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(54) Tip cover of a steam turbine for the drainage of water droplets

(57) A steam turbine includes: a turbine rotor shaft; a plurality of blades that are provided on the turbine rotor shaft and are rotated by a steam flow; tip covers that are attached to tip ends of the respective blades and are connected to and in contact with one another; at least one water drip fin that is provided along a circumferential direction at the tip cover, and outwardly extends in a radial direction of each of the blades; and a diaphragm outer ring that is disposed at an outer circumferential side from each of the blades, and has a drain catcher opposed to a tip end portion of the water drip fin, wherein the tip cover is provided with a leading edge that is formed at a downstream side in an axial direction from a leading edge of the blade or at a position in the axial direction corresponding to the leading edge of the blade in the axial direction.

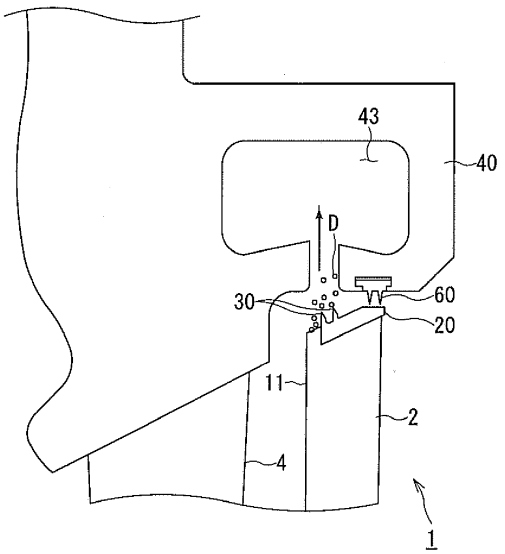

FIG. 7

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Description

FIELD

[0001] Embodiments described herein relates to a steam turbine and a blade of the steam turbine.

BACKGROUND

[0002] In the turbine low pressure section of a nuclear power turbine, a geothermal turbine or a thermal power turbine, the temperature of turbine driving steam becomes comparatively low. A part of the turbine driving steam condenses during expansion, and becomes water to flow to the inner and outer circumferential walls of the steam passage and the turbine blades.

[0003] The water that flows on the inner and outer circumferential walls of the steam passage and the turbine blades eventually grows to be water droplets with relatively large particle sizes. The water droplets become the factors that erode the leading edges of the turbine blades, generate a collision resistance to the rotation of the turbine blades, and reduce the blade efficiency of the turbine blades.

[0004] As described above, the presence of the water in the turbine adversely affects the turbine efficiency and reliability. In contrast, there has been conventionally known a steam turbine that has the structure for removing adhering water. Specifically, the steam turbine has a seal fin which is provided at the tip end portion of each of the turbine blades, and a space portion provided for the purpose of capturing water, at the tip end side of the seal fin. The water that flows inside the steam turbine is scattered in the outer circumferential direction by the centrifugal force by hitting against the seal fins, and is captured by the space portion (see Japanese Patent Laid-Open No. 2005-2917).

[0005] The conventional steam turbine captures the water in the steam turbine by the seal fins provided at the turbine blade tip end portions. However, the conventional steam turbine has been provided with seal fins which are originally intended for prevention of steam leakage, and therefore, collection of water is not necessarily be sufficient. Specifically, due to the effect of the steam flow in the steam turbine and the centrifugal force, the water cannot be favorably guided to the space portion, even though the seal fines are used.

[0006] As a result, the conventional steam turbine has the problem of being unable to suppress erosion by the drain which occurs to the steam turbine and reduction of the rotational resistance of the turbine blades.

[0007] Embodiments described herein is made in view of the circumstances as described above, and has an object to provide a steam turbine and a blade of the steam turbine that can favorably collect water generated in the steam turbine, and prevent reduction in turbine efficiency.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008]

Fig. 1 is a configuration diagram showing one embodiment of a steam turbine according to the present invention;

Fig. 2 is a plan view showing blades of the steam turbine of Fig. 1 from an outer circumferential side;

Fig. 3 is a configuration diagram for explaining a positional relation in an axial direction, of a water drip fin and an opening portion of a drain catcher;

Fig. 4 is an explanatory view of a flow of steam in the steam turbine;

Fig. 5 is a configuration diagram showing a steam turbine as a first modified example in which a water droplet guide groove is formed;

Fig. 6 is a plan view of blades of the steam turbine of Fig. 5 from an outer circumferential side;

Fig. 7 is a configuration diagram showing a steam turbine as a second modified example in which a plurality of water drip fins are provided;

Fig. 8 is a plan view showing blades of the steam turbine of Fig. 7 from an outer circumferential side; and

Fig. 9 is a configuration diagram showing a steam turbine as a third modified example in which water drip fins are discontinuously disposed.

DETAILED DESCRIPTION

[0009] An embodiment of a steam turbine and a blade of the steam turbine according to the present invention will be described based on the accompanying drawings. The steam turbine and the blade of the steam turbine in the present embodiment are applied to, for example, a low pressure section of a turbine.

[0010] Fig. 1 is a configuration diagram showing one embodiment of the steam turbine according to the present invention.

[0011] The steam turbine 1 includes a turbine rotor shaft 3, a plurality of blades 2 that are provided on the turbine rotor shaft 3 and are rotated by a steam flow, tip covers 20 that are attached to tip ends of the respective blades 2 and are connected to and in contact with one another, at least one water drip fin 30 that is provided along a circumferential direction of the tip cover 20 and outwardly extends in a radial direction of each of the blades 2, and a diaphragm outer ring 40 that is disposed at an outer circumferential side from each of the blades 2 and has a drain catcher 43 which is opposed to a tip end portion of the water drip fin 30.

[0012] Fig. 2 is a plan view showing blades 2 of a steam turbine 1 of Fig. 1 from an outer circumferential side.

[0013] The tip cover 20 is provided with a leading edge 25 that is formed at a downstream side in the axial direction from the leading edge 12 of the blade 2 or a position in the axial direction corresponding to the leading edge

12 of the blade 2 in the axial direction.

[0014] Illustration in Figs. 1 and 2 is on the precondition that the steam flows from the left to the right. In the blade 2, the description is made with the left side as a front, and the right side as a rear. In the steam turbine 1, a flowing direction of the steam corresponds to a direction of the turbine rotor shaft 3, and therefore, the flowing direction of the steam is defined as the axial direction.

[0015] As shown in Fig. 1, the steam turbine 1 mainly has the turbine rotor shaft 3, the blades 2 and vanes 4.

[0016] The blades 2 are disposed at a downstream side of the vanes 4 to be opposed to the vanes 4, and form a row of blades in a circumferential direction of the turbine rotor shaft 3. The blade 2 has a tip cover 20 formed integrally with the blade 2 at a blade tip end.

[0017] As shown in Fig. 2, the tip cover (cover) 20 is formed by a back side cover 21 that extends in a circumferential direction of a back side of the blade 2, and a front side cover 22 that extends in a circumferential direction of a front side of the blade 2. The adjacent covers 20 are in contact with each other. A position in the axial direction of a cover leading edge 25 of the front side cover 22 is at a rear side in the axial direction (downstream side in the axial direction) from a blade effective portion leading edge 12 of the blade 2, or corresponds to the blade effective portion leading edge 12 in the axial direction. When untwist (torsional moment which occurs in a direction opposite to the torsion of the blade) occurs to the cover 20 due to the centrifugal force of the blade 2, the back side cover 21 and the front side cover 22 of the adjacent blades 2 are in contact with each other on a cover contact surface 23. Thereby, the steam turbine 1 obtains a vibration damping effect of a group of the blades 2 on an entire circumference.

[0018] The cover 20 has a tip water drip fin 30 which is formed integrally with the cover 20, on a cover outer circumferential surface 27. The tip water drip fin (water drip fin) 30 is a fin outwardly extending in the radial direction of the blade 2 along the cover leading edge 25, and is provided in a ring shape throughout an entire circumference of the cover 20. Note that the water drip fin 30 may be provided at a rear side from the cover leading edge 25.

[0019] As shown in Fig. 1, an outside diameter ϕB at a tip end position of the water drip fin 30 is smaller than a maximum outside diameter ϕA of the cover 20. The cover 20 has an inclination slanting downward to the front, and has an outside diameter which is larger at a cover trailing edge 26 side and smaller at a cover leading edge 25 side, and a length in the radial direction of the water drip fin 30 is determined so that the outside diameter ϕB does not become larger than the cover trailing edge 26.

[0020] The vane 4 is provided between the nozzle diaphragm outer ring 40 and a nozzle diaphragm inner ring 45 which is located in an inner side in a radial direction of the nozzle diaphragm outer ring 40. The nozzle diaphragm outer ring (diaphragm outer ring) 40 has a nozzle strip 60 and the drain catcher 43.

[0021] The nozzle strip 60 is provided at the diaphragm outer ring 40 that is opposed to the rear side of the blade 2. The nozzle strip 60 functions as resistance of a watercourse of a space between the cover 20 and the diaphragm outer ring 40, and reduces a tip side leakage steam flow amount.

[0022] The drain catcher 43 is a space for collecting water droplets removed from the water drip fin 30. The drain catcher 43 has an opening portion 46 at a position in the axial direction that is opposed to the tip end of the water drip fin 30.

[0023] Here, Fig. 3 is a configuration diagram for explaining a positional relation in the axial direction of the water drip fin 30 and the opening portion 46 of the drain catcher 43.

[0024] In general, a differential expansion in the axial direction of the low pressure turbine is approximately 20 mm at the maximum. For the water drip fin 30, a size of the opening portion 46 of the drain catcher 43 (position in the axial direction of the water drip fin 30 with respect to the opening portion 46) is determined with the differential expansion taken into consideration.

[0025] Specifically, as shown in Fig. 3, even when the maximum differential expansion occurs in the longitudinal direction to the water drip fin 30 (turbine rotor shaft 3) at a time of a steady state operation, the maximum differential expansion at the tip end of the water drip fin 30 is configured to be within a width in the axial direction of the opening portion 46 of the drain catcher 43.

[0026] An opening portion inlet side 47 of the drain catcher 43 expands in the shape of a trumpet in sectional view, and a position in the axial direction of the opening portion inlet side 47 is from a front side axial position X1 to a rear side axial position X2 (positions X1 and X2 are the positions where the trumpet-shaped opening starts to close) of Fig. 3. The tip end of the water drip fin 30 is within the range in the axial direction of the opening portion inlet side 47 at a time of stoppage and at a time of the steady state operation when the maximum differential expansion can occur.

[0027] Next, an operation of the steam turbine 1 and the blade 2 will be described.

[0028] Fig. 4 is an explanatory view of a flow of the steam in the steam turbine 1.

[0029] During operation of the steam turbine 1, a part of the driving steam condenses, and becomes liquid films L to adhere to the vanes 4. When the liquid film L reaches a vane trailing edge 5 of the vane 4, the liquid film L becomes a water droplet D and scatters from the vane trailing edge 5 as the arrow A in the drawing. At this time, energy of the steam is used for acceleration of the water droplet D, and the energy of the steam is consumed.

[0030] The water droplet D cannot completely ride on the flow of the steam due to inertia, and collides with and adheres to the blade effective portion leading edge 12 of the rotating blade 2. Collision of the water droplet D becomes a braking force to the rotation of the blade 2, and

reduces the turbine efficiency. Further, collision of the water droplet D becomes the factor that causes erosion of the blade effective portion leading edge 12 of the blade 2 due to an impact thereof.

[0031] As shown in Fig. 1, the water droplet D moves outwardly on a blade surface of the blade 2 in the radial direction by the centrifugal force, and reaches a tip end in the radial direction of a blade effective portion side surface 11. Among the water droplets D which reach the tip end in the radial direction of the blade effective portion side surface 11, the water droplet D, which is present at a front side from the cover end surface 24 of the cover leading edge 25, rides onto a blade effective portion outer circumferential surface 13 by the surface tension at a boundary between the blade effective portion side surface 11 and the blade effective portion outer circumferential surface 13.

[0032] The water droplet D on the blade effective portion outer circumferential surface 13 moves rearward by the steam force, and reaches the water drip fin 30. The water droplet D which reaches the water drip fin 30 moves to the tip end of the water drip fin 30 by the centrifugal force, is blown off to the outer circumferential side of the blade 2 from the tip end, and is captured by the drain catcher 43.

[0033] Further, it is known that distribution of the amount of water adhering to the vane 4 (diaphragm outer ring 40) is larger at the outer circumferential side and that a large amount of water is also present on an inner circumferential wall surface 42 of the diaphragm outer ring 40. Further, the water droplet D which is scattered from the vane 4 is deflected to the outer circumferential side by the centrifugal force due to a velocity component in the circumferential direction of itself. Therefore, some of the water droplets D which are scattered from the vane 4 and the inner circumferential wall surface 42 directly adhere to the cover end surface 24 of the cover leading edge 25, the cover outer circumferential surface 27 or the fin end surface 31 at the front side of the tip water drip fin 30, and are captured by the drain catcher 43 as described above.

[0034] The steam turbine 1 and the blade 2 in the present embodiment can effectively remove and collect the water droplets D adhering to the blade 2. Thereby, the steam turbine 1 and the blade 2 can prevent erosion by the water droplets D. Further, the steam turbine 1 and the blade 2 can suppress the rotational resistance of the blade 2 by the water droplets D, and can prevent reduction of the turbine efficiency.

[0035] In particular, the blade 2 is provided with the cover that has the cover leading edge 25 which corresponds to the rear side from the blade effective portion leading edge 12 of the blade 2 or the blade effective portion leading edge 12, and therefore, the water droplets D which adhere to the blade effective portion side surface 11 and further reaches the blade effective portion outer circumferential surface 13 can be efficiently removed.

[0036] Further, the water drip fin 30 is provided not for the purpose of sealing leaking steam but for capturing the water droplets D in the drain catcher 43, therefore the outside diameter ϕB at the tip end position of the water drip fin 30 can be made smaller than the maximum outside diameter ϕA of the tip cover 20. Therefore, the risk of the tip end of the water drip fin 30 interfering with the inner circumferential surface of the diaphragm outer ring 40 or the nozzle strip 60 can be avoided, at a time of assembly and at a time of operation of the steam turbine 1.

[0037] Note that the steam turbine 1 and the blade 2 in the present embodiment may be configured as a modified example described as follows.

[0038] Fig. 5 is a configuration diagram showing the steam turbine 1 as the first modified example in which a water droplet guide groove 15 is formed.

[0039] Fig. 6 is a plan view showing the blades 2 of the steam turbine 1 of Fig. 5 from an outer circumferential side.

[0040] The blade 2 has one water droplet guide groove 15 or more (two in Figs. 5 and 6) at a front side (blade effective portion leading edge 12 side) from the cover leading edge 25 in a blade-back-side side surface 14. The water droplet guide groove 15 extends in the radial direction of the blade 2 and one end portion reaches the tip end of the blade 2.

[0041] When the water droplet D adhering to the blade-back-side side surface 14 moves in the outer circumferential direction of the blade 2, the blade 2 moves the water droplet D to the blade effective portion outer circumferential surface 13 by the water droplet guide groove 15. Thereby, the steam turbine 1 and the blade 2 can remove the water which adheres to the blade-back-side side surface 14 more reliably.

[0042] Fig. 7 is a configuration diagram showing the steam turbine 1 as a second modified example in which a plurality of water drip fins 30 are provided.

[0043] Fig. 8 is a plan view showing the blades 2 of the steam turbine 1 of Fig. 7 from an outer circumferential side.

[0044] The cover 20 has a plurality (two in Figs. 7 and 8) of water drip fins 30 arranged in the axial direction. By providing a plurality of water drip fins 30, the water droplets D which reach the cover outer circumferential surface 27 can be reliably captured in the drain catcher 43.

[0045] Fig. 9 is a configuration diagram showing the steam turbine 1 as a third modified example in which the water drip fins 30 are discontinuously disposed.

[0046] The water drip fins 30 outwardly extend in the radial direction of the blades 2 along the cover leading edges 25, and are discontinuously provided in the circumferential direction of the covers 20. The water drip fin 30 is provided with the objective of mainly removing the water from the blade effective portion outer circumferential surface 13. Therefore, when the trajectory of the water droplet D from the blade effective portion outer circumferential surface 13 is properly predicted, the water drip fin 30 can be discontinuously disposed to correspond

to the trajectory of the water droplet D.

[0047] While certain embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions. Indeed, the novel embodiments described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the embodiments described herein may be made without departing from the spirit of the inventions. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the inventions.

[0048] For example, the outside diameter ϕB at the tip end position of the water drip fin 30 may be larger than the maximum outside diameter ϕA of the cover 20. In this case, a distance between the opening portion inlet side 47 (see Fig. 3) of the drain catcher 43 and the tip end of the water drip fin 30 becomes small, which is effective in that the water droplet D can be reliably guided to the drain catcher 43.

[0049] Further, in place of the nozzle strip 60 of the diaphragm outer ring 40, a tip seal fin that is provided in a ring shape throughout the entire circumference may be provided integrally with the cover outer circumferential surface 27 of the tip cover 20.

[0050] It is explicitly stated that all features disclosed in the description and/or the claims are intended to be disclosed separately and independently from each other for the purpose of original disclosure as well as for the purpose of restricting the claimed invention independent of the composition of the features in the embodiments and/or the claims. It is explicitly stated that all value ranges or indications of groups of entities disclose every possible intermediate value or intermediate entity for the purpose of original disclosure as well as for the purpose of restricting the claimed invention, in particular as limits of value ranges.

Claims

1. A steam turbine, comprising:

a turbine rotor shaft (3);
a plurality of blades (2) that are provided on the turbine rotor shaft and are rotated by a steam flow;
tip covers (20) that are attached to tip ends of the respective blades and are connected to and in contact with one another;
at least one water drip fin (30) that is provided along a circumferential direction at the tip cover, and outwardly extends in a radial direction of each of the blades; and
a diaphragm outer ring (40) that is disposed at an outer circumferential side from each of the blades, and has a drain catcher (43) opposed to a tip end portion of the water drip fin (30),
wherein the tip cover is provided with a leading edge (25) that is formed at a downstream side in an axial direction from a leading edge (12) of the blade (2) or at a position in the axial direction corresponding to the leading edge of the blade in the axial direction.

2. The steam turbine according to claim 1, wherein the water drip fin is provided along the leading edge of the tip cover.

3. The steam turbine according to claim 1 or 2, wherein a tip end position of the water drip fin has an outside diameter smaller than a maximum outside diameter of the tip cover.

4. The steam turbine according to one of claims 1 to 3, wherein a plurality of the water drip fins are provided at the tip cover along the circumferential direction.

5. The steam turbine according to one of claims 1 to 4, wherein each of the blades has a water droplet guide groove that extends in the radial direction of the blade, with one end portion reaching the tip end of the blade, at an upstream side from the leading edge of the tip cover in a side surface at a back side.

6. The steam turbine according to one of claims 1 to 5, wherein the drain catcher has an opening portion with a maximum differential expansion being within a width in the axial direction of an opening even when the maximum differential expansion occurs at a position in the axial direction of the tip end of the water drip fin at a time of a steady state operation.

7. A blade of a steam turbine, comprising:

blades (2) rotated by a steam flow;
tip covers (20) that are attached to tip ends of the blades and are connected to and in contact with one another; and
at least one water drip fin (30) that is provided along a circumferential direction at the tip cover, and outwardly extends in a radial direction of each of the blades,
wherein the tip cover is provided with a leading edge that is formed at a downstream side in an axial direction from a leading edge of the blade or at a position in the axial direction corresponding to the leading edge of the blade in the axial direction.

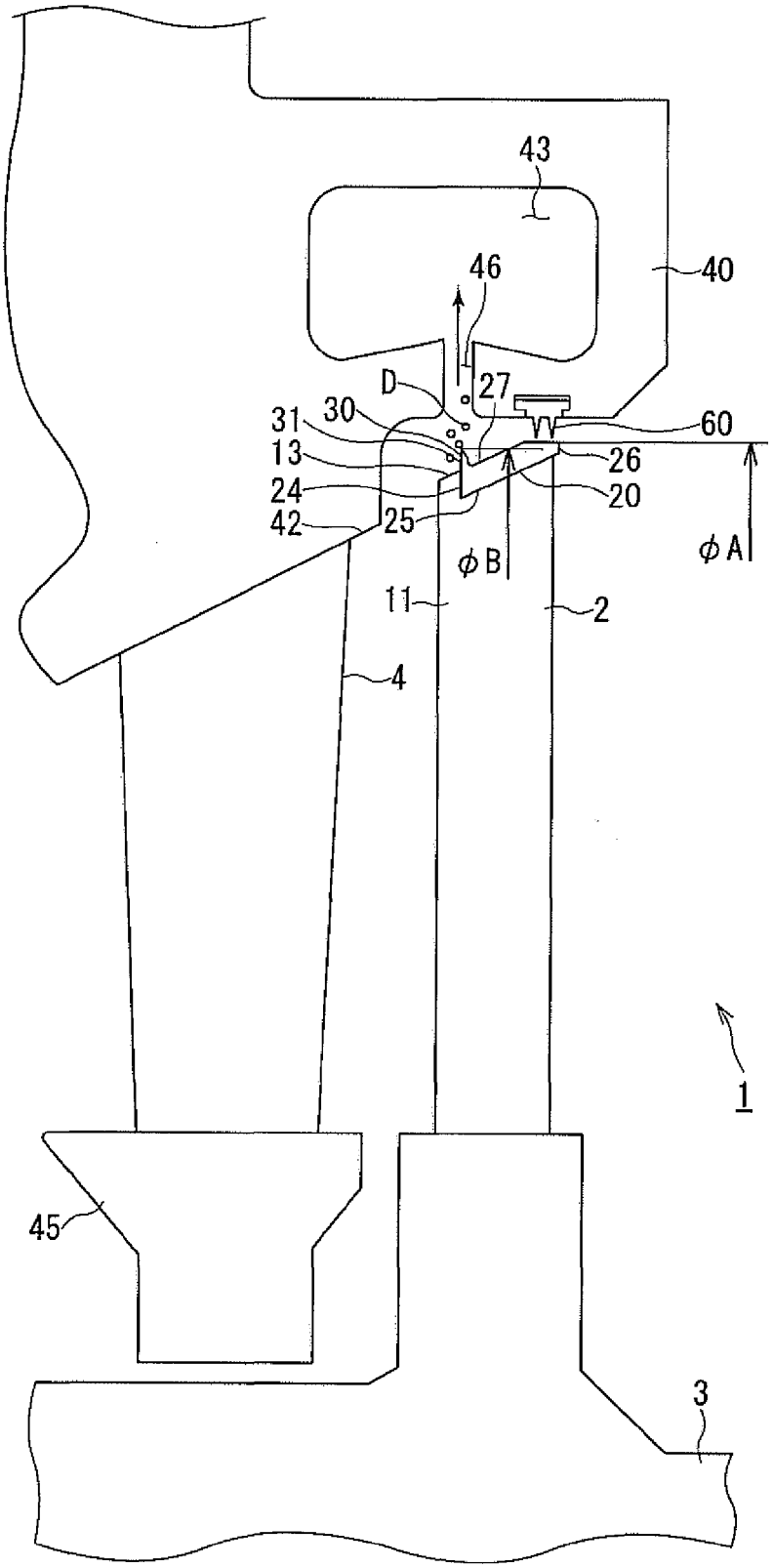

FIG. 1

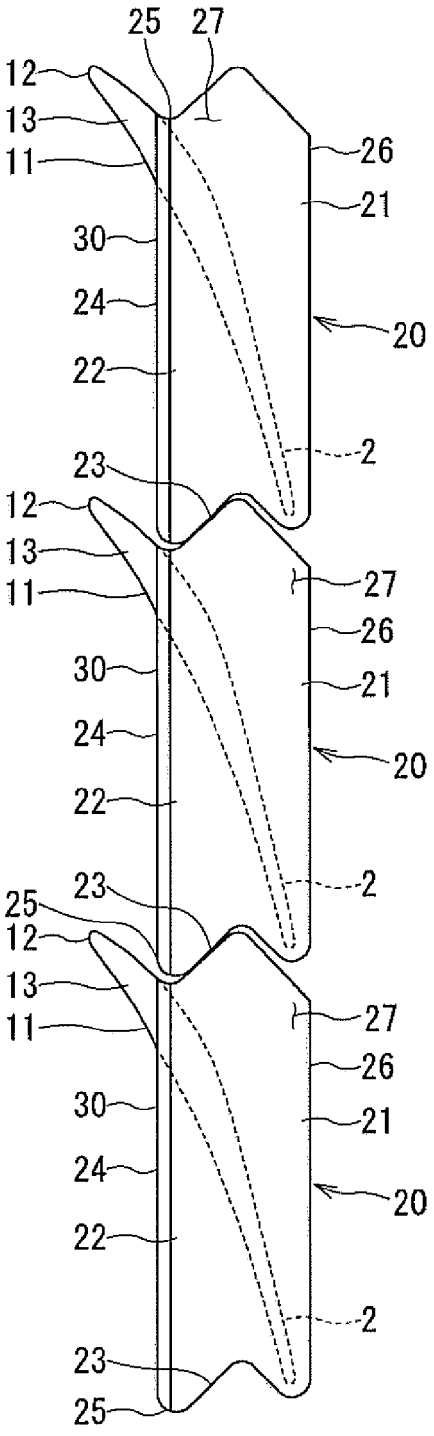
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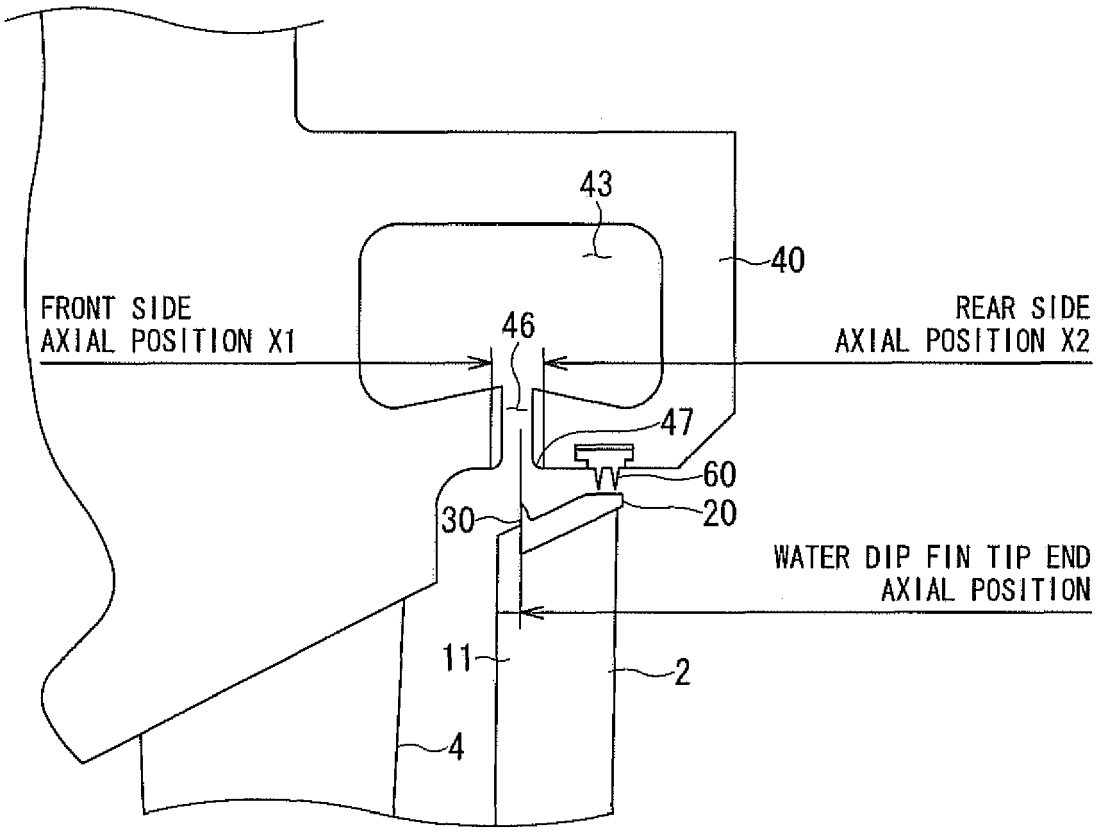
FIG. 2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WATER DIP FIN TIP END
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FIG. 3

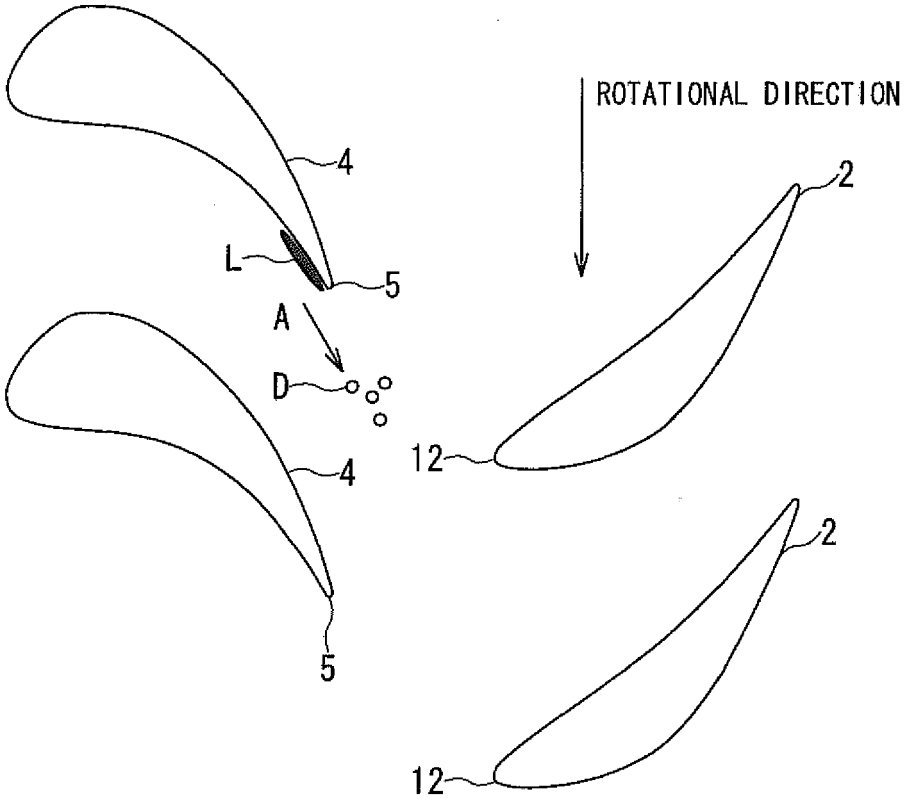

FIG. 4

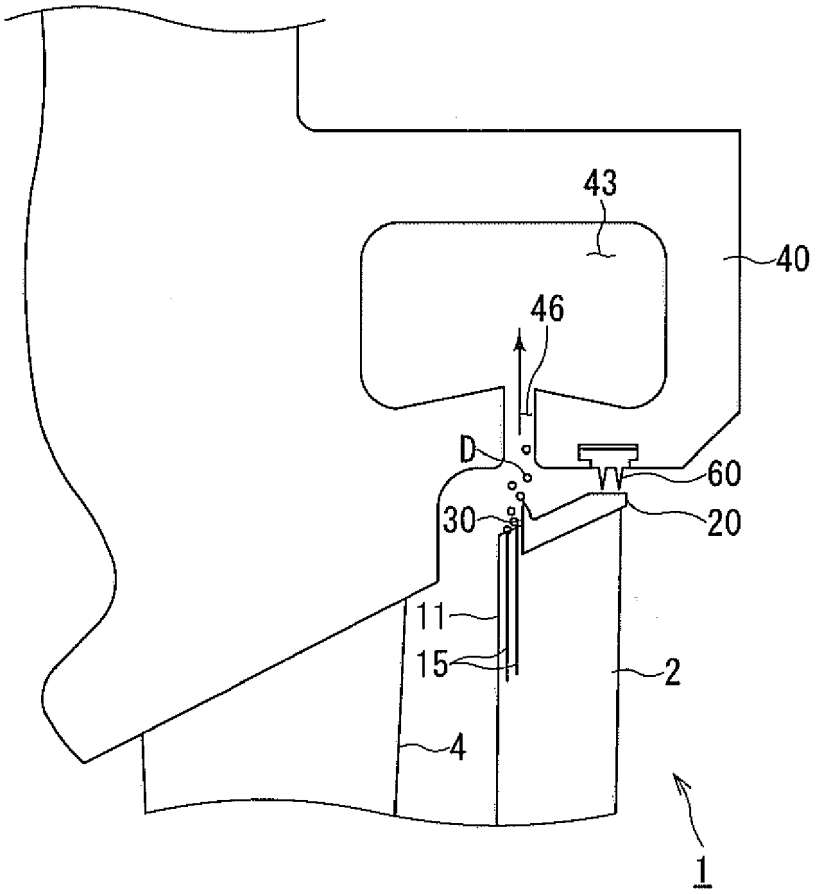

FIG. 5

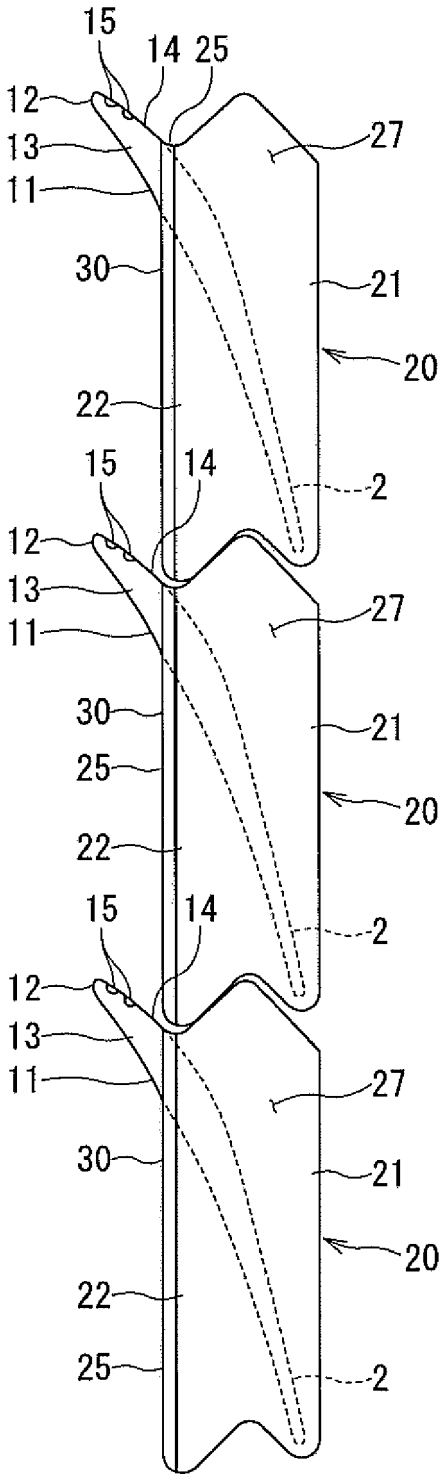
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FIG. 6

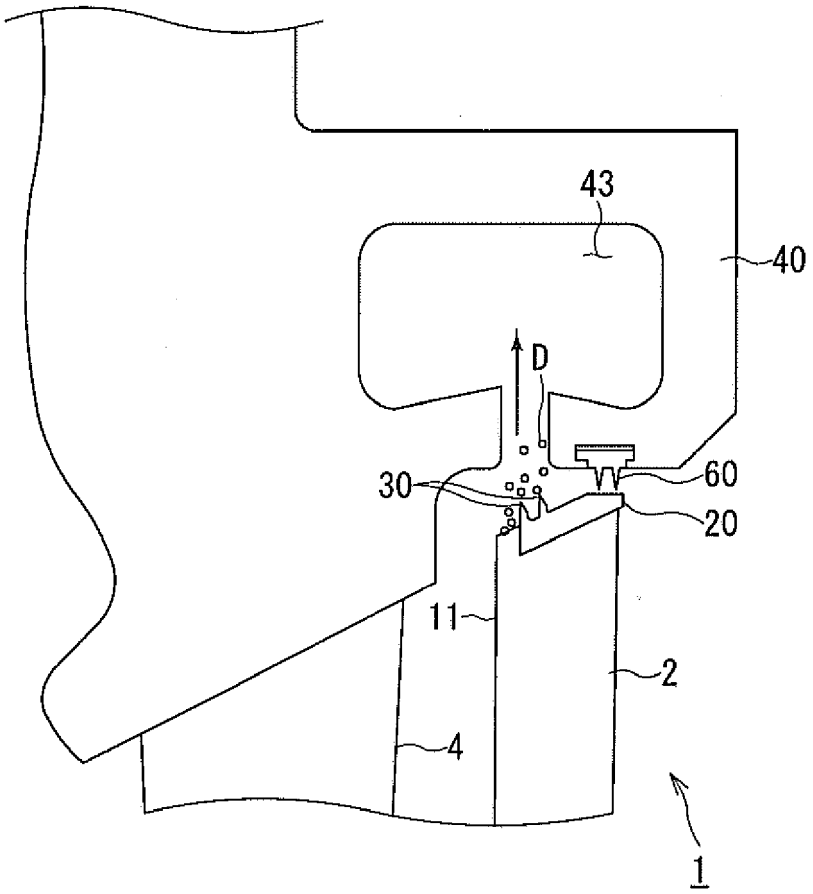

FIG. 7

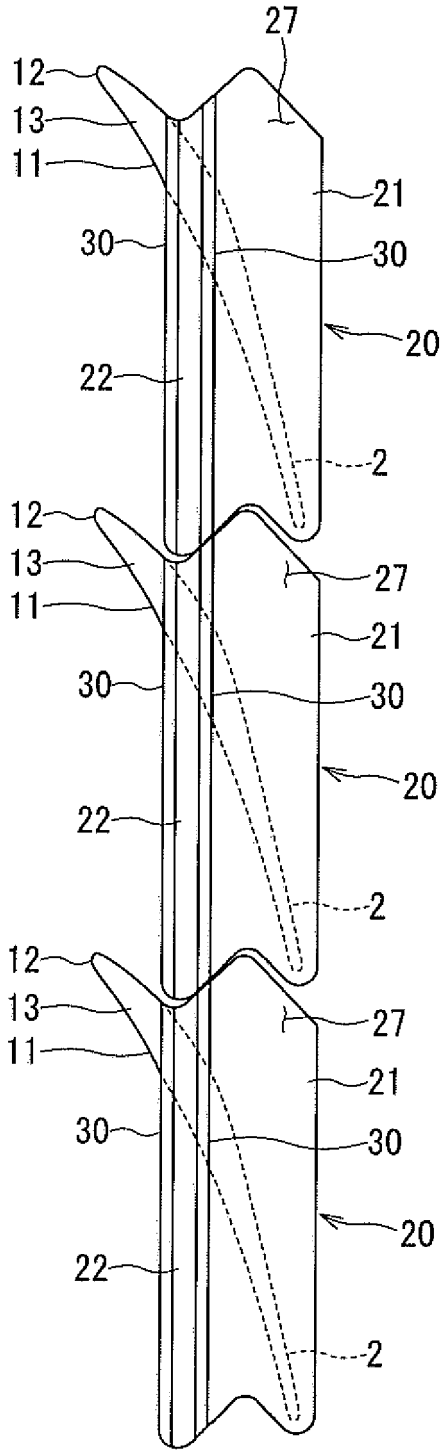
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FIG. 8

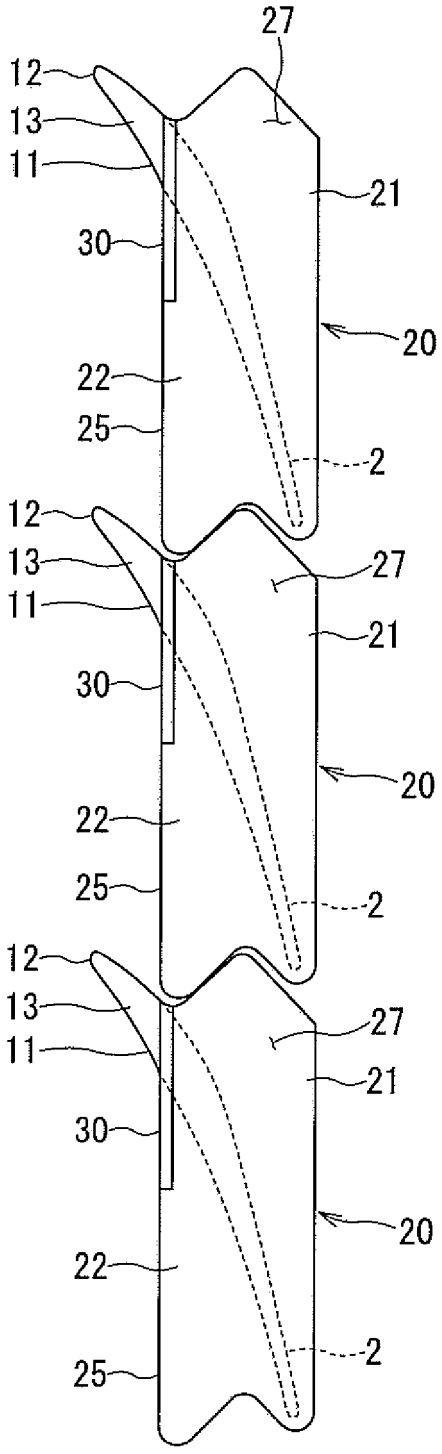
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FIG. 9

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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