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unidirectionally on a base side of the vane portion 3 and engaged with a blade groove 6 formed in the outer circumference of a turbine rotor 8. The turbine rotor 8 circumferential position of the end of the blade base portion 5 on the side toward the blade leading edge 21 is different from the turbine rotor 8 circumferential position of the end of the blade base portion 5 on the side toward the blade trailing edge 22.

Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to a turbine rotor blade for a turbine such as a steam turbine or a gas turbine. The present invention also relates to a fixation structure of such a turbine rotor blade.

2. Description of the Related Art

[0002] A blade base portion (blade implant portion) of a turbine rotor blade for a steam turbine, gas turbine, or the like is variously shaped. The turbine rotor blade is engaged with a blade groove to be mounted on a turbine rotor, the blade groove being complementarily shaped relative to the blade base portion.

[0003] At a high- or intermediate-pressure stage in which the turbine rotor blade is exposed to high-temperature steam or gas, high centrifugal force is applied to the turbine rotor blade for a long period of time in a high-temperature atmosphere. Therefore, the blade base portion may suffer creep damage. In view of such circumstances, a technology concerning a steam turbine rotor blade is developed to bore a platform through-hole from the bottom of the blade by an electric spark forming method or the like for the purpose of decreasing the weight of the blade and reducing the stress caused by centrifugal force (refer, for instance, to JP-2005-195021-A).

[0004] However, as the electric spark forming method or the like is selected for the above-described turbine rotor blade, the forming of the turbine rotor blade takes a considerable amount of time. Further, steam-induced oscillatory load is imposed on the steam turbine rotor blade. Therefore, if there is a hole in a platform, bending load on the blade may impose increased stress on the platform.

SUMMARY OF THE INVENTION

[0005] An object of the present invention is to provide a turbine rotor blade that is highly manufacturable and capable of reducing the stress caused by centrifugal force.

[0006] In accomplishing the above object, according to one aspect of the present invention, there is provided a turbine rotor blade comprising: a vane portion having a blade leading edge positioned upstream in the distribution direction of working fluid and a blade trailing edge positioned downstream of the blade leading edge; and/or a blade base portion which is extended unidirectionally on a base side of the vane portion and engaged with a blade groove formed in the outer circumference of a turbine rotor; wherein an end of the blade base portion at the side of the blade leading edge is positioned to be different in the circumferential direction of the turbine ro-

tor from an end of the blade base portion at the side of the blade trailing edge.

[0007] The present invention enables the blade groove to efficiently support the centrifugal load on the turbine rotor blade through the blade base portion, thereby making it possible to reduce the stress on the blade groove with ease.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008]

FIG. 1 is a front view taken in an axial direction of a turbine rotor to illustrate a turbine rotor blade according to an embodiment of the present invention.

FIG. 2 is a perspective view of the turbine rotor blade according to an embodiment of the present invention.

FIG. 3 is a view that is taken in the direction of arrow B in FIG. 1 to illustrate the turbine rotor blade according to an embodiment of the present invention.

FIG. 4 is a view that is taken in the same direction as in FIG. 3 to present a comparative example of the turbine rotor blade according to an embodiment of the present invention.

FIGS. 5A and 5B are schematic diagrams illustrating blade base portions of the turbine rotor blade according to an embodiment of the present invention and of a conventional turbine rotor blade.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0009] Embodiments of the present invention will now be described with reference to the accompanying drawings.

[0010] FIG. 1 is a front view taken in an axial direction of a turbine rotor to illustrate a turbine rotor blade according to an embodiment of the present invention. FIG. 2 is a perspective view of the turbine rotor blade. A radial direction of a turbine rotor, a circumferential direction of a turbine rotor, and an axial direction of a turbine rotor are defined as indicated in these figures.

[0011] Turbine rotor blades 40a and 40b shown in FIGS. 1 and 2 are used with a steam turbine. The turbine rotor blades 40a and 40b each include: a vane portion 3; a shroud 1 which is provided on the leading end of the vane portion 3 (the outer end portion in the radial direction of the turbine rotor); a seal (fin seal) 1a which is provided on the outer circumference of the shroud 1; blade base portion 5 (5a, 5b, and 5c, 5d) which engages with blade groove 6 (6a, 6b, and 6c, 6d) provided on the outer circumference of a turbine rotor 8; and a platform 4 which is provided between the vane portion 3 and the blade base portion 5.

[0012] The blade base portion 5 is extended unidirectionally on a base side of the vane portion 3 (on the inner end of the vane portion 3 in the radial direction of the turbine rotor), and inserted into the blade groove 6 along

the extension direction of the blade base portion 5. The extension direction of the blade base portion 5 will now be described with reference to FIG. 3.

[0013] FIG. 3 is a view taken in the direction of arrow B in FIG. 1. Like elements in FIGS. 1 to 3 are designated by the same reference numerals and will not be redundantly described (the same is also true for the subsequent drawings).

[0014] Referring to FIG. 3, the vane portion 3 includes a blade leading edge 21 which is positioned upstream in the distribution direction of working fluid, and a blade trailing edge 22 which is positioned downstream of the blade leading edge 21. When the working fluid flows in a direction indicated by arrow C in the figure (an axial direction of a turbine rotor) and toward the turbine rotor blade 40a, the turbine rotor 8 rotates downward in FIG. 3.

[0015] At a blade base portion 5a (5b) shown in FIG. 3, an end (leading edge side end) 51a (51b) of the blade base portion 5a (5b) at the side of the blade leading edge 21 is positioned to be different in the circumferential direction of the turbine rotor from an end (trailing edge side end) 52a (52b) of the blade base portion 5a (5b) at the side of the blade trailing edge 22. In other words, the blade base portions 5a and 5b are not extended in parallel with the rotation axis of the turbine rotor 8 (the axial direction C of the turbine rotor), but extended in a direction that is inclined at an angle of D (see FIG. 3) from the axial direction C of the turbine rotor. Further, the blade grooves 6a and 6b are provided in the outer circumference of the turbine rotor 8 and arranged in a direction (an axial direction of a groove) that is inclined at an angle of D from the axial direction of the turbine rotor, as is the case with the blade base portions 5a and 5b. When the blade base portion 5 and blade groove 6 are positioned as described above, they are longer than those when they are positioned in parallel with the axial direction C of the turbine rotor. Therefore, the contact area between the blade base portion 5 and blade groove 6 can be increased.

[0016] Meanwhile, the vane portion 3 according to the present embodiment is configured so that the position of the blade trailing edge 22 in the circumferential direction of the turbine rotor is displaced in the rotational direction of the turbine rotor with respect to that of the blade leading edge 21 in the circumferential direction of the turbine rotor, and the degree of reaction of the vane portion 3 is several tens of percent. When the vane portion 3 has such a high degree of reaction, the blade base portion 5 should preferably be configured in accordance with the shape of the vane portion 3 so that the position of the trailing edge side end portion 52 (52a, 52b) in the circumferential direction of the turbine rotor is displaced in the rotational direction of the turbine rotor (downward in FIG. 3) with respect to that of the leading edge side end portion 51 (51a, 51b) in the circumferential direction of the turbine rotor. The reason is that when the blade base portion 5 is configured as described above, the overlap between the vane portion 3 and the blade base portion 5 can be increased. This makes it possible to effectively support

the vane portion 3 even when centrifugal force is applied to a turbine rotor blade 40a, 40b during an operation. It is also preferred that the blade base portion 5 be provided along the direction G of the blade chord length, that is, the direction of a line joining the blade leading edge 21 to the blade trailing edge 22, as shown in FIG. 3. In other words, the blade base portion 5 should preferably be configured so that the angle D formed between the blade base portion 5 and the axial direction C of the turbine rotor is equal to the angle formed between the direction G of the blade chord length and the axial direction C of the turbine rotor. The reason is that such a configuration makes it possible to further increase the overlap and efficiently position the blade base portion 5 relative to the vane portion 3.

[0017] Referring again to FIGS. 1 and 2, the turbine rotor blade 40a of this embodiment includes the two blade base portions 5a and 5b. The two blade base portions 5a and 5b are dovetail-shaped type, and are molded integral with the vane portion 3, the platform 4, and the shroud 1. When the number of blade base portions 5 is larger than that of vane portions 3 for one turbine rotor blade 40a, 40b as described above, it is possible to reduce the stress that arises due to steam force acting on the turbine rotor blades 40a, 40b during a steam turbine operation.

[0018] The blade base portions 5a, 5b are projected inward in the radial direction of the turbine rotor from the platform 4. The directions of their projections are parallel to each other. In other words, the centerline 41a (41c) of the blade base portion 5a (5c) is parallel to the centerline 41b (41d) of the blade base portion 5b (5d). Further, a blade hook portion 7 is projected toward each side in the circumferential direction of the turbine rotor from the leading ends of the blade base portion 5. The blade hook portion 7 is engaged with a groove hook portion 13 which is projected in the circumferential direction of the turbine rotor from the blade groove 6. Such an engagement structure fastens the turbine rotor blades 40a and 40b to the turbine rotor 8.

[0019] A contact area between the blade hook portion 7 and groove hook portion 13 is provided with a pinhole 9a which is extended in the axial direction of the turbine rotor through the blade hook portion 7 and groove hook portion 13. A fixing pin 9b is inserted in the axial direction of the turbine rotor into the pinhole 9a. The fixing pin 9b is inserted into the pinhole 9a after the blade base portion 5 is implanted in the blade groove 6 to accurately fasten the turbine rotor blades 40a and 40b in the circumferential direction of the turbine rotor and in the radial direction of the turbine rotor. When the turbine rotor blades 40a and 40b are fastened with the fixing pin 9b as described above, they are fastened more securely than when they are fastened merely by an engagement method. This makes it possible to reduce the stress applied to the blade base portion 5 and blade groove 6.

[0020] Operations and advantages of the present embodiment will now be described with reference to a com-

parative example.

[0021] FIG. 4 is a view that is taken in the same direction as in FIG. 3 to present a comparative example of the turbine rotor blade according to the present embodiment.

[0022] The turbine rotor blade 90 shown in FIG. 4 includes blade base portions 91a and 91b which are extended in the same direction as the axial direction C of the turbine rotor. Further, the turbine rotor has blade grooves 92a and 92b which are provided in the same direction as the blade base portions 91a and 91b. When the turbine rotor blade 90 is formed as described above, the lengths of the blade base portions 91a and 91b are decreased to reduce the area that supports the load on the turbine rotor blade 90. Therefore, when the turbine rotor blade 90 described above is used, increased stress is imposed on the blade base portions 91a, 91b and blade grooves 92a, 92b.

[0023] Particularly when the employed turbine rotor blade 90 includes a vane portion 93 having a high degree of reaction, its platform 94 may not stay quadrilateral, as shown in FIG. 4, while providing adequate clearance to an adjacent turbine rotor blade. Therefore, the blade base portion 91b has to terminate at a point (91e) before the end of the platform 94 on the side of the blade trailing edge 22. As a result, the blade base portion 91b is shorter than the platform 94. Decreasing the length of the blade base portion 91b in this manner not only increases the stress imposed on the blade base portion 91b but also produces a gap 92e in the blade groove 92b. This further increases the imposed stress.

[0024] On the other hand, the turbine rotor blade according to the present embodiment includes the blade base portion 5 which is formed so that the position of the leading edge side end portion 51 is different from that of the trailing edge side end portion 52 in the circumferential direction. When the blade base portion 5 is formed as described above, the portion can be made longer than when it is formed in parallel with the axial direction C of the turbine rotor. Therefore, the contact area between the blade groove 6 and blade base portion 5 can be increased. As this increases an area that supports the load on the turbine rotor blade portion 40, the stress imposed on the blade base portion 5 and blade groove 6 decreases, making it easy to enhance the structural reliability of the blade base portion 5 and blade groove 6.

[0025] Further, when the vane portion 3 is configured as described in connection with the present embodiment so that the position of the blade trailing edge 22 in the circumferential direction of the turbine rotor is displaced in the rotational direction of the turbine rotor with respect to that of the blade leading edge 21 in the circumferential direction of the turbine rotor, the blade base portion 5 should preferably be configured in accordance with the shape of the vane portion 3 so that the position of the trailing edge side end portion 52 in the circumferential direction of the turbine rotor is displaced in the rotational direction of the turbine rotor with respect to that of the leading edge side end portion 51 in the circumferential

direction of the turbine rotor. Configuring the blade base portion 5 as described above makes it possible to increase the overlap between the vane portion 3 and blade base portion 5. Consequently, the centrifugal force applied to the turbine rotor blade portion 40 can be effectively shared by the blade base portion 5 and blade groove 6. As a result, the structural reliability of the blade base portion 5 and blade groove 6 can be further enhanced.

[0026] Furthermore, the blade base portion 5 should preferably be configured so that the angle D formed between the blade base portion 5 and the axial direction C of the turbine rotor is equal to the angle formed between the direction G of the blade chord length and the axial direction C of the turbine rotor. Configuring the blade base portion 5 as described above makes it possible to not only further increase the overlap between the vane portion 3 and blade base portion 5, but also dispose the blade base portion 5 efficiently in relation to the vane portion 3. Consequently, the structural reliability can be further enhanced. The present invention produces a striking effect particularly when the vane portion has a high degree of reaction (e.g., several tens of percent) and its blade chord length direction G is oblique to the axial direction of the turbine rotor.

[0027] The present embodiment has been described on the assumption that the blade base portion 5 is dovetail-shaped. However, the present invention can be applied to a turbine rotor blade as far as an engagement structure is employed to couple the blade base portion to the blade groove. A typical turbine rotor blade of this type includes blade base portion that is shaped like an inverted Christmas tree. More specifically, the width of this blade base portion increases outward in the radial direction of the turbine rotor with a plurality of convexes projected toward both sides in the width direction. When the inverted-Christmas-tree-shaped blade base portion is extended in the above-described direction, the area of contact with the blade groove can be unprecedentedly large as implied earlier. This makes it possible to reduce the stress resulting from centrifugal load.

[0028] Meanwhile, the blade base portion 5 according to the present embodiment has the following features which contribute toward stress reduction. Such stress reduction features will be described below with reference to FIGS. 5A and 5B.

[0029] FIGS. 5A and 5B schematically illustrate the blade base portions of the turbine rotor blade according to the present embodiment and of a conventional turbine rotor blade. FIG. 5A is a schematic diagram illustrating the blade base portion 5 according to the present embodiment and their vicinity. FIG. 5B is a schematic diagram illustrating the blade base portion of a conventional turbine rotor blade and their vicinity.

[0030] Referring to FIG. 5A, the centerline 41a of the dovetail 5a is parallel to the centerline 41b of the dovetail 5b. Further, the distance E between the dovetail 5a and dovetail 5b is maintained constant. On the other hand,

the dovetails 50a and 50b of the conventional example are disposed so that their centerlines 42a and 42b respectively radiate from the center 43 of the turbine rotor 8. In other words, the distance between the dovetail 50a and dovetail 50b decreases with closing to the center 43, and equals F ($F < E$) at their leading ends.

[0031] Meanwhile, the stress imposed on the dovetails and blade grooves in the area between the dovetails generally increases with a decrease in the distance between the dovetails. According to the present embodiment, the distance E between the dovetails can be longer than the conventional distance F. Therefore, the stress imposed on the dovetails 5a, 5b and blade groove 6 can be reduced. This makes it possible to further reduce the stress in addition to the stress reduction effect based on the direction in which the blade base portion 5 is extended.

[0032] The present invention has been described with reference to the turbine rotor blade having the vane portion 3 which is configured so that the positions of the blade leading edge 21 and blade trailing edge 22 in the circumferential direction are different from each other. However, the stress resulting from centrifugal load can also be reduced even when the present invention is applied to a turbine rotor blade having a vane portion which is configured so that the positions of the blade leading edge and blade trailing edge in the circumferential direction are equal to each other. In addition, while the present invention has been described with reference to a case where the present invention is applied to a steam turbine, the present invention is also applicable to a gas turbine.

[0033] Features, components and specific details of the structures of the above-described embodiments may be exchanged or combined to form further embodiments optimized for the respective application. As far as those modifications are apparent for an expert skilled in the art they shall be disclosed implicitly by the above description without specifying explicitly every possible combination.

Claims

1. A turbine rotor blade comprising:

a vane portion (3) having a blade leading edge (21) positioned upstream in the distribution direction of working fluid and a blade trailing edge (22) positioned downstream of the blade leading edge (21); and

a blade base portion (5) which is extended unidirectionally on a base side of the vane portion (3) and engaged with a blade groove (6) formed in the outer circumference of a turbine rotor (8); wherein an end of the blade base portion (5) at the side of the blade leading edge (21) is positioned to be different in the circumferential direction of a turbine rotor (8) from an end of the blade base portion (5) at the side of the blade trailing edge (22).

2. The turbine rotor blade according to claim 1, wherein the position of the blade trailing edge (22) in the circumferential direction of the turbine rotor (8) is displaced in the rotational direction of the turbine rotor (8) with respect to that of the blade leading edge (21) in the circumferential direction of the turbine rotor (8).

3. The turbine rotor blade according to claim 2, wherein the position of the end of the blade base portion (5) at the side of the blade trailing edge (22) in the circumferential direction of the turbine rotor (8) is displaced in the rotational direction of the turbine rotor (8) with respect to that of the end of the blade base portion (5) at the side of the blade leading edge (21) in the circumferential direction of the turbine rotor (8).

4. The turbine rotor blade according to claim 2 or 3, wherein the blade base portion (5) is provided along the direction of a line joining the blade leading edge (21) to the blade trailing edge (22).

5. The turbine rotor blade according to at least one of claims 1 to 4, wherein the blade base portion (5) is a plurality of dovetails (50a, 50b) which are projected inward in the radial direction of the turbine rotor (8).

6. The turbine rotor blade according to claim 5, wherein the projection directions of the plurality of dovetails (50a, 50b) are parallel to each other.

7. The turbine rotor blade according to at least one of claims 1 to 6, wherein the blade base portion (5) is shaped like an inverted Christmas tree.

8. The turbine rotor blade according to at least one of claims 1 to 7, further comprising:

a pinhole (9a) which is provided between the blade base portion (5) and the blade groove (6); and
a fixing pin (9b) which is inserted into the pinhole (9a).

9. A turbine rotor blade comprising:

a vane portion (3) having a blade leading edge (21) positioned upstream in the distribution direction of working fluid and a blade trailing edge (22) positioned downstream of the blade leading edge (21); and

a blade base portion (5) which is extended unidirectionally on a base side of the vane portion (3) and engaged with a blade groove (6) formed in the outer circumference of a turbine rotor (8); wherein the blade base portion (5) is a plurality of dovetails (50a, 50b) which are projected inward in radial direction of the turbine rotor (8), with the plurality of dovetails (50a, 50b) being

projected in the direction parallel to each other.

10. A turbine rotor blade fixation structure comprising:

a turbine rotor blade that includes 5

a vane portion (3) having a blade leading edge (21) positioned upstream in the distribution direction of working fluid and a blade trailing edge (22) positioned downstream of the blade leading edge (21), and 10
a blade base portion (5) which is extended unidirectionally on a base side of the vane portion (3) and projected inward in the radial direction of the turbine rotor (8); and 15

a blade groove (6) that is engaged with the blade base portion (5) and provided in the outer circumference of a turbine rotor (8);
wherein the position of the end of the blade base portion (5) at the side of the blade trailing edge (21) in the circumferential direction of the turbine rotor (8) is displaced in the rotational direction of the turbine rotor (8) with respect to that of the end of the blade base portion (5) at the side of the blade leading edge (21) in the circumferential direction of the turbine rotor (8), and 20
wherein the blade base portion (5) is extended in a direction inclined from the rotation axis of the turbine rotor (8). 25
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FIG. 1

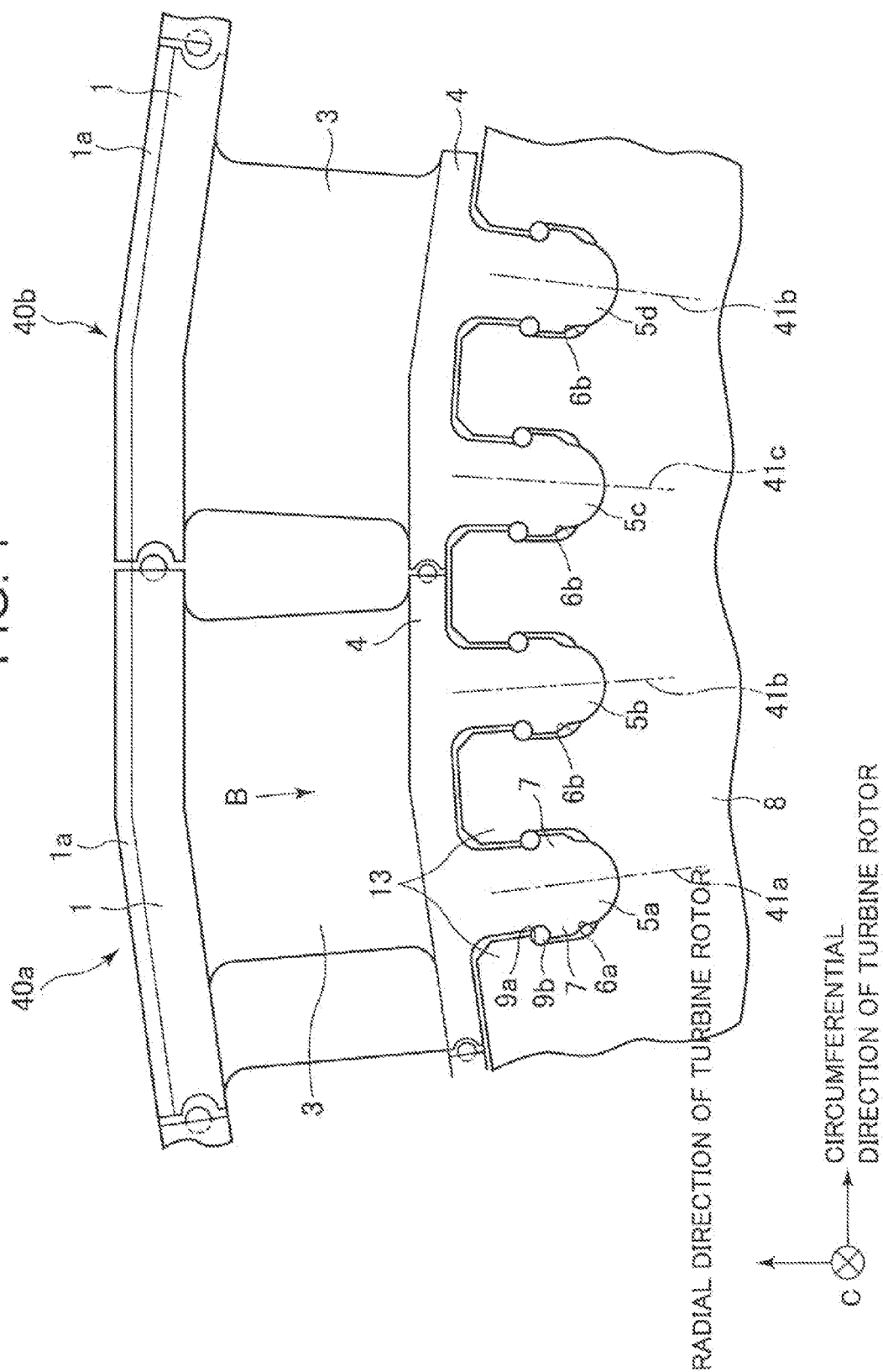


FIG.2

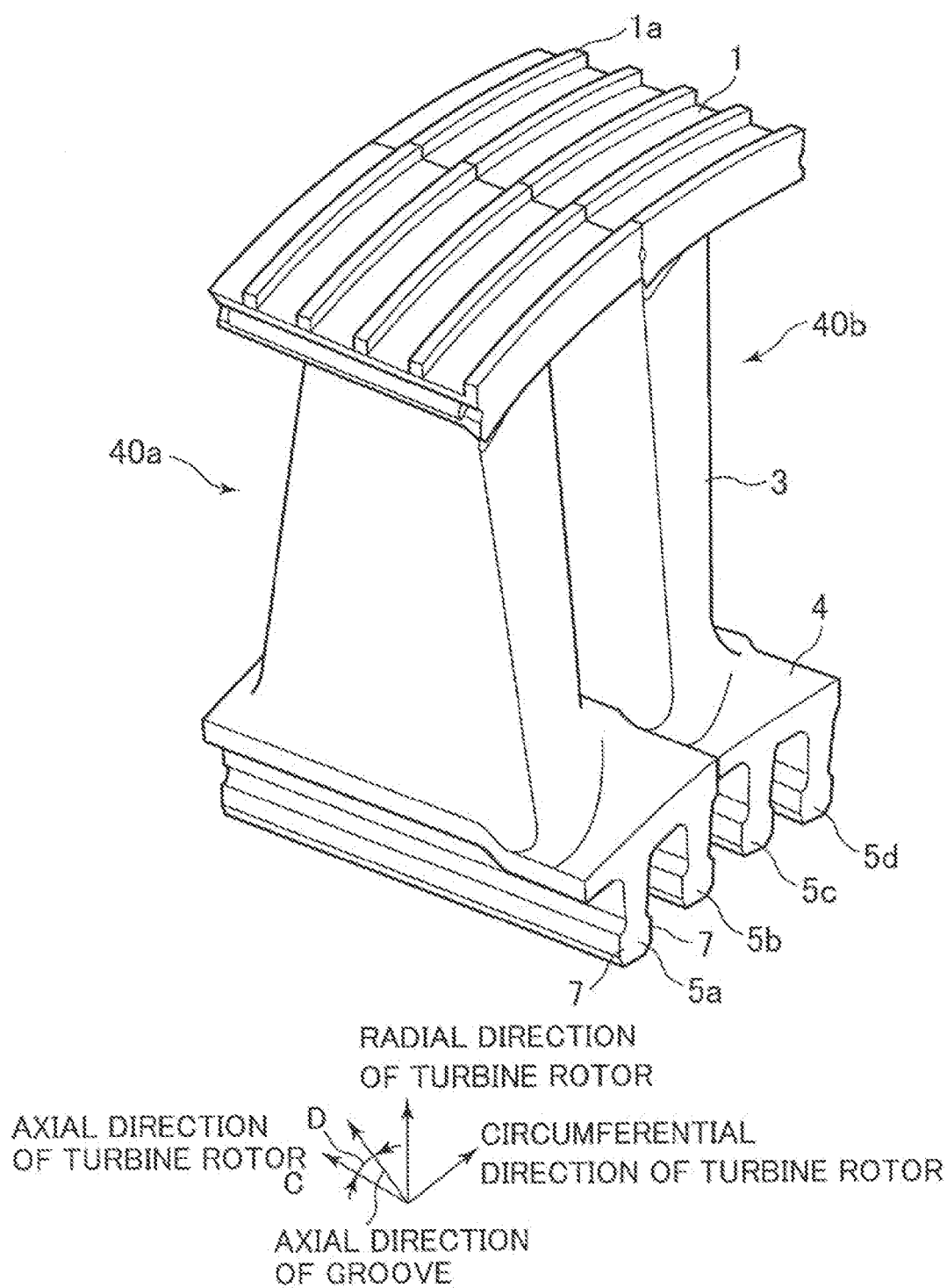


FIG.3

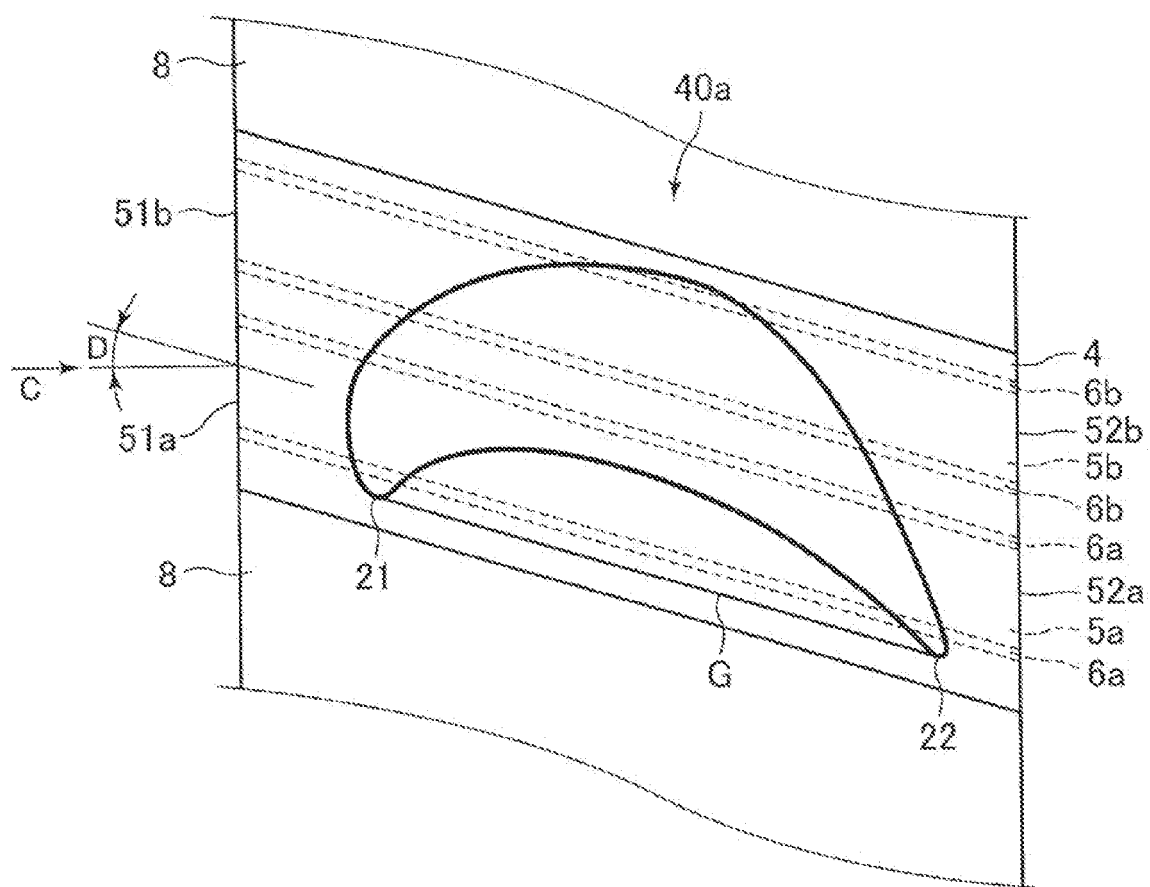


FIG.4

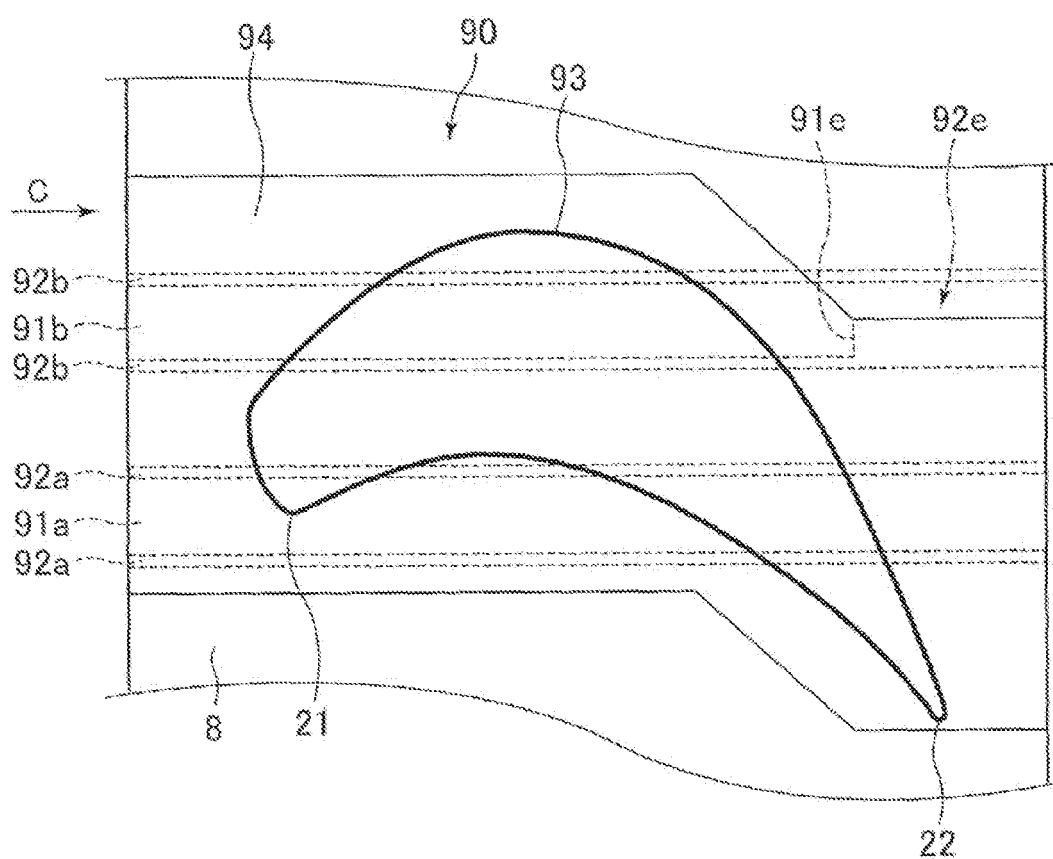


FIG.5A

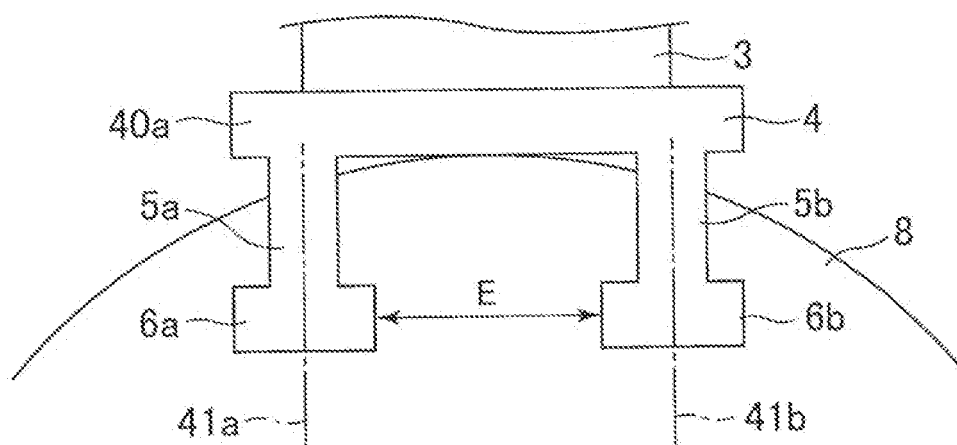
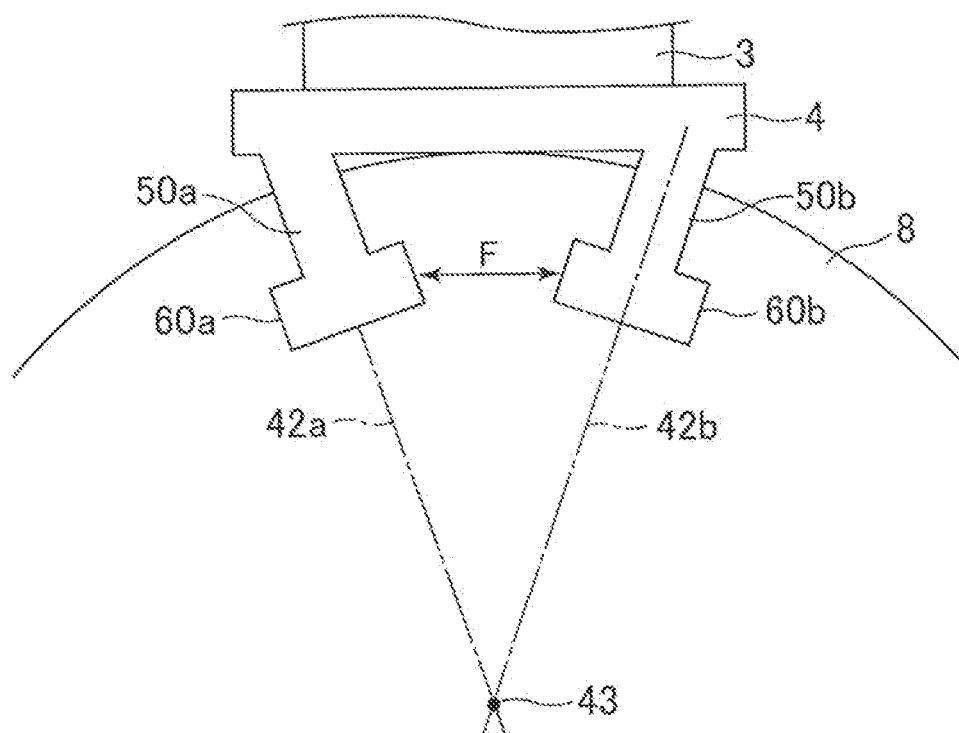


FIG.5B



REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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