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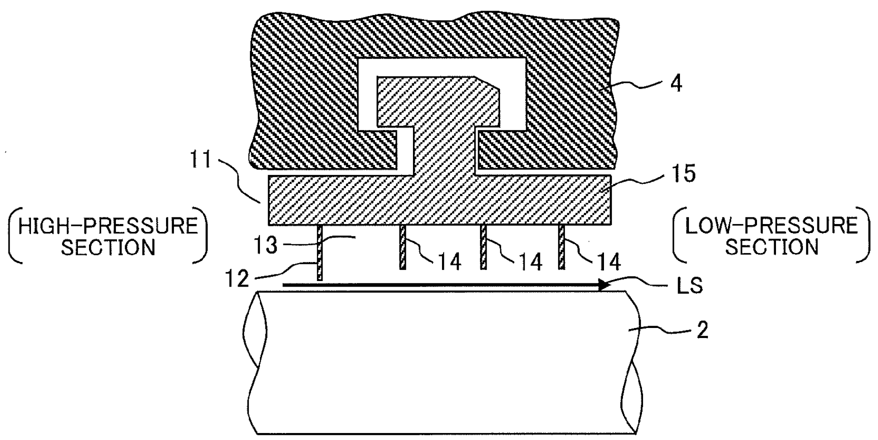
(54) **Turbo-machinery sealing arrangement**

(57) Turbo machinery includes a rotating body (2), a stator (3, 4, 5), and a labyrinth seal (11) disposed in a gap between the rotating body and the stator. The labyrinth seal (11) includes a first seal fin (12) and a second seal fin (14). The first seal fin (12) protrudes fromaportionof one of the rotating body and the stator, which is disposed on the high-pressure side of the center of the labyrinth seal in the axial direction of the rotating body, toward an opposing portion of the other one of the rotating body and the stator. The second seal fin (14) is disposed on the low-pressure side of the first seal fin to form a cavity (13) together with the first seal fin and protrude from a portion of one of the rotating body and the stator toward an opposing portion of the other one of the rotating body and the stator. A gap to the portion opposing the first seal fin (12) is smaller than a gap to the portion opposing the second seal fin (14).

FIG. 3



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Description

[Technical Field]

[0001] The present invention relates to turbo machinery, and more particularly to high-speed, high-pressure turbo machinery such as a steam turbine.

[Background Art]

[0002] In the turbo machinery such as a steam turbine, a labyrinth seal is often disposed between a rotor (rotating shaft) and a casing in order to prevent working fluid in the casing, which houses the rotor, from leaking along the rotor.

[0003] The labyrinth seal generally includes a plurality of seal fins, which are disposed along the axial direction of the rotor. A pressure drop void is formed between fins along the outer circumference of the rotor.

[0004] The labyrinth seal uses the pressure drop void to cause a pressure drop in a downward leakage flow therein. The pressure drop inhibits leakage to let the labyrinth seal perform its sealing function.

[0005] When the above-described labyrinth seal is used, the downward leakage flow therein may cause unstable vibration of the rotor. More specifically, the leakage flow in the labyrinth seal causes a fluid to flow in the same rotation direction as the direction of rotor rotation due to a drag turning effect produced by rotor rotation. This circumferential flow forms a high-pressure section upstream of the rotor, the axial center of which is displaced by vibration, or which is vibration-displaced, in the direction of rotor rotation. The high-pressure section then produces an unequal pressure pattern. The speed of circumferential flow increases with an increase in the rotation speed of the rotor. The unequal pressure pattern generates a fluid force perpendicular to the direction of vibration displacement of the rotor in accordance with the flow speed.

[0006] In the high-pressure turbo machinery such as a steam turbine, therefore, the fluid force exerted perpendicularly to the vibration displacement of the rotor during high-speed rotation acts to whirl the rotor in the direction of rotation. This may decrease the vibrational stability of the rotor to cause unstable vibration.

[0007] The above-described problem with the labyrinth seal, which causes unstable vibration of the rotor, can be solved by suppressing the fluid force exerted perpendicularly to the vibration displacement of the rotor. Well-known technologies for suppressing the fluid force are disclosed, for instance, in Japanese Unexamined Patent Application Publications No. 2010-38114 (PTL 1) and No. Hei 7 (1995)-19005 (PTL 2).

[0008] A seal shape described in PTL 1 is such that a damper seal producing a great damping effect is disposed upstream with respect to the direction of leakage flow whereas the labyrinth seal is disposed downstream. As the damper seal produces the damping effect and suppresses a flow in the direction of rotation, the fluid force exerted perpendicularly to the vibration displacement of the rotor is reduced.

[0009] The labyrinth seal described in PTL 2 is configured so that a seal ring is provided with a steam path for allowing a cavity to communicate with a region outside the seal, which is positioned upstream with respect to the direction of leakage flow, namely, positioned on the high-pressure side. The steam path is used to extract high-pressure steam to the cavity. The extracted steam then collides against a circumferential flow to suppress the circumferential flow, which is caused by the fluid force.

[Citation List]

[Patent Literature]

[0010]

[PTL 1] Japanese Unexamined Patent Publication No. 2010-38114
[PTL 2] Japanese Unexamined Patent Publication No. Hei 7 (1995)-19005

[Summary of Invention]

[Technical Problem]

[0011] A seal structure disclosed in PTL 1 will lead to a decrease in the efficiency of the turbo machinery because the damper seal disposed upstream is inferior to the labyrinth seal in sealing performance.

[0012] A structure disclosed in PTL 2 can efficiently suppress the circumferential flow. However, it may allow the extracted steam to increase the amount of downstream leakage flow, thereby degrading the sealing performance.

[0013] The present invention has been made in view of the above circumstances and provides turbo machinery provided with a labyrinth seal that not only suppresses the generation of a fluid force exerted in the direction of swirling within a seal to suppress the unstable vibration of a rotor but also provides adequate sealing performance.

[Solution to Problem]

[0014] According to an aspect of the present invention, there is provided turbo machinery including a rotating body, a stator, and a labyrinth seal. The stator is disposed around the rotating body, but with a gap to the rotating body. The labyrinth seal is disposed in a gap between the rotating body and the stator to reduce the flow of leakage that flows in the gap from the high-pressure side to the low-pressure side. The labyrinth seal includes a first seal fin and a second seal fin. The first seal fin protrudes from a portion of one of the rotating body and the stator, which is disposed on the high-pressure side of the center of the labyrinth seal in the axial direction of the rotating body, toward an opposing portion of the other one of the rotating body and the stator. The second seal fin is disposed on the low-pressure side of the first seal fin to form a cavity together with the first seal fin and protrude from a portion of one of the rotating body and the stator toward an opposing portion of the other one of the rotating body and the stator. A gap to the portion opposing the first seal fin is smaller than a gap to the portion opposing the second seal fin.

[Advantageous Effects of Invention]

[0015] According to an aspect of the present invention, a circumferential pressure peak within the cavity is generated at an enlarging portion of a flow path in the cavity during the vibration displacement of the rotating body. Therefore, the fluid force exerted perpendicularly to the vibration displacement of the rotating body works in such a direction as to suppress a whirling motion in the rotation direction of the rotating body. This makes it possible to suppress the unstable vibration of the rotating body. Further, adequate sealing performance is assured because a structure for increasing the amount of leakage flow is not attached to the labyrinth seal.

[Brief Description of Drawings]

[0016]

FIG. 1 is a cross-sectional view illustrating essential parts of a steam turbine;
FIG. 2 is a schematic diagram illustrating the pressure distribution in the cavity of a conventional labyrinth seal;
FIG. 3 is an axial cross-sectional view illustrating a labyrinth seal according to a first embodiment of the present invention;
FIG. 4 is a partially enlarged view illustrating the labyrinth seal shown in FIG. 3;
FIG. 5 is a schematic diagram illustrating the pressure distribution in the cavity of the labyrinth seal according to the first embodiment;
FIG. 6 is an axial cross-sectional view illustrating the labyrinth seal according to a second embodiment of the present invention;
FIG. 7 is an axial cross-sectional view illustrating the labyrinth seal according to a third embodiment of the present invention; and
FIG. 8 is an axial cross-sectional view illustrating the labyrinth seal according to a fourth embodiment of the present invention.

[Description of Embodiments]

[0017] Embodiments of the present invention will now be described with reference to the accompanying drawings.

[First Embodiment]

[0018] A first embodiment of the present invention will be described below with reference to FIGS. 1 to 5. The first embodiment is an example in which the present invention is applied to a labyrinth seal device for use in a steam turbine.

[0019] First of all, the structure of essential parts of the steam turbine to which the present invention is applied and the problem with a conventional labyrinth seal device will be described.

[0020] FIG. 1 is a cross-sectional view illustrating an exemplary structure of essential parts of a common steam turbine.

[0021] In the steam turbine 1 shown in FIG. 1, reference numeral 2 denotes a rotor, reference numeral 3 denotes a rotor casing, reference numeral 4 denotes a nozzle diaphragm inner ring, reference numeral 5 denotes a nozzle diaphragm outer ring, reference numeral 6 denotes a rotor blade, reference numeral 7 denotes a nozzle, reference numeral 8 denotes a diaphragm packing, reference numeral 9 denotes a tip seal, and reference numeral 10 denotes a shaft packing.

[0022] A steam turbine mainly includes the rotor 2 and the rotor casing 3. The rotor 2 and the rotor blade 6 form a turbine, which is a rotating body. The rotor casing 3 is a stationary body that includes and retains the rotor 2, and forms a flow path of steam 17, which is a working fluid. A plurality of rotor blades 6 are circumferentially disposed and fastened to the rotor 2. A plurality of nozzles 7 are positioned upstream of the rotor blades 6 in an opposing manner with respect to the direction of steam flow and circumferentially disposed and fastened to the rotor casing 3 through the nozzle diaphragm outer ring 5. The outer circumferential end of the nozzle 7 is fastened to the nozzle diaphragm outer ring 5, which is fastened to the rotor casing 3. The inner circumferential end of the nozzle 7 is secured by the nozzle diaphragm inner ring 4. In the steam turbine, a stage is formed by the rotor blade 6 and the nozzle 7, which is disposed upstream of the rotor blade 6 in an opposing manner. A plurality of stages are formed in the axial direction of the rotor 2.

[0023] The steam 17, which is a working fluid, is accelerated when it passes through the nozzle 7, and then forwarded to the rotor blade 6. The rotor blade 6 converts velocity energy to kinetic energy, thereby rotating the rotor 2. As the rotor 2 is connected to a generator (not shown), the rotation of the turbine is converted to electrical energy by the generator. The output is obtained as electrical energy.

[0024] A gap is provided between the rotor 2, which is a rotating body, and the rotor casing 3, which is a stationary body, in such a manner as not to obstruct the rotation of the rotor 2. Part of the steam 17 flows in the gap as a leakage flow from the high-pressure side to the low-pressure side. As the leaked steam is not effectively used for the rotary motion of the rotor 2, it becomes one of the factors that decrease the efficiency of the steam turbine.

[0025] As such being the case, a seal device, such as a labyrinth seal device, is disposed in the gap between the rotor 2, which is a rotating body, and the rotor casing 3, which is a stationary body, in order to avoid the outflow of the steam.

[0026] For example, a labyrinth seal is used as the diaphragm packing 8 for preventing the leakage of steam from a gap between the rotor 2 and the nozzle diaphragm inner ring 4 disposed on the inner circumferential side of the nozzle 7, as the tip seal 9 for preventing the leakage of steam from a gap between the rotor blade 6 and the rotor casing 3, and as the shaft packing 10 for preventing the leakage of steam from a gap between the rotor 2 and the rotor casing 3.

[0027] The labyrinth seal includes a plurality of seal fins that belong to either a rotor or a stator and protrude in the radial direction of the rotor. A ring-shaped pressure drop void (cavity 13) is positioned between the seal fins disposed along the axial direction of the rotor and disposed along the outer circumference of the rotor 2. The pressure drop void enables the labyrinth seal to cause a pressure drop in a leakage flow within the seal. This pressure drop suppresses the leakage flow to let the labyrinth seal perform its sealing function.

[0028] However, the conventional labyrinth seal has the following problem.

[0029] FIG. 2 is a schematic diagram illustrating the circumferential pressure distribution in the cavity 13 of the conventional labyrinth seal.

[0030] In axial flow turbo machinery such as a steam turbine, the leakage flow generally rotates in the rotation direction R of the rotor 2 due to a drag turning effect produced by the rotation of the rotor 2. This causes a circumferential flow RS.

[0031] When the rotor 2 becomes unidirectionally eccentric, or suffers unidirectional vibration displacement, the cavity 13 narrows in the direction of displacement. The circumferential flow RS is blocked upstream of the rotor 2 with respect to the direction of displacement. This results in the generation of a high-pressure section. This unequal pressure pattern generates a fluid force F, which presses the rotor 2 in the rotation direction R. When the above phenomenon is repeated, the rotor 2 whirls and suffers unstable vibration.

[0032] A labyrinth seal according to the present embodiment will now be described in consideration of the above-described problem with the conventional labyrinth seal.

[0033] The present embodiment is an example in which the present invention is applied to a labyrinth seal device for a steam turbine, or more specifically, an example in which the present invention is applied to a labyrinth seal device for the diaphragm packing 8.

[0034] FIG. 3 is an axial cross-sectional view illustrating a labyrinth seal 11 according to the first embodiment. FIG. 4 is a partially enlarged view illustrating a portion between the most upstream end with respect to the direction of leakage flow of the labyrinth seal 11 according to the first embodiment, which is shown in FIG. 3, and the second seal fin. FIG. 5 is a schematic diagram illustrating the pressure distribution in the cavity of cross-section X-X of the labyrinth seal 11 according to the first embodiment, which is shown in FIG. 4.

[0035] In the labyrinth seal 11, as shown in FIG. 3, a seal ring 15, which is assembled into a ring shape, is disposed on the inner circumferential side of the nozzle diaphragm inner ring 4, which is toric in shape. Apluralityof seal fins are disposed along the axial direction of the rotor 2 and fastened to the inner circumferential side of the seal ring 15. The cavity 13 is formed between the seal fins. The inlet side of the labyrinth seal 11 differs in pressure from the outlet side thereof. The inlet side is higher in pressure than the outlet side. In the present embodiment, a long seal fin is used as a first seal fin 12, which is closest to the high-pressure section. A narrow gap is provided between the seal fin 12 and an opposing portion of the rotor 2. A seal fin 14 having a shorter radial length than the seal fin 12 is used as a second seal fin 14 and subsequent seal fins, which are disposed on the low-pressure side of the seal fin 12, in order to provide a larger gap between the rotor 2 and the fin than for the first seal fin 12. The seal fin 12 should be formed to be longer than the seal fin 14.

[0036] Operational advantages of the present invention will now be described with reference to FIGS. 4 and 5.

[0037] As shown in FIG. 4, when the axial center of the rotor 2 is displaced by an eccentricity e in the radial direction due, for instance, to rotor vibration, the gap in the displacement direction between the first seal fin 12 and the rotor 2 narrows by the eccentricity e. Therefore, the leakage flow LS is blocked. On a side opposite the displacement direction, however, the gap between the first seal fin 12 and the rotor 2 widens by the eccentricity e. Therefore, the flow path for the leakage flow LS enlarges to increase the amount of leakage flow into a cavity 13c.

[0038] In a cavity 13d, which is included in the cavity 13 between the first seal fin and the second seal fin and positioned in the displacement direction, the inflow of the leakage flow LS, which flows from an upstream area, is suppressed. Meanwhile, the leakage flow in the cavity 13d passes through the seal fin 14 to a downstream area. Thus, the cavity 13d in the displacement direction is under low pressure as the differential pressure relative to an upstream cavity 13b increases. On the other hand, in the cavity 13c, which is included in the cavity 13 between the first seal fin and the second seal fin and positioned opposite the displacement direction, the amount of leakage flow LS from an upstream area increases to decrease the differential pressure relative to an upstream cavity 13a. Therefore, the cavity 13c is under high pressure.

[0039] In the cavity 13 in the above instance, the circumferential flow RS goes into the cavity 13c, which is an enlarged flow path on the side opposite the displacement direction, in spite of a pressure gradient as shown in FIG. 5. Hence, a pressure peak P occurs in an area on the side opposite the displacement direction that is positioned upstream with respect to the circumferential flow. In other words, there is an increase in the pressure of the circumferential flow RS that goes into the cavity 13c, which is an enlarged flowpath on the side opposite the displacement direction. This pressure distribution is obtained by inverting the circumferential pressure distribution in the labyrinth seal 11 shown, for instance, in FIG. 2. This pressure distribution generates a fluid force G so that the rotor 2 is pressed in a direction opposite the direction of the fluid force F. As a result, it is possible to inhibit the rotor 2 from whirling and suffering unstable vibration. Further, the above-described structure eliminates the necessity of attaching an additional structure for increasing the leakage flow to the labyrinth seal.

[0040] In the present embodiment, the high-pressure side seal fin 12 is long whereas the low-pressure side seal fin 14 is short. Alternatively, the seal fins 12, 14 may differ in seal shape as far as the seal fin 12 delivers higher sealing performance than the downstream seal fin 14. However, as the present invention makes use of circumferential gap changes encountered when eccentricity occurs, it is necessary that the seal fin 12 positioned upstream with respect to the leakage flow include a gap. The present invention cannot be applied, for instance, to a seal without a gap such as a brush seal.

[0041] Further, the labyrinth seal 11 need not be shaped so that the seal ring 15 has a seal fin. Alternatively, the labyrinth seal 11 may be shaped so that the rotor 2 has a seal fin or that the rotor 2 and the seal ring 15 both have a seal fin.

[0042] In the labyrinth seal, the pressure of the leakage flow decreases with a decrease in the distance to the low-pressure side. Therefore, a relatively great fluid force is exerted on the high-pressure side. It is conceivable that the influence of the fluid force on vibration decreases with a decrease in the distance to the low-pressure side. Therefore, the seal fin structure according to the present embodiment should be applied to a high-pressure side of the center of the labyrinth seal in the axial direction of a rotating body. It is most preferred that the seal fin structure according to the present embodiment be applied to a labyrinth seal inlet under the highest pressure.

[0043] The present embodiment has been described on the case that the present invention is applied to the labyrinth seal device for the diaphragm packing 8. However, the present invention is also applicable to a case where the labyrinth seal device is used for the shaft packing 10 or for the tip seal 9.

[Second Embodiment]

[0044] A second embodiment of the present invention will now be described. FIG. 6 is an exemplary axial cross-sectional view illustrating the labyrinth seal device according to the second embodiment. Like elements in the first and second embodiments are designated by the same reference numerals and will not be redundantly described.

[0045] In the first embodiment, which has been described earlier, the high-pressure side seal fin 12 is long whereas the low-pressure side seal fin 14 is short. In the second embodiment, on the other hand, the seal fins have a predetermined (fixed) length, and both the rotor 2 and the seal ring 15 have fins. The seal fins for the rotor 2 and the seal ring 15 are spaced at unequal intervals so that a seal fin 12a positioned at a high-pressure side of a stationary body agrees in axial position with a seal fin 12b positioned at a high-pressure side of a rotating body, and that low-pressure side seal fins 14 do not agree with each other in axial position. As the seal fins are disposed as described above, the seal fins 12 disposed upstream with respect to the direction of leakage flow have a small gap, whereas the seal fins 12 disposed downstream have a large gap.

[0046] In addition, the axial thickness of the seal fin 12b disposed on the rotor side is increased. Therefore, the sealing performance of the high-pressure side seal fin 12 can be maintained even when the seal fin is axially displaced due to the difference in axial thermal elongation between the rotor and the casing.

[0047] Moreover, the present embodiment is configured so that the high-pressure side seal fin 12b on the rotor side is increased in width. Alternatively, however, the seal fin 12a on the stator side may be increased in width.

[0048] Even if the seal fin is axially displaced due to the difference in thermal elongation, the high-pressure side seal fin 12b need not be increased in thickness as far as the sealing performance of the high-pressure side seal fin 12 is maintained. High-precision axial position alignment may be performed to ensure that the high-pressure side seal fin 12a agrees in axial position with the high-pressure side seal fin 12b. However, the present embodiment makes it easier to maintain the sealing performance than high-precision axial position alignment.

[0049] The structure according to the present embodiment also makes it possible to invert the circumferential pressure distribution in the cavity 13. Therefore, the present embodiment can not only maintain the sealing performance, as is the case with the first embodiment, but also effectively prevent the unstable vibration of the rotor 2 by inverting the circumferential pressure distribution. In addition, the structure according to the present embodiment eliminates the necessity of attaching an additional structure for increasing the leakage flow to the labyrinth seal.

[Third Embodiment]

[0050] A third embodiment of the present invention will now be described. FIG. 7 is an exemplary axial cross-sectional view illustrating the labyrinth seal 11 according to the third embodiment. Like elements in the first and third embodiments are designated by the same reference numerals and will not be redundantly described.

[0051] In the first embodiment, which has been described earlier, the high-pressure side seal fins 12 have a relatively large gap to prevent the fins from rubbing on an opposing portion of the rotor due to the difference in radial thermal elongation between the rotor and the casing. In the third embodiment, on the other hand, the high-pressure side seal fins 12 are long, and an abradable layer 16 is formed on portions opposing the high-pressure side seal fins 12 to ensure that the high-pressure side seal fins 12 have a very small gap. Even when an upstream seal fin 12 rubs against the seal ring 15 due to the difference in radial thermal elongation between the rotor and the casing, the abradable layer 16 prevents the generation of heat and avoids damage to the seal fin. The example shown in FIG. 7 depicts a case where the seal fin is disposed toward the rotor 2 and the abradable layer 16 is disposed toward the seal ring 15. However, an alternative is to dispose the abradable layer 16 toward the rotor 2 and dispose the seal fin toward the seal ring 15.

[0052] The structure according to the present embodiment can also invert the circumferential pressure distribution in the cavity 13. Therefore, the present embodiment can not only maintain the sealing performance, as is the case with the first embodiment, but also effectively prevent the unstable vibration of the rotor 2 by inverting the circumferential pressure distribution. In addition, the structure according to the present embodiment eliminates the necessity of attaching an additional structure for increasing the leakage flow to the labyrinth seal.

[0053] Moreover, the present embodiment can effectively reduce the amount of leakage because it reduces the likelihood of leakage by narrowing the upstream gap that significantly affects the sealing performance.

[Fourth Embodiment]

[0054] A fourth embodiment of the present invention will now be described. FIG. 8 is an exemplary axial cross-sectional view illustrating the labyrinth seal 11 according to the fourth embodiment. Like elements in the first and fourth embodiments are designated by the same reference numerals and will not be redundantly described.

[0055] In the second embodiment, which has been described earlier, the seal fins have a fixed length, and both the rotor 2 and the seal ring 15 have fins. In the fourth embodiment, on the other hand, there is a level difference 18 between the high-pressure side seal fins 12 and the seal ring 15. As the level difference 18 is provided between the seal ring 15 and the seal fins 12 disposed upstream with respect to the direction of leakage flow, the seal fins are allowed to be equal in length. While the fins are equal in length, the circumferential pressure distribution in the cavity 13 can be inverted without providing both the rotor 2 and the seal ring 15 with fins. Further, as the high-pressure side seal fins 12 are not increased in length, the strength of the high-pressure side seal fins 12 can be maintained. Furthermore, the structure according to the present embodiment eliminates the necessity of attaching an additional structure for increasing the leakage flow to the labyrinth seal.

[0056] Moreover, the present embodiment is configured so that the level difference 18 is provided on the seal ring 15. Alternatively, however, the level difference 18 may be provided on the rotor 2.

[0057] In addition, the present embodiment is configured so that the level difference 18 has a triangular cross-section. Alternatively, however, the level difference 18 may have a differently shaped cross-section.

[0058] The present invention is not limited to the above-described embodiments, but extends to various modifications in terms of shape that nevertheless fall within the scope of the appended claims. It should also be noted that the above-described embodiments are offered by way of example only in order to facilitate the understanding of the present invention. Further, the present invention is not limited to embodiments that include all the above-described elements.

[0059] The foregoing embodiments have been described on the case that the present invention is applied to a steam turbine. However, the present invention is also applicable to the other turbo machinery such as a centrifugal compressor.

[Reference Signs List]

[0060]

1... Steam turbine
2... Rotor
3... Rotor casing
4... Nozzle diaphragm inner ring
5... Nozzle diaphragm outer ring
6... Rotor blade
7... Nozzle
8... Diaphragm packing
9... Tip seal
10... Shaft packing
11... Labyrinth seal
12, 14... Seal fin
13... Cavity
15... Seal ring
16... Abradable layer
17... Steam
18... Level difference
LS... Leakage flow
RS... Circumferential flow
R... Rotation direction

Claims

1. Turbo machinery comprising:

   a rotating body (2, 7);

a stator (3, 4, 5) disposed around the rotating body, but with a gap to the rotating body; and alabyrinthseal (11) disposed in a gap be tween the rotating body and the stator to reduce the flow (LS) of leakage flowing in the gap from the high-pressure side to the low-pressure side; wherein the labyrinth seal includes

a first seal fin (12) protruding from a portion of one of the rotating body and the stator toward an opposing portion of the other one of the rotating body and the stator and disposed on the high-pressure side of the center of the labyrinth seal in the axial direction of the rotating body, and

a second seal (14) fin disposed on the low-pressure side of the first seal fin to form a cavity (13) together with the first seal fin and protruding froma portion of one of the rotating body and the stator toward an opposing portion of the other one of the rotating body and the stator,

a gap to the portion opposing the first seal fin being smaller than a gap to the portion opposing the second seal fin.

2. The turbo machinery according to claim 1, wherein the portion opposing the first seal fin is provided with an abradable layer (16).

3. The turbo machinery according to claim 1 or 2, wherein the portion opposing the first seal fin (12a) is provided with a third seal fin (12b) protruding toward the first seal fin (12a); and wherein one of the first seal fin and the third seal fin has a greater axial thickness than the other one of the first seal fin and the third seal fin.

4. The turbo machinery according to any one of claims 1 to 3, wherein the first seal fin is a seal fin disposed closer to a high-pressure section than any other seal fins included in the labyrinth seal.

FIG. 1

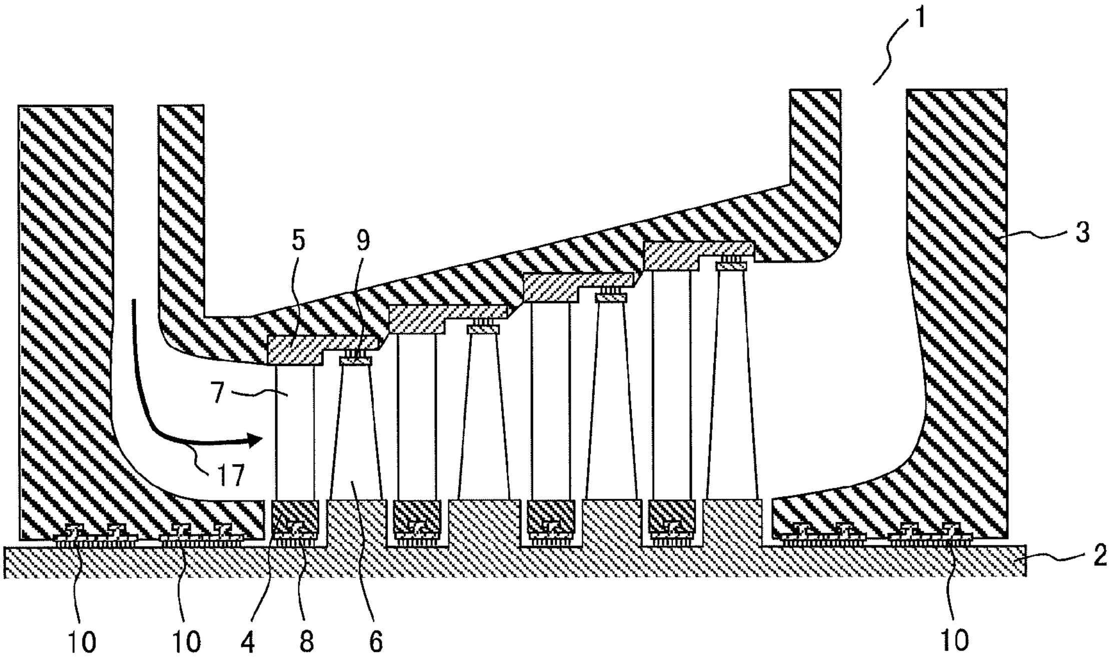


FIG. 2

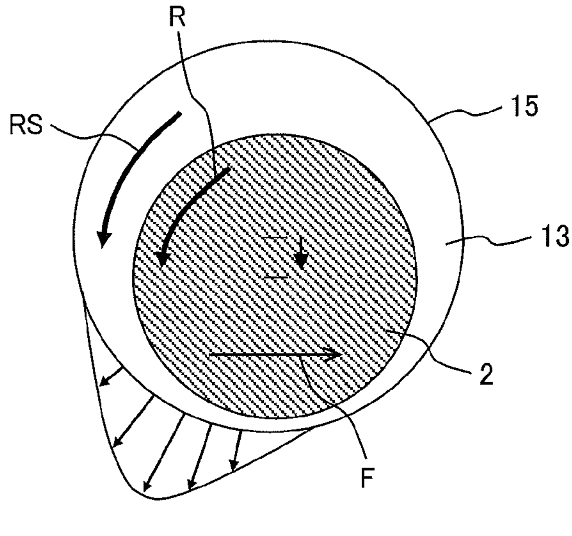


FIG. 3

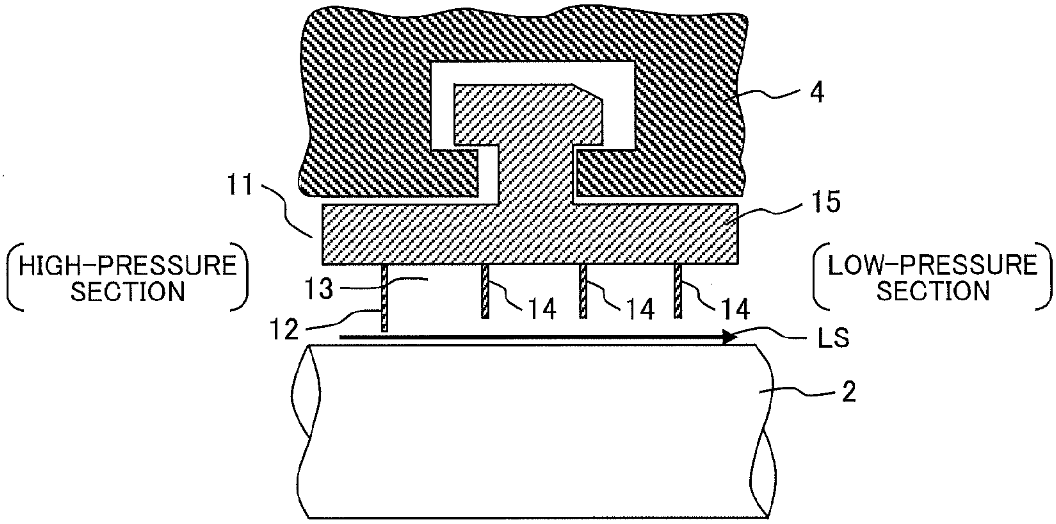

4
11
15
HIGH-PRESSURE SECTION
LOW-PRESSURE SECTION
13
14
14
14
12
LS
2

FIG. 4

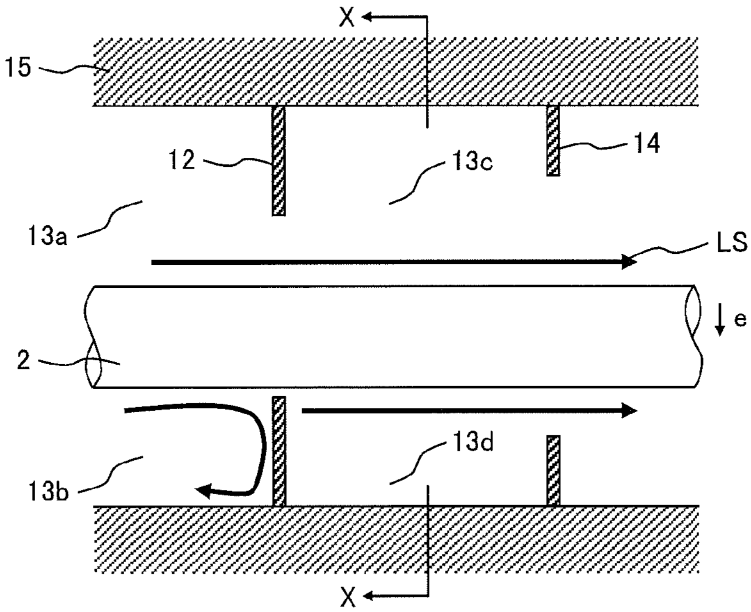

X
15
12
13c
14
13a
LS
e
2
13d
13b
X

FIG. 5

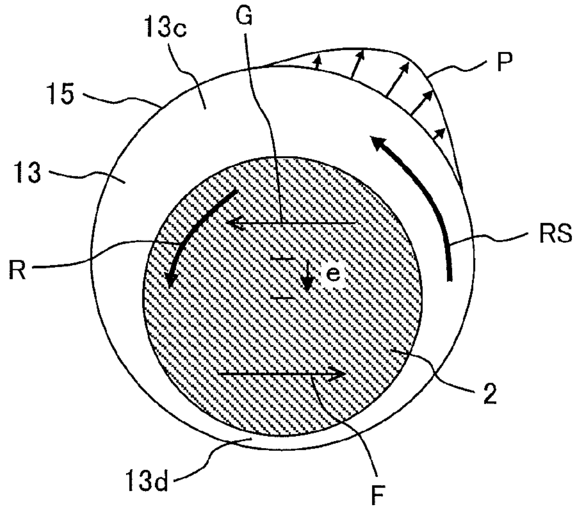


FIG. 6

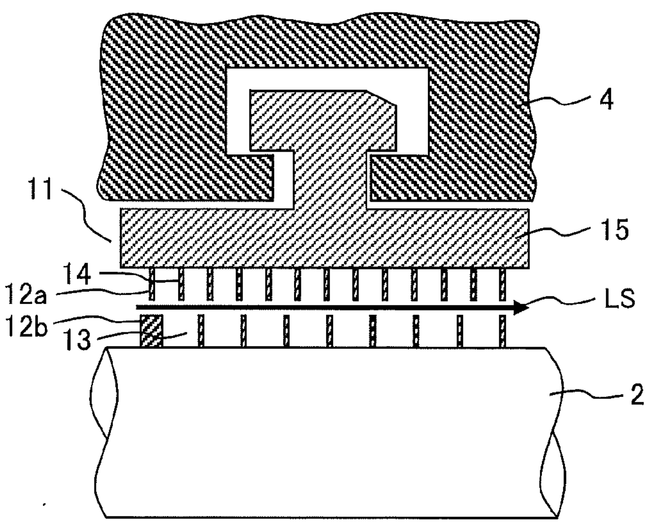


FIG. 7

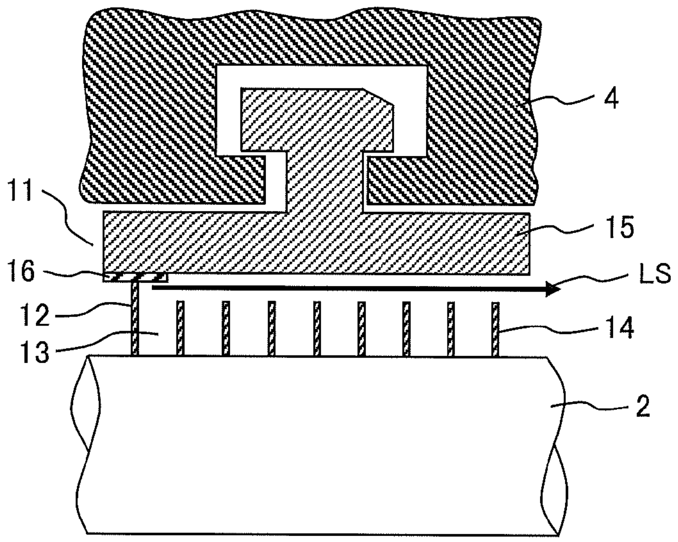
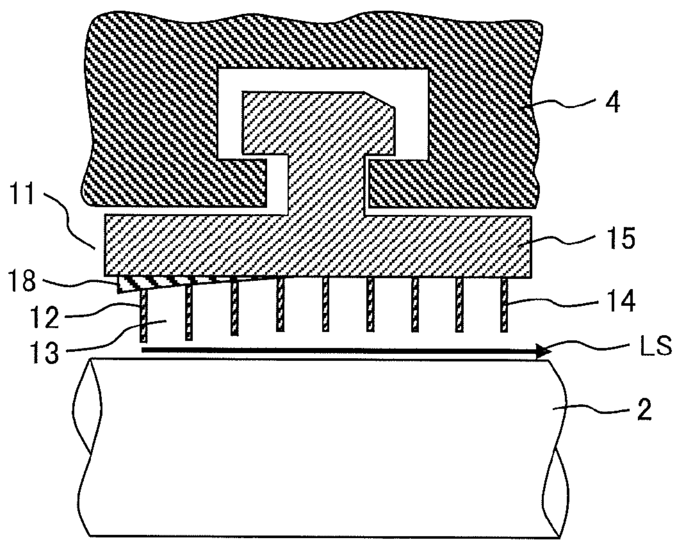


FIG. 8



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