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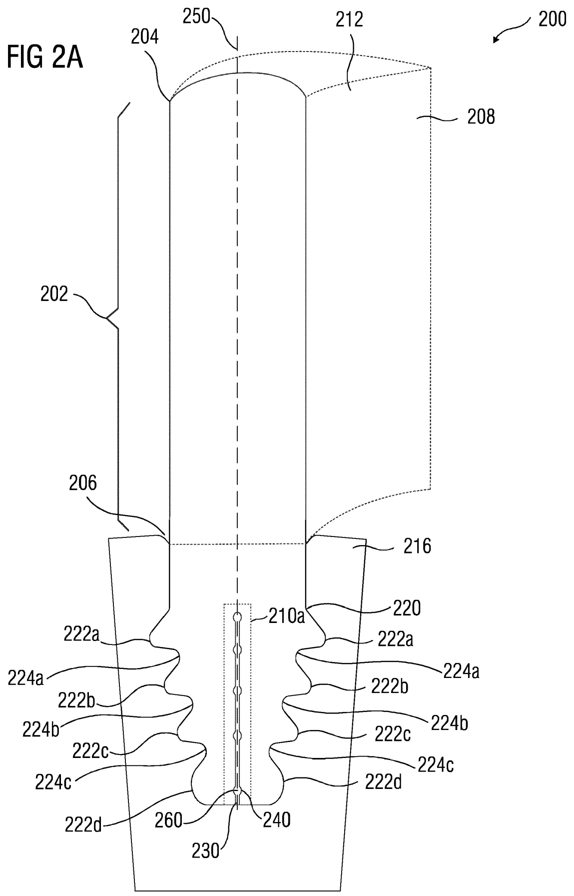
(54) TURBINE BLADE ASSEMBLY AND METHOD FOR MANUFACTURING SUCH BLADES

(57) A turbine blade assembly (200) for turbo-machines including a blade body (202) including a free end (204) and a joint end (206), the blade body (202) comprising an airfoil section along at least one side of the blade body extending from the joint end to the free end. Further, the turbine blade assembly includes a blade platform at the joint end (206) of the blade body, suitable to abut a disc of a turbo-machine; and a blade root (220) that extends from the blade platform towards the disc (216), the blade root (220) comprising a plurality of lugs (222a-222d) and a plurality of fillets (224a-224c). The turbine blade assembly characterised in that the blade root (220) comprise a stress reducing structure (210a, 210b) including at least one slot (230, 235) having one of a continuous and discon-tinuous profile capable of countering stress at the plurality of fillets (224a-224c).

FIG 2A



EP 3 575 556 A1

Description

[0001] The invention relates to turbine engines. More particularly, the invention relates turbine blade assembly and blade slot in a turbine engine.

[0002] A turbine blade is an important component in turbo-machines as it is responsible for the transfer of energy between a turbo-machine and an operating fluid. During operation, a turbine blade experiences a combination of centrifugal force and cantilever force. The combination of centrifugal force and cantilever force is transferred to a disc on which the turbine blade is mounted. The disc in operation is rotatable and can also be referred to as rotating disc. The transfer of forces on the disc is achieved by a joint between a blade root of the turbine blade and a blade slot in the disc that is itself attached to a shaft of the turbo-machine. The blade slot can also be referred to as disc slot as the disc has the disc slot to receive the blade root.

[0003] The blade root is mated with the blade slot through a joint. When the disc is in operation, the blade root of the turbine blade experiences stress concentration due to a high inertial load generated by weight of the turbine blade body. Further, aerodynamic load from the operating fluid contributes to the stress concentration on the blade root.

[0004] To reduce the stresses in the blade root, the contact surfaces are generally angled to a radial axis for optimal distribution of loads between the blade root and the rotating disc. Nevertheless, the stresses in the blade root adversely impact life of the turbine blade. For example, in case of a fir-tree profiled blade root, localized concentration of high stresses is seen in lugs at surfaces in contact with the rotating disc. The high stresses are also seen at fillets connecting the lugs in the fir-tree profiled blade root. The high stress act as source of crack initiation and hence limit the turbine blade life. For example, fillets experience high tensile stresses during operation. The tensile stresses adversely impact the life of the turbine blade as they tend to propagate and open cracks in the blade root.

[0005] Such blade roots with minimized stress concentration is disclosed in the publication "Turbine blade fir-tree root design optimization using intelligent CAD and finite element analysis", Computers & Structures, 2002: 1853-1867. The publication mainly focuses on geometric design and dimensioning of the fir-tree profile.

[0006] Therefore, it is an object of the present invention to provide a turbine blade assembly with improved useful life by minimizing the effect of the stress generated in the blade root. In an exemplary embodiment, the useful life is improved by reducing magnitude of the maximum tensile stresses observed in the blade root.

[0007] The invention achieves this object by a stress reducing structure including at least one bridge and at least one recess capable of countering stress at the fillets in the blade root. Further, the stress reducing structure is provided in the blade slot as the blade slot experiences similar stresses as that of the blade root. The region between two blade slots in the disc can exhibit behaviour as that of the blade root, when viewed from a radially inward direction. Thus, disc fillets in the blade slot between two disc lugs also experience tensile stresses. Accordingly, the stress reducing structure provided in the blade slots can therefore be used to reduce the stresses in the blade slots. This is advantageous as improving the life of the disc is desirable as replacing the disc can be expensive and cumbersome.

[0008] As used herein the "stress reducing structure" refers a pattern in the blade root or the blade slot or both, that can either be an inclusion or a void or a combination of both. The pattern is shaped to as a longitudinal slot that is continuous or discontinuous at predetermined intervals. The pattern can also include recess or holes in at the predetermined intervals.

[0009] As used herein the term "tensile stresses" refers to stress created when opposite forces are applied in opposing directions on the turbine blade assembly and the rotating disc. The tensile stress can be experienced in a hoop direction and a radial direction. The term tensile stress can also be referred to as tensile principal stress.

[0010] The term "hoop direction" refers to circumferential direction i.e. along a circumferential direction of the rotating disc. Stress experience in the hoop direction can be tensile stresses or compressive stresses.

[0011] As used herein the term "compressive stresses" refer to the stress created when opposite forces are applied in an inward direction on the turbine blade assembly and the rotating disc.

[0012] Further, the term "radial direction" refers to direction along the radius of the rotating disc. Stress experience in the radial direction can be tensile stresses or compressive stresses.

[0013] According to the present invention, a turbine blade assembly for turbo-machines is provided. Each turbine has multiple turbine blade assemblies assembled around the periphery of a turbine rotor to guide an operating fluid.

[0014] The turbine blade assembly includes a blade body with a free end and a joint end. The blade body includes an airfoil section along one side that extends from the joint end to the free end. The blade body also includes a shroud at the free end of the blade body. The turbine blade assembly also includes a blade platform at the joint end of the blade body. The blade platform is a section of the turbine blade assembly that abuts a disc of a turbo-machine.

[0015] Further, the turbine blade assembly includes a blade root that extends from the blade platform towards a disc. The disc in operation is rotatable and can also be referred to as rotating disc. The blade root is a section of the turbine blade assembly that is used to hold the blade body with the rotating disc. The disc includes a blade slot to receive the blade root. The blade slot can also be referred to as disc slot as the disc has the slot to receive the blade root.

[0016] Typically, the blade root is configured with several profile types such as dovetail, fir-tree, etc. In a preferred embodiment, the blade root has the fir tree profile that includes a plurality of fillets or necks that define a plurality of lugs.

[0017] The stress reducing structure shaped as a longitudinal slot is capable of countering tensile stress at the plurality of fillets. The stress reducing structure is advantageous as it effectively reduces the magnitude of tensile principal stress in the fillets of the blade root by generating a compressive force. The stress reducing structure also ensures an improved contact between the blade root and the disc to ensure reduced concentration of stresses at the contact interface between blade root and slot. The position, pattern, and dimensions of the stress reducing structure are optimized in order to minimize the tensile stress seen in the fillets.

[0018] According to an embodiment of the present invention, the stress reducing structure includes one or more recesses that are provided along the slot at predetermined intervals. As used herein the term "slot" as used herein refers to a line shaped aperture. Further, the term "recess" refers to a through-hole along thickness of the slot. In an embodiment, only one recess is provided on top of the slot. The recesses are provided with a pin along its length i.e. thickness of the slot. The pin is advantageous as it is capable of generating a compressive action on the plurality of fillets.

[0019] In a preferred embodiment, each recess is positioned between the two lugs and the pin is capable of generating the compressive action between the two lugs along the disc radius to counter tensile stress at a fillet connecting the two lugs.

[0020] In an embodiment, the pins are interference fitted in each recess so that two symmetric halves, of the blade root, move apart from each other with respect to a central longitudinal axis. This action can introduce compressive state of stress in the lug fillets which can potentially help to reduce the tensile state of stress generated during operation because of centrifugal forces and to increase the crack initiation life. This technique which generate compressive stress through the thickness of lug fillet, is significantly advantageous than an alternate technique called shot-peening, generally used for generating compressive state of stress only over the surface.

[0021] According to another embodiment, stress reducing structure includes multiple bridges distributed at the predetermined intervals on the slot. The multiple bridges are formed due to the discontinued profile of the slot. The bridges are advantageous as they are capable of generating compressive action to counter the stress at the plurality of fillets.

[0022] In a preferred embodiment, each bridge of the plurality of bridges is provided between the two lugs and the bridge is capable of generating the compressive action between the two lugs along the disc radius to counter tensile stress the fillet connecting the two lugs.

[0023] According to an embodiment of the present invention, the slot is a longitudinal slot along a central longitudinal axis of the blade root. The turbine blade assembly includes a central root section along the central longitudinal axis of the blade root. The stress reducing structure is provided in the central root section between two lugs of the plurality of lugs. The positioning of the stress reducing structure in the central root section is advantageous as the slot with the pins or the bridges are capable of uniformly generating the compressive action.

[0024] The introduction of discontinuities / slots through the thickness of the blade root, with bridges optimally positioned in the body of the root is advantageous as each bridge corresponds to one symmetric pair of lug fillets. The hoop component of the reaction forces at each lug contribute to compressive state of stress at corresponding lug fillets which can compensate the high tensile state of stress due to the radial inertial loads thus effectively increasing the useful fatigue life the blade root.

[0025] According to a second object the present invention, there is also disclosed a turbo-machine with improved useful life. The turbo-machine includes a housing and a rotor housed within the housing. The rotor includes a disc that includes one or more blade slots. The turbo-machine includes one more of turbine blade assemblies with the stress reducing structure in the blade roots, as mentioned above. Further, the blade roots are insertable into the blade slots in an axial direction to engage the blade slots to secure the turbine blade assembly to the rotating disc. In a preferred embodiment, the turbine blade assembly includes a blade root with lugs and fillets. Accordingly, the blade slots also include one or more disc fillets to compliment the lugs of the blade root. The turbo-machine according to the present invention is advantageous as the blade slots include the stress reducing structure capable of countering tensile stress in the disc fillets of the blade slots.

[0026] According to a third object of the present invention, a method for manufacturing of a turbo-machine comprising a turbine blade assembly and a blade slot is provided. The method includes the steps of generating the blade slot and the turbine blade assembly with the stress reducing structure via one of electrical discharge machining (EDM), laser cutting techniques and additive manufacturing techniques. In an embodiment, the wire cut EDM is used to generate the blade slot and the turbine blade assembly. In another embodiment, the laser cutting techniques include wet laser cutting. In yet another embodiment, the additive manufacturing techniques of either selective laser sintering or selective laser melting or electron beam melting are used to generate the blade root and the blade slot.

[0027] The above-mentioned and other features of the invention will now be addressed with reference to the accompanying drawings of the present invention. The illustrated embodiments are intended to illustrate, but not limit the invention.

[0028] The present invention is further described hereinafter with reference to illustrated embodiments shown in the accompanying drawings, in which:

FIG 1 is a schematic of stress experienced in a turbine blade assembly;

FIG 2A and 2B are schematics of a turbine blade assembly with stress reducing structures, according to the present invention;

FIG 3 illustrates operation of the stress reducing structure of the turbine blade assembly in FIG 2A and 2B;

FIG 4A and 4B are schematic of blade slot for a turbine blade assembly, according to the present invention; and

FIG 5 is a schematic of a rotor of a turbo machine according to the present invention.

[0029] Various embodiments are described with reference to the drawings, wherein like reference numerals are used to refer the drawings, wherein like reference numerals are used to refer to like elements throughout. In the following description, for the purpose of explanation, numerous specific details are set forth in order to provide thorough understanding of one or more embodiments. It may be evident that such embodiments may be practiced without these specific details.

[0030] FIG 1 is a schematic of stress experienced in a turbine blade root 102. As shown in FIG 1, the figure is a free body diagram showing the load applied on the turbine blade root 102 and reaction forces 112 generated at a contact interface between the turbine blade root and the slot in the rotating disc. The blade root 102 is part of a turbine blade assembly 100 that includes a blade body 108. The blade root 102 includes multiple lugs 104 and fillets 106 and a central root section 155 along a central longitudinal axis 150. During operation, the blade body 108 and the blade root 102 exert a centrifugal force 110 on the blade root 102 in view of the rotational movement. Additionally, the lugs 104 of the blade root 102 experience a reaction force 112 from a disc (not shown in FIG 1) in which blade root 102 is mounted. The operation also results in generation of tensile stress in the fillets 106 in a radial direction 120 and a hoop direction 130.

[0031] FIG 2A and 2B are schematic of a turbine blade assembly 200 with stress reducing structure 210a and 210b, according to the present invention. The turbine blade assembly 200 includes a blade body 202 including a free end 204 and a joint end 206. The blade body 202 includes an airfoil section 208 along one side of the blade body 202 extending from the joint end 206 to the free end 204. The blade body 202 also includes a shroud 212 at the free end 204 of the blade body 202.

[0032] As shown in FIG 2A and 2B, the turbine blade assembly 200 includes a blade platform at the joint end 206 of the blade body 202. The blade platform abuts a disc 216 of a turbo-machine.

[0033] Further, the turbine blade assembly 200 includes a blade root 220 that extends from the blade platform towards the disc 216. The blade root 220 includes lugs 222a-222d, collectively referred as lugs 222. The blade root 220 also includes fillets 224a-224c, which in combination with the lugs 222 holds the blade body 202 in the disc 216. The fillets 224a, 224b and 224c are collectively referred to as 224. The blade root 220 further includes the stress reducing structure 210a and 210b capable of countering tensile stress at the fillets 224.

[0034] In FIG 2A, the stress reducing structure 210a is along a central longitudinal axis 250 of the turbine blade assembly 200. The stress reducing structure 210a includes recess 240 provided at predetermined intervals on a longitudinal slot 230. The stress reducing structure 210a also includes pin 260 provided in the recess 240. The pin 260 acts as an interference fitted in the recess 240 such that symmetric halves of the blade root 220 move apart from each other with respect to the central longitudinal axis 250. This action introduces compressive state of in the fillets 224 which reduce the tensile state of stress generated during operation because of centrifugal forces.

[0035] In FIG 2B, the stress reducing structure 210b includes a central longitudinal slot 235 with a plurality of bridges 245. The longitudinal slot 235 is introduced through the thickness of the blade root 220. The bridges 245 are optimally positioned in the blade root 220. The bridges 245 enable formation of symmetric pair of fillets 224. The hoop component of the reaction forces at each lug 222 contribute to compressive state of stress at corresponding fillets 224 which can compensate the high tensile state of stress due to the radial inertial loads.

[0036] The operation of the stress reducing structures 210a and 210b can be explained by a free body diagram in FIG 3. Accordingly, FIG 3 illustrates operation of the stress reducing structure of the turbine blade assembly in FIG 2A and 2B.

[0037] As shown in FIG 3, the blade root can be divided into two symmetic halves at the central longitudinal axis 350. The halved cross section of the blade root is used to explain distribution of stress in the lugs 222a-222d and fillets 224a-224b. The blade root experiences countering forces 330 and 335. A hoop reaction force 330 is a stress exerted in the hoop direction due to a reaction force from the rotating disk housing the blade root. The counter force 335 is generated due to the pin 260 or the bridge 245 provided in the stress reducing structures 210a, 210b, respectively.

[0038] FIG 3 includes a free body representatation 300a with the lugs 222a-222d and fillets 224a-224b and a beam represenation 300b simplifying the blade root into a supported beam 325 with the forces 330 and 335 acting as bending loads. The position of the pin 260 or bridge 245 generates an offset 340 between the hoop reaction force 330 by introducing inward bending of the root body between pins 260 or bridges 245. Due to the introduction of the inward bending due to counter force 335 the effective tensile stress state at the fillets 224a-224b are reduced and thereby help to increase the useful fatigue life of the blade root.

[0039] FIG 4A and 4B are schematics of a blade slot 402 in a disc with a stress reducing structures 210a and 210b according to the present invention. The blade slot 402 includes multiple disc fillets 405, 407, 409 and 411 and multiple disc lugs 404, 406, 408 and 410.

[0040] In FIG 4A, the stress reducing structure 210a includes recess 240 provided at predetermined intervals on a longitudinal slot 230. The stress reducing structure 210a also includes pin 260 provided in the recess 240. In FIG 4B, the stress reducing structure 210b includes the central longitudinal slot 235 with the bridges 245. When a turbo-machine is in operation, the turbine blade assembly is subject to a large centrifugal force, primarily due to self weight of the turbine blade assembly. A blade root is under a large amount of tensile stress, which in turn causes tensile stress at the disc fillets 405, 407, 409 and 411. To counter the tensile stress the pins 260 and bridges 245 are provided in the stress reducing structures 210a and 210b to generate a counter compressive stress. The working of the stress reducing structures is in the same lines as that of FIG 3.

[0041] FIG 5 is a schematic of a rotor 500 of a turbo machine according to the present invention. The rotor 500 is housed in a housing of the turbo-machine (not shown in FIG 5). The rotor 500 includes a disc 516 comprising blade slots 530. The blade slots 530 include disc fillets and disc lugs to form a fir tree profile.

[0042] The rotor 500 also includes turbine blade assemblies 505 that engage with the blade slots 530 by means of blade roots 520 insertable into the blade slot 530. The disc fillets and disc lugs receive lugs 522 and fillets 524 of the blade roots 520. The blade roots 520 engage the blade slots 530 to secure the turbine blade assemblies 505 to the disc 516.

[0043] As shown in FIG 5, a stress reducing structure 510 can be patterned in the blade root 520 and/or the blade slots 530. The stress reducing structure 510 is capable of reducing tensile stress in the fillets 524 as illustrated in FIGs 2A, 2B, and 3. Further, the stress reducing structure 510 in the blade slots 530 are capable of countering tensile stress in the disc fillets (where the lugs 522 engage with the blade slot 530).

[0044] It will be appreciated that the aforementioned stress reducing structure 510 is not limited to the pattern shown in the figures, specifically FIG 5. For example, the shape and pattern of the stress reducing structure 510 can be patterned according to the structures illustrated in FIGs 2A and 2B or a combination of both. Even though the present disclosure has been described in detail with reference to specific embodiments, it will be appreciated that the various modifications and changes can be made to these embodiments without departing from the scope of the present disclosure as set forth in the claims. The specification and the drawings are to be regarded as an illustrative thought instead of merely restrictive thought.

[0045] The foregoing examples have been provided merely for the purpose of explanation and are in no way to be construed as limiting of the present invention disclosed herein. While the invention has been described with reference to various embodiments, it is understood that the words, which have been used herein, are words of description and illustration, rather than words of limitation. Further, although the invention has been described herein with reference to particular means, materials, and embodiments, the invention is not intended to be limited to the particulars disclosed herein; rather, the invention extends to all functionally equivalent structures, methods and uses, such as are within the scope of the appended claims. Those skilled in the art, having the benefit of the teachings of this specification, may affect numerous modifications thereto and changes may be made without departing from the scope of the invention in its aspects.

Bezugszeichenliste / Reference List

[0046]

FIG 1
turbine blade assembly 100
turbine blade root 102
lugs 104
fillets 106
blade body 108
centrifugal force 110
reaction forces 112
radial direction 120
hoop direction 130
central longitudinal axis 150
central root section 155

FIG 2A and 2B
turbine blade assembly 200
stress reducing structure 210a and 210b
blade body 202
free end 204
joint end 206
airfoil section 208
shroud 212
disc 216
blade root 220
lugs 222a-222d
fillets 224a-224c
longitudinal slot 230, 235
recess 240
bridges 245
central longitudinal axis 250
pin 260

FIG 3
free body representation 300a
beam represenation 300b

supported beam 325
countering forces 330 and 335
hoop reaction force 330
offset 340
central longitudinal axis 350

FIG 4A and 4B
blade slot 402
disc fillets 405, 407, 409 and 411
disc lugs 404, 406, 408 and 410.

FIG 5
rotor 500
disc 516
blade roots 520
lugs 522
fillets 524
blade slots 530

Claims

1. A turbine blade assembly (200) for turbo-machines comprising:

a blade body (202) including a free end (204) and a joint end (206), the blade body (202) comprising:
an airfoil section along at least one side of the blade body extending from the joint end to the free end; and
a blade platform at the joint end (206) of the blade body, suitable to abut a disc of a turbo-machine; and
a blade root (220) that extends from the blade platform towards the disc (216), the blade root (220) comprising a plurality of lugs and a plurality of fillets, wherein the turbine blade assembly **characterised in that** the blade root (220) comprise a stress reducing structure (210a, 210b) including at least one slot having one of a continuous and discontinuous profile capable of countering stress at the plurality of fillets (224a-224c).

2. The turbine blade assembly (200) according to claim 1, wherein the stress reducing structure (210a) comprises:

at least one recess (240) provided along the at least one slot (230) at predetermined intervals; and
a pin (260) provided along a length of the at least one recess, wherein the pin is capable of generating a compressive action on the plurality of fillets (224a-224c).

3. The turbine blade assembly according to claim 1, wherein the stress reducing structure (210b) comprises a plurality of bridges (245) distributed at the predetermined intervals on the at least one slot capable of generating compressive action to counter the stress at the plurality of fillets, wherein the discontinuous profile of the at least one slot results in formation of the plurality of bridges.

4. The turbine blade assembly (200) according to claim 3, wherein size and position of the at least one recess (240) and the bridges (245), length and thickness of the at least one slot (230,235) are optimized to counter and distribute the stress at the plurality of fillets.

5. The turbine blade assembly according to claim 1, wherein the at least one slot (230, 235) is longitudinal slot along a central longitudinal axis of the blade root.

6. The turbine blade assembly according to claim 5, wherein the blade root comprises:
a central root section along central longitudinal axis (250) of the blade root; wherein the stress reducing structure (210a, 210b) is provided in the central root section between at least two lugs of the plurality of lugs.

7. The turbine blade assembly (200) according to one of claim 6 and claim 2, wherein the at least one recess 240 is positioned between the at least two lugs and wherein the pin (260) is capable of generating the compressive action between the at least two lugs (222b, 222c) along the disc radius to counter tensile stress at an at least one fillet (224b) connecting the at least two lugs.

8. The turbine blade assembly according to one of claim 6 and claim 3, wherein a bridge (245) of the plurality of bridges is provided between the at least two lugs (222b, 222c) and wherein the bridge is capable of generating the compressive action between the at least two lugs (222b, 222c) along the disc radius to counter tensile stress at an at least one fillet (224b) connecting the at least two lugs (222b, 222c).

9. A turbo-machine comprising:

a housing; and
a rotor (500) housed within the housing, the rotor comprising:

a disc (516) comprising at least one blade slot (530), wherein the at least one blade slot comprises at least one disc fillet,
wherein the turbo-machine **characterized by**
at least one turbine blade assembly (505) according to claims 1-8, each comprising a blade root (520) insertable into the at least

one blade slot in an axial direction to engage the at least one blade slot (520) to secure the turbine blade assembly to the disc, wherein the at least one blade slot comprises a stress reducing structure (510) capable of countering stress in the at least one disc fillet (522).

10. The turbo-machine according to claim 9, wherein position and pattern of the stress reducing structure (510) in the at least one blade slot is optimized to counter the stress at the at least one disc fillet.

11. A method for manufacturing of a turbo-machine comprising a turbine blade assembly and a blade slot, the method comprising the steps of:

generating the blade slot comprising a stress reducing structure according to claims 9-10, via one of electrical discharge machining, laser cutting techniques and additive manufacturing techniques; and
generating the turbine blade assembly comprising the stress reducing structure according to the claims 1 to 8 via one of electrical discharge machining, laser cutting techniques and additive manufacturing techniques.

FIG 1

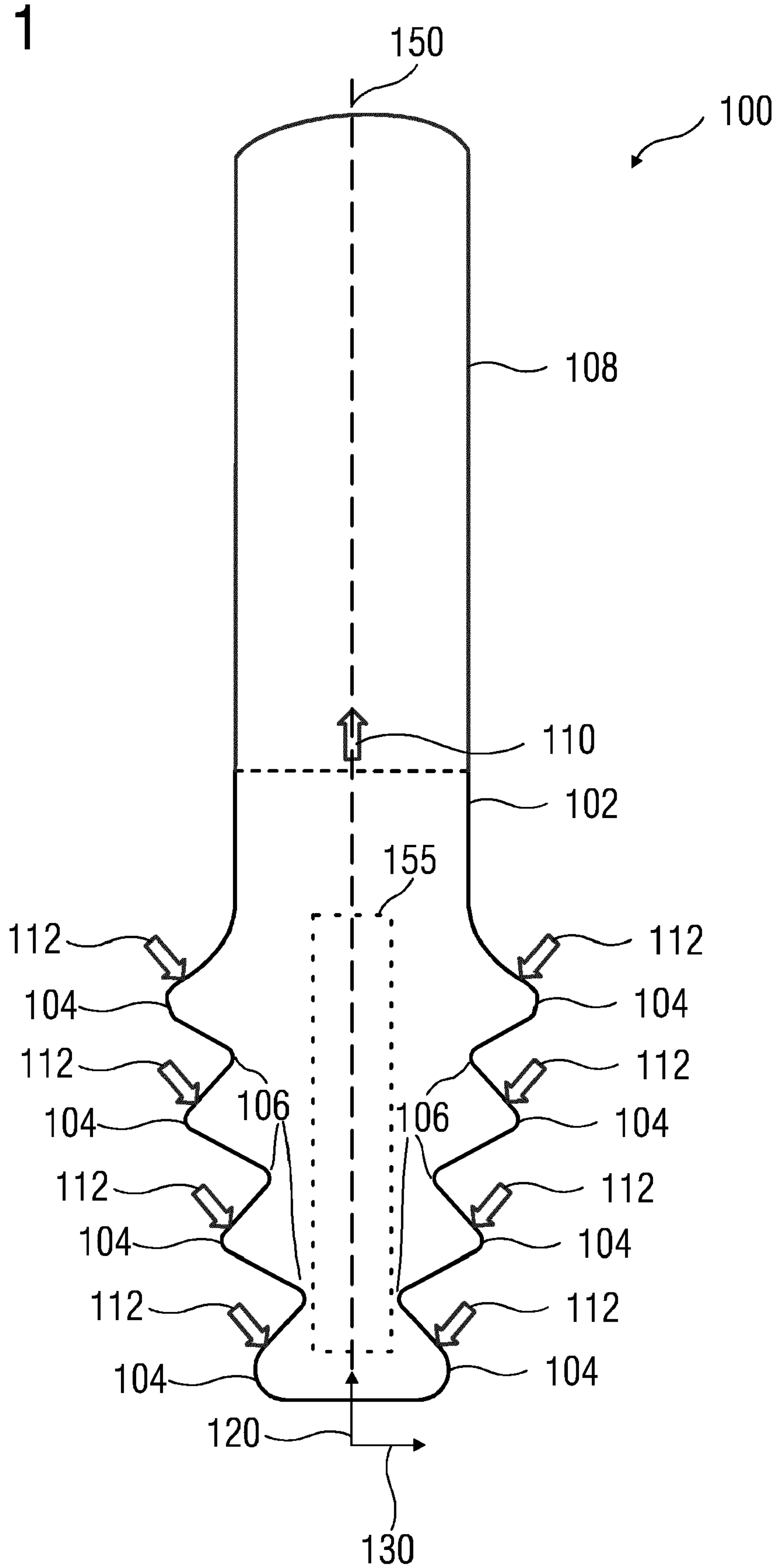

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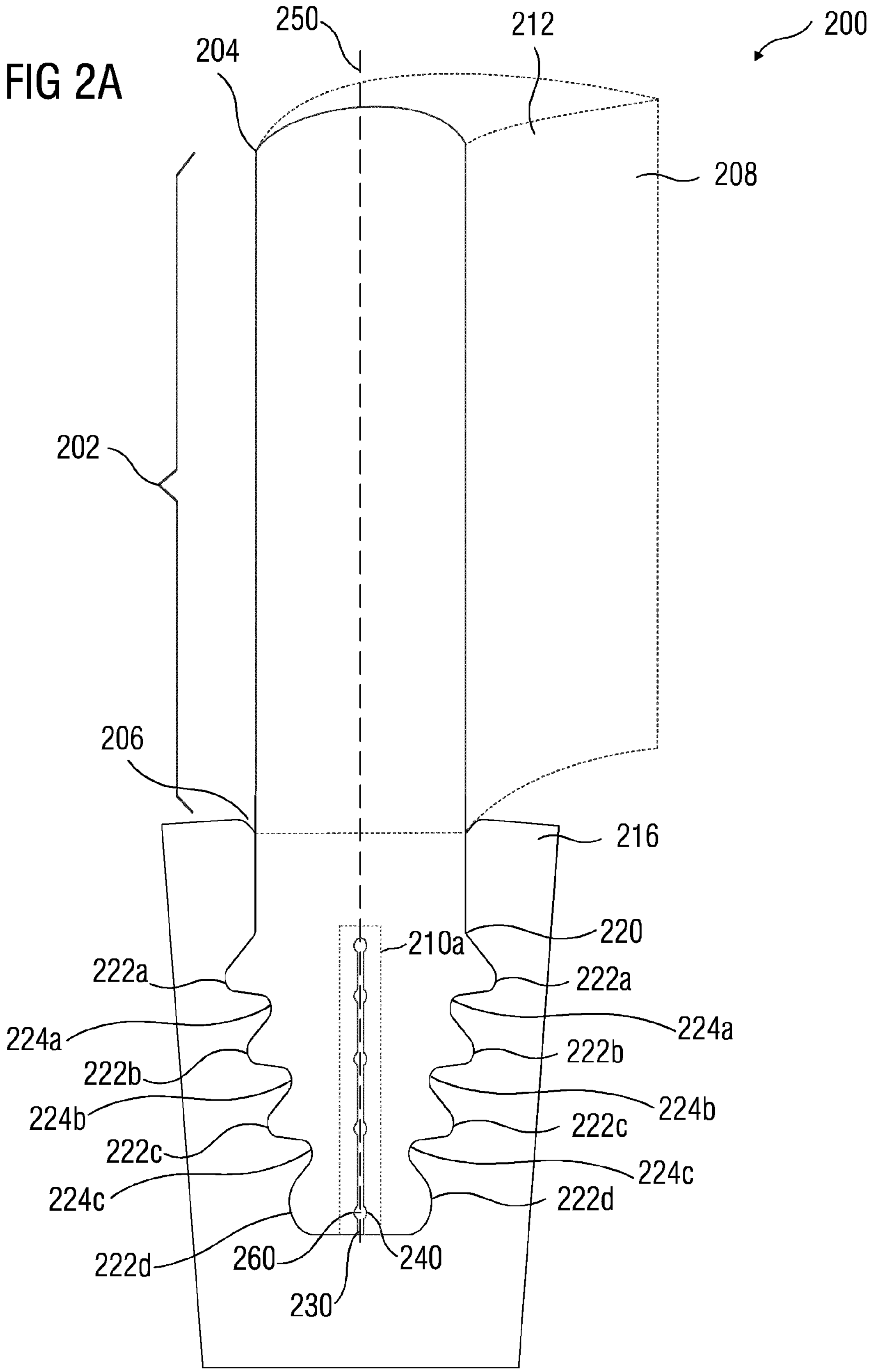
FIG 2A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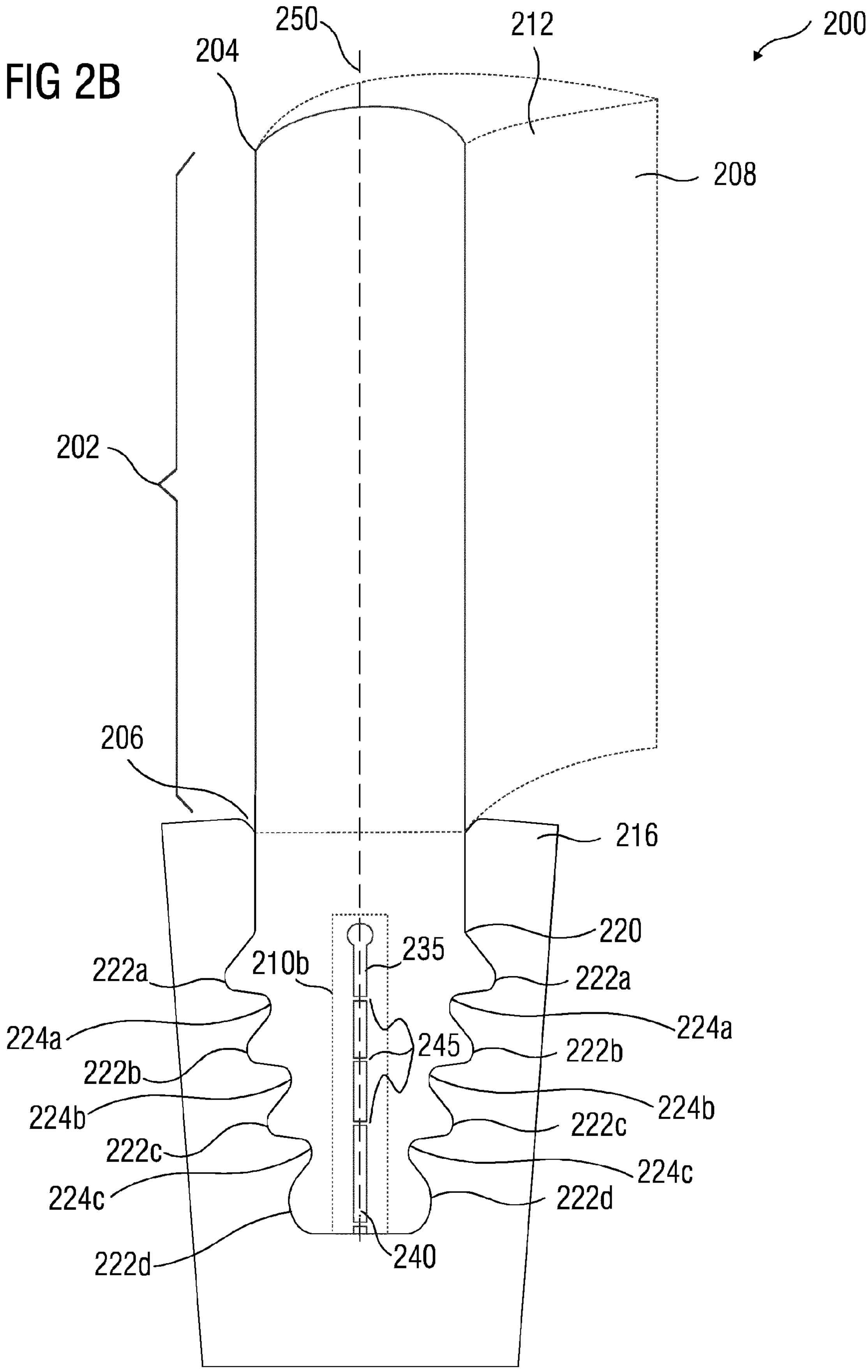
222d
222d
260
240
230

FIG 2B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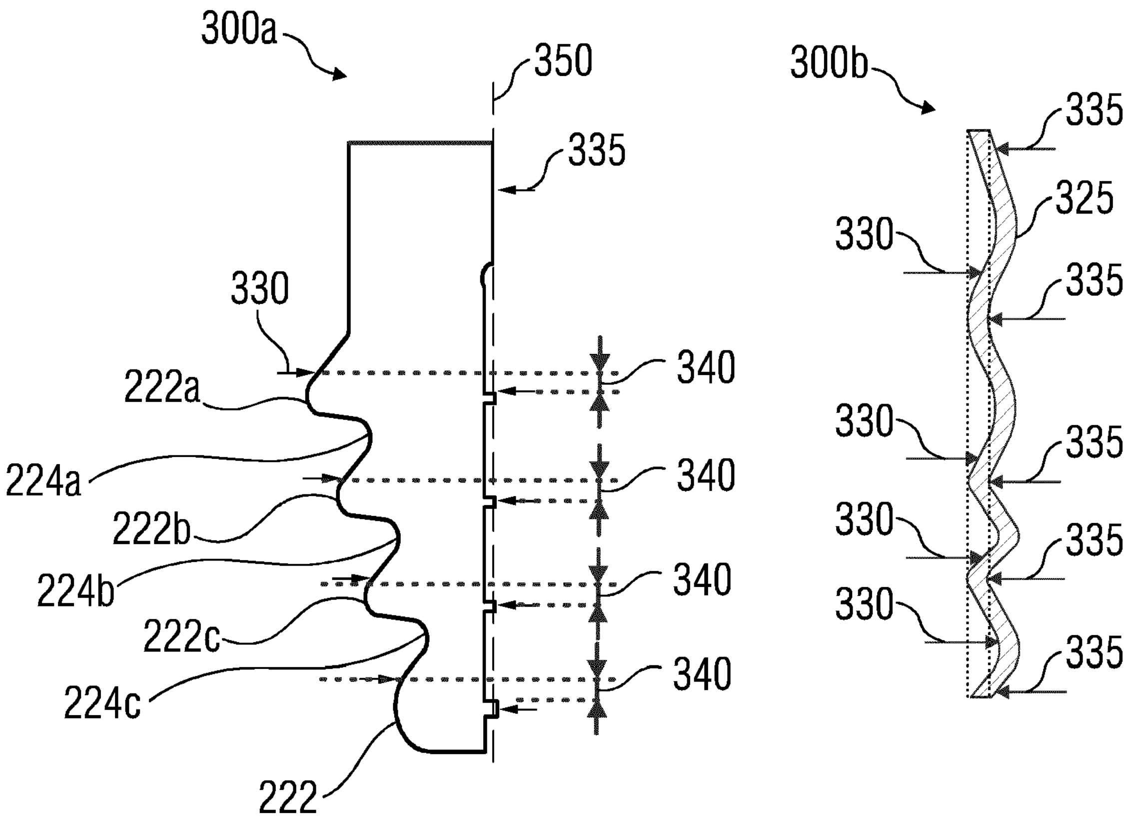
240

FIG 3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222c
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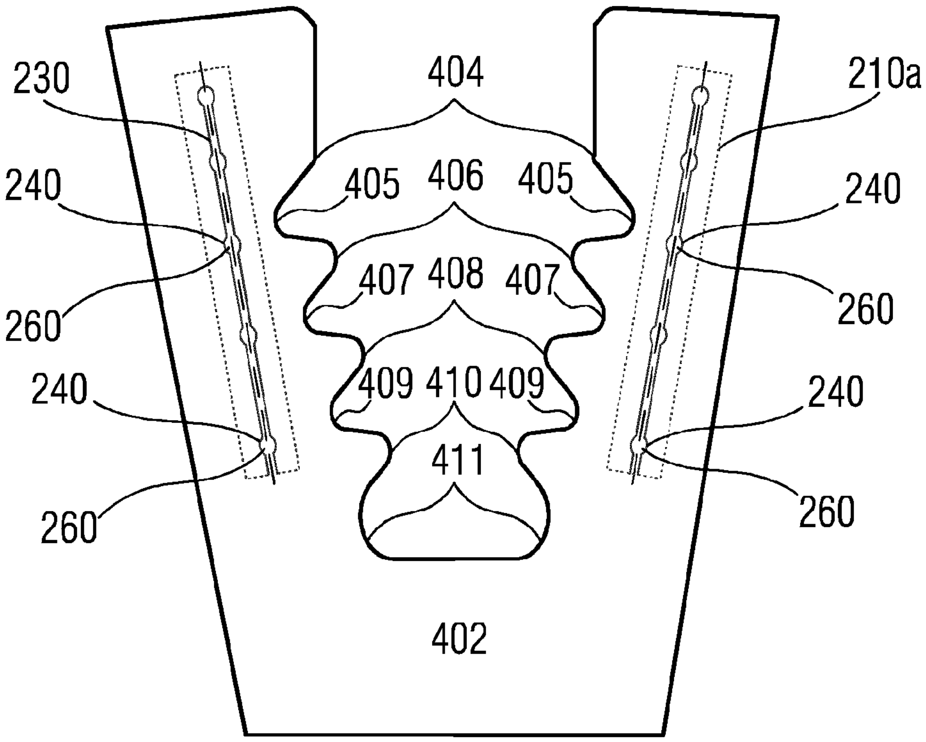
FIG 4A


230
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210a
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FIG 4B

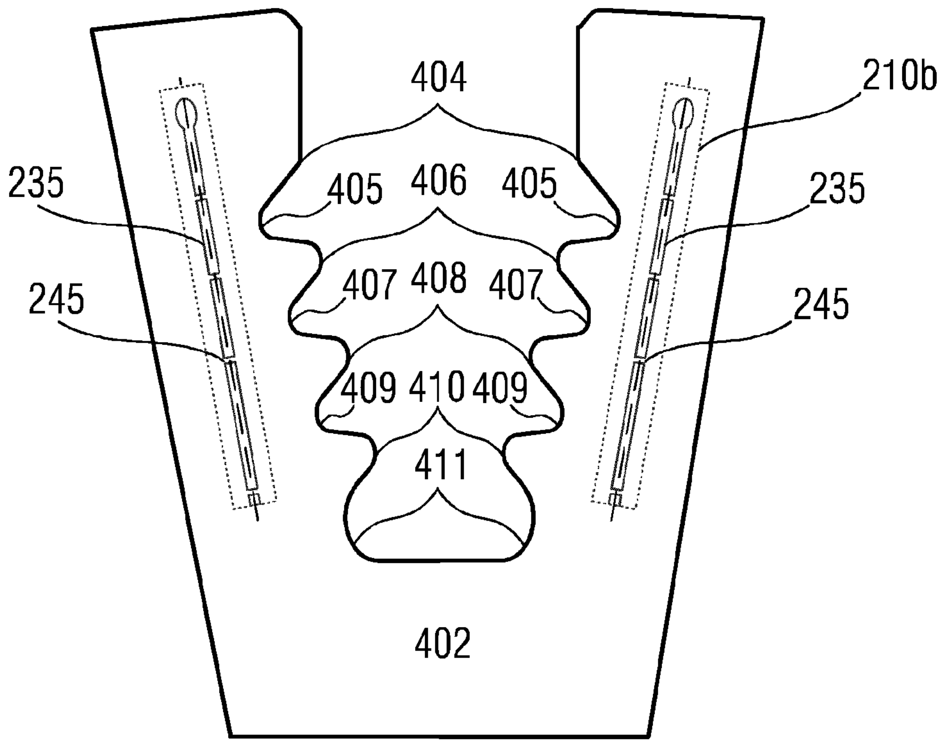
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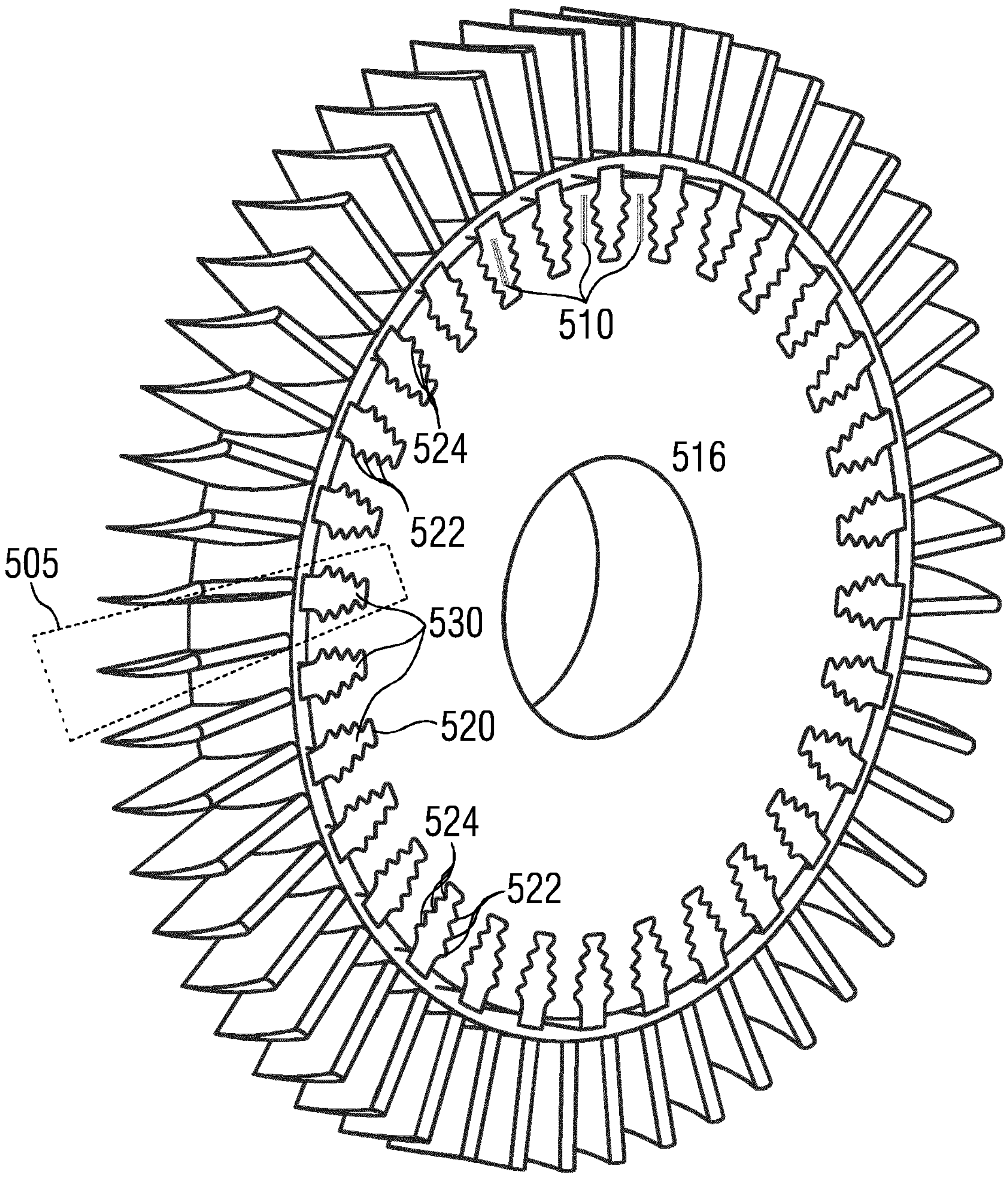
FIG 5



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EUROPEAN SEARCH REPORT

Application Number
EP 18 17 5544

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	US 2016/201484 A1 (ENGEL TODD Z [US] ET AL) 14 July 2016 (2016-07-14) * paragraph [0089] * * figure 11 *	1-7,11 8-10	INV. F01D5/30
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Place of search	Date of completion of the search	Examiner
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