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Ishikawa et al.(10) **Pub. No.: US 2014/0126994 A1**(43) **Pub. Date: May 8, 2014**(54) **RADIAL GAS EXPANDER**(52) **U.S. CL.**(76) Inventors: **Hiroki Ishikawa**, Hiroshima-shi (JP);
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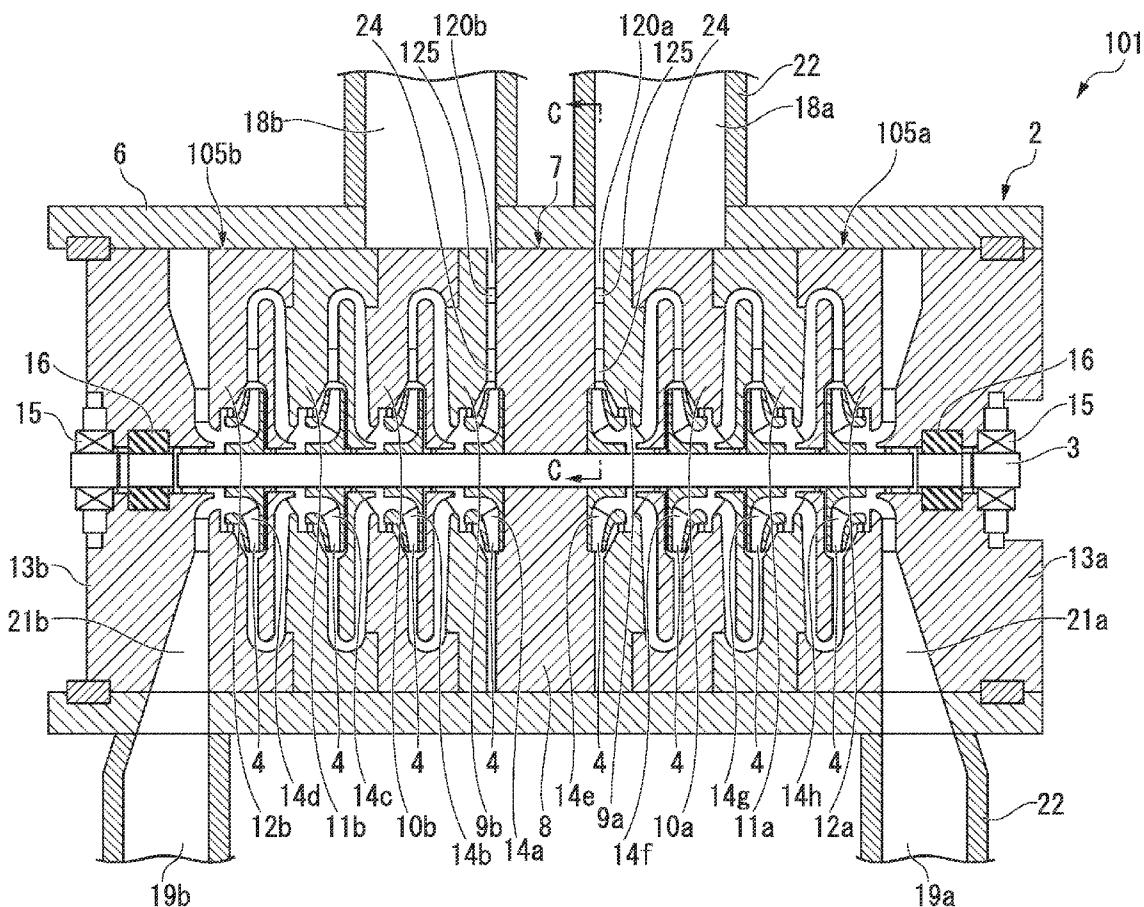
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(57) **ABSTRACT**

This radial gas expander is provided with a rotating shaft, an impeller which is fixed to the rotating shaft, and a casing by which the rotating shaft is supported in a rotatable manner and in which an introduction channel introducing fluid to the impeller is formed. The introduction channel includes a nozzle blade which guides fluid flowing into the impeller and a support member which is provided in the upstream side of the nozzle blade and which supports wall surfaces of the introduction channel, wherein the wall surfaces are mutually opposed, and the support member has a wing shape in a cross-sectional view.



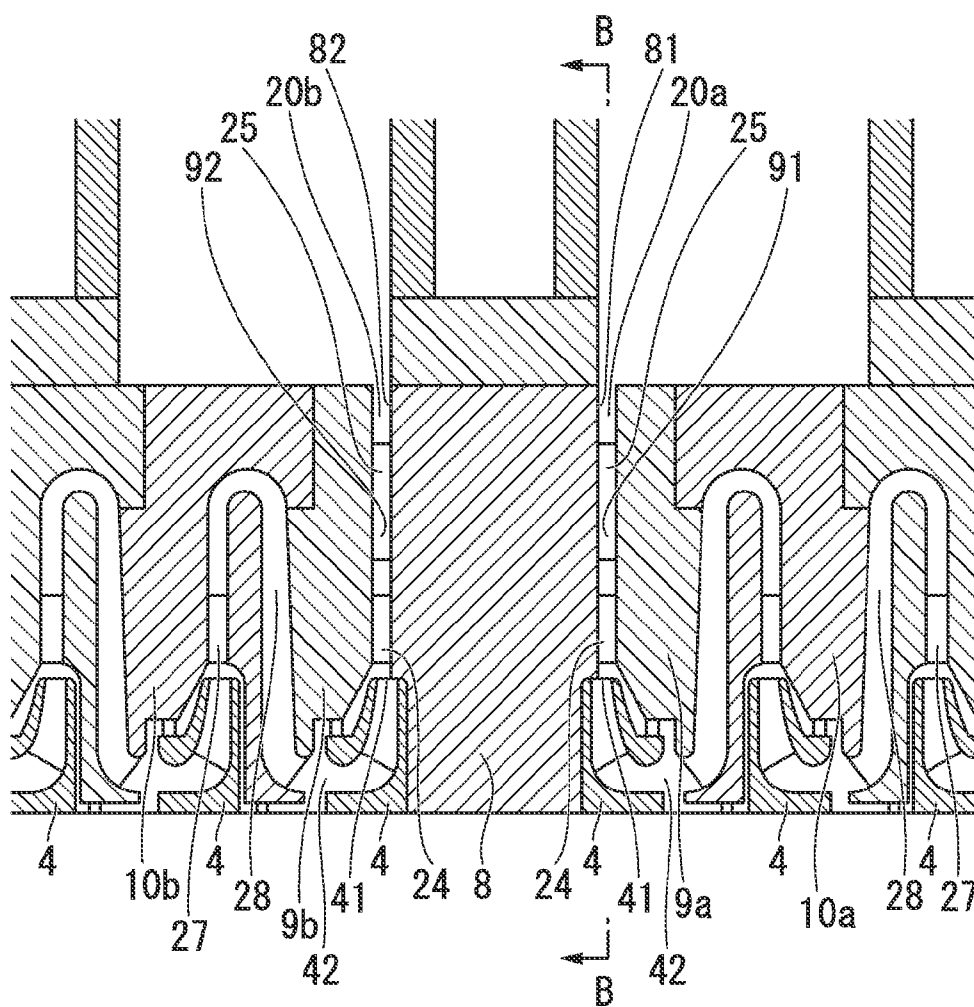


FIG. 3

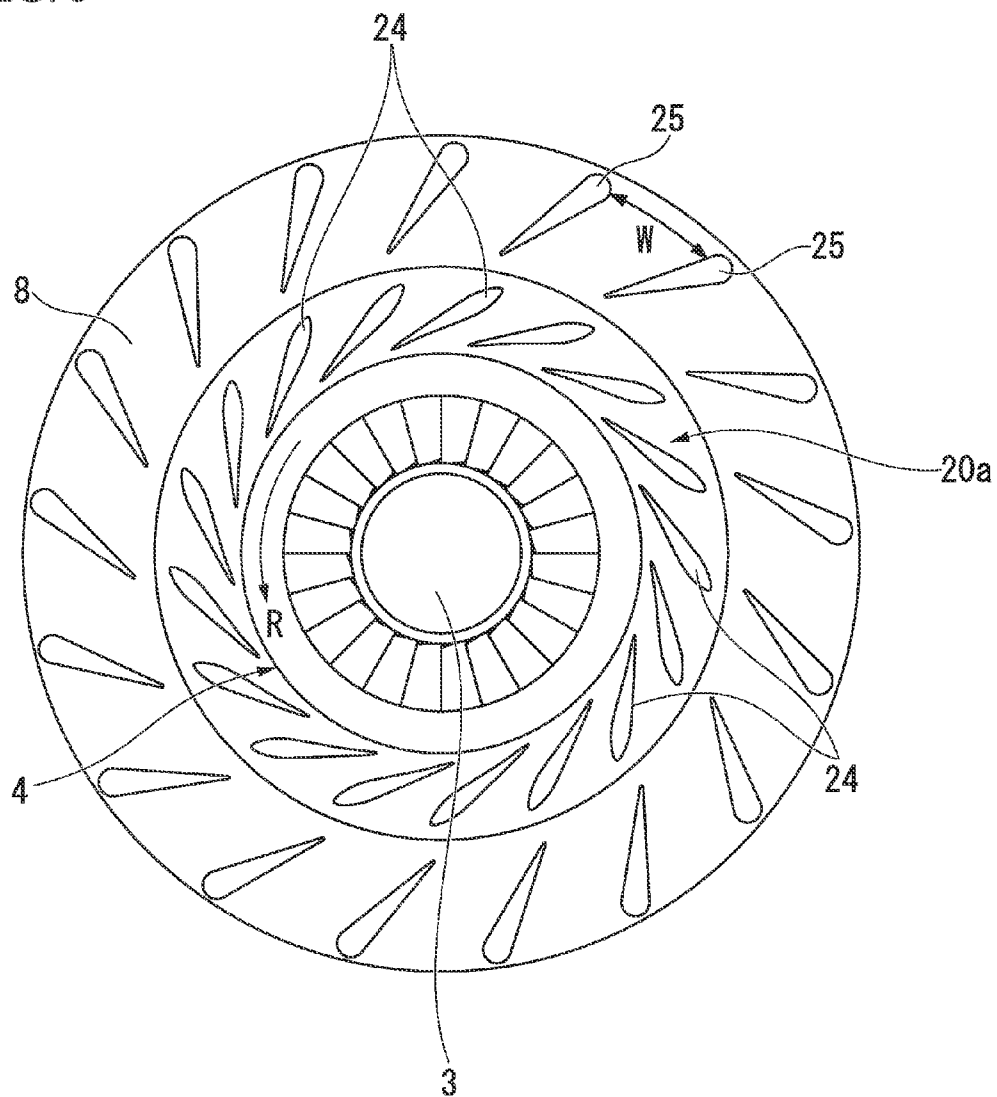
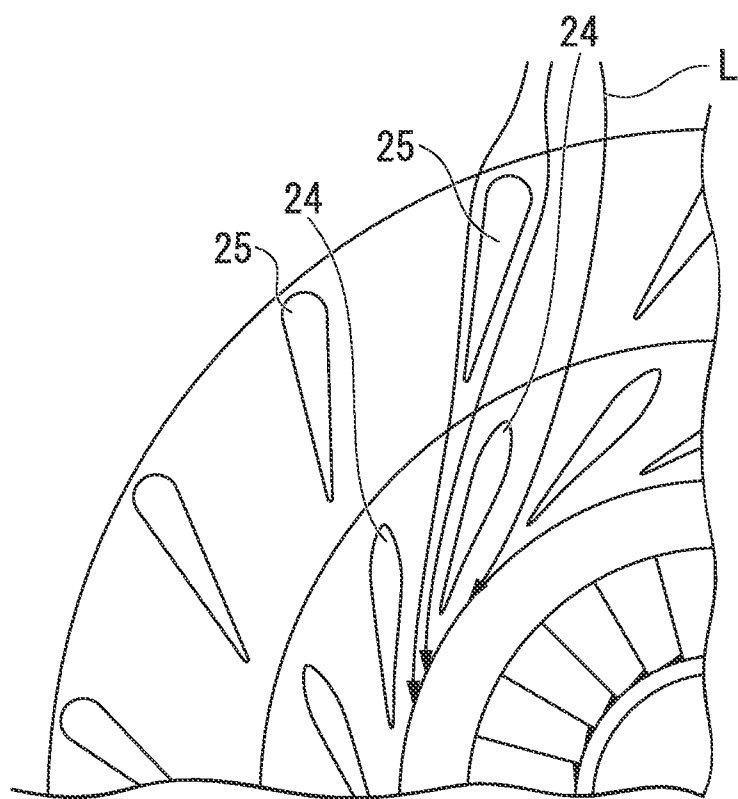


FIG. 4



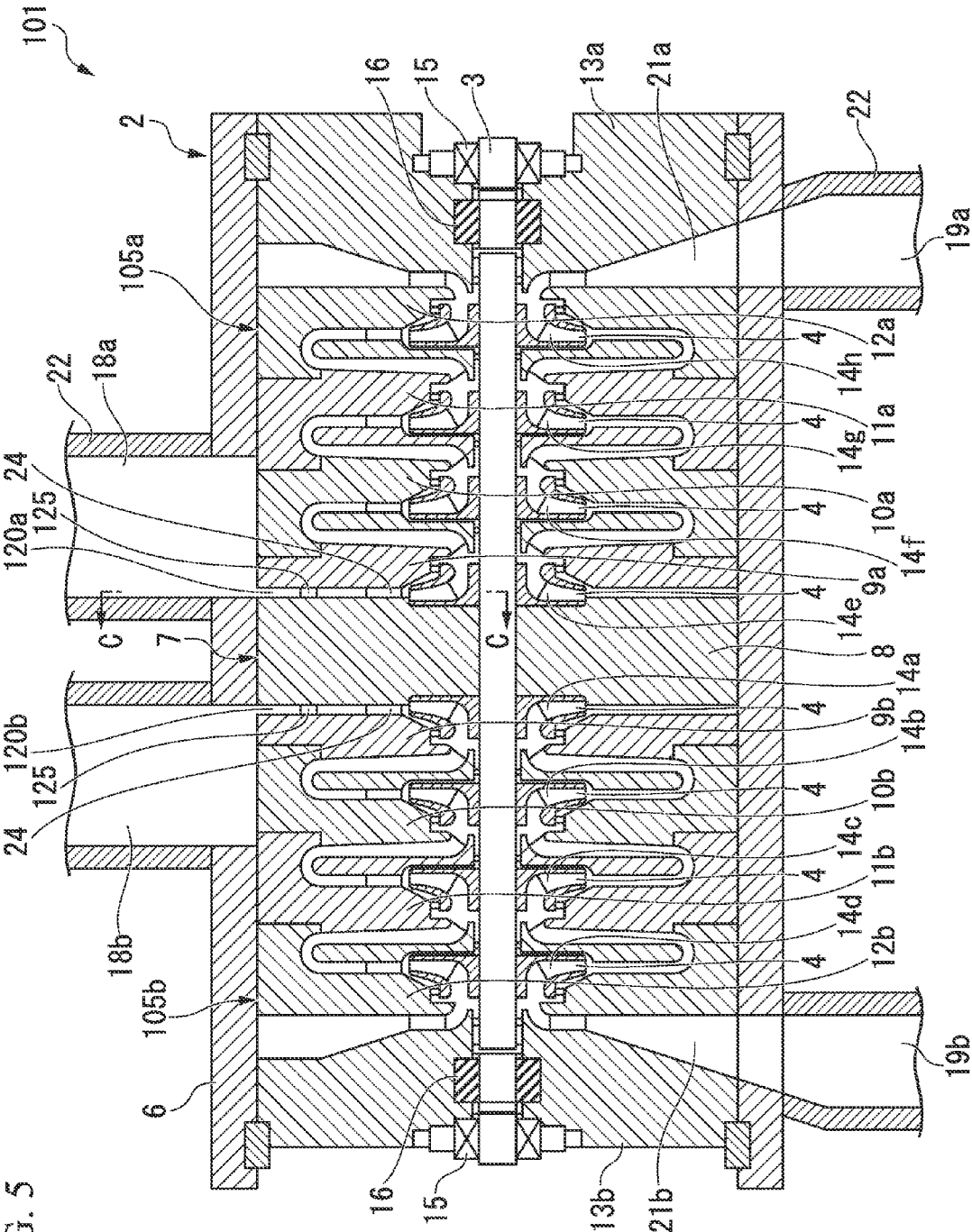
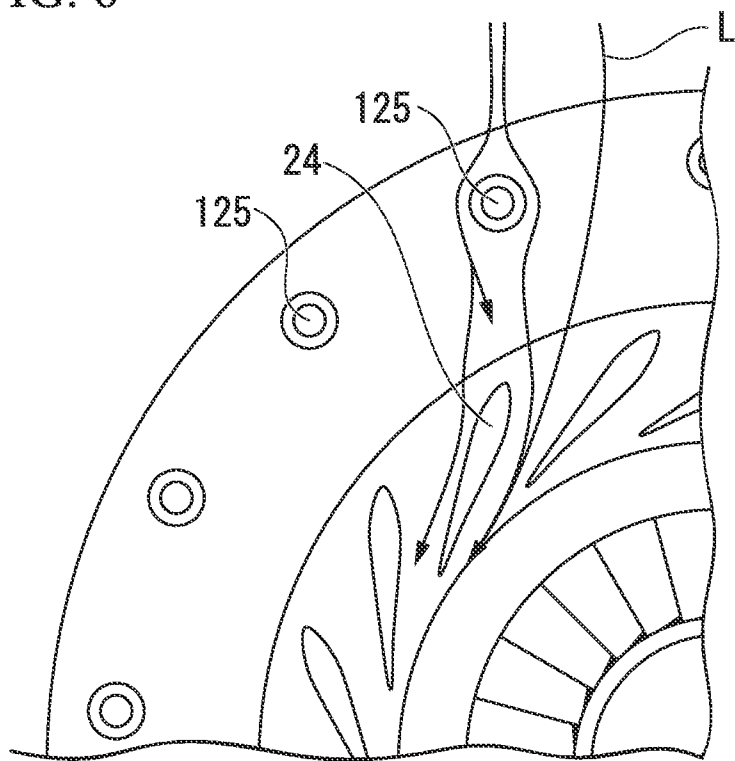


FIG. 5

FIG. 6



RADIAL GAS EXPANDER

TECHNICAL FIELD

[0001] The present invention relates to a radial gas expander (a radial flow gas expander) in which impellers are arranged on a single shaft in multiple stages.

[0002] Priority is claimed on Japanese Patent Application No. 2011-190525, filed Sep. 1, 2011, the content of which is incorporated herein by reference.

BACKGROUND ART

[0003] The gas expander is used to suction and expand high pressure gas discharged from a plant, convert pressure energy of the gas into speed energy (mechanical energy), and thus, recover power and reduce the power of a driving motor or the like.

[0004] In recent years, a gas expander which corresponds to higher pressure energy has been required. As such a gas expander, a radial gas expander in which a plurality of impellers is provided in multiple stages is known. As an example of the radial gas expander, a geared (speed-increasing gear) radial gas expander is known, which is configured of a driving gear, a speed-increasing gear configured of a pinion gear engaging with the driving gear, and a plurality of impellers disposed in a pinion shaft (for example, refer to Patent Document 1).

[0005] Moreover, a radial gas expander is also known in which the plurality of impellers are arranged between bearings on a single shaft and the impellers are built in a single casing. In the radial gas expander in which the plurality of impellers are arranged on the single shaft, the shaft is the single shaft in spite of including the multistage impeller. Accordingly, compared to the geared radial gas expander or the like, the number of high-pressure seals or high-pressure casing can be reduced to a minimum, and a radial gas expander having high reliability can be realized even in a higher pressure condition (for example, refer to Patent Document 2).

[0006] As shown in FIGS. 5 and 6, a radial gas expander 101 of the related art includes a casing 2, a rotating shaft 3 which is rotatably provided in the casing 2, and a plurality of impellers 4 which are fixed to the rotating shaft 3.

[0007] The radial gas expander 101 includes two gas expander sections 105a and 105b to expand the gas in the inner portion of the gas expander. The casing 2 is configured of a casing main body 6 and a diaphragm group 7 including a plurality of diaphragms which are built in the casing main body 6 and integrally connected. The gas expander sections 105a and 105b are configured to connect a plurality of diaphragms 8, 9a, 9b, 10a, 10b, 11a, 11b, 12a, 12b, 13a, and 13b, in which return bends connecting stages are formed, in an axial direction.

[0008] The expander section 105a and 105b includes gas introduction channels 120a and 120b communicating with suction ports 18a and 18b of the casing 2 and gas outflow channels 21a and 21b communicating with discharge ports 19a and 19b of the casing 2 in each section.

[0009] Among these, the gas introduction channels 120a and 120b are defined between the center diaphragm 8 which is provided in the center between two gas expander sections 105a and 105b and diaphragms 9a and 9b which are nearest to the center among the plurality of diaphragms except for the center diaphragm 8.

[0010] Nozzle blades 24, which generate a gas flow corresponding to profiles of the impellers 4, are provided in the upstream side of the impellers 4 on the gas introduction channel 120.

[0011] In the radial gas expander 101 having the above-described configuration, after the gas introduced via the suction port 18a from a plant (not shown) is expanded in one gas expander section 105a, the gas is introduced to the other gas expander section 105b via gas pipes 22 and the suction port 18b and is further expanded.

[0012] However, in the radial gas expander 101 of the related art, in order to secure channel widths of the gas introduction channel 120a and the gas introduction channel 120b, spacers 125 are installed in the upstream sides of the nozzle blades 24 of the gas introduction channels 120a and 120b.

RELATED ART DOCUMENTS

Patent Document

[0013] [Patent Document 1] Japanese Patent No. 3457828

[0014] [Patent Document 2] Japanese Unexamined Patent Application, First Publication No. 2011-43070

SUMMARY OF THE INVENTION

Problems to be Solved by the Invention

[0015] However, since the spacers 125 are installed in the upstream sides of the nozzle blades 24, there is a problem that a flow of the gas flowing into the nozzle blades 24 is disturbed. As shown in FIG. 6, when a streamline L of the introduced gas is disturbed by the spacers 125, loss occurs when the gas flows into the nozzle blades 24. Moreover, since the spacers are installed in the vicinity of inlets of the gas introduction channels 120a and 120b, reduction effects of an introduction channel width change are decreased due to differential pressure. Accordingly, a gas flow rate is changed according to the change of the channel width, a desired gas flow rate is not generated when the gas flows into the nozzle blades 24, and loss occurs. In this way, the spacers 125 impede expansion performance of the impellers 4, and furthermore, a decrease in the performance of the radial gas expander 101 occurs.

[0016] The present invention is made in consideration of the above-described circumstances, and an object thereof is to provide a radial gas expander capable of obtaining a desired performance. Moreover, an object thereof is to provide a radial gas expander capable of securing the channel widths of the gas introduction channels 120a and 120b and preventing walls of diaphragms configuring the casing from being deformed.

Means for Solving the Problems

[0017] In order to achieve the above-described objects, the present invention provides the following means.

[0018] According to a first aspect of the present invention, a radial gas expander includes: a rotating shaft; an impeller which is fixed to the rotating shaft; and a casing by which the rotating shaft is supported in a rotatable manner and in which an introduction channel introducing fluid to the impeller is formed. Moreover, the introduction channel includes: a nozzle blade which guides fluid flowing into the impeller; and a support member which is provided in an upstream side of the nozzle blade and which supports wall surfaces of the

introduction channel, wherein the wall surfaces are mutually opposed. In addition, the support member has a wing shape in a cross-sectional view.

[0019] According to this configuration, distances from lower ends of the mutually opposing wall surfaces of the introduction channel provided in the casing to supporting points are shortened due to the support member, a deformation amount of the opposing wall surfaces can be decreased, and a desired channel width can be secured. Moreover, since the support member is formed in the wing shape in a cross-sectional view, the flow of the fluid flowing into the nozzle blade can be prevented from being disturbed.

[0020] Moreover, according to a second aspect of the present invention, a radial gas expander includes: a rotating shaft; two sets of impeller groups which are configured of impellers fixed to the rotating shaft, and are symmetrically provided in an axial direction;

[0021] and a casing by which the rotating shaft is supported in a rotatable manner, and in which a first introduction channel which introduces fluid to an impeller group of a first set, and a second introduction channel which is provided to be adjacent to the first introduction channel and introduces the fluid discharged from the impeller group of the first set to an impeller group of a second set are formed. Moreover, the second introduction channel includes: a nozzle blade which guides fluid flowing into the impeller; and a support member which is provided in an upstream side of the nozzle blade and which supports wall surfaces of the second introduction channel, wherein the wall surfaces are mutually opposed, and the support member has a wing shape in a cross-sectional view.

[0022] According to this configuration, a desired channel width can be secured in the first introduction channel and the second introduction channel. Moreover, even when a pressure difference between the fluid flowing into the first introduction channel and the fluid flowing into the second introduction channel is large, the deformation amounts of a center wall and the mutually opposing wall surfaces of the second introduction channel can be decreased due to the support member, and since the support member is formed in the wing shape in a cross-sectional view, the flow of the fluid flowing into the nozzle blade can be prevented from being disturbed.

[0023] According to a third aspect of the present invention, a plurality of the support members are provided around the rotating shaft, and a width of the support member is formed to be gradually narrowed from an outer circumferential in a radial direction toward an inner circumferential so that clearances between the support members are equal in the radial direction.

[0024] According to this configuration, the fluid passing through the vicinity of the support member can be smoothly introduced to the nozzle blade without an increase in flow rate of the fluid.

[0025] Moreover, according to a fourth aspect of the present invention, the casing includes a casing main body and a plurality of diaphragms which are built in the casing main body and are integrally connected. The introduction channel is formed in the plurality of diaphragms.

[0026] According to this configuration, the casing, to which the nozzle blade and the support member formed in the wing shape are incorporated, can be easily assembled. Moreover, maintenance of an inner portion can be easily performed.

Effect of the Invention

[0027] According to the present invention, a radial gas expander, which obtains desired performance and can decrease the deformation amount of the wall of the diaphragm configuring the casing, can be provided.

BRIEF DESCRIPTION OF DRAWINGS

[0028] FIG. 1 is a cross-sectional view of a radial gas expander according to an embodiment of the present invention.

[0029] FIG. 2 is an enlarged view of a portion A of FIG. 1.

[0030] FIG. 3 is a view when viewed from B of FIG. 2.

[0031] FIG. 4 is a view showing a streamline of gas which flows around a support blade.

[0032] FIG. 5 is a cross-sectional view of a radial gas expander of the related art.

[0033] FIG. 6 is a view when viewed from C of FIG. 5, and is a view showing a streamline of gas which flows around a spacer.

DESCRIPTION OF EMBODIMENTS

[0034] An embodiment of the present invention will be described in detail with reference to the drawings.

[0035] As shown in FIGS. 1 and 2, a radial gas expander 1 according to the embodiment of the present invention includes a tubular casing 2, a rotating shaft 3 which is supported to the casing 2 in a rotatable manner and extends in an axial direction of the casing 2, and a plurality of impellers 4 which are fixed to the rotating shaft 3.

[0036] Moreover, in descriptions below, the axial direction of the casing 2 coincides with the axial direction of the rotating shaft 3. Moreover, the axial direction of the casing 2 and the axial direction of the rotating shaft 3 are simply referred to as the axial direction.

[0037] The radial gas expander 1 includes two sections to expand gas in the inner portion. That is, the radial gas expander 1 includes two gas expander sections 5a and 5b which are configured of a gas expander section 5a which is disposed in a first side of the axial direction and a gas expander section 5b which is disposed in a second side of the axial direction.

[0038] The radial gas expander 1 of the present embodiment has a configuration which obtains a rotating drive force by the gas introduced to the first gas expander section 5a and further obtains a rotating drive force by introducing the expanded gas discharged from the first gas expander section 5a to the second gas expander section 5b.

[0039] The casing 2 includes a casing main body 6 and a diaphragm group 7 which is provided in the inner portion of the casing main body 6. The diaphragm group 7 is configured of eleven diaphragms 8, 9a, 9b, 10a, 10b, 11a, 11b, 12a, 12b, 13a, 13b which are configured to be capable of being pulled off in the axial direction.

[0040] The first gas expander section 5a includes the diaphragm 8 which is disposed in the center and the diaphragms 9a, 10a, 11a, 12a, and 13a which are connected in a first side of the diaphragm 8. Moreover, the second gas expander section 5b includes the diaphragm 8 which is disposed in the center and the diaphragms 9b, 10b, 11b, 12b, and 13b which are connected in a second side of the diaphragm 8.

[0041] That is, two gas expander sections 5a and 5b have the central diaphragm 8 as a common component.

[0042] A suction port **18a** for introducing the gas to the first gas expander section **5a** and a suction port **18b** for introducing the gas to the second gas expander section **5b** are formed in the casing main body **6**.

[0043] Moreover, a discharge port **19a** for discharging the gas from the first gas expander section **5a** and a discharge port **19b** for discharging the gas from the second gas expander section **5b** are formed in the casing main body **6**.

[0044] In addition, the discharge port **19a** of the first gas expander section **5a** and the suction port **18b** of the second gas expander section **5b** are connected by a gas pipe **22**.

[0045] The rotating shaft **3** is disposed to penetrate the center of the diaphragm group **7**. Both end portions of the rotating shaft **3** are supported to diaphragms **13a** and **13b**, which are end plates of each of two gas expander sections **5a** and **5b**, in a rotatable manner via bearings **15**. Moreover, dry gas seals **16** are provided in the inner circumferences of the diaphragms **13a** and **13b** which are positioned inside each bearing **15**.

[0046] The plurality of impellers **4** are fixed onto the rotating shaft **3**, and impellers **4** of four stages configuring the first gas expander section **5a** and impellers **4** of four stages configuring the second gas expander section **5b** are arranged so as to be opposite to each other.

[0047] In each impeller **4**, when the opening portion which opens toward the outer circumferential in the radial direction of the impeller **4** is set to an inlet port **41** and the opening portion which opens toward the axial direction is set to a discharge port **42**, the impellers **4** of four stages configuring the first gas expander section **5a** and the impellers **4** of four stages configuring the second gas expander section **5b** are disposed so that in which the inlet ports **41** are positioned at sides of the central diaphragm **8**. That is, the impellers **4** configuring the first gas expander section **5a** are disposed so that the discharge port **42** faces the first side of the axial direction, and the impellers **4** configuring the second gas expander section **5b** are disposed so that the discharge port **42** faces the second side of the axial direction.

[0048] Moreover, although the same reference numerals are attached to the plurality of impellers **4**, the sizes of the plurality of impellers **4** are different from one another. Specifically, the sizes of the plurality of impellers **4** are changed to adapt to an expansion stroke of the gas.

[0049] A first introduction channel **20a** and a second introduction channel **20b** which communicate with the suction ports **18a** and **18b** respectively are formed between the diaphragms **9a** and **9b** which are positioned in both sides of the central diaphragm **8**. That is, the first introduction channel **20a** of the first gas expander section **5a** is formed between a wall surface **81** of the first side of the central diaphragm **8** and a wall surface **91** of the second side of the diaphragm **9a**. Moreover, the second introduction channel **20b** of the second gas expander section **5b** is formed between a wall surface **82** of the second side of the central diaphragm **8** and a wall surface **92** of the first side of the diaphragm **9b**.

[0050] Accordingly, the first introduction channel **20a** and the second introduction channel **20b** are disposed to be adjacent to each other via the central diaphragm **8**.

[0051] Similarly, outlet channels **21a** and **21b**, which communicate with the above-described discharge ports **19a** and **19b** respectively, are formed between the diaphragms **13a** and **13b** which are end plates and the diaphragms **12a** and **12b** adjacent to the diaphragms **13a** and **13b**.

[0052] Among these, the outlet channel **21a** of the first gas expander section **5a** communicates with the discharge port **19a** of the casing main body **6**, and the outlet channel **21b** of the second gas expander section **5b** communicates with the discharge port **19b** of the casing main body **6**.

[0053] A plurality of nozzle blades **24**, which guide the inflow of the gas to the impellers **4**, are provided in the upstream sides of the impellers **4** in each of the first introduction channel **20a** and the second introduction channel **20b**. In the present embodiment, **17** nozzle blades **24** are provided.

[0054] As shown in FIG. 3, the nozzle blades **24** are disposed at equal intervals in the circumferential direction. Each nozzle blade **24** has a wing shape in which a leading edge is round and a trailing edge is sharp in a cross-sectional shape when viewed in the axial direction. Moreover, in the nozzle blades **24**, the leading edges are disposed in the outer circumferential side of diaphragm in the circumferential direction, the trailing edges are disposed in the inner circumferential side of diaphragm in the circumferential direction, and the nozzle blades **24** are disposed to be inclined in a rotating direction in a rotation direction **R** with respect to the leading edges so that the trailing edges are along the rotation direction **R** of the rotating shaft **3**. That is, front ends are disposed in the upstream in the flow direction of the gas, and rear ends are disposed in the downstream.

[0055] In addition, for example, the cross-sectional shape of the nozzle blade **24** is determined using Computational Fluid Dynamic (CFD) analysis. Accordingly, the cross-sectional shape of the nozzle blade **24** of the present embodiment is formed to be asymmetrical with respect to a center line along the flow direction (hereinafter, referred to as a streamline direction) of the gas. That is, the nozzle blade **24** has a shape which smoothly introduces the flow of the gas to the impeller **4** to promote an operation which expands and accelerates the gas in the impeller **4**.

[0056] A plurality (seventeen sheets) of support blades **25** which are support members are provided in the further outer circumferential side of the nozzle blade **24**. Similar to the nozzle blades **24**, the support blades **25** are disposed at equal intervals in the circumferential direction. Each support blade **25** has a so-called wing shape in which a leading edge is round and a trailing edge is sharp in a cross-sectional shape when viewed in the axial direction. Moreover, in the support blades **25**, the leading edges are disposed in the outer circumferential side of diaphragm in the circumferential direction, the trailing edges are disposed in the inner circumferential sides of diaphragm in the circumferential direction, and the support blades **25** are disposed to be inclined in the rotating direction in the rotation direction **R** with respect to the leading edges so that the trailing edges are along the rotation direction **R**. That is, in the support blades **25**, the front ends are disposed in the upstream in the streamline direction, and the rear ends are disposed in the downstream.

[0057] Moreover, the shapes of the support blades **25** are formed so that a width of the support blade **25** is gradually narrowed from the outer circumferential in the radial direction toward the inner circumferential. Moreover, clearances **W** between the support blades **25** are approximately equal in the streamline direction, that is, the radial direction.

[0058] In addition, the cross-sectional shape of the support blade **25** is different from that of the nozzle blade **24** and is formed to be symmetrical with respect to the center line along the streamline direction. The shape, the position in the circumferential direction, and the position in the radial direction

of the support blade **25** are also determined using CFD or the like so as to influence the gas introduced to the nozzle blades **24** as little as possible, and particularly, it is preferable that the shape of the support blade has a shape along the streamline. Moreover, it is preferable that the length in the streamline direction be set within a range in which the influence to the streamline is small (which does not disturb the streamline) and be shortened as much as possible. In addition, since the streamline is changed according to a flow rate of the gas, it is preferable that the flow rate be appropriately determined according to the use conditions.

[0059] In the intermediate diaphragms **9a**, **10a**, **11a**, **12a**, **9b**, **10b**, **11b**, and **12b** in each of the gas expander sections **5a** and **5b**, a return bend (intermediate channel) **27** having an U-shaped cross-section is formed which connects the discharge port **42** of the impeller **4** in the preceding stage and the inlet port **41** of the impeller **4** in the subsequent stage. Seventeen sheets of return vanes **28** are provided in the return bend **27** so that the gas flow to the nozzle blade **24** positioned in the upstream side of the impeller **4** and the inlet port **41** of the impeller **4** in the subsequent stage is efficient.

[0060] An operation of the radial gas expander **1** having the above-described configuration will be described. First, the gas having high temperature and high pressure is introduced to the first gas expander section **5a** via the suction port **18a** from a predetermined plant. In the first gas expander section **5a**, the suction and expansion are repeated over four stages by the impellers **4** of four stages, and the gas is discharged from the discharge port **19a**. Subsequently, the gas is introduced to the second gas expander section **5b** via the gas pipe **22** and the suction port **18b**, is expanded in the second gas expander section **5b**, and is discharged from the discharge port **19b**.

[0061] The inflow gas flows in the axial direction in the inner portion of two gas expander sections **5a** and **5b**. However, according to the above-described configuration, the gas flows in the directions opposite to each other. That is, the gas flows from the second side of the axial direction to the first side of the axial direction in the gas expander section **5a**. Moreover, the gas flows from the first side of the axial direction to the second side of the axial direction in the gas expander section **5b**.

[0062] Here, compared to the pressure of the gas which is introduced to the first introduction channel **20a** via the suction port **18a**, the pressure of the gas which is introduced to the second introduction channel **20b** via the suction port **18b** is low. That is, the pressure difference between the pressures in the first introduction channel **20a** and the second introduction channel **20b** which are adjacent to each other via the diaphragm **8** is increased.

[0063] According to the above-described embodiment, the pressure difference between the pressure in the first introduction channel **20a** and the pressure in the second introduction channel **20b** is increased, and even when a force of a degree as to cause the deformation of the diaphragm **8** is applied to the central diaphragm **8** formed between the first introduction channel **20a** and the second introduction channel **20b**, deformation amount can be decreased by providing the support blades **25**. Moreover, the support blade **25** is formed in the wing shape in a cross-sectional view, and thus, as shown in FIG. 4, disturbance of the streamline **L** of the gas flowing around the support blades **25** can be decreased.

[0064] Moreover, the shapes of the support blades **25** are formed so that a width of the support blade **25** is gradually narrowed from the outer circumferential in the radial direc-

tion toward the inner circumferential. Moreover, clearances **W** between the support blades **25** are equal in the radial direction. As a result, the gas passing through the vicinities of the support blades **25** can be smoothly introduced to the nozzle blade **24** without requiring an increase in flow rate of the gas.

[0065] In addition, since the support blade **25** has the shape which is symmetrical in the streamline direction, the support blades can be more easily manufactured.

[0066] Moreover, since the plurality of diaphragm groups **7** configuring the casing **2** can be divided in the axial direction, maintenance in the inner portion can be easily performed.

[0067] In addition, the technical scope of the present invention is not limited to the above-described embodiments, and various modifications can be applied within a scope which does not depart from the gist of the present invention. For example, the support blade **25** may have an asymmetrical shape in the streamline direction.

INDUSTRIAL APPLICABILITY

[0068] According to the radial gas expander of the present invention, desired performance is obtained and the deformation amount of the wall of the diaphragm configuring the casing can be decreased.

DESCRIPTION OF REFERENCE NUMERALS

- [0069]** 1: radial gas expander
- [0070]** 2: casing
- [0071]** 3: rotating shaft
- [0072]** 4: impeller
- [0073]** 5: gas expander section
- [0074]** 6: casing main body
- [0075]** 7: diaphragm group
- [0076]** 8, 9a, 9b, 10a, 10b, 11a, 11b, 12a, 12b, 13a, and 13b: diaphragm
- [0077]** 20a: first introduction channel (introduction channel)
- [0078]** 20b: second introduction channel (introduction channel)
- [0079]** 24: nozzle blade
- [0080]** 25: support blade (support member)
- [0081]** 27: return bend

1. A radial gas expander comprising:

a rotating shaft;

an impeller which is fixed to the rotating shaft; and

a casing by which the rotating shaft is supported in a rotatable manner and in which an introduction channel introducing fluid to the impeller is formed,

wherein the introduction channel includes:

a nozzle blade which guides fluid flowing into the impeller; and

a support member which is provided in an upstream side of the nozzle blade and which supports wall surfaces of the introduction channel, wherein the wall surfaces are mutually opposed, and

wherein the support member has a wing shape in a cross-sectional view.

2. A radial gas expander comprising:

a rotating shaft;

two sets of impeller groups which are configured of impellers fixed to the rotating shaft, and are symmetrically provided in an axial direction; and

a casing by which the rotating shaft is supported in a rotatable manner, and in which a first introduction channel which introduces fluid to an impeller group of a first set, and a second introduction channel which is provided to be adjacent to the first introduction channel and introduces the fluid discharged from the impeller group of the first set to an impeller group of a second set are formed, wherein the second introduction channel includes:

a nozzle blade which guides fluid flowing into the impeller; and

a support member which is provided in an upstream side of the nozzle blade and which supports wall surfaces of the second introduction channel, wherein the wall surfaces are mutually opposed, and

wherein the support member has a wing shape in a cross-sectional view.

3. The radial gas expander according to claim 1,

wherein a plurality of the support members are provided around the rotating shaft, and a width of the support member is formed to be gradually narrowed from an outer circumferential in a radial direction toward an inner circumferential so that clearances between the support members are equal in the radial direction.

4. The radial gas expander according to claim 1,

wherein the casing includes a casing main body and a plurality of diaphragms which are built in the casing main body and are integrally connected, and

wherein the introduction channel is formed between the diaphragms.

5. The radial gas expander according to claim 2,

wherein a plurality of the support members are provided around the rotating shaft, and a width of the support member is formed to be gradually narrowed from an outer circumferential in a radial direction toward an inner circumferential so that clearances between the support members are equal in the radial direction.

6. The radial gas expander according to claim 2,

wherein the casing includes a casing main body and a plurality of diaphragms which are built in the casing main body and are integrally connected, and wherein the introduction channel is formed between the diaphragms.

7. The radial gas expander according to claim 3,

wherein the casing includes a casing main body and a plurality of diaphragms which are built in the casing main body and are integrally connected, and wherein the introduction channel is formed between the diaphragms.

8. The radial gas expander according to claim 5,

wherein the casing includes a casing main body and a plurality of diaphragms which are built in the casing main body and are integrally connected, and wherein the introduction channel is formed between the diaphragms.

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