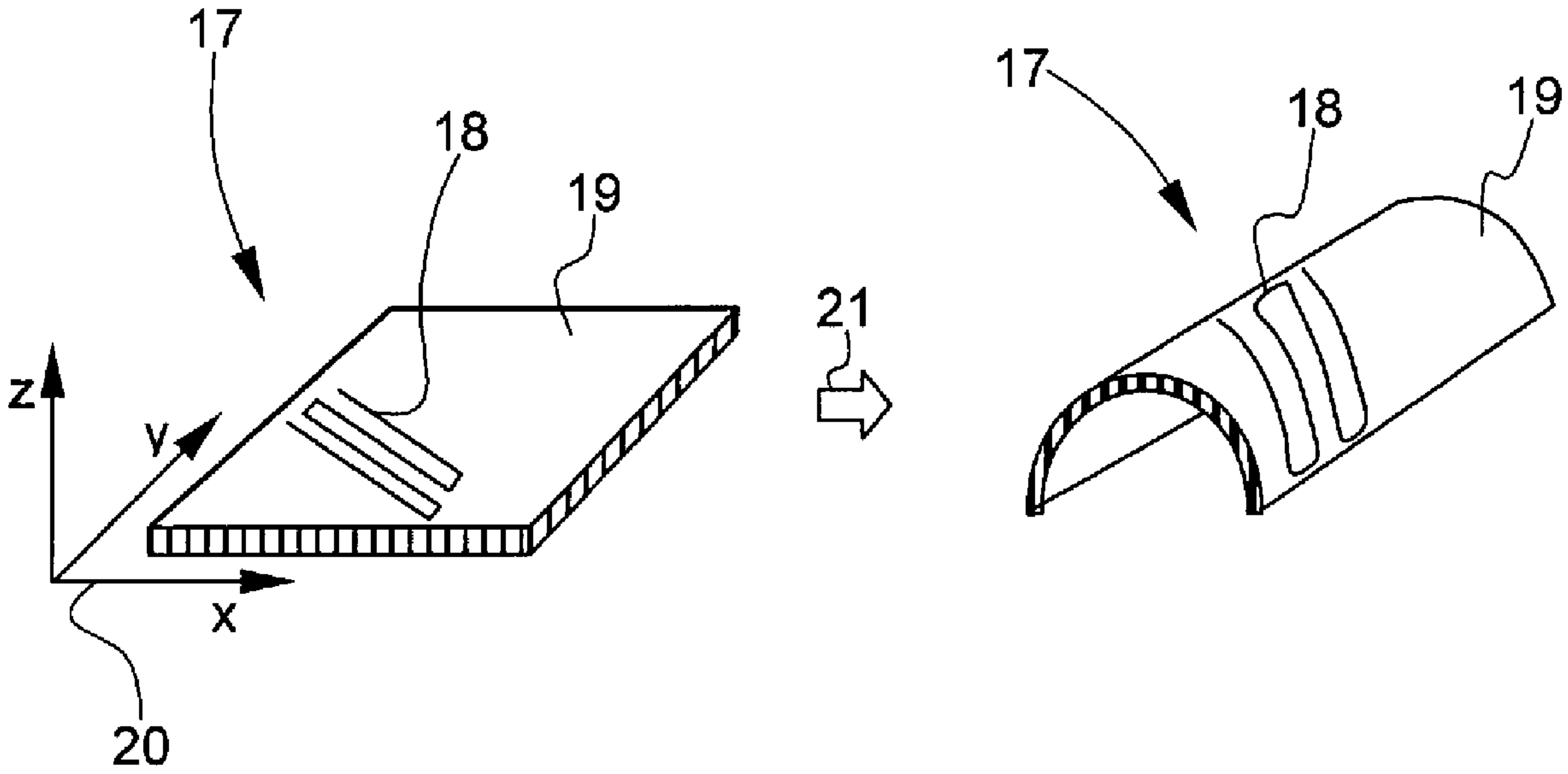


Fig. 2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