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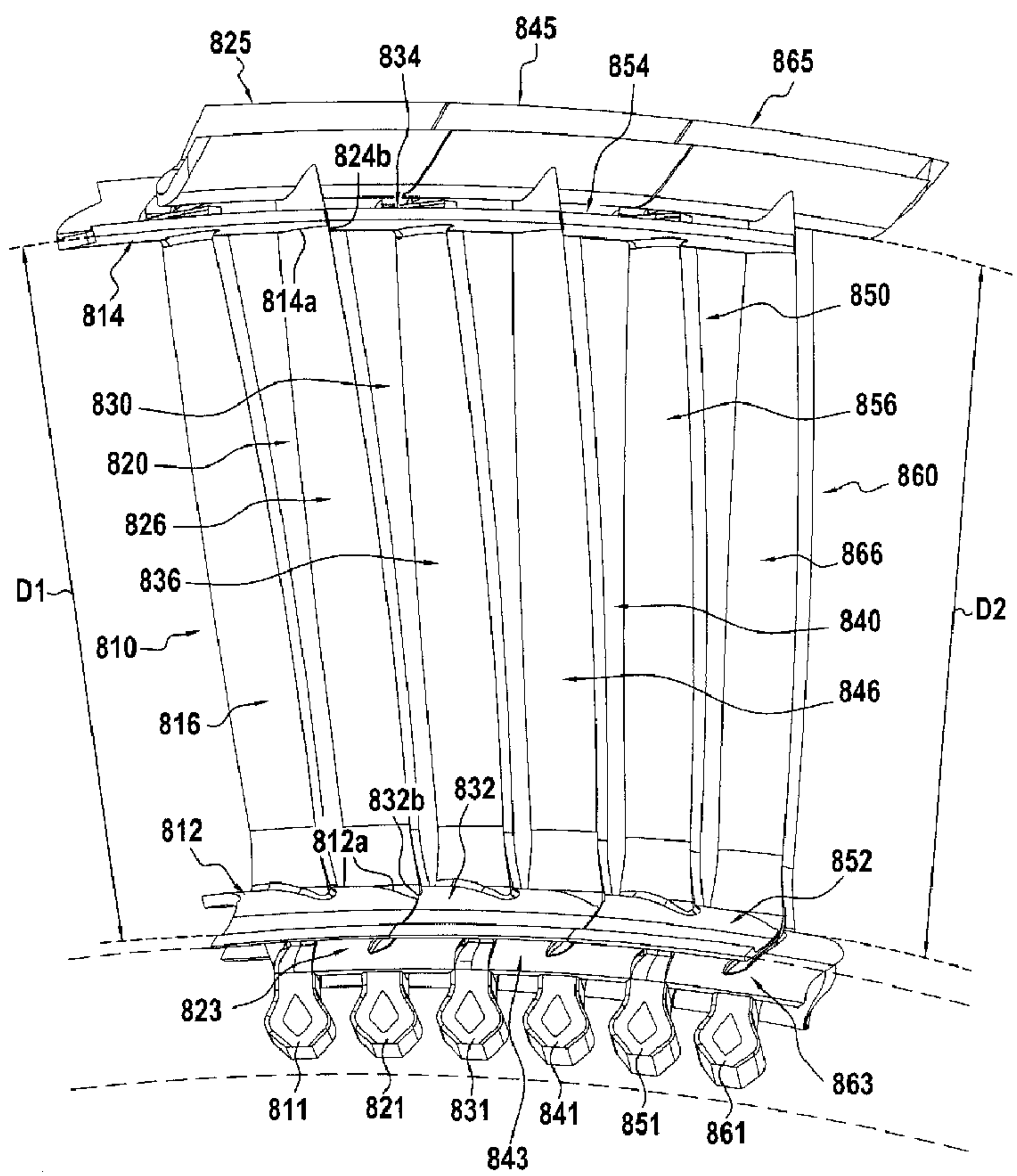
(72) **Inventeurs/Inventors:**
ROUSSILLE, CLEMENT, FR;
MATEO, JULIEN, FR

(73) **Propriétaires/Owners:**
HERAKLES, FR;
SNECMA, FR

(74) **Agent:** SIM & MCBURNEY

(54) **Titre : AUBE DE TURBOMACHINE A GEOMETRIE COMPLEMENTAIRE PAIRE/IMPAIRE ET SON PROCEDE DE FABRICATION**
(54) **Title: TURBOMACHINE BLADE HAVING COMPLEMENTARY EVEN/ODD GEOMETRY AND ITS MANUFACTURING METHOD**



(57) **Abrégé/Abstract:**
Turbomachine blade made of composite material including a fiber reinforcement obtained by three-dimensional weaving of yarns and densified by a matrix, the blade including a first portion constituting an airfoil and a blade root. The first portion constitutes a

(57) **Abrégé(suite)/Abstract(continued):**
single piece with at least one second portion constituting a blade inner platform, said blade then lacking a blade anti-tilting wall, or a blade anti-tilting wall, said blade then lacking a blade inner platform. The first portion also constitutes a single piece with at least one third portion constituting a blade outer platform spoiler plate, said blade then lacking a blade outer platform wiper plate, or a blade outer platform wiper plate, said blade then lacking a blade outer platform spoiler plate.

ABSTRACT

Turbomachine blade made of composite material including a fiber reinforcement obtained by three-dimensional weaving of yarns and densified by a matrix, the blade including a first portion constituting an airfoil and a blade root. The first portion constitutes a single piece with at least one second portion constituting a blade inner platform, said blade then lacking a blade anti-tilting wall, or a blade anti-tilting wall, said blade then lacking a blade inner platform.

The first portion also constitutes a single piece with at least one third portion constituting a blade outer platform spoiler plate, said blade then lacking a blade outer platform wiper plate, or a blade outer platform wiper plate, said blade then lacking a blade outer platform spoiler plate.

Title of the invention

Turbomachine blade having complementary even/odd geometry and its manufacturing method

Background of the invention

The invention relates to turbomachine blades made of composite material including a fiber reinforcement densified by a matrix.

The intended field is that of gas turbine blades for aeroengines or industrial turbines.

The fabrication of turbomachine blades of composite material has already been proposed. Reference can be made in particular to international patent application PCT/FR2009/052309 filed jointly by SNECMA and SNECMA Propulsion Solide. This application describes the fabrication of a turbomachine blade made of composite material including a fiber reinforcement densified by a matrix. More precisely, this method exhibits the feature that the fiber blank fabricated by three-dimensional weaving is shaped to obtain a one-piece fiber preform having a first portion constituting an airfoil and blade root preform and at least one second portion constituting an inner platform or blade outer platform preform. Thus, after densification of the preform, it is possible to obtain a blade made of composite material having a fiber reinforcement consisting of the preform and densified by the matrix, and forming a single piece with integrated inner platform and/or outer platform.

The blade obtained by such a method has the disadvantage that its outer platform cannot integrate both a function of sealing (through the presence of wipers) to the housing which surrounds the blades and an aerodynamic function (by the presence of covering spoilers defining the outside of the flowpath of the gas stream in the turbine).

French patent application No. 09 58931 filed jointly by SNECMA and SNECMA Propulsion Solide, describes the fabrication of a blade made of composite material forming a single piece with integrated inner platform and outer platform, the outer platform providing both the sealing function and the aerodynamic function.

However, the fabrication of such an outer platform with the method described in French patent application No. 09 58931 involves in particular shaping and molding operations with two-layer fiber structures, operations which are completely feasible but which can be more complex to carry out than with single-layer structures. In addition, the blade thus fabricated does not incorporate an anti-tilting wall.

Further, in the event of damage to the outer platform of the blade fabricated according to the method described in French patent application No. 09 58931, the aerodynamic function and the sealing function are both impacted because the outer platform is formed in a single piece providing both functions

Object and summary of the invention

It is therefore desirable to be able to have available turbomachine blades made of composite material, particularly but not necessarily made of thermostructural composite material such as CMC, for turbomachine compressors or turbines, blades that are relatively simple to fabricated and which incorporate the required functions, particularly the functions of sealing, of defining the passage for the flow stream (aerodynamic function), and of anti-tilting.

To this end, according to the present invention, a method is proposed for fabricating a turbomachine blade made of composite material including a fiber reinforcement densified by a matrix, the method including:

- the fabrication by three-dimensional weaving of a one-piece fiber blank,

- the shaping of the fiber blank to obtain a one-piece fiber blade perform having:

- a first portion constituting a blade and blade root preform,

- a second portion constituting a preform of a blade *inner* platform, said blade preform then lacking a preform of a blade anti-tilting wall, or constituting a blade anti-tilting wall, said blade preform then lacking a blade inner platform perform, and

- a third portion constituting the preform of a blade outer platform spoiler plate, said blade preform then lacking a blade outer platform wiper plate preform, or

- a second portion constituting the preform of a blade anti-tilting wall, said blade preform then lacking a blade inner platform preform, and

- a third portion constituting the preform of a blade outer platform spoiler plate, said blade preform then lacking a blade outer platform wiper plate preform, or constituting the preform of a blade outer platform wiper plate, said blade preform then lacking a blade outer platform spoiler plate preform,

- the densification of the preform by a matrix to obtain a blade made of composite material having a fiber reinforcement consisting of the preform and densified by the matrix, and forming a single part with two of the following elements: blade inner platform, blade anti-tilting wall, blade outer platform spoilers or with two of the following elements: blade anti-tilting wall, blade outer platform spoilers and blade outer platform wipers.

Compared to the method described in patent application No. 09 58931, the invention contemplates a first blade providing two of the following functions: radially inward flow passage definition, radially outward flow passage definition, sealing and anti-tilting, and a second blade providing the two other functions not provided for by the first blade, each of these functions being accomplished by distinct portions of the blades which are manufactured with single-layer textures. The first and second blades thus fabricated exhibit complementary geometries which make it possible, by interleaving these first and second blades in succession, to provide all the functions required on both surfaces of the airfoils facing each of said blades.

According to one advantageous feature of the method, in the longitudinal direction of the fiber blank corresponding to the longitudinal direction of the blade to be fabricated, the fiber blank includes a first set of several layers of yarns which are interlinked to constitute a first portion of the blank corresponding to the preform of the blade and blade root, and a second set of several layers of yarns which are interlinked at least locally to constitute a second portion of the blank corresponding to a preform of a platform or of an anti-tilting wall and a third portion of the blank corresponding to a blade outer platform spoiler or wipers plate preform, the yarns of the second set of yarn layers not being linked to the yarns of the second set of yarn layers, and the first set of yarn layers having yarns from the second set of yarn layers running through it at the or each second portion of the blank.

The provision of areas of separation allows shaping of the fiber preform without cutting connecting yarns, as such cutting can reduce the mechanical strength of the fiber reinforcement, hence of the fabricated blade.

According to another feature of the method, the fiber blank is woven with a second continuous set of yarn layers and the shaping of the fiber blank includes the elimination, by cutting them out, of portions of the second set of yarn layers outside of the second portion of the fiber blank and of the third portion of the fiber blank.

According to still another feature of the method, at the location or at least at one of the locations where the first set of yarn layers has yarns from the second set of yarn layers passing through it, the intersection of a yarn layer of the first set and a yarn layer of the second set follows a line that is not orthogonal to the longitudinal direction of the fiber blank.

It is also possible to fabricate a blade made of composite material with an inner platform and/or an outer platform that extends generally non-perpendicularly to the longitudinal direction of the blade.

According to yet another feature of the method, in the first portion of the fiber blank and in a direction corresponding to that extending along the profile of a variable thickness airfoil in the blade to be fabricated, the number of yarn layers in the longitudinal direction in the first set of yarn layers is constant. The yarns of the first set of yarns can then be of variable weight and/or count.

Advantageously, a strip comprising a succession of fiber blanks is fabricated by three-dimensional weaving. These can then be cut out of the strip. The blanks can be woven with the longitudinal direction of the blade to be fabricated in the weft direction or in the warp direction.

According to the present invention, a turbomachine blade made of composite material is also proposed having a fiber reinforcement obtained by three-dimensional weaving of yarns and densified by a matrix, the blade including a first portion constituting an airfoil and a blade root,

characterized in that said first portion constitutes a single part with at least:

- a second portion constituting a blade platform, said blade then lacking a blade anti-tilting wall, or a blade anti-tilting wall (250), said blade then lacking a blade inner platform, and

- a third portion constituting a blade outer platform spoiler plate, said blade then lacking a blade outer platform wiper plate, or

- a second portion constituting a blade anti-tilting wall, said blade then lacking a blade inner platform, and

- a third portion constituting a blade outer platform spoiler plate, said blade then lacking a blade outer platform wiper plate, or a blade outer platform wiper plate, said blade then lacking a blade outer platform spoiler plate.

The invention also proposes a blade set comprising a first and a second blade according to the blade of the invention, the second portion of the first blade constituting a blade inner platform, the first blade then lacking a blade anti-tilting wall, the third portion of the first blade constituting a blade outer platform spoiler plate, the first blade then lacking a blade outer platform wiper plate, the second portion of the second blade constituting a blade anti-tilting wall, the second blade then lacking a blade inner platform, the third portion of the second blade constituting a blade outer platform wiper plate, the second blade then lacking a blade outer platform spoiler plate.

According to one variant of implementation, the invention also proposes a blade set comprising a first and a second blade according to the blade of the invention, the second portion of the first blade constituting a blade anti-tilting wall, the first blade then lacking a blade inner platform, the third portion of the first blade constituting a blade outer platform spoiler plate, the first blade then lacking a blade outer platform wiper plate, the second portion of the second blade constituting a blade inner platform, the second blade then lacking a blade anti-tilting wall, the third portion of the second blade constituting a blade outer platform wiper plate, the second blade then lacking a blade outer platform spoiler plate.

The blade can be made of a ceramic matrix composite material.

According to one feature of the blade, the yarns constituting the portion of the fiber reinforcement corresponding to the second portion of the blade run through the portion of the fiber reinforcement corresponding to the first portion of the blade.

The airfoil of the blade can have a variable thickness profile along which the part of the fiber reinforcement corresponding to the first portion of the blade has, in the longitudinal direction of the blade, a constant number of layers of yarns having a variable weight and/or count, or a variable number of yarn layers.

In another aspect a method for fabricating a turbomachine set of blades made of composite material including a fiber reinforcement densified by a matrix is proposed, the method comprising: fabrication by three-dimensional weaving of a first one-piece fiber blank; shaping of the first fiber blank to obtain a first one-piece fiber blade preform having: a first portion constituting a preform of an airfoil and a blade root; a second portion constituting a preform of a blade inner platform, said blade preform then lacking a blade anti-tilting wall preform, or constituting of a blade; and a third portion constituting a preform of a blade outer platform spoiler plate, said blade preform then lacking a blade outer platform wiper plate preform; and fabrication by three-dimensional weaving of a second one-piece fiber blank; shaping of the second fiber blank to obtain a second one-piece fiber blade preform having: a first portion constituting a preform of an airfoil and a blade root; a second portion constituting a preform of a blade anti-tilting wall, said blade preform then lacking a blade inner platform preform; and a third portion constituting a preform of a blade outer platform wiper plate, said blade preform then lacking a blade outer platform spoiler plate preform; and densification of the first and second preforms by a matrix to obtain first and second blades made of composite material having a fiber reinforcement consisting of the preform and densified by the matrix, said first blade constituting a single part with a blade inner platform and blade outer platform spoilers, and a second blade constituting a single part with a blade anti-tilting wall and blade outer platform wipers; or the method comprising: fabrication by three-dimensional weaving of a first one-piece fiber blank; shaping of the first fiber blank to obtain a first one-piece fiber blade preform having: a first portion constituting a preform of an airfoil and a blade root; a second portion constituting a blade anti-tilting wall preform, said blade preform then lacking blade inner platform preform; and a third portion constituting a preform of a blade outer platform spoiler plate, said blade preform then lacking a blade outer platform wiper plate preform; and fabrication by three-dimensional weaving of a second one-piece fiber blank; shaping of the second fiber blank to obtain a second one-piece fiber blade preform having: a first portion constituting a preform of an airfoil and a blade root; a second portion constituting a preform of a blade inner platform preform, said blade preform then lacking a blade anti-tilting wall; and a third portion constituting a preform of a blade outer platform wiper plate, said blade preform then lacking a blade outer platform spoiler plate preform; and densification of the first and second preforms by a matrix to obtain first and second blades made of composite material having a fiber reinforcement consisting of the preform and densified by the matrix, said first blade constituting a single part with a blade anti-tilting wall and blade outer platform spoilers, and said second blade constituting a single part with a blade inner platform and blade outer platform wipers.

In another aspect a set of first and second turbomachine blades made of composite material including a fiber reinforcement obtained by three-dimensional weaving and densified by a matrix is proposed, the first blade including: a first portion constituting an airfoil and a blade root; a second portion constituting a blade inner platform, said blade then lacking a blade anti-tilting wall; and a third portion constituting a blade outer platform spoiler plate, said blade then lacking a blade outer platform wiper plate; and the second blade including: a first portion constituting an airfoil and a blade root; a second portion constituting a blade anti-tilting wall, said blade then lacking a blade inner platform; and a third portion constituting a blade outer platform wiper plate, the blade then lacking a blade outer platform spoiler plate; or the first blade including: a first portion constituting an airfoil and a blade root; a second portion constituting a blade anti-tilting wall preform, said blade preform then lacking blade inner platform preform; and a third portion constituting a preform of a blade outer platform spoiler plate, said blade preform then lacking a blade outer platform wiper plate preform; and the second blade including: a first portion constituting a preform of an airfoil and a blade root; a second portion constituting a preform of a blade inner platform preform, said blade preform then lacking a blade anti-tilting wall; and a third portion constituting a preform of a blade outer platform wiper plate, said blade preform then lacking a blade outer platform spoiler plate preform.

In yet another aspect a method for making at least a segment of a turbomachine wheel is proposed, the method comprising: assembling together a plurality of first blades or vanes and a plurality of second blades or vanes in alternation with the first blades or vanes, the first and second blades or vanes being made of composite material including a fiber reinforcement made by three-dimensional weaving and densified by a matrix; each of the first blades or vanes comprising a first portion forming at least an airfoil and formed integrally with: a second portion selected from a flowpath delimiting inner platform portion and an inner portion of an inner platform; and a third portion selected from a flowpath delimiting outer platform portion and an outer portion of an outer platform; each of the second blades or vanes comprising a first portion forming at least an airfoil and formed integrally with: a second portion selected from a flowpath delimiting inner platform portion and an inner portion of an inner platform, the second portion of a second blade or vane being different from the second portion of a first blade or vane; and a third portion selected from a flowpath delimiting outer platform portion and an outer portion of an outer platform, the third portion of a second blade or vane being different from the third portion of a first blade or vane.

In still yet another aspect a method for fabricating a turbomachine turbine nozzle segment or compressor stator segment out of a composite material is proposed, the method comprising: assembling and connecting together a plurality of first vanes and a plurality of second vanes in alternation with the first vanes, the first and second vanes being made of composite material including a fiber reinforcement made by three-dimensional weaving and densified by a matrix, wherein: each of the first vanes comprises a first portion forming an airfoil and formed integrally with a second portion forming an inner platform and with a third portion forming a flowpath delimiting outer platform portion; each of the second vanes comprises a first portion forming an airfoil and formed integrally with a second portion forming an inner platform and with a third portion forming an outer platform portion constituting hooking legs; and the third portion of the first vanes lacking an outer platform portion constituting hooking legs and the third portion of the second vanes lacking a flowpath delimiting outer platform portion; the making of each vane comprises: making a one-piece fiber blank by three-dimensional weaving; shaping of the fiber blank to obtain a one-piece vane preform having a first preform portion forming a preform for the first vane portion and a second preform portion forming a preform for the second and third vane portion; and densifying the preform with a matrix to obtain a composite material vane having fiber reinforcement constituted by the preform and densified by the matrix; the vanes are connected together by a process including a step selected from a brazing step and a step of connection by co-densification by a matrix of a plurality of vanes assembled together at an intermediary stage of densification; and the making of each vane comprises a step of partial densification of the vane preform by a matrix and a subsequent machining step; and the connection of a plurality of vanes together comprises assembling machined vanes together and co-densification by a matrix of the assembled machined vanes.

In another aspect a method for fabricating a turbomachine turbine nozzle segment or compressor stator segment out of a composite material is proposed, the method comprising: assembling and connecting together a plurality of first vanes and a plurality of second vanes in alternation with the first vanes, the first and second vanes being made of composite material including a fiber reinforcement made by three-dimensional weaving and densified by a matrix, wherein: each of the first vanes comprises a first portion forming an airfoil and formed integrally with a second portion forming a flowpath delimiting inner platform portion and with a third portion forming an outer platform; each of the second vanes comprises a first portion forming an airfoil and formed integrally with a second portion forming an inner platform portion constituting hooks or overhangs and with a third portion forming an outer platform; the second portion of the first vanes lacking an inner platform portion constituting hooks or overhangs and the second portion of the second vanes lacking a flowpath delimiting inner platform portion; the making of each vane comprises: making a one-piece fiber blank by three-dimensional weaving; shaping of the fiber blank to obtain a one-piece vane preform having a first preform portion forming a preform for the first vane portion and a second preform portion forming a preform for the second and third vane portion; and densifying the preform with a matrix to obtain a composite material vane having fiber reinforcement constituted by the preform and densified by the matrix; and the vanes are connected together by a process including a step selected from a brazing step and a step of connection by co-densification by a matrix of a plurality of vanes assembled together at an intermediary stage of densification.

In yet another aspect a turbomachine turbine nozzle segment or compressor stator segment is proposed comprising: a plurality of first and second vanes which are connected together with the first vanes alternating with the second vanes, the first and second vanes being made of composite material including a fiber reinforcement made by three-dimensional weaving and densified by a matrix; each of the first vanes comprising a first portion forming an airfoil and formed integrally with a second portion forming an inner platform and with a third portion forming a flowpath delimiting outer platform portion; each of the second vanes comprising a first portion forming an airfoil and formed integrally with a second portion forming an inner platform and with a third portion forming an outer platform portion constituting hooking legs; and the third portion of the first vanes lacking an outer platform portion constituting hooking legs and the third portion of the second vanes lacking a flowpath delimiting outer platform portion.

In still yet another aspect the invention relates to a turbomachine turbine nozzle segment or compressor stator segment comprising a plurality of first and second vanes which are connected together with the first vanes alternating with the second vanes, the first and second vanes being made of composite material including a fiber reinforcement made by three-dimensional weaving and densified by a matrix; each of the first vanes comprising a first portion forming an airfoil and formed integrally with a second portion forming a flowpath delimiting inner platform portion and with a third portion forming an outer platform; each of the second vanes comprises a first portion forming an airfoil and formed integrally with a second portion forming an inner platform portion constituting hooks or overhangs and with a third portion forming an outer platform; and the second portion of the first vanes lacking an inner platform portion constituting hooks or overhangs and the second portion of the second vanes lacking a flowpath delimiting inner platform portion.

The invention also relates to a turbomachine rotor or disk and a turbomachine equipped with a plurality of blade sets such as those defined in the foregoing.

Brief description of drawings

The invention will be better understood from the description given hereafter, by way of indication but without limitation, with reference to the appended drawings wherein:

- Figure 1 is a perspective view of a turbomachine blade with integrated inner platform and outer platform spoiler;

- Figure 2 is a perspective view of a turbomachine blade with integrated anti-tilting wall and outer platform wiper plate;

- Figure 3 illustrates very schematically the arrangement of two sets of yarn layers in a three-dimensionally woven fiber blank intended for the fabrication of a fiber preform for a blade such as that illustrated by Figure 1;

- Figures 4 and 5 illustrate successive steps of the fabrication of a fiber preform for a blade such as that illustrated by Figure 1, starting with the fiber blank of Figure 3;

- Figures 6 and 7 illustrate successive steps of the fabrication of a fiber preform for a blade such as that illustrated by Figure 2, starting from the fiber blank of Figure 3;

- Figure 8 is a section view showing the flattened profile of a blade airfoil such as that in Figure 1 or 2;

- Figure 9 is a section view of a set of warp yarn layers making it possible to obtain a profile such as that in Figure 8;

- Figures 10A and 10B are warp section views showing one method of weaving of the fiber blank of Figure 1;

- Figure 11A is a partial section view in a plane parallel to the warp and weft directions in a portion of the fiber blank Figure 3 corresponding to the location of junction between the airfoil and the blade inner platform or anti-tilting wall;

- Figure 11B is a partial weft section view in a portion of the fiber blank of Figure 3 corresponding to the location of the junction between the airfoil and the blade inner platform or anti-tilting wall;

- Figure 12A is a partial section view in a plane parallel to the warp and weft directions in a portion of the fiber blank of Figure 3 corresponding to the location of the junction between the airfoil and the blade outer platform spoiler or wiper plate;

- Figure 12B is a partial section view in a portion of the of the fiber blank of Figure 3 corresponding to the location of the junction between the airfoil and the blade outer platform spoiler or wiper plate;

- Figure 13A is a weft section view showing an example of an arrangement of weft yarns in a portion of the fiber blank corresponding to a portion of the airfoil root;

- Figures 13B through 13D are weft section views showing warp planes for a three-dimensional (multilayer) weaving example in the fiber blank portion of Figure 13A;

- Figure 14 is a partial schematic section view showing another embodiment of a blank portion corresponding to an airfoil root;

- Figures 15 and 16 illustrate very schematically two embodiments of a woven fiber strip obtained by three-dimensional weaving including a plurality of fiber blanks like that of Figure 3;

- Figure 17 indicates successive steps of an embodiment of a manufacturing method for a turbomachine blade in conformity with the invention;

- Figure 18 indicates successive steps of another embodiment of a manufacturing method for a turbomachine blade in conformity with the invention; and

- Figure 19 shows the assembly to a turbomachine rotor of a plurality of blades similar to those of Figures 1 and 2.

Detailed description of embodiments

The invention is applicable to different types of turbomachines with integrated inner platforms and/or outer platforms, particularly compressor and turbine blades of different gas turbine bodies, for example a low pressure (BP) turbine rotor blade, like those illustrated Figures 1 and 2.

Figure 1 illustrates a first blade 100 which includes, in well-known manner, an airfoil 120, a root 130 consisting of a portion having greater thickness, for example with a bulb-shaped section, continuing with a tang 132. The airfoil 120 extends in the longitudinal direction between its root 130 and its tip 121 and has a dished profile in transverse section with variable thickness defining two surfaces 122 and 123, corresponding respectively to the upper surface and to the lower surface of the airfoil 120 and each connecting the leading edge 120a and the trailing edge 120b of the last mentioned.

The blade 100 is assembled onto a turbine rotor (not illustrated) by inserting the root 130 into a matching shape recess provided in the periphery of the rotor.

In conformity with one embodiment of the invention, the airfoil 120 also includes a blade inner platform 140 and a blade outer platform spoiler plate 160.

More precisely, at its radially inward end, the airfoil 120 connects to the blade inner platform 140 the outer (or upper) surface 142 whereof defines, radially inside, the flow passage of a gas stream f. In its upstream and downstream end portions (in the direction f of the gas stream flow), the inner platform 140 terminates in covering spoilers 144 and 146. In addition, between its upstream and downstream end portions, the inner platform 140 exhibits a hollowed portion 147 on its edge located on the side of the surface 123 of the airfoil 120, the shape of the hollowed portion 147 being defined so as to cooperate with the surface 222 (upper surface) of the blade 200 described hereafter and with which the blade 100 is designed to cooperate. On its opposite edge, that is the one present on the side 122 of the airfoil 120, the inner platform 140 exhibits a projecting portion 148 the shape whereof is defined so as to cooperate with the surface 223 (lower surface) of the airfoil 200 described hereafter and with which the blade 100 is designed to cooperate.

In the example illustrated, the surface 142 of the inner platform is substantially perpendicular to the longitudinal direction of the blade. Depending on the desired profile of the inner surface of the flow passage of the gas stream, the surface 142 of the inner platform can also be tilted, making a generally nonzero angle relative to the normal to the longitudinal direction of the blade, or the surface 142 could have a generally non-rectilinear profile, dished for example.

The blade 120 also connects at its radially outward end to a blade outer platform spoiler plate 160 which defines on its inner (lower) surface 161, radially outward, the flow passage of the gas stream f. In its upstream and downstream end portions, the blade outer platform spoiler plate 160 ends in covering spoilers 162 and 163.

In addition, between its upstream and downstream end parts, the blade outer platform spoiler plate 160 exhibits a hollowed portion 164 on its edge located on the side of the surface 123 of the airfoil 120, the shape of the hollowed portion 164 being defined so as to cooperate with the surface 222 (upper surface) of the airfoil 200 described hereafter and with which the airfoil 100 is designed to cooperate. On its opposite edge, that is the one present on the side 122 of the airfoil 120, the blade outer platform spoiler plate 160 exhibits a projecting portion 165 the shape whereof is defined so as to cooperate with the surface 223 (lower surface) of the airfoil 200 described hereafter and with which the airfoil 100 is designed to cooperate.

In the example illustrated, the surface 161 of the blade outer platform spoiler plate 160 extends substantially perpendicularly to the longitudinal direction of the blade. As a variant, depending on the desired profile of the outer surface of the flow passage of the gas stream, the surface 161 could be tilted, making a generally nonzero angle relative to the normal to the longitudinal direction of the blade or the surface 161 could have a generally non-rectilinear profile, dished for example.

Further, the airfoil 120 lacks an anti-tilting wall at its radially inward end and blade outer platform wipers at its radially outward end.

Figure 2 illustrates a second blade 200 designed to cooperate with the blade 100 and which includes an airfoil 220, a root 230 constituted by a portion having greater thickness, having for example a bulb-shaped section, continuing in a tang 232. The airfoil 200 extends in a longitudinal direction between its root 230 and its tip 221 and exhibits in cross-section a dished profile with variable thickness defining two surfaces 222 and 223, corresponding respectively to the upper surface and to the lower surface of the airfoil 200 and each connecting the leading edge 220a and the trailing edge 220b of the latter. The blade 200 is mounted onto a turbine rotor (not illustrated) by inserting the root 230 into a recess of matching shape provided in the periphery of the rotor.

In conformity with one embodiment of the invention, at its radial end, the airfoil 220 connects to an anti-tilting wall 250 which comprises at its upstream and downstream ends flanks 251 and 252 capable of preventing tilting of the blade when the latter is mounted on the turbine rotor.

Between its upstream and downstream ends, the anti-tilting wall 250 exhibits a hollowed portion 253 on its edge located on the side of the surface 223 of the airfoil 220, the shape of the hollowed portion 253 being defined so as to cooperate with the surface 122 (upper surface) of the airfoil 100 described previously and with which the blade 200 is designed to cooperate. On its opposite edge, that is the one present on the side 222 of the airfoil 220, the anti-tilting wall 250 exhibits a projecting portion 254 the shape whereof is defined so as to cooperate with the surface 123 (lower surface) of the airfoil 100 described hereafter and with which the blade 200 is designed to cooperate.

In addition, at its radially outward end, the airfoil 220 connects to a blade outer platform wiper plate 270. On its outer (upper) surface 272, the blade outer platform wiper plate 270 defines a depression or bathtub 273. Along the upstream and downstream edges of the bathtub 273, the plate 270 bears wipers 274 and 275 having tooth-shaped profiles, the tips whereof can penetrate into a layer of abradable material of a turbine ring (not shown) to reduce the clearance between the blade tip and the turbine ring.

The central portions of the anti-tilting wall 250 and of the blade outer platform wiper plate 270 extend substantially perpendicularly to the longitudinal direction of the blade. As a variant, depending on the desired profile of the outer surface of the flow passage of the gas stream, the central portions of these elements could be tilted, forming a generally nonzero angle relative to the normal to the longitudinal direction of the blade or could have a generally non-rectilinear profile, dished for instance.

Furthermore, the airfoil 220 lacks an inner platform at its radially inward end and a blade outer platform spoiler plate at its radially outward end, these two elements being assembled onto the airfoil 200 during its assembly to airfoils 100 as explained hereafter.

Thus, with its inner platform 140 and its blade outer platform spoiler plate 160, the blade 100 provides the function of defining the passage while, with its anti-tilting wall 250 and its blade outer platform wiper plate 270, the blade 200 provides the anti-tilting and sealing functions.

Figure 3 shows very schematically a fiber blank 300 starting from which a fiber blade preform can be shaped in order to obtain, after densification by a matrix and possible machining, a blade made of composite material having an integrated inner platform and outer platform spoiler plate like the blade 100 illustrated by Figure 1.

The blank 300 consists of two portions 302, 304 obtained by three-dimensional weaving or multilayer weaving, only the envelopes of these two portions being shown in Figure 3. The portion 302 is designed, after shaping, to constitute a portion of a fiber blade preform corresponding to an airfoil and blade root preform, this portion exhibiting a surface 302a designed to constitute the lower surface of the airfoil and a surface 302b designed to constitute the upper surface of the airfoil. The portion 304 is designed, after shaping, to constitute the portions of a fiber blade preform corresponding to inner platform and blade outer platform spoiler plate preforms.

The two portions 302, 304 are in the form of strips extending generally in a direction X corresponding to the longitudinal direction of the blade to be fabricated. The fiber strip 302 exhibits, in its portion designed to form a blade preform, a variable thickness determined according to the thickness of the airfoil profile of the blade to be fabricated. In its portion designed to constitute a root preform, the fiber strip 302 exhibits an extra thickness 303 determined according to the thickness of the root of the blade to be fabricated.

The fiber strip 302 has a width l selected according to the length of the developed (flattened) profile of the airfoil and of the blade root to be fabricated, while the fiber strip 304 has a width L greater than l selected according to the developed lengths of the inner platform and of the outer platform spoiler plate of the blade to be fabricated (or of the anti-tilting wall and the blade outer platform wiper plate to be fabricated).

The fiber strip 304 has a substantially constant thickness determined according to the thicknesses of the inner platform and of the blade outer platform spoiler plate to be fabricated (or of the anti-tilting wall and the blade outer platform wiper plate). The strip 304 includes a first portion 304a which extends along and in vicinity of a first surface 302a (lower surface) of the strip 302, a second portion 304b which extends along and in the vicinity of the second surface 302b (upper surface) of the strip 302 and a third portion 305a which extends along and in the vicinity of the first face 302a of the strip 302.

The portions 304a and 304b are by a connection portion 304c which extends transversely relative to the strip 302 at a location corresponding to that of the inner platform of the blade to be fabricated. The connection portion 340c runs through the strip substantially perpendicularly to the longitudinal direction of the fiber blank. The portions 304b and 305a are by a connection portion 350c which extends transversely relative to the strip 302 following a wavy profile at a location corresponding to that of the outer platform spoiler plate to be fabricated. Depending on the desired geometry at the outer platform spoiler plate of the blade, the connection portion 340c and/or the connection portion 350c can pass through the strip 302 forming a nonzero angle relative to the normal to the longitudinal direction X of the blank. In addition, the profile of the connection portion 340c and/or that of the connection portion 350c can be curvilinear instead of being rectilinear as in the example illustrated.

As described in greater detail later, the strips 302 and 304 are woven simultaneously by three-dimensional weaving, with no linkage between the strip 302 and the portions 304a, 304b and 305a of the strip 304, and by continuously weaving a plurality of successive blanks 300 in the X direction.

Figures 4 through 6 show very schematically how a fiber preform having a shape near to that of the blade to be fabricated can be obtained starting with the fiber blank 300.

The fiber strip 302 is cut at one end through the extra thickness 303 and at another end slightly beyond the connection portion 350c to have a strip 320 corresponding to the longitudinal dimension of the blade to be fabricated with a swollen portion 330 constituted by a portion of the extra thickness 303 and situated at a location corresponding to the position of the root of the blade to be fabricated. The strip 320 exhibiting a surface 320a designed to constitute the lower surface side of the airfoil and a surface 320b designed to constitute the upper surface side of the airfoil.

In addition, cutouts are made at the ends of the portions 304a, 305a of the strip 304 and in the portion 304b thereof to leave segments 340a and 340b remaining on either side of the connection portion 340c, and segments 350a and 350b on either side of the connection portion 350c, as shown by Figure 4. The lengths of the segments 340a, 340b and 350a, 350b are determined according to the inner platform and outer platform spoiler plate lengths in the blade to be fabricated.

Due to the absence of linkage between the strip 302 of the fiber blank, on the one hand, and the portions 304a, 304b and 305a, on the other, the segments 340a, 340b, 350a and 350b can be folded perpendicularly to the strip 302 without cutting yarns to form plates 340, 360, as shown by Figure 5.

A fiber preform 400 of the blade to be fabricated is then obtained by molding with deformation of the strip 302 to reproduce the dished profile of the blade airfoil and deformation of the plates 340, 360 to reproduce shapes similar to those of the inner platform and of the blade outer platform spoiler plate, as shown by Figure 6. A preform is thus obtained having an airfoil preform portion 420, a root preform portion 430 (with tang preform) and inner platform preform and outer platform preform portions 440, 460.

Figure 7 shows very schematically a fiber preform 500 making it possible to obtain, after densification by a matrix and possibly machining, a blade made of composite material having an integral anti-tilting wall and outer platform wiper plate like the blade 200 illustrated by Figure 2. The preform 500 is obtained by three-dimensional weaving or multilayer weaving in three portions and cutting out these portions in segments as already described earlier in relation to Figures 3 through 5, and by molding with deformation of the strip to reproduce the dished profile of the blade airfoil and deformation of the lower and upper plates to reproduce shapes similar to those of the anti-tilting wall and of the outer platform wiper plate, as shown by Figure 7. A preform 500 is thus obtained with an airfoil preform portion 520, a root preform portion 550 (with tang preform) and anti-tilting wall preform and outer platform wiper plate preform portions 550, 570.

As described later, the steps in fabricating a blade preform starting with a fiber blank are advantageously performed after treatment of the fibers of the blank and its impregnation with a consolidation compound.

A method of three-dimensionally weaving the fiber blank 300 will now be described in greater detail.

It is assumed that the weaving is performed with warp yarns extending in the longitudinal direction X of the blank, it being specified that weaving with weft yarns in this direction is also possible.

The variation of thickness of the strip 302 over its width is obtained by using warp yarns having variable weight. As a variant or additionally, it is possible to vary the count of the warp yarns (number of yarns per unit length in the weft direction), a lower count allowing greater thinning during the shaping of the preform by molding.

Thus, to obtain a blade airfoil profile such as that shown in flattened projection in Figure 8, 3 layers of warp yarns having variable weight and count can be used as illustrated by Figure 9.

In one example of implementation, the yarns used can be silicon carbide (SiC) yarns supplied under the name of "Nicalon" by the Japanese company Nippon Carbon and having a weight (number of filaments) of 0.5K (500 filaments).

The warp is made with 0.5K SiC yarns and 1K SiC yarns obtained by combining two 0.5K yarns, the two yarns being combined by covering. The covering is advantageously performed with a yarn of a temporary nature capable of being eliminated after weaving, for example a yarn made of polyvinyl alcohol (PVA) that can be eliminated by dissolving it in water.

Table I below specifies, for each column of warp yarns, the count (number of yarns/cm in the length of the profile), the number of 0.5K yarns, the number of 1K yarns and the thickness of the profile in mm, this varying here between approximately 1 mm and 2.5 mm:

Table I

Column	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Count	6	6	6	6	6	6	6	8	8	8	8	8	8	8	8	8	8	8	6
No of 0.5K yarns	3	3	3	3	3	3	3	2	1	0	0	0	0	0	0	0	2	1	3
No of 2x0.5K yarns	0	0	0	0	0	0	0	1	2	3	3	3	3	3	3	3	1	2	0
Thickness	1	1	1	1	1	1	1.2	1.5	2	2.2	2.4	2.5	2.4	2.4	2.2	2.1	1.8	1.5	1.2

Naturally, depending on the available yarn weights, different combinations of numbers of yarn layers and of variations of count and of weight could be adopted for the profile to be obtained.

Figures 10A, 10B show, in warp section, two successive planes of a weave that can be used for weaving the fiber blank 300 outside of the extra thickness 303.

The strip 302 of the fiber blank 300 includes a set of layers of warp yarns, the number of layers here being equal to 3 for example (layers C_{11}, C_{12}, C_{13}). The warp yarns are with weft yarns t_1 by three-dimensional weaving.

The strip 304 also includes a set of warp yarn layers also equal to 3 for example (layers C_{21}, C_{22}, C_{23}) with weft yarns t_2 by three-dimensional weaving, like the strip 302.

It is noted that the weft yarns t_1 do not extend into the warp yarn layers of the strip 304 and that the weft yarns t_2 do not extend into the warp yarn layers of the strip 302 in order to ensure that they are not linked together.

In the example illustrated, the weave is a multilayer weave performed with a satin or multi-satin type weave. Other three-dimensional weave types can be used, for example a multilayer weave with a multiple plain weave or weaving with an "interlock" type weave. The term "interlock weave" is used herein to mean a type of weave wherein each layer of weft yarns connects several layers of warp yarns with all the yarns of the same warp column having the same path in the plane of the weave.

Different three-dimensional weaving methods are described in particular in document WO 2006/136755.

Figure 11A is a section view parallel to the warp and weft directions at the crossing of the strip 302 by the connection portion 340c of the strip 304 of the fiber blank of Figure 3, the warp yarns of this connection portion being viewed in section. Each layer of warp yarns extends, in this connection portion 340c, in a direction perpendicular to the weft direction of the strip 302. The passage of the strip 304 from one side to the other of the strip 302 is provided, during weaving, by having each warp yarn of the strip 304 run through all the warp and weft yarns of the strip 302, individually.

Figure 11B is a weft section view at the crossing of the strip 302 by the connection portion 340c of the strip 304 of the fiber blank Figure 3. In the example illustrated, as already stated, the connection portion 340c extends perpendicularly to the warp direction of the strip 302. However it is possible to have a connection portion 350c which extends to as to form a nonzero angle relative to the normal to the warp direction, depending on the desired orientation of the blade outer platform spoiler plate (or of the outer platform wiper plate).

Figure 12A is a section view parallel to the warp and weft directions at the crossing of the strip 302 by the connection portion 350c of the strip 304 of the fiber blank of Figure 3, the warp yarns of this connection portion being viewed in section. Each layer of warp yarns extends, in this connection portion 350c, in a direction perpendicular to the weft direction of the strip 302 following a wavy profile.

Figure 12B is a weft section view at the crossing of the strip 302 by the connection portion 350c of the strip 304. In the example illustrated, as stated previously, the connection portion 350c extends perpendicularly to the warp direction of the strip 302 following a wavy profile. However, as for the connection portion 340c, it is possible to have a connection portion 350c which extends rectilinearly while forming a nonzero angle relative to the normal to the warp direction, depending on the desired orientation of the blade outer platform spoiler plate (or of the outer platform wiper plate).

The extra thickness 303 can be obtained by using weft yarns with greater weight and supplementary layers of weft yarns, as shown for example by Figure 13A.

On Figure 13A, the number of layers of weft yarns changes in this example from 4 to 7 between a portion 302_1 of the strip 302, corresponding to the tang of the blade and the portion 302_3 of the strip 302 exhibiting the extra thickness 303.

In addition, weft yarns t_1, t'_1, t''_1 of different weights are used, the yarns t_1 being for example "Nicalon" SiC yarns with a weight of 0.5K (500 filaments), the yarns t'_1 being obtained by the combination of two 0.5K yarns and the yarns t''_1 by the combination of three 0.5K yarns.

The weave in the blank portion 302_3 necessitates a greater number of warp thread layers than in the portion 302_1. This is advantageously accomplished during the transition between the 302_1 and the portion 302_3 by reducing the number of warp planes by constituting each warp plane in the portion 302_3 by combining warp yarns from two warp planes of the portion 302_1. Figures 13B and 13C show two neighboring warp planes in the portion 302_1 and Figure 13D shows a warp plane obtained in the portion 302_3 by combining the warp planes from Figures 13B and 13C. In Figures 13B, 13C and 13D, the different weights of the warp yarns (as shown in Figure 9) or of the weft yarns (as shown in Figure 13A) are not shown, for the sake of simplicity. Between Figures 13B, 13C, on the one hand, and Figure 13D, on the other hand, the dashes show how the warp yarns of the different layers in Figures 13B, 13C constitute the warp yarn layers of Figure 13D.

Of course, different combinations of numbers of weft layers and of weights of weft threads can be selected to constitute the extra thickness 303.

According to another embodiment shown schematically in Figure 14, the extra thickness 303 can be obtained by introducing an insert during weaving of the strip 302.

In Figure 14, the set T_1 of weft yarn layers of the portion 302_1 of the strip 302 corresponding to the tang of the blade is divided by the absence of linkage during weaving into two subsets T_{11}, T_{12} between which an insert 303_1 is inserted. In the example illustrated, the portion 302_1 has a greater thickness than that of the portion 302_2 of the strip 302 corresponding to the airfoil of the blade. The transition between the portion 302_2 and the portion 302_1 can be fabricated in the same manner as described above for the transition between the portions 302_1 and 302_3 of Figure 13A. The crossing of the strip 302 by the strip 304 at the connection portion 340c of Figure 3 can possibly be accomplished through the portion 302_1 having greater thickness.

At the end of the insert 303 opposite to the portion 302_1, the subsets T_{11}, T_{12} of weft yarn layers are again woven together to constitute a portion $302'_1$ having the same thickness as the portion 302_1, then, by thickness reduction, a portion $302'_2$ having the same thickness as the portion 302_2, the portion $302'_2$ constituting the portion corresponding to a blade airfoil for the following woven blank.

The insert 303_1 is preferably made of monolithic ceramic, preferably the same ceramic material as that of the matrix of the composite material of the blade to be fabricated. Thus, the insert 303_1 can be a block of SiC obtained by sintering SiC powder.

As shown very schematically by Figure 15, a plurality of fiber blanks 600 can be obtained by weaving a strip 300 wherein are formed one or more rows of successive fiber blanks. Some extra-length areas 610, 620 are provided in the warp direction (warp yarns only) and in the weft direction (weft threads only) to avoid edge effects connected with weaving, allow greater freedom to deform during shaping of the preform and provide transition areas between blanks 100.

Figure 16 shows a variant of implementation according to which a strip 700 is fabricated with a row of blanks 300 woven in the weft direction perpendicular to the longitudinal direction of the strip. Extra-length areas 710, 720 are also provided in the warp direction and in the weft direction. Several rows of blanks 300 can be woven, the width of the strip 400 being adjusted for this purpose.

Successive steps of a fabrication method for a blade made of composite material according to one embodiment of the invention are indicated in Figure 17.

At step 501, a fiber strip is woven by three-dimensional weaving that includes a plurality of fiber blanks, for example several rows of fiber blanks oriented in the warp direction, as shown in Figure 15. For turbomachine blades designed for use at high temperature and particularly in a corrosive environment (particularly humidity), yarns made of ceramic fibers are used for weaving, particularly silicon carbide (SiC) fibers.

At step 502, the fiber strip is treated to eliminate oiling present on the fibers and the presence of oxide on the surface of the fibers. The elimination of oxide is obtained by acid treatment, particularly by immersion in a bath of hydrofluoric acid. If the oiling cannot be eliminated by the acid treatment, a prior treatment for eliminating oiling is carried out, for example by decomposition of the oiling by a brief heat treatment.

At step 503, a thin layer of interphase coating is formed on the fibers of the fiber strip by chemical vapor infiltration or CVI. The material of the interphase coating is for example pyrolytic carbon or pyrocarbon (PyC), boron nitride (BN) or boron-doped carbon (BC, with for example 5 atom percent (%at) to 20 %at of B, the remainder being C). The thin layer of interphase coating is preferably of small thickness, for example equal at most to 100 nanometers, even equal at most to 50 nanometers, so as to retain a good ability to deform in the fiber blanks. Preferably, the thickness is at least equal to 10 nanometers.

At step 504, the fiber strip with the fibers coated with a thin layer of interphase coating is impregnated by a consolidation composition, typically a resin possibly diluted in a solvent. A carbon precursor resin can be used, for example a phenolic or furanic resin, or a ceramic precursor resin, for example a polysilazane or polysiloxane precursor of SiC.

After drying by eliminating the solvent, if any, from the resin (step 505), a pre-curing of the resin can be performed (step 506). Pre-curing, or partial crosslinking, makes it possible to increase the stiffness, hence the strength, while maintaining the capacity to deform needed for the fabrication of blade preforms.

At step 507, the fiber blanks are cut out, as illustrated by Figure 4.

At step 508, a fiber blank thus cut out is shaped (as illustrated by Figures 5 through 7) and placed in a mold, made of graphite for example, for conforming of the airfoil and root preform portion and of the inner platform and outer platform preform portions.

Thereafter, the crosslinking of the resin is completed (step 509) and the crosslinked resin is pyrolyzed (step 510). The crosslinking and the pyrolysis can be concatenated by progressive elevation of the temperature in the mold.

After pyrolysis, a fiber preform consolidated by the pyrolysis residue is obtained. The quantity of consolidation resin is selected so that the pyrolysis residue binds the fibers of the preform sufficiently that it can be handled while retaining its shape without the help of tooling, it being specified that the quantity of consolidation resin is preferably selected as small as possible.

Steps consisting of elimination of oiling, of acid treatment and of formation of the interphase coating for a SiC fiber substrate are known. Reference can be made to document US 5 071 679.

A second interphase coating is formed by CVI (step 511) in order to generally obtain a fiber-matrix interphase having sufficient thickness to provide its function of brittleness relief of the composite material. The second interphase layer can be made of a material selected from among PyC, BN, BC, not necessarily the same as that of the first interphase layer. The thickness of the second interphase layer is preferably at least equal to 100 nanometers.

The fabrication of an interphase in two layers, as indicated earlier, is preferred. It is described in the French patent application filed under No. 08 54937 by the applicant.

Densification by a matrix of the consolidated preform is then performed. For a turbomachine blade designed for use at elevated temperature, and particularly in a corrosive environment, the matrix is made of ceramic, for example SiC. The densification can be performed by CVI, in which case the formation of the second interphase layer and the densification by the matrix can be concatenated in the same oven.

Densification can be carried out in two successive steps (steps 512 and 514) separated by a step 513 consisting of machining the blade to the desired dimensions.

It will be noted that pre-machining can be carried out between steps 509 and 510, that is after crosslinking and before pyrolysis of the resin.

Successive steps of a method for manufacturing a blade made of composite material according to another embodiment of the invention are indicated in Figure 17.

Step 601 consisting of three-dimensional weaving of a fiber strip including a plurality of fiber blanks and step 602 consisting of treating to eliminate oiling and oxide are similar to steps 501 and 502 of the fabrication method of Figure 16.

At step 603, individual fiber blanks are cut out of the fiber strip, then each individual fiber blank is shaped in a mold or former (step 604) to obtain a fiber blade preform by forming of the airfoil and root preform and of the inner platform and outer platform preform portions.

At step 605, an interphase brittleness relief coating is formed by CVI on the fibers of the preform held in the former. The coating material is for example PyC, BN or BC as previously mentioned. The thickness of the coating is roughly one to a few hundred nanometers.

The preform still being held in the former, a consolidation of the preform by partial densification is carried out (step 606), the consolidation being performed by formation of a ceramic deposit on the fibers by CVI.

The formation of the interphase coating by CVI and the consolidation by ceramic deposit by CVI can be concatenated in the same CVI oven.

The former is preferably of graphite and exhibits holes facilitating the passage of reactive gas phases giving the interphase deposit and the ceramic deposit by CVI.

When the consolidation is sufficient that the preform can be handled while still maintaining its shape without the assistance of holding tooling, the consolidated preform is extracted from the former and densification by a ceramic matrix is carried out. The densification can be performed in two successive steps (steps 607 and 609) separated by a step 608 consisting of machining the blade to the desired dimensions.

In the foregoing, the fabrication of a variable thickness airfoil profile has been considered, based on the use of yarns with variable weight and/or count. It is possible, as a variant, to fabricate the portion of the fiber blank corresponding to the airfoil preform portion with a certain number of layers of yarns of the same weight and with a constant count, the variation of thickness of profile being accomplished during machining after the first densification step or during a pre-machining of the consolidated blade preform.

Further, depending on the conditions of use contemplated for the blade, the fibers of the fiber reinforcement can be made of a material other than a ceramic, of carbon for example, and the matrix can be of a material other than a ceramic, for example carbon or a resin, the invention of course being also applicable to the manufacture of blades made of organic matrix composite materials.

Figure 19 shows the assembly onto a rotor or turbomachine disk 800 of a plurality of blades 810, 820, 830, 840, 850 and 860, the blades 810, 830 and 850 exhibit a structure similar to the blade 100 of Figure 1 while the blades 820, 840 and 860 exhibit a structure similar to the blade 200 of Figure 2.

The blades 810, 820, 830, 840, 850 and 860 are assembled onto the rotor 800 by insertion of the roots 811, 821, 831, 841, 851 and 861 of each blade respectively into recesses 801, 802, 803, 804, 805 and 806 with a matching shape provided on the periphery of the rotor.

As described previously for the blade 100, the blades 810, 830 each 850 comprise respectively, at the radially inward of their airfoil 816, 836 and 856, an inner platform 812, 832 and 852 (including covering spoilers at its ends) while still lacking an anti-tilting wall that is customarily also present in this area. In addition, the blades 810, 830 and 850 each comprise respectively, at the radially outward end of their airfoil 816, 836 and 856, a blade outer platform spoiler plate 814, 834 and 854 while still lacking wipers that are customarily also present in this area.

Further, as described earlier for the blade 200, the blades 820, 840 and 860 each comprise respectively, at the radially inward end of their airfoil 826, 846 and 866, an anti-tilting wall 823, 843 and 863 while still lacking an inner platform that is customarily also present in this area. In addition, the blades 820, 840 and 860 each respectively comprise, at the radially outward end of their airfoil 826, 846 and 866, a blade outer platform wiper plate 825, 845 and 865 while still lacking spoilers that are customarily also present in this area.

As shown in Figure 19, the blades nest with one another, the blades 820, 840 and 860 accommodating above their anti-tilting wall 823, 843 and 863 the inner platforms 812, 832 and 852 of the blades 810, 830 and 850. More precisely, each radially inward end of the blade airfoils of the same type as the blade 100 already described, for example the blade 820, is surrounded on the lower surface side of the airfoil, here the airfoil 826, by the hollowed portion 812a of the inner platform 812 of the blade 810, and on the upper surface side by the projecting portion 832b of the inner platform 832 of the blade 830. Thus it is possible to accommodate the radially inward end of an airfoil of a blade of the same type as the blade 200 already described between the inner platforms of two blades of the same type as the blade 100 already described and arranged on either side of the blade of the same type as the blade 200. The other portions of the edges of an inner platform situated on either side of the hollowed portion and of the projecting portion are in contact with the corresponding portions of the inner platforms of the adjacent blades so as to constitute a substantially continuous surface making it possible to define radially inward the flow passage of the gas stream.

Likewise, each radially outward end of the airfoils of blades of the same type as the blade 100 already described, for example the blade 820, is surrounded on the lower surface side of the airfoil, here the airfoil 826, by the hollowed portion 814a of the spoiler plate 814 of the blade 810 and on the upper surface side by the projecting portion 834b of the spoiler plate 834 of the blade 830. Thus, it is possible to accommodate the radially outward end of an airfoil of a blade of the same type as the blade 200 already described between the spoiler plates of two blades of the same type as the blade 100 already described and arranged on either side of the blade of the same type as the blade 200. The other portions of the edges of the blade outer platform spoiler plates located on either side of the hollowed portion and of the projecting portion are in contact with the corresponding parts of the spoiler plates of the adjacent blades so as to constitute a substantially continuous surface making it possible to define radially outward the flow passage of the gas stream. In other words, the passage definition function is provided by the combination of the inner platforms 812, 832 and 852 and of the outer platform spoiler plates 814, 834 and 854.

The combination of the blade outer platform wiper plates 825, 845 and 865 constitutes a continuous wall of wipers above the blade outer platform spoiler plates, thus providing a sealing function.

In the example considered here, the edges of adjacent anti-tilting walls do not meet. However, the edges of these walls can be extended and exhibit complementary shapes so as to form a continuous wall under the inner platforms.

The distance D1 between the inner platforms 812, 832 and 852 and the spoiler plates 814, 834 and 854 of the blades 810, 830 and 850 is less than the distance D2 between the anti-tilting walls 823, 843 and 863 and the blade outer platform wiper plates 825, 845 and 865 of the blades 820, 840 and 860 in order to allow their nesting with one another.

A set of blades according to the invention can consist of a first blade and a second blade, respectively of the same type as the blade 100 and of the blade 200 described previously.

The blade 100 described previously in relation to Figure 2 includes an inner platform 140 and a blade outer platform spoiler plate 160 while still lacking an anti-tilting wall and blade outer platform spoilers while the blade 200 includes an anti-tilting wall 150 and a blade outer platform wiper plate 170 while still lacking an inner platform and blade outer platform spoilers.

According to variants of implementation, a first blade of the blade set according to the invention can includes an inner platform and a blade outer platform spoiler plate and be lacking an anti-tilting wall and a blade outer platform spoiler plate while the second blade of the blade set can include an anti-tilting wall and a blade outer platform spoiler plate and be lacking an inner platform and a blade outer platform wiper plate.

The invention claimed is:

1. A method for fabricating a turbomachine set of blades made of composite material including a fiber reinforcement densified by a matrix,

the method comprising:

fabrication by three-dimensional weaving of a first one-piece fiber blank;

shaping of the first fiber blank to obtain a first one-piece fiber blade preform having:

a first portion constituting a preform of an airfoil and a blade root;

a second portion constituting a preform of a blade inner platform, said blade preform then lacking a blade anti-tilting wall preform, or constituting of a blade; and

a third portion constituting a preform of a blade outer platform spoiler plate, said blade preform then lacking a blade outer platform wiper plate preform; and

fabrication by three-dimensional weaving of a second one-piece fiber blank;

shaping of the second fiber blank to obtain a second one-piece fiber blade preform having:

a first portion constituting a preform of an airfoil and a blade root;

a second portion constituting a preform of a blade anti-tilting wall, said blade preform then lacking a blade inner platform preform; and

a third portion constituting a preform of a blade outer platform wiper plate, said blade preform then lacking a blade outer platform spoiler plate preform; and

densification of the first and second preforms by a matrix to obtain first and second blades made of composite material having a fiber reinforcement consisting of the preform and densified by the matrix, said first blade constituting a single part with a blade inner platform and blade outer platform spoilers, and a second blade constituting a single part with a blade anti-tilting wall and blade outer platform wipers;

or the method comprising:

fabrication by three-dimensional weaving of a first one-piece fiber blank;

shaping of the first fiber blank to obtain a first one-piece fiber blade preform having:

a first portion constituting a preform of an airfoil and a blade root;

a second portion constituting a blade anti-tilting wall preform, said blade preform then lacking blade inner platform preform; and

a third portion constituting a preform of a blade outer platform spoiler plate, said blade preform then lacking a blade outer platform wiper plate preform; and

fabrication by three-dimensional weaving of a second one-piece fiber blank;

shaping of the second fiber blank to obtain a second one-piece fiber blade preform having:

a first portion constituting a preform of an airfoil and a blade root;

a second portion constituting a preform of a blade inner platform preform, said blade preform then lacking a blade anti-tilting wall; and

a third portion constituting a preform of a blade outer platform wiper plate, said blade preform then lacking a blade outer platform spoiler plate preform; and

densification of the first and second preforms by a matrix to obtain first and second blades made of composite material having a fiber reinforcement consisting of the preform and densified by the matrix, said first blade constituting a single part with a blade anti-tilting wall and blade outer platform spoilers, and said second blade constituting a single part with a blade inner platform and blade outer platform wipers.

2. A method according to claim 1, wherein, in the longitudinal

direction of the fiber blank corresponding to the longitudinal direction of the blade to be fabricated, the fiber blank includes a first set of several layers of yarns which are interlinked to constitute a first portion of the blank corresponding to the airfoil and the blade root preform, and a second set of several layers of yarns which are interlinked at least locally to constitute a second portion of the blank corresponding to an inner platform or blade anti-tilting wall preform and a third portion of the blank corresponding to a spoiler or blade root wiper plate preform, the yarns of the first set of yarn layers being not linked to the yarns of the second set of yarn layers, and the first set of yarn layers has yarns of the second set of yarn layers passing through it at the second and at the third portion of the blank.

3. A method according to claim 2, wherein the fiber blank is woven with a second continuous set of yarn layers and the shaping of the fiber blank includes the elimination by cutting out of portions of the second set of yarn layers outside of the second portion of the fiber blank and of the third portion of the fiber blank.

4. A method according to claim 2, wherein, at the location or at least at one of the locations where the first set of yarn layers has yarns of the second set of yarn layers passing through it, the intersection between a yarn layer of the first set and a yarn layer of the second set follows a line that is not orthogonal to the longitudinal direction of the fiber blank.

5. A method according to claim 1, wherein, in the first portion of the fiber blank and in a direction corresponding to that extending along the profile of an airfoil of variable thickness in the blade to be fabricated, the number of yarn layers in the first set of yarn layers is constant.

6. A method according to claim 5, wherein the yarns of the

first set of yarn layers are of variable weight.

7. A method according to claim 5, wherein the count of the yarns of the first set of yarn layers is variable.

8. A method according to claim 1, wherein a strip including a succession of fiber blanks is fabricated by three-dimensional weaving.

9. A method according to claim 1, wherein the blanks are woven with their longitudinal direction corresponding to that of the blades to be fabricated extending in the weft direction.

10. A method according to claim 1, wherein the blanks are woven with their longitudinal direction corresponding to that of the blades to be fabricated extending in the warp direction.

11. A set of first and second turbomachine blades made of composite material including a fiber reinforcement obtained by three-dimensional weaving and densified by a matrix,

the first blade including:

a first portion constituting an airfoil and a blade root;

a second portion constituting a blade inner platform, said blade then lacking a blade anti-tilting wall; and

a third portion constituting a blade outer platform spoiler plate, said blade then lacking a blade outer platform wiper plate; and

the second blade including:

a first portion constituting an airfoil and a blade root; a second portion constituting a blade anti-tilting wall, said blade then lacking a blade inner platform; and

a third portion constituting a blade outer platform wiper plate, the blade then lacking a blade outer platform spoiler plate;

or the first blade including:

a first portion constituting an airfoil and a blade root;

a second portion constituting a blade anti-tilting wall preform, said blade preform then lacking blade inner platform preform; and

a third portion constituting a preform of a blade outer platform spoiler plate, said blade preform then lacking a blade outer platform wiper plate preform; and

the second blade including:

a first portion constituting a preform of an airfoil and a blade root;

a second portion constituting a preform of a blade inner platform preform, said blade preform then lacking a blade anti-tilting wall; and

a third portion constituting a preform of a blade outer platform wiper plate, said blade preform then lacking a blade outer platform spoiler plate preform.

12. A turbomachine disk having a plurality of sets of blades according to claim 11.

13. A turbomachine equipped with a plurality of sets of blade according to claim 11.

14. A method for making at least a segment of a turbomachine wheel, the method comprising:

assembling together a plurality of first blades or vanes and a plurality of second blades or vanes in alternation with the first blades or vanes, the first and second blades or vanes being made of composite material including a fiber reinforcement made by three-dimensional weaving and densified by a matrix;

each of the first blades or vanes comprising a first portion forming at least an airfoil and formed integrally with:

a second portion selected from a flowpath delimiting inner platform portion and an inner portion of an inner platform; and a third portion selected from a flowpath delimiting outer platform portion and an outer portion of an outer platform;

each of the second blades or vanes comprising a first portion forming at least an airfoil and formed integrally with:

a second portion selected from a flowpath delimiting inner platform portion and an inner portion of an inner platform, the second portion of a second blade or vane being different from the second portion of a first blade or vane; and

a third portion selected from a flowpath delimiting outer platform portion and an outer portion of an outer platform, the third portion of a second blade or vane being different from the third portion of a first blade or vane.

15. A method according to claim 14, wherein the making of each blade or vane comprises:

the fabrication by three-dimensional weaving of a one-piece fiber blank, the shaping of the fiber blank to obtain a one-piece fiber blade or vane preform having:

a first portion constituting a preform of the first blade or vane portion;

a second portion constituting a preform of the second blade or vane portion; and

a third portion constituting a preform of the third blade or vane portion; and

the densification of the preform by a matrix to obtain a blade or vane made of composite material having a fiber reinforcement consisting of the preform and densified by the matrix; and incorporating in a single part said first, second and third blade or vane portions.

16. A method according to claim 15, wherein, in the longitudinal direction of the fiber blank corresponding to the longitudinal direction of the blade or vane to be fabricated, the fiber blank includes:

a first set of several layers of yarns which are linked together at least partially to constitute a first portion of the blank corresponding to the first preform portion; and

a second set of several layers of yarns which are linked together at least locally to constitute a second and a third portion of the blank corresponding to the second and the third preform portion;

the yarns of the first set of yarn layers being not linked to the yarns of the second set of yarn layers; and

the first set of yarn layers has yarns of the second set of yarn layers passing through it at the second and at the third portion of the blank.

17. A method according to claim 14 for making a turbomachine rotating wheel by assembling first and second blades together with a rotor disk, wherein the first portion of each first and second blade forms an airfoil and a blade root, and the blade roots are inserted into recesses provided at the periphery of the rotor disk, the second portion of a first or second blade being selected from a flowpath delimiting inner platform portion and an inner anti-tilting wall of an inner platform, and the third portion of a first or second blade being selected from a flowpath delimiting outer platform portion and an outer wiper plate of an outer platform.

18. A method for fabricating a turbomachine turbine nozzle segment or compressor stator segment out of a composite material, the method comprising:

assembling and connecting together a plurality of first vanes and a plurality of second vanes in alternation with the first vanes, the first and second vanes being made of composite material including a fiber reinforcement made by three-dimensional weaving and densified by a matrix, wherein:

each of the first vanes comprises a first portion forming an airfoil and formed integrally with a second portion forming an inner platform and with a third portion forming a flowpath delimiting outer platform portion;

each of the second vanes comprises a first portion forming an airfoil and formed integrally with a second portion forming an inner platform and with a third portion forming an outer platform portion constituting hooking legs; and

the third portion of the first vanes lacking an outer platform portion constituting hooking legs and the third portion of the second vanes lacking a flowpath delimiting outer platform portion;

the making of each vane comprises:

making a one-piece fiber blank by three-dimensional weaving;

shaping of the fiber blank to obtain a one-piece vane preform having a first preform portion forming a preform for the first vane portion and a second preform portion forming a preform for the second and third vane portion; and

densifying the preform with a matrix to obtain a composite material vane having fiber reinforcement constituted by the preform and densified by the matrix;

the vanes are connected together by a process including a step selected from a brazing step and a step of connection by co-densification by a matrix of a plurality of vanes assembled together at an intermediary stage of densification; and

the making of each vane comprises a step of partial densification of the vane preform by a matrix and a subsequent machining step; and

the connection of a plurality of vanes together comprises assembling machined vanes together and co-densification by a matrix of the assembled machined vanes.

19. A method according to claim 18 for fabricating a turbine nozzle segment or compressor stator segment out of a ceramic matrix composite material, wherein the assembling of the machined vanes together comprises a pre-ceramic bonding step.

20. A method according to claim 18 for fabricating a turbine nozzle segment or compressor stator segment out of a ceramic matrix composite material, wherein the making of each vane comprises a first and a second step of densification by a ceramic matrix separated by a machining step, and the connection of a plurality of vanes together comprises a step of brazing together vanes assembled together after the second densification step.

21. A method according to claim 18, wherein, in the longitudinal direction of the fiber blank that corresponds to the longitudinal direction of a vane that is to be made, the fiber blank comprises a first set of a plurality of layers of yarns that are linked together at least partially together to form a first portion of the blank that corresponds to the first portion of the preform, and a second set of a plurality of layers of yarns that are linked together at least locally to form a second portion of the blank that corresponds to the second portion of the preform and to form a third portion of the blank that corresponds to the third portion of the preform, the yarns of the first set of layers of yarns being not linked to the yarns of the second set of layers of yarns, and yarns of the second set of layers of yarns crossing through the first set of layers of yarns at first and second crossing locations corresponding to the locations of the second and third portions of the blank, respectively.

22. A method for fabricating a turbomachine turbine nozzle segment or compressor stator segment out of a composite material, the method comprising:

assembling and connecting together a plurality of first vanes and a plurality of second vanes in alternation with the first vanes, the first and second vanes being made of composite material including a fiber reinforcement made by three-dimensional weaving and densified by a matrix, wherein:

each of the first vanes comprises a first portion forming an airfoil and formed integrally with a second portion forming a flowpath delimiting inner platform portion and with a third portion forming an outer platform;

each of the second vanes comprises a first portion forming an airfoil and formed integrally with a second portion forming an inner platform portion constituting hooks or overhangs and with a third portion forming an outer platform;

the second portion of the first vanes lacking an inner platform portion constituting hooks or overhangs and the second portion of the second vanes lacking a flowpath delimiting inner platform portion;

the making of each vane comprises:

making a one-piece fiber blank by three-dimensional weaving;

shaping of the fiber blank to obtain a one-piece vane preform having a first preform portion forming a preform for the first vane portion and a second preform portion forming a preform for the second and third vane portion; and

densifying the preform with a matrix to obtain a composite material vane having fiber reinforcement constituted by the preform and densified by the matrix; and

the vanes are connected together by a process including a step selected from a brazing step and a step of connection by co-densification by a matrix of a plurality of vanes assembled together at an intermediary stage of densification.

23. A method according to claim 22, wherein the making of each vane comprises a step of partial densification of the vane preform by a matrix and a subsequent machining step, and the connection of a plurality of vanes together comprises assembling machined vanes together and co-densification by a matrix of the assembled machined vanes.

24. A method according to claim 23 for fabricating a turbine nozzle segment or compressor stator segment out of a ceramic matrix composite material, wherein the assembling of the machined vanes together comprises a pre-ceramic bonding step.

25. A method according to claim 22 for fabricating a turbine nozzle segment or compressor stator segment out of a ceramic matrix composite material, wherein the making of each vane comprises a first and a second step of densification by a ceramic matrix separated by a machining step, and the connection of a plurality of vanes together comprises a step of brazing together vanes assembled together after the second densification step.

26. A method according to claim 22, wherein, in the longitudinal direction of the fiber blank that corresponds to the longitudinal direction of a vane that is to be made, the fiber blank comprises a first set of a plurality of layers of yarns that are linked together at least partially together to form a first portion of the blank that corresponds to the first portion of the preform, and a second set of a plurality of layers of yarns that are linked together at least locally to form a second portion of the blank that corresponds to the second portion of the preform and to form a third portion of the blank that corresponds to the third portion of the preform, the yarns of the first set of layers of yarns being not linked to the yarns of the second set of layers of yarns, and yarns of the second set of layers of yarns crossing through the first set of layers of yarns at first and second crossing locations corresponding to the locations of the second and third portions of the blank, respectively.

27. A turbomachine turbine nozzle segment or compressor stator segment comprising:

a plurality of first and second vanes which are connected together with the first vanes alternating with the second vanes, the first and second vanes being made of composite material including a fiber reinforcement made by three-dimensional weaving and densified by a matrix;

each of the first vanes comprising a first portion forming an airfoil and formed integrally with a second portion forming an inner platform and with a third portion forming a flowpath delimiting outer platform portion;

each of the second vanes comprising a first portion forming an airfoil and formed integrally with a second portion forming an inner platform and with a third portion forming an outer platform portion constituting hooking legs; and

the third portion of the first vanes lacking an outer platform portion constituting hooking legs and the third portion of the second vanes lacking a flowpath delimiting outer platform portion.

28. A turbomachine turbine nozzle segment or compressor stator segment comprising a plurality of first and second vanes which are connected together with the first vanes alternating with the second vanes, the first and second vanes being made of composite material including a fiber reinforcement made by three-dimensional weaving and densified by a matrix;

each of the first vanes comprising a first portion forming an airfoil and formed integrally with a second portion forming a flowpath delimiting inner platform portion and with a third portion forming an outer platform;

each of the second vanes comprises a first portion forming an airfoil and formed integrally with a second portion forming an inner platform portion constituting hooks or overhangs and with a third portion forming an outer platform; and

the second portion of the first vanes lacking an inner platform portion constituting hooks or overhangs and the second portion of the second vanes lacking a flowpath delimiting inner platform portion.

29. A turbine nozzle or compressor stator comprising a casing and a plurality of segments according to claim 27 mounted in the casing by means of said hooking legs.

30. A turbine nozzle or compressor stator comprising a plurality

of segments according to claim 28 supporting an abradable material carrying ring by means of said hooks.

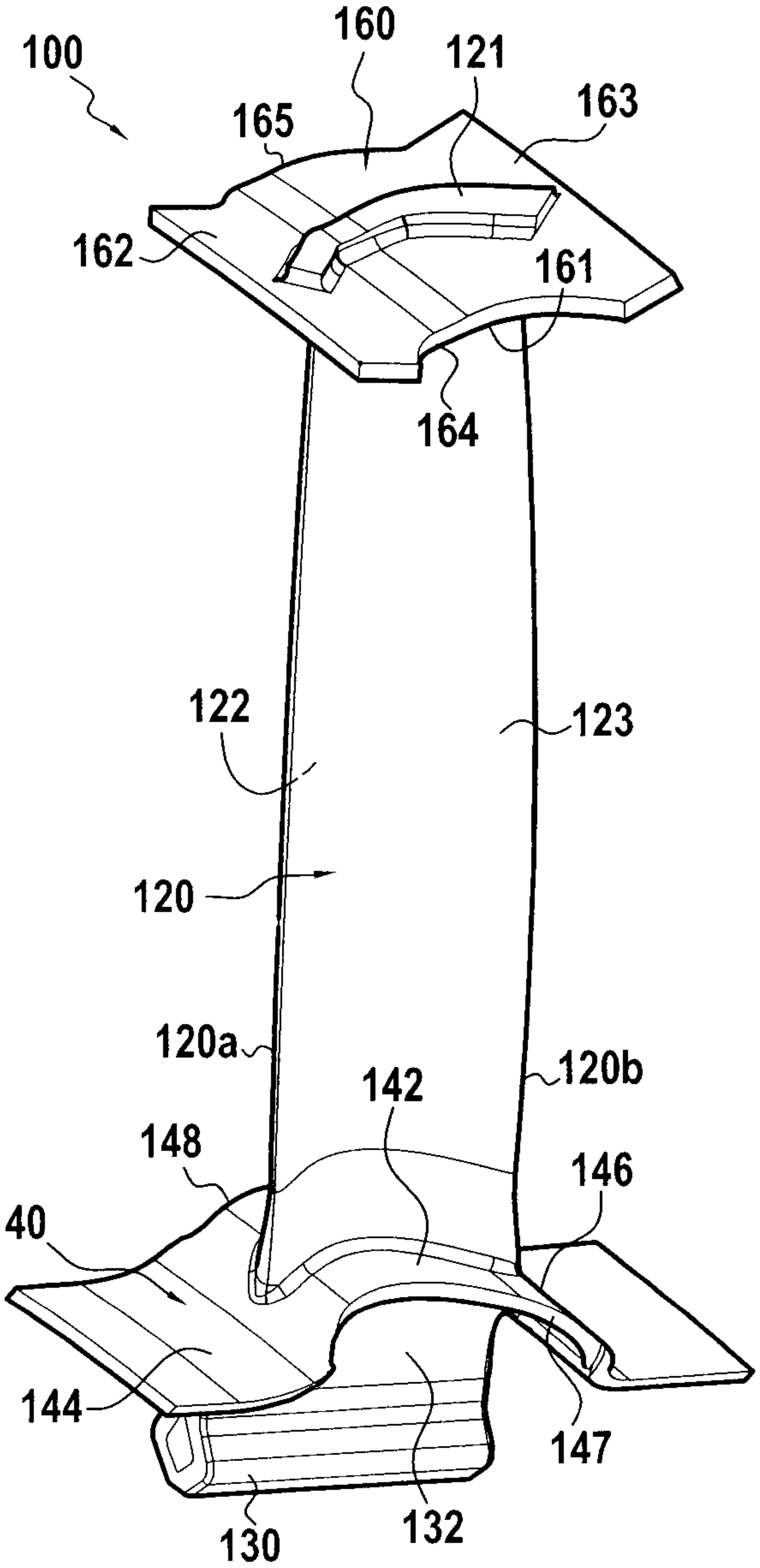

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FIG.1

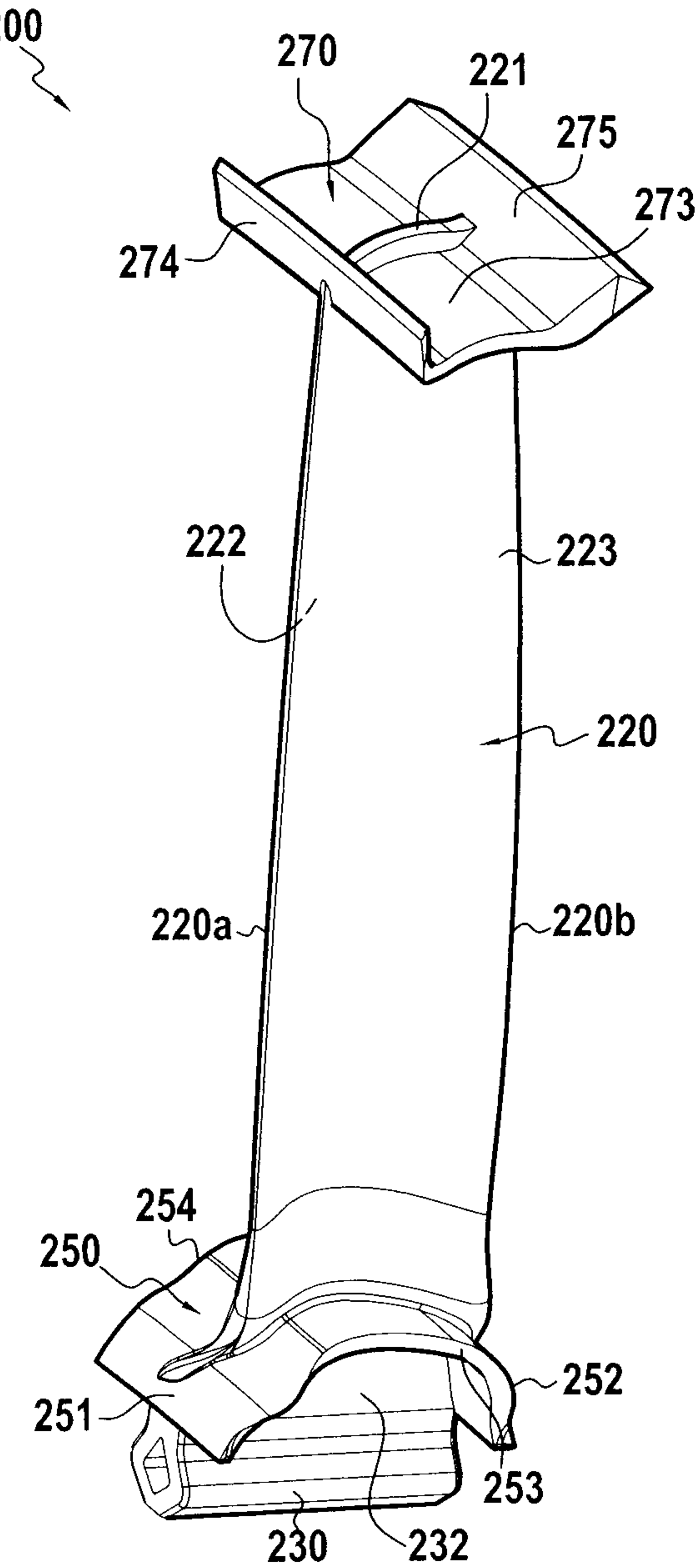
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FIG.2

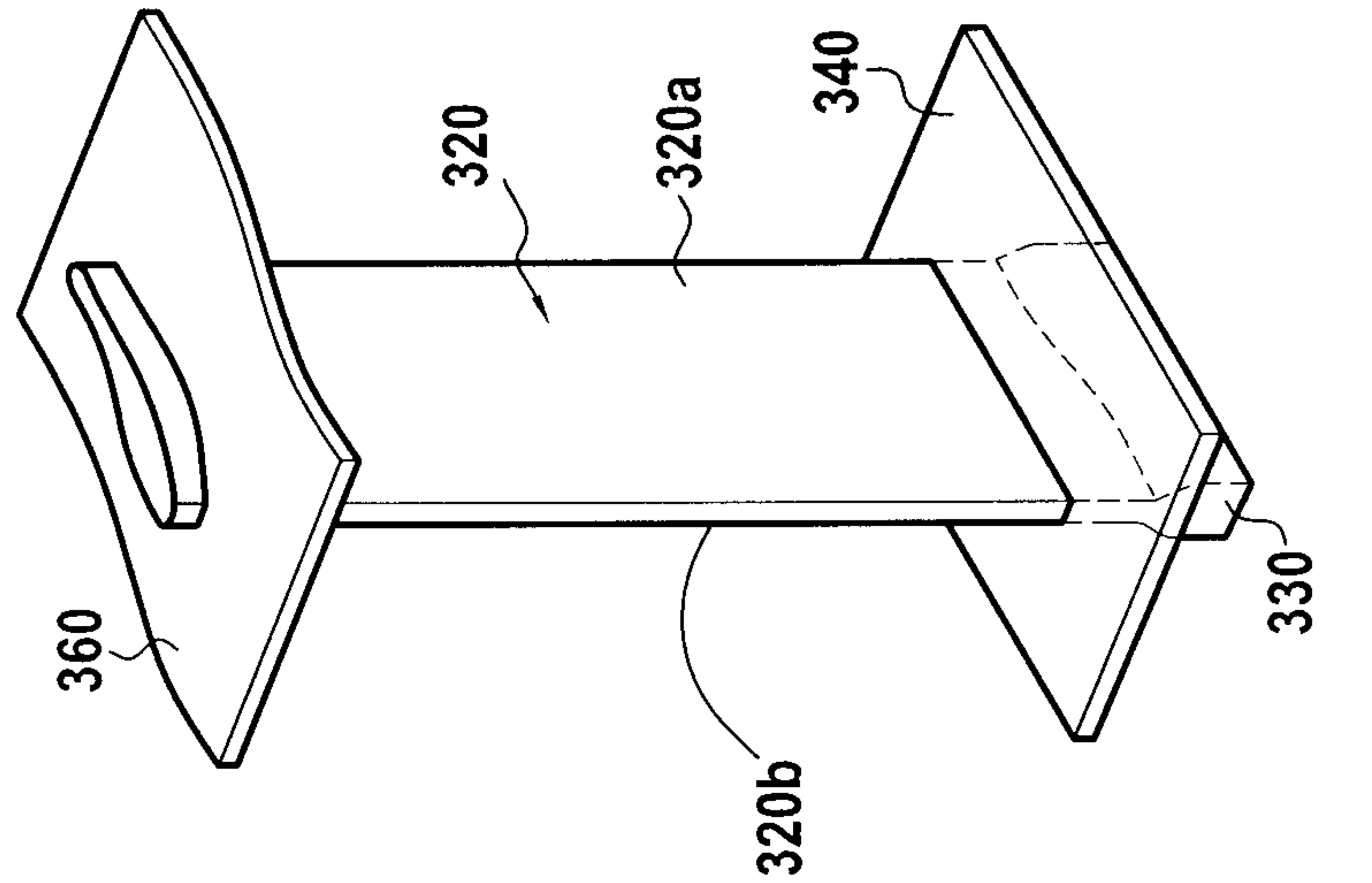


FIG.5

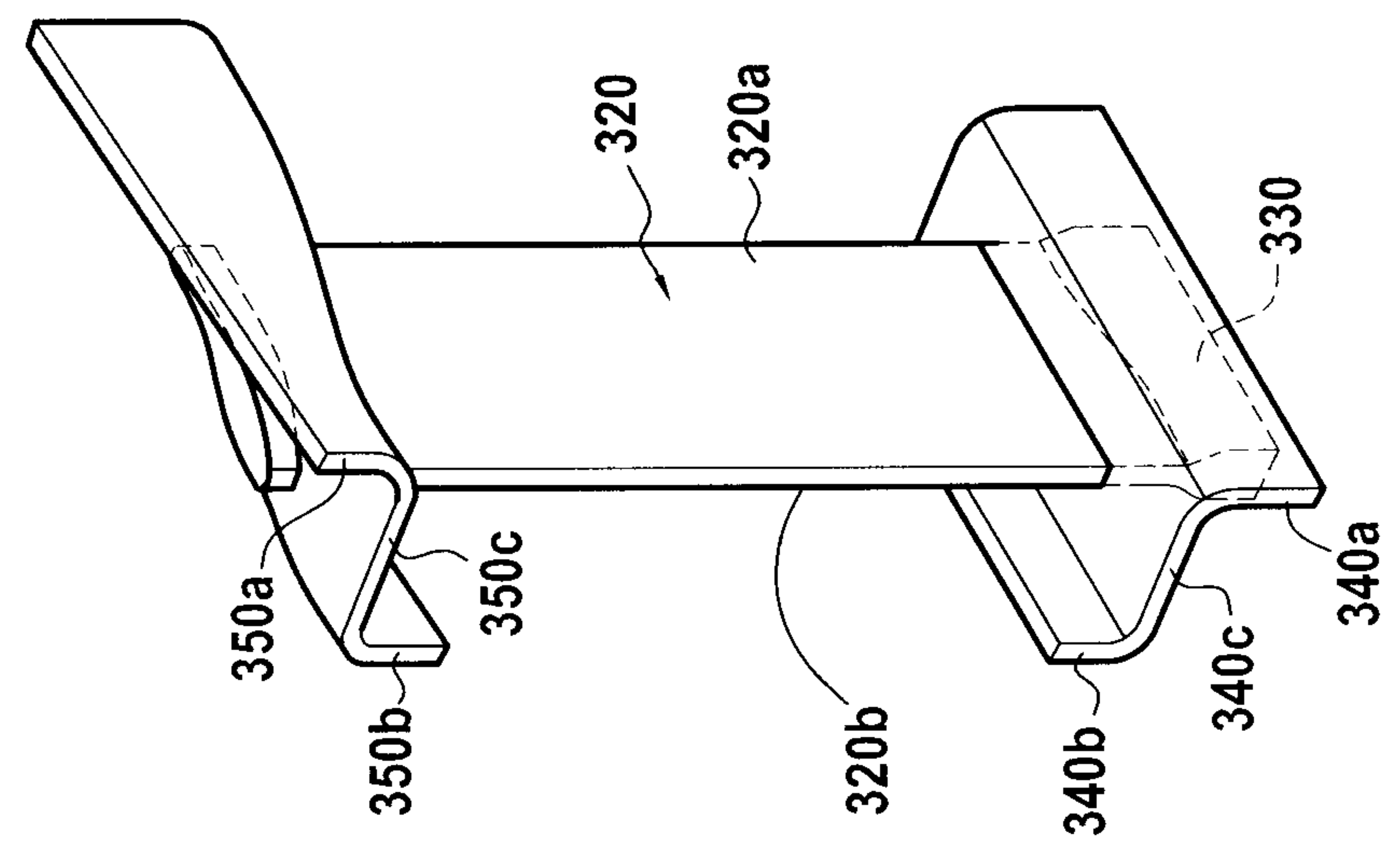


FIG.4

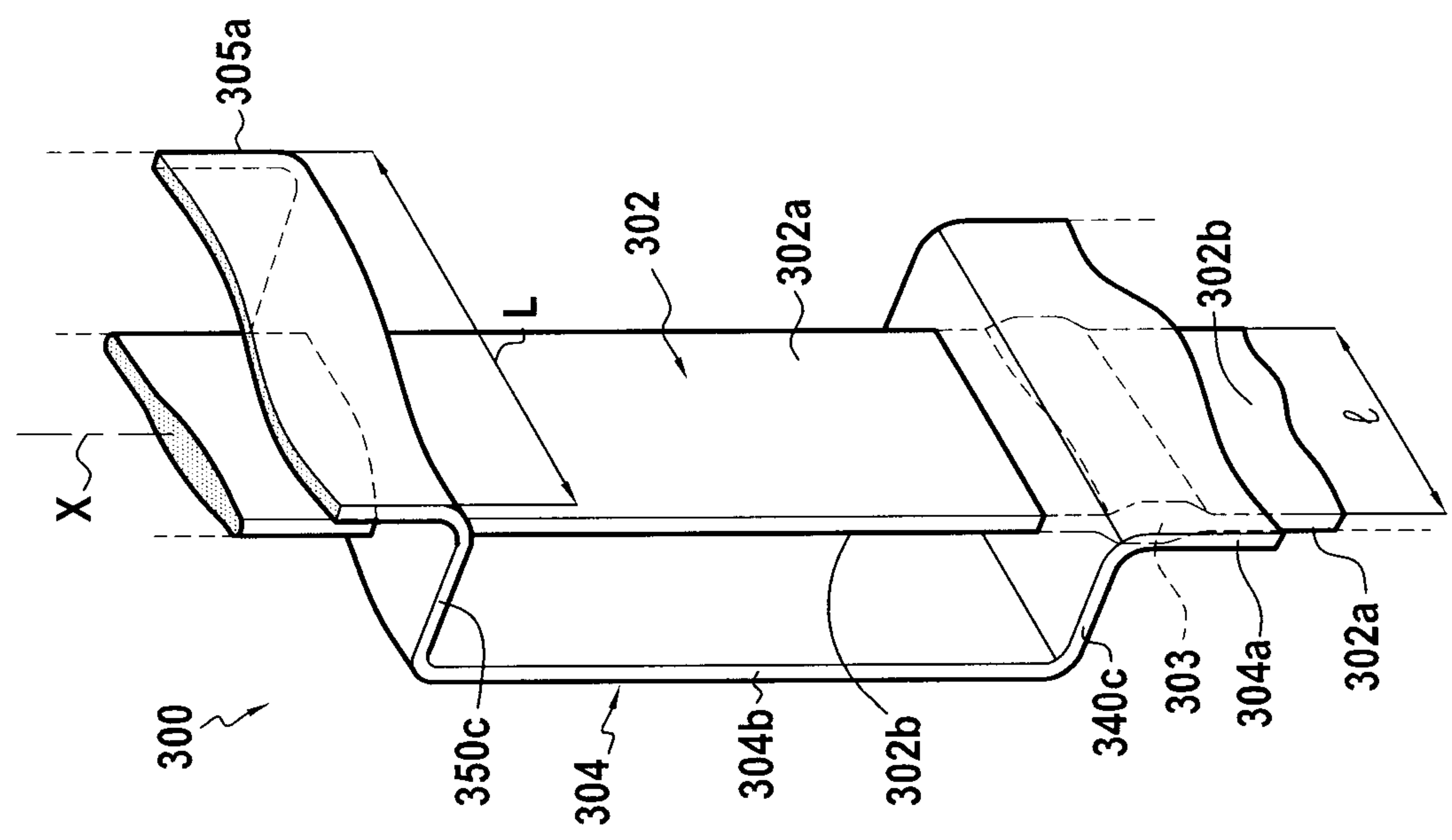


FIG.3

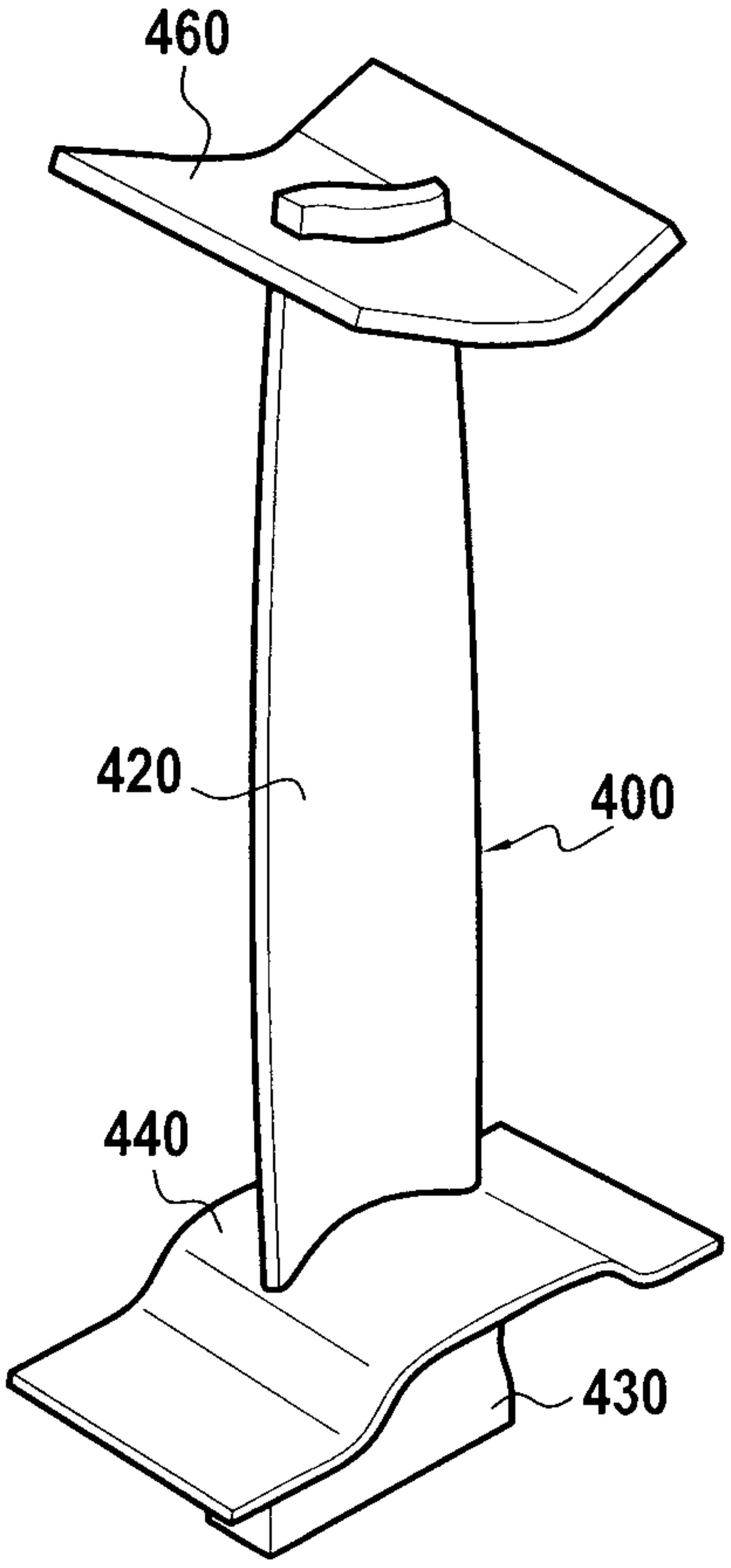


FIG.6

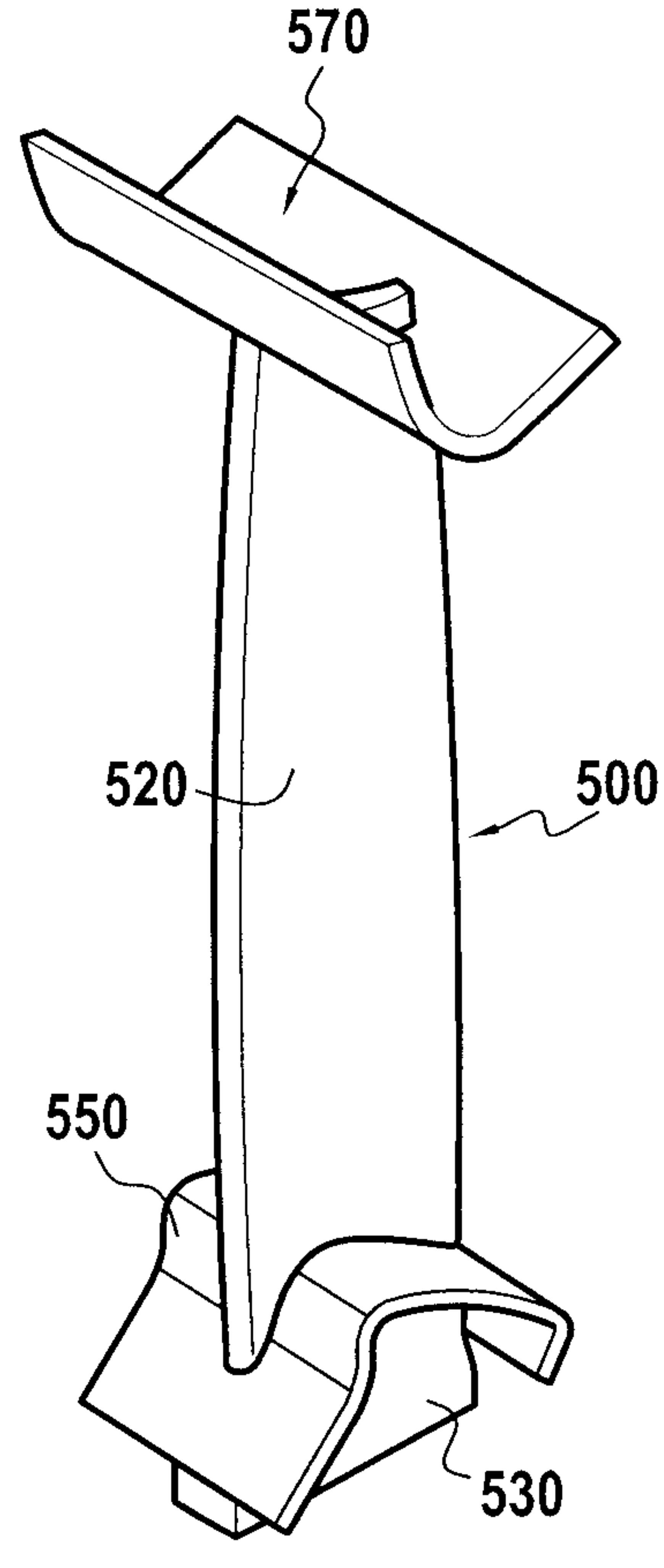


FIG.7

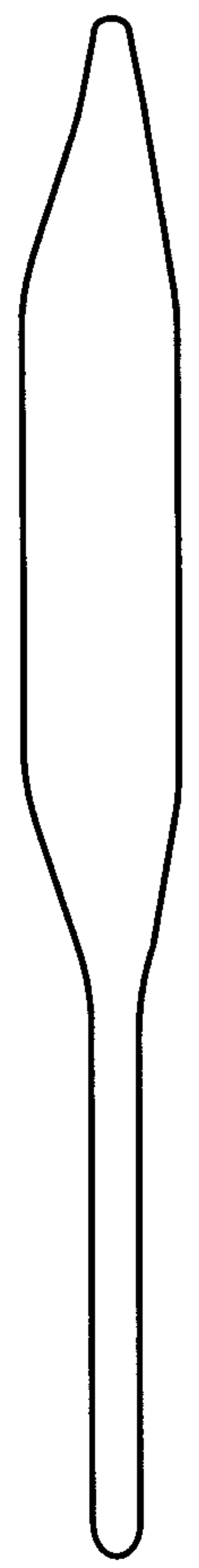


FIG.8

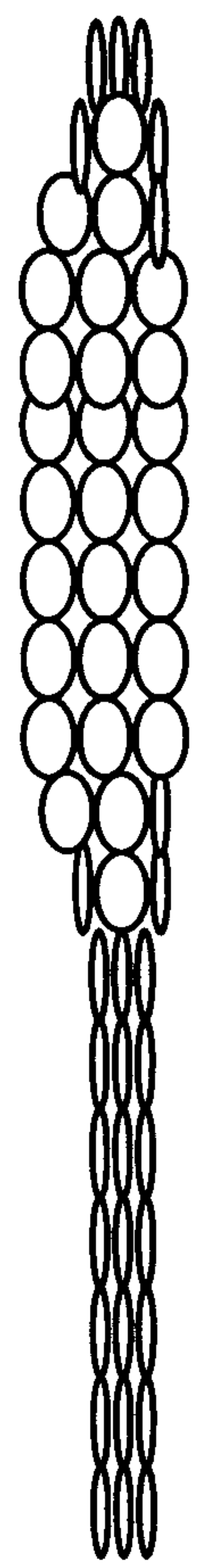


FIG.9

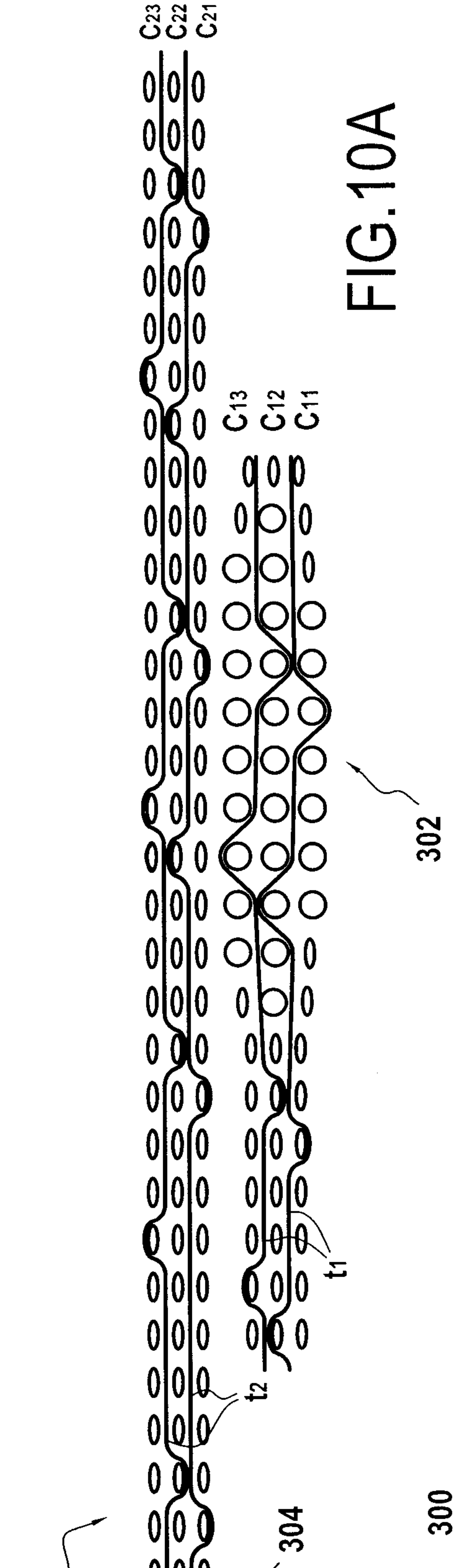


FIG.10A

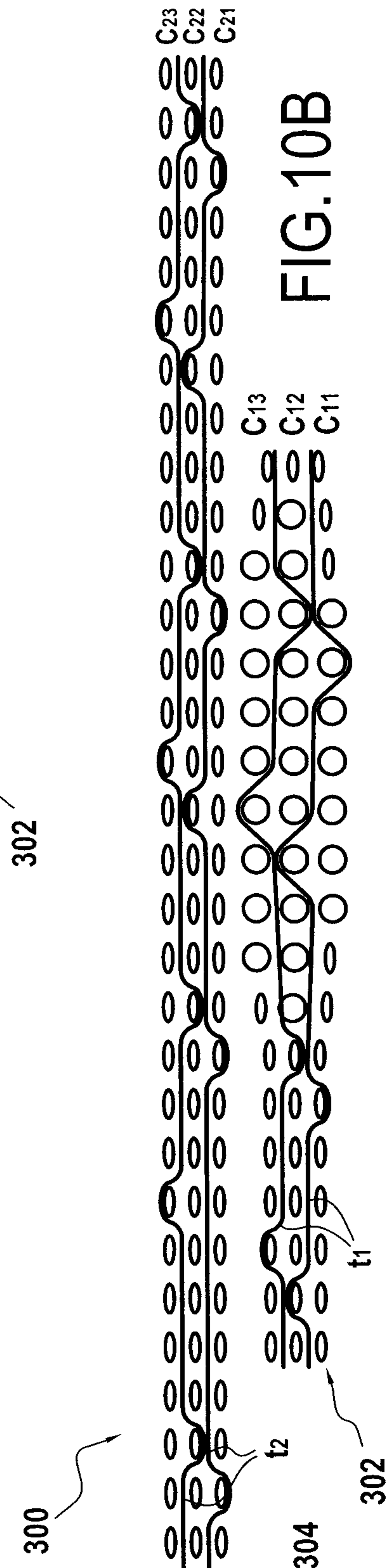


FIG.10B

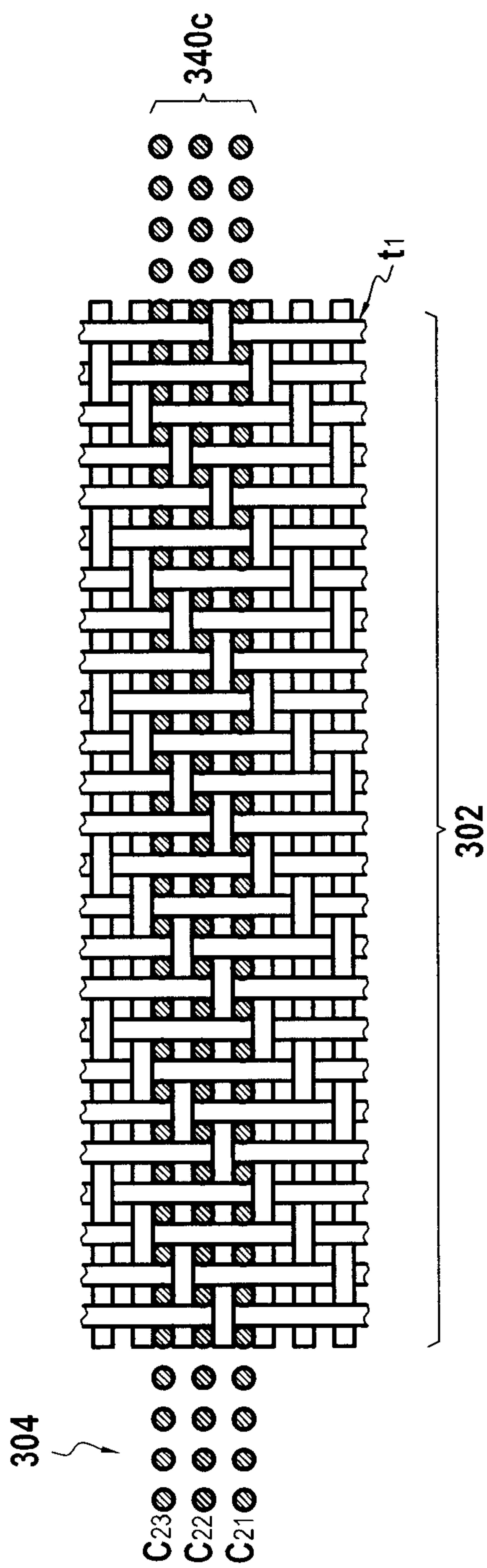


FIG.11A

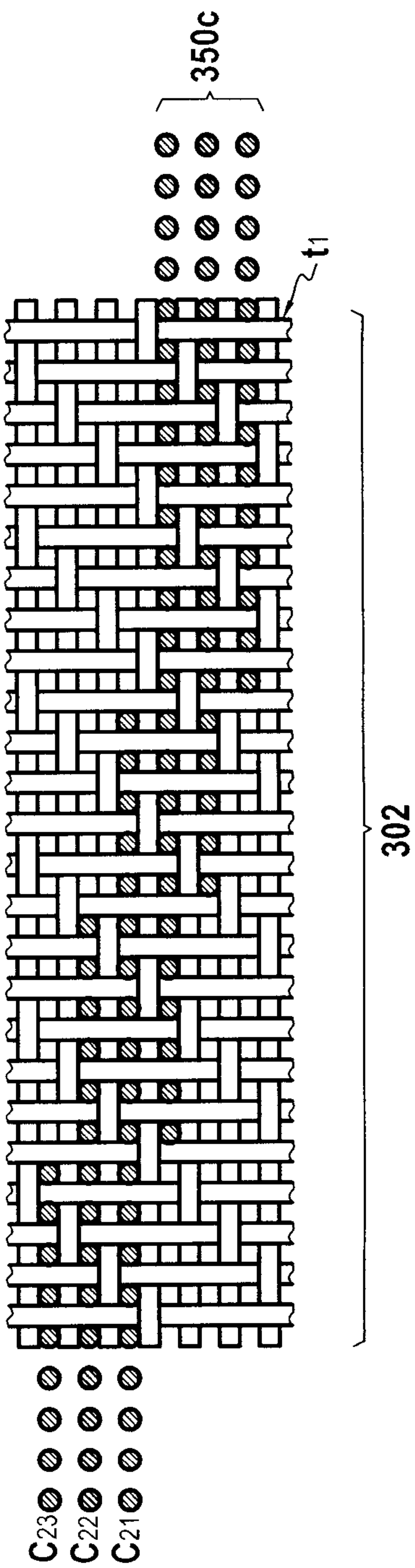


FIG.12A

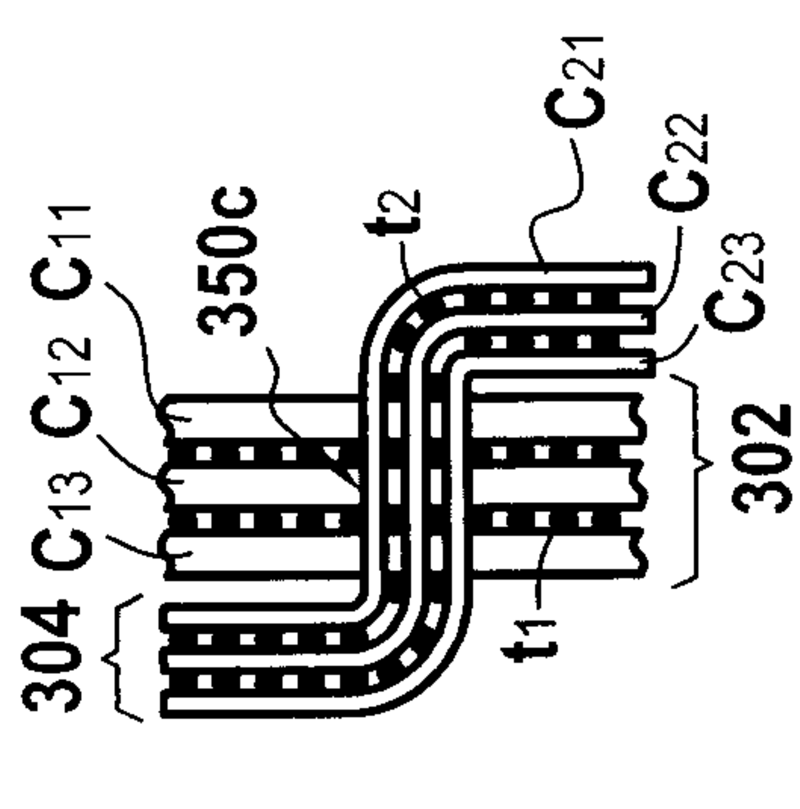


FIG.11B

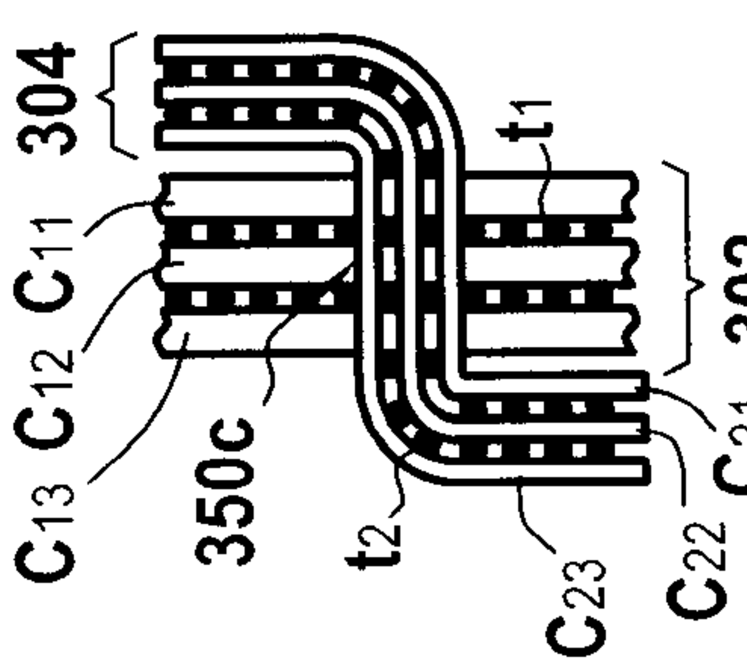


FIG.12B

FIG.13A

FIG.13B

FIG.13C

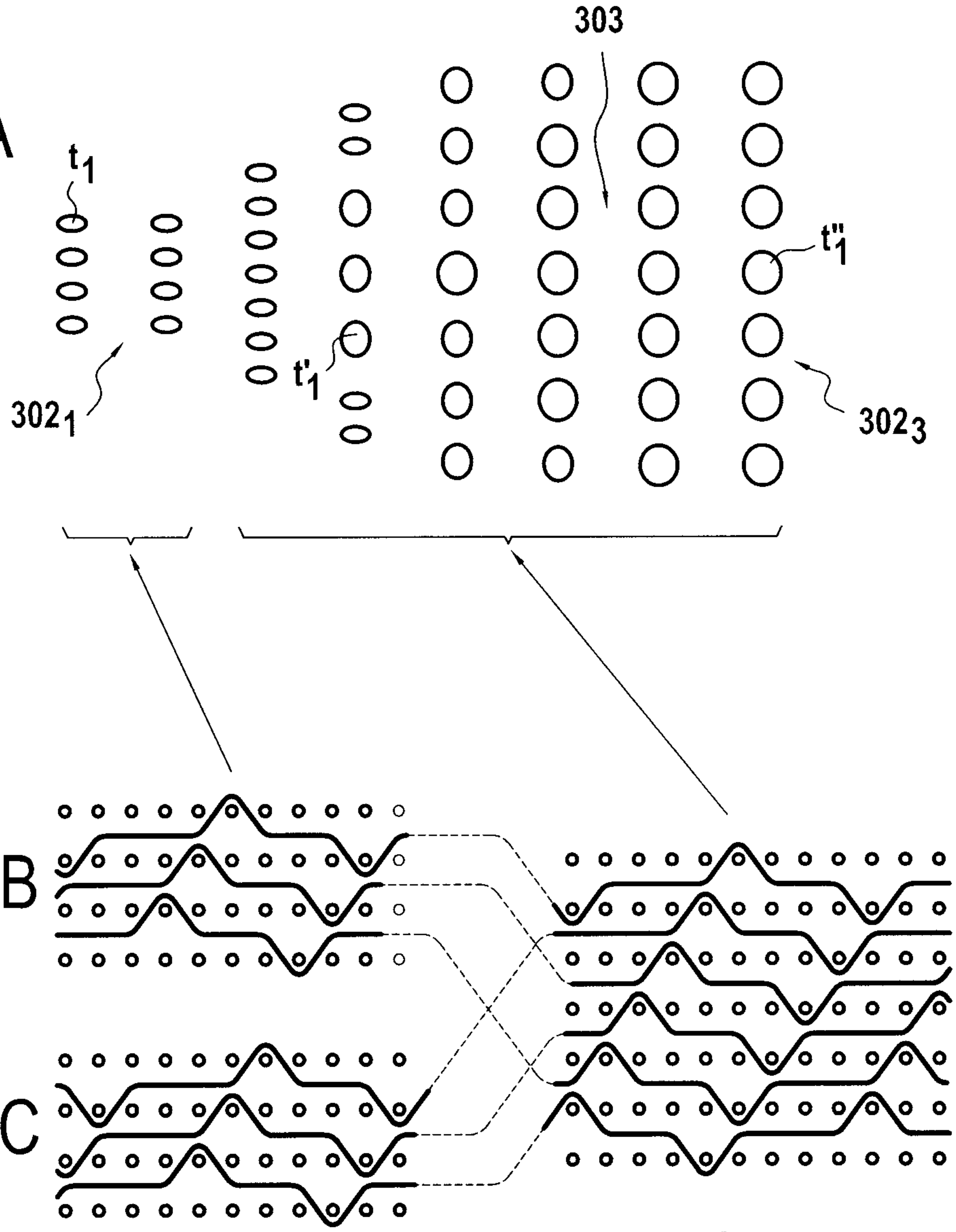


FIG.13D

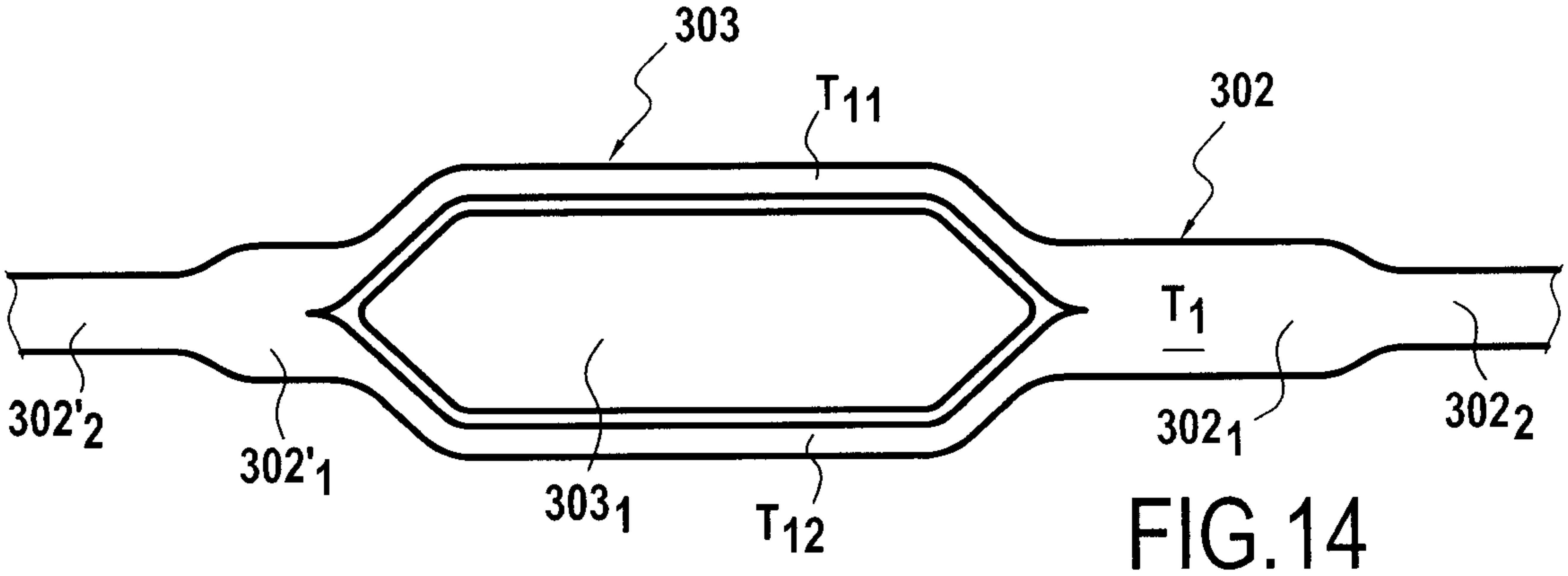


FIG.14

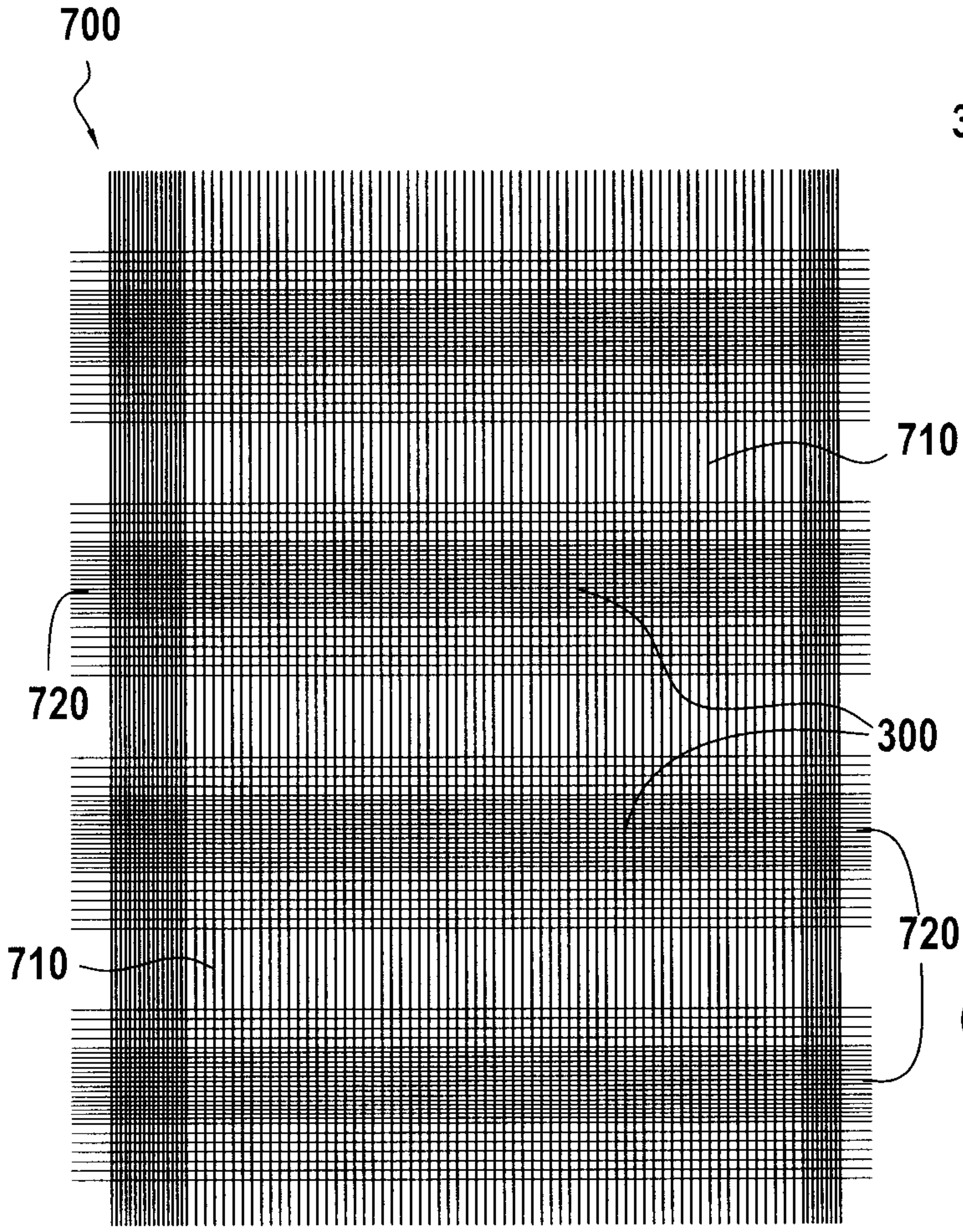


FIG.16

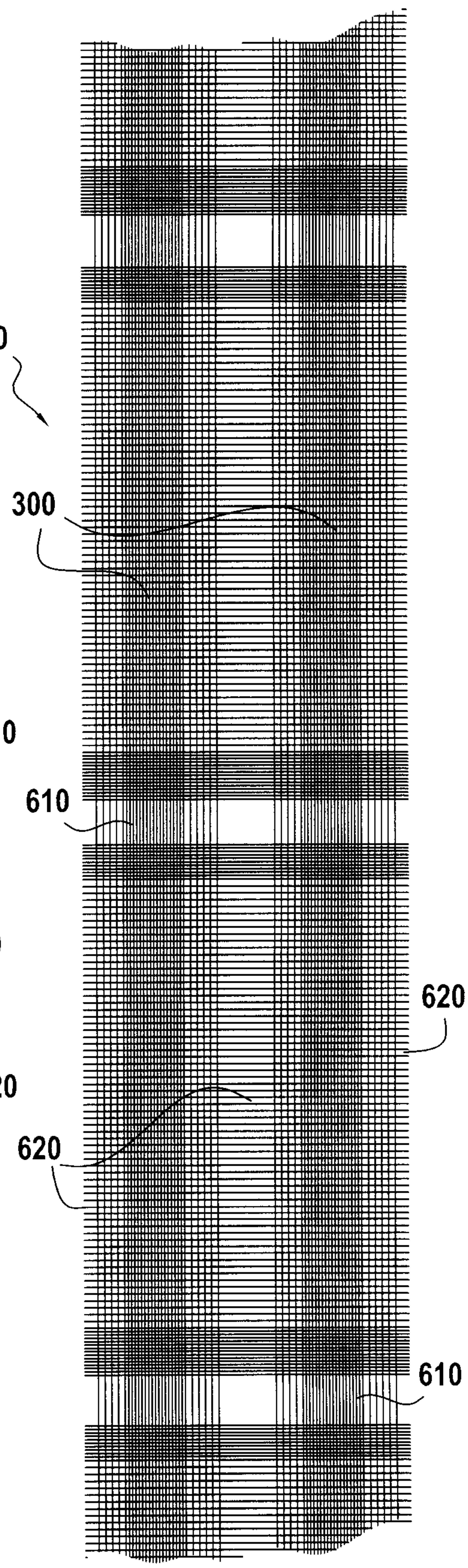
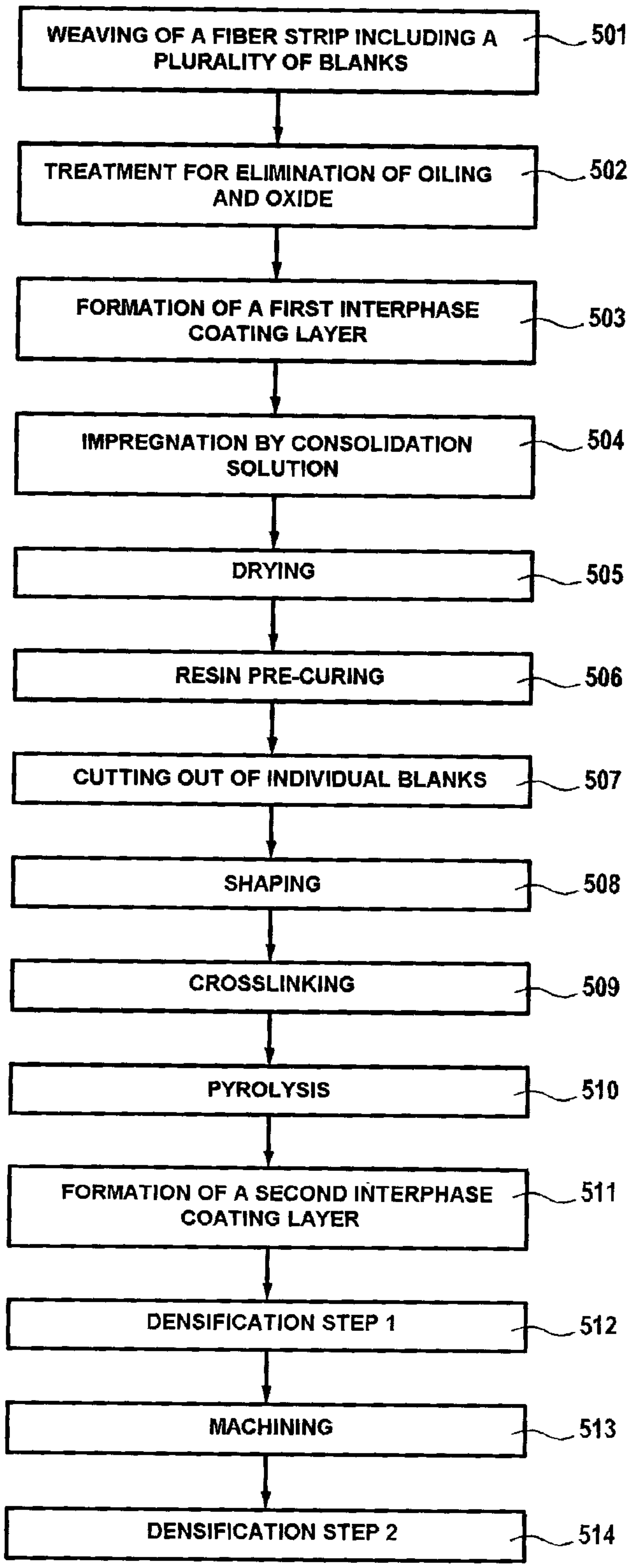


FIG.15


WEAVING OF A FIBER STRIP INCLUDING A PLURALITY OF BLANKS
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TREATMENT FOR ELIMINATION OF OILING AND OXIDE
502
FORMATION OF A FIRST INTERPHASE COATING LAYER
503
IMPREGNATION BY CONSOLIDATION SOLUTION
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DRYING
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RESIN PRE-CURING
506
CUTTING OUT OF INDIVIDUAL BLANKS
507
SHAPING
508
CROSSLINKING
509
PYROLYSIS
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FORMATION OF A SECOND INTERPHASE COATING LAYER
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DENSIFICATION STEP 1
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MACHINING
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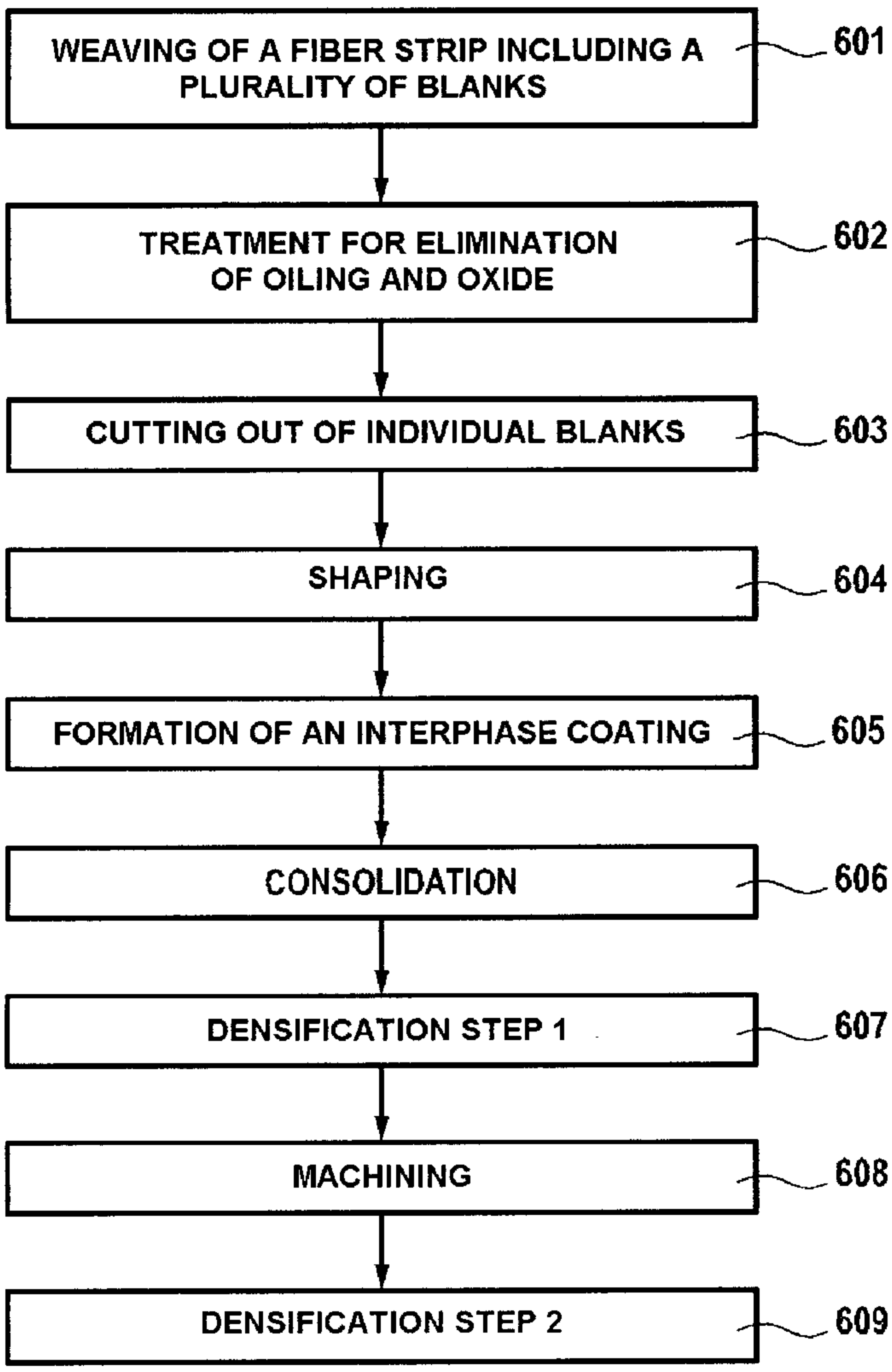
DENSIFICATION STEP 2
514

FIG.17


WEAVING OF A FIBER STRIP INCLUDING A PLURALITY OF BLANKS
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TREATMENT FOR ELIMINATION OF OILING AND OXIDE
602
CUTTING OUT OF INDIVIDUAL BLANKS
603
SHAPING
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FORMATION OF AN INTERPHASE COATING
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CONSOLIDATION
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DENSIFICATION STEP 1
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MACHINING
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DENSIFICATION STEP 2
609

FIG.18

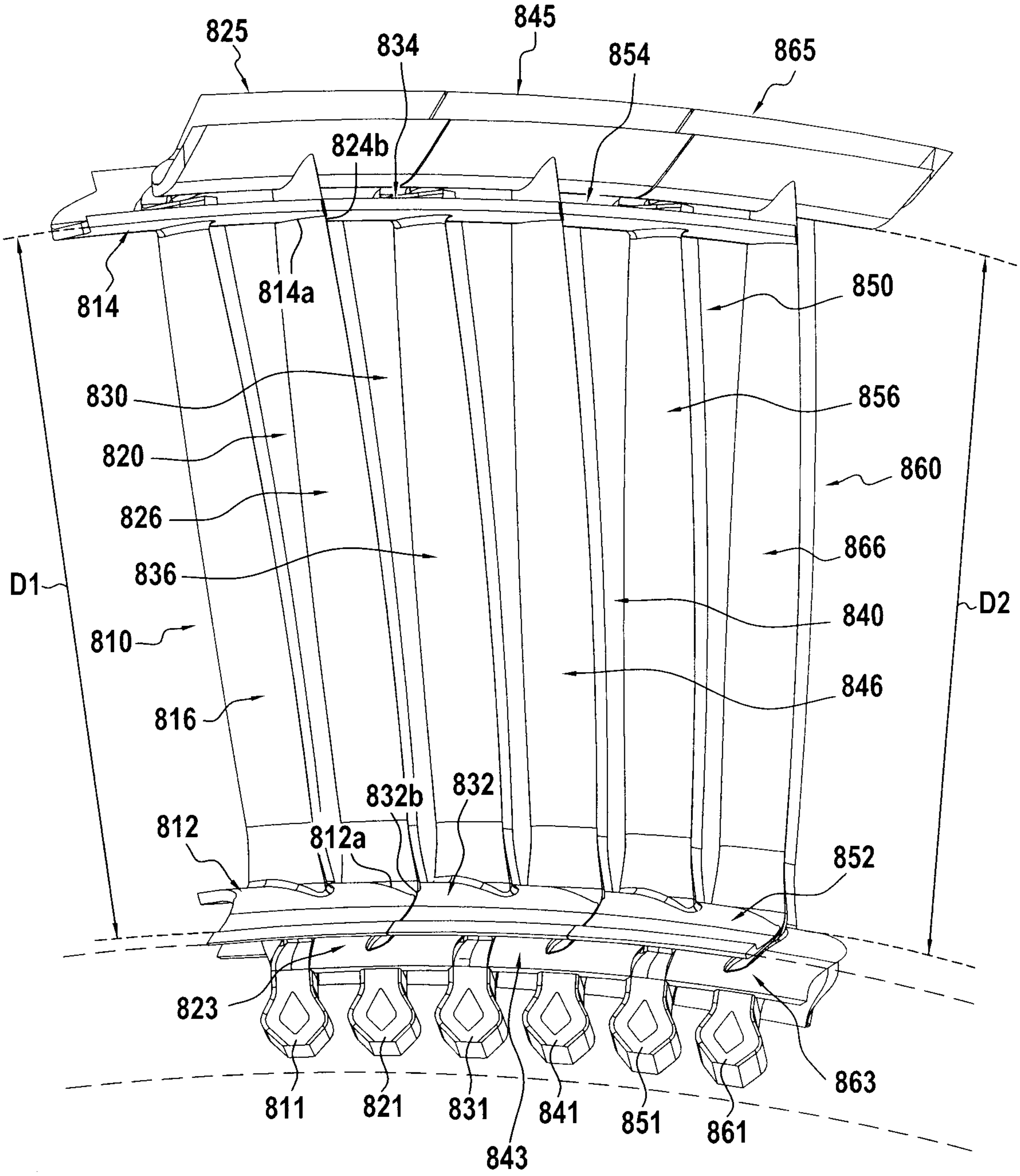
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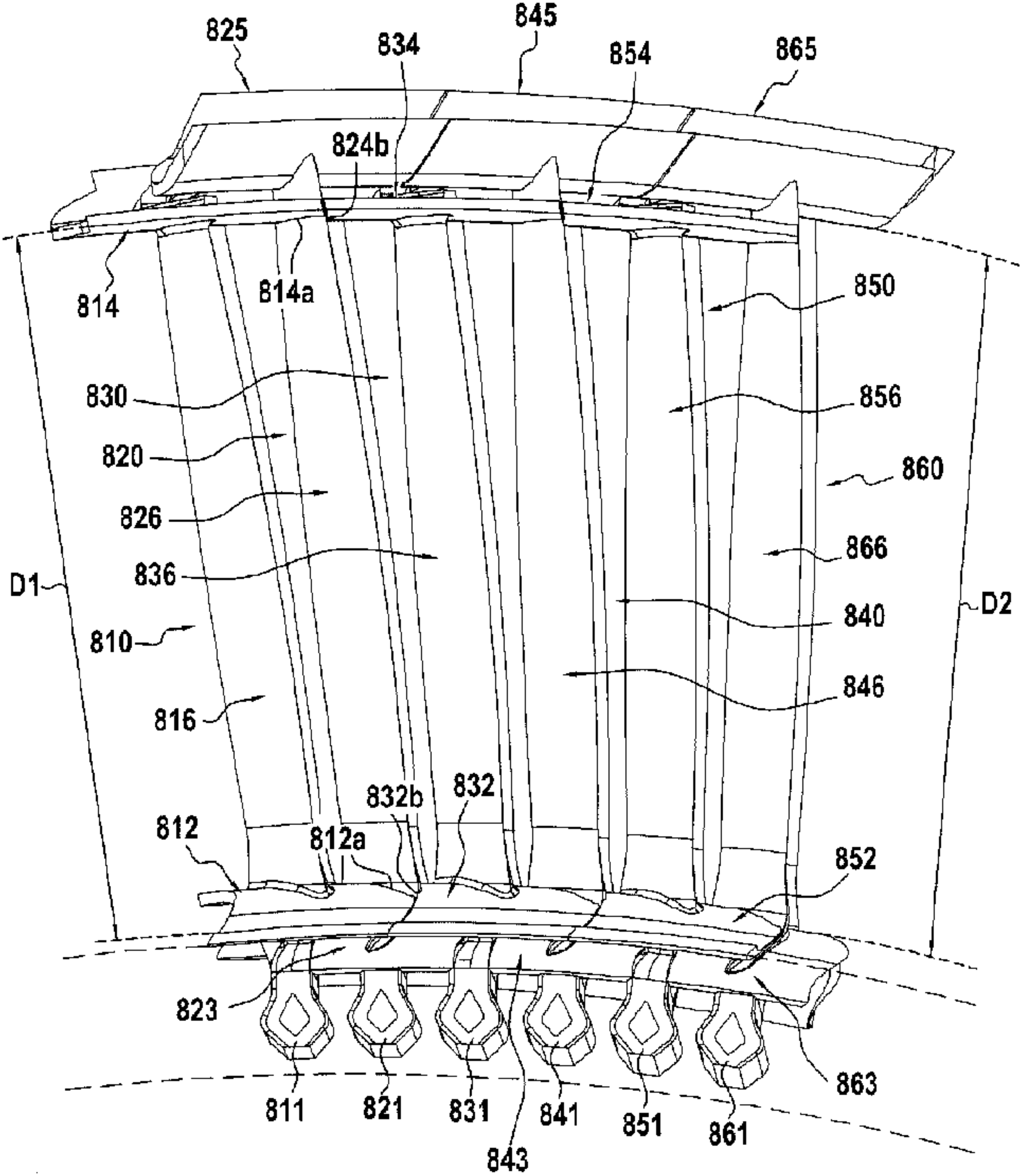
FIG.19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