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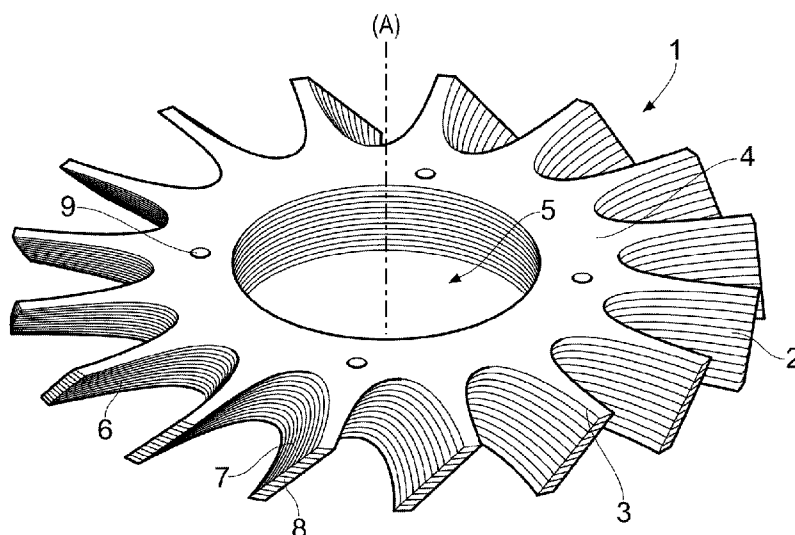


FIG. 1

(57) Abstract: A rotor or stator stage for a vacuum pump, the rotor or stator stage comprising an array of radially extending rotor or stator blades. The rotor or stator stage is made from two or more preformed laminate layers, and two or more of said preformed laminate layers comprise a portion of every radially extending rotor or stator blade of the rotor or stator stage.



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ROTOR OR STATOR BLADES FOR A VACUUM PUMP

Field of the Invention

5 The present invention relates to rotor or stator blades for a vacuum pump, especially a turbomolecular pump; and methods for manufacturing the same.

Background

10 A turbomolecular pump generally comprises a rotor having a plurality stages in the form of axially spaced, annular arrays of radially outwardly extending inclined rotor blades. The rotor blades are substantially uniformly spaced within each stage and extend radially outwards from a central hub. Generally, a stator stack of the pump surrounds the rotor, and comprises series of stator stages
15 comprising annular arrays of inclined stator blades. In use, the stator stages are situated between adjacent rotor stages. Each annular array of rotor and stator blades forms a rotor or stator stage of the turbomolecular pump. As the rotor rotates, the rotor blades impact incoming gas molecules and transfer the mechanical energy of the blades into gas molecule momentum, that is directed
20 from the pump inlet through the stages towards the pump outlet.

 A rotor stack typically comprises a series of coaxially aligned rotor arrays, wherein adjacent rotor arrays are axially separated by spacers. Similarly, stator arrays in stator stacks are commonly separated by annular or semi-annular
25 spacers.

 The compression ratio of the pump is dependent, inter alia, upon the number of stages of rotor and stator blades, the number of blades within each array, the angle of inclination of the blades, the profile of the blades, and the rotational
30 speed of the rotor shaft. In order to enhance the inlet capacity of the turbomolecular pump, the sizes of the blades of the inlet stage of the pump, that is, the stage closest to the pump inlet, are generally relatively large, with the

sizes of the blades of the stages gradually decreasing from the pump inlet towards the pump outlet. In other words, the axial lengths of the arrays of rotor and stator blades gradually decrease from the pump inlet towards the pump outlet. Likewise, the angle of the blades tends to decrease from the pump inlet towards the pump outlet.

Blade arrays with complex blade geometries can be produced by machining, but to achieve the necessary level of accuracy may take up to 100 hours of machining to produce a single rotor stack. To produce blade arrays in this manner is therefore prohibitively costly, both in terms of machining hours, but also the wasted material inherent to the machining production method. Thus, the production of current blade arrays must compromise between optimised performance and manufacturing costs/time.

There is therefore an ongoing need for improved rotor and stator blade arrays. In particular, there is a need for blade arrays with complex blade geometries that are cost-effective and quick to produce.

The present invention addresses these and other problems with known rotor and stator blade units.

Summary of the Invention

Accordingly, in a first aspect, the invention provides a rotor or stator stage for a vacuum pump, typically a turbomolecular pump. The rotor or stator stage comprising an array of radially extending rotor or stator blades, wherein the rotor or stator stage is made from two or more preformed laminate layers, and wherein two or more of said preformed laminate layers comprise a portion of every radially extending rotor or stator blade of the rotor or stator stage.

Typically, a rotor or stator stage may comprise an array of blades, said array comprising a plurality of blades extending from a main body. The array of blades typically comprises from about 12 to about 40 radially extending blades, preferably from about 14 to about 20 blades, for example 16 blades.

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The term rotor stage may refer to a substantially annular array of radially extending rotor blades. A series of rotor stages may be coaxially stacked with spacers therebetween to form the rotor stack. Typically, a rotor stage may comprise an axial shaft. The blades may be regularly circumferentially spaced around the axial shaft. Preferably, the blades may be integrally formed with the shaft. The shaft may be substantially cylindrical. Additionally, or alternatively, the shaft may be substantially tubular. For a rotor stage, typically the rotor blades may extend substantially radially outwardly from the shaft.

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The term stator stage refers to an annular array of radially extending stator blades. A series of stator stages may be coaxially stacked with spacers therebetween to form a stator stack. Typically, stator stages may comprise two or more semi-annular units, as to enable the stator stage to be assembled around the rotor stage. When in use in a turbomolecular pump, the stator stack substantially surrounds the rotor stack such that adjacent stages of rotor blades are axially interspaced by an array of stator blades. For the avoidance of doubt, in stator embodiments a preformed laminate layer may comprise two or more part-annular sections, such as semi-annular sections, that are configured to be coupled together to form an annular array comprising a portion of every radially extending stator blade of the stator stage.

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For a stator stage, each semi-annular unit may comprise a portion of the main body. Said portion may be a semi-annular section in which the blades are supported. The stator blades may be regularly circumferentially spaced around the semi-annular section. Typically, the blades of the stator stage may extend radially inwardly from each semi-annular section.

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The rotor or stator stage comprises two or more preformed laminate layers, preferably these preformed laminate layers are coaxially aligned within the rotor or stator stage. Preferably the rotor or stator stage comprises from about 2 to about 50 preformed laminate layers, more preferably from about 2 to about 10 preformed laminate layers, most preferably 3 preformed laminate layers. The number of preformed laminate layers may depend on the position of the stage in the rotor or stator stack, the size of the stage, and/or the complexity of the stage geometry. Typically, the stage height decreases along the pump direction of the stack.

The term preformed denotes that the laminate layers are each individually formed before the manufacture of a rotor or stator stage. Typically, this involves laying up, cutting, punching, and/or moulding each laminate layer material to the desired dimensions. Cutting and punching are particularly preferred. The skilled person will appreciate that this is not an exhaustive list, and that the preformed laminate layers may be produced with specific dimensions using any relevant method known in the art. Advantageously, this enables the dimensions of each laminate layer to be specifically selected and produced prior to the assembly of a rotor or stator stage. Thereby, precise dimensional control of each preformed laminate layer may be achieved. Thus, the production of a rotor or stator stage with a complex blade geometry may be achieved quickly and without the requirement for expensive tooling, by building up the preformed laminate layers. Additionally, the present invention further enables the skilled person to produce laminate layers each with different geometries.

Preferably, no machining is performed after the preformed laminate layers have been stacked. Preferably no material is removed from preformed laminate layers after they have been stacked.

In an embodiment, each preformed laminate layer may undergo a curing process prior to its use in the assembly of a rotor or stator stage. The cured preformed laminate layers may then be stacked and coupled to form a rotor or stator stage of the invention.

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In an alternative embodiment, a plurality of laminate layers may be stacked and undergo a curing process collectively to couple said layers and form the rotor or stator stage. This process may comprise heating the component whilst under a load. Preferably, the laminate layers may be placed into a mould comprising a cavity having the dimensions of the rotor or stator stage. Once all the laminate layers have been added to the mould, the plurality of laminate layers undergo a curing process.

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In a further alternative embodiment, the preformed laminate layers may not require a curing process.

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Typically, each preformed laminate layer may comprise a portion of every radially extending blade of the rotor or stator stage. For example, if a rotor or stator stage comprises an array of 16 blades, every preformed laminate layer comprises 16 radially extending blade portions. When said preformed laminate layers are coaxially stacked, each blade of the stage comprises a single blade portion from a series of consecutive preformed laminate layers, preferably a single blade portion from each preformed laminate layer.

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Typically, each blade portion comprises a first end adjoined to the main body of the rotor or stator stage, and a second end radially distal therefrom. The second end may comprise a blade tip.

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Each preformed laminate layer may be of substantially uniform and substantially equal thickness. The thickness of each preformed laminate layer may be from about 0.1 mm to about 8 mm, preferably from about 0.5 mm to

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about 5 mm, more preferably from about 1 mm to about 2 mm. Beneficially, this enables the preformed laminate layers to be produced from a source material of substantially uniform and substantially equal thickness, e.g. a sheet of “pre-impregnated” fibres in a thermosetting polymer matrix material, or cut from a metallic sheet. Advantageously, this simplifies the production of the laminate layers, and enables many preformed laminate layers to be produced quickly and with consistency. Furthermore, having preformed laminate layers with substantially uniform and substantially equal thickness eases the design process for the rotor or stator stage according to the present invention, as the stage may be axially divided into equal thickness laminate layers. This further simplifies the production process.

Typically, a vacuum pump will have an inlet at a first end, and an exhaust at an axially distant second end. The pump direction may be defined by the axial direction from the first end to the second end. Typically, each blade of the rotor or stator stage may have a leading face and a trailing face. Preferably, the blade may be inclined such that at least a portion of the leading face is angled substantially towards a pump direction. Additionally, preferably at least a portion of the trailing face may be angled substantially against a pump direction.

Typically, the rotor or stator stage may comprise more than two preformed laminate layers, and the leading face of each rotor or stator blade may comprise an exposed underside surface of more than one of said preformed laminate layers. Preferably wherein, in use, said exposed underside surface may be in a plane tangential to a rotational axis of the turbomolecular pump impeller. Preferably, the exposed underside surface is in a plane perpendicular to the pump direction.

The exposed underside surface of a laminate layer may be provided by having a circumferential rotational offset between adjacent preformed laminate layers forming the rotor or stator stage. Additionally, or alternatively, the exposed

underside surface of a preformed laminate layer may be provided by having differing blade portion geometries between adjacent preformed laminate layers.

5 Typically, the blade portions of each preformed laminate layer may further comprise an edge surface, preferably wherein the edge surface may be substantially perpendicular to the underside surface. The leading face of the rotor or stator stage may thus further comprise a portion of the edge surface of at least one of the preformed laminate layers, the leading edge surface.

10 The shape of the leading edge may be determined by the geometry of the desired blade. For instance, the leading edge may be substantially linear between a first end and a second end of the blade portion. Alternatively, the leading edge may be substantially non-linear, e.g. curved, between a first end and a second end of the blade portion. Alternatively, the leading edge may
15 comprise both substantially linear and substantially non-linear sections. The shape of the leading edges of the blade portions of adjacent preformed laminate layers in a stage may be substantially uniform. Alternatively, the shape of the leading edge of the blade portions of the preformed laminate layers may differ. Advantageously, this enables the production of complex blade geometries.
20 Typically, the shape of the leading edge is the same on the all the blades portions of a single laminate layer.

Typically, the leading face of each rotor or stator blade may comprise an exposed leading edge of each blade portion of more than one of said preformed
25 laminate layers, preferably the leading edge of each blade portion of every preformed laminate layer.

Preferably, the leading face and/or the trailing face of each rotor or stator blade has a stepped profile, and the leading edge and/or the trailing edge of two
30 adjacent preformed laminate layers has a different shape. This may enable the overall shape of the leading face and/or the trailing face of each rotor or stator blade to be specifically tailored. The shape of the leading face and/or trailing

face includes both the shape of the blade portion from the first end to the second end of the blade portion, and the angle of incline of the blade portions.

5 Accordingly, the leading face of each rotor or stator blade may have a stepped profile comprising more than one exposed underside surface, and more than one leading edge of each blade portion. However, this does not substantially affect the pumping characteristics in comparison to a rotor or stator blade of the prior art. The greater the number of preformed laminate layers that are used to produce the rotor or stator stage, the smoother the overall profile of the leading
10 edge.

Beneficially, the present invention enables complex geometries of the leading face of rotor or stator blades to be produced in a time efficient manner. The skilled person may achieve such complex geometries by selecting the shape of
15 the leading edge of the blade portions of the preformed laminate layers, additionally, or alternatively, by selecting the size of the exposed underside surface of each of the preformed laminate layers. As each preformed laminate layer is individually and independently formed, tight dimensional control of the laminate layer geometry may be easily achievable, and thus the overall
20 geometry of the rotor or stator stage.

Typically, the rotor or stator blade stage may comprise more than two preformed laminate layers, wherein the trailing face of each rotor or stator blade may comprise an exposed topside surface of more than one laminate layer,
25 typically, of all the laminate layers. Preferably wherein, in use, said exposed topside surface may be in a plane substantially tangential to a rotational axis of the turbomolecular pump impeller.

The exposed topside surface of a laminate layer may be provided by having a
30 circumferential offset between adjacent preformed laminate layers forming the rotor or stator stage. Additionally, or alternatively, the exposed topside surface

of a laminate layer may be provided by having adjacent preformed laminate layers with differing blade portion geometries.

5 The trailing face of the rotor or stator stage may further comprise a portion of the edge surface of at least one of the preformed laminate layers, said portion of the edge surface being the trailing edge.

10 Much like the leading edge, the trailing edge may be substantially linear between a first end and a second end of the blade portion. Alternatively, the trailing edge may be substantially non-linear, e.g. curved, between a first end and a second end of the blade portion. Alternatively, the trailing edge may comprise both substantially linear and substantially non-linear regions between a first end and a second end of the blade portion. The shape of the trailing edges of the blade portions of adjacent preformed laminate layers in a stage
15 may be substantially uniform. Alternatively, the shape of the trailing edge of the blade portions of adjacent preformed laminate layers may differ. Advantageously, this enables the production of complex blade geometries.

20 The trailing face of each rotor or stator blade may further comprise an exposed trailing edge of each blade portion of more than one of said preformed laminate layers, preferably the trailing edge of each blade portion of every preformed laminate layer.

25 Accordingly, the trailing face of each rotor or stator blade may have a stepped profile comprising more than one exposed topside surface, and more than one trailing edge of each blade portion. This does not substantially affect the pumping characteristics in comparison to a rotor or stator blade of the prior art. However, the greater the number of preformed laminate layers that are used to produce the rotor or stator stage, the smoother the overall profile of the trailing
30 edge.

Beneficially, the present invention enables complex geometries of the trailing face of rotor or stator blades to be achieved in a time efficient manner. The skilled person may achieve such complex geometries by selecting the shape of the trailing edge of the blade portions of the preformed laminate layers, additionally, or alternatively, by selecting the shape of the exposed topside surface of each of the preformed laminate layers. As each preformed laminate layer is individually and independently formed, tight dimensional control of the laminate layer geometry is easily achievable, and thus the overall geometry of the rotor or stator stage.

The geometries of the leading face and the trailing face of the rotor or stator blades may be selected to optimise the pump performance characteristics of the rotor or stator stage in use.

Typically, the preformed laminate layers of a rotor or stator blade according to the present invention may comprise a metallic material, a polymeric material, or a composite material. Preferably, said preformed laminate layers may comprise a composite material, more preferably a fibre reinforced composite material. Said fibres may be selected from any appropriate material, for example carbon fibres, glass fibres, or aramid fibres. The fibres may be embedded in a thermoset polymer matrix, for example an epoxy resin. Alternatively, the composite material may be a metal matrix composite, for example having ceramic particles or fibres embedded in an alloy such as an aluminium, magnesium or titanium alloy. The skilled person will appreciate that numerous materials may be appropriate for use as the preformed laminate layers.

The preformed laminate layers may all comprise the same material, alternatively, some layers may comprise a different material to other layers. Advantageously, this enables the properties of each layer to be specifically

tailored according to the required specification of the component in use, for example factors to consider may be weight, tensile strength, and cost.

5 In use, the preformed laminate layers may be subjected to significant forces. Accordingly, to prevent failure of the component, the preformed laminate layers may be reinforced to strengthen against said forces. During production of the laminate layers, such regions may be selectively reinforced to increase their resistance to failure. Preferably, in embodiments wherein the preformed laminate layers comprise a fibre reinforced composite material, the lay-up of
10 the fibres may be selected to provide increased directional strength and increase the resistance to failure.

15 In an embodiment, the preformed laminate layers may comprise at least two apertures, each dimensioned to receive a rod. Thus, the rotor or stator stage may comprise two or more preformed laminate layers, each preformed laminate layer comprising at least two apertures, wherein the rotor or stator stage further may comprise a rod inserted through the corresponding apertures of each preformed laminate layer, in a substantially axial direction. The rod may be substantially linear, or alternatively may be substantially helical. Thus, the rod
20 may introduce a circumferential offset between adjacent preformed laminate layers. Advantageously, the rods may secure the preformed laminate layers, and enable simple assembly of the rotor or stator stage. Preferably, the rotor or stator stage may comprise from 2 to 8 rods, preferably from 2 to 6 rods, for example 4 rods. Preferably, the rods may be configured in a “squirrel cage”
25 formation.

Typically, each laminate layer is rotationally offset from each adjacent laminate layer about the longitudinal axis of the rotor or stator stage, preferably after laminate layers forming the rotor or stator stage have been stacked and/or
30 before adjacent layers are substantially permanently affixed to each other.

Typically, the preformed laminate layers each comprise a substantially annular or disk-like section from which the radially extending rotor or stator blade portions extend. In the case of rotor stage, the preformed laminate layer may comprise a disk-like or annular section with radially outwardly extending rotor blade portions. Preferably, two or more of said preformed laminate layers include at least two apertures, said at least two apertures perforating said preformed laminate layer, preferably, said substantially annular or disk-like section or said radially extending rotor or stator blade portions. Preferably the preformed laminate layers comprise from about 2 to about 8 of such apertures, more preferably about 4 apertures. Preferably, the apertures of adjacent layers are substantially aligned, preferably so as to form longitudinally extending apertures through the rotor or stator stage.

Typically, the rotor or stator stage comprises two or more longitudinally extending rods, each rod passing through at least one of said preformed laminate layers, preferably two or more of said preformed laminate layers, preferably all of said preformed laminate layers. Preferably the rotor or stator stage comprises from about 2 to about 8 of said rods, more preferably about 4 rods.

Preferably, two or more of said longitudinally extending rods are located within said apertures. More preferably, each rod passes through the apertures of two or more adjacent laminate layers. Most preferably, each rod passes through an aperture of each preformed laminate layer.

Typically, the rods are substantially linear or helical.

Typically, the rods may comprise a metallic material, polymeric material, ceramic material, or a composite material. Preferably, the rods may comprise a metallic material, for example a steel or an aluminium alloy.

Each rod may have a longitudinal length such that when the rod is located within the apertures of two or more preformed laminate layers, the ends of the rod may be substantially flush with a surface of the preformed laminate layers at either end of the rotor or stator stage. Alternatively, an end of a rod may extend
5 from an aperture of a preformed laminate layer at either end of the rotor or stator stage. In such embodiments, the exposed end of the rod may be removed such that the rod is substantially flush with the exposed surface of the preformed laminate layer. Such removal may be achieved by shearing, or removal by cutting means. Additionally, or alternatively, an uppermost and/or lowermost
10 laminate layer may cap the rod within the rotor or stator stage.

Additionally, or alternatively, each preformed laminate layer may comprise a central aperture (or bore). Typically, the bore has a substantially circular cross-section. Advantageously, the bore may enable the preformed laminate layers
15 to be coaxially located onto a rotor hub. Preferably, at least one preformed laminate layer may be secured to the hub via an interference fit with the bore. The diameter of the bore of each laminate layer of a rotor stage may be substantially the same throughout the rotor stage, and/or rotor stack, or, alternatively, the diameter of the aperture may differ between the preformed
20 laminate layers. Preferably, the bore of at least one, preferably two or more, preformed laminate layers may be dimensioned to have an interference fit with the hub, and the bore of at least one different preformed laminate layer may be dimensioned to have a larger bore diameter, for example 2% larger. Typically, the at least one preformed laminate layer with an interference fit to the hub may
25 additionally secure the other preformed laminate layer(s) with bore(s) of greater diameter. Advantageously, the preformed laminate layers with a greater bore diameter may enable reduced friction during assembly.

The preformed laminate layer(s) may be laminated over a metallic boss.
30 Advantageously, the use of a metallic boss may provide strengthening to the rotor or stator stage. Also, a metallic boss may enable tight dimensional control

and thus improved interference fit between the boss and a preformed laminate layer.

In embodiments, the rotor or stator blades of a stage may axially overlap. That is to say, each blade of a rotor or stator stage at least partially overlaps an adjacent blade. In such embodiments, the circumferential rotational offset may be greater than for stages without axial overlap. In embodiments, a stage may be axially opaque. That is to say, no spaces are visible between the blades when the unit is viewed directly from above or below.

In a further aspect, the invention provides a method for assembling a rotor or stator stage of a vacuum pump, the rotor or stator stage comprising an array of radially extending blades, the method comprising the steps of:

- a. providing two or more preformed laminate layers, each preformed laminate layer comprising a portion of every radially extending blade of the rotor or stator stage,
- b. stacking two or more of the preformed laminate layers,
- c. optionally rotating one or more of the preformed laminate layers about its longitudinal axis, and
- d. affixing adjacent layers to form the rotor or stator stage.

Typically, the two or more preformed laminate layers of step (a) may be provided by independently forming or cutting the laminate layers. Each laminate layer may be of substantially the same thickness, or alternatively the layers may differ. Preferably each layer is of substantially uniform thickness.

Typically, the preformed laminate layers may be stacked. The preformed laminate layers may be stacked in a mould. Alternatively, the preformed laminate layers may be stacked onto longitudinal rods, wherein said rods are received by apertures formed in the preformed laminate layers. Alternatively, the preformed laminate layers may be stacked, then have rods inserted into

them. Advantageously, these approaches locate and secure the preformed laminate layers relative to one another.

5 A benefit of this assembly method is that it enables a rotor or stator stage with a complex geometry to be produced efficiently and at a low cost. The method allows for tight dimensional control of the preformed laminate layers, and hence the rotor or stator stage as a whole. Additionally, the amount of material waste is reduced in comparison to production via machining or other methods used in the prior art.

10 The preformed laminate layers may be affixed by any number of methods. They may be affixed by adhesives, or alternatively they may be affixed as part of a curing process, or alternatively they may be affixed by affixing means, e.g. rods. The skilled person will appreciate that numerous affixing methods may be appropriate for this purpose.

20 The method may further comprise the step of rotating one or more of the preformed laminate layers about its longitudinal axis. Advantageously, this enables the preformed laminate layers to be arranged such that they form the desired geometry of the rotor or stator stage. Additionally, or alternatively, the dimensions of the preformed laminate layers may each be selected such that when they are assembled they form the desired geometry of the rotor or stator stage. Preferably, no machining is performed after the preformed laminate layers have been stacked. Preferably no material is removed from preformed laminate layers after they have been stacked.

25 The method may further comprise the step of providing two or more rods, and stacking the two or more preformed laminate layers in step b) by passing each rod through at least one aperture in each preformed laminate layer.

In a further aspect, the present invention provides a process for manufacturing a rotor or stator stage for a vacuum pump, said method comprising the steps of:

- 5 a) designing the rotor or stator stage, each stage comprising an array of radially extending rotor or stator blades;
- b) dividing the rotor or stator stage so designed into series of layers, each layer being in a plane substantially tangential to a longitudinal axis of the rotor or stator stage;
- c) separately manufacturing each of the layers; and
- 10 d) stacking the layers so manufactured to form the rotor or stator stage.

Typically, the step (a) of designing a rotor or stator stage involves selecting the number of blades, the geometry of said blades, the incline angle of the blades, and/or any further features of the rotor or stator stage. The design of the rotor
15 or stator stage, more specifically the shape, angle, curvature and number of the blades effect the overall performance of the pump, and thus a design must be selected that optimises said performance. Advantageously, the process of the present invention enables complex blade geometries to be produced that would otherwise be undesirably expensive or time-consuming to produce via the
20 traditional production methods. Therefore, a greater pumping performance may be achieved for a wider range of applications.

The rotor or stator stage may be divided into a series of layers. Typically, the rotor or stator stage may be divided into a series of about 2 to about 50 layers,
25 preferably from about 2 to about 30 layers, for example 3 layers. Typically, the layers may be of substantially uniform thickness. Alternatively, the layers may be designed to have differing thicknesses.

Advantageously, separately manufacturing each of the layers enables the
30 layers to have complex geometries and be made to tight tolerances, in a time efficient manner. In embodiments wherein all of the layers have the same geometry, the time taken to produce the set of layers that form the rotor or stator

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stage is further reduced. Furthermore, separately manufacturing each of the layers has the benefit that layers may be made from the same material, or alternatively from different materials.

5 Typically, the layers may then be stacked to form the rotor or stator stage. Preferably the layers may be stacked coaxially. One or more layers may then be rotated about its longitudinal axis. Beneficially, this enables the blade angle of the rotor or stator stage to be adjusted to ensure optimum pumping characteristics of the component in use.

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The layers may each comprise at least two apertures dimensioned to each receive a rod. The layers may be stacked by slotting a first layer onto the rods such that a rod is inserted into each aperture, followed by slotting a second layer onto the rods in a similar fashion. If there are further layers, then they are
15 slotted onto the rods in the same way. The rods may be substantially linear, or alternatively they may be substantially helical. When the rods are substantially helical, this causes the layers to be rotated about their longitudinal axis relative to each adjacent layer.

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Typically, each layer may be coupled to each adjacent layer prior to use of the rotor or stator stage.

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In a further aspect, the present invention provides a multiblade array for a vacuum pump comprising a rotor and stator stack, each stack comprising a plurality of rotor or stator stages and each rotor or stator stage comprising an series of radially extending rotor or stator blades, said multiblade array comprising a longitudinal spine with a series of either rotor or stator blades extending therefrom, wherein each blade of the multiblade array corresponds to a different stage of the rotor or stator stack.

30

Typically, a rotor or stator stack comprises from X to about Y rotor or stator stages, respectively, preferably Z rotor or stator stages. Accordingly, each

multiblade array may comprise a number of rotor or stator blades extending from its spine corresponding to the number of rotor or stator stages.

Typically, the multiblade array may comprise a metallic material, a polymeric material, or a composite material. Preferably, the multiblade array may comprise a composite material, more preferably a fibre reinforced composite material. Said fibres may be selected from any appropriate material, for example carbon fibres, glass fibres, or aramid fibres. The fibres may be embedded in a thermoset polymer matrix, for example an epoxy resin. Alternatively, the composite material may comprise a metal matrix composite. The spine and rotor or stator blades may comprise the same material, or alternatively, the spine and rotor or stator blades may comprise different materials.

The multiblade array may comprise a series of laminate layers. Alternatively, the blades may comprise a series of laminate layers. Advantageously, this enables complex geometries of the spine and/or blades to be formed in a time efficient manner, and at a low cost.

Typically, the spine may be configured to couple the multiblade array to a main body of the rotor or stator stack. Preferably, the spine may have a substantially constant longitudinal cross-sectional. Advantageously, this enables the multiblade array to be coupled to the main body of the rotor or stator stack without the requirement of further attachment means. Preferably, the spine may be coupled to the main body of the rotor or stator stack by inserting it into a groove comprising a reciprocal geometry dimensioned to secure the spine.

Typically, the spaces between adjacent rotor or stator blades on the spine may be configured to receive a stage of the other of the rotor or stator stack. In use, the rotor stack may be surrounded by the stator stack, wherein the rotor blades of adjacent rotor stages may be interspaced by the stator blades of a stator stage, or vice versa. The spaces between the adjacent rotor or stator blades

may be substantially uniform, or alternatively they may differ. The size of the spaces may correspond to the size of the adjacent blades in the stack. The same applies for stator blades *mutatis mutandis*.

5 In a further aspect, the present invention may comprise a stator or rotor stack for a vacuum pump, the stack comprising a substantially tubular hub and plurality of multiblade arrays as described previously, coupled to the hub.

10 Typically, for a rotor hub, the multiblade arrays may be coupled to the hub such that the rotor blades extend substantially radially outwardly from the hub. Conversely, for a stator hub, the multiblade arrays may be coupled to the hub such that the stator blades extend substantially radially inwardly from the hub.

15 Typically, the hub may comprise a plurality of conduits or prominences, wherein each conduit or prominence is dimensioned to receive or be coupled to at least one multiblade array. Preferably, each conduit or prominence may extend longitudinally from a first end to a second end of the hub.

20 In embodiments comprising conduits, the conduit may further comprise a longitudinal opening on a face of the hub. Preferably, the opening may be dimensioned to secure the multiblade array within the conduit, whilst enabling the rotor or stator blades to extend from the conduit substantially radially from the hub.

25 Preferably the conduit or prominence may be substantially helical along the length of the hub. Advantageously, this enables the rotor or stator blades to be angled, by selecting a helix angle, thus ensuring improved pump performance.

30 Typically, the substantially tubular hub may comprise a single part comprising a metallic material, a polymeric material, or a composite material. Preferably the substantially tubular hub may comprise a metallic material, for example an

- 20 -

aluminium alloy. Preferably, the substantially tubular hub may be produced by machining, for example by turning followed by milling of the plurality of conduits.

5 In a further aspect, the present invention provides a rotor stack hub for the impeller of a vacuum pump comprising a plurality of rotor stages, the rotor stack hub comprising a substantially cylindrical, preferably tubular, main body, said main body comprising a series of substantially circumferentially uniformly spaced couplings located on an outwardly facing longitudinally extending surface thereof, each coupling being configured to couple to a multiblade array
10 comprising rotor blades for two or more rotor stages, and wherein the number of couplings in the series is equal to the number of rotor blades in the two or more rotor stages.

Advantageously, this configuration enables individual multiblade arrays to be
15 removed and inserted independently, thereby easing maintenance. If a blade of a rotor stack according to the prior art required replacing then the entire stack would be required to be disassembled to remove it, whereas, a multiblade array according to the present invention may be removed and replaced without having to remove any other of the multiblade arrays from the main body.

20 Typically, each coupling may comprise a longitudinally extending conduit or prominence, preferably a helical conduit or prominence. Each conduit or prominence may be dimensioned to be coupled to more than one multiblade array, arranged in an end-to-end configuration longitudinally along the hub.

25 For the avoidance of doubt, all aspects and embodiments described hereinbefore may be combined mutatis mutandis.

Brief Description of the Figures

30 Preferred features of the present invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 shows a rotor stage according to the invention.

Figure 2 shows a preformed laminate layer according to the invention.

5

Figure 3 shows a portion of a preformed laminate layer according to the invention, wherein the direction of the fibre reinforcement is shown.

Figure 4 shows a cross section of a blade portion of a rotor or stator stage according to the invention.

10

Figure 5 shows a multiblade array according to the invention.

Figure 6 shows a tubular hub for a rotor stack with a multiblade array coupled thereto, according to the invention.

15

Figure 7 shows an alternative embodiment of a tubular hub for a rotor stack with a multiblade array coupled thereto, according to the invention.

Figure 8 shows a tubular hub having a plurality of multiblade arrays coupled thereto, according to the invention.

20

Detailed Description of the Invention

The present invention provides a rotor or stator stage for use in a vacuum pump (not shown).

25

As illustrated in Fig. 1, the rotor stage (1) comprises an array of radially extending rotor blades (2). The rotor or stator stage is formed of a plurality of preformed laminate layers (3), as shown in Fig. 2. Two or more of said preformed laminate layers (3) comprise a portion of every radially extending rotor blade (2) or the rotor stage (1).

30

In this embodiment, the rotor stage (1) comprises 16 rotor blades (2) extending radially outwardly from the longitudinal axis (A) of the rotor stage (1). The rotor blades (2) are evenly circumferentially spaced around the substantially annular main body (4). The main body (4) comprising a bore (5).

The rotor blades (2) each comprise a leading face (6) and a trailing face (7). In this embodiment, both the leading face (6) and trailing face (7) of each rotor blade (2) are inclined. This angle of incline is caused by each preformed laminate layer (3) being offset about the longitudinal axis (A) relative to the preformed laminate layer(s) adjacent thereto. In this embodiment, the angle of offset about the longitudinal axis is consistent between each pair of adjacent preformed laminate layers.

The rotor blades (2) each further comprise a blade tip face (8), which may form part of an imaginary cylindrical surface. In use, the blade tip face (8) is in a face-to-face relationship with the inner surface of the stator stack (not shown). The smaller the gap between the blade tip face (8) and the inner surface of the stator stack, the greater the pump performance. The skilled person will appreciate that the gap should be large enough to prevent the rotor blades (2) from touching the stator stack in use.

The rotor stage (1) further comprises four conduits (9), formed in the main body (4) and passing axially therethrough. Said conduits (9) are each dimensioned to receive a rod (not shown) therein.

To manufacture a rotor stage (1) according to the invention, first, the laminate layers must be produced. The preformed laminate layers may be punched, cut, machined, extruded, moulded, stitched, laid up, photo etched or additively manufactured, from a source material. The laminate layers may preferably comprise a fibre reinforced composite material, for example a carbon fibre reinforced composite.

The preformed laminate layers (3) may then be stacked. This may involve inserting the preformed laminate layers into a mould, wherein the mould comprises a cavity that is of the dimensions of the rotor stage to be produced.

Alternatively, the layers may be stacked, and a preformed laminate layer (3) may be rotated about its longitudinal axis (A) relative to an adjacent preformed laminate layer (3). Subsequent preformed laminate layers may be added and rotated accordingly. The angle of rotation will depend on the desired geometry of the rotor stack (1).

Additionally, or alternatively, the layers may be stacked and have a rod inserted through each conduit (9) of each layer. If the preformed laminate layers (3) have already been rotated, then each rod will be dimensioned to match the angle of rotation of the stack of preformed laminate layers. If the preformed laminate layers have not been rotated, then the interaction of the rod with a conduit (9) during insertion of the rod may be used to rotate the layers. Alternatively, the layers may not need to be rotated and the rods are each simply inserted into a conduit (9).

Each preformed laminate layer (3) may be affixed to adjacent layers in the stack. The preformed laminate layers may be cured such that they form a single unitary piece that is the rotor stage (1), preferably the preformed laminate layers may be cured under elevated temperature and pressure. Additionally, or alternatively, the preformed laminate layers (3) may be affixed by an adhesive layer between each pair of adjacent preformed laminate layers (3), an example. Alternatively, the stack may be retained by the interaction of the rods with the conduits (9).

As illustrated in Fig. 2, each preformed laminate layer (3) of the rotor stage (1) comprises a plurality of blade portions (10), wherein each blade portion (10) forms a portion of a rotor blade (2) of the rotor stage (1). The blade portions (10) extend substantially radially outwardly from the longitudinal axis (A), and

are connected to a substantially annular ring (11) of the preformed laminate layer (3) at a first end (12). The substantially annular ring (11) forms a portion of the main body (4) of the rotor stage (1).

5 The blade portions (10) in this example each further comprise a topside surface (13), and an underside surface (not shown). Also, each blade portion (10) comprises a first edge (14) and a second edge (15). The direction of rotation of the rotor stage (1) in use defines which of the first edge (14) and second edge (15) forms part of the leading face (6) of the rotor blade (2), and which forms
10 part of the trailing face (7) of the rotor blade (2). The first edge (14) and second edge (15) are each substantially perpendicular to the topside surface (13) and underside surface and are typically substantially linear in a longitudinal direction (A).

15 Each blade portion (10) further comprises a tip face (16) that forms a part of the blade tip face (8) of the rotor blade (2). The tip face (16) is at a second end (17) of the blade portion (10) that is radially distal from the first end (12). Each tip face (16) also comprises a portion of the imaginary cylindrical surface.

20 The first edge (14) and second edge (15) are each substantially curved at a first end (12) and become substantially linear towards a second end (17). The first edge (14) of a first blade portion and the second edge (15) of a circumferentially adjacent second blade portion are contiguous at a first end (12) of the first and second blade portions, in the form of a continuous arcuate surface.

25 The preferred direction of rotation of the rotor stage (1) when in use is shown by arrow (D).

30 The skilled person will appreciate that the embodiment shown in Fig. 2 is just a single example of the multitude of dimensions that the preformed laminate layer (3) may take. Indeed the dimensions of the blade portions (10) of the layer may be varied by changing the longitudinal thickness of the layer (3), the length and

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the path of taken by the first (14) and second (15) edges between a first (12) and second (17) ends, and the presence of, or dimensions of the tip face (16).

5 The specific dimensions of the rotor stage (1) and hence preformed laminate layers (3) will depend on numerous factors, including where the stage (1) is positioned in the rotor stack, the number of rotor blades (2) per stage (1), the angle of said rotor blades (2), the angle of the stator blades, among others.

10 The preformed laminate layer (3) is substantially planar and has four apertures (18) substantially evenly circumferentially spaced in the substantially annular ring (11). The apertures are formed through the substantially annular ring (11), and each form a portion of a conduit (9) of the rotor stage (1).

15 As illustrated in Fig. 3, the preformed laminate layer (3) may comprise a fibre reinforced composite material. Fibre reinforcements have anisotropic properties and thus have a higher tensile strength when a force is applied longitudinally on the fibre, than, for example, when a shearing force is applied to the fibre. Therefore, the orientation of the fibre reinforcements within the preformed laminate layer (3) will affect the local material properties of the component.

20 Accordingly, as shown in Fig. 3, the fibre reinforcement layup directions may be selected to provide structural reinforcement to the blade portions (10), specifically to the first (14) and second edges (15) of each blade portion (10), along with the substantially annular ring (11). If the preformed laminate layer (3) comprises apertures (18), then the fibre reinforcement lay-up may be selected to provide structural reinforcement in this area.

30 The skilled person will appreciate that the specific directional layup of the reinforcing fibre direction will depend on the specific dimensions and performance requirements of the rotor stage (1).

As illustrated in Fig. 4, a cross-section of a rotor blade (2) is shown. A plurality of blade portions (10) of preformed laminate layers (3) are visible. The leading face (6) is shown to comprise a first edge (14) of each blade portion (10), along with an exposed underside surface (19) of each preformed laminate layer. The leading face (6) therefore has a stepped profile. Due to the size of the exposed underside layer (19) differing between adjacent blade portions (10) across the depth of the leading face (6), the overall shape of the leading face (B) is curved.

The trailing face (7) is shown to comprise a second edge (15) of each blade portion (10), along with an exposed topside surface (20) of each blade portion. The trailing face (7) also has a stepped profile. The size of the exposed topside surface (20) is substantially consistent between adjacent blade portions (10) across the depth of the trailing face (7). Thus, the overall shape of the trailing face (C) is substantially planar.

Fig. 4 further illustrates that the width of each blade portion (10), i.e. the distance between a first edge (14) and a second edge (15) of a particular longitudinal cross-section, may differ between adjacent blade portions (10). Thus, the shape of the blade portions (10) may differ between adjacent preformed laminate layers.

The overall shape of the leading (B) and trailing (C) faces are shown to depend on both the rotation of adjacent preformed laminate layers (3), and/or differing shapes of the blade portions (10) of adjacent preformed laminate layers (3) in the rotor stage (1). The skilled person will appreciate that, advantageously, there are countless different shapes of the rotor blades (2) that can be formed using the present invention. Thus, the shape of the rotor blades (2) can be optimised as the skilled person sees fit.

The leading (6) and trailing (7) faces may be substantially smooth rather than stepped as in Fig. 4.

Preferably, the rotor blades (2) of each rotor stage may be substantially uniform.

The skilled person will appreciate that although Figs. 1-4 only exhibit components for a rotor stage (1), the above disclosure also applies to a stator stage *mutatis mutandis*.

As illustrated in Fig. 5, a further embodiment of the invention is shown, comprising a multiblade array (21), itself comprising a longitudinal spine (22) having a series of extending rotor blades (23) extending therefrom. The rotor blades (23) extend radially from the spine (22) and are spaced longitudinally thereon. Between each rotor blade (23) is a space (24). The space (24) is dimensioned such that, in use, the stator blades from a stator stack may be received in the space (24).

The longitudinal spine (22) may be substantially arcuate. Preferably, the spine (22) may be substantially helical.

The spine (22) may comprise a support portion (25), from which the rotor blades (23) extend. The support portion (25) provides structural stability to the rotor blades (23). The spine (22) may further have a coupling portion (26), by which the multiblade array (21) is coupled to the main body of the rotor stack. The coupling portion (26) extends the length of the spine (22), and has a thickness that is greater than that of the support portion (25). The coupling portion (26) may comprise a longitudinal bead.

The rotor blades (23) each form part of a different rotor stage of the rotor stack. The rotor blades (23) may be substantially uniform along the length of the spine (22). Alternatively, the rotor blades may differ in height (H), thickness (T), and/or angle. Preferably, the rotor blades (23) towards the pump inlet have a larger surface area and a more open angle towards the pump inlet, than the rotor blades (23) towards the pump outlet. Advantageously this enables the rotor blades (23) towards the pump inlet to have a larger surface area and thus a

greater frequency of interactions with gas molecules, propelling them into and through the pump. Likewise, the spaces (24) may be substantially uniform or may differ. This enables the pumping characteristics to be varied throughout the stack to achieve optimal pump performance.

5

The multiblade arrays (21) may comprise a metallic material or a fibre-reinforced composite material. The coupling portion (26) may be formed from a separate part incorporated as part of the lamination process, or may be formed during the final moulding operation.

10

The multiblade array (21) may be manufactured by being punched, cut, machined, extruded, moulded, stitched, laid up, photo etched, or additively manufactured from a source material.

15

As illustrated in Figs. 6 and 7, a multiblade array (21) as shown in Fig. 5 may be coupled to a substantially tubular hub (27). The tubular hub (27) has a longitudinal axis (A). The tubular hub (27) further comprises an inner surface (28) and an outer surface (29).

20

The tubular hub (27) further comprises a plurality of grooves (30) dimensioned to receive at least one multiblade array (21) therein. The grooves (30) are substantially evenly circumferentially spaced around the outer surface (29). The grooves (30) are substantially helical in shape. The shape of each groove (30) is substantially uniform.

25

The grooves (30) each comprise a longitudinal opening (31), wherein the longitudinal opening (31) extends the entire length of the groove (30). The longitudinal opening (31) having a substantially uniform width, wherein the width is narrower than the maximum diameter of the coupling portion (26) of a longitudinal spine (22). The groove (30) comprises a portion having a maximum diameter that is wider than the coupling portion (26) of the spine (22) and is dimensioned to receive said coupling portion (26) therein.

30

The tubular hub (27) may be produced by machining, preferably by turning or milling, and may comprise a metallic material, preferably an aluminium alloy.

5 The tubular hub (27) of Fig. 6 comprises grooves (30) that extend from a first end to a second distal end of the tubular hub (27). In an alternative embodiment, the tubular hub (27) of Fig. 7 comprises grooves (30) that extend only a portion of the length of the tubular hub (27).

10 As illustrated in Fig. 8, a tubular hub (27) comprising a plurality of grooves (30), wherein each groove (30) receives a multiblade array (21) such that the rotor blades (23) of each multiblade array (21) extend substantially radially outwardly through the longitudinal opening (31) of each groove (30). Each multiblade array (21) comprises a plurality of rotor blades (23), wherein each rotor blade
15 of the array (21) forms part of a different rotor stage of the rotor stack (32).

The rotor stack (32) comprises a first blade angle region (33) in which all of the grooves (30) are evenly spaced and follow a first substantially helical path. The rotor stack (32) further comprises a second blade angle region (34) in which all
20 of the grooves (30) are substantially evenly circumferentially spaced and follow a second substantially helical path. The multiblade arrays (21) of the first (33) and second (34) blade angle regions are different.

The benefit of having multiple blade angle regions (33,34) is that the pump
25 characteristics may be changed along the length of the rotor stack (32) by having specific blade angles. Furthermore, it enables easy removal and maintenance of the multiblade arrays (21).

To assemble the rotor stack (32), a tubular hub (27) according to the invention
30 must be provided. The first step is to couple a first multiblade array (21) to a groove (30) by inserting said array (21) longitudinally into the groove (30). This step may then be repeated until each groove (30) has a multiblade array (21)

- 30 -

coupled to it. Additionally, or alternatively, each groove (30) may be dimensioned to receive more than one multiblade array (21) longitudinally therein, in an end-to-end configuration. In this case, the assembly process may comprise the step of inserting a further multiblade array (21) into each groove (30).

5

The skilled person will appreciate that although Figs. 5-8 only exhibit components for a rotor stack, the above disclosure also applies to a stator stack *mutatis mutandis*.

10

It will be appreciated that various modifications may be made to the embodiments shown without departing from the spirit and scope of the invention as defined by the accompanying claims as interpreted under patent law.

REFERENCE KEY

	1. Rotor stage
	2. Rotor blade
	3. Preformed laminate layer
5	4. Main body
	5. Bore
	6. Leading face
	7. Trailing face
	8. Blade tip face
10	9. Conduit
	10. Blade portion
	11. Annular ring
	12. First end
	13. Topside surface
15	14. First edge
	15. Second edge
	16. Tip face
	17. Second end
	18. Aperture
20	19. Exposed underside surface
	20. Exposed topside surface
	21. Multiblade array
	22. Longitudinal spine
	23. Rotor blades
25	24. Space
	25. Support portion
	26. Coupling portion
	27. Tubular hub
	28. Inner surface
30	29. Outer surface
	30. Groove
	31. Longitudinal opening
	32. Rotor stack

Claims

1. A rotor or stator stage for a vacuum pump, the rotor or stator stage comprising an array of radially extending rotor or stator blades, wherein the rotor or stator stage is made from two or more preformed laminate layers, and wherein two or more of said preformed laminate layers comprise a portion of every radially extending rotor or stator blade of the rotor or stator stage.
2. The rotor or stator stage according to any preceding claim wherein each laminate layer is rotationally offset from each adjacent laminate layer about the longitudinal axis of the rotor or stator stage, preferably after laminate layers forming the rotor or stator stage have been stacked and/or before adjacent layers are substantially permanently affixed to each other.
3. The rotor or stator stage according to claim 1 or 2, wherein the preformed laminate layers each comprise a substantially annular or disk-like section from which the radially extending rotor or stator blade portions extend, wherein two or more of said preformed laminate layers include at least two apertures, said at least two apertures perforating said preformed laminate layer, preferably said substantially annular or disk-like section or said radially extending rotor or stator blade portions.
4. The rotor or stator stage according to claim 1 or 2 or 3, comprising two or more longitudinally extending rods, each rod passing through at least one of said preformed laminate layers, preferably two or more of said preformed laminate layers, preferably all of said preformed laminate layers.
5. The rotor or stator stage according to claim 4 when dependent upon claim 3, wherein two or more of said longitudinally extending rods are located within said apertures, preferably wherein each rod passes through the

apertures of two or more adjacent laminate layers, preferably wherein each rod passes through an aperture of each preformed laminate layer.

5 6. The rotor or stator stage according to claims 4 or 5 wherein said rods are substantially linear or helical.

7. The rotor or stator stage according to any preceding claim, wherein the leading face and/or the trailing face of each rotor or stator blade has a stepped profile, and wherein the leading edge and/or the trailing edge of
10 two adjacent preformed laminate layers have different shapes.

8. The rotor or stator blade stage according to any preceding claim, wherein the preformed laminate layers comprise a composite material, preferably a fibre reinforced composite material.
15

9. A method of assembling a rotor or stator stage of a vacuum pump, the rotor or stator stage comprising an array of radially extending blades, the method comprising the steps of:

20 a. providing two or more preformed laminate layers, each preformed laminate layer comprising a portion of every radially extending blade of the rotor or stator stage,

b. stacking two or more of the preformed laminate layers,

c. optionally rotating one or more of the preformed laminate layers about its longitudinal axis, and

25 d. affixing adjacent layers to form the rotor or stator stage.

10. A method according to claim 9, further comprising the step of providing two or more rods, and stacking the two or more preformed laminate layers in step b) by passing each rod through at least one aperture in each preformed
30 laminate layer.

11. A multiblade array for a vacuum pump comprising a rotor and stator stack, each stack comprising a plurality of rotor or stator stages and each rotor or stator stage comprising an series of radially extending rotor or stator blades, said multiblade array comprising a longitudinal spine with a series of either rotor or stator blades extending therefrom, wherein each blade of the multiblade array corresponds to a different stage of the rotor or stator stack.
12. The multiblade array according to claim 11 wherein the spine is configured to couple the multiblade array to a main body of the rotor or stator stack.
13. The multiblade array according to claim 11 or 12 wherein spaces between adjacent rotor or stator blades on the spine are configured to receive a stage of the other of the rotor or stator stack.
14. A stator or rotor stack for a vacuum pump, the stack comprising a substantially tubular hub and plurality of multiblade arrays according claims 11 to 13 coupled to the hub.
15. A rotor stack hub for the impeller of a vacuum pump comprising a plurality of rotor stages, the rotor stack hub comprising a substantially cylindrical, preferably tubular, main body, said main body comprising a series of substantially circumferentially uniformly spaced couplings located on an outwardly facing longitudinally extending surface thereof, each coupling being configured to couple to a multiblade array comprising rotor blades for two or more rotor stages, and wherein the number of couplings in the series is equal to the number of rotor blades in the two or more rotor stages, preferably wherein each coupling comprises a longitudinally extending conduit or prominence, preferably a helical conduit or prominence.

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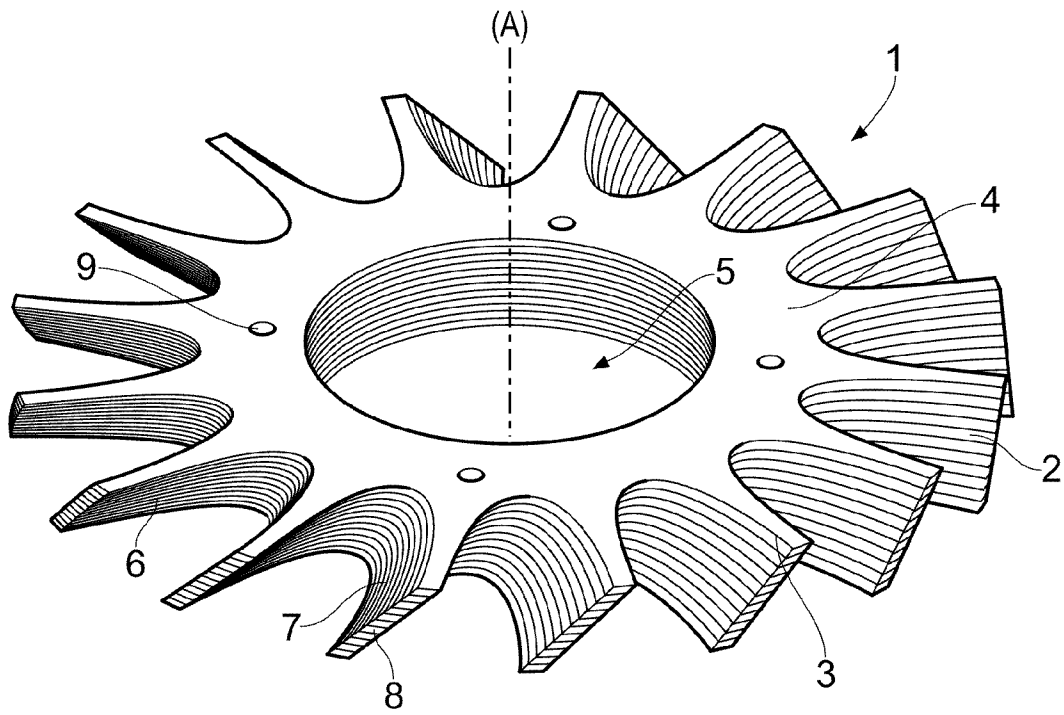


FIG. 1

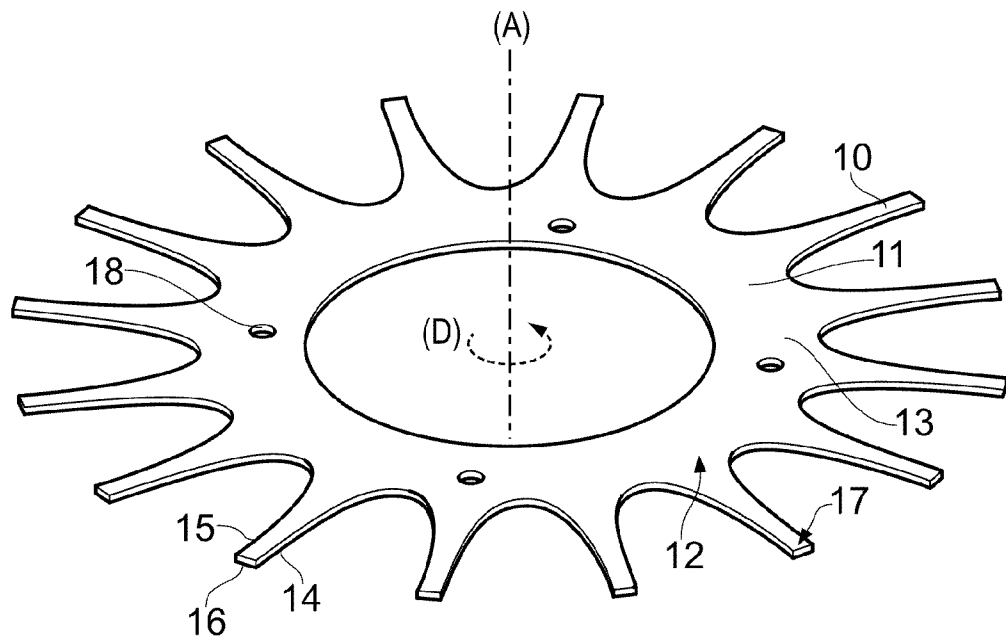


FIG. 2

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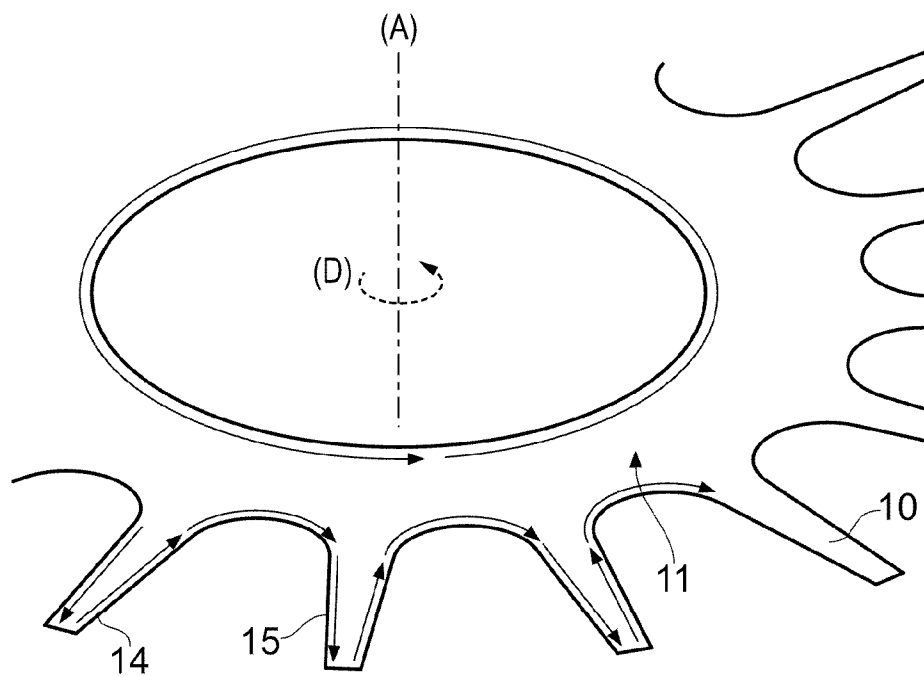


FIG. 3

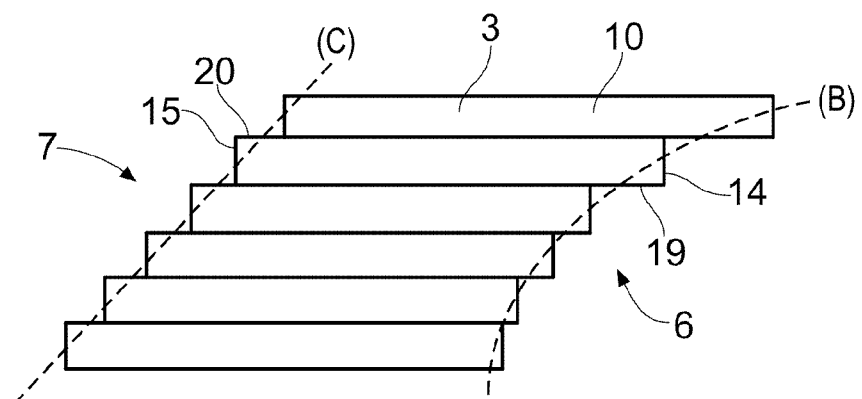


FIG. 4

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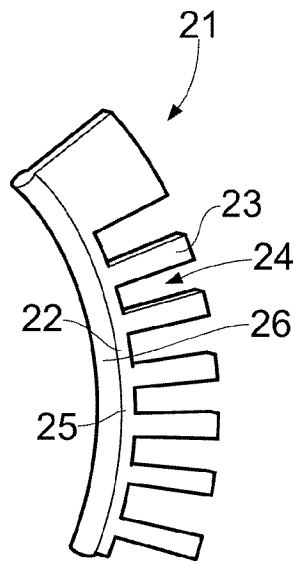


FIG. 5

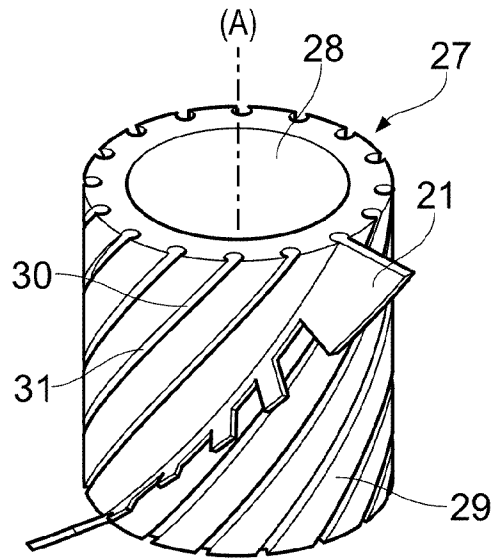


FIG. 6

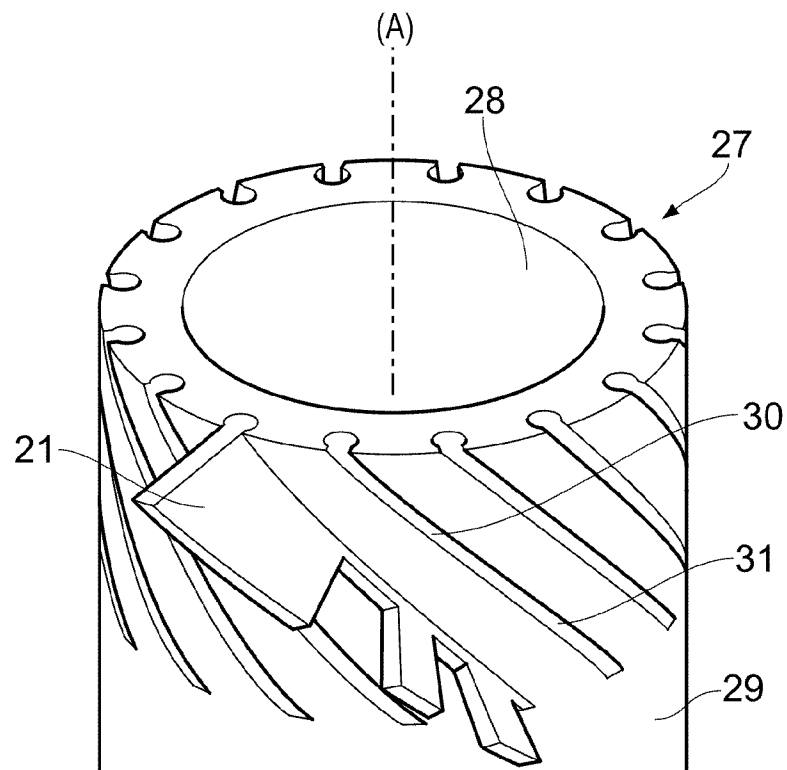


FIG. 7

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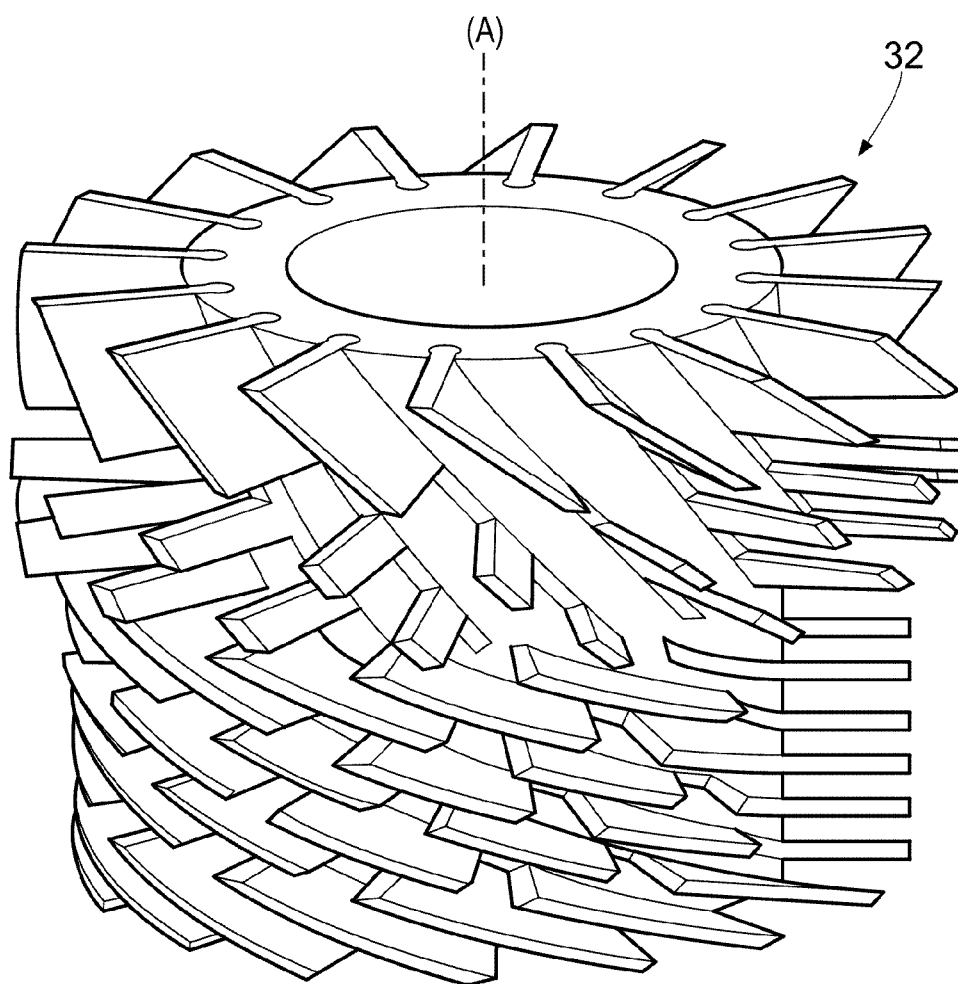


FIG. 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2020/051165

A. CLASSIFICATION OF SUBJECT MATTER INV. F04D19/04 F04D29/02 F04D29/32 F04D29/54 ADD.		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) F04D		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal, WPI Data		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 1 850 011 A2 (PFEIFFER VACUUM GMBH [DE]) 31 October 2007 (2007-10-31) paragraph [0001] paragraph [0021] - paragraph [0023] figures 1-3	1-10
X	JP H09 303288 A (DAIKIN IND LTD) 25 November 1997 (1997-11-25) abstract figures 2, 3	1-10
X A	US 2018/100510 A1 (HÖLZER RAINER [DE] ET AL) 12 April 2018 (2018-04-12) paragraph [0037] - paragraph [0044] figure 1 ----- -/-	1,3-6, 8-10 2,7
☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 21 September 2020		Date of mailing of the international search report 22/10/2020
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Oliveira, Damien

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2020/051165

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP H01 237395 A (DAIKIN IND LTD) 21 September 1989 (1989-09-21)	11-15
A	abstract figures 1, 7 -----	1-10
X	JP S54 117919 A (OSAKA SHINKU KIKI SEISAKUSHO) 13 September 1979 (1979-09-13)	11-14
A	abstract figures 1, 3 -----	1-10, 15
A	US 6 619 911 B1 (ENGLAENDER HEINRICH [DE] ET AL) 16 September 2003 (2003-09-16) column 3, line 16 - line 34 figures 1-2e, 6a-6d -----	1-15
A	EP 3 093 496 A1 (PFEIFFER VACUUM GMBH [DE]) 16 November 2016 (2016-11-16) paragraph [0063] - paragraph [0066]; figures 1, 4, 7 -----	1-15
A	DE 20 2015 004001 U1 (OERLIKON LEYBOLD VACUUM GMBH [DE]) 12 September 2016 (2016-09-12) paragraph [0005] - paragraph [0007] -----	1-10

INTERNATIONAL SEARCH REPORT

International application No.
PCT/GB2020/051165

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☒ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-10

Rotor or stator stage for a vacuum pump made from at least two preformed laminate layers.

2. claims: 11-15

Multiblade array for a vacuum pump comprising rotor or stator blades of different stages attached together by a spine to be coupled to a hub, each blade corresponding to a different stage.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2020/051165

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