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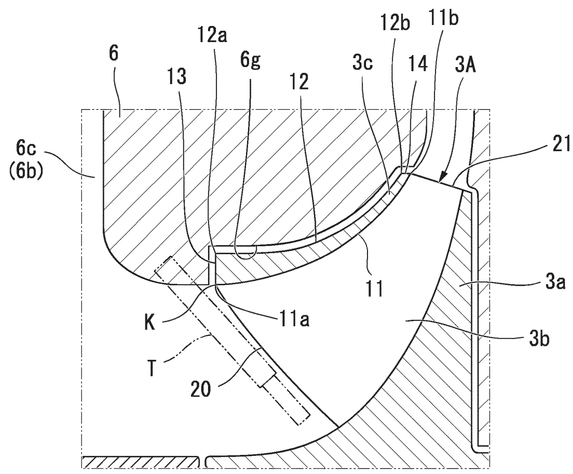
(54) **IMPELLER, ROTARY MACHINE, AND IMPELLER MANUFACTURING METHOD**

(57) An impeller includes a disc (3a) having a disc shape about an axis, a plurality of blades (3b) formed on a surface facing a first side in an axial direction of the disc (3a) at intervals in a circumferential direction around the axis, and a cover (3c) surrounding the plurality of blades (3b) from the first side in the axial direction. The cover (3c) includes an inner circumferential surface (11) connected to the blade (3b) with a diameter decreasing from the second side toward a first side in the axial direction, and a distal end surface (13) extending from an end portion of the inner circumferential surface (11) on the first side in the axial direction toward the outside in a radial direction and facing the first side in the axial direction. A front edge portion (20), which is an edge portion of the blade (3b) on the first side in the axial direction, extends from a boundary (K) between the inner circumferential surface (11) and the distal end surface (13) toward the inside in the radial direction.

FIG. 2



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Description

[Technical Field]

[0001] The present invention relates to an impeller, a rotary machine, and a method of manufacturing an impeller.

[0002] Priority is claimed on Japanese Patent Application No. 2016-56045, filed March 18, 2016, the content of which is incorporated herein by reference.

[Background Art]

[0003] As a rotary machine used in industrial compressors, turbo refrigerators, small gas turbines, or the like, one having an impeller in which a plurality of blades are attached to a disc fixed to a rotating shaft is known. Such rotary machines impart pressure energy and velocity energy to a gas by rotating the impeller.

[0004] Patent Document 1 describes a centrifugal compressor having a so-called closed impeller in which a cover is integrally attached to a blade.

[0005] In such impellers, there is a case in which a one-piece manufacturing method in which a cover, a blade, and a disc are molded in an integrated state from the beginning is employed instead of a three-piece manufacturing method in which the cover, the blade and the disc are separately molded and then assembled or a two-piece manufacturing method in which the cover only is separately molded and then assembled. Particularly, when a working fluid is a corrosive gas, since a corrosion-resistance material cannot be easily welded, a one-piece manufacturing method is often employed in many cases.

[0006] This one-piece manufacturing method is employed also in a case in which a width of a flow path is extremely small such as in a small diameter impeller, a leg length of a welded portion becomes too large with respect to the width of the flow path, and thus concern about performance reliability, or the like is caused.

[Citation List]

[Patent Document]

[0007] Patent Document 1: Japanese Unexamined Patent Application, First Publication No. 2015-175250

[Summary of Invention]

[Technical Problem]

[0008] In the closed impeller described in Patent Document 1, particularly when making the impeller in one piece is intended or the like, processing such as a complicated cutting process, electro-discharge machining, or the like may be required in some cases. At the time of this cutting process, since a base of a tool is thick, a depth between blades into which the tool can be inserted in an axial direction of the impeller is limited. Therefore, when processing a disc side or a cover side of the impeller, the tool is obliquely inserted with respect to an axis of the impeller. However, there are cases in which the cutting tool interferes with the cover or the like of the impeller, and there is a problem in that skill is required for processing the impeller. Also, in a case of electro-discharge machining, there are cases in which a shape of a discharge electrode needs to be complicatedly formed, thus resulting in an increase in costs.

[0009] An object of the present invention is to provide an impeller, a rotary machine, and a method of manufacturing an impeller in which processing can be easily performed.

[Solution to Problem]

[0010] According to a first aspect of the present invention, an impeller includes a disc, a plurality of blades, and a cover. The disc has a disc shape about an axis. The plurality of blades are formed on a surface facing a first side in an axial direction of the disc at intervals in a circumferential direction around the axis. The cover surrounds the plurality of blades from the first side in the axial direction. The cover includes an inner circumferential surface and a distal end surface. The inner circumferential surface is connected to the blades with a diameter decreasing from the other side toward the first side in the axial direction. The distal end surface extends from an end portion of the inner circumferential surface on the first side in the axial direction toward the outside in a radial direction and faces the first side in the axial direction. A front edge portion, which is an edge portion of the blade on the first side in the axial direction, extends from a boundary between the inner circumferential surface and the distal end surface toward the inside in the radial direction.

[0011] With such a configuration, it is possible to prevent the cover from protruding toward the first side in the axial direction from the front edge of the blade. Therefore, it is possible to prevent a tool from interfering with the cover, or a shape of a discharge electrode from becoming complicated, and thereby processing can be easily performed. Further, a swirling flow generated just before the front edge of the blade due to rotation of the cover can be reduced. Therefore, on a side of the cover, a boundary layer in the vicinity of the front edge of the blade can be made thin and thus performance of the impeller can be improved.

[0012] According to a second aspect of the present invention, the distal end surface according to the first aspect may have a convex curved surface disposed on the other side in the axial direction toward the inside in the radial direction.

[0013] With such a configuration, interference of a tool or the like can be further prevented.

[0014] According to a third aspect of the present invention, the edge portion according to the first or second aspect may have a protruding edge portion toward the first side in the axial direction on a radial outer side thereof.

[0015] By providing the protruding edge portion at a portion on the radial outer side of the front edge portion of the blade in this manner, regardless of the shape of the front edge portion of the blade, the front edge portion of the blade can be formed to be continuous from the boundary between the inner circumferential surface and the distal end surface via the protruding edge portion.

[0016] According to a fourth aspect of the present invention, a rotary machine includes an impeller according to any one of the first to third aspects.

[0017] With such a configuration, it is possible to easily manufacture the rotary machine, and it is possible to improve efficiency of the rotary machine with improvement of the impeller performance.

[0018] According to a fifth aspect of the present invention, there is provided a method of manufacturing an impeller including a disc, a plurality of blades, and a cover. The disc has a disc shape about the axis. The plurality of blades are formed on a surface facing a first side in an axial direction of the disc at intervals in a circumferential direction around the axis. The cover surrounds the plurality of blades from the first side in the axial direction. The cover has an inner circumferential surface and a distal end surface. The inner circumferential surface is connected to the blade with a diameter decreasing from the other side toward the first side in the axial direction. The distal end surface extends from an end portion of the inner circumferential surface on the first side in the axial direction toward the outside in the radial direction and faces the first side in the axial direction. The method of manufacturing an impeller includes a process of forming a front edge portion, which is an edge portion of the blade on the first side in the axial direction, to extend from a boundary between the inner circumferential surface and the distal end surface toward the inside in the radial direction.

[0019] In this way, interference of the tool with the disc can be prevented. Therefore, the impeller can be easily manufactured.

[Advantageous Effects of Invention]

[0020] According to the above-described impeller, processing can be easily performed.

[Brief Description of Drawings]

[0021]

FIG. 1 is a configuration diagram showing a schematic configuration of a centrifugal compressor in a first embodiment of the present invention.

Fig. 2 is an enlarged view of an impeller in the first embodiment of the present invention.

Fig. 3 is a graph in which a horizontal axis represents a position in a span direction (Span Normalized) with respect to a blade and a vertical axis represents an absolute value of a circumferential velocity of a gas (Vt_abs).

FIG. 4 is a flowchart showing a method of manufacturing the impeller in the first embodiment of the present invention.

Fig. 5 is an enlarged view corresponding to Fig. 2 in a second embodiment of the present invention.

FIG. 6 is an enlarged view corresponding to Fig. 2 in a modified example of the first embodiment of the present invention.

[Description of Embodiments]

(First embodiment)

[0022] An impeller and a rotary machine according to a first embodiment of the present invention will be described below on the basis of the drawings.

[0023] FIG. 1 is a configuration diagram showing a schematic configuration of a centrifugal compressor according to the first embodiment of the present invention.

[0024] As shown in Fig. 1, a centrifugal compressor 1 includes a rotating shaft 2, an impeller 3A, a journal bearing 5A, a thrust bearing 5B, and a casing 6.

[0025] The rotating shaft 2 is formed in a columnar shape extending in an axis O direction. The rotating shaft 2 is rotatably supported by the journal bearings 5A on a side of a first end portion 2a (a first side in an axial direction) and a side of a second end portion 2b (a second side in the axial direction) in the axis O direction. Further, the first end portion 2a of the rotating shaft 2 is supported by the thrust bearing 5B.

[0026] A plurality of impellers 3A are provided in the axis O direction with respect to the rotating shaft 2. These impellers 3A are attached to the rotating shaft 2 by fitting or the like. Each of the impellers 3A includes a disc 3a, blades 3b, and a cover 3c.

[0027] The disc 3a is formed in a disc shape about the axis O. More specifically, the disc 3a is provided so that a diameter thereof gradually increase outward in the radial direction of the rotating shaft 2 going from a side of the first end portion 2a of the rotating shaft 2 to a side of the second end portion 2b thereof. A central axis of the disc 3a overlaps the axis O of the rotating shaft 2. Therefore, in the following description, the axis of the disc 3a is also referred to as "axis O."

[0028] A plurality of blades 3b are formed on a surface of the disc 3a facing the first end portion 2a in the axis O direction at intervals in a circumferential direction around the axis O. Further, these blades 3b extend to separate from the disc 3a and are radially disposed about the axis O.

[0029] The cover 3c covers the plurality of blades 3b from the first end portion 2a side in the axis O direction. In other words, the cover 3c is provided to face the disc 3a with the blades 3b interposed therebetween. An inner circumferential surface 11 of the cover 3c is provided so that a diameter thereof decrease outward in the radial direction of the rotating shaft 2 going from the side of the second end portion 2b to the side of the first end portion 2a. From the inner circumferential surface 11, the blades 3b described above extend toward the disc 3a.

[0030] By constituting the surface of the disc 3a which face the first end portion 2a side in the axis O direction, the blades 3b, and the inner circumferential surface 11 of the cover 3c, a flow path extending toward the outside in a radial direction going from the side of the first end portion 2a to the side of the second end portion 2b in the axis O direction is formed in the impeller 3A.

[0031] The rotating shaft 2 of the centrifugal compressor 1 in this embodiment includes a plurality of impellers 3A in the axis O direction, and thereby a multistage impeller group 3G is formed.

[0032] The casing 6 is formed in a cylindrical shape and accommodates the rotating shaft 2, the impellers 3A, the journal bearings 5A, and the like. The casing 6 rotatably supports the rotating shaft 2 with the journal bearings 5A interposed therebetween. Thereby, the impellers 3A attached to the rotating shaft 2 are rotatable relative to the casing 6.

[0033] The casing 6 includes an intake port 6a, a connection flow path 6b, a casing flow path 6c, a connection flow path 6d, and a discharge port 6e.

[0034] The intake port 6a is provided in the casing 6 located on the first end portion 2a in the axis O direction. The intake port 6a receives a gas supplied from outside. The intake port 6a is disposed on a side closest to the first end portion 2a in the axis O direction of the outer circumferential surface 6f of the casing 6.

[0035] The connection flow path 6b connects the intake port 6a to a first stage impeller 3A disposed closest to the first end portion 2a among the plurality of impellers 3A. That is, this connection flow path 6b supplies a gas received by the intake port 6a to the first stage impeller 3A.

[0036] The casing flow path 6c connects flow paths of the impellers 3A that are adjacent to each other in the axis O direction. More specifically, an impeller accommodating space in the vicinity of an outer circumferential end portion of the impeller 3A disposed on an upstream side communicates with an impeller accommodating space in the vicinity of a front end portion of the impeller 3A disposed on a downstream side. The casing flow path 6c temporarily guides a gas pressurized by the impeller 3A disposed on the upstream side toward the outside in the radial direction, then guides the gas radially inwards, and supplies the gas to the front end portion of the impeller 3A disposed on the downstream side. Thereby, the gas flowing through the casing flow path 6c is pressurized in stages by the plurality of impellers 3A. A diffuser, a return vane, or the like may be provided in the casing flow path 6c.

[0037] The connection flow path 6d connects a final stage impeller 3A disposed closest to the second end portion 2b to the discharge port 6e. That is, the connection flow path 6d guides the gas pressurized by the multistage impeller group 3G to the discharge port 6e.

[0038] The discharge port 6e discharges the gas guided by the connection flow path 6d to the outside of the casing 6. The discharge port 6e is disposed on a side closest to the second end portion 2b in the axis O direction of the outer circumferential surface 6f of the casing 6.

[0039] Fig. 2 is an enlarged view of the impeller in the first embodiment of the present invention.

[0040] As shown in Fig. 2, each of the cover 3c of the impeller 3A includes the inner circumferential surface 11, an outer circumferential surface 12, a distal end surface 13, and a rear end surface 14. The inner circumferential surface 11 has a shape as described above and is a convex curved surface in a cross section including the axis O shown in Fig. 2.

[0041] Similarly to the inner circumferential surface 11, the outer circumferential surface 12 is provided so that a diameter thereof decrease outward in the radial direction of the rotating shaft 2 going from the side of the second end portion 2b (right side as viewed in Fig. 2) to the side of the first end portion 2a (left side as viewed in Fig. 2). The outer circumferential surface 12 is a concave curved surface in a cross section including the axis O shown in Fig. 2. The outer circumferential surface 12 is disposed to face an inner circumferential surface 6g of the casing 6 in which the impeller 3A is accommodated with a slight gap interposed therebetween. The outer circumferential surface 12 gradually separates from the inner circumferential surface 11, from the side of the second end portion 2b to the side of the first end portion 2a in the axis O direction. In other words, the cover 3c is provided so that a thickness thereof gradually increase going from the side of the first end portion 2a to the side of the second end portion 2b. A sealing mechanism such as a labyrinth seal may be provided between the inner circumferential surface 6g of the casing 6 and the outer circumferential surface 12 of the cover 3c.

[0042] The distal end surface 13 extends toward the outside in a radial direction going from an end portion 11a of the inner circumferential surface 11 on the side of the first end portion 2a to with respect to the axis O. That is, the distal end surface 13 faces the first end portion 2a side in the axis O direction. The distal end surface 13 is formed to extend from the end portion 11a of the inner circumferential surface 11 to an end portion 12a of the outer circumferential surface 12 on the side of the first end portion 2a in the axis O direction. In this embodiment, the distal end surface 13 is formed in a plane perpendicular to the axis O. On the inner circumferential surface 6g of the casing 6 in this embodiment, a plane facing the distal end surface 13 is formed.

[0043] The rear end surface 14 is formed to extend from an end portion 11b of the inner circumferential surface 11 to an end portion 12b of the outer circumferential surface 12 on the side of the second end portion 2b in the axis O direction.

[0044] Each of the blades 3b includes a front edge portion 20 which is an edge portion on the side of the first end portion 2a in the axis O direction. The front edge portion 20 extends from a boundary portion K at which the inner circumferential surface 11 and the distal end surface 13 intersect each other toward the inside in the radial direction with respect to the axis O. The front edge portion 20 can be formed to be continuous with the distal end surface 13. The front edge portion 20 in this embodiment is formed in a slightly curved shape substantially close to a straight line. Further, the front edge portion 20 is inclined to be disposed closer to the second end portion 2b from the radial outer side toward the radial inner side with respect to the axis O with respect to a plane perpendicular to the axis O. Since the front edge portion 20 is inclined in this way, in the blade 3b, a difference between a distance from the front edge portion 20 on a side of the cover 3c to the rear edge portion 21 in the blade 3b and a distance from the front edge portion 20 on a side of the disc 3a to the rear edge portion 21 in the blade 3b becomes small. The boundary portion K described above includes not only the position at which the inner circumferential surface 11 intersects the distal end surface 13 but also a position deviated from the position at which the inner circumferential surface 11 intersects with the distal end surface 13 by about 1 mm to 2 mm (this also applies to a subsequent second embodiment).

[0045] Fig. 3 is a graph in which a horizontal axis represents a position in a span direction (Span Normalized) with respect to the blade and a vertical axis represents an absolute value of a circumferential velocity of a gas (Vt_abs).

[0046] In the graph of Fig. 3, a broken line is a comparative example. This comparative example is a case in which the front edge portion 20 of the blade 3b extends toward the inside in the radial direction from a position on a side closer to the second end portion 2b with respect to the boundary portion K. In the graph of Fig. 3, a solid line represents a case of the embodiment (example) described above. As shown in Fig. 3, in the comparative example, there is a region in which the absolute value of the circumferential velocity of the gas rises immediately before the position of the front edge portion 20 of the blade 3b (indicated by an arrow in Fig. 3) in the span direction. It is thought that the absolute value of the circumferential velocity of the gas rises because the cover 3c disposed on the side closer to the first end portion 2a than the front edge portion 20 of the blade 3b comes into contact with the gas.

[0047] On the other hand, in the impeller 3A in this embodiment, the front edge portion 20 extends from the boundary portion K toward the radial inner side. Therefore, immediately before the front edge portion 20 of the blade 3b, the rise in the absolute value of the circumferential velocity of the gas due to the contact between the gas and the cover 3c does not occur.

[0048] Next, a method of manufacturing the impeller 3A will be described.

[0049] FIG. 4 is a flowchart showing a method of manufacturing the impeller according to the first embodiment of the present invention.

[0050] First, a base material having the outer circumferential surface 12 and the distal end surface 13 of the cover 3c formed therein with a metal such as stainless steel is formed (step S01), for example.

[0051] Next, the blade 3b, the inner circumferential surface 11 of the cover 3c, and the disc 3a are formed by a cutting process using a cutting tool T as shown in Fig. 2 (step S02). At this time, the blade 3b is formed by cutting so that the front edge portion 20 of the blade 3b extends toward the inside in the radial direction from the boundary portion K between the inner circumferential surface 11 and the distal end surface 13 of the cover 3c. Thereafter, finish processing such as surface polishing is performed as needed.

[0052] According to the first embodiment described above, it is possible to prevent the cover 3c from protruding toward the first end portion 2a side in the axis O direction with respect to the front edge portion 20 of the blade 3b. Therefore, it is possible to prevent a tool from interfering with the cover 3c and thereby processing can be easily performed. Further, a swirling flow generated just before the front edge portion 20 of the blade 3b due to rotation of the cover 3c can be reduced. Therefore, on the side of the cover 3c, a boundary layer in the vicinity of the front edge portion 20 of the blade 3b can be made thin and thus performance of the impeller 3A can be improved.

(Second embodiment)

[0053] Next, an impeller according to a second embodiment of the present invention will be described on the basis of the drawings. The second embodiment differs from the first embodiment only in a shape of the distal end surface 13. Therefore, portions the same as those in the first embodiment are denoted by the same reference signs, and duplicated descriptions thereof will be omitted.

[0054] Fig. 5 is an enlarged view corresponding to Fig. 2 in the second embodiment of the present invention.

[0055] As shown in Fig. 5, each of impellers 3B in the second embodiment includes a disc 3a, a blade 3b, and a cover 103c.

[0056] The cover 103c covers a plurality of blades 3b from a side of a first end portion 2a in an axis O direction (left side as viewed in Fig. 5). The cover 103c is provided to face the disc 3a, and includes an inner circumferential surface 11, an outer circumferential surface 12, a distal end surface 113, and a rear end surface 14, respectively.

[0057] The inner circumferential surface 11, the outer circumferential surface 12, and the rear end surface 14 have the same configuration as those of the first embodiment described above. That is, the inner circumferential surface 11 is formed to decrease in diameter from a side of a second end portion 2b (right side as viewed in Fig.

5) to a side of the first end portion 2a in the axis O direction. From this inner circumferential surface 11, the blade 3b extends toward the disc 3a.

[0058] Similarly to the inner circumferential surface 11, the outer circumferential surface 12 is formed to decrease in diameter from the side of the second end portion 2b to the side of the first end portion 2a in the axis O direction. The outer circumferential surface 12 is disposed to face an inner circumferential surface 6g of a casing 6 in which the outer circumferential surface 12 is accommodated with a slight gap interposed therebetween. The outer circumferential surface 12 gradually separates from the inner circumferential surface 11, from the side of the second end portion 2b to the side of the first end portion 2a in the axis O direction.

[0059] The rear end surface 14 is formed to extend from an end portion 11b of the inner circumferential surface 11 to an end portion 12b of the outer circumferential surface 12 on the side of the second end portion 2b in the axis O direction.

[0060] The distal end surface 113 extends from an end portion 11a of the inner circumferential surface 11 on a side of the first end portion 2a in the axis O direction toward the outside in the radial direction with respect to the axis O. The distal end surface 113 faces the first end portion 2a side in the axis O direction. The distal end surface 113 is formed to extend from the end portion 11a of the inner circumferential surface 11 to the end portion 12a of the outer circumferential surface 12 on the side of the first end portion 2a. At least a portion of the distal end surface 113 in the second embodiment is a convex curved surface in a cross section including the axis O.

[0061] More specifically, in the cover 103c in the second embodiment, the end portion 11a of the inner circumferential surface 11 on the side of the first end portion 2a is disposed closer to the second end portion 2b than the end portion 12a of the outer circumferential surface 12 on the side of the first end portion 2a in the axis O direction. The distal end surface 113 formed to extend from the end portion 11a to the end portion 12a has a convex curved surface formed at the radial inner portion thereof with respect to the axis O to be curved from the side of the first end portion 2a to the side of the second end portion 2b from the radial outer side toward the radial inner side.

[0062] Similarly to the first embodiment, the blade 3b extends from a boundary portion K between the distal end surface 113 and the inner circumferential surface 11 toward the inside in the radial direction with respect to the axis O. Also in this second embodiment, a front edge portion 20 of the blade 3b is formed in a curved shape slightly curved substantially close to a straight line. Further, the blade 3b is inclined to be disposed closer to the second end portion 2b from the radial outer side toward the radial inner side with respect to the axis O with respect to a plane perpendicular to the axis O.

[0063] According to the second embodiment described above, since the distal end surface 113 has the convex curved surface, interference with a cutting tool T can be prevented when a cutting process or the like is performed. Even when the cutting tool T interferes, since it is a convex curved surface, obstruction in moving the cutting tool T or the like or damage to the cutting tool T can be prevented.

(Other modified examples)

[0064] In each of the embodiments described above, a case in which the whole of the front edge portion 20 of the blade 3b extends toward the inside in the radial direction from the boundary portion K has been described as an example. However, the present invention is not limited to the configuration.

[0065] FIG. 6 is an enlarged view corresponding to Fig. 2 in a modified example of the first embodiment of the present invention.

[0066] As shown in Fig. 6, a front edge portion 20C of an impeller 3C may have a protruding edge portion 22 protruding toward a side of the first end portion 2a in the axis O direction on a radial outer side thereof.

[0067] The protruding edge portion 22 is formed to protrude toward the first end portion 2a side in the axis O direction from an extension line E of a remaining portion 20Cb of the front edge portion 20C and extend diagonally from the boundary portion K to the radial inner side with respect to the axis O and to a side of the second end portion 2b to be continuous with the remaining portion 20Cb. By providing this protruding edge portion 22, for example, even when the whole of the front edge portion 20 cannot be disposed on a side of the first end portion 2a in the axis O direction as in the first embodiment, the front edge portion 20C can be formed to extend from the boundary portion K toward the radial inner side with respect to the axis O.

[0068] The present invention is not limited to the above-described embodiments, and includes various modifications added to the above-described embodiments without departing from the spirit and scope of the present invention. That is, the specific shapes and configurations and the like exemplified in the embodiments are merely examples, and can be appropriately changed.

[0069] In the above-described embodiments, a centrifugal compressor has been described as an example, but the present invention is not limited to a compressor, and can be applied to rotary machines such as a turbine.

[0070] An example in which six impellers 3A are provided in series to the rotating shaft 2 of the centrifugal compressor 1 has been shown in the embodiment described above. However, in the centrifugal compressor 1, at least one impeller 3A may be provided to the rotating shaft 2. Similarly, in a case of having the impellers 3B and 3C, only one of the impellers 3B and 3C may be provided.

[0071] Further, in each of the above-described embodiments, the case in which the impellers 3A, 3B, and 3C are formed by a cutting process has been described, but they may be formed by electro-discharge machining. Also in the case of the electro-discharge machining, when the present invention is applied, a shape of the discharge electrode thereof need not be formed complicatedly and an increase in costs can be prevented.

[Industrial Applicability]

[0072] The present invention can be applied to an impeller. According to the present invention, processing can be easily performed.

[Reference Signs List]

[0073]

1 Centrifugal compressor
2 Rotating shaft
2a First end portion
2b Second end portion
3A, 3B, 3C Impeller
3a Disc
3b Blade
3c, 103c Cover
3G Multistage impeller group
5A Journal bearing
5B Thrust bearing
6 Casing
6a Intake port
6b Connection flow path
6c Casing flow path
6d Connection flow path
6e Discharge port
6f Outer circumferential surface
6g Inner circumferential surface
7 Sealing device
11 Inner circumferential surface
11a End portion
11b End portion
12 Outer circumferential surface
12a End portion
12b End portion
13 Distal end surface
14 Rear end surface
20 Front edge portion
21 Rear edge portion
22 Protruding edge portion
E Extension line
T Cutting tool

Claims

1. An impeller comprising:

    a disc having a disc shape about an axis;
    a plurality of blades formed on a surface facing a first side in an axial direction of the disc at intervals in a circumferential direction around the axis; and
    a cover surrounding the plurality of blades from the first side in the axial direction, wherein
    the cover includes:

        an inner circumferential surface connected to the blades with a diameter decreasing from the second side toward a first side in the axial direction; and
        a distal end surface extending from an end portion of the inner circumferential surface on the first side in the axial direction toward the outside in a radial direction and facing the first side in the axial direction, and

    a front edge portion, which is an edge portion of the blade on the first side in the axial direction, extends from a boundary between the inner circumferential surface and the distal end surface toward the inside in the radial direction.

2. The impeller according to claim 1, wherein the distal end surface has a convex curved surface disposed on the second side in the axial direction toward the inside in the radial direction.

3. The impeller according to claim 1 or 2, wherein the front edge portion has a protruding edge portion protruding toward the first side in the axial direction on a radial outer side thereof.

4. A rotary machine comprising an impeller according to any one of claims 1 to 3.

5. A method of manufacturing an impeller including:

    a disc having a disc shape about an axis;
    a plurality of blades formed on a surface facing a first side in an axial direction of the disc at intervals in a circumferential direction around the axis; and
    a cover surrounding the plurality of blades from the first side in the axial direction, wherein
    the cover has:

        an inner circumferential surface connected to the blade with a diameter decreasing from the second side toward the first side in the axial direction; and
        a distal end surface extending from an end portion of the inner circumferential surface on the first side in the axial direction toward the outside in a radial direction and facing the first side in the axial direction, and

    the method of manufacturing an impeller comprising:

a process of forming a front edge portion, which is an edge portion of the blade on the first side in the axial direction, to extend from a boundary between the inner circumferential surface and the distal end surface toward the inside in the radial direction.

FIG. 1

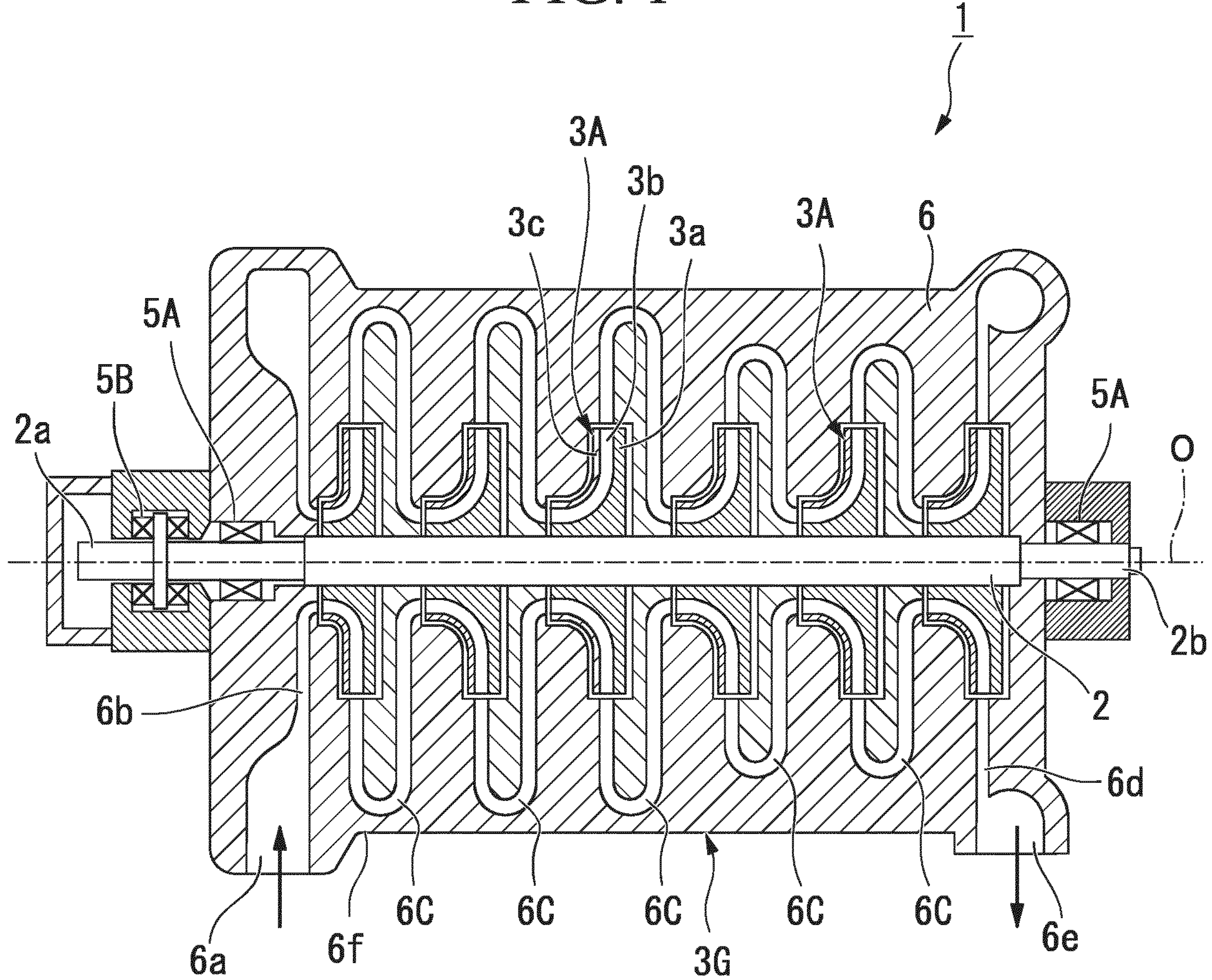


FIG. 2

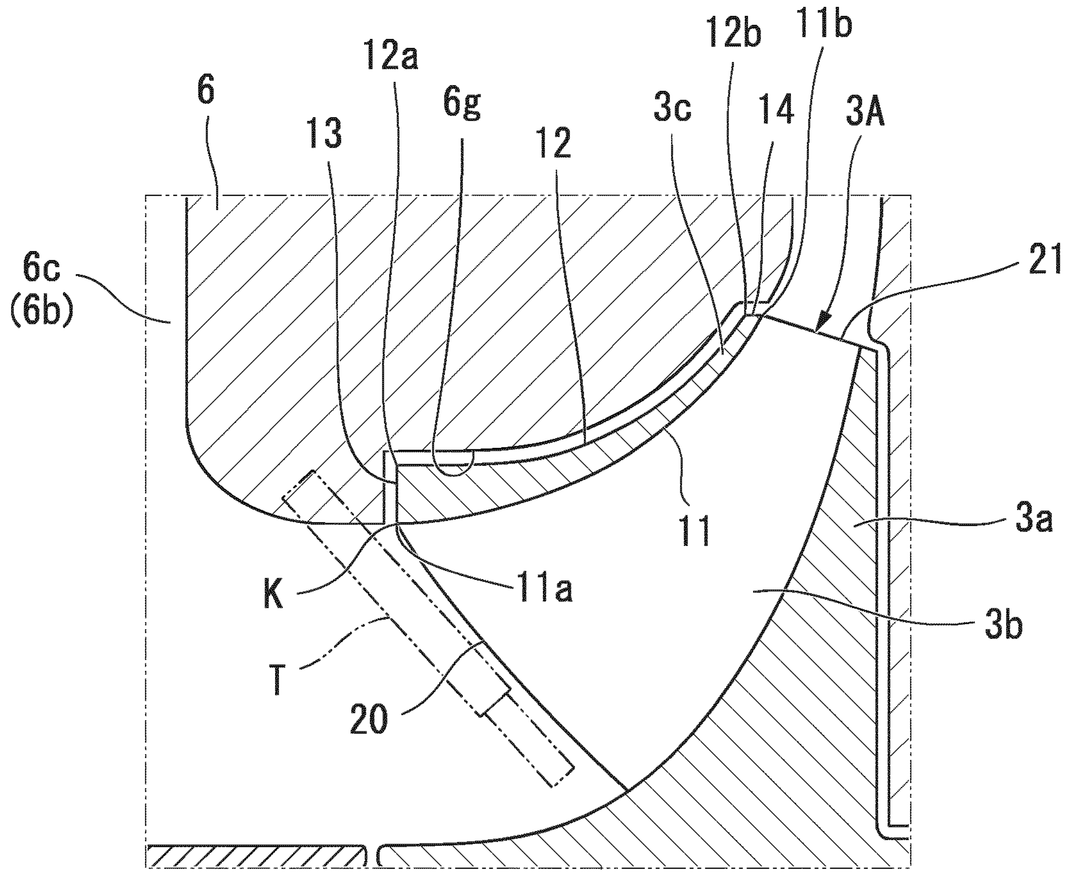


FIG. 3

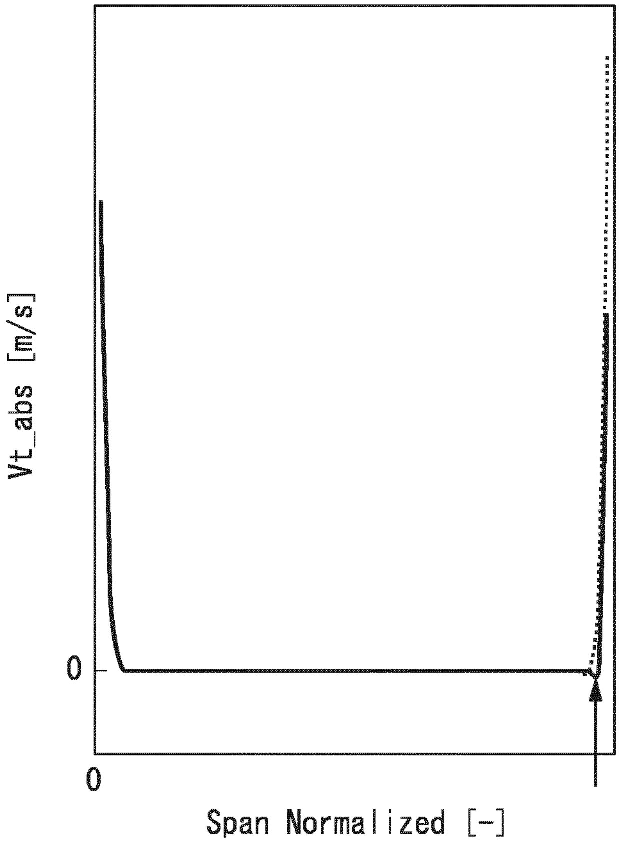

Vt_abs [m/s]
0
0
Span Normalized [-]

FIG. 4

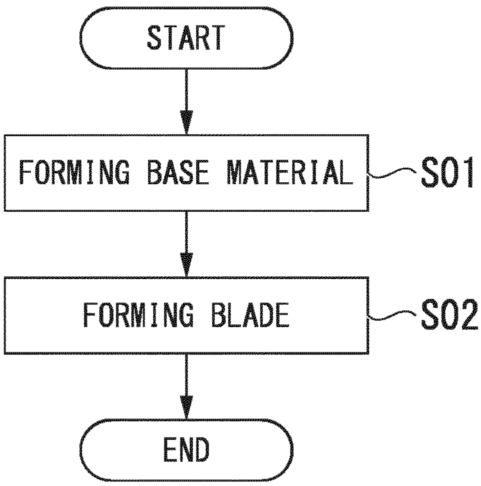

START
FORMING BASE MATERIAL
S01
FORMING BLADE
S02
END

FIG. 5

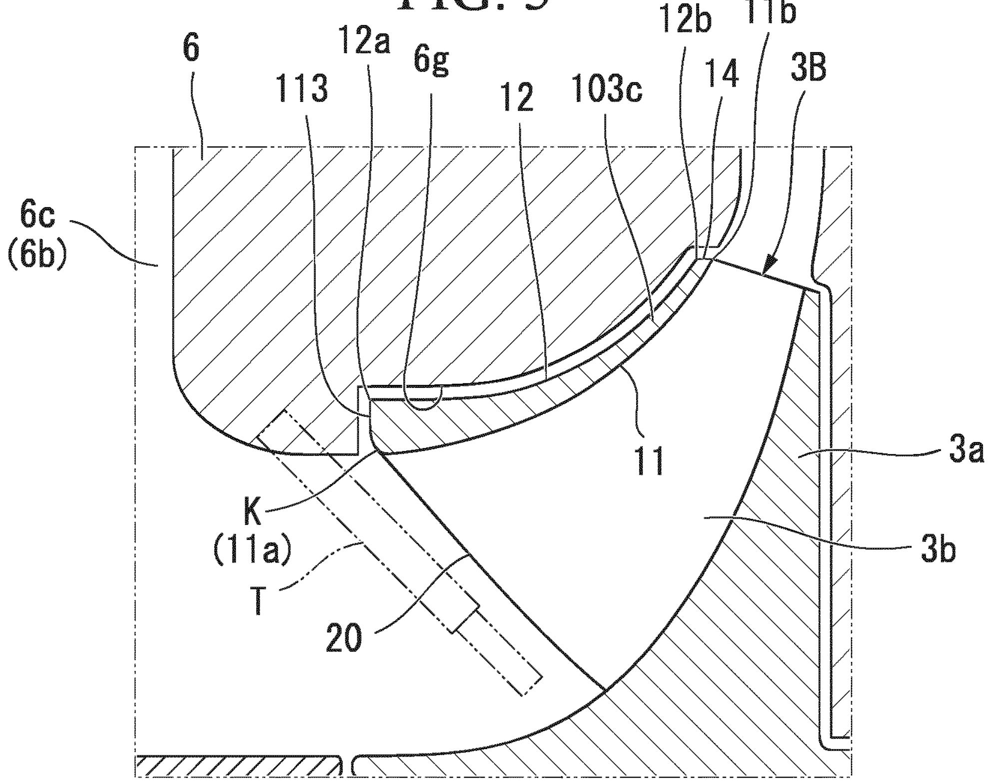
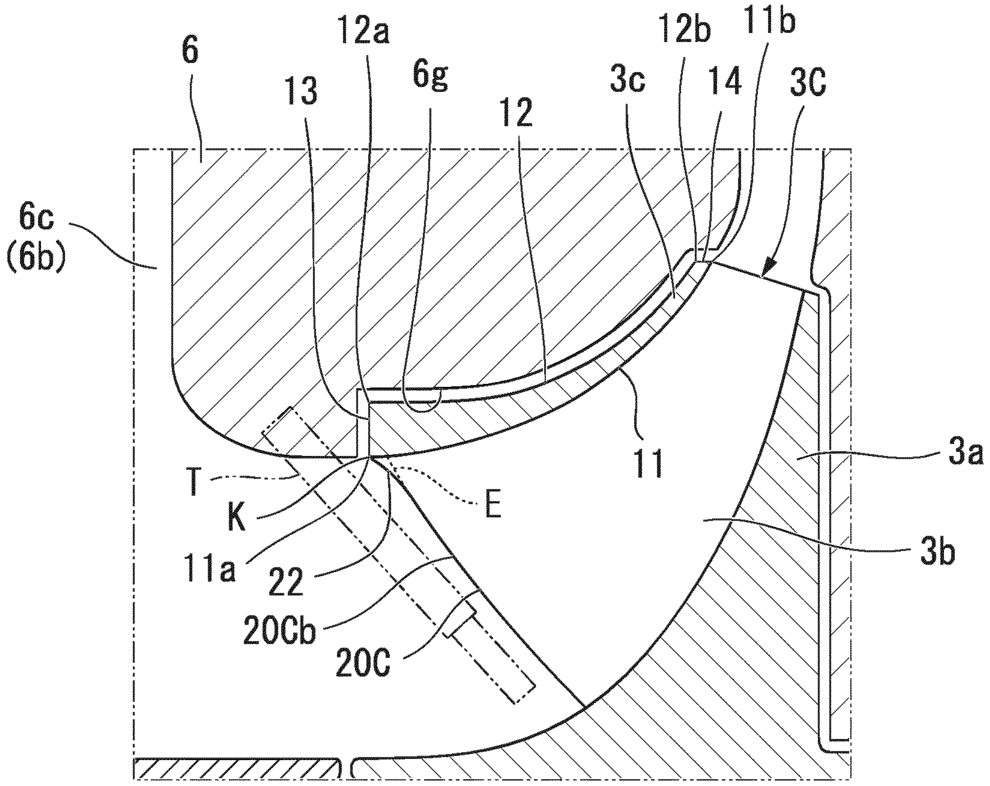

6
12a
6g
113
12
103c
12b
11b
14
3B
6c
(6b)
11
3a
K
(11a)
3b
T
20

FIG. 6


6
12a
6g
13
12
3c
12b
11b
14
3C
6c
(6b)
11
3a
T
K
E
3b
11a
22
20Cb
20C

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2017/010391

A. CLASSIFICATION OF SUBJECT MATTER
F04D29/24(2006.01)i, *F04D29/30*(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)
F04D29/24, F04D29/30

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	1996-2017
Kokai Jitsuyo Shinan Koho	1971-2017	Toroku Jitsuyo Shinan Koho	1994-2017

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.
X A	GB 690951 A (CARRIER ENGINEERING CO., LTD.), 29 April 1953 (29.04.1953), page 2, right column, lines 100 to 111; fig. 1 to 3 (Family: none)	1-2,4-5 3
X A	JP 2-19696 A (Matsushita Electric Industrial Co., Ltd.), 23 January 1990 (23.01.1990), page 1, lower right column, lines 8 to 10; page 2, lower right column, lines 10 to 16; fig. 1 to 2 (Family: none)	1,3-5 2

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

* Special categories of cited documents:
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"E" earlier application or patent but published on or after the international filing date
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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
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"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
24 April 2017 (24.04.17)	16 May 2017 (16.05.17)

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3,Kasumigaseki,Chiyoda-ku, Tokyo 100-8915,Japan	Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 2016056045 A **[0002]**
- JP 2015175250 A **[0007]**