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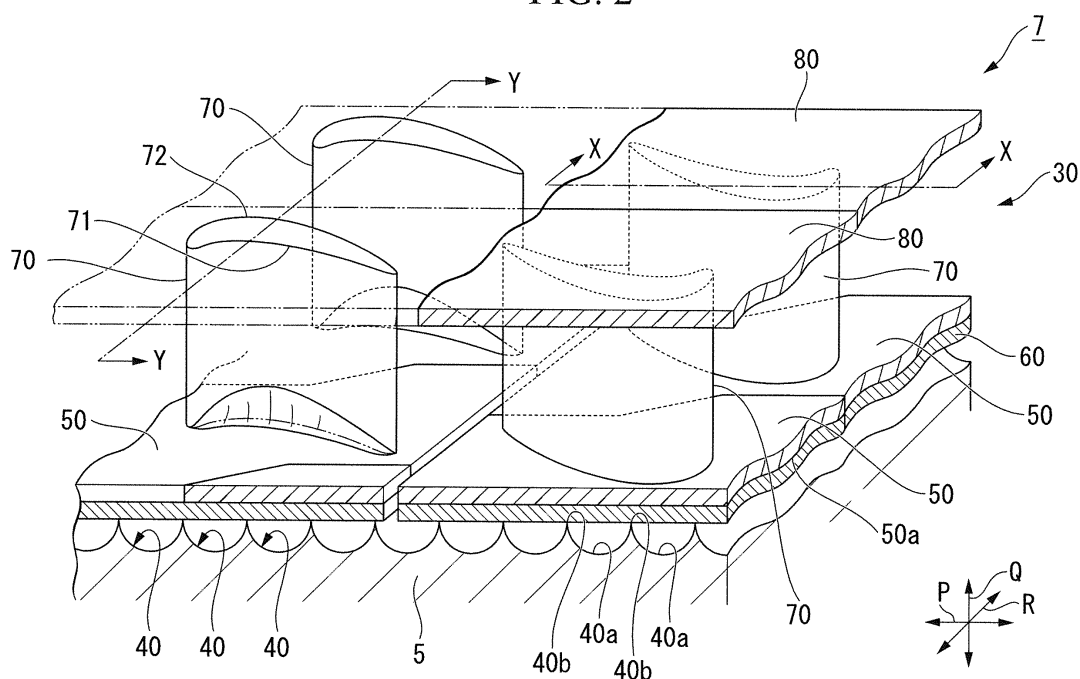
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(54) SEALING STRUCTURE AND ROTATING MACHINE EQUIPPED WITH SAME

(57) Provided is a seal structure, which includes fins configured to protrude from an outer circumferential surface of a rotor in a circumferential direction, and stator blades having an abradable coating formed on an inner

circumferential surface of an inner shroud so as to face the fins. The inner circumferential surface of the inner shroud is formed in an uneven shape, and the abradable coating is formed along the uneven shape.

FIG. 2



Description

[Field of the Invention]

[0001] The present invention relates to a seal structure and a rotating machine equipped therewith.

[0002] This application claims priority to and the benefits of Japanese Patent Application No. 2012-023071 filed on February 6, 2012, the disclosure of which is incorporated herein by reference.

[Background Art]

[0003] In general, in rotating machines such as steam turbines and gas turbines, an amount of leakage of fluid is reduced to the utmost by minimizing a clearance between a rotor and a stationary side member such as a stator blade around the rotor, which is important from the viewpoint of improving the performance of the rotating machine.

[0004] Thus, a seal structure equipped with fins, which protrudes from an outer circumferential surface of a rotor in a circumferential direction, and a seal member, in which an abrasible material having high cuttability is thermally sprayed on places of a stationary side member which are opposite to the fins, is employed (see Patent Document 1 below). In this seal structure, during rotation of the rotor, even when the rotor and the stationary side member are brought into contact with each other, the abrasible material is cut out. Thereby, the generation of heat can be reduced at a contact place so as to maintain the performance of the rotating machine.

[0005] Here, the seal member is an annular member extending in the circumferential direction, and is formed with an abrasible coating on an inner circumferential surface thereof which is formed by thermally spraying the abrasible material.

[Related Art Documents]

[Patent Documents]

[0006] [Patent Document 1] Japanese Unexamined Patent Application, First Publication No. 2009-174655

[Disclosure of the Invention]

[Problems to be Solved by the Invention]

[0007] However, in the seal structure set forth in Patent Document 1 above, since the seal member needs to be provided, there are problems in that labor is consumed in view of manufacturing, and in that a machining cost is increased to lead to an increase in cost.

[0008] On the other hand, technology of omitting the seal member and directly thermally spraying the abrasible member on the stationary side member is taken into consideration.

[0009] Here, during rotation of the rotor, since a shear force occurs between inner shrouds of neighboring stator blades in a shaft direction, the abrasible material should bear the shear force. However, since the abrasible material has high cuttability, the abrasible material that is just thermally sprayed directly on the stator blade is damaged by the shear force, and furthermore there is a possibility of peeling off of the abrasible material from the stator blade. As such, it is not possible to simply use only thermal spraying.

[0010] The present invention has been made in consideration of these circumstances, and an object of the present invention is to provide a seal structure capable of preventing an abrasible material from peeling off even when damage is caused to the abrasible material.

[Means for Solving the Problems]

[0011] According to a first aspect of the present invention, there is provided a seal structure, which includes a fin configured to protrude from an outer circumferential surface of a rotor in a circumferential direction, and a stator blade having an abrasible coating formed on an inner circumferential surface of an inner shroud so as to face the fins. The inner circumferential surface of the inner shroud is formed in an uneven shape, and the abrasible coating is formed along the uneven shape.

[0012] In this seal structure, the abrasible coating is formed along the uneven shape, and an abrasible material enters and is hardened and deposited in the uneven shape portion. As such, the bonding area can be increased, and the abrasible coating can be strongly bonded. Accordingly, even when the abrasible coating is damaged, the abrasible coating can be prevented from being separated from the stator blade because the abrasible coating is strongly bonded.

[0013] In the seal structure according to the first aspect of the present invention, the uneven shape may be configured by a concave portion formed from one of the inner circumferential surface of the inner shroud and an outer circumferential surface of the abrasible coating toward an interior thereof.

[0014] In this seal structure, the uneven shape is formed by, for instance, the concave portion formed from the inner circumferential surface of the inner shroud toward the interior thereof. Accordingly, since the abrasible coating enters the concave portion, the bonding force can be reliably improved. Thus, even when the abrasible coating is damaged, the abrasible coating can be prevented from being separated from the stator blade.

[0015] In the seal structure according to the first aspect of the present invention, the concave portion may be formed so as to extend in the circumferential direction.

[0016] In this seal structure, the bonding force of the abrasible coating can be improved throughout the circumferential direction. Accordingly, even when the abrasible coating is damaged, the abrasible coating can be prevented from being separated from the stator

blade.

[0017] In the seal structure according to the first aspect of the present invention, the concave portion may be formed so as to extend in an axial direction of the rotor.

[0018] In this seal structure, the bonding force of the abrasion-resistant coating can be improved throughout the axial direction. Accordingly, even when the abrasion-resistant coating is damaged, the abrasion-resistant coating can be prevented from being separated from the stator blade.

[0019] In the seal structure according to the first aspect of the present invention, the concave portion may be formed on a boundary line between the inner shrouds adjacent in the circumferential direction.

[0020] In this seal structure, the concave portion is capable of being formed on the boundary line between the neighboring inner shrouds, and the abrasion-resistant coating is capable of entering the concave portion. Accordingly, when a shear force occurs between the inner shrouds adjacent to the boundary line, the shear force can be reduced according to the amount of the abrasion-resistant coating that enters the concave portion. As such, the deformation caused by the distortion of the stator blades can be prevented.

[0021] In the seal structure according to the first aspect of the present invention, the one of the inner circumferential surface of the inner shroud and the outer circumferential surface of the abrasion-resistant coating may be formed with a second concave portion so as to be opposite to the concave portion formed in the other of the inner circumferential surface of the inner shroud and the outer circumferential surface of the abrasion-resistant coating, and the seal structure may include a pin member inserted between the concave portion and the second concave portion.

[0022] In this seal structure, for example, when the concave portion is formed on the side of the inner shroud, an axial displacement of the inner shroud can be reduced by fitting and bonding of the concave portion and the pin member. Further, the bonding force of the abrasion-resistant coating can be improved by bonding of the second concave portion and the pin member.

[0023] In the seal structure according to the first aspect of the present invention, the concave portion may be formed so that a width thereof in a cross section perpendicular to an extending direction thereof gradually widens from the one of the inner circumferential surface of the inner shroud and the outer circumferential surface of the abrasion-resistant coating toward a bottom thereof.

[0024] In this seal structure, the bonding area of the abrasion-resistant coating can be increased. Further, when force is applied to the abrasion-resistant coating in a separating direction, a resistance force is applied to an inclined surface of the abrasion-resistant coating which corresponds to a surface formed toward the bottom of the concave portion. As such, the abrasion-resistant coating can be more strongly bonded. Accordingly, even when the abrasion-resistant coating is damaged, the abrasion-resistant coating can be prevented from being separated from the stator blade because the abrasion-resistant

coating is strongly bonded.

[0025] In the seal structure according to the first aspect of the present invention, the concave portion may be formed in an arcuate shape in which a cross section perpendicular to an extending direction thereof swells from the one of the inner circumferential surface of the inner shroud and the outer circumferential surface of the abrasion-resistant coating.

[0026] In this seal structure, since the bonding area of the abrasion-resistant coating can be increased, the bonding force can be improved.

[0027] According to a second aspect of the present invention, there is provided a rotating machine having any one of the foregoing seal structures.

[0028] According to this configuration, since the rotating machine is equipped with any one of the foregoing seal structures, a desired seal function can be exerted, and the abrasion-resistant coating can be prevented from being separated from the stator blade even when the abrasion-resistant coating is damaged.

[Effects of the Invention]

[0029] According to the aforementioned seal structure and the rotating machine equipped therewith, the abrasion-resistant coating enters and is hardened and deposited in the uneven shape portion. Thereby, the abrasion-resistant coating can be strongly bonded. For this reason, even when the abrasion-resistant coating is damaged, the abrasion-resistant coating can be prevented from being separated from the stator blade.

[Brief Description of the Drawings]

[0030]

FIG. 1 is a schematic view of a gas turbine (rotating machine) according to an embodiment of the present invention.

FIG. 2 is a perspective view of a seal structure according to an embodiment of the present invention. FIG. 3 is a cross-sectional view taken along line X-X of FIG. 1 and showing a stator blade that is a constituent member of a seal structure according to a first embodiment of the present invention.

FIG. 4 is a cross-sectional view taken along line X-X of FIG. 1 and showing a stator blade that is a constituent member of a seal structure according to a second embodiment of the present invention.

FIG. 5 is a cross-sectional view taken along line X-X of FIG. 1 and showing a stator blade that is a constituent member of a seal structure according to a third embodiment of the present invention.

FIG. 6 is a cross-sectional view taken along line X-X of FIG. 1 and showing a stator blade that is a constituent member of a seal structure according to a fourth embodiment of the present invention.

FIG. 7 is a cross-sectional view taken along line X-

X of FIG. 1 and showing a stator blade that is a constituent member of a seal structure according to a fifth embodiment of the present invention.

FIG. 8 is a cross-sectional view taken along line Y-Y of FIG. 1 and showing a stator blade that is a constituent member of a seal structure according to a sixth embodiment of the present invention.

FIG. 9 is a cross-sectional view taken along line Y-Y of FIG. 1 and showing a stator blade that is a constituent member of a seal structure according to a seventh embodiment of the present invention.

FIG. 10 is a cross-sectional view taken along line Y-Y of FIG. 1 and showing a stator blade that is a constituent member of a seal structure according to an eighth embodiment of the present invention.

FIG. 11 is a cross-sectional view showing the stator blade that is the constituent member of the seal structure according to the eighth embodiment of the present invention.

[Mode for Carrying out the Invention]

(First Embodiment)

[0031] Hereinafter, a rotating machine according to a first embodiment of the present invention will be described with reference to the drawings.

[0032] The first embodiment of the present invention will be described with reference to FIG. 1. A gas turbine (rotating machine) 1 is equipped with a compressor 2 producing compressed air, a combustor 3 mixing fuel with the compressed air produced by the compressor 2 and burning the mixture to produce a combustion gas M, and a turbine 4 rotatably driven using the combustion gas M produced by the combustor 3 as a working fluid.

[0033] A rotor 5 is inserted into the compressor 2 and the turbine 4. The compressor 2 includes a compressor casing 2a into which the rotor 5 is inserted, compressor rotor blades 2b rotatable along with the rotor 5, and compressor stator blades 2c fixed to the compressor casing 2a. The plurality of compressor rotor blades 2b and the plurality of compressor stator blades 2c are radially installed in a circumferential direction R. The compressor rotor blades 2b and the compressor stator blades 2c are alternately installed in a shaft direction (axial direction) P, and are each installed in multiple stages, each of which is made up of the plurality of blades installed in the circumferential direction R. Thus, the suctioned air is flown between the compressor stator blades 2c, and is repetitively compressed by rotation of the compressor rotor blades 2b downstream therefrom. Thereby, the compressed air is produced.

[0034] Further, the turbine 4 includes a turbine casing 10 into which the rotor 5 is inserted, turbine rotor blades 20 rotatable along with the rotor 5, and turbine stator blades (stator blades) 30 fixed to the turbine casing 10. The plurality of turbine rotor blades 20 and the plurality of turbine stator blades 30 extend in a radial direction Q,

and are radially installed in the circumferential direction R. Further, the turbine rotor blades 20 and the turbine stator blades 30 are alternately installed in the shaft direction P, and are each installed in multiple stages, each of which is made up of the plurality of blades installed in the circumferential direction R. Thus, the combustion gas M, which is the working fluid introduced from the combustor 3, is flown between the turbine stator blades 30, and repetitively rotates the turbine rotor blades 20 downstream therefrom. Thereby, the rotor 5 to which the turbine rotor blades 20 are fixed is torqued and rotated.

[0035] Further, a plurality of seal structures 7 for preventing the combustion gas M from leaking from a high pressure side to a low pressure side are installed in the shaft direction P. Hereinafter, the seal structures 7 will be described in detail.

[0036] As shown in FIG. 2, each seal structure 7 is equipped with a plurality of fins 40 protruding from an outer circumferential surface of the rotor 5, and the turbine stator blades 30.

[0037] The plurality of fins 40 protrude from the outer circumferential surface of the rotor 5 in the circumferential direction R, and are disposed at intervals in the shaft direction P. Further, each fin 40 is configured so that the outer circumferential surface of the rotor 5 is set as a proximal end 40a, and so that a distal end 40b is formed such that a width thereof narrows from the proximal end 40a toward the turbine stator blades 30. In this way, the plurality of fins 40, 40 ... are configured so that the proximal ends 40a and the distal ends 40b of any fin 40 and the proximal ends 40a and the distal ends 40b of the neighboring fin 40 are alternately arranged in the shaft direction P.

[0038] The turbine stator blade 30 includes an inner shroud 50 installed on the side of the rotor 5, an abradable coating 60 formed on the inner shroud 50, a blade body 70 extending from the inner shroud 50 in a radial direction, and an outer shroud 80 installed on an end of the blade body 70.

[0039] The inner shroud 50 is called a Z-patterned shroud in which a Z pattern is made when viewed from the inner side in the radial direction Q. Further, the inner shroud 50 has the Z pattern so as to suppress leakage of a high-temperature gas between itself and its neighboring inner shroud 50 and to prevent distortion of the blade body 70.

[0040] Further, the inner shroud 50 is disposed in the shaft direction P, and is disposed in contact with the inner shroud 50 adjacent in the circumferential direction R.

[0041] In addition, as shown in FIG. 3, an inner circumferential surface 50a of the inner shroud 50 is formed in an uneven shape. In the present embodiment, a concave portion 51 is formed from the inner circumferential surface 50a of the inner shroud 50 toward an interior of the inner shroud 50, that is, toward an outer side in the radial direction Q, so that the concave portion 51 extends in the circumferential direction R.

[0042] The concave portion 51 has a shroud-side base

51a, a pair of shroud-side walls 51b formed from the inner circumferential surface 50a at approximately a right angle, and a shroud-side bottom 51c connecting the pair of shroud-side walls 51b and is formed at approximately a right angle with respect to the shroud-side walls 51b.

[0043] Further, the abrasible coating 60 is formed on the inner circumferential surface 50a of the inner shroud 50 so as to be opposite to the fins 40 (see FIG. 2) in such a way that, in the present embodiment, an abrasible material is thermally sprayed. In addition, the abrasible coating 60 is formed along the uneven shape. In the present embodiment, the abrasible coating 60 has a convex portion 61 formed from the shroud-side base 51a to the shroud-side bottom 51c of the concave portion 51 by thermal spraying.

[0044] The convex portion 61 protrudes from an outer circumferential surface 60a of the abrasible coating 60 toward the interior of the inner shroud 50, and has an abrasible-side base 61a, a pair of abrasible-side walls 61b formed from the outer circumferential surface 60a at approximately a right angle, and an abrasible-side top 61c connecting the pair of abrasible-side walls 61b.

[0045] Further, the shroud-side base 51a of the concave portion 51 and the abrasible-side base 61a of the convex portion 61 are bonded to each other. The shroud-side walls 51b of the concave portion 51 and the abrasible-side walls 61b of the convex portion 61 are bonded to each other. The shroud-side bottom 51c of the concave portion 51 and the abrasible-side top 61c of the convex portion 61 are bonded to each other.

[0046] As the abrasible material, for example, a nickel-based alloy may be employed.

[0047] As shown in FIG. 2, the blade body 70 is formed by a pressure side surface 71 constituting a pressure side and a suction side surface 72 constituting a suction side.

[0048] The pressure side surface 71 is curved so as to swell toward the suction side surface 72, and the suction side surface 72 is curved so as to swell toward the same side as the pressure side surface 71.

[0049] The outer shroud 80 is disposed in contact with the other outer shroud 80 adjacent in the shaft direction P and in the circumferential direction R.

[0050] In the gas turbine 1 having the seal structure 7 configured in this way, since the abrasible material as the convex portion 61 enters and is hardened and deposited in the concave portion 51 formed in the inner shroud 50, a bonding area on which the inner shroud 50 and the abrasible coating 60 are bonded is increased. Accordingly, as the bonding area increases, the inner shroud 50 and the abrasible coating 60 are strongly bonded. Furthermore, since the concave portion 51 is formed so as to extend in the circumferential direction R, a bonding force between the inner shroud 50 and the abrasible coating 60 can be improved throughout the circumferential direction R. Thus, for example, although the abrasible coating 60 is damaged when the gas turbine 1 is operated, the abrasible coating 60 can be pre-

vented from being peeled off of the inner shroud 50.

[0051] Further, in the present embodiment, the abrasible material can be directly formed on the inner shroud 50. Accordingly, in comparison with a conventional structure in which the abrasible material is thermally sprayed onto the seal member installed on the inner shroud 50, the distance between the rotor 5 and the turbine stator blades 30 can be reduced with the amount in which the seal member is not required. Thus, the installation of the turbine 4, and ultimately, of the entire gas turbine 1 can be made small.

(Second Embodiment)

[0052] Hereinafter, a gas turbine 201 according to a second embodiment of the present invention will be described using FIG. 4.

[0053] In this embodiment, members common with the members used in the aforementioned embodiment will be denoted by the same numerals and symbols, and a description thereof will be omitted here.

[0054] In the seal structure 7 of the first embodiment, the pair of shroud-side walls 51b of the concave portion 51 formed in the inner shroud 50 are formed at approximately a right angle with respect to the shroud-side base 51a. In contrast, in a seal structure 207 of the present embodiment, a shroud-side wall 251b is formed at approximately a right angle with respect to a shroud-side base 251a, whereas a shroud-side wall 251d is formed at an acute angle with respect to the shroud-side base 251a.

[0055] That is, a concave portion 251 of an inner shroud 250 is formed so that a width of a cross section thereof perpendicular to an extending direction (circumferential direction R) of the concave portion 251 widens from an inner circumferential surface 250a of the inner shroud 250 toward a shroud-side bottom 251c of the concave portion 251. In the present embodiment, the shroud-side wall 251b is formed at approximately a right angle with respect to a shroud-side base 251a, whereas the shroud-side wall 251d is formed farther from the opposite shroud-side wall 251b as it is closer to the shroud-side bottom 251c. In this way, in the cross section perpendicular to the extending direction (circumferential direction R) of the concave portion 251, the width 261f of the shroud-side bottom 251c of the concave portion 251 is wider than the width 261e of the shroud-side base 251a of the concave portion 251.

[0056] Further, a convex portion 261 of an abrasible coating 260 has a shape corresponding to the concave portion 251, and is configured so that an abrasible-side wall 261d is formed farther from an abrasible-side wall 261b as it is closer to an abrasible-side top 261c.

[0057] In the gas turbine 201 having the seal structure 207 configured in this way, since the shroud-side wall 251d and the abrasible-side wall 261d are formed at an angle, a bonding area on which the inner shroud 250 and the abrasible coating 260 are bonded can be further

increased. Further, when force is applied to the abradable coating 260 toward an inner side in a radial direction Q that is a separating direction, a resistant force is applied to the abradable-side wall 261 d toward an outer side in the radial direction Q so as to prevent the separation. Accordingly, since the inner shroud 250 and the abradable coating 260 can be more strongly bonded, even when the abradable coating 260 is damaged, the abradable coating 260 can be prevented from peeling off of the inner shroud 250.

(Third Embodiment)

[0058] Hereinafter, a gas turbine 301 according to a third embodiment of the present invention will be described using FIG. 5.

[0059] In this embodiment, members common with the members used in the aforementioned embodiment will be denoted by the same numerals and symbols, and a description thereof will be omitted here.

[0060] In the seal structure 207 of the second embodiment, the shroud-side wall 251b is formed at approximately a right angle with respect to the shroud-side base 251a, and the shroud-side wall 251 d is formed at an acute angle with respect to the shroud-side base 251 a. In contrast, in a seal structure 307 of the present embodiment, a shroud-side wall 351b is formed at an acute angle with respect to a shroud-side base 351a along with a shroud-side wall 351d.

[0061] That is, a concave portion 351 of an inner shroud 350 is formed so that a width of a cross section thereof perpendicular to an extending direction (circumferential direction R) of the concave portion 351 widens from an inner circumferential surface 350a of the inner shroud 350 toward a shroud-side bottom 351c of the concave portion 351. In the present embodiment, the shroud-side walls 351b and 351d are formed farther from each other as it is closer to the shroud-side bottom 351c. In this way, in the cross section perpendicular to the extending direction (circumferential direction R) of the concave portion 351, the width 361f of the shroud-side bottom 351c of the concave portion 351 is wider than the width 361e of the shroud-side base 351a of the concave portion 351.

[0062] Further, a convex portion 361 of an abradable coating 360 has a shape corresponding to the concave portion 351, and abradable-side walls 361b and 361d are formed farther from each other as it is closer to an abradable-side top 361c.

[0063] In the gas turbine 301 having the seal structure 307 configured in this way, since the shroud-side walls 351b and 351d and the abradable-side walls 361b and 361d are formed at an angle, a bonding area on which the inner shroud 350 and the abradable coating 360 are bonded can be further increased. Further, when force is applied to the abradable coating 360 toward an inner side in a radial direction Q that is a separating direction, a resistant force is applied to the abradable-side walls 361b

and 361d toward an outer side in the radial direction Q so as to prevent the separation simultaneously. Accordingly, since the inner shroud 350 and the abradable coating 360 can be even more strongly bonded, even when the abradable coating 360 is damaged, the abradable coating 360 can be prevented from peeling off of the inner shroud 350.

(Fourth Embodiment)

[0064] Hereinafter, a gas turbine 401 according to a fourth embodiment of the present invention will be described using FIG. 6.

[0065] In this embodiment, members common with the members used in the aforementioned embodiment will be denoted by the same numerals and symbols, and a description thereof will be omitted here.

[0066] In the concave portion 51 of the inner shroud 50 in the seal structure 7 of the first embodiment, the shroud-side base 51 a and the shroud-side walls 51b are approximately perpendicular to each other, and the shroud-side walls 51b and the shroud-side bottom 51c are approximately perpendicular to each other as well. In contrast, a concave portion 451 in a seal structure 407 of the present embodiment is formed so that a cross section perpendicular to an extending direction (circumferential direction R) of the concave portion 451 has an arcuate shape so as to swell from an inner circumferential surface 450a of an inner shroud 450.

[0067] That is, the concave portion 451 of the inner shroud 450 has a semi-circular shape in which it swells from the inner circumferential surface 450a toward an interior of the inner shroud 450.

[0068] Further, a convex portion 461 of an abradable coating 460 has a shape corresponding to the concave portion 451, and has a semi-circular shape in which it swells outward from an outer circumferential surface 460a.

[0069] Even in the gas turbine 401 having the seal structure 407 configured in this way, since a bonding area on which the inner shroud 450 and the abradable coating 460 are bonded can be increased, the inner shroud 450 and the abradable coating 460 can be strongly bonded.

(Fifth Embodiment)

[0070] Hereinafter, a gas turbine 501 according to a fifth embodiment of the present invention will be described using FIG. 7.

[0071] In this embodiment, members common with the members used in the aforementioned embodiment will be denoted by the same numerals and symbols, and a description thereof will be omitted here.

[0072] In the seal structure 7 of the first embodiment, the concave portion 51 is formed from the side of the inner circumferential surface 50a of the inner shroud 50 toward the interior of the inner shroud 50. In contrast, in a seal structure 507 of the present embodiment, a con-

cave portion 561 is formed from an outer circumferential surface 560a of an abradable coating 560 toward an interior of the abradable coating 560.

[0073] That is, the concave portion 561 includes an abradable-side base 561a, a pair of abradable-side walls 561b formed from the outer circumferential surface 560a at approximately a right angle, and an abradable-side bottom 561c connecting the pair of abradable-side walls 561b and formed at approximately a right angle to the abradable-side walls 561b.

[0074] Further, a convex portion 551 has a shape corresponding to the concave portion 561, protrudes from an inner circumferential surface 550a of an inner shroud 550 toward the interior of the abradable coating 560, and includes an inner-shroud base 551a, a pair of shroud-side walls 551b formed from the inner circumferential surface 550a at approximately a right angle, and a shroud-side top 551c connecting the pair of shroud-side walls 551b.

[0075] Even in the gas turbine 501 having the seal structure 507 configured in this way, since a bonding area where the inner shroud 550 and the abradable coating 560 are bonded can be increased, the inner shroud 550 and the abradable coating 560 can be strongly bonded.

[0076] Further, since any one of the inner shroud 550 and the abradable coating 560 may be selectively provided with a concave portion and the other may be provided with a convex portion, a degree of freedom of design is widened.

(Sixth Embodiment)

[0077] Hereinafter, a gas turbine 601 according to a sixth embodiment of the present invention will be described using FIG. 8.

[0078] In this embodiment, members common with the members used in the aforementioned embodiment will be denoted by the same numerals and symbols, and a description thereof will be omitted here.

[0079] In the seal structure 7 of the first embodiment, the concave portion 51 is formed so as to extend in the circumferential direction R. In contrast, in a seal structure 607 of the present embodiment, a concave portion 651 is formed so as to extend in the shaft direction P.

[0080] That is, the plurality of concave portions 651 are located in the radial direction Q inside respective boundary lines 654 between inner shrouds 650, 650 . . . adjacent in the circumferential direction R, follow the shaft direction P, and are formed at intervals in the circumferential direction R.

[0081] Further, an abradable coating 660 enters the concave portions 651 to be formed as convex portions 661.

[0082] In the gas turbine 601 having the seal structure 607 configured in this way, since each concave portions 651 is formed so as to extend in the shaft direction P, a bonding force between the inner shroud 650 and the abradable coating 660 can be improved throughout the

shaft direction P.

[0083] Further, on the boundary lines 654 between the neighboring inner shrouds 650, 650 . . . , shear forces between the inner shrouds 650, 650 . . . occur. However, the shear force can be reduced according to the amount of the abradable coating 660 which forms the convex portions 661 that enters the concave portions 651. Accordingly, deformation caused by distortion of the turbine stator blades 630 can be prevented, and stability of the gas turbine 601 itself can be improved.

(Seventh Embodiment)

[0084] Hereinafter, a gas turbine 701 according to a seventh embodiment of the present invention will be described using FIG. 9.

[0085] In this embodiment, members common with the members used in the aforementioned embodiment will be denoted by the same numerals and symbols, and a description thereof will be omitted here.

[0086] In the seal structure 607 of the sixth embodiment, the concave portions 651 are formed in the radial direction Q inside the boundary lines 654 between the inner shrouds 650, 650 . . . adjacent in the circumferential direction R. In contrast, in a seal structure 707 of the present embodiment, concave portions 751 are formed within dimensions of the shaft direction P of respective inner shrouds 750.

[0087] That is, the plurality of concave portions 751 are located approximately in the middle of the dimensions of the shaft direction P of the inner shrouds 750, follow the shaft direction P, and are formed at intervals in the circumferential direction R.

[0088] In the gas turbine 701 having the seal structure 707 configured in this way, since the concave portions 751 are formed so as to extend in the shaft direction P, a bonding force between the inner shroud 750 and the abradable coating 760 can be improved throughout the shaft direction P.

(Eighth Embodiment)

[0089] Hereinafter, a gas turbine 801 according to an eighth embodiment of the present invention will be described using FIGS. 10 and 11.

[0090] Here, FIG. 10 is a cross-sectional view taken along line Y-Y of FIG. 1 in a seal structure 807 according to the present embodiment, and FIG. 11 is a cross-sectional view in which portions of inner shrouds 850 of the seal structure 807 are cut out.

[0091] In this embodiment, members common with the members used in the aforementioned embodiment will be denoted by the same numerals and symbols, and a description thereof will be omitted here.

[0092] In the seal structure 607 of the sixth embodiment, the concave portions 651 are configured only by being merely formed from the inner circumferential surfaces 650a of the inner shrouds 650 toward the interiors

of the inner shrouds 650. In contrast, in the seal structure 807 of the present embodiment, each concave portion is made up of a concave portion 851 formed from an inner circumferential surface 850a of one of the inner shrouds 850 toward an interior of the inner shroud 850 and a second concave portion 862 facing the concave portion 851 and formed from an outer circumferential surface 860a of an abradable coating 860 toward an interior of the abradable coating 860. Further, a pin member 890 is inserted between the concave portion 851 and the second concave portion 862.

[0093] That is, as shown in FIG. 10, the plurality of concave portions 851 are formed in the radial direction Q inside boundary lines 854 between the inner shrouds 850, 850 . . . adjacent in the circumferential direction R, and from the inner circumferential surfaces 850a of the inner shrouds 850 toward the interiors of the inner shrouds 850 at intervals in the circumferential direction R. Further, as shown in FIG. 11, the concave portions 851 are formed at two spots for each inner shroud 850 and are spaced apart from each other in the shaft direction P.

[0094] This numerical value is an example, and the number of spots is not limited to this numerical value, and three or more spots may be used.

[0095] Further, as shown in FIG. 10, the plurality of second concave portions 862 are formed in the radial direction Q inside boundary lines 854 between the inner shrouds 850 and 850 adjacent in the circumferential direction R, and from the outer circumferential surface 860a of the abradable coating 860 toward the interior of the abradable coating 860 at intervals in the circumferential direction R. Further, as shown in FIG. 11, the second concave portions 862 are formed at two spots for each inner shroud 850 and are spaced apart from each other in the shaft direction P.

[0096] Further, the pin member 890 is a rod-like member, and is configured so that one end 890a thereof is disposed at a shroud-side bottom 851c of the concave portion 851 and so that the other end 890b thereof is disposed at an abradable-side bottom 861c of the second concave portion 862.

[0097] Further, as a method of manufacturing the seal structure 807, the pin members 890 are inserted into the concave portions 851 of the inner shroud 850, and an abradable material is thermally sprayed to fix the pin members 890 in the concave portions 851 and to form the abradable coating 860.

[0098] In the gas turbine 801 having the seal structure 807 in this way, the pin member 890 can strongly couple the neighboring inner shrouds 850, 850 . . . in the circumferential direction R, and reduce displacement in the shaft direction P.

[0099] Further, when the abradable material is thermally sprayed, since the side of the other end 890b of the pin member 890 protrudes, the abradable material can be deposited well to form the abradable coating 860. Accordingly, the inner shrouds 850 and the abradable

coating 860 can be strongly bonded via the pin members 890.

[0100] All the shapes and combinations of each constituent member shown in the aforementioned embodiments are given as an example, and thus may be variously modified based on design requirements without departing from the gist of the present invention.

[0101] Further, in the above embodiments, as an example of the rotating machine, the gas turbine has been described. However, the present invention may be also applied to other rotating machines such as a steam turbine.

[Industrial Applicability]

[0102] According to the aforementioned seal structure and the rotating machine equipped therewith, the abradable coating enters and is hardened and deposited in the uneven shape portions. Thereby, the abradable coating can be strongly bonded. For this reason, even when the abradable coating is damaged, the abradable coating can be prevented from being separated from the stator blade.

[Description of Reference Numerals]

[0103]

1, 201, 301, 401, 501, 601, 701, 801: gas turbine (rotating machine)
 5: rotor
 7, 207, 307, 407, 507, 607, 707, 807: seal structure
 30: turbine stator blade (stator blade)
 40: fin
 50, 250, 350, 450, 550, 650, 750, 850: inner shroud
 50a, 250a, 350a, 550a, 650a, 850a: inner circumferential surface
 51, 251, 351, 451, 561, 651, 751, 851: concave portion
 60, 260, 360, 460, 560, 660, 760, 860: abradable coating
 60a, 260a, 360a, 560a, 860a: outer circumferential surface
 654, 854: boundary line
 R: circumferential direction

Claims

1. A seal structure comprising:

a fin configured to protrude from an outer circumferential surface of a rotor in a circumferential direction; and
 a stator blade including an abradable coating formed on an inner circumferential surface of an inner shroud so as to face the fin, wherein the inner circumferential surface of the

inner shroud is formed in an uneven shape, and the abradable coating is formed along the uneven shape.

2. The seal structure according to claim 1, 5
 wherein the uneven shape is configured by a concave portion formed from one of the inner circumferential surface of the inner shroud and an outer circumferential surface of the abradable coating toward an interior thereof. 10
3. The seal structure according to claim 2, 15
 wherein the concave portion is formed so as to extend in the circumferential direction.
4. The seal structure according to claim 2, 20
 wherein the concave portion is formed so as to extend in an axial direction of the rotor.
5. The seal structure according to claim 3, 25
 wherein the concave portion is formed on a boundary line between the inner shrouds adjacent in the circumferential direction.
6. The seal structure according to claim 4, wherein: 25
 the one of the inner circumferential surface of the inner shroud and the outer circumferential surface of the abradable coating is formed with a second concave portion so as to be opposite 30
 to the concave portion formed in the other of the inner circumferential surface of the inner shroud and the outer circumferential surface of the abradable coating; and 35
 the seal structure includes a pin member inserted between the concave portion and the second concave portion.
7. The seal structure according to any one of claims 3 to 5, 40
 wherein the concave portion is formed so that a width thereof in a cross section perpendicular to an extending direction thereof gradually widens from the one of the inner circumferential surface of the inner shroud and the outer circumferential surface of the abradable coating toward a bottom thereof. 45
8. The seal structure according to any one of claims 2 to 5, 50
 wherein the concave portion is formed in an arcuate shape in which a cross section perpendicular to an extending direction thereof swells from the one of the inner circumferential surface of the inner shroud and the outer circumferential surface of the abradable coating. 55
9. A rotating machine having the seal structure according to any one of claims 1 to 7.

FIG. 1

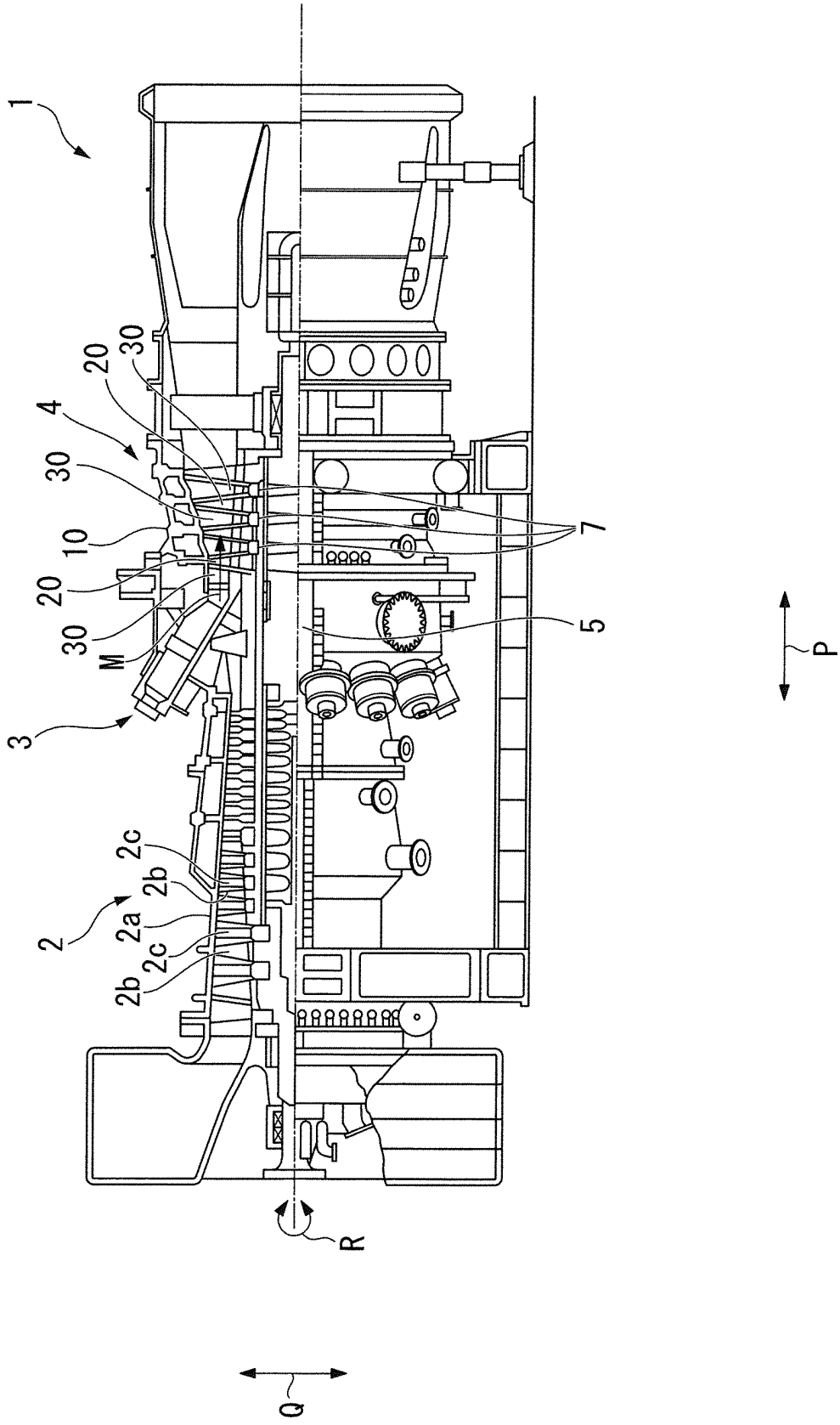


FIG. 2

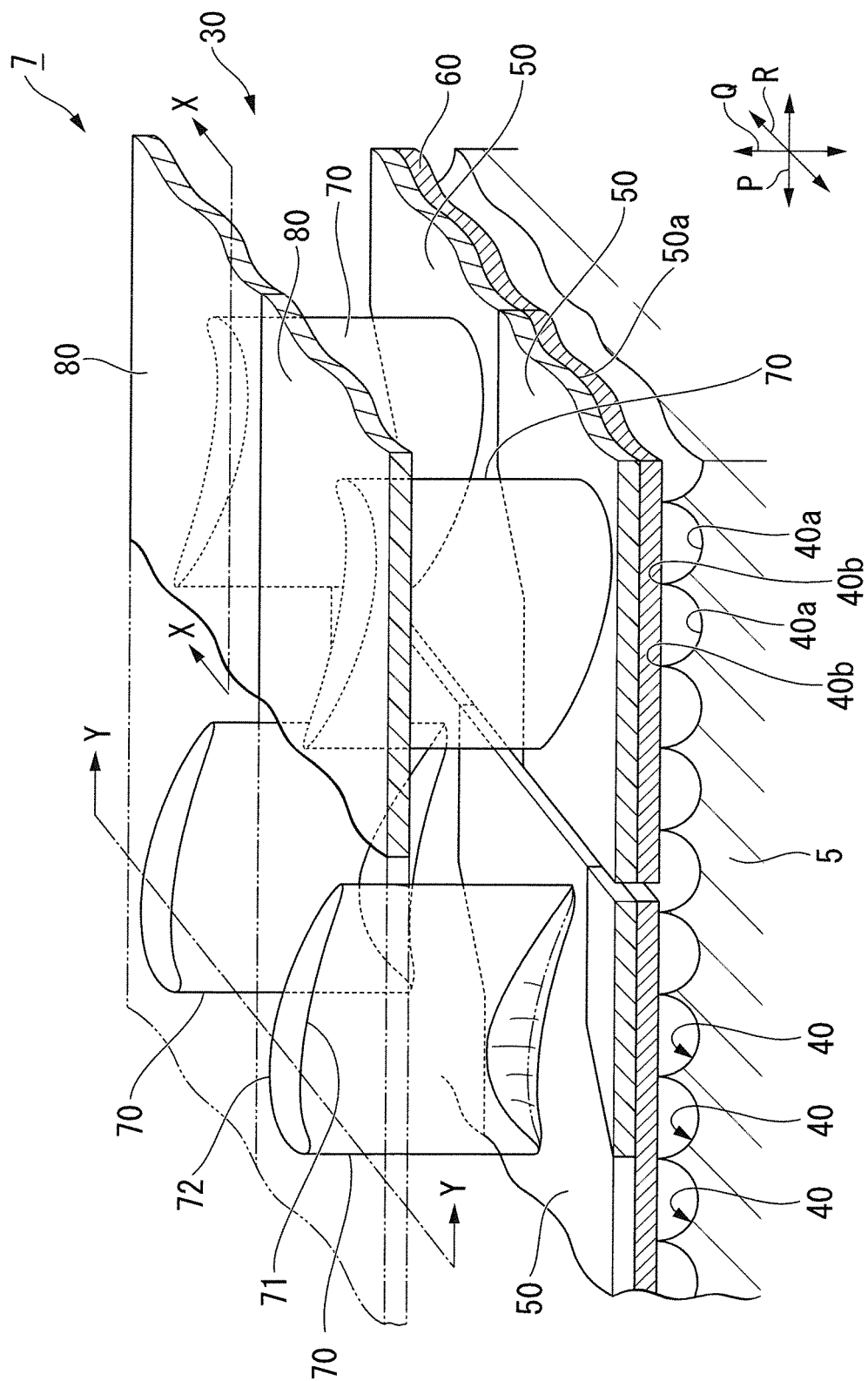


FIG. 3

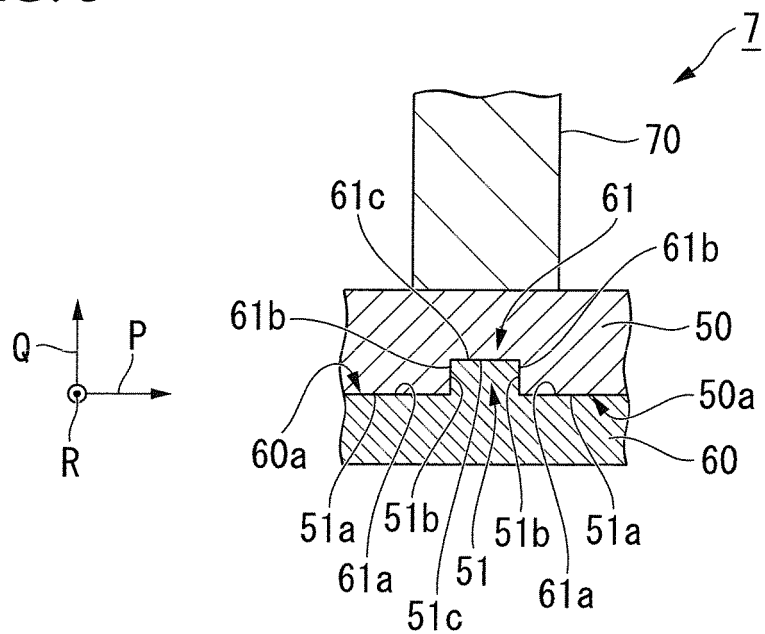


FIG. 4

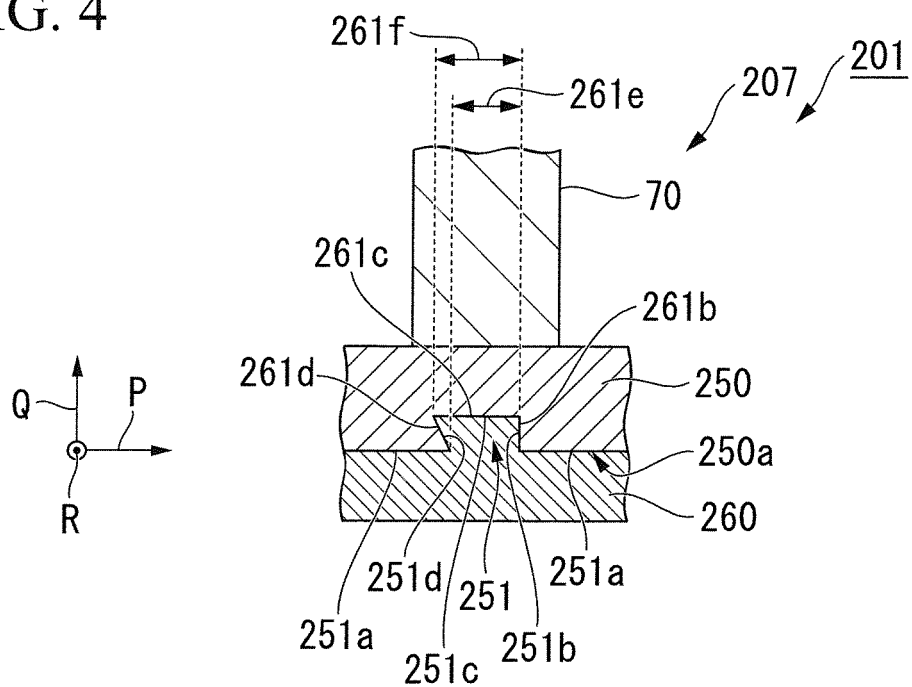


FIG. 5

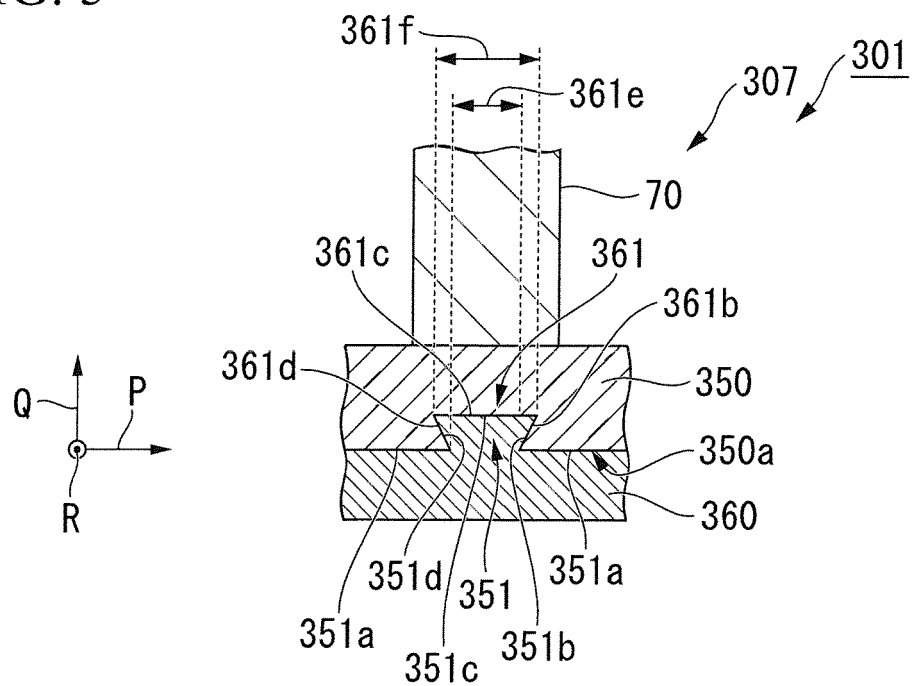


FIG. 6

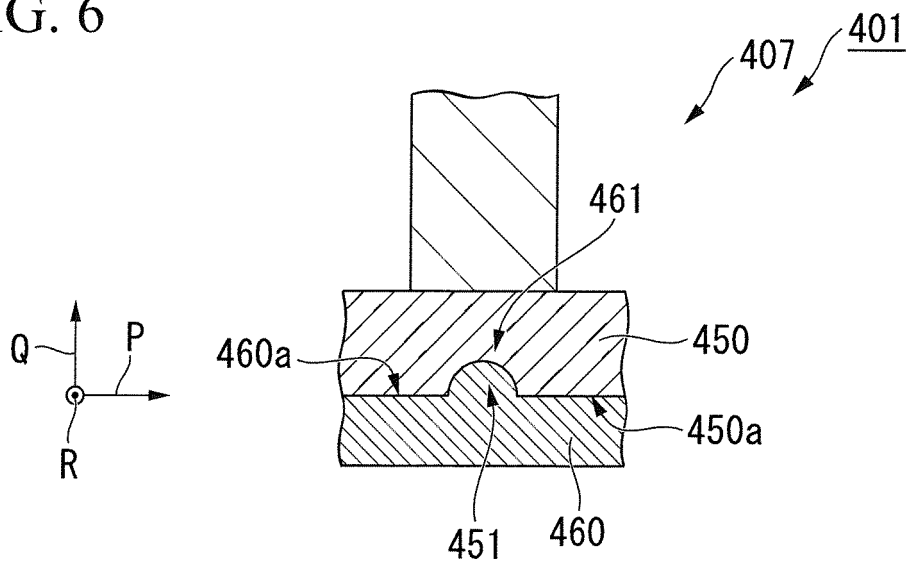


FIG. 7

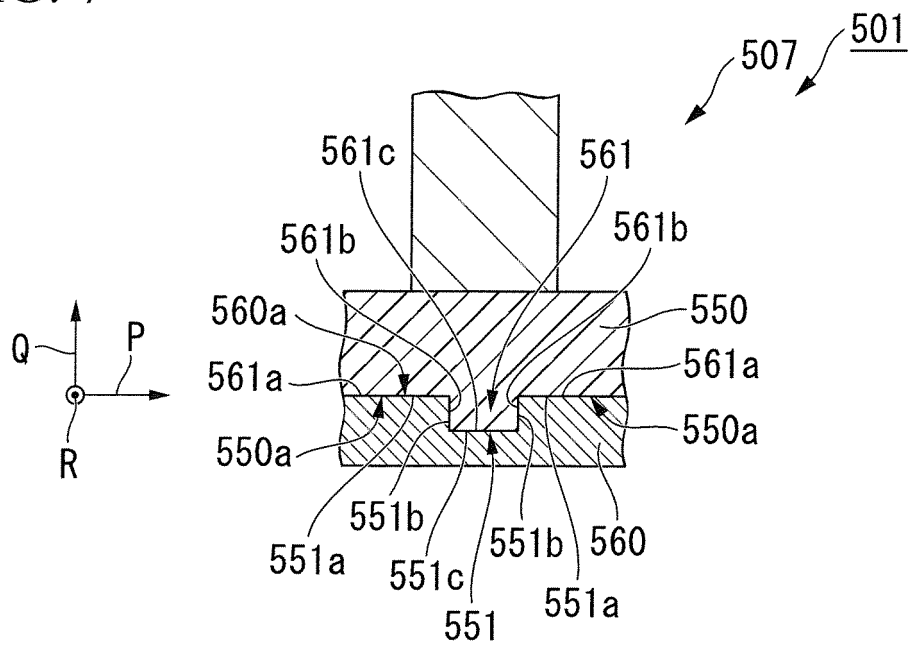


FIG. 8

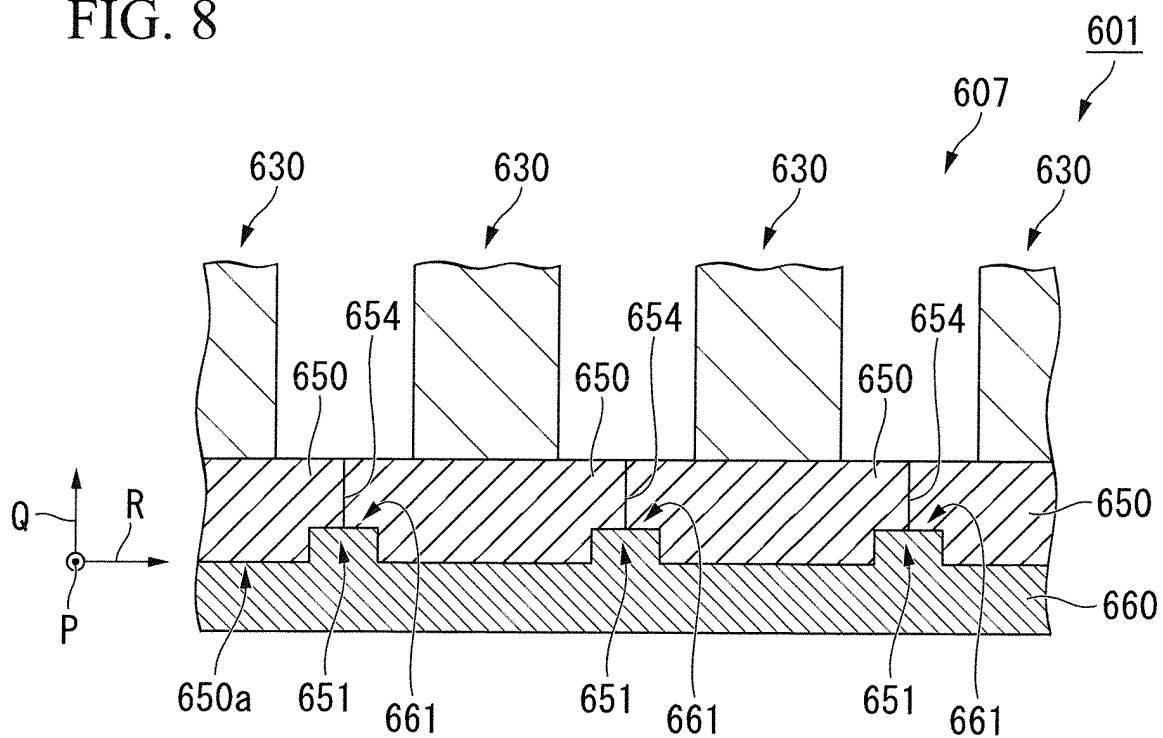


FIG. 9

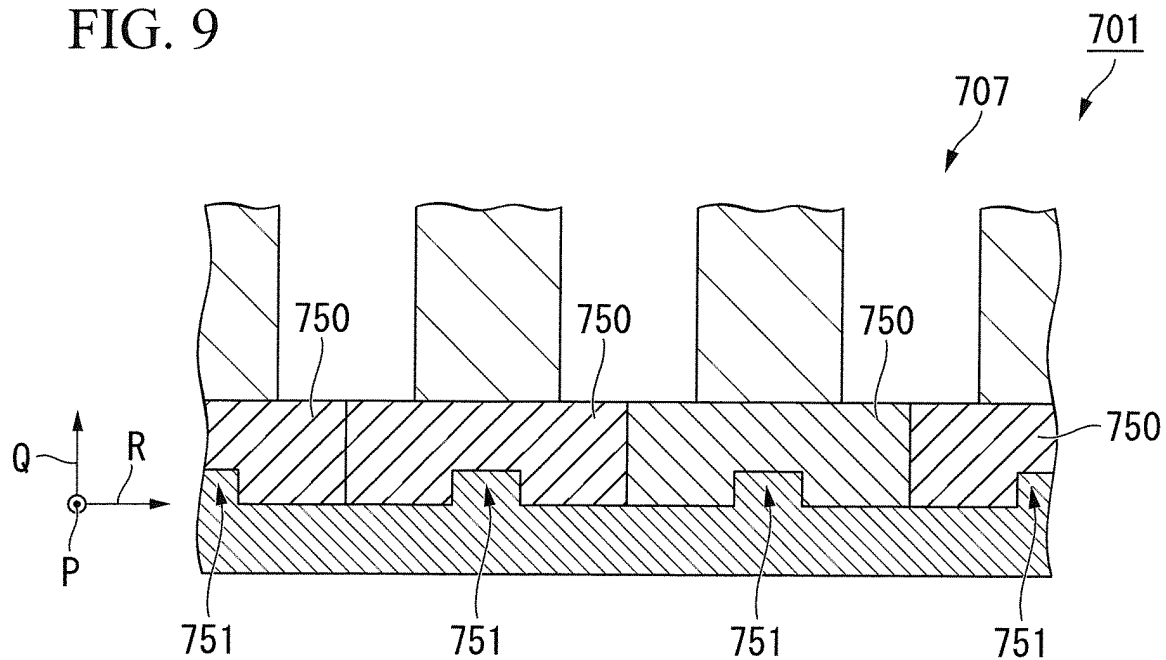


FIG. 10

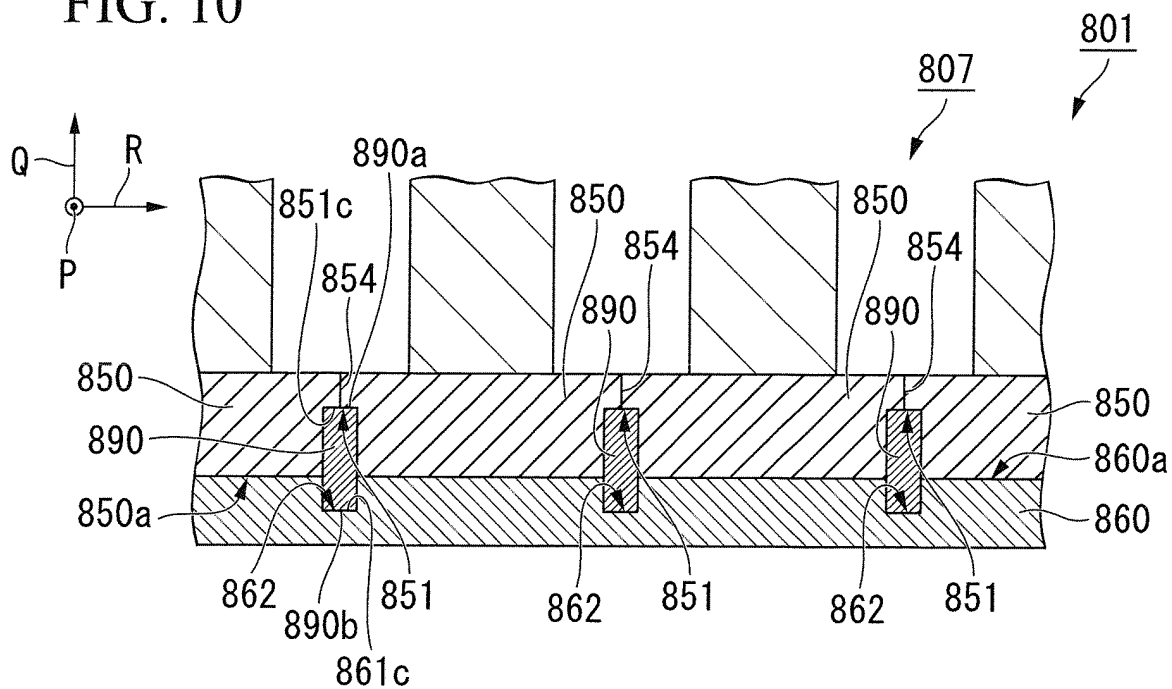
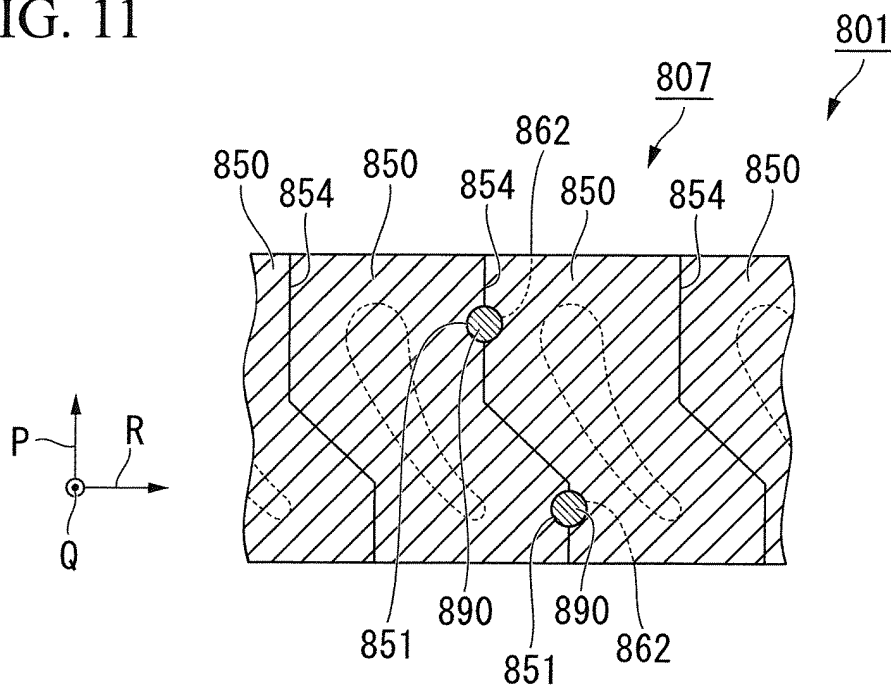


FIG. 11



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2013/052564

A. CLASSIFICATION OF SUBJECT MATTER

F16J15/453(2006.01)i, F01D11/02(2006.01)i, F02C7/28(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F16J15/453, F01D11/02, F02C7/28

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2013
Kokai Jitsuyo Shinan Koho	1971-2013	Toroku Jitsuyo Shinan Koho	1994-2013

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 2005-214148 A (Ishikawajima-Harima Heavy Industries Co., Ltd.), 11 August 2005 (11.08.2005), paragraph [0045]; fig. 3(b) (Family: none)	1-4, 7-9 5-6
Y A	JP 2006-132328 A (Toshiba Corp.), 25 May 2006 (25.05.2006), paragraphs [0017] to [0018]; fig. 1 (Family: none)	1-4, 7-9 5-6
Y	JP 2011-185272 A (Sulzer Metco AG), 22 September 2011 (22.09.2011), paragraph [0012]; fig. 1 to 12 & US 2001/0004436 A1	1-4, 7-9

☒ Further documents are listed in the continuation of Box C.
 ☐ See patent family annex.

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Date of the actual completion of the international search
27 February, 2013 (27.02.13)Date of mailing of the international search report
12 March, 2013 (12.03.13)Name and mailing address of the ISA/
Japanese Patent Office

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Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2013/052564

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 10-18016 A (Suzuki Motor Corp.), 20 January 1998 (20.01.1998), paragraph [0010]; fig. 2 (Family: none)	1-4, 9
A	FR 2895021 A1 (SNECMA SA), 22 June 2007 (22.06.2007), entire text; all drawings (Family: none)	1

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2012023071 A [0002]
- JP 2009174655 A [0006]