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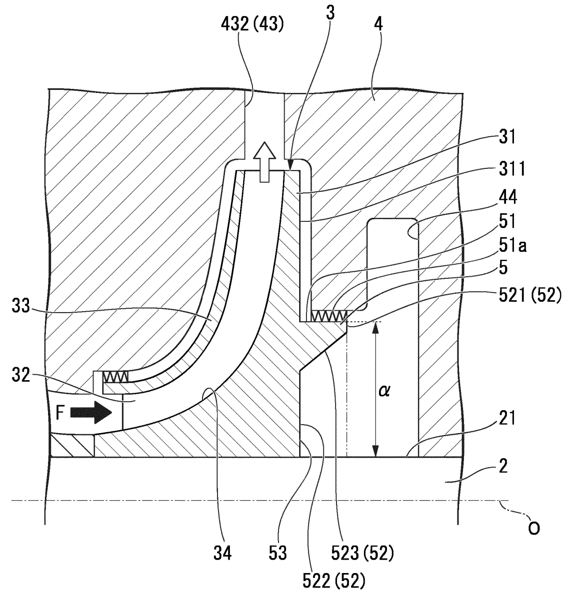
(54) ROTARY MACHINE

(57) A rotary machine is provided with a plurality of impellers (3) which have a disk (31) rotating with a rotary shaft (2), the impellers being arranged side by side; and a casing (4) in which a casing flow passage (43) is formed to distribute a working medium therein. An impeller (3) disposed farthest away from a second side in the axial direction is disposed in a space communicating with an upstream part of the casing flow passage (43), and a protrusion portion (5) protruding from a back side (311) of the disk (31). The protrusion portion (5) has a sealing surface (51) which is formed to be parallel to an outer surface (21) of the rotary shaft (2) to seal a gap between itself and the casing (4), and a pressure receiving surface (51) which extends from the outer surface (21) to the sealing surface (51).

FIG. 2



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Description

[Technical Field]

[0001] The present invention relates to a rotary machine.

[Background Art]

[0002] A rotary machine such as a centrifugal compressor compresses a working fluid using a centrifugal force generated when an impeller rotates, by flowing the working fluid inside the rotating impeller. As a centrifugal compressor, a multistage centrifugal compressor is known which gradually compresses the working fluid using a plurality of impellers.

[0003] An example of such a multistage centrifugal compressor is described in Patent Literature 1. The centrifugal compressor described in Patent Literature 1 is a single-shaft multistage centrifugal compressor in which a plurality of impellers are mounted on the same rotary shaft. In the single-shaft multistage centrifugal compressor, a plurality of impellers are mounted to the rotary shaft in the casing side by side in the axial direction.

[Citation List]

[Patent Literature]

[Patent Literature 1]

[0004] Japanese Unexamined Patent Application, First Publication No.2001-107888

[Summary of Invention]

[Technical Problem]

[0005] Incidentally, in the aforementioned centrifugal compressor, a thrust force is generated so that the impeller turns and compresses the working fluid to press the impeller toward a first side in the axial direction in which the working fluid flows with respect to the rotary shaft. In particular, in a structure in which a plurality of impellers are disposed in the same direction like in a multistage centrifugal compressor, the thrust force increases. Thus, in such a centrifugal compressor, in order to weaken the thrust force to the first side in the axial direction generated by the impellers, a balance piston, which balances the thrust forces acting on the rotary shaft by generating a thrust force in the opposite direction, is disposed to be adjacent to the last stage of the impellers.

[0006] However, in a rotary machine such as a multistage centrifugal compressor in which the high-pressure working fluid is distributed, a high-pressure working fluid enters a gap between the impeller and the balance piston. For this reason, when using the working fluid in which a solid product is easily generated, there is a risk of deposition of the solid product in such a gap, which may hinder the operation of the rotary machine.

[0007] An object of the present invention is to provide a rotary machine capable of balancing the thrust forces acting on the rotary shaft by preventing formation of this gap.

[Solution to Problem]

[0008] According to a first aspect of the present invention, there is provided a rotary machine which is provided with a rotary shaft which rotates about an axis; a plurality of impellers which have a disk rotating with the rotary shaft, and an internal flow passage formed to discharge a working fluid, which flows in from a first side in an axial direction in which the axis extends, toward an outer side in a radial direction, the plurality of impellers being disposed side by side in the axial direction; and a casing in which a casing flow passage is formed to flow the working fluid from the impeller disposed on the first side in the axial direction to the impeller adjacent to a second side, wherein among the plurality of impellers, an impeller disposed nearest to the second side in the axial direction has a protrusion portion which is disposed in a space communicating with an upstream part of the casing flow passage, which protrudes from a back side facing the second side of the disk in the axial direction, and which is integrally formed with the disk, and the protrusion portion has a sealing surface which is formed to be parallel to an outer surface of the rotary shaft to seal a gap in a radial direction between the protrusion portion and the casing, and a pressure-receiving surface which extends from the outer surface of the rotary shaft to the sealing surface.

[0009] According to such a rotary machine, since the protrusion portion is provided on the disk of the last stage impeller nearest to the second side in the axial direction. As a result, a thrust force directed in the opposite direction to the thrust force generated by the plurality of other impellers can be generated on the rotary shaft by the last stage impeller. Thus, the thrust force acting on the rotary shaft can be adjusted. Further, by adjusting the thrust force generated on the rotary shaft by the protrusion portion integrally formed with the disk, the balance piston and the disk can substantially be integrally formed. Accordingly, it is unnecessary to use a separate member, and it is possible to prevent formation of an unnecessary gap.

[0010] In the rotary machine according to another aspect of the present invention, a suction port may be formed in the casing to allow the working fluid to flow into the casing flow passage from the outside, and the suction port and the space may communicate with each other.

[0011] According to such a rotary machine, since the space communicates with the suction port, it is possible to maximize the force acting on the pressure-receiving surface pulling from the first side toward the second side in the axial direction. Therefore, it is possible to increase the thrust force directed toward the second side in the axial direction acting on the rotary shaft from the impellers via the disk provided with the protrusion portion. Thus, even when a large thrust force is generated on the rotary shaft, it is possible to stably balance the thrust forces generated on the rotary shaft.

[0012] In the rotary machine according to another aspect of the present invention, the protrusion portion may have a recess portion which is recessed from the pressure-receiving surface toward the first side in the axial direction, at a radially inner side of the sealing surface.

[0013] According to such a centrifugal compressor, by forming the recess portion, an increase in weight of the impeller having the protrusion portion can be limited.

[0014] According to a second aspect of the present invention, there is provided an impeller disposed nearest to a second side of a rotary machine in an axial direction, and the rotary machine includes, a rotary shaft which rotates about an axis, a plurality of impellers which have a disk rotating with the rotary shaft, and an internal flow passage formed to discharge a working fluid, which flows in from a first side in the axial direction in which the axis extends, toward an outer side in a radial direction, the plurality of impellers being disposed side by side in the axial direction, and a casing in which a casing flow passage is formed to circulate the working fluid from the impeller disposed on the first side in the axial direction to the impeller adjacent to the second side, the impeller includes: a protrusion portion which protrudes from a back side facing the second side of the disk in the axial direction, and which is integrally formed with the disk, and which is disposed in a space communicating with an upstream side of the casing flow passage, wherein the protrusion portion has a sealing surface which is formed to be parallel to an outer surface of the rotary shaft to seal a gap in the radial direction between the protrusion portion and the casing, and a pressure-receiving surface which extends from the outer surface of the rotary shaft to the sealing surface.

[Advantageous Effects of Invention]

[0015] According to the aforementioned rotary machine, it is possible to balance the thrust forces acting on the rotary shaft by the protrusion portion integrally formed with the disk. Further, it is possible to prevent formation of a gap on the rear surface of the disk.

[Brief Description of Drawings]

[0016]

Fig. 1 is a schematic diagram showing a centrifugal compressor in an embodiment of the present invention.

Fig. 2 is an enlarged view showing an impeller of the last stage of the centrifugal compressor according to the embodiment of the present invention.

[Description of Embodiments]

[0017] Hereinafter, an embodiment of the present invention will be described with reference to Figs. 1 and 2.

[0018] A rotary machine of the present embodiment is a centrifugal compressor 1, and is a single-shaft multistage centrifugal compressor in the present embodiment. The centrifugal compressor 1 of the present embodiment is used, for example, in a nitric acid plant or the like, and distributes and compresses the nitric acid as a working fluid F. As shown in Fig. 1, the centrifugal compressor 1 of the present embodiment includes a rotary shaft 2 which rotates about an axis O, a plurality of impellers 3 fixed to the rotary shaft 2 to be integrally rotatable, and a casing 4 which houses the rotary shaft 2 and the impellers 3 therein.

[0019] The rotary shaft 2 has a columnar shape extending along the axis O and is rotated around the axis O by a power source such as an electric motor (not shown). The impellers 3 housed in the casing 4 are externally fitted to the rotary shaft 2. The rotary shaft 2 and the impellers 3 turn together about the axis O. The rotary shaft 2 is rotatably supported on the casing 4 by a journal bearing 41 and a thrust bearing 42, and is rotationally driven by an electric motor (not shown).

[0020] The plurality of impellers 3 are disposed side by side at intervals in the direction of the axis O (i.e., extending direction of the axis O of the rotary shaft 2), and are housed inside the casing 4. The centrifugal compressor 1 of the present embodiment includes five compressor stages 11, 12, 13, 14 and 15 to correspond to the respective impellers 3 disposed in the direction of the axis O. The five compressor stages include a first stage compressor stage (a foremost stage compressor stage) 11 disposed at a foremost stage nearest to the first side (the left side of the sheet in Fig. 1) in the direction of the axis O to a fifth stage compressor stage (a last stage compressor stage) 15 disposed at a last stage nearest to the second side (the right side of the sheet in Fig. 1) in the direction of the axis O.

[0021] The casing 4 is formed to make a substantially columnar outline and the rotary shaft 2 is disposed to penetrate through the center thereof. The casing 4 is provided with journal bearings 41 on both sides in the direction of the axis O. The casing 4 is provided with a thrust bearing 42 on the first side in the direction of the axis O. That is, the casing 4 supports the rotary shaft 2 via the journal bearings 41 and the thrust bearing 42. The casing 4 is provided with an internal space that repeatedly reduces and expands in diameter. The casing 4 houses the plurality of impellers 3 in the internal space. A casing flow passage 43 is formed in the casing 4 to distribute the working fluid F from the impeller 3 disposed on the upstream side (i.e., the first side in the direction of the axis O) to the impeller 3 adjacent on the downstream side (i.e., the second side in the direction of the axis O). In the casing 4, a low-pressure space 44 as a space communicating with the upstream part (which is the upstream side from this low-pressure space 44) of the casing flow passage 43 is formed.

[0022] The casing flow passage 43 communicates with the interior of the casing 4 via the impeller 3, from a suction port 431 which causes the working fluid F to flow in from the outside, to a discharge port 434 which discharges the working fluid F to the outside. The suction port 431 is provided at the end portion of the casing 4 of one side (i.e., the first side of the rotary shaft 2 in the direction of the axis O) which causes the working fluid F to flow in from the outside. The discharge port 434 is provided at the end portion of the other side (i.e., the second side facing the opposite side to the first side in the direction of the axis O).

[0023] Specifically, the casing flow passage 43 of the present embodiment has a suction port 431, a diffuser flow passage 432, a return flow passage 433, and a discharge port 434. The suction port 431 causes the working fluid F to flow in from the outside. The working fluid F is introduced from the internal flow passage 34 of the impeller 3 to be described later into the diffuser flow passage 432. The working fluid F is introduced from the diffuser flow passage 432 into the return flow passage 433 and introduce the working fluid F into the internal flow passage 34 of the impeller 3 from the return flow passage 433. The discharge port 434 discharges the working fluid F to the outside.

[0024] The suction port 431 communicates with the outside of the casing 4 at the end portion of the first side of the casing 4 in the direction of the axis O. The suction port 431 is connected to an inlet of the internal flow passage 34 of the foremost stage impeller 3 provided at the end portion of the first side in the direction of the axis O.

[0025] In the diffuser flow passage 432, the radially inner side of the casing 4 centered around the rotary shaft 2 communicates with the outlet of the internal flow passage 34 of the impeller 3 to distribute the working fluid F increased in pressure by the impeller 3 toward the outside in the radial direction.

[0026] A first end side of the return flow passage 433 communicates with the diffuser flow passage 432. A second end side of the return flow passage 433 communicates with the inlet of the internal flow passage 34 of the impeller 3. The return flow passage 433 reverses the flow direction of the working fluid F, which has flowed toward the outside in the radial direction through the diffuser flow passage 432, to face inward in the radial direction.

[0027] The discharge port 434 communicates with the outside of the casing 4 at the second end portion of the casing 4 in the direction of the axis O. The discharge port 434 is connected to the outlet of the internal flow passage 34 of the last stage impeller 3 provided at the second end portion in the direction of the axis O.

[0028] The low-pressure space 44 is formed on the second side of the last stage impeller 3 of the casing 4 in the direction of the axis O. The low-pressure space 44 communicates with the casing flow passage 43 on the upstream side of the last stage impeller 3. That is, the low-pressure space 44 communicates with a portion in the casing flow passage 43 that has a pressure lower than that of the working fluid F compressed by the last stage impeller 3. In the present embodiment, the low-pressure space 44 communicates with the suction port 431 having the lowest pressure in the casing flow passage 43, and has the same pressure as the suction port 431.

[0029] As shown in Fig. 2, each of the impellers 3 has a substantially disc-like disk 31 and a plurality of blades 32. The disk 31 gradually increases in diameter toward the outside in the radial direction. The blades 32 are radially attached to the disk 31 and arranged in the circumferential direction to stand from the surface of the disk 31 toward a first side of the rotary shaft 2 in the direction of the axis O. The impeller 3 has a cover 33 attached to cover the plurality of blades 32 in the circumferential direction from the first side in the direction of the axis O.

[0030] Each impeller 3 may be an open impeller that does not have the cover 33.

[0031] The impeller 3 is formed with an internal flow passage 34 which is a space through which the working fluid F flowing in from the first side in the direction of the axis O is circulated to be discharged toward the outside in the radial direction.

[0032] This internal flow passage 34 is defined by two surfaces of the pair of blades 32 adjacent to each other in the circumferential direction, and by surfaces of the disk 31 and the cover 33 which are provided on both sides of the blade 32 in the direction of the axis O. The internal flow passage 34 takes in and discharges the working fluid F by the blade 32 being rotated integrally with the disk 31. Specifically, the internal flow passage 34 serves as an inlet through which the working fluid F flows into the first side in the direction of the axis O of the blade 32, that is, the inside in the radial direction of the blade 32, and takes in the working fluid F from this inlet. The internal flow passage 34 serves as an outlet from which the working fluid F flows out in the radial direction, and discharges the guided working fluid F from this outlet..

[0033] The disk 31 has a small diameter on the front side facing the first side in the direction of the axis O, and a large diameter on a back side 311 facing the second side in the axis O direction. The disk 31 gradually increases in diameter from the front side which is the first side in the direction of the axis O toward the back side 311 which is the second side. That is, the disk 31 has a substantially disk shape when viewed in the direction of the axis O, and has an approximately umbrella shape as a whole.

[0034] On the radially inner side of the disk 31, a through-hole penetrating the disk 31 in the direction of the axis O is formed. By inserting the rotary shaft 2 into the through-hole to be fitted via shrinkage fitting (not shown) or a key, the impeller 3 is fixed to the rotary shaft 2 and can turn integrally with the rotary shaft 2.

[0035] Among the plurality of impellers 3, at least the impeller 3 disposed nearest to the second side in the direction of the axis O has a protrusion portion 5 which is formed integrally with the disk 31. In the present embodiment, as shown in Fig. 1, only the impeller 3 disposed at the fifth stage compressor stage 15 of the last stage which is the second most side in the direction of the axis O has the protrusion portion 5.

[0036] The protrusion portion 5 protrudes rearward in the direction of the axis O from the back side 311 of the disk 31 which is a surface intersecting with the outer surface 21 of the rotary shaft 2. The protrusion portion 5 is disposed in the low-pressure space 44. The protrusion portion 5 of this embodiment annularly protrudes from the back side 311 of the disk 31 to surround the through-hole of the disk 31. As shown in Fig. 2, the protrusion portion 5 of the present embodiment has a sealing surface 51, a pressure-receiving surface 52 and a recess portion 53. The sealing surface 51 is formed to be parallel to the outer surface 21 of the rotary shaft 2. The pressure-receiving surface 52 is extending from the outer surface 21 of the rotary shaft 2 to the sealing surface 51. The recess portion 53 is recessed from the pressure-receiving surface 52.

[0037] The sealing surface 51 seals a radial gap between the casing 4 and the disk 31. The sealing surface 51 is a horizontal surface that faces the radially outer side of the protrusion portion 5 and extends to be parallel to the axis O. The sealing surface 51 of the present embodiment has a labyrinth seal 51a. The sealing surface 51 extends from the back side 311 of the disk 31 by a width necessary for sealing the working fluid F from a first side to a second side in the direction of the axis O. That is, the sealing surface 51 of the present embodiment seals between the the disk 31 and the horizontal plane facing the radially inner side of the casing 4. Therefore, the sealing surface 51 limits leakage of the high-pressure working fluid F discharged from the internal flow passage 34 of the impeller 3 toward the low-pressure space 44.

[0038] In the present embodiment, a protrusion portion amount of the protrusion portion 5 from the back side 311 of the disk 31 is determined by the width of the sealing surface 51 in the direction of the axis O.

[0039] The sealing surface 51 is formed at a position spaced apart from the outer surface 21 of the rotary shaft 2 by a predetermined distance. Specifically, the predetermined distance from the outer surface 21 of the rotary shaft 2, on which the sealing surface 51 is formed in this embodiment, is a radial length of the pressure-receiving surface 52 from the outer surface 21 of the rotary shaft 2 when the pressure-receiving surface 52 is viewed from the second side in the direction of the axis O. The predetermined distance is a value which is preset for each centrifugal compressor 1. The predetermined distance is determined depending on the magnitude of the force received by the pressure-receiving surface 52 to balance the thrust forces acting on the rotary shaft 2. The predetermined distance of the present embodiment is determined by the ratio of the magnitude of the pressure of the low-pressure space 44 to the magnitude of the pressure of the working fluid F compressed by the last stage impeller 3.

[0040] Therefore, the sealing surface 51 of the present embodiment is determined, for example, such that a force, which has the same magnitude as the thrust force to the first side in the direction of the axis O generated on the rotary shaft 2 by the other four impellers 3 other than the last stage impeller 3, and has a magnitude capable of generating a force to the second side in the direction of axis O as the opposite side to the first side on the rotary shaft 2, acts on the pressure-receiving surface 52 only via the last stage impeller 3 provided with the protrusion portion 5.

[0041] The pressure-receiving surface 52 is a surface which is formed to face the low-pressure space 44 and faces the second side of the protrusion portion 5 in the direction of the axis O. The pressure-receiving surface 52 receives a force so as to be drawn toward the low-pressure space 44 to the second side in the direction of the axis O. The pressure-receiving surface 52 of the present embodiment includes a main pressure-receiving surface 521 and a first pressure-receiving surface 522 and a second pressure-receiving surface 523. The main pressure-receiving surface 521 is formed by being connected to the second end portion of the sealing surface 51 in the direction of the axis O. The first pressure-receiving surface 522 and the second pressure-receiving surface 523 are formed by the recess portion 53 to be described later.

[0042] The main pressure-receiving surface 521 is a surface which perpendicularly extends radially inward from the second end portion of the sealing surface 51 in the direction of the axis O. That is, the main pressure-receiving surface 521 is a surface orthogonal to the outer surface 21 of the rotary shaft 2 and faces the second side in the direction of the axis O.

[0043] The recess portion 53 is recessed to the first side in the direction of the axis O from the pressure-receiving surface 52 on the radially inner side of the sealing surface 51. The recess portion 53 of the present embodiment is recessed from the main pressure-receiving surface 521 to form a first pressure-receiving surface 522 and a second pressure-receiving surface 523. The first pressure-receiving surface 522 is a part of the pressure-receiving surface 52 and is orthogonal to the outer surface 21 of the rotary shaft 2. The second pressure-receiving surface 523 is inclined to face the outer surface 21 of the rotary shaft 2 on the radially outer side of the first pressure-receiving surface 522.

[0044] The first pressure-receiving surface 522 is a surface which vertically extends radially outward from the second end portion of the through-hole of the disk 31 in the direction of the axis O. That is, the first pressure-receiving surface 522 is formed to be parallel to the main pressure-receiving surface 521 and the back side 311 of the disk 31. The first pressure-receiving surface 522 faces the second side in the direction of the axis O. The first pressure-receiving surface 522 of the present embodiment is formed such that the position in the direction of the axis O is the same as the position of the rear surface 311 of the disk 31.

[0045] The second pressure-receiving surface 523 is a surface which connects the first pressure-receiving surface 522 and the main pressure-receiving surface 521. More specifically, the second pressure-receiving surface 523 is extending to the second side in the direction of the axis O from the radially outer end portion of the first pressure-receiving surface 522 toward the outer side in the radial direction. The second pressure-receiving surface 523 is formed to be connected to the radially inner end portion of the main pressure-receiving surface 521. That is, the second pressure-receiving surface 523 is inclined to face the second side in the direction of the axis O and the inner side in the radial direction.

[0046] Next, the operation of the centrifugal compressor 1, which is the rotary machine having the above-described structure, will be described.

[0047] In the centrifugal compressor 1 as described above, the working fluid F flowing into the suction port 431 flows, while being compressed in the order of the internal flow passage 34, the diffuser flow passage 432 and the return flow passage 433 of the first stage impeller 3 disposed at the first stage compressor stage 11. And thereafter, the working fluid F flows, while being compressed in the order of the internal flow passage 34, the diffuser flow passage 432 and the return flow passage 433 of the second stage impeller 3 disposed at the second compressor stage 12. Further, the working fluid F flowing from the final stage impeller 3 disposed at the fifth stage compressor stage 15 to the diffuser flow passage 432 is discharged to the outside via the discharge port 434. The working fluid F is compressed, by flowing through the internal flow passage 34 of each impeller 3, while flowing in the aforementioned order. That is, in the centrifugal compressor 1 of the present embodiment, the working fluid F is gradually compressed by the plurality of impellers 3, thereby obtaining a large compression ratio.

[0048] According to the centrifugal compressor 1 as described above, by gradually compressing the working fluid F using the plurality of impellers 3, on the rotary shaft 2 fixed to the impeller 3 via the disk 31, the thrust force is generated toward the first side in the direction of the axis O. However, since the protrusion portion 5 is provided on the disk 31 of the last stage impeller 3 of the nearest the second side in the direction of the axis O, it is possible to generate the thrust force directed to the second side in the direction of the axis O, which is in the direction opposite to the thrust force generated by the impellers 3 from the first stage to the fourth stage, on the rotary shaft 2, by the last stage impeller 3.

[0049] Specifically, the protrusion portion 5 is provided in the low-pressure space 44, and the high-pressure working fluid F discharged from the internal flow passage 34 of the last stage impeller 3 is sealed by the sealing surface 51 to prevent the working fluid from leaking out toward the low-pressure space 44. Therefore, with the sealing surface 51 as a boundary, the pressure of the low-pressure space 44 on the second side in the direction of the axis O becomes lower than the pressure around the impeller 3 on the first side in the direction of the axis O. Therefore, a pressure lower than that on the cover 33 and the back side 311 acts on the pressure-receiving surface 52 constituted by the first pressure-receiving surface 522, the second pressure-receiving surface 523 and the main pressure-receiving surface 521. As a result, the thrust force directed toward the second side in the direction of the axis O from the last stage impeller via the disk 31 provided with the protrusion portion 5 can be generated on the rotary shaft 2

[0050] As a result, the thrust force applied to the rotary shaft 2 by the impellers 3 from the first stage to the fourth stage can be weakened by the last stage impeller 3. Thus, the thrust force acting on the rotary shaft 2 can be adjusted. Therefore, it is possible to prevent the rotary shaft 2 from deviating in the direction of the axis O.

[0051] Further, for example, as in the present embodiment, if the centrifugal compressor 1 is used in a nitric acid plant and nitric acid is used as the working fluid F, when some of ammonia used in a previous process erroneously flows into the casing flow passage 43, nitric acid and ammonia react with each other, and ammonium nitrate is produced as a solid product. Therefore, if an annular separate member as a balance piston is disposed on the back side 311 of the disk 31 of the last stage impeller 3 to try to adjust the thrust force generated in the rotary shaft 2, when the high-pressure working fluid F flows in, the solid product is accumulated in the gap formed between the back side 311 of the disk 31 and the separate member.

[0052] Even when the back side 311 of the disk 31 and the separate member are brought into contact with each other in a sealable state with metal touch so that no gap is formed, since the flowing working fluid F is at a high pressure, it is difficult to prevent the working fluid F from flowing into the gap.

[0053] However, by adjusting the thrust force generated on the rotary shaft 2 by the protrusion portion 5 formed integrally with the disk 31, since the balance piston and the disk 31 can substantially be integrally formed, it is unnecessary to use a separate member, and it is possible to prevent the formation of an unnecessary gap.

[0054] This enables prevention of the formation of a gap and balancing of the thrust forces on the rotary shaft 2.

[0055] Further, since the low-pressure space 44 communicates with the suction port 431 having the lowest pressure in the casing flow passage 43, it is possible to maximize the force which acts on the pressure-receiving surface 52 pulling from the first side toward the second side in the direction of the axis O. Therefore, it is possible to increase the thrust force from the last stage impeller 3 toward the second side in the direction of the axis O acting on the rotary shaft 2 via the disk 31 provided with the protrusion portion 5. Thus, by providing a plurality of impellers 3, even when a large thrust force is generated on the rotary shaft 2, it is possible to stably balance the thrust force generated in the rotary shaft 2. Therefore, it is possible to stably limit the deviation of the rotary shaft 2 in the direction of the axis O.

[0056] Further, since the position in the radial direction at which the sealing surface 51 is formed is determined depending on the magnitude of the force acting on the pressure-receiving surface 52 to the second side in the direction of the axis O which is the low-pressure space 44 side, when simply forming the protrusion portion 5, the protrusion portion 5 is formed to be large in the radial direction. However, since the recess portion 53 recessed from the pressure-receiving surface 52 is formed, it is possible to form the protrusion portion 5 to be small by reducing the thickness of the protrusion portion 5, while forming the pressure-receiving surface 52. Therefore, by forming the recess portion 53, it is possible to limit an increase in the weight of the impeller 3 having the protrusion portion 5.

[0057] Further, since the protrusion portion 5 is formed integrally with the disk 31, it is not necessary to fix a separate member such as a balance piston on the back side 311 of the disk 31. Therefore, it is not necessary to secure a space on the outer surface 21 of the rotary shaft 2 in order to fix the separate member to the rotary shaft 2 by shrink-fitting. As a result, the length of the rotary shaft 2 in the direction of the axis O can be shortened, and vibration of the rotary shaft 2 can be suppressed.

[0058] Further, since the sealing surface 51 is formed to be parallel with the outer surface 21 of the rotary shaft 2, even when elongation in the direction of the axis O occurs in the rotary shaft 2, it is possible to prevent the rotary machine such as the centrifugal compressor 1 having a plurality of impellers 3 from being influenced by the elongation. For example, if the sealing surface 51 is formed to be inclined or formed in a stepwise shape, when elongation in the direction of the axis O occurs in the rotary shaft 2, there is a risk of contact of the sealing surface 51 with the casing 4. As a result, there is a risk of damage to the rotary shaft 2 as well as damage to the sealing performance. However, since the sealing surface 51 is formed to be parallel with the outer surface 21 of the rotary shaft 2, even when the position of the sealing surface 51 moves in the direction of the axis O, it is possible to secure the sealing performance, without coming into contact with the casing 4.

[0059] Although the embodiments of the present invention have been described in detail with reference to the drawings, the respective configurations in each embodiment, combinations thereof, and the like are merely examples, and additions, omissions substitutions and other changes of configurations may be made within the scope that does not depart from the spirit of the present invention. Also, the present invention is not limited by the embodiments, and is limited only by the claims.

[0060] In the present embodiment, the recess portion 53 is formed to form the first pressure-receiving surface 522 and the second pressure-receiving surface 523 on the protrusion portion 5, but the present invention is not limited to such a structure. For example, the recess portion 53 may have an arbitrary shape such that the recess portion 53 is recessed from the main pressure-receiving surface 521 in a semicircular cross section. In addition, the recess portion 53 itself may not be formed in the protrusion portion 5.

[0061] Further, the impeller 3 is not limited to a configuration in which five impellers 3 are disposed as in the centrifugal compressor 1 of the present embodiment. For example, impellers 3 with less than four stages may be provided, and six stages or more of impellers 3 may be provided.

[Industrial Applicability]

[0062] According to the aforementioned rotary machine, it is possible to prevent generation of a gap by the protrusion portion 5 integrally formed with the disk 31, and it is possible to balance the thrust forces acting on the rotary shaft 2.

[Reference Signs List]

[0063]

O	Axis
F	working fluid
1	Centrifugal compressor
2	Rotary shaft
21	Outer surface
3	Impeller
31	Disk
311	Back side
32	Blade
33	Cover
34	Internal flow passage
5	Protrusion portion
51	Sealing surface
51a	Labyrinth seal
52	Pressure-receiving surface
521	Main pressure-receiving surface
522	First pressure-receiving surface
523	Second pressure-receiving surface
53	Recess portion
4	Casing
41	Journal bearing
42	Thrust bearing
43	Casing flow passage
431	Suction port
432	Diffuser flow passage
433	Return flow passage
434	Discharge port
44	Low-pressure space

Claims

1. A rotary machine comprising:

    a rotary shaft which rotates about an axis;
    a plurality of impellers which have a disk rotating with the rotary shaft, and an internal flow passage formed to discharge a working fluid, which flows in from a first side in an axial direction in which the axis extends, toward an outer side in a radial direction, the plurality of impellers being disposed side by side in the axial direction; and
    a casing in which a casing flow passage is formed to flow the working fluid from an impeller disposed on the first side in the axial direction to an impeller adjacent to a second side,
    wherein among the plurality of impellers, an impeller disposed nearest to the second side in the axial direction has a protrusion portion which is disposed in a space communicating with an upstream part of the casing flow passage, which protrudes from a back side facing the second side of the disk in the axial direction, and which is formed integrally with the disk, and
    the protrusion portion has:

        a sealing surface which is formed to be parallel to an outer surface of the rotary shaft to seal a gap in a radial direction between the protrusion portion and the casing, and
        a pressure-receiving surface which extends from the outer surface of the rotary shaft to the sealing surface.

2. The rotary machine according to claim 1, wherein a suction port is formed in the casing to allow the working fluid to flow into the casing flow passage from the outside, and the suction port and the space communicate with each other.

3. The rotary machine according to claim 1 or 2, wherein the protrusion portion has a recess portion which is recessed from the pressure-receiving surface toward the first side in the axial direction on a radially inner side of the sealing surface.

4. An impeller disposed nearest to a second side of a rotary machine in an axial direction, the rotary machine including, a rotary shaft which rotates about an axis, a plurality of impellers which have a disk rotating with the rotary shaft, and an internal flow passage formed to discharge a working fluid, which flows in from a first side in the axial direction in which the axis extends, toward an outer side in a radial direction, the plurality of impellers being disposed side by side in the axial direction, and a casing in which a casing flow passage is formed to circulate the working fluid from an impeller disposed on the first side in the axial direction to an impeller adjacent to the second side, the impeller comprising:

    a protrusion portion which protrudes from a back side facing the second side of the disk in the axial direction, which is integrally formed with the disk, and which is disposed in a space communicating with an upstream side of the casing flow passage,
    wherein the protrusion portion has:

        a sealing surface which is formed to be parallel to an outer surface of the rotary shaft to seal a gap in the radial direction between the protrusion portion and the casing, and
        a pressure-receiving surface which extends from the outer surface of the rotary shaft to the sealing surface.

FIG. 1

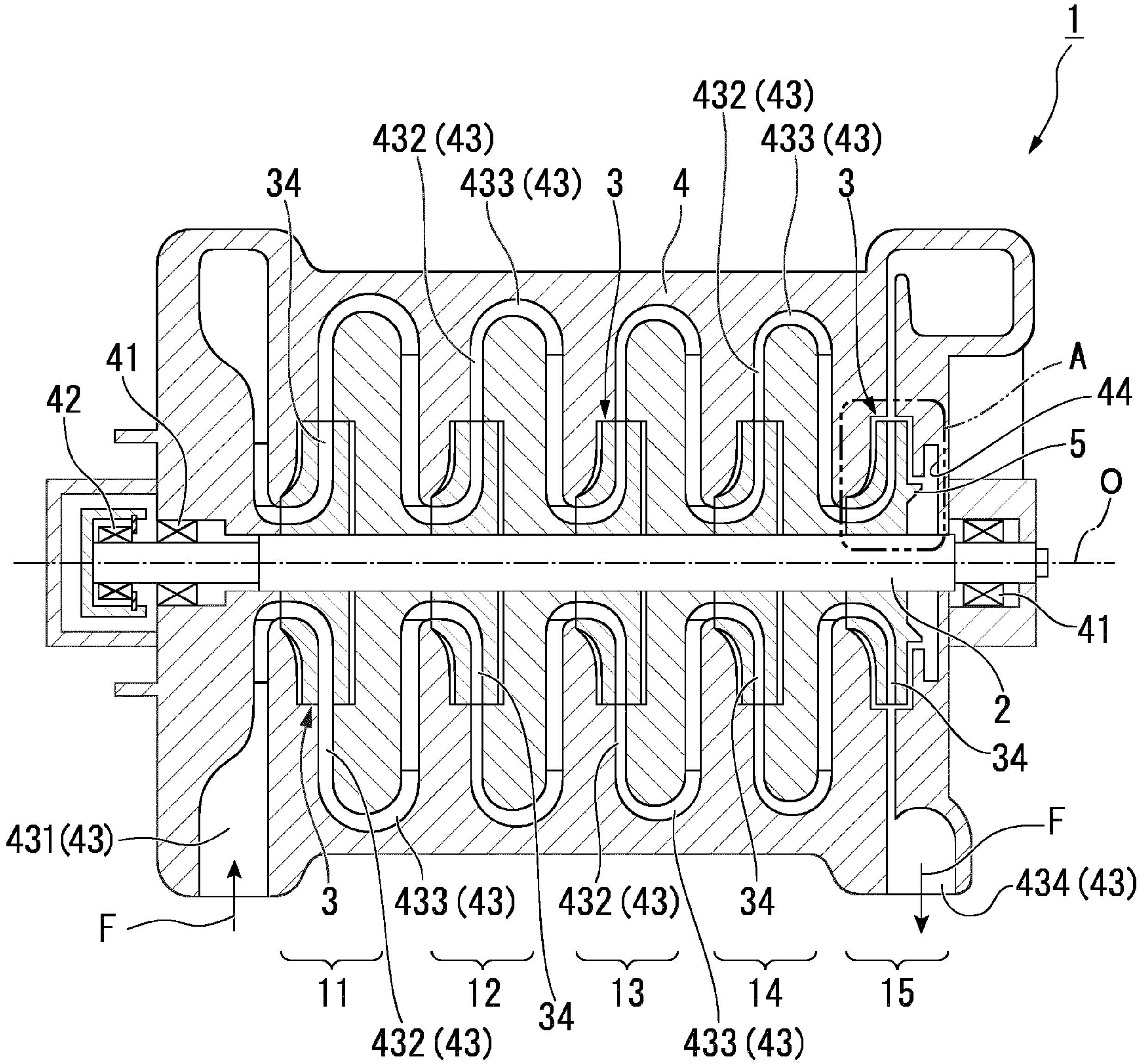
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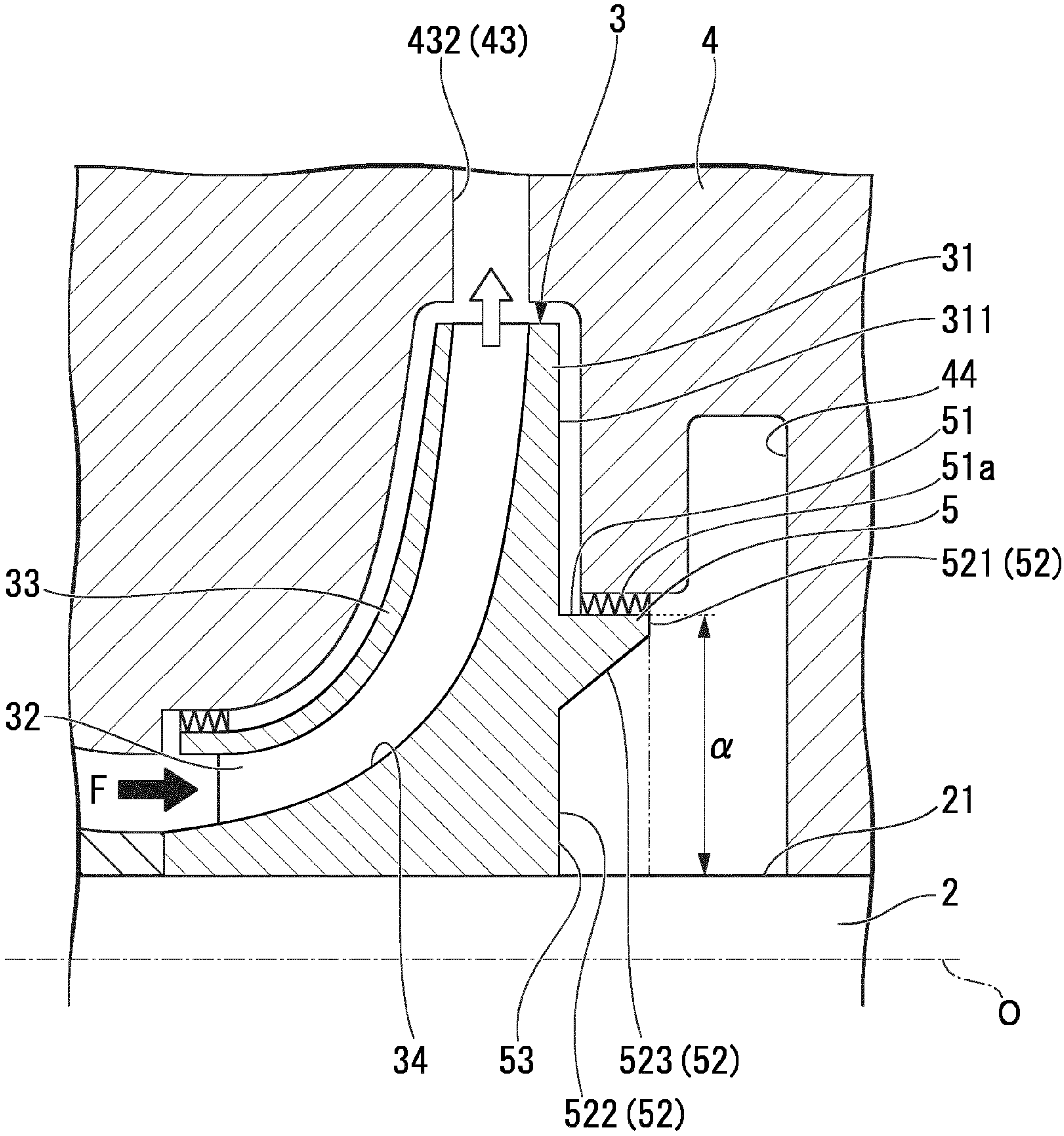
FIG. 2



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2014/073685

A. CLASSIFICATION OF SUBJECT MATTER
F04D1/08(2006.01)i, *F04D29/041*(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)
F04D1/08, F04D29/041

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	1996-2014
Kokai Jitsuyo Shinan Koho	1971-2014	Toroku Jitsuyo Shinan Koho	1994-2014

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	JP 2002-257080 A (Mitsubishi Heavy Industries, Ltd.), 11 September 2002 (11.09.2002), entire text; all drawings (Family: none)	1-4
Y	JP 2001-107883 A (Mitsubishi Heavy Industries, Ltd.), 17 April 2001 (17.04.2001), paragraph [0045]; fig. 5 (Family: none)	1-4

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
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"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 November, 2014 (13.11.14)	25 November, 2014 (25.11.14)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
Facsimile No.	Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2014/073685

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 49-38641 B1 (Nikkiso Co., Ltd.), 19 October 1974 (19.10.1974), page 3, left column, lines 17 to 23; fig. 2 & US 3664758 A & GB 1300660 A & DE 2105485 A & FR 2101348 A & CH 529929 A	1-4
A	JP 2004-190569 A (Mitsubishi Heavy Industries, Ltd.), 08 July 2004 (08.07.2004), entire text; all drawings (Family: none)	1-4

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

REFERENCES CITED IN THE DESCRIPTION

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- JP 2001107888 A **[0004]**