(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 078 866 A1

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
15.07.2009 Bulletin 2009/29

(21) Application number: **07708290.7**

(22) Date of filing: **09.02.2007**

(51) Int Cl.:
F04D 29/46 *(2006.01)*

(86) International application number:
PCT/JP2007/052354

(87) International publication number:
WO 2008/053605 (08.05.2008 Gazette 2008/19)

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU LV MC NL PL PT RO SE SI SK TR

(30) Priority: **30.10.2006 JP 2006294408**

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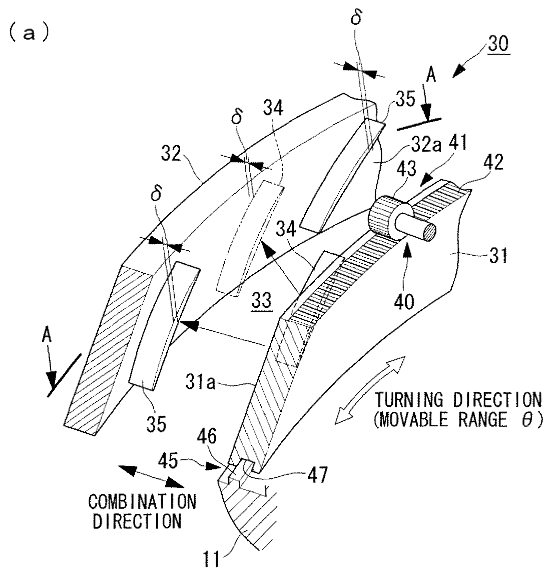
(54) **VARIABLE DIFFUSER AND COMPRESSOR**

(57) There is provided a variable diffuser for a compressor in which the efficiency can be further improved. In a variable diffuser 30 in which a diffuser passage 33, which restores a static pressure from a dynamic pressure by decelerating an air flow that is discharged from an outer peripheral end of an impeller that rotates within a housing, is formed between a hub side wall 32a and a shroud side wall 31a, and diffuser vanes are provided in the diffuser passage 33, fixed vanes 35 and movable vanes 34 that are the diffuser vanes, are alternately fixed in the circumferential direction to a fixed circular plate 32 and a movable circular plate 31 that form the hub side wall 32a and the shroud side wall 31a, and there is provided a driving device 40 that turns the movable circular plate 31 about the same axis as the rotation of the impeller.

FIG. 1



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Description

Technical Field

[0001] The present invention relates to a variable diffuser applied to, for example, centrifugal compressors and mixed flow compressors, and a compressor furnished with this variable diffuser.

Background Art

[0002] Heretofore, centrifugal compressors, such as turbochargers utilized in internal combustion engines for automobiles, are known.
FIG. 17 is a cross-sectional view showing the main parts of a conventional centrifugal compressor. The centrifugal compressor 10 shown in the drawing compresses fluids, such as gas and air introduced from the exterior of a housing 11, by means of the rotation of an impeller 13, which is provided with a plurality of vanes 12, within the housing 11. The flow of the fluid (air flow), which is formed in this manner, is delivered to the exterior through an impeller exit (hereunder also referred to as the "diffuser entrance") 14 that becomes the outer peripheral end of the impeller 13, a diffuser 15, and a scroll (omitted from the drawing). Reference symbol 16 in the figure is a shaft axis about which the impeller 13 rotates.
[0003] The diffuser 15 mentioned above is an air flow passage provided between the impeller exit 14 and the scroll, and has a function of restoring static pressure from dynamic pressure by decelerating the air flow that is discharged from the impeller exit 14. This diffuser 15 is normally formed by a pair of opposing walls, and in the explanation below, one wall amongst the opposing pair is referred to as a shroud side wall 17, and the other is referred to as a hub side wall 18.
Furthermore, examples of the diffuser 15 mentioned above include a vaned diffuser furnished with a diffuser vane (hereunder referred to as a "vane") 19 such as is shown in FIG. 18, and a vaneless diffuser that does not have a vane 19.
[0004] A common centrifugal compressor that is furnished with a vaned diffuser employs a fixed vane diffuser in which the vane 19 is immovable. However, in a case where a flow rate range enlargement of the centrifugal compressor is necessary, a variable diffuser, in which the vane leading edge angle βk shown in FIG. 20 (hereunder referred to as "vane angle βk") can be varied by making the vane 19 movable, is employed.
A general construction of the variable diffuser is, for example, as shown in FIG. 18, one that varies the vane angle βk by providing a pivot shaft 20 to the vane 19, and supporting the vane 19 on the shroud side wall 17 and the hub side wall 18, as well as rotating the vane 19 about this pivot shaft 20.
[0005] In regard to such a variable diffuser, a drive unit in which the angle of a plurality of diffuser vanes is variable by a simple construction has been proposed. This drive unit is furnished with a large gear that rotates by means of an actuator, and the like, and a plurality of gears that engage the large gear, and the angle is varied by turning the diffuser vanes that are connected to the gears. (For example, refer to Patent Document 1)
Furthermore, in regard to a centrifugal compressor that is furnished with a vaned diffuser, provision of a second stationary vane that is freely rotatable with an object of expanding the operation on the small flow rate side has been proposed. (For example, refer to Patent Documents 2 and 3)

Patent Document 1: Japanese Unexamined Patent Application, Publication No. Hei 7-310697
Patent Document 2: Publication of Japanese Patent No. 2865834
Patent Document 3: Publication of Japanese Patent No. 3513729

Disclosure of Invention

[0006] Incidentally, in regard to the vane 19 of the variable diffuser, in a case where the vane shape of the vane is designed, it is given a shape such that the flow rate is in the middle of a desired flow rate variation range. Accordingly, in conventional variable diffusers in which the vane 19 is turned about the pivot shaft 20 and the vane angle βk is variable, variations in the characteristics occur as shown in FIG. 19. That is to say, the flow rate range, which is prescribed by the surge flow rate Qs and the choke flow rate Qc, for example as shown in FIG. 20, becomes wider by the amount of the fluctuations of each corresponding surge flow rate Qs and choke flow rate Qc as a result of turning the vane 19 within the range of a turning range θ from the maximum vane angle βmax to the minimum vane angle βmin.
[0007] However, in a case where the flow rate range (the range between which flow rate variations are possible) mentioned above is widely set, as shown in FIG. 21, the flow angle β and the vane angle βk of the vane 19 take variations of respectively different inclinations. Consequently, since the incidence (In) in the small flow rate region and the large flow rate region becomes large, there is a problem in that the efficiency decreases due to an increase in losses. The incidence is a value that is defined by the difference between the vane leading edge angle βk and the flow angle β.
Furthermore, in regard to the turning type variable diffuser construction, a space δ (refer to FIG. 18) is provided between both side ends of the vane 19 and the shroud side wall 17 and the hub side wall 18 in order to make smooth turning of the vane 19 possible. Consequently, leaks occur in the air flow that flows through the space δ, and a problem in that the efficiency decreases over all flow rate ranges has been pointed out.
[0008] In this manner, since conventional variable diffusers have a problem in the efficiency decreasing due to increases in the incidence and leaks from the space

δ, it is desired for these problems to be solved and to further improve the efficiency.

The present invention has been achieved taking the above circumstances into account, with an object thereof in providing a variable diffuser in which the efficiency can be further improved, and a compressor furnished with this variable diffuser.

[0009] The present invention employed the following means in order to solve the problems mentioned above.

The variable diffuser according to the present invention is one which in a variable diffuser in which a diffuser passage, which restores a static pressure from a dynamic pressure by decelerating an air flow that is discharged from an outer peripheral end of an impeller that rotates within a housing, is formed between a hub side wall and a shroud side wall, and diffuser vanes are provided in the diffuser passage, is **characterized in that** said diffuser vanes are alternately fixed in the circumferential direction to a wall member that forms the hub side wall and the shroud side wall, and there is provided a driving device that turns either one of the wall members about the same axis as the rotation of the impeller.

[0010] According to such a variable diffuser, since the diffuser vanes are alternately fixed in the circumferential direction to the wall member that forms the hub side wall and the shroud side wall, and there is provided the driving device that turns either one of the wall members about the same axis as the rotation of the impeller, then by turning the wall member of the movable side, the throat area can be varied without changing the vane leading edge angle. Furthermore, the space 5 formed between the diffuser vane and the hub side wall and the shroud side wall decreases since it becomes either one of the faces.

In this case, it is preferable for a movable range of the wall member which turns as a result of the driving device, to be set such that it encompasses the entire width of an interval between adjacent diffuser vanes that are fixed on the wall member of the fixed side.

[0011] In the above aspect of the invention, it is preferable for a leading edge radius (R1) of a diffuser vane provided on a turning side of the wall member to be set larger than a leading edge radius (R2) of a diffuser vane provided on a fixed side of the wall member (R1 > R2). As a result, increases in the leading edge thickness of overlapping vanes can be prevented.

[0012] In the above aspect of the invention, it is preferable for a vane leading edge angle (αk1) of a diffuser vane provided on a turning side of the wall member to be set smaller than a leading edge angle (αk2) of a diffuser vane provided on a fixed side of the wall member at the same radial position ($\alpha k1 < \alpha k2$). As a result, the average vane leading edge angle in a state where two vanes are overlapped can be decreased.

[0013] In the above aspect of the invention, it is preferable for a vane leading edge angle (αk1) of a diffuser vane provided on a turning side of the wall member to be set larger than a leading edge angle (αk2) of a diffuser vane provided on a fixed side of the wall member at the same radial position ($\alpha k1 > \alpha k2$). As a result, the average vane leading edge angle in a state where two vanes are overlapped can be increased.

[0014] In the above aspect of the invention, it is preferable for a diffuser vane provided on a fixed side of the wall member to be a low chord-pitch ratio vane. As a result, the characteristics at the time of a small flow rate can be improved while retaining the characteristics of the low chord-pitch ratio.

In this case, it is preferable for a trailing edge radius (R3) of a diffuser vane provided on a turning side of the wall member to be set larger than a trailing edge radius (R4) of a diffuser vane provided on a fixed side of the wall member (R3 > R4). As a result, wide ranging of the flow rate range, and the high pressure ratio can be simultaneously achieved.

[0015] In the above aspect of the invention, the setting of the fixed side and the turning side may be reversed.

That is to say, the entrance radius (R2) of the diffuser vane provided on the fixed side of the wall member may be set larger than the entrance radius (R1) of the diffuser vane provided on the turning side of the wall member (R2 > R1).

Furthermore, the vane leading edge angle (αk2) of the diffuser vane provided on the fixed side of the wall member may be set smaller than the leading edge angle (αk1) of the diffuser vane provided on the turning side of the wall member at the same radial position ($\alpha k2 < \alpha k1$).

Furthermore, the diffuser vane provided on the turning side of the wall member may be made a low chord-pitch ratio vane.

Furthermore, the trailing edge radius (R4) of the diffuser vane provided on the fixed side of the wall member may be set larger than the trailing edge radius (R3) of the diffuser vane provided on the turning side of the wall member (R4 > R3).

[0016] In the above aspect of the invention, it is preferable for the driving device to be furnished with a sliding mechanism section that moves a turning side of the wall member back and forth between a space formation position and a space reduction position with respect to a fixed side of the wall member. As a result, the space δ can be minimized and the efficiency can be improved.

[0017] The compressor according to the present invention comprises a variable diffuser according to any of claim 1 to claim 9 on the peripheral end of the impeller that rotates within the housing.

[0018] According to such a compressor, increases in the incidence, and efficiency decreases resulting from leaks from the space δ are resolved, and it becomes a compressor furnished with a variable diffuser that can further improve efficiency.

[0019] According to the present invention mentioned above, since the throat area can be varied without changing the leading edge angle of the movable side, efficiency decreases resulting from increases in the incidence can be resolved, and accordingly, a variable diffuser with further improved efficiency and a compressor furnished with this variable diffuser can be provided.

Furthermore, since the space δ formed between the diffuser vane and the hub side wall and the shroud side wall becomes only one of the faces and decreases, it becomes possible to resolve efficiency decreases resulting from leaks from the space δ.

Brief Description of Drawings

[0020]

FIG. 1 is a drawing showing a first embodiment according to a variable diffuser of the present invention, in which (a) is an enlarged perspective view of the main parts, and (b) is a cross-sectional view along A-A in (a).

FIG. 2 is a drawing showing the movement of the variable diffuser shown in FIG. 1, in which (a) shows a case where A11 = A12 is set, (b) shows a state in which a movable vane is in contact with the pressure face of a fixed vane, and (c) shows a case where it is set in the middle of (a) and (b).

FIG. 3 is a drawing showing the movement of a variable diffuser according to a second embodiment of the present invention, in which (a) shows a case where the movable vane leading edge radius has been made large compared to the fixed vane, (b) shows a case where the leading edge of the movable vane is turned upstream of the intersection point X, and (c) shows a case where the leading edge of the movable vane is turned downstream of the intersection point X.

FIG. 4 is a drawing showing a variable diffuser according to a third embodiment of the present invention.

Fig. 5 is a drawing showing the characteristics of the variable diffuser shown in FIG. 4.

FIG. 6 is a drawing showing a variable diffuser according to a fourth embodiment of the present invention.

FIG. 7 is a drawing showing the characteristics of the variable diffuser shown in FIG. 6.

FIG. 8 is a drawing showing a variable diffuser according to a fifth embodiment of the present invention.

FIG. 9 is a drawing showing a modified example of the variable diffuser according to the fifth embodiment shown in FIG. 8.

FIG. 10 is a drawing showing the relationship between the pressure recovery factor and the number of vanes in regard to a vaned diffuser and a low chord-pitch ratio diffuser.

FIG. 11 is a perspective view of the main parts showing a variable diffuser according to a sixth embodiment of the present invention.

FIG. 12 is an explanatory drawing of the sliding mechanism section shown in FIG. 11, in which (a) is a drawing showing the movement of a sliding face with respect to a guiding face, and (b) is a drawing showing a space δ, which varies together with the turning of a movable circular plate.

FIG. 13 is a drawing showing the state of the movable circular plate and the movable vanes, which move by means of the sliding mechanism section shown in FIG. 11.

FIG. 14 is a cross-sectional view showing a configuration example in which a sliding face is provided to a wall that becomes the vane interval between the movable vanes and the fixed vanes.

FIG. 15 is a drawing showing a first modified example of the sliding mechanism section shown in FIG. 11.

FIG. 16 is a drawing showing a second modified example of the sliding mechanism section shown in FIG. 11.

FIG. 17 is a cross-sectional view showing the main parts of a conventional centrifugal compressor.

FIG. 18 is a perspective view showing the main parts of a conventional example of a variable diffuser.

FIG. 19 is a drawing showing the characteristics of the variable diffuser shown in FIG. 18.

FIG. 20 is an explanatory drawing showing the movement of the variable diffuser shown in FIG. 19.

FIG. 21 is a drawing showing the relationship between incidence (In), and flow angle (β) and vane angle (βk).

Explanation of Reference Signs:

[0021]

30: Variable diffuser
31: Movable circular plate
31a: Shroud side wall
32: Fixed circular plate
32a: Hub side wall
33: Diffuser passage
34, 34A-E: Movable diffuser vane (movable vane)
35: Fixed diffuser vane (fixed vane)
40, 40A: Driving device
41: Gear driving section
42: Rack gear section
43: Pinion gear
45, 45A: Sliding mechanism section
46: Guide rail
47: Concave groove section
48: Guiding groove
48a: Guiding face
49: Convex section
49a: Sliding face

Best Mode for Carrying Out the Invention

[0022] Hereunder, an embodiment of a variable diffuser and a compressor according to the present invention is described with reference to the drawings.

<First Embodiment>

[0023] The variable diffuser 30 shown in FIG. 1, for example, restores a static pressure from a dynamic pressure by decelerating the air flow that is discharged from the peripheral end of an impeller that rotates within the housing of a centrifugal compressor, a mixed flow compressor, or the like. In regard to this variable diffuser 30, as well as a diffuser passage 33 being formed between the opposing shroud side wall 31a and hub side wall 32a, movable diffuser vanes (hereunder called the "movable vanes") 34 and fixed diffuser vanes (hereunder called the "fixed vanes") 35 are provided within the diffuser passage 33.

Here, the vanes are made movable by providing the shroud side wall 31a with the movable vanes 34, although they may be made movable by providing the hub side wall 32a with the movable vanes 34.

[0024] Specifically describing the configuration of the movable diffuser 30, the movable vanes 34 are fixed on a movable circular plate (wall member) that forms the shroud side wall 31a, and the fixed vanes 35 are fixed on a fixed circular plate (wall member) 32 that forms the hub side wall 32a. The movable vanes 34 and the fixed vanes 35 are made the same vane shape, and with respect to the shroud side wall 31a and the hub side wall 32a, a plurality (vane number N) of the same respective number is positioned in the circumferential direction at a predetermined pitch.

FIG. 1 (a) shows a state where the movable circular plate 31 and the fixed circular plate 32, which is an opposing pair, have been separated. From this state, the movable circular plate 31 and the fixed circular plate 32 slide in the combination direction shown by the arrow in the drawing and are integrated, such that the movable vanes 34 of the shroud side wall 31a and the fixed vanes 35 of the hub side wall 32a become alternately positioned in a predetermined reference position in the circumferential direction at the same pitch. That is to say, in an assembled state in which the movable circular plate 31 and the fixed circular plate 32 have been integrated, the movable vanes 31 and the fixed vanes 32 are alternately arranged in a reference position in the circumferential direction at the same pitch. The cross-sectional view of FIG. 1 (b) shows the A-A cross-section of FIG. 1 regarding a diffuser passage 33 that is formed by integrating the movable circular plate 31 and the fixed circular plate 32.

[0025] A driving device 40 for turning the movable circular plate 31 through a predetermined turning range θ in the turning direction of the same axis as the rotation of the impeller (shown by the white arrows in the drawing), is provided on the movable circular plate 31 side. This driving device 40 is, for example, configured by a gear driving section 41 that is provided on the upper end section of the movable circular plate 31, and a sliding mechanism section 45 that is provided on the lower end section. The turning range θ in this case is, compared to the pitch at which the movable vanes 31 and the fixed vanes 32 are alternately arranged in the circumferential direction in the predetermined reference position mentioned above, essentially approximately doubled although a difference corresponding to the thickness of the vanes is generated. In other words, the movable range θ becomes the entire width between adjacent fixed vanes 35.

[0026] The gear driving section 41 is a configuration in which a rack gear section 42 and a pinion gear 43 formed on the upper end face of the movable circular plate 31 are intermeshed. The pinion gear 43 is connected to a drive source such as an electric motor (not shown in the drawing), and is turnable as necessary in the desired direction.

The sliding mechanism section 45 is a portion in which the movable circular plate 31 is connected with respect to the housing 11 such that it is slidable in the circumferential direction. In the example shown in the drawing, a convex-shaped guide rail 46 formed on the housing 11 and a concave groove section 47 formed on the lower end face of the movable circular plate 31 are engaged, and the movable circular plate 31 is configured such that it slides along the guide rail 46. In regard to such a sliding mechanism section 45, a leakage stopping measure (not shown in the drawing) is provided between the guide rail 46 and the concave groove section 47 in order to prevent leaking of the high pressure air flow, in which a static pressure has been restored at the exit of the diffuser passage 33, from the back face of the movable circular plate 31 to the entrance side of the diffuser passage 33.

[0027] As a result, the movable circular plate 31 is guided by the sliding mechanism section 45 and turned in the same axis as the rotation axis of the impeller gear driving section 41 as a result of the turning of the pinion gear 43, and therefore, it relatively moves with respect to an immobile fixed circular plate 32. Then the movable vanes 34 which are integral with the movable circular plate 31, are moved from the reference position in both circumferential directions within the range of the movable range θ. That is to say, the movable vanes 34 rotate towards the fixed vanes 35 on both adjacent sides by turning from the reference position where they are arranged at the same pitch, and as shown by the imaginary line in FIG. 1 (b), they become turnable within the movable range θ without changing the angle of the vanes, from a position in which the pressure faces of the movable vanes 34 make contact with the negative pressure face of the adjacent fixed vane 35, to a position in which the negative pressure faces of the movable vanes 34 make contact such that they overlap with the pressure face of the adjacent fixed vane 35.

[0028] The movable range θ of the movable vanes 34 is more specifically described based on FIG. 2.

FIG. 2 (a) shows a case where the movable vanes 34 are in the reference position. In this state, in regard to the movable vanes 34 and the fixed vanes 35 which have the same vane shape, the respective same number (N) are arranged in the circumferential direction at the same pitch. In this state, the throats A11 and A12 which are formed between the movable vane 34 and the fixed vanes 35 that are adjacent on both sides, become equal. Consequently, the throat area of the variable diffuser 30 becomes a value in which the number N of movable vanes 34 has been multiplied to the total value (A11 + A12) of the throats formed on both sides of the movable vanes 34.

[0029] FIG. 2 (b) shows a state where the movable vanes 34 are making contact with the pressure face of the fixed vanes 35. In this case, since the vanes are making contact with each other at some point, as well as the throat A12 becoming approximately zero, the throat A11 becomes a maximum (A11max). Then, such a maximum throat becomes larger than the total value of the throats at the reference position mentioned above (A11max > A11 + A12), and the area of the throats increases by approximately 1.2 to 1.3 times. In the explanation below, the state in which the throat area becomes a maximum is referred to as the throat maximum position.

In a case where the movable vanes 34 have turned in the opposite direction from the reference position, since there is no change in that both vanes are making contact at some point, it becomes the same result.

[0030] Fig. 2 (c) shows a case where the movable vanes 34 are in an intermediate position between FIG. 2 (a) and FIG. 2 (b). The throat area in this case is an approximately intermediate value between the reference position and the throat maximum position. Accordingly, by turning the movable vanes 34 in a range within the movable range θ, the throat area can be appropriately varied in a range between approximately 1.2 to 1.3 times the reference value.

[0031] In regard to the configuration of the variable diffuser 30 mentioned above, the number of diffuser vanes, which consists of the number of movable vanes 34 and fixed vanes 35, essentially changes such that it doubles from N vanes to 2N vanes. That is to say, in a case where N movable vanes 34 are installed to the movable circular plate 31, and N fixed vanes 35 are installed to the fixed circular plate 32, 2N diffuser vanes are present in a state where the movable vanes 34 and the fixed vanes 35 are mutually separated. However, in a state where the adjacent movable vanes 34 and fixed vanes 35 are mutually making contact, the air flow essentially flows between N diffuser vanes.

As a result, by varying the throat area, the flow rate of the compressor characteristic is varied. That is to say, since the throat area increases by approximately 1.2 to 1.3 times, it is possible to widen the flow rate range by varying the choke flow rate Qc shown in FIG. 19 by 20 to 30%.

[0032] Furthermore, since the fixed vanes 35 and also the vane leading edge angle (vane angle) β of the movable vanes 34 are normally fixed, compared to a conventional variable diffuser in which the vane angle β varies as a result of the turning of the vane 19, as shown by the two-dot chain line in FIG. 21, the change in the incidence is very small. Accordingly, since a compressor that is furnished with this variable diffuser 30 can reduce the increasing losses when the incidence becomes large, the efficiency can be improved over conventional technology.

Furthermore, since one end of the movable vanes 34 and the fixed vanes 35 are fixed to a wall that forms the diffuser passage 33, a space δ is consequently formed only in one of the vane width directions. Accordingly, compared to the conventional structure in which the vane 19 is turned, since the area of the space δ can be reduced by half, the losses resulting from leakage of the air flow are reduced by half, and the efficiency can be improved.

<Second Embodiment>

[0033] Next, a second embodiment of the present invention is described based on FIG. 3.

In regard to the movable vanes 34A of this embodiment, the entrance radius R1 is set larger than the entrance radius R2 of the fixed vanes 35. That is to say, the entrance radius R1 of the movable vanes 34A is, in a case where the movable vanes 34A are in an intermediate position between the adjacent fixed vanes 35, set such that the leading edges of the movable vanes 34A are on the upstream side with respect to the throat A2 formed between the adjacent fixed vanes 35. In the example shown in the drawing, the throat area varies only within a range in which the leading edges of the movable vanes 34A are upstream with respect to the intersection point X between the throat A2 and the radius R1.

[0034] Hereunder, this is specifically described based on the drawings.

As shown in FIG. 3 (a), in a case where the movable vanes 34A are positioned approximately in the center of the fixed vanes 35, the throat area becomes a minimum.

As shown in FIG. 3 (b), in a case where the movable vanes 34A are positioned upstream of the throat A2, the total value of the throat A11 and the throat A12 (A11 + A12) gradually increases.

As shown in FIG. 3 (c), when the leading edge of the movable vanes 34A is positioned downstream of the throat A2, the throat area becomes a value in which the number of vanes N has been multiplied to the throat A2, and the throat reaches a maximum A2, and it does not increase even if the movable vanes 34A are rotated.

[0035] Incidentally, in the state of FIG. 2 (b) mentioned above, the vane ends of the movable vanes 34 and the fixed vanes 35 mutually overlap with a limited space, and it becomes a state where the vane thickness of the diffuser vane leading edges has become thick. Such an increase in the vane thickness not only becomes a problem that increases the throat area to the maximum, but it also increases damage to the vane leading edges.

However, in the state shown in FIG. 3 (c), the leading edges of the movable vanes 34A are positioned downstream of the leading edges of the fixed vanes 35. Accordingly, compared to the state shown in FIG. 2 (b), the sizes of the throat becomes A2 > A11max. In this manner, if the entrance radius R1 is set larger than the entrance

radius R2 (R1 > R2), in regard to the movable range of the throat area, the maximum value becomes larger.
Furthermore, in the state shown in FIG. 3 (c), the vane leading edges are essentially reduced by half to the number of fixed vanes 35, and damage to the vane leading edges decreases.

<Third Embodiment>

[0036] Next, a third embodiment of the present invention is described based on FIG. 4 and FIG. 5.
In regard to the movable vanes 34B of the present embodiment, in the same radial position, the vane leading edge angle (vane angle) $\alpha k1$ is set smaller than the vane angle $\alpha k2$ of the fixed vanes 35, and the movable vanes 34B are driven from the middle between the fixed vanes 35 towards the negative pressure faces of the fixed vanes 35.
If made such a configuration, although the maximum value of the throat A12 becomes small compared to the throat A2, in a state where two vanes have been made to overlap, the average vane angle αk can be decreased.
[0037] As a result, in regard to the characteristics of the compressor, as shown in FIG. 5, the flow angle α at the maximum angle becomes smaller, and from the comparison between the solid line representation and the broken line representation, it can be understood that the performance when the flow rate is low has been improved. Furthermore, also at an intermediate angle, from the comparison between the solid line representation and the broken line representation, it can be understood that the performance at the time of a small flow rate when the flow angle α is small has been improved, though not as much as at the time of a maximum angle.
That is to say, the setting of the vane angle αk such that $\alpha k1 < \alpha k2$ places an importance on the performance at the time of a small flow rate when the flow angle α is small, and at the time of the maximum angle and the time of an intermediate angle, a performance improvement that improves the pressure ratio in the low flow rate regions can be obtained.

<Fourth Embodiment>

[0038] Next, a fourth embodiment of the present invention is described based on FIG. 6 and FIG. 7.
In regard to the movable vanes 34C of this embodiment, the vane leading edge angle (vane angle) $\alpha k1$ is set larger than the vane angle $\alpha k2$ of the fixed vanes 35 at the same radial position, and the movable vanes 34C are driven from the middle of the fixed vanes 35 towards the pressure face of the fixed vanes 35.
If made such a configuration, in the same manner to the second embodiment mentioned above, in regard to the throat, A2 becomes a maximum value. On the other hand, in regard to the choke flow rate Qc, since the flow angle α of the diffuser entrance flows approximately perpendicular to the throat A2, it also becomes an even larger angle with respect to the pressure face angle of the fixed vanes 35. Consequently, the negative incidence becomes large, the losses are large, and it essentially becomes a cause of the reduction of the choke flow rate.
[0039] However, in this embodiment, in a state where the movable vanes 34C and the fixed vanes 35 are making contact, and two vanes have come together, the average vane angle αk can be increased.
As a result, in regard to the characteristics of the compressor, as shown in FIG. 7, at the time of a large flow rate at a maximum angle when the flow angle α is large, from the comparison between the solid line representation and the broken line representation, it can be understood that the performance has improved as a result of a rise in the pressure ratio. Furthermore, also at an intermediate angle, from the comparison between the solid line representation and the dotted line representation, it can be understood that the performance at the time of a large flow rate when the flow angle α is large has been improved, though not as much as at the time of the maximum angle.
That is to say, the setting of the vane angle αk such that $\alpha k1 > \alpha k2$ places an importance on the performance at the time of a large flow rate when the flow angle α is large, and at the time of the maximum angle and at the time of an intermediate angle, a performance improvement that improves the pressure ratio in the large flow rate regions can be obtained.

<Fifth Embodiment>

[0040] Next, a fifth embodiment of the present invention is described based on FIG. 8 to FIG. 10.
In regard to vaned diffusers, those in which the shortest distance between adjacent vanes is not formed in the perpendicular direction from the vane negative pressure face, or in other words, those in which a throat is not formed, are generally distinguished by being called a "low chord-pitch ratio diffuser". This low chord-pitch ratio diffuser has the following characteristics.
[0041] In regard to a vaneless diffuser, since the surge flow rate Qs is small and the choke flow rate Qc is large, it has a characteristic in that although the flow rate range is wide, the efficiency is low.
On the other hand, in regard to a vaned diffuser, since the surge flow rate Qs is large, and the choke flow rate Qc is only 10 to 20% larger than the surge flow rate Qs, it has a characteristic in that although the flow rate range is narrow, the efficiency is high.
In contrast, in regard to the low chord-pitch ratio diffuser, since a throat is not formed, the choke flow rate Qc becomes larger than in the vaned diffuser, and the surge flow rate Qs becomes larger than in the vaned diffuser. Accordingly, the low chord-pitch ratio diffuser has a characteristic in that the efficiency becomes higher than the vaneless diffuser. In regard to the low chord-pitch ratio diffuser, the movable vanes, in which a throat is not formed, are called "low chord-pitch ratio vanes".

[0042] FIG. 10 shows, as the characteristics of the diffuser, in regard to the vaned diffuser and the low chord-pitch ratio diffuser, the relationship between the pressure restoration factor and the number of vanes.

When the number of vanes is varied in a normal vaned diffuser, as shown by the solid line in the drawing, when the number of vanes becomes a small number of vanes from approximately 10 vanes, the pressure restoration factor quickly decreases, and the case of zero vanes as the limit corresponds to a vaneless diffuser.

On the other hand, in the low chord-pitch ratio diffuser, since vanes where the size of the vane itself is smaller than in a normal vaned diffuser are used, then as shown with by the chain line in the drawing, even if the number of vanes is made large, the pressure restoration factor does not become high to the level of the normal vaned diffuser.

[0043] Therefore, in the fifth embodiment, in a low chord-pitch ratio diffuser as shown in FIG. 8, provided with low chord-pitch ratio vanes with a sufficiently small number of fixed vanes 35 and in which a throat is not formed, an imaginary throat A2 is formed, and the second embodiment mentioned above is applied.

That is to say, in regard to the movable vanes 34D of this embodiment, the entrance radius R1 is set larger than the entrance radius R2 of the fixed vanes 35. Accordingly, in regard to the entrance radius R1 of the movable vanes 34D, in a case where the movable vanes 34D are in an intermediate position between the adjacent fixed vanes 35, the vane leading edge of the movable vane 34D is set such that it becomes on the upstream side with respect to the imaginary throat A2 formed between adjacent fixed vanes 35.

[0044] In such a configuration, it exhibits the same pressure restoration factor as N low chord-pitch ratio vanes in a case where the movable vanes 34D and the fixed vanes 35 are overlapped, and in a case where both vanes are installed with the same spacing, the pressure restoration factor becomes high since the number of vanes becomes 2N. Accordingly, if the configuration of the present embodiment is employed, the performance can be improved, while retaining the characteristics of the low chord-pitch ratio diffuser, by setting the movable vanes 34D and the fixed vanes 35 at the same spacing at the time of a small flow rate.

[0045] Next, a modified example of the present embodiment is shown in FIG. 9 and is described. In this modified example, the fixed vanes 35 are low chord-pitch ratio vanes in the same manner as the embodiment shown in FIG. 8, and furthermore, the trailing edge radius R3 of the movable vanes 34E is set larger than the trailing edge radius R4 of the fixed vanes 35.

In such a configuration, the following characteristics can be obtained. That is to say, as shown in FIG. 9 (a), in a case where the movable vanes 34E and the fixed vanes 35 are separated and the number of vanes becomes 2N, since the vane area of the movable vanes 34E becomes larger than the low chord-pitch ratio diffuser, the pressure restoration factor rises.

Furthermore, in a case where the movable vanes 34E are in the position shown in FIG. 9 (b), it exhibits wide-range characteristics in which a throat is not formed.

Then, in a case where the movable vanes 34E are in the position shown in FIG. 9 (c), a high pressure restoration factor is exhibited in the same manner as the normal vaned diffuser in which the number of vanes has been made N vanes.

[0046] Consequently, when the movable vanes 34E are farther on the pressure face side of the fixed vanes 35 than the actual throat, since the fixed vanes 35 function as low chord-pitch ratio vanes, while retaining the wide ranging in which the flow rate range defined by the choke flow rate Qc and the surge flow rate Qs is expanded, an effect in which the pressure buildup is increased by the movable vanes 34E is obtained. Accordingly, if the configuration of this embodiment is employed, since the characteristics can be improved, while retaining the characteristics of the low chord-pitch ratio diffuser, by setting the movable vanes 34E and the fixed vanes 35 at the same spacing at the time of a small flow rate, wide ranging (expansion of the flow rate range) and a high pressure ratio can be simultaneously achieved.

<Sixth Embodiment>

[0047] Next, a sixth embodiment of the present invention is described based on FIG. 11 to FIG. 16.

This embodiment relates to the sliding mechanism section 45 of the driving device 40 that turns the movable circular plate 31, and in particular, relates to a suitable structure for reducing the space δ between the wall of the fixed circular plate 32 and the movable vanes 34.

A driving device 40A shown in FIG. 11 is furnished with a sliding mechanism section 45A that is configured by a guiding groove 48 that is formed on the housing 11, and a convex section 49 that is provided on the lower end section of the movable circular plate 31.

[0048] On one side face of the guiding groove 48, a guiding face 48a, to which circular arc-shaped (radius R) concavities and convexities are formed, is provided. In the same manner, on the convex section 49 side, with respect to the side face that opposes the guiding face 48a, a sliding face 49a to which the same circular arc-shaped (radius R) concavities and convexities are formed, is provided. This sliding face 49a makes contact with the guiding face 48a, and as a result of the movable circular plate 31 turning, the circular arc-shaped concave and convex contact positions that are formed on both faces move in the circumferential direction.

Furthermore, on the housing 11 is installed a sealing member 50 that exhibits a sealing function by making contact with a face that becomes the outer circumferential side of the movable circular plate 31 viewed from the diffuser passage 33 side. This sealing member 50 prevents the air flow which flows through the diffuser passage 33, from passing through the sliding mechanism section 45A and leaking.

[0049] In such a configuration, the movable circular plate 31 moves according to the concave and convex contact positions with the guiding face 48a and the sliding face 49a, in a direction that approaches or a direction that separates from the fixed circular plate 32, and the interfacial distance with the fixed circular plate 32 is varied. Hereunder, this interfacial distance variation is specifically described with reference to FIG. 12 and FIG. 13.

The movable circular plate 31, as a result of the movable circular plate 31 side turning, moves back and forth in the circular arc radius R direction between the space forming position at which the convex section formed on the guiding face 48a of the fixed side and the convex section formed on the sliding face 49a make contact (indicated by the broken line in FIG. 12 (a)), and the space reducing position at which the concavities and convexities of the guiding face 48a and the concavities and the convexities of the sliding face 49a mutually engage (indicated by the solid line in FIG. 12 (a)).

[0050] As a result, the space δ formed between the end of the movable vanes 34 and the hub side wall 32a is, as shown in FIG. 13, varied within a range from a maximum value at the space forming position (indicated by the chain in the drawing) to a minimum value at the space reduction position (indicated by the solid line in the drawing).

FIG. 12 (b) shows the change in the space δ that corresponds to the movable range θ of the movable circular plate 31. The minimum space at the space reduction position can, by optimizing the concavities and convexities of the guiding face 48a and the concavities and convexities of the sliding face 49a, be made $\delta \approx 0$, which is equivalent to almost none. Consequently, at the space reduction position, since the leakage amount that passes through the space δ decreases, the efficiency of the compressor furnished with the variable diffuser can be improved.

[0051] Furthermore, it is preferable for the sliding mechanism section 45A mentioned above to utilize the space reduction position at which the concavities and convexities of the guiding face 48a and the concavities and convexities of the sliding face 49a engage, and for it to be turned in stages at the pitch of the concavities and the convexities.

That is to say, since the position of the movable vanes 34 is fixed in stages, it becomes possible to prevent fluctuations of the vane position resulting from play in the driving device 40A and vibrations from the exterior, and the characteristics of the compressor can be stabilized.

[0052] Furthermore, in the variable diffuser mentioned above, for example as shown in FIG. 14, a sliding face 51 is formed on the shroud side wall 31a, which becomes the interval between the movable vanes 34, and on the hub side wall 32a, which becomes the interval between the fixed vanes, in order to obtain satisfactory slidability even in a state where there is no space δ. Specifically, it is acceptable if, on the walls that become the interval between both vanes, for example, the sliding face is formed by applying a fluororesin such as 4-fluoroethylene.

In such a configuration, smooth turning of the movable circular plate 31 becomes possible even if there is no space δ. Furthermore, by pressing from the back face side of the movable circular plate 31 as a result of the diffuser exit pressure, it is possible to achieve an improvement in efficiency even if there are no concavities and convexities such as on the guiding face 48a and the sliding face 49a as mentioned above, and without a space δ.

[0053] Incidentally, in the explanation above, the guiding face 48a and the sliding face 49a were made a circular arc shape, although as in a first modified example shown in FIG. 15, it is acceptable for it to be made a guiding face 48b and a sliding face 49b having mutually identical sine wave-shaped concavities and convexities.

Alternatively, as in a second modified example shown in FIG. 16, it may be made a configuration in which a guiding groove 48' is formed on the housing 11 which becomes the fixed side, and freely turning rotation rings 52 are installed in a necessary number at appropriate positions on this guiding groove 48'. In this case, when the movable circular plate 31 turns, the circular arc-shaped or sine wave-shaped sliding face 49a slides with respect to the rotation rings 52. Therefore in the same manner as with the guiding faces 48a and 48b mentioned above, the space δ can be eliminated at the space reduction position.

[0054] Furthermore, in regard to the setting of the movable vanes and the fixed vanes described in the embodiments mentioned above, the setting of the fixed side and the turning side may be reversed. That is to say, the same respective operating effects can be obtained even if the magnitude of the entrance radius of the fixed vanes and the entrance radius of the movable vanes are reversed, or the magnitude of the vane leading edge angle of the fixed vanes and the vane leading edge angle of the movable vanes is reversed, or the vanes of the fixed vanes and the movable vanes that are made the low chord-pitch ratio vanes are reversed, and furthermore, if the magnitude of the trailing edge radius of the fixed vanes and the trailing edge radius of the movable vanes are reversed.

[0055] In this manner, according to the variable diffuser structure of the present invention, efficiency decreases resulting from increases in the incidence, and leakage from the space δ are resolved, and a variable diffuser, in which the efficiency is even more improved, can be provided. Accordingly, in regard to compressors such as centrifugal compressors and mixed flow compressors, that are furnished with this variable diffuser, the performance thereof can be even more improved.

The present invention is in no way restricted to the embodiments mentioned above, and appropriate changes are possible within a range that does not depart from the gist of the present invention.

Industrial Applicability

[0056] The diffuser and the compressor of the present invention is, for example, applicable to turbochargers, marine superchargers, aeronautical small gas turbines, and industrial centrifugal compressors and mixed flow compressors.

Claims

1. A variable diffuser in which a diffuser passage, which restores a static pressure from a dynamic pressure by decelerating an air flow that is discharged from an outer peripheral end of an impeller that rotates within a housing, is formed between a hub side wall and a shroud side wall, and diffuser vanes are provided in the diffuser passage,
said diffuser vanes being alternately fixed in the circumferential direction to a wall member that forms said hub side wall and said shroud side wall, and there being provided a driving device that turns either one of said wall members about the same axis as the rotation of said impeller.

2. A variable diffuser according to claim 1, wherein a movable range of said wall member which turns as a result of said driving device, is set such that it encompasses the entire width of an interval between adjacent diffuser vanes that are fixed on the wall member of the fixed side.

3. A variable diffuser according to either one of claim 1 and claim 2, wherein a leading edge radius (R1) of a diffuser vane provided on a turning side of said wall member is set larger than a leading edge radius (R2) of a diffuser vane provided on a fixed side of said wall member (R1 > R2).

4. A variable diffuser according to claim 3, wherein a vane leading edge angle (αk1) of a diffuser vane provided on a turning side of said wall member is set smaller than a leading edge angle (αk2) of a diffuser vane provided on a fixed side of said wall member at the same radial position ($\alpha k1 < \alpha k2$).

5. A variable diffuser according to claim 3, wherein a vane leading edge angle (αk1) of a diffuser vane provided on a turning side of said wall member is set larger than a leading edge angle (αk2) of a diffuser vane provided on a fixed side of said wall member at the same radial position ($\alpha k1 > \alpha k2$).

6. A variable diffuser according to claim 3, wherein a diffuser vane provided on a fixed side of said wall member is a low chord-pitch ratio vane.

7. A variable diffuser according to claim 6, wherein a trailing edge radius (R3) of a diffuser vane provided on a turning side of said wall member is set larger than a trailing edge radius (R4) of a diffuser vane provided on a fixed side of said wall member (R3 > R4).

8. A variable diffuser according to any one of claim 3 through and claim 7, wherein the setting of the fixed side and the turning side is reversed.

9. A variable diffuser according to any one of claim 1 through and claim 7, wherein said driving device is furnished with a sliding mechanism section that moves a turning side of said wall member back and forth between a space formation position and a space reduction position with respect to a fixed side of said wall member.

10. A compressor comprising a variable diffuser according to any one of claim 1 through claim 9 on the peripheral end of the impeller that rotates within the housing.

FIG. 1

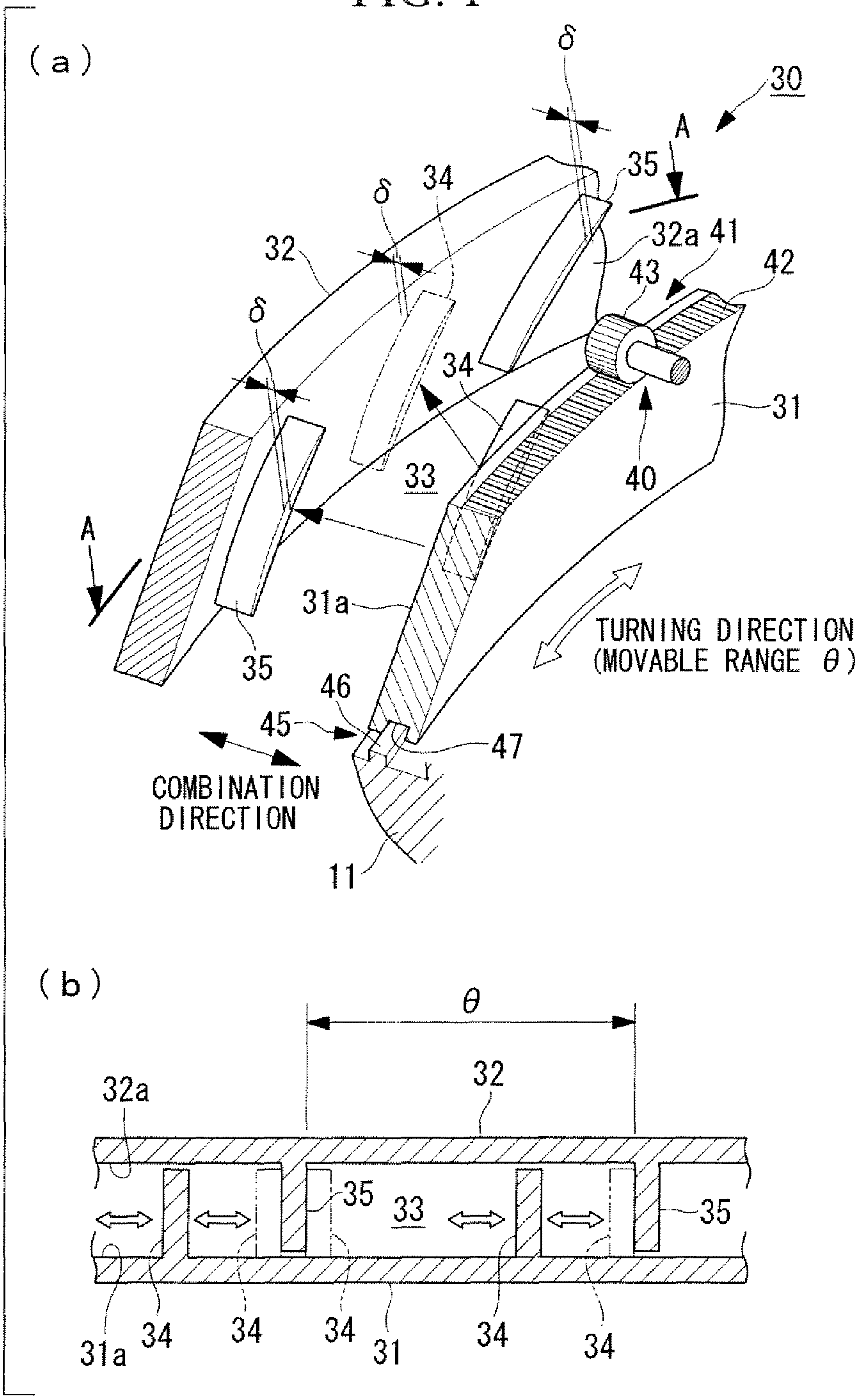

(a)
30
A
δ
35
34
δ
32
32a
41
42
43
δ
34
31
33
40
A
31a
TURNING DIRECTION
(MOVABLE RANGE θ)
35
46
45
47
COMBINATION
DIRECTION
11
(b)
θ
32
32a
35
33
35
31a
34
34
34
31
34
34

FIG. 2

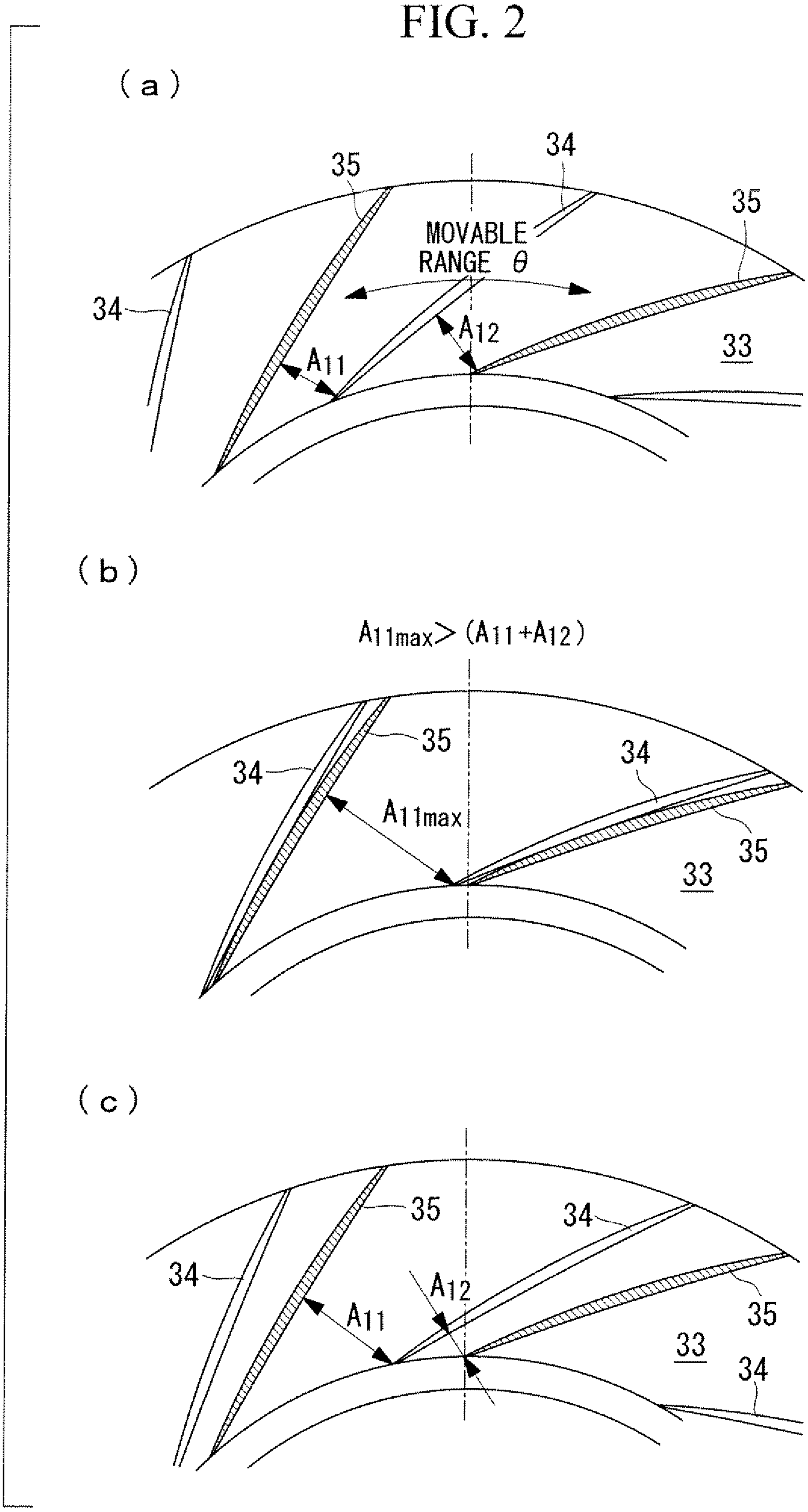

(a)
35
34
35
34
MOVABLE
RANGE θ
A11
A12
33
(b)
A11max>(A11+A12)
34
35
34
A11max
35
33
(c)
34
35
34
A12
A11
35
33
34

FIG. 3

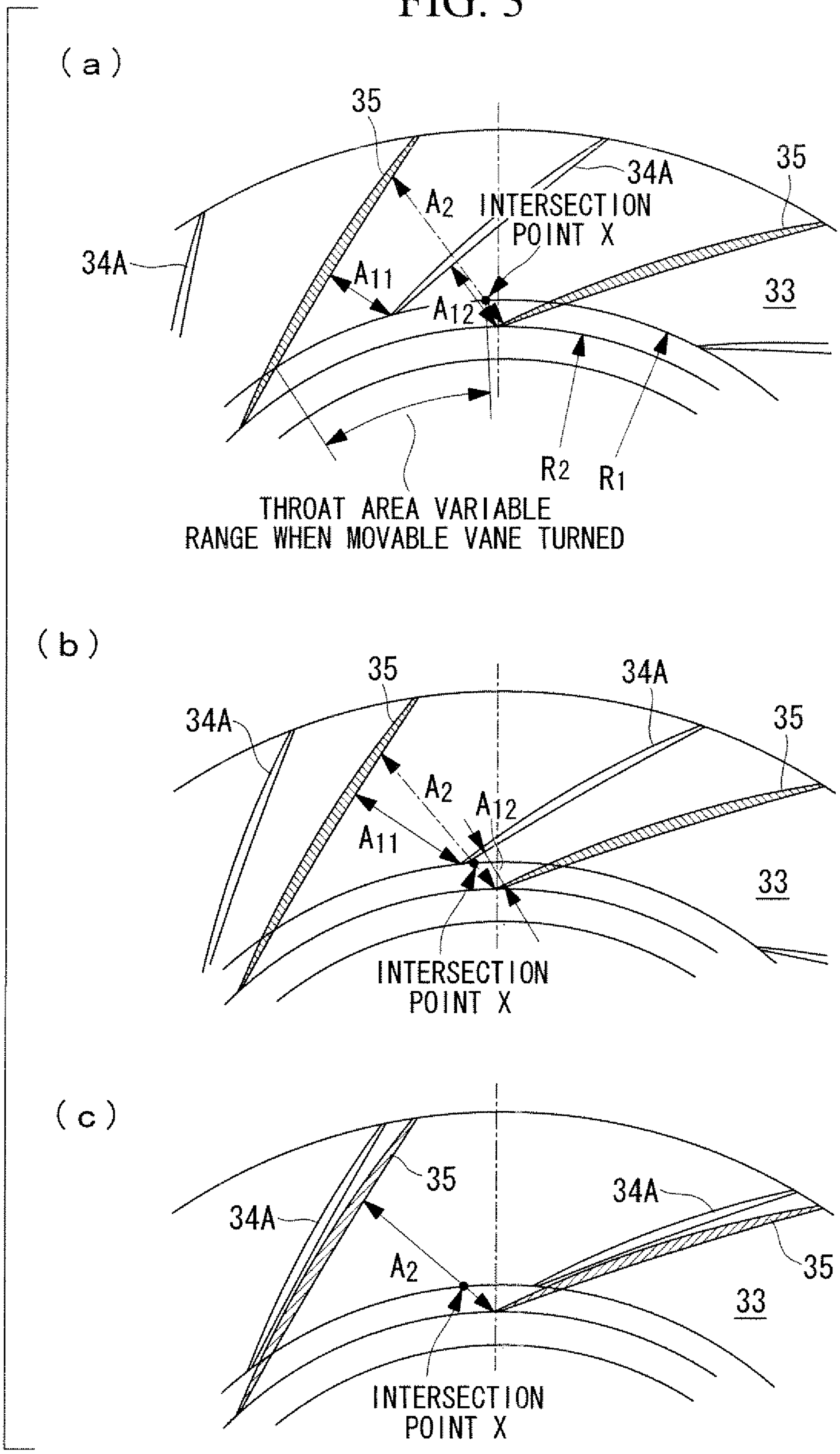

(a)
35
34A
35
A2
INTERSECTION POINT X
34A
A11
A12
33
R2
R1
THROAT AREA VARIABLE RANGE WHEN MOVABLE VANE TURNED
(b)
35
34A
34A
35
A2
A12
A11
33
INTERSECTION POINT X
(c)
35
34A
34A
35
A2
33
INTERSECTION POINT X

FIG. 4

(VANE ANGLE SET TO $\alpha_{K1} < \alpha_{K2}$)

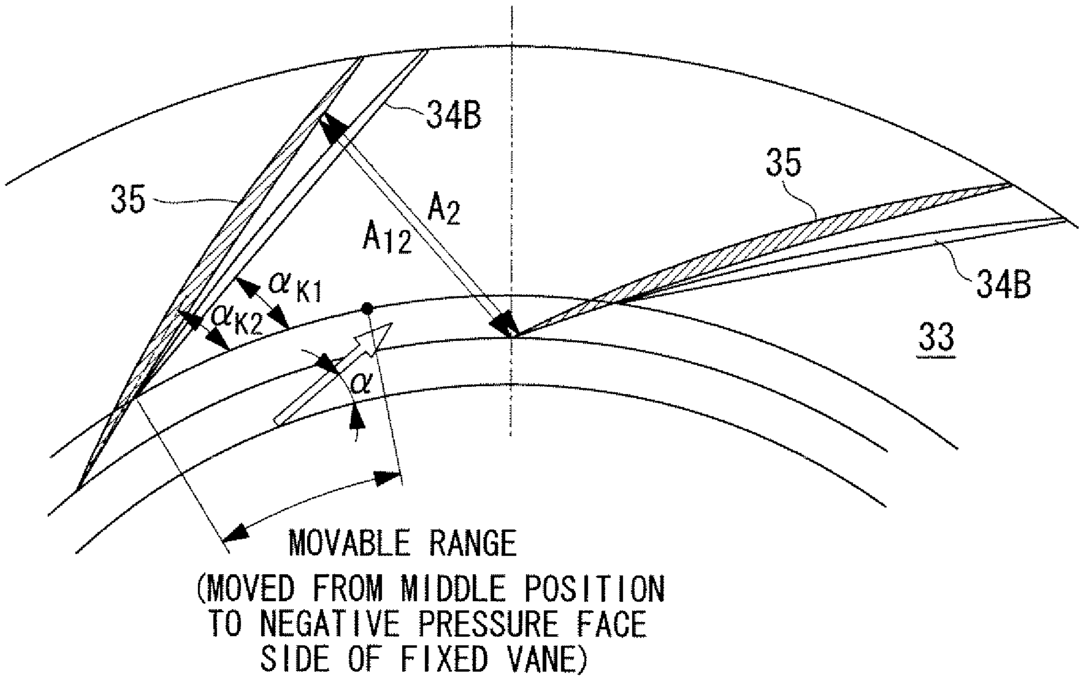


FIG. 5

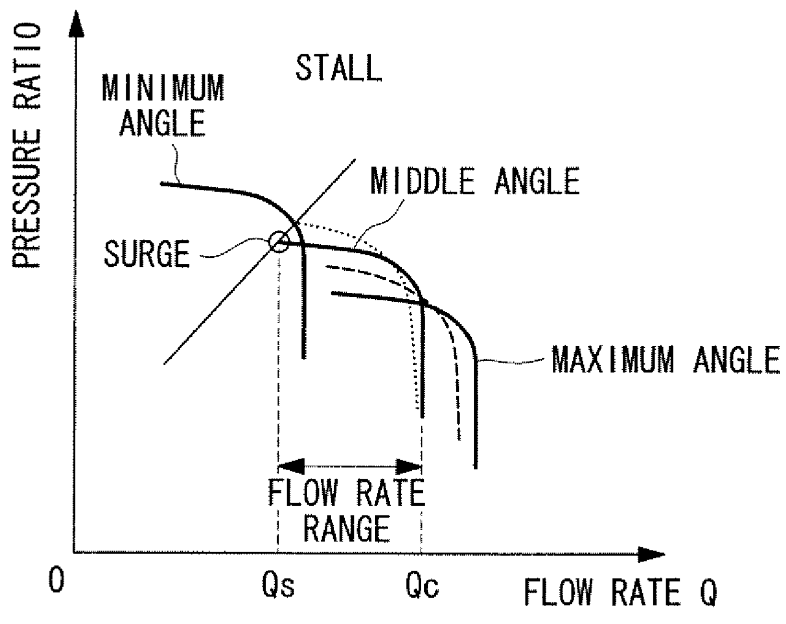


FIG. 6

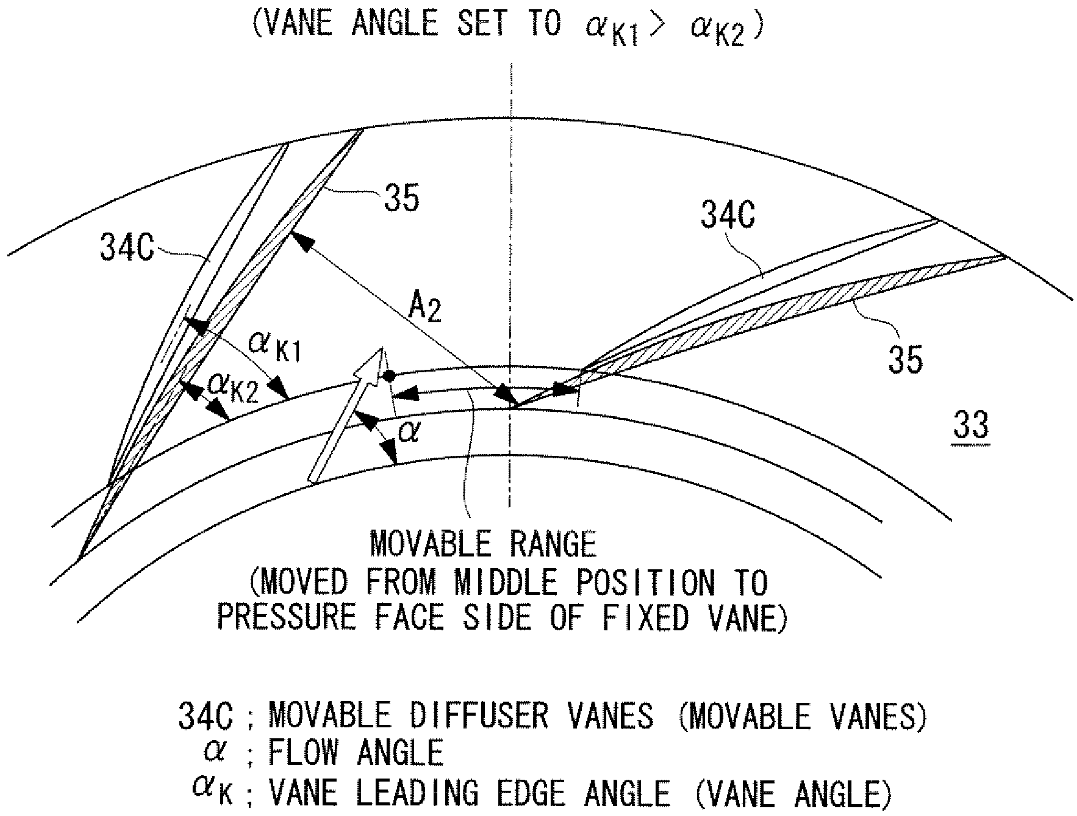

(VANE ANGLE SET TO $\alpha_{K1} > \alpha_{K2}$)
35
34C
34C
A2
α_{K1}
α_{K2}
α
35
33
MOVABLE RANGE
(MOVED FROM MIDDLE POSITION TO
PRESSURE FACE SIDE OF FIXED VANE)
34C ; MOVABLE DIFFUSER VANES (MOVABLE VANES)
α ; FLOW ANGLE
α_K ; VANE LEADING EDGE ANGLE (VANE ANGLE)

FIG. 7

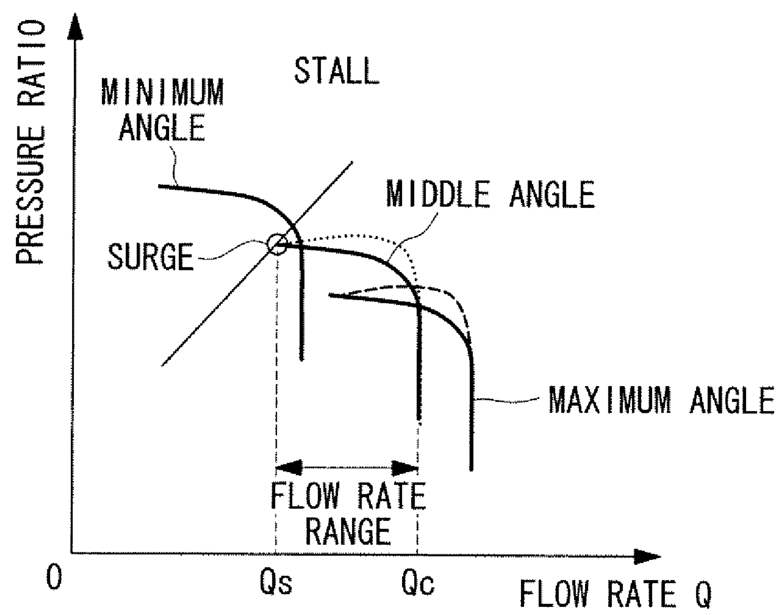

PRESSURE RATIO
MINIMUM
ANGLE
STALL
MIDDLE ANGLE
SURGE
MAXIMUM ANGLE
FLOW RATE
RANGE
0
Qs
Qc
FLOW RATE Q

FIG. 8

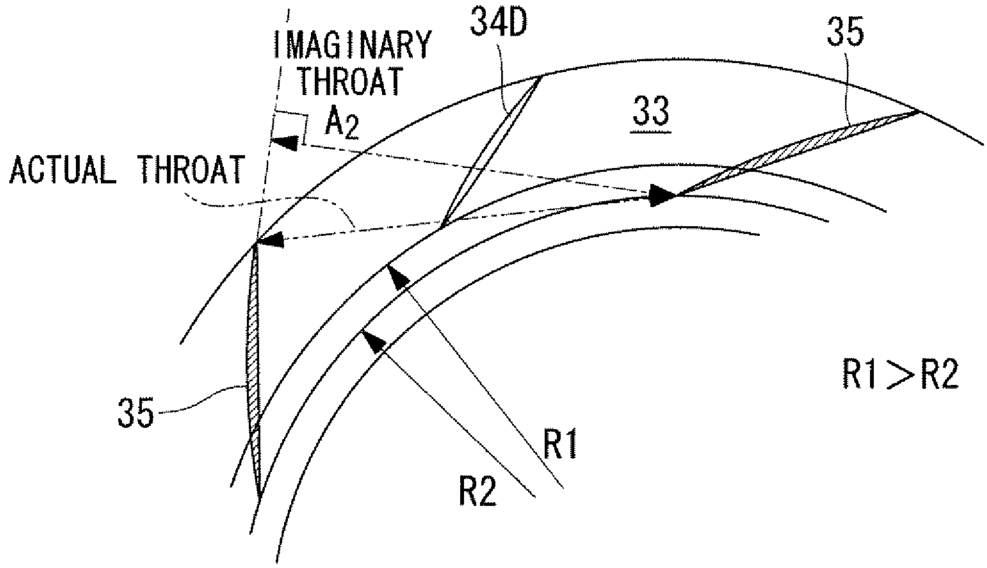


FIG. 9

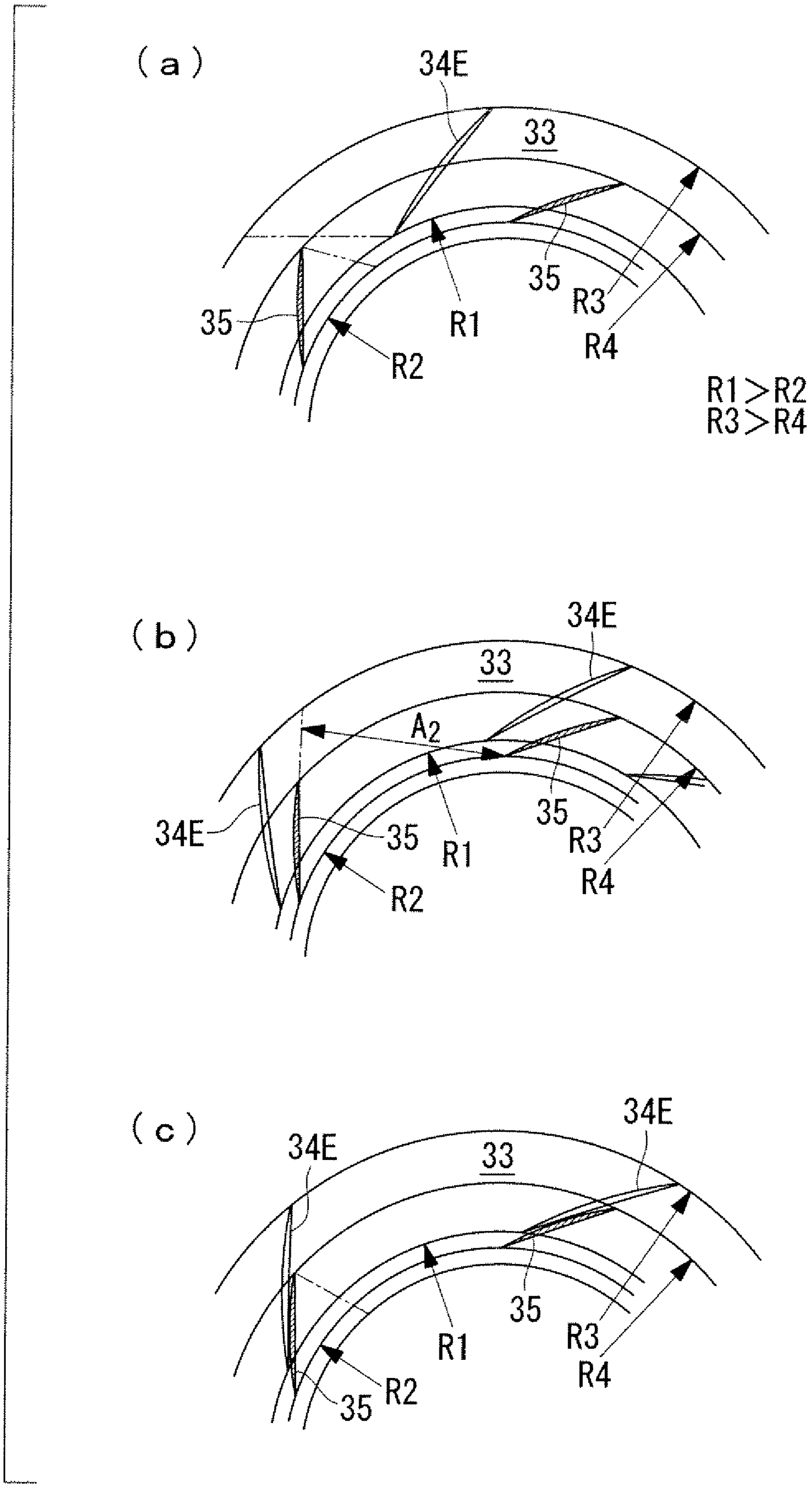

(a)
34E
33
35
35
R1
R2
R3
R4
R1>R2
R3>R4
(b)
34E
33
A_2
34E
35
35
R1
R2
R3
R4
(c)
34E
34E
33
35
35
R1
R2
R3
R4

FIG. 10

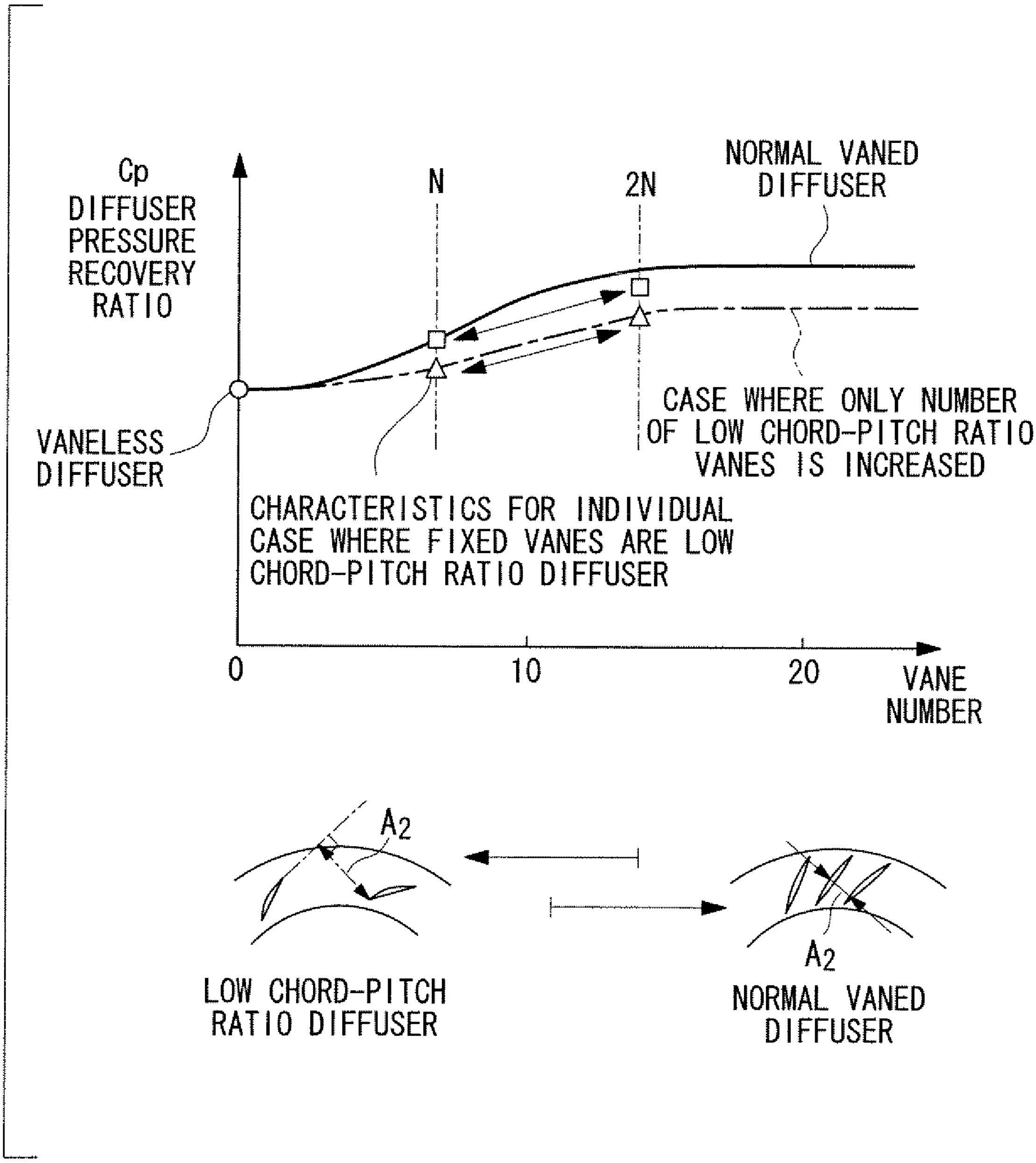

Cp
DIFFUSER
PRESSURE
RECOVERY
RATIO
N
2N
NORMAL VANED
DIFFUSER
VANELESS
DIFFUSER
CASE WHERE ONLY NUMBER
OF LOW CHORD-PITCH RATIO
VANES IS INCREASED
CHARACTERISTICS FOR INDIVIDUAL
CASE WHERE FIXED VANES ARE LOW
CHORD-PITCH RATIO DIFFUSER
0
10
20
VANE
NUMBER
A2
A2
LOW CHORD-PITCH
RATIO DIFFUSER
NORMAL VANED
DIFFUSER

FIG. 11

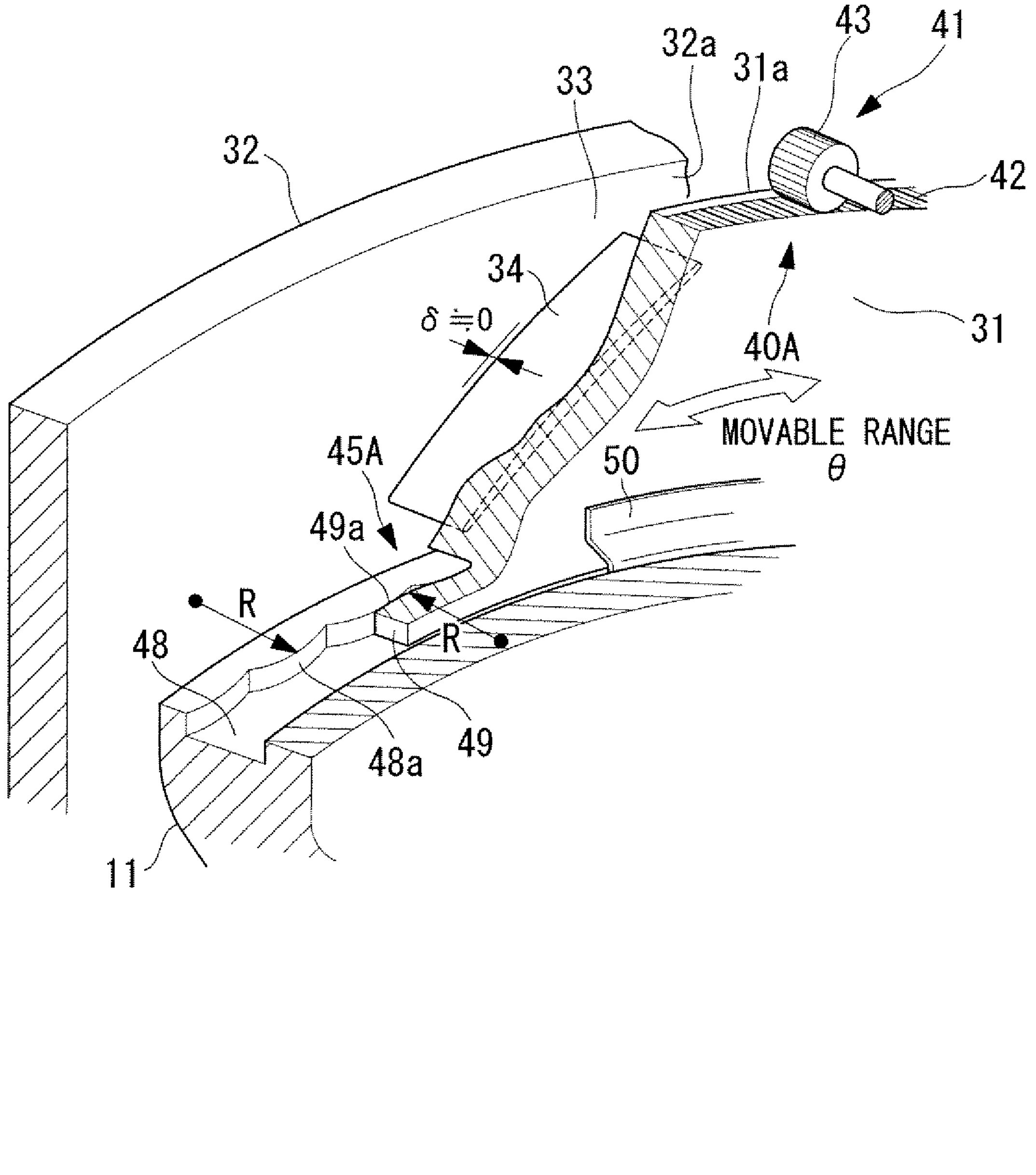

32
33
32a
31a
43
41
42
34
31
δ ≒0
40A
MOVABLE RANGE
θ
45A
50
49a
R
R
48
48a
49
11

FIG. 12

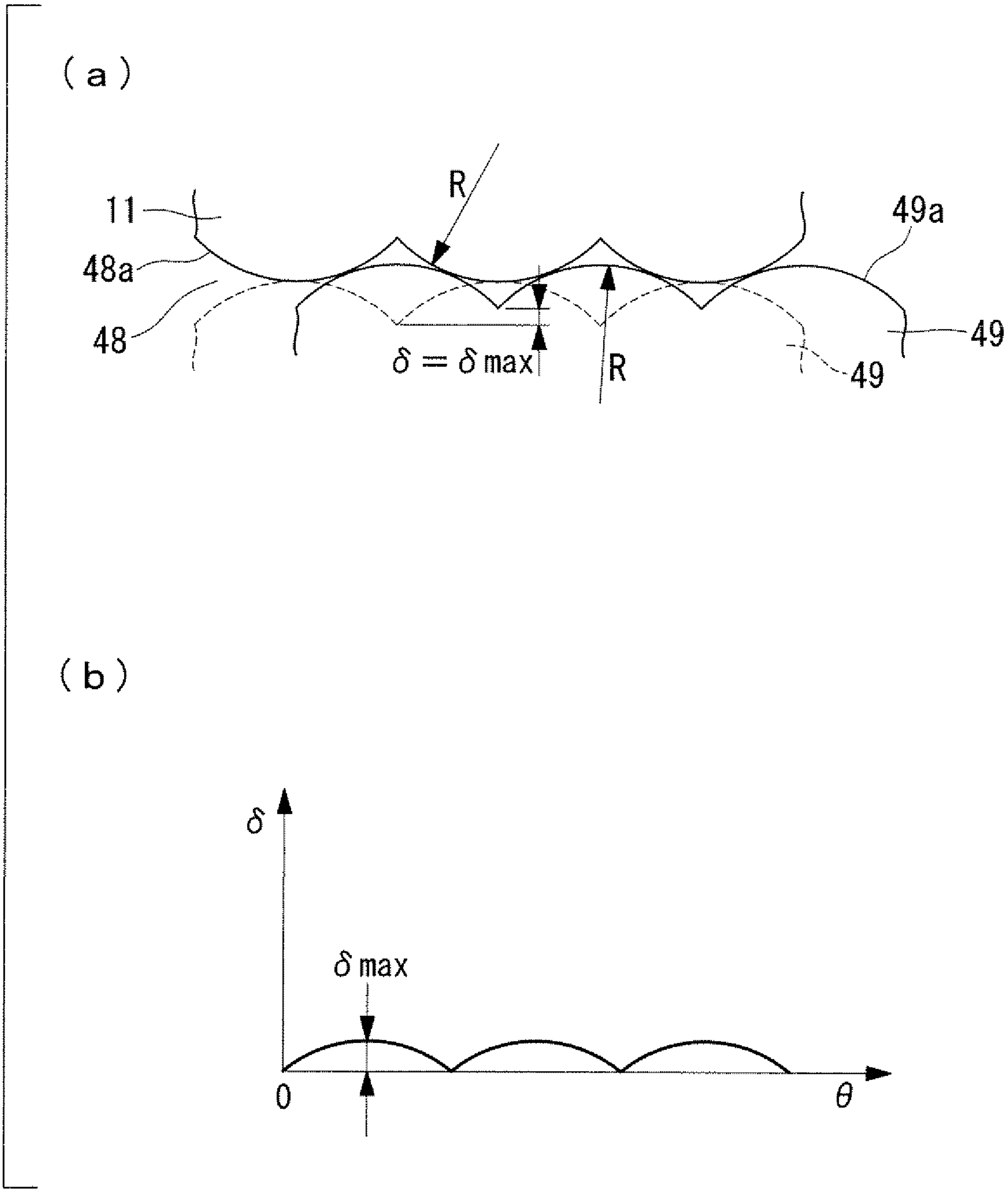


FIG. 13

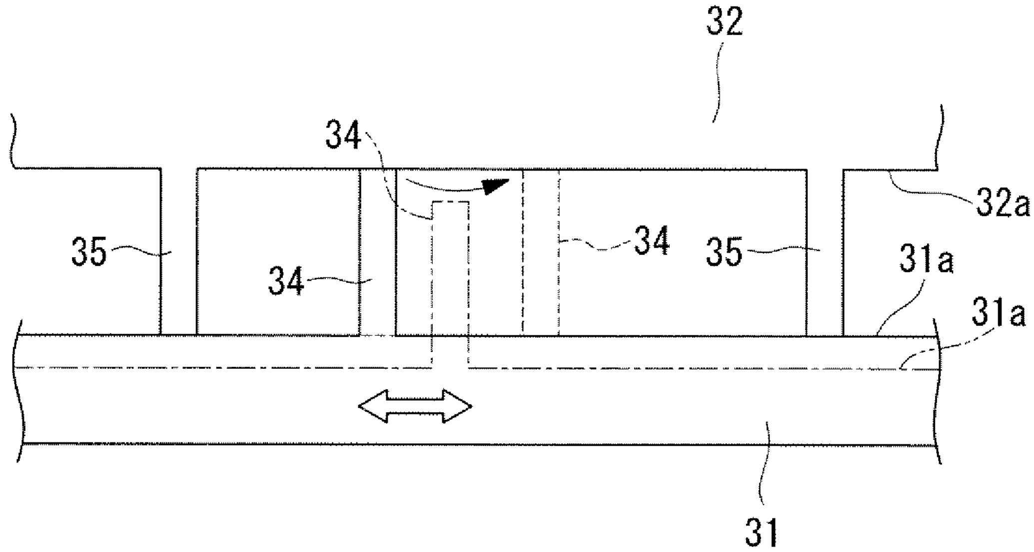
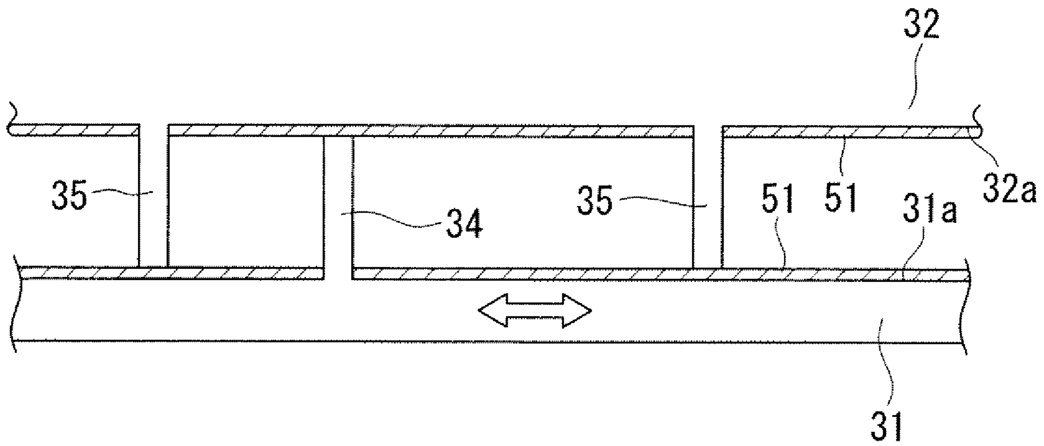


FIG. 14



51: SLIDING FACE

FIG. 15

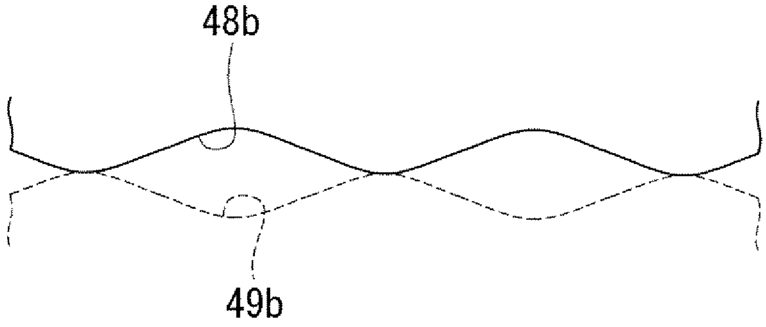


FIG. 16

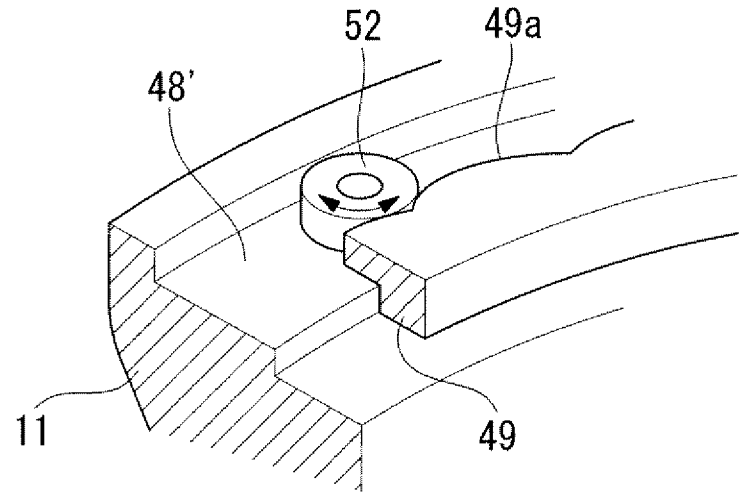


FIG. 17

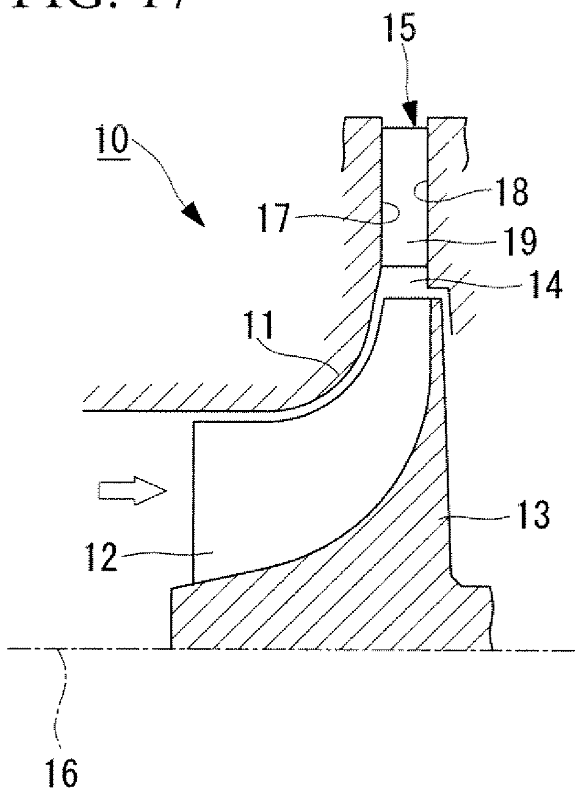


FIG. 18

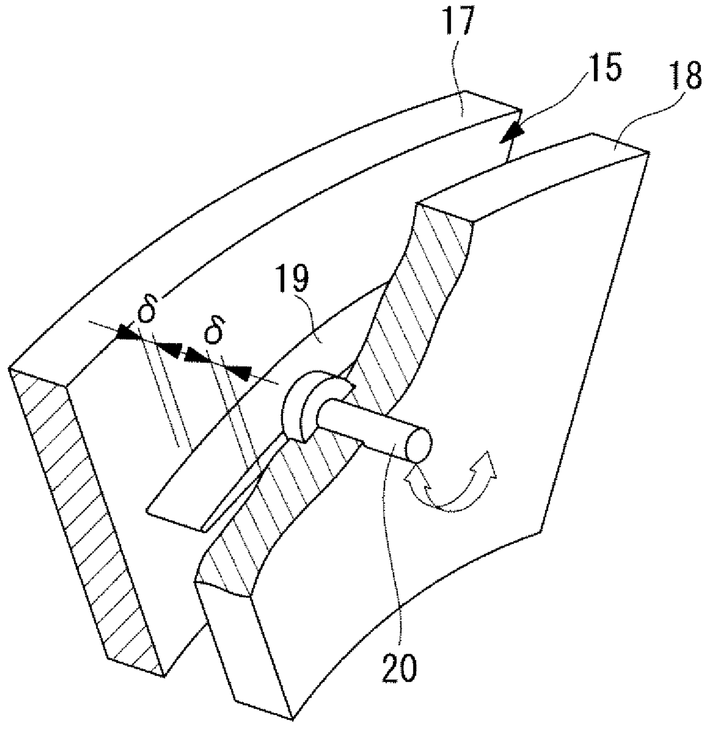


FIG. 19

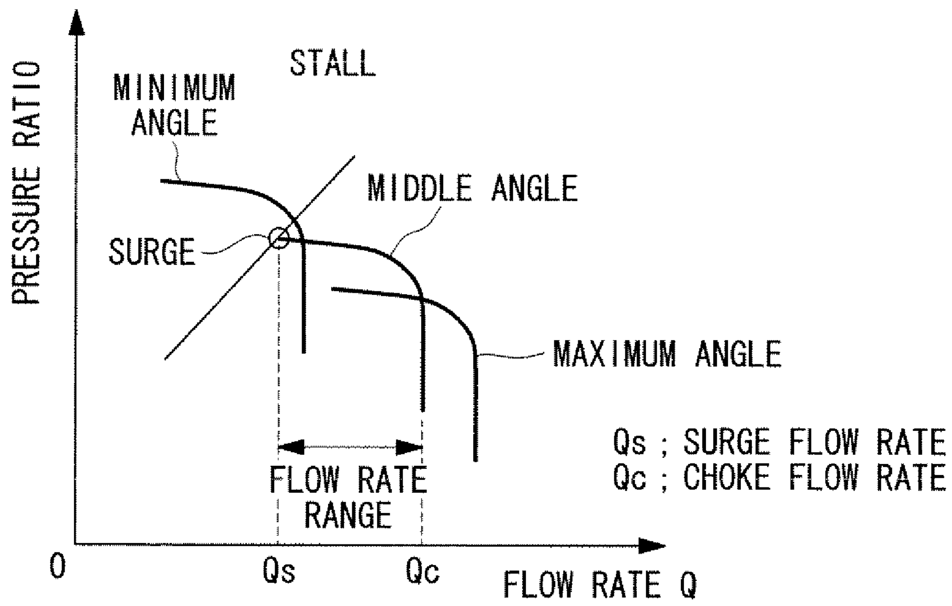

PRESSURE RATIO
STALL
MINIMUM ANGLE
MIDDLE ANGLE
SURGE
MAXIMUM ANGLE
Qs ; SURGE FLOW RATE
Qc ; CHOKE FLOW RATE
FLOW RATE RANGE
0
Qs
Qc
FLOW RATE Q

FIG. 20

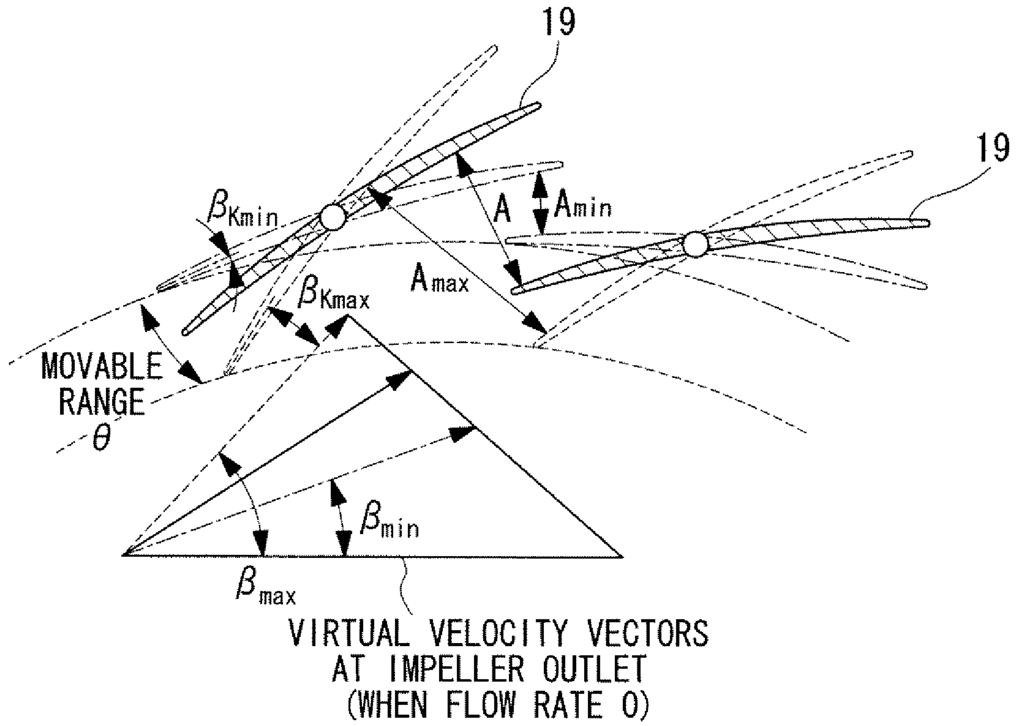
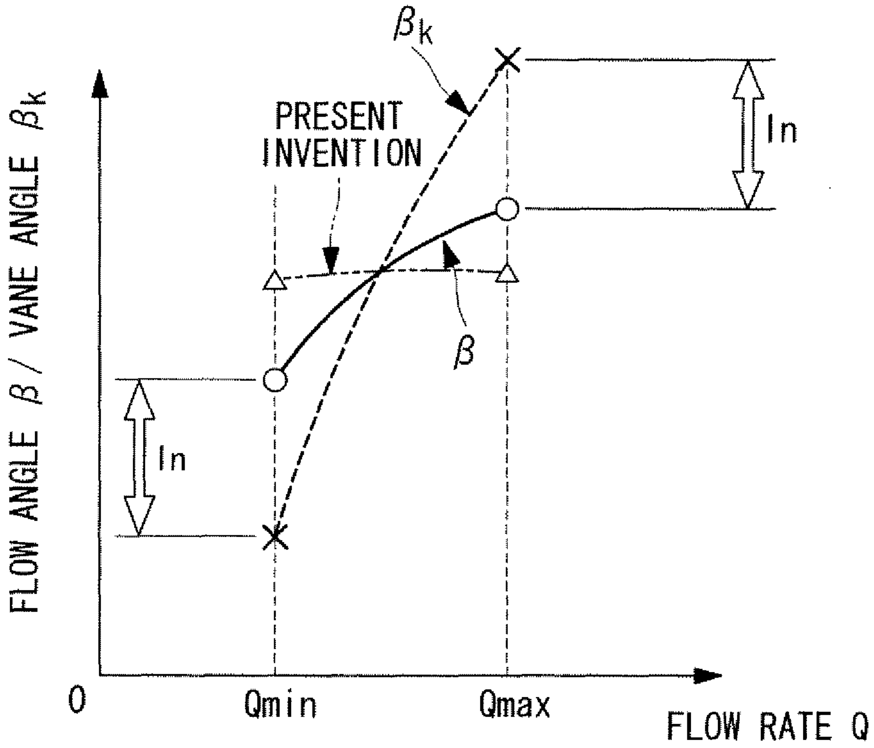

19
19
β_{Kmin}
A
A_{min}
A_{max}
β_{Kmax}
MOVABLE RANGE θ
β_{min}
β_{max}
VIRTUAL VELOCITY VECTORS
AT IMPELLER OUTLET
(WHEN FLOW RATE 0)

FIG. 21



In ; INCIDENCE

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2007/052354

A. CLASSIFICATION OF SUBJECT MATTER
F04D29/46(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)
F04D29/46

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	1996-2007
Kokai Jitsuyo Shinan Koho	1971-2007	Toroku Jitsuyo Shinan Koho	1994-2007

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.
A	JP 46-43737 B1 (Escher Wyss AG.), 25 December, 1971 (25.12.71), Full text; Figs. 1a to 3b & CH 486636 A & US 3588270 A & GB 1270330 A & DE 69028037 U & FR 2015956 A	1-10
A	US 4737071 A (Williams International Corp.), 12 April, 1988 (12.04.88), Full text; Figs. 1 to 4 & DE 3889488 C & AT 105463 E & AU 1381388 A & AU 8797691 A & DK 164888 A & DK 164888 A0	1-10

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

* Special categories of cited documents:
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"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)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
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"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
29 March, 2007 (29.03.07)	10 April, 2007 (10.04.07)

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

Form PCT/ISA/210 (second sheet) (April 2005)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP HEI7310697 B **[0005]**
- JP 2865834 B **[0005]**
- JP 3513729 B **[0005]**