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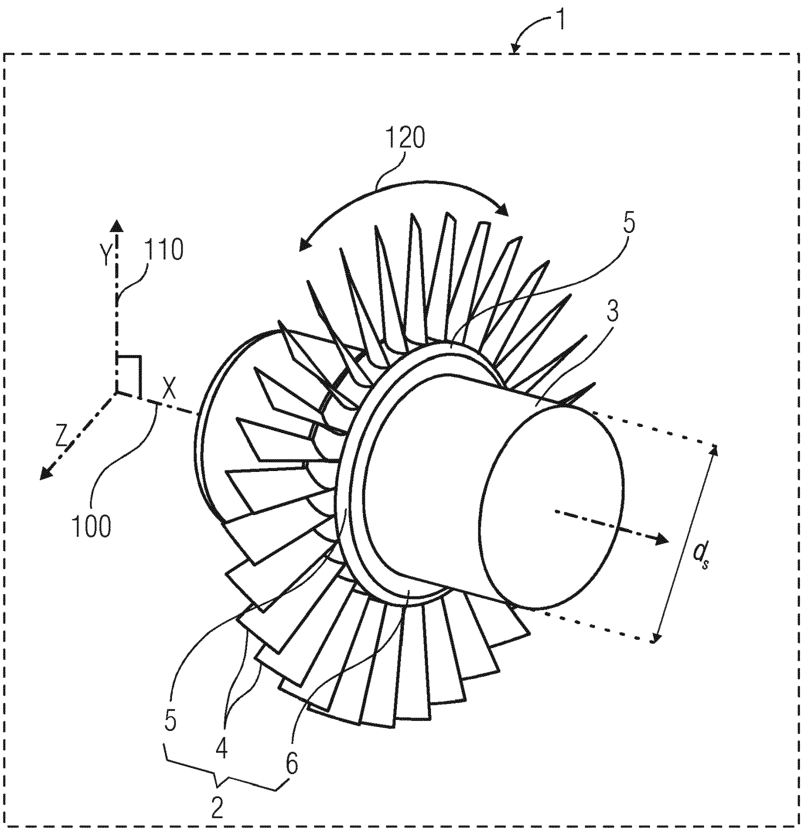
(54) A rotor unit for a turbomachine and a method for construction thereof

(57) For creating a rotor unit (1) for a turbomachine, the rotor unit (1) comprising a blade module (2) comprising a hub (5) and a plurality of blades (4), wherein the plurality of blades (4) is disposed on the hub (5), and an axial shaft module (3), wherein the axial shaft module (3) is connected to the blade module (2), which has a stable and a simple design, it is proposed that the plurality of the blades (4) and the hub (5) are integral to each other.

FIG 1



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Description

[0001] The present invention relates to a rotor unit for a turbomachine comprising a blade module comprising a hub and a plurality of blades, wherein the plurality of blades is disposed on the hub and an axial shaft module, wherein the axial shaft module is connected to the blade module.

[0002] The present invention also relates to a method for construction of a rotor unit for a turbomachine wherein the rotor unit is provided with a blade module comprising a hub and a plurality of blades and an axial shaft module.

[0003] Such a turbomachine and such a method are known to skilled person.

[0004] A turbomachine is a rotary mechanical device wherein mechanical energy from a fluid flow is converted into electric power by means of a generator comprised in the turbomachine. Examples of such turbomachines include steam turbines, gas turbines, et cetera. The turbomachine comprises a moving part termed as a rotor and a stationary part termed as a stator. The rotor in turn consists of an axial shaft whereon a multitude of blades is disposed. The rotor unit comprises a plurality of stages, wherein the stages are arranged contiguously in an axial direction. Each stage of the rotor comprises a portion of the axial shaft whereon a plurality of blades is disposed in a circumferential direction. Therefore, an assembly of blades for the turbomachine extends both axially and circumferentially.

[0005] The number of blades comprised in a certain stage, and/or the number of stages comprised in the rotor for the turbomachine depends on the design of the turbomachine, application of the turbomachine, and the intended power output of the turbomachine. The moving fluid however acts on the blades, imparts rotational energy to the rotor, thereby enabling the generation of power.

[0006] It is known that each of the blades for respective rotor units is individually assembled and coupled to the respective axial shaft portion. Each blade is provided with a root portion shaped as a fir-tree serration, T-root joint, fork root, et cetera, for the purpose of affixing the blade to the axial shaft portion. The axial shaft portion is provided with a complementary space, which is profiled to accommodate the root portion of the blade. Thereafter, the blade is coupled to the axial shaft portion using any of the well-known coupling techniques, such as flanges, tie bolts, rivets, welding, brazing, et cetera. Thereafter, other blades are disposed in a similar manner, in order to obtain a certain stage of the rotor.

[0007] The aforementioned assembly of the rotor unit leads to stress concentrations in those specific root fixity regions, where the rotor and blade are coupled to each other. The stress concentrations can lead to potential failures in the form of cracks, blade dislodgement, undesired blade vibrations (which are caused due to loosening of the blades), rotor stability, et cetera, during the operation of the turbomachine. Additionally, the blades are always prone to fretting at the root portions due to a discontinuous profile at the blade root-shaft interface. This increases the possibility of blade loosening and eventual dislodgement during the operation of the turbomachine, and such occurrences can hamper the operation of the turbomachine, thereby leading to equipment losses and shutting down of the turbomachine.

[0008] The object of the present invention is to provide a rotor unit of the aforementioned kind which has a stable and a simple design.

[0009] Regarding the rotor unit, the aforementioned objective is achieved as the plurality of blades and the hub that are integral to each other.

[0010] According to the present invention a rotor unit for a turbomachine comprises a blade module and an axial shaft module, which are connected with each other. Herein, the blade module and the axial shaft module are connected such that proper rotary operation of the rotor unit is enabled, i.e. the connecting force between the blade module and the axial shaft module is greater than the rotational forces experienced by the rotor unit during the operation of the turbomachine.

[0011] The blade module comprises a plurality of blades and a hub, where the plurality of blades and the hub are integral to each other. For example, the blade module can comprise any number of blades, for example, eight blades, sixteen blades, twenty blades, et cetera.

[0012] The plurality of blades is not capable of being dismantled as a separate part from the hub under normal operating conditions, because the plurality of blades and the hub are integral to each other. Since the plurality of the blades and the hub are integral to each other, the rotor unit has considerable strength benefits in comparison with the blades held individually with a rotor by root serrations. In this way, stress concentrations and fretting at the root of the blades is prevented due to the integral nature of the plurality of blades and the hub.

[0013] According to an embodiment of the invention, a material of the plurality of blades is identical to a material of the hub. Since the materials are identical, the mechanical coupling of the plurality of blades and the hub is further enhanced, leading to an increased robustness of the blade module. Therewith, a homogenous blade module is obtained, which is capable of being manufactured easily, and such a blade module also offers enhanced resistance against thermal stresses.

[0014] According to another embodiment of the invention, the hub is annular. According to yet another embodiment of the invention, the plurality of blades is annularly disposed on the hub. Popular time-saving and efficient machining techniques such as 360° machining techniques can be applied advantageously, in order to obtain the annular hub and the annular disposition of the blades.

[0015] According to yet another embodiment of the invention, the blade module further comprises a support rim. The support rim extends in an axial as well as in the circumferential direction, and is further arranged to contact the axial shaft module. The support rim is beneficial for increasing the area of coupling between the axial shaft module and the blade module. The support rim is an axial and a circumferential extension of the hub. The support rim also extends in accordance with a contour of the hub. The area of coupling comprises inner surfaces of the support rim and the hub, and the outer surface of the axial shaft module. By increasing the area of coupling, a frictional force between the blade module and the axial shaft module is increasable, wherewith an enhanced coupling strength is achievable, which is beneficial in preventing the slippage between the blade module and the axial shaft module during the operation of the rotor unit. An increased area of coupling provides enhanced coupling strength to the blade module and the axial shaft module.

[0016] According to yet another embodiment of the invention, the support rim is integral to the hub. Therewith, greater strength and sturdiness of the blade module are achieved. Advantageously, techniques such as shrink-fitting can be employed to clamp the blade module to the axial shaft module, which increases the simplicity of production of the rotor units.

[0017] According to yet another embodiment of the invention, the hub comprises a cooling channel. A coolant fluid is dispensable into the cooling channel during an operation of the rotor unit for cooling the plurality of the blades. This is beneficial in keeping the rotor unit at an optimal temperature during the operation of the rotor unit. Therewith, any malfunctioning arising out of overheating of the blade module can be avoided.

[0018] Regarding the aforementioned method the object of the invention is solved by manufacturing the blade module, such that the plurality of blades is disposed on the hub, and wherein the plurality of blades and the hub are integral to each other. The blade module and the axial shaft module are connected to each other. Since the plurality of the blades and the hub are manufactured such that the plurality of the blades and the hub are integral to each other, the strength of the rotor unit is enhanced as compared to a rotor unit comprising the blades, wherein the blades are held individually on a shaft using root serrations. Thus, stress concentrations and fretting at the root of the blades are prevented due to the integral nature of the plurality of blades and the hub.

[0019] According to an embodiment of the method, the blade module is shrink-fitted onto the axial shaft module. Shrink fitting is a simple and a cost-effective mechanical process of manufacturing the rotor unit. Furthermore, it is beneficial for reducing the production time for the rotor unit.

[0020] According to another embodiment of the method, the blade module is fabricated monolithically. This is beneficial for obtaining a homogenous blade module, which offers enhanced resistance against thermal stresses. According to yet another embodiment of the method, the monolithic fabrication of the blade module is achieved by any of the processes such as casting, laser sintering, moulding, machining, Electrical Discharge Machining, forging, or welding. The aforementioned processes are well-known processes, wherewith the time required for machining and production of such a blade module is considerably reduced.

[0021] The aforementioned and other embodiments of the present invention related to a rotor unit for a turbomachine and a method for construction of the rotor unit will now be addressed with reference to the accompanying drawings of the present invention. The illustrated embodiments are intended to illustrate, but not to limit the invention. The accompanying drawings herewith contain the following figures, in which like numbers refer to like parts, throughout the description and drawings.

[0022] The figures illustrate in a schematic manner further examples of the embodiments of the invention, in which:

FIG 1	depicts a perspective view of a rotor unit for a turbomachine in accordance with one or more embodiments of the present invention,
FIG 2	depicts a monolithic fabrication process for obtaining a blade module for the rotor unit referred to in FIG 1,
FIG 3	depicts a cross-sectional view of the blade module referred to in FIG 2,
FIG 4	depicts a flowchart of a method for construction of the rotor unit referred to in FIG 1,
FIG 5a	depicts an intermediate step of fabrication of the rotor unit referred to in FIG 1 according to a certain embodiment of the method referred to in FIG 4, and
FIG 5b	depicts the final step of fabrication of the rotor unit referred to in FIG 1 according to a certain embodiment of the method referred to in FIG 4.

[0023] FIG 1 shows an embodiment of the rotor unit 1 according to the invention in a perspective view.

[0024] The rotor unit 1 is part of a turbomachine (not depicted), such as a gas turbine, a steam turbine, a combined cycle power plant, et cetera.

[0025] A blade module 2 and an axial shaft module 3 are comprised in the rotor unit 1. The axial shaft module 3 is a portion of the axial shaft (not depicted) of the said turbomachine. Herein, the blade module 2 is disposed on the axial shaft module 3. The axial shaft module 3 has a diameter 'd_S', and the axial shaft module 3 extends along a longitudinal axis 100 of the turbomachine. The longitudinal axis 100 is 'a rotational axis' of the turbomachine. The blade module 2 and the axial shaft module 3 are further connected together for enabling the operation of the rotor unit 1. Herein the rotor unit 1 rotates along a circumferential direction 120 during the operation of the turbomachine.

[0026] Herein, the blade module 2 comprises a plurality of blades 4, a hub 5 and a support rim 6. The hub 5 is annular, and the plurality of blades 4 is annularly disposed on the hub 5. Each of the plurality of blades 4 extends both axially and radially. The support rim 6 is a part of the hub 5, and the support rim 6 extends both circumferentially and axially. The support rim 6 is present in a coupling region, i.e. the region where the blade module 2 and the axial shaft module 3 are connected to each other, and the support rim 6 is beneficial as this increases the surface area of contact between the blade module 2 and the axial shaft module 3 which in turn leads to an increased area of coupling, wherewith a tight coupling between the blade module 2 and the axial shaft module 3 is achievable.

[0027] FIG 2 depicts an exemplary monolithic fabrication process for the blade module 2.

[0028] FIG 1 is also referred to herein for the purpose of elucidation of FIG 2. In accordance with an embodiment, the blade module 2 is fabricated from an annular ring 7, and the annular ring 7 is a monolithic component. The annular ring 7 is provided as an input to a machining system 20, and the blade module 2 is obtained as an output of the machining system 20.

[0029] The annular ring 7 has an inner diameter 'd_{B1}' and an outer diameter of 'D_0'. The annular ring 7 preferably comprises two concentric regions, viz. a first region 8 and a second region 9, which are capable of being machined to form the blade module 2. Herein, the second region 9 surrounds the first region 8. According to an aspect of the present invention, the machining system 20 is configured to machine the annular ring 7 such that the plurality of blades 4 is machined out of the second region 9, and the hub is machined out of the first region, in order to obtain the integrated blade module 2. The integral aspect of the blade module 2 is noticeable in FIG 3 and elucidated therein.

[0030] Furthermore, the support rim 6 is also obtained by machining the first region 8. Herein, the machining system 20 is a 360° machining tool such as a lathe, which is well known in the art. However, it may be noted that other machining tools and techniques may be used for the purpose of machining the annular ring 7 for the purpose of obtainment of the blade module 2. It may be noted herein that the inner diameter of the blade module 2 is also 'd_{B1}'.

[0031] Herein, according to another aspect of the present invention, the annular ring 7 preferably consists of a single material, which can be for example, a metal, an alloy, or a composite material. Therefore, the hub 5 and the plurality of blades 4, which are obtained after machining the annular ring 7, are also made of the same material.

[0032] Without loss of generality, the monolithic fabrication of the blade module 2 can also be achieved by other well-known techniques, such as die-casting, laser sintering, moulding, Electrical Discharge Machining, forging and welding, etc.

[0033] FIG 3 depicts a cross-sectional view of the blade module 2 along a section III-III as depicted in FIG 2.

[0034] The preceding FIGURES are also referred to herein for the purpose of elucidation of FIG 3. A view shown in FIG 3 is of a pair of antipodal blades which is integral to the hub 5.

[0035] It may be noted herein that the fabrication of the blade module 2 is such that root portions 11 of the respective blades are integrated into the hub 5, which in turn increases the robustness, and strength of the blade module 2. Furthermore, the probability of dislodgement of a certain blade during the operation of the rotor unit 1 is reduced further, thereby increasing the stability of the rotor unit 1.

[0036] The hub 5 also comprises a cooling channel 10, wherein the cooling channel 10 extends circumferentially along the hub 5. Furthermore, the cooling channel 10 is located internal to the hub 5, and the cooling channel 10 is also located proximal to the root portions 11 of the plurality of blades 4. A coolant fluid may be circulated within the cooling channel 10 for cooling the blade module 2, especially the root portions 11 of the plurality of blades 4, during the operation of the rotor unit 1.

[0037] FIG 4 depicts a flowchart 40 for a method for construction of the rotor unit 1.

[0038] Cross-references are also made to the preceding FIGURES for the purpose of elucidation of FIG 4.

[0039] In step 42, the blade module 2 is manufactured from the annular ring 7. The annular ring 7 is 360°-machined to obtain the plurality of blades 4 and the hub 5. The annular ring 7 is 360°-machined, such that plurality of blades 4 is integrally disposed on the hub 5, wherewith the plurality of blades 4 and the hub 5 form a monolithic component. The annular ring 7 is 360°-machined by techniques, such as die-casting, laser sintering, moulding, Electrical Discharge Machining, forging and welding, etc.

[0040] In a subsequent step 44, the axial shaft module 3 is provided. In the next step 46, the blade module 2 and the axial shaft module 3 are connected to each other. The blade module 2 and the axial shaft module 3 are connected to each other by an exemplary shrink fitting process. An overview of the shrink fitting process is elucidated with reference to FIGS 5a and 5b.

[0041] Referring to FIG 5a, which depicts an intermediate step of the shrink-fitting process, the blade module 2 is heated along the hub 5, such that the inner diameter of the blade module 2 is increased to d_{B2} (i.e. $d_{B2} > d_{B1}$). Herein, the diameter 'd_S' of the axial shaft module 3 however remains a constant. The axial shaft module 3 and the blade module 2 are then arranged, such that the blade module 2 (with the increased diameter d_{B2}) is annularly disposed on the axial shaft module 3. The blade module 2 is then coupled with the axial shaft module 3 at a user-desired region and the blade module 2 is subsequently cooled to achieve a tight fit.

[0042] Referring to FIG 5b, the blade module 2 is clamped on to the axial shaft module 3. This figure depicts a final step of the shrink-fitting process, the blade module 2 is cooled, such that the inner diameter of the blade module 2 is reduced to d_{B3}, wherein $d_{B2} > d_{B3} > d_{B1}$. Herein, the final inner diameter d_{B3} of the blade module 2 is however marginally greater than the diameter d_S of the axial shaft module 3. In FIG 5b the shrink fittable attribute of the blade module 2 increases the robustness of the rotor unit 1, because the strength of coupling between the axial shaft module 3 and the blade module 2 is enhanced.

[0043] In the embodiment shown in FIG 5b the blade module 2 and the axial shaft module 3 are made of the same material, wherewith the strength of coupling between the blade module 2 and the axial shaft module 3 is increased after the shrink-fitting process.

[0044] According to another aspect of the invention (not shown), the blade module 2 and the axial shaft module 3 can be connected to each other by welding also. The blade module 2 and the axial shaft module 3 can also be made of different materials.

[0045] Though the invention has been described herein with reference to specific embodiments, this description is not meant to be construed in a limiting sense. Various examples of the disclosed embodiments, as well as alternate embodiments of the invention, will become apparent to persons skilled in the art upon reference to the description of the invention. It is therefore contemplated that such modifications can be made without departing from the embodiments of the present invention as defined.

Claims

1. A rotor unit (1) for a turbomachine, the rotor unit (1) comprising:

- a blade module (2) comprising a hub (5) and a plurality of blades (4), wherein the plurality of blades (4) is disposed on the hub (5), and
- an axial shaft module (3), wherein the axial shaft module (3) is connected to the blade module (2),

characterized in that the plurality of the blades (4) and the hub (5) are integral to each other.

2. The rotor unit (1) according to claim 1, **characterized in that** a material of the plurality of blades (4) is identical to a material of the hub (5).

3. The rotor unit (1) according to claim 1 or 2, **characterized in that** the hub (5) is annular.

4. The rotor unit (1) according to claim 3, **characterized in that** the plurality of blades (4) is annularly disposed on the hub (5).

5. The rotor unit (1) according to any of the claims 1 to 4, **characterized in that** the blade module (2) further comprises a support rim (6), wherein the support rim (6) extends in an axial direction, and wherein the support rim (6) is further arranged to contact the axial shaft module (3).

6. The rotor unit (1) according to claim 5, **characterized in that** the support rim (6) further extends in a circumferential direction.

7. The rotor unit (1) according to claim 5 or 6, **characterized in that** the support rim (6) is integral to the hub (5).

8. The rotor unit (1) according to any of the claims 1 to 7, **characterized in that** a material of the blade module (2) is identical to a material of the axial shaft module (3).

9. The rotor unit (1) according to any of the claims 1 to 8, **characterized in that** the blade module (2) is clamped onto the axial shaft module (3).

10. The rotor unit (1) according to any of the claims 1 to 9, **characterized in that** the hub (5) comprises a cooling channel (10), wherein a coolant fluid is dispensable into the cooling channel (10) during an operation of the rotor unit (1) for cooling the plurality of the blades (4).

11. A method (40) for construction of a rotor unit (1) for a turbomachine,
wherein the rotor unit (1) is provided with:

- a blade module (2) comprising a hub (5) and a plurality of blades (4), and
- an axial shaft module (3),

the method (40) comprising:

- (42) manufacturing the blade module (2), such that the plurality of blades (4) is disposed on the hub (5), and wherein the plurality of blades (4) and the hub (5) are integral to each other, and
- (46) connecting the blade module (2) and the axial shaft module (3).

12. The method (40) according to claim 11, **characterized in that** connecting the blade module (2) and the axial shaft module (3) comprises shrink fitting the blade module (2) on the axial shaft module (3).

13. The method (40) according to claim 11 or 12, **characterized in that** (42) the blade module (2) is fabricated monolithically.

14. The method (40) according to claim 13, **characterized in that** a process for monolithically fabricating the blade module (2) is selected from a group comprising, casting, laser sintering, moulding, machining, Electrical Discharge Machining, forging and welding.

FIG 1

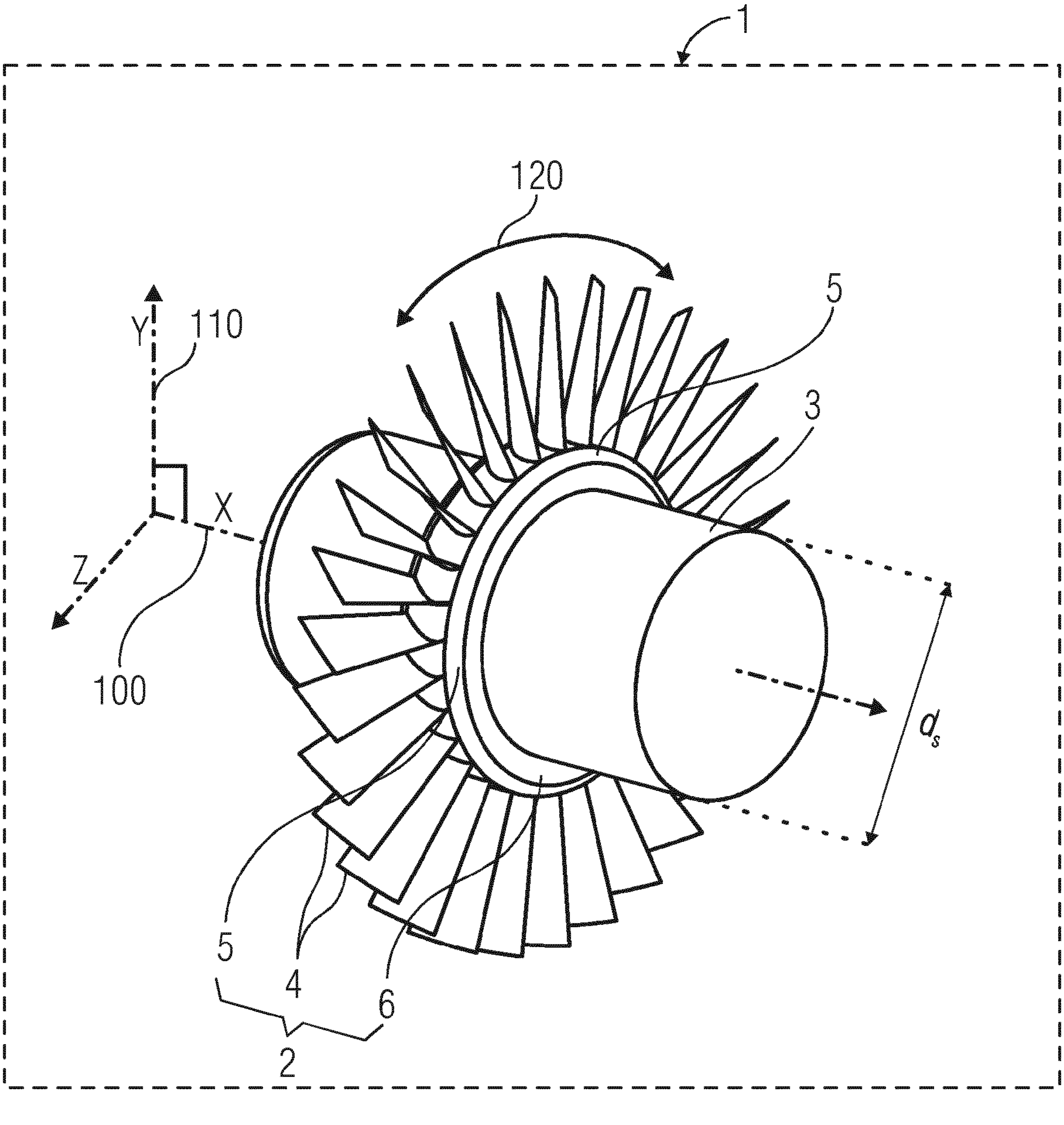


FIG 2

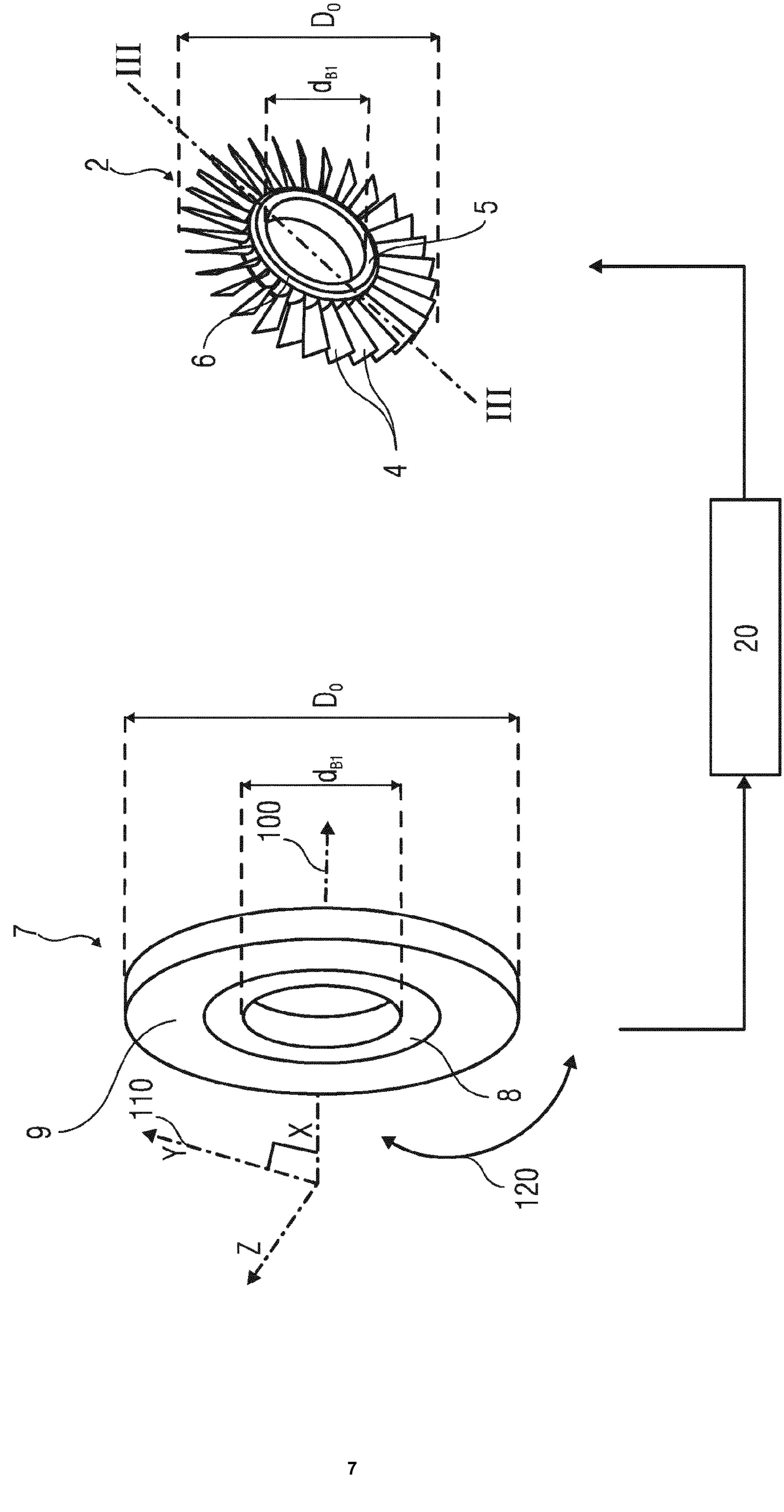


FIG 3

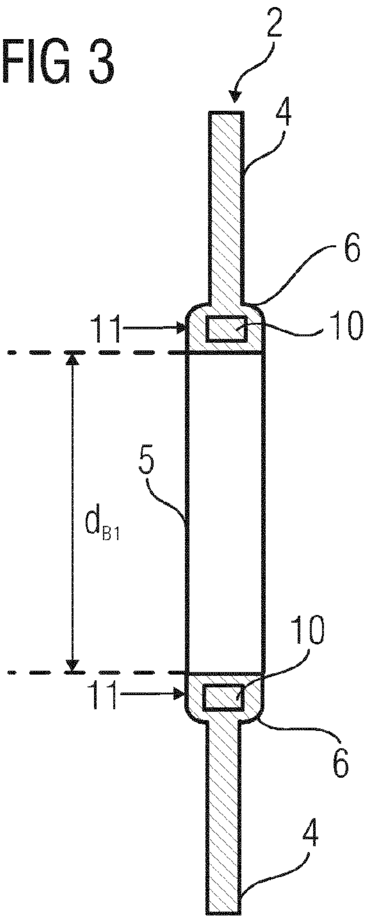


FIG 4

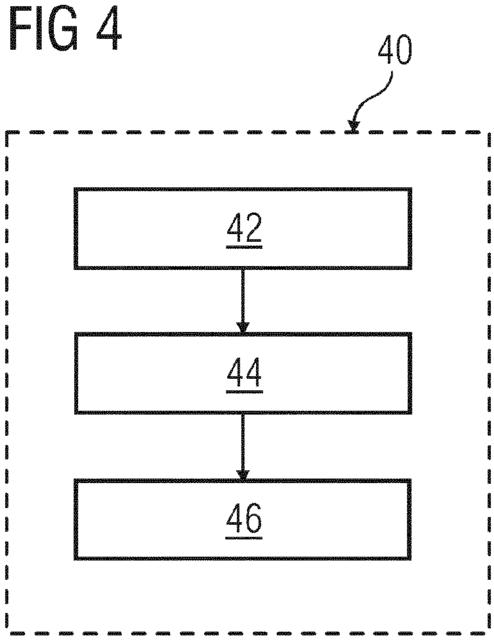


FIG 5A

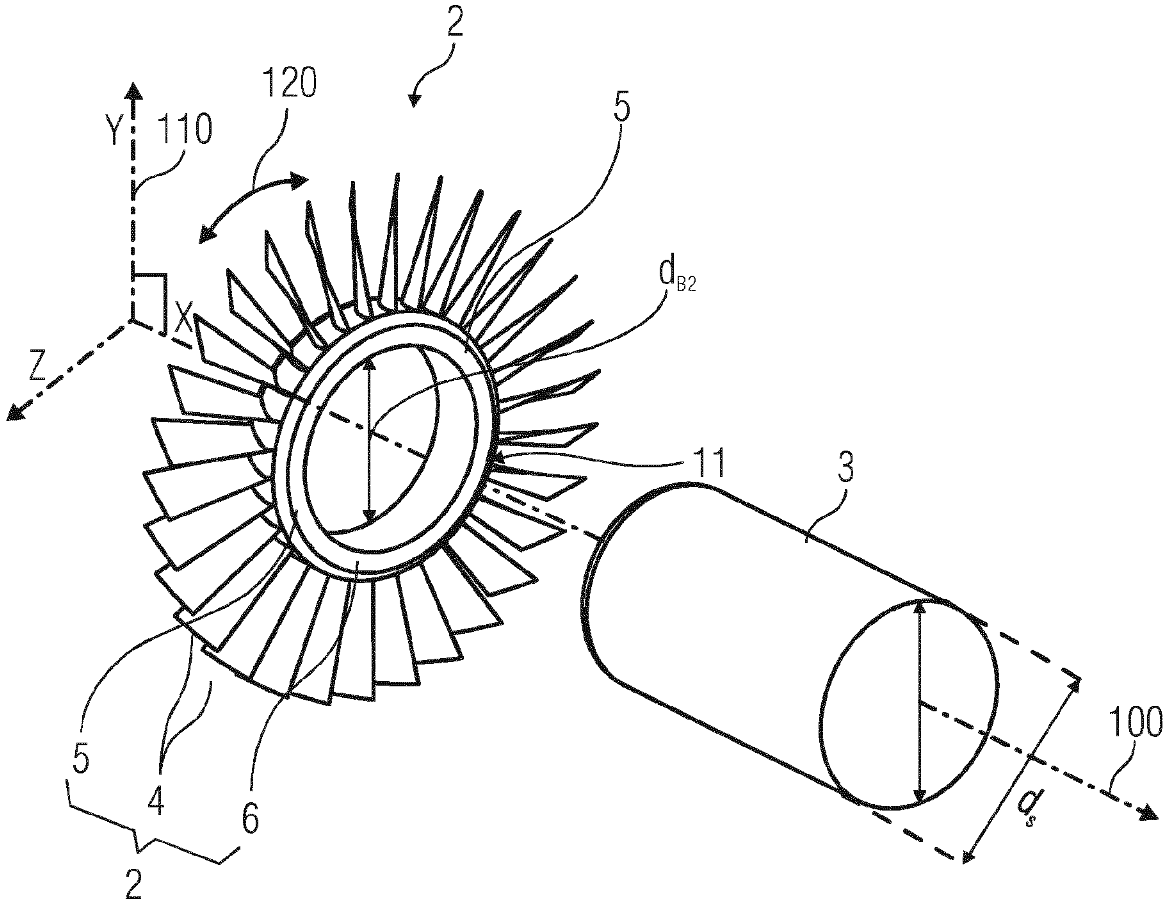
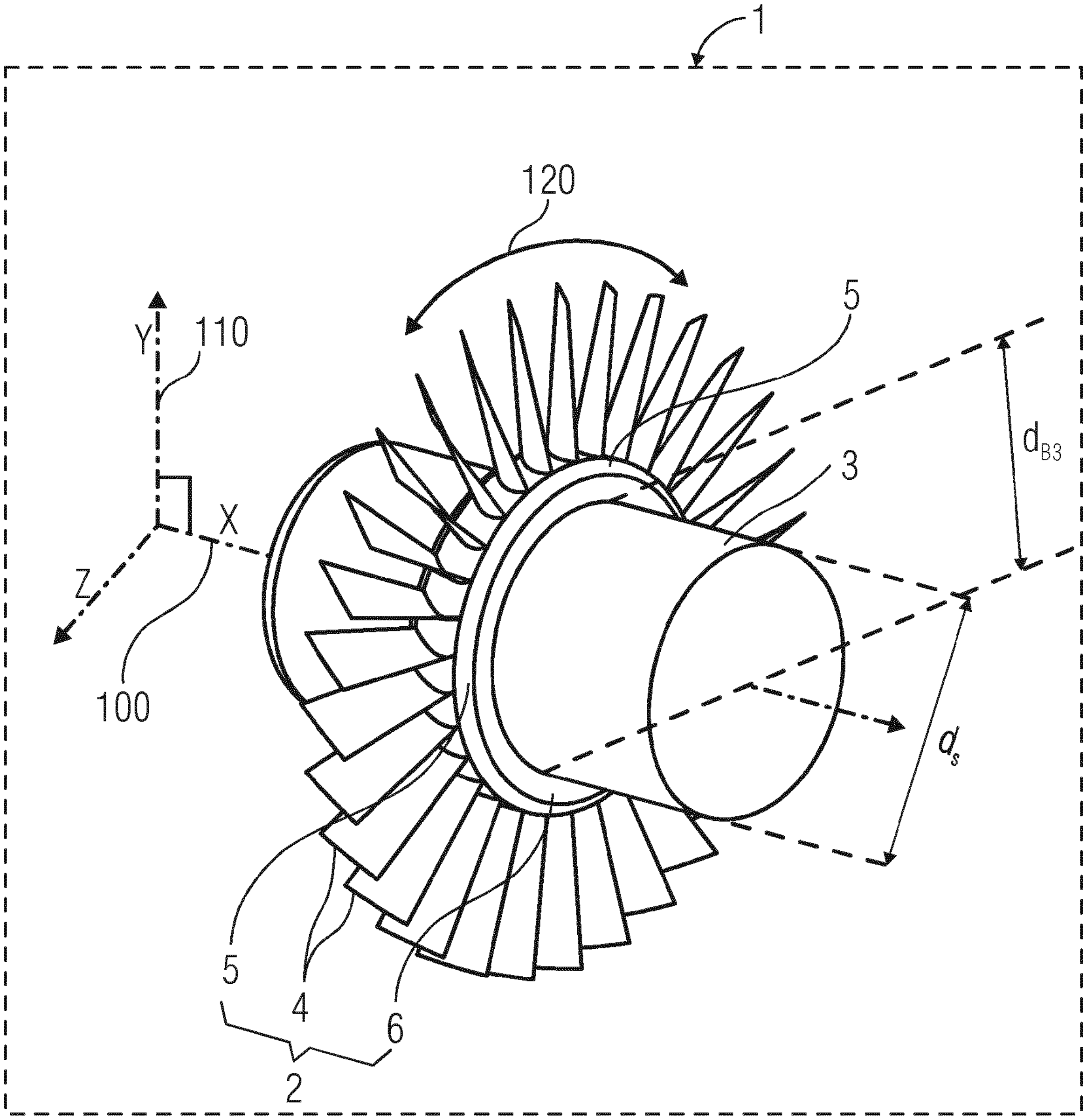


FIG 5B



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EUROPEAN SEARCH REPORT

Application Number
EP 14 17 2598

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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
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CATEGORY OF CITED DOCUMENTS

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