



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

(43) Date of publication:
31.10.2012 Bulletin 2012/44

(21) Application number: **10839038.6**

(22) Date of filing: **30.09.2010**

(51) Int Cl.:
F01D 25/24 (2006.01) **F01D 1/06** (2006.01)
F01D 5/04 (2006.01) **F01D 9/02** (2006.01)
F02C 7/00 (2006.01)

(86) International application number:
PCT/JP2010/067065

(87) International publication number:
WO 2011/077801 (30.06.2011 Gazette 2011/26)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO SE SI SK SM TR

(30) Priority: **24.12.2009 JP 2009292600**

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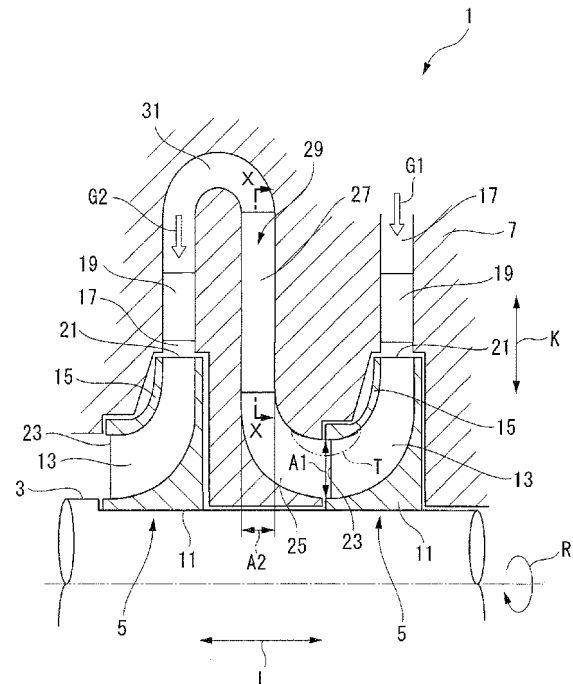
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(54) **MULTISTAGE RADIAL TURBINE**

(57) A multi-stage radial turbine that is capable of reducing the number of bearings and of improving the conversion efficiency is provided. Provided are a plurality of radial turbine rotor blades (5) that are attached at intervals to a single rotating shaft (3); a plurality of nozzles (19) that are individually installed on an upstream side of each of the radial turbine rotor blades and that accelerate a flow of fluid; a connecting channel portion (9) that connects gas an outlet portion (23) of the radial turbine rotor blade (5) on the front stage side and an upstream side of the nozzle (19) on the rear stage side, the connecting channel portion (9) being provided with a U-shaped bent portion (25) that deflects outward in the radial direction the flow of fluid that is made to flow out from the radial turbine rotor blade (5) in the shaft direction; a vane portion having a plurality of deflecting vanes (27) that deflect the flow of fluid inward in a rotation direction (R) while guiding the flow of fluid from the U-shaped bent portion (25) outward in the radial direction; and a return bent portion (31) that deflects inward in the radial direction the flow that is made to flow out from the vane portion (29) while swirling outward in the radial direction.

FIG. 1



Description

{Technical Field}

[0001] The present invention relates to a multi-stage radial turbine.

{Background Art}

[0002] A radial turbine has a configuration in which a plurality of centrifugal blades are secured to a hub that is secured to a rotating shaft, and air or gas, which is a working fluid that flows inward from an outer peripheral side in the radial direction by using the space between substantially parallel circular plates as a flow channel, acts on the centrifugal blades, causing the hub to rotate, and flows out in substantially a shaft direction.

Since it is possible to obtain a high expansion ratio with a single stage, a radial turbine is generally employed with a single-stage configuration.

[0003] In order to effectively utilize the energy of a working fluid that shows a large heat drop at a high pressure ratio, it has been proposed to utilize a multi-stage configuration in a radial turbine, that is, to utilize the working fluid in series.

For example, as disclosed in Patent Literature 1, it has been proposed to arrange a plurality of radial turbines in a row, wherein a flow of fluid expelled from one radial turbine is introduced into an inlet of the next radial turbine to recover the energy of the working fluid. In this case, each radial turbine has a shaft with a differing rotational speed, and work is performed by using the rotation of the individual shafts.

{Citation List}

{Patent Literature}

[0004]

{PTL 1} Japanese Unexamined Patent Application, Publication No. Sho 59-79096.

{Summary of Invention}

{Technical Problem}

[0005] With the disclosure in Patent Literature 1, because each radial turbine has a rotating shaft, the numbers of bearings and shaft seals increase. Because of this, bearing loss and leakage loss increase; therefore, it has not been possible to efficiently convert the energy of a high-pressure working fluid into rotational motive power.

For example, when motive power is supplied for one operation, a rotational force is transmitted from the individual output shafts to a shaft for that operation by, for example, employing gears; therefore, there is a problem in

that the structure thereof becomes large.

[0006] In light of the above-described circumstances, an object of the present invention is to provide a multi-stage turbine that is capable of reducing the number of bearings and of improving conversion efficiency.

{Solution to problem}

[0007] In order to solve the above-described problems, the present invention employs the following solution.

Specifically, an aspect of the present invention is a multi-stage radial turbine including a single rotating shaft; a plurality of radial turbine rotor blades that are attached at intervals to the rotating shaft and that cause a flow of fluid that flows in from an outer peripheral side in a radial direction to flow out in substantially a shaft direction; a plurality of nozzles that are individually installed on an upstream side of each of the radial turbine rotor blades and that accelerate the flow of fluid in a rotation direction; a connecting channel portion that connects an outlet portion of the radial turbine rotor blade on a front stage side and an upstream side of the nozzle on a rear stage side, the connecting channel portion being provided with a U-shaped bent portion that deflects outward in the radial direction the flow of fluid that is made to flow out from the radial turbine rotor blade in the shaft direction; a vane portion having a plurality of deflecting vanes that deflect the flow of fluid in the rotation direction of the radial turbine rotor blades while guiding the flow of fluid from the U-shaped bent portion outward in the radial direction; and a return bent portion that deflects inward in the radial direction the flow that flows out from the vane portion while swirling outward in the radial direction.

[0008] With this aspect, the flow of fluid that flows in from the outer peripheral side in the radial direction is accelerated in the rotation direction by the nozzle and is introduced to the outer peripheral portion of the radial turbine rotor blade. The fluid that has been introduced to the radial turbine rotor blade is made to flow out in the shaft direction from the radial turbine rotor blade, passes through the U-shaped bent portion to be deflected outward in the radial direction, and is subsequently deflected in the rotation direction of the radial turbine rotor blade while being guided outward in the radial direction with the deflecting vanes when passing through the vane portion. The fluid that is made to flow out from the vane portion while swirling outward in the radial direction passes through the return bent portion to be deflected inward in the radial direction and is made to flow into the nozzle of the next stage from the outer peripheral side in the radial direction. The flow of fluid repeatedly undergoes these processes and is made to flow out in, for example, substantially the shaft direction from the radial turbine rotor blade of the final stage. Consequently, the rotation of each radial turbine rotor blade is transmitted to the single rotating shaft, and the rotating shaft is rotated.

Since the plurality of radial turbine rotor blades are attached at intervals to the single rotating shaft in this way,

bearings and shaft seals need to be provided only for the single rotating shaft, and, naturally, the numbers thereof can be reduced as compared with a case in which a plurality of rotating shafts are provided.

Therefore, because the bearing loss and the leakage loss can be reduced, the energy of high-pressure working fluid can be efficiently converted to a rotational motive force. Furthermore, the structures of the radial turbine rotor blades and the rotating shaft can be made similar to the conventional structures, and it is possible to suppress an increase in the size of the structure of the multi-stage radial turbine.

[0009] In the above-described aspect, the U-shaped bent portion may be configured such that a downstream-portion channel area at an end portion closer to the vane portion is made smaller than an upstream-portion channel area at an end portion closer to the radial turbine rotor blade.

[0010] Since the U-shaped bent portion is configured in this way such that the downstream-portion channel area at the end portion closer to the vane portion is smaller than the upstream-portion channel area at the end portion closer to the radial turbine rotor blade, it is possible to accelerate the flow of fluid at the U-shaped bent portion.

By doing so, it is possible to suppress flow separation due to the influence of the low-flow-speed regions that may occur at the outlet portions of the radial turbine rotor blade.

[0011] With the above-described configuration, it is preferable that the downstream-portion channel area be set to be equal to or less than 0.8 to 0.9 times the size of the upstream-portion channel area.

[0012] The low-flow-speed regions that may occur at the outlet portions of the radial turbine rotor blade generally occupy 10 to 20% of the channel area at the outlet portions of the radial turbine rotor blade.

With this aspect, because the flow of fluid can be accelerated at the U-shaped bent portion by at least 10 to 20%, it is possible to alleviate the influence of this low-flow-speed region portion.

[0013] In the above-described aspect, it is preferable that the deflecting vanes be configured to form involute curves.

[0014] With this configuration, a change between the channel area at the inlet portion between the deflecting vanes of the vane portion and the channel area at the outlet portion thereof can be reduced.

Accordingly, it is possible to reduce the loss due to deceleration, and the loss due to deflection at the vane portion can be reduced.

{Advantageous Effects of Invention}

[0015] With the present invention, because a plurality of radial turbine rotor blades are attached at intervals to a single rotating shaft, bearings and shaft seals need to be provided only for a single rotating shaft, and, naturally,

the numbers thereof can be reduced as compared with a case in which a plurality of rotating shafts are provided. Therefore, because bearing loss and leakage loss can be reduced, it is possible to efficiently convert the energy of a high-pressure working fluid to rotational motive power.

Furthermore, structures of the radial turbine rotor blades and the rotating shaft can be made similar to conventional structures, and an increase in the size of structures of the multi-stage radial turbine can be suppressed.

{Brief Description of Drawings}

[0016]

{Fig. 1} Fig. 1 is a partial sectional view showing, in outline, the configuration of a single-shaft multi-stage radial turbine (multi-stage radial turbine) according to an embodiment of the present invention.

{Fig. 2} Fig. 2 is a sectional view taken along X-X in Fig. 1.

{Description of Embodiments}

[0017] A single-shaft multi-stage radial turbine 1 according to an embodiment of the present invention will be described below with reference to Figs. 1 and 2.

Fig. 1 is a partial sectional view, showing, in outline, the configuration of the single-shaft multi-stage radial turbine 1. Fig. 2 is a sectional view taken along X-X in Fig. 1.

[0018] The single-shaft multi-stage radial turbine 1 is provided with a rotating shaft 3, a plurality of, for example, two, radial turbine rotor blades 5, a casing 7, and a connecting flow channel portion 9.

The rotating shaft 3 is supported on the casing 7 at one end by a radial bearing (not shown), and the other end thereof is supported by a radial bearing (not shown) and a thrust bearing (not shown).

The plurality of radial turbine rotor blades 5 are attached at intervals in a shaft direction L of the rotating shaft 3 and make a flow of fluid that has flowed in from an outer peripheral side in a radial direction K flow out substantially in the shaft direction L.

[0019] The radial turbine rotor blades 5 are provided with hubs 11 that are secured to the rotating shaft 3, numerous centrifugal blades 13 that are secured on surfaces of the hubs 11 at equal intervals in the circumferential direction, and shrouds 15 that are attached at tips of the centrifugal blades 13.

In the radial turbine rotor blades 5, gas channels through which gas (working fluid) passes are defined by the hubs 11, the centrifugal blades 13, and the shrouds 15. Portions of the gas channels that are located away from the rotating shaft 3 serve as gas inlet portions 21, and portions thereof closer to the rotating shaft 3 serve as gas outlet portions (outlet portions) 23.

[0020] A doughnut-shaped inlet channel 17 is formed at a portion of the casing 7 located on the outer peripheral

side of the gas inlet portions 21 in the radial direction K. The inlet channel 17 is configured so that the gas flows inward in the radial direction K from the outer side of the radial direction K.

An airfoil nozzle 19 that accelerates a gas flow in a rotation direction R is installed on the downstream side of the inlet channel 17, in other words, on an upstream side of the radial turbine rotor blade 5.

[0021] The connecting channel portion 9 is a channel provided in the casing 7 that connect the gas outlet portions 23 of the radial turbine rotor blade 5 on a front-stage side and an upstream side of the nozzle 19 on a rear-stage side.

The connecting channel portion 9 is provided with a U-shaped bent portion 25 that deflects a gas flow that has flowed out in the shaft direction L from the radial turbine rotor blade 5 outward in the radial direction K, a vane portion 29 that has a plurality of deflecting vanes 27 that deflect the gas flow from the U-shaped bent portion 25 in the rotation direction R of the radial turbine rotor blades 5, while guiding the gas flow outward in the radial direction K, and a return bent portion 31 that deflects inward in the radial direction K the gas that flows out from the vane portion 29 while swirling outward in the radial direction K.

[0022] A downstream-portion channel area A2 at an end portion of the U-shaped bent portion 25 closer to the vane portion 29 is set to have at most 0.8 to 0.9 times the area of an upstream-portion channel area A1 at an end portion closer to the radial turbine rotor blade 5. In other words, the downstream-portion channel area A2 is made smaller than the upstream-portion channel area A1.

This ratio is determined in consideration of low-flow-speed regions T that occur at least at the outlet portions of the radial turbine rotor blade 5. The low-speed regions T generally occur so as to occupy 10 to 20% of an outlet-portion channel area, that is, the upstream-portion channel area A1, of the radial turbine rotor blade 5.

Although it is preferable that the downstream-portion channel area A2 be smaller than the upstream-portion channel area A1, it may be made substantially equal in size or larger, depending of the usage circumstances.

[0023] As shown in Fig. 2, the deflecting vanes 27 of the vane portions 29 are configured so as to form involute curves.

The amount of change between a channel area A3 at an inlet portion between the deflecting vanes 27 of the vane portion 29 and a channel area A4 at an outlet portion thereof can be made considerably smaller as compared with the amount of change between a channel area A5 at an inlet portion between deflecting vanes 33, which linearly expand as shown with two-dot chain lines in Fig. 2, and a channel area A6 at an outlet portion thereof.

Although it is preferable that the deflecting vanes 27 form the involute curves, they are not limited thereto, and they may be appropriately shaped.

[0024] The operation of the single-shaft multi-stage ra-

dial turbine 1 according to this embodiment, configured as above, will now be described.

A gas flow G1 that is supplied from a gas source (not shown) to the inlet channel 17 of a first stage passes through the inlet channel 17 and flows inward in the radial direction K into the nozzle 19 from the outer peripheral side in the radial direction K.

The nozzle 19 accelerates this gas flow G1 in the circumferential direction R and supplies it to the gas inlet portions 21 located at an outer peripheral portion of the radial turbine rotor blade 5.

[0025] The gas that has been introduced to the radial turbine rotor blade 5 is expanded when passing through the gas channel defined by the hub 11, the centrifugal blades 13, and the shroud 15. The centrifugal blades 13 are pushed by means of this expansion and move in the rotation direction R. Since the hub 11 is rotationally moved in the rotation direction R due to this movement of the centrifugal blades 13, the rotating shaft 3 is rotated.

The gas flow that has flowed out in the shaft direction L from the gas outlet portions 23 of the radial turbine rotor blade passes through the U-shaped bent portion 25 and is deflected outward in the radial direction K.

[0026] At this time, because the downstream-portion channel area A2 of the U-shaped bent portion 25 is set to be at most 0.8 to 0.9 times the area of the upstream-portion channel area A1, the gas flow that passes through the U-shaped bent portion 25 is accelerated by at least 10 to 20%, corresponding to the reduction of the channel area, for example.

Although the low-speed regions T that occupy 10 to 20% of the channel area generally occur in front of and behind the gas outlet portions 23 of the radial turbine rotor blade 5, because at least a corresponding level of acceleration occurs at the U-shaped bent portion 25, it is possible to substantially eliminate the low-speed regions T. In other words, the influence of the low-flow-speed regions T can be alleviated.

[0027] Because the influence of the low-speed regions T can be alleviated in this way, by concentrating the low-flow-speed regions T that occur at the gas outlet portions 23 of the radial turbine rotor blade 5, it is possible suppress the occurrence of flow separation by means of the curvature of a surface of the shroud 15 on the downstream side.

Furthermore, in the case in which the downstream-portion channel area A2 can be made smaller than 0.8 to 0.9 times the area of the upstream-portion channel area A1, it is possible to further suppress flow separation; therefore, the curvatures of individual portions can be reduced further.

By doing so, the total shaft length of the multi-stage configuration in particular can be made shorter; therefore, the total length of the single-shaft radial turbine 1 can be made shorter, and the single-shaft radial turbine 1 can be made more compact.

[0028] When the gas flow subsequently passes through the vane portion 29, it is deflected in the rotation

direction R of the radial turbine rotor blade 5 while being guided outward in the radial direction K by the deflecting vanes 27.

At this time, because the deflecting vanes 27 are configured to form involute curves, the amount of change between the channel area A3 at the inlet portion between the deflecting vanes 27 and the channel area A4 at the outlet portion thereof is made small. Accordingly, at the vane portion 29, it is possible to reduce the loss due to deceleration of the gas flow and the loss due to deflection. Furthermore, by adjusting the angles of the deflecting vanes 27, a flow angle at the inlet of the nozzle 19 on the downstream side can be adjusted. For example, if the flow angle at the inlet of the nozzle 19 is adjusted to be 40 to 50 degrees in the circumferential direction, the inlet-collision loss at the nozzle 19 can be reduced.

[0029] The flow that flows out from the vane portion 29 outward in the radial direction K while swirling passes through the return bent portion 31, is deflected inward in the radial direction K, and is made to flow into the inlet channel 17 of the next stage from the outer peripheral side in the radial direction K.

A gas flow G2 supplied from the return bent portion 31 passes through the inlet channel 17 and flows into the nozzle 19 inward in the radial direction K from the outer peripheral side in the radial direction K.

The nozzle 19 accelerates this gas flow G2 in the circumferential direction R and supplies it to the gas inlet portions 21 located at the outer peripheral portion of the radial turbine rotor blade 5.

[0030] The gas that is introduced to the radial turbine rotor blade 5 is expanded when passing through the gas channel defined by the hub 11, the centrifugal blades 13, and the shroud 15. The centrifugal blades 13 are pushed by means of this expansion and move in the rotation direction R. Since the hub 11 is rotationally moved in the rotation direction R due to this movement of the centrifugal blades 13, the rotating shaft 3 is rotated.

The gas flow that has flowed out in the shaft direction L from the gas outlet portions 23 of the radial turbine rotor blade passes through a discharge channel (not shown) and is discharged to the exterior of the single-shaft radial turbine 1.

[0031] Since the plurality of radial turbine rotor blades 5 are attached at intervals to the single rotating shaft 3 in this way, bearings and shaft seals need to be provided only for the single rotating shaft 3, and, naturally, the numbers thereof can be reduced as compared with a case in which a plurality of rotating shafts are provided. Therefore, because bearing loss and leakage loss can be reduced, the energy of high-pressure working fluid can efficiently be converted to a rotational motive force. Moreover, the heat drop thereof can be converted to a rotational motive force with one single-shaft radial turbine.

Furthermore, together with the fact that the structures of the radial turbine rotor blades 5 and the rotating shaft 3 can be made similar to the conventional structures, it is

possible to suppress an increase in the size of the structures in the single-shaft radial turbine 1.

[0032] The present invention is not limited to the above-described embodiment, various modifications may be made within a range that does not depart from the spirit of the present invention.

For example, although two stages of the radial turbine rotor blades 5 are employed in this embodiment, this may be changed to three stages or greater. In this case, the radial turbine rotor blades 5 that are adjacent to each other are connected with the connecting channel portions 9.

{Reference Signs List}

[0033]

1	single-shaft radial turbine
3	rotating shaft
5	radial turbine rotor blade
9	connecting channel portion
19	nozzle
25	U-shaped bent portion
27	deflection vane
29	vane portion
31	return bent portion
A1	upstream-portion channel area
A2	downstream-portion channel area
K	radial direction
L	shaft direction
R	rotation direction

Claims

1. A multi-stage radial turbine comprising:

- a single rotating shaft;
- a plurality of radial turbine rotor blades that are attached at intervals to the rotating shaft and that cause a flow of fluid that flows in from an outer peripheral side in a radial direction to flow out in substantially a shaft direction;
- a plurality of nozzles that are individually installed on an upstream side of each of the radial turbine rotor blades and that accelerate the flow of fluid in a rotation direction;
- a connecting channel portion that connects an outlet portion of the radial turbine rotor blade on a front stage side and an upstream side of the nozzle on a rear stage side,
- the connecting channel portion being provided with a U-shaped bent portion that deflects outward in the radial direction the flow of fluid that is made to flow out from the radial turbine rotor blade in the shaft direction;
- a vane portion having a plurality of deflecting vanes that deflect the flow of fluid in the rotation

direction of the radial turbine rotor blades while guiding the flow of fluid from the U-shaped bent portion outward in the radial direction; and a return bent portion that deflects inward in the radial direction the flow that flows out from the vane portion while swirling outward in the radial direction.

2. A multi-stage radial turbine according to Claim 1, wherein the U-shaped bent portion is configured such that a downstream-portion channel area at an end portion closer to the vane portion is made smaller than an upstream-portion channel area at an end portion closer to the radial turbine rotor blade.
3. A multi-stage turbine according to Claim 2, wherein the downstream-portion channel area is set to be equal to or less than 0.8 to 0.9 times the size of the upstream-portion channel area.
4. A multi-stage radial turbine according to any one of Claims 1 to 3, wherein the deflecting vanes are configured to form involute curves.

FIG. 1

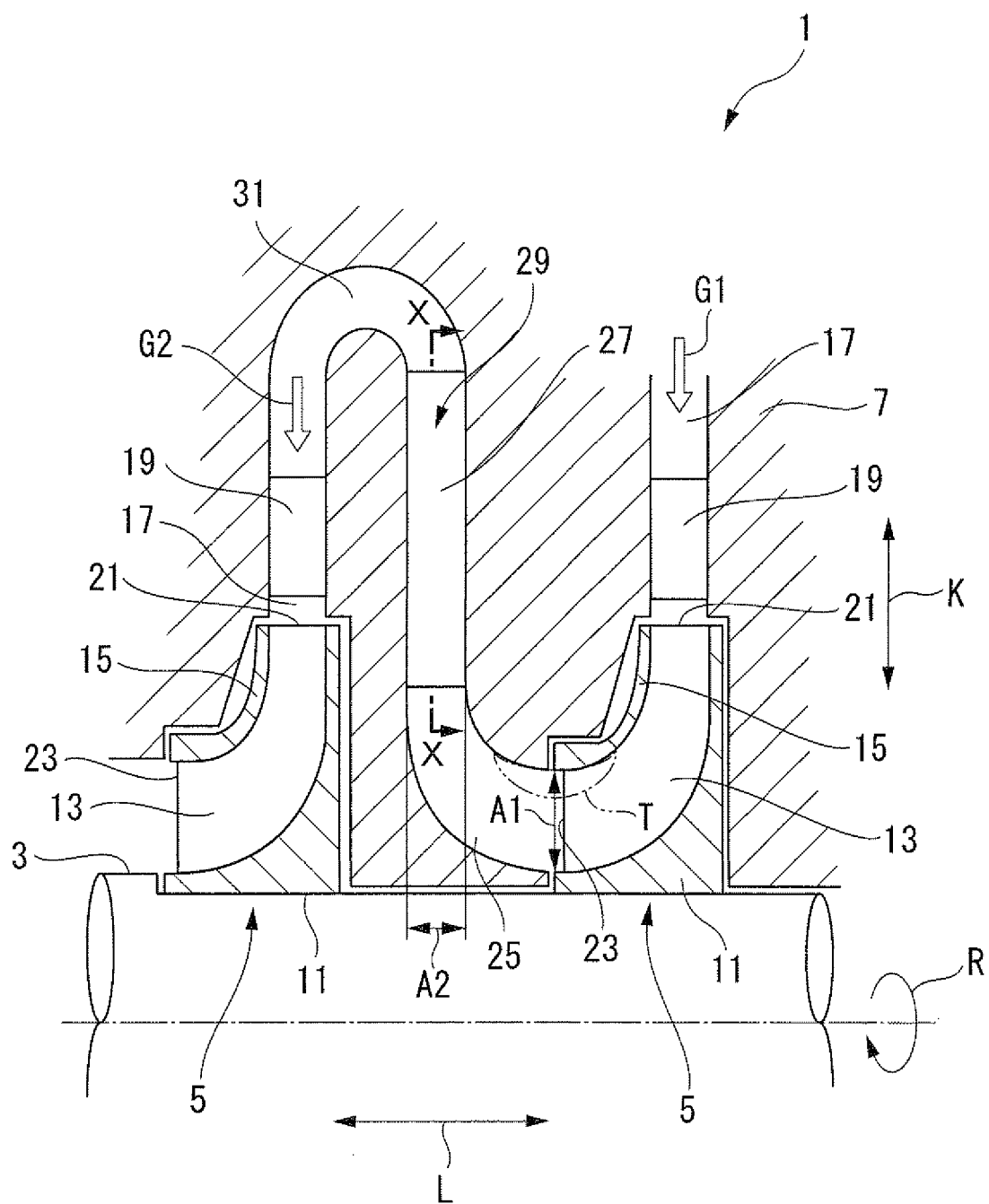
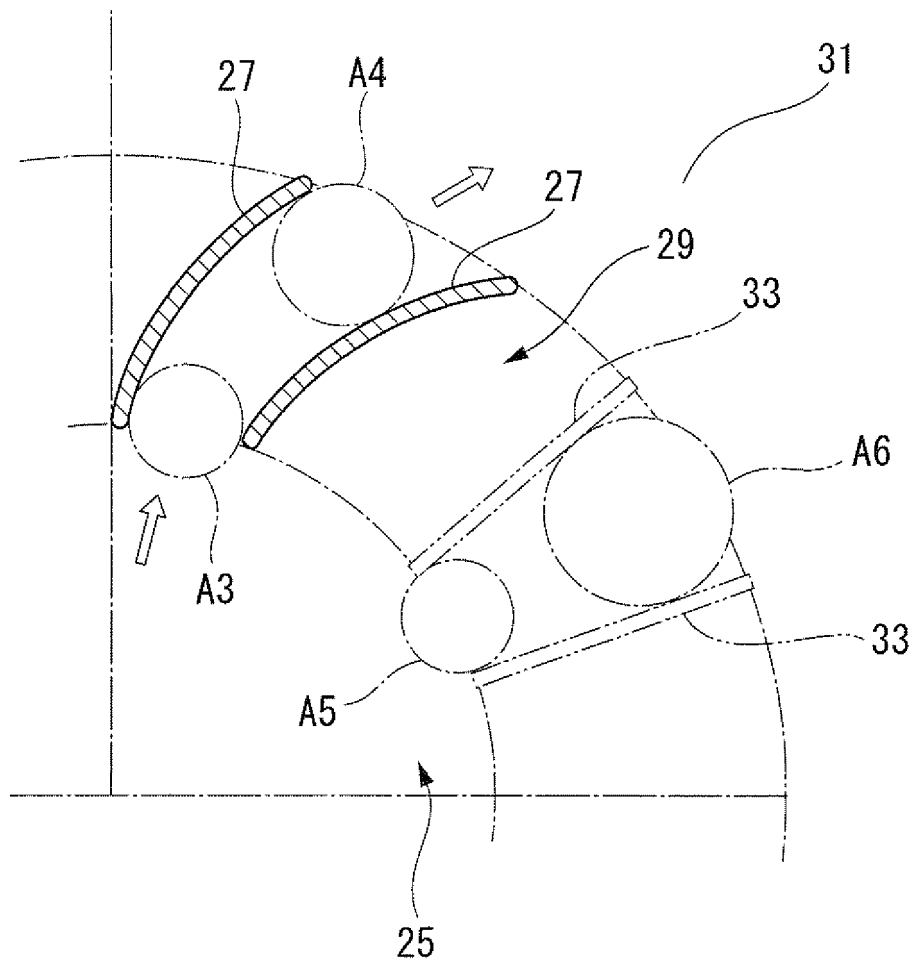


FIG. 2



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2010/067065

A. CLASSIFICATION OF SUBJECT MATTER

F01D25/24(2006.01)i, F01D1/06(2006.01)i, F01D5/04(2006.01)i, F01D9/02(2006.01)i, F02C7/00(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)
F01D25/24, F01D1/06, F01D5/04, F01D9/02, F02C7/00

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	1996-2010
Kokai Jitsuyo Shinan Koho	1971-2010	Toroku Jitsuyo Shinan Koho	1994-2010

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4130989 A (Richard E. WIRTH), 26 December 1978 (26.12.1978), column 3, line 1 to column 7, line 14; fig. 1, 3, 6 & US 3771312 A	1-4
Y	US 3226085 A (Herbert BACHL), 28 December 1965 (28.12.1965), column 3, line 36 to column 4, line 32; fig. 1 to 3 (Family: none)	1-4
Y	JP 64-000561 B2 (Ebara Corp.), 06 January 1989 (06.01.1989), column 3, lines 5 to 17; fig. 2, 3 (Family: none)	2-4

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

* Special categories of cited documents:

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Date of the actual completion of the international search
13 December, 2010 (13.12.10)

Date of mailing of the international search report
28 December, 2010 (28.12.10)

Name and mailing address of the ISA/
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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2010/067065

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2007-503546 A (TTL Dynamics Ltd.), 22 February 2007 (22.02.2007), paragraphs [0117] to [0119]; fig. 4 & US 2007/0007771 A1 & GB 2405448 A & EP 1668226 A & WO 2005/021936 A2 & DE 602004011087 D	1-4
A	JP 61-116031 A (Kobe Steel, Ltd.), 03 June 1986 (03.06.1986), page 2, lower right column, line 14 to page 3, lower right column, line 8; fig. 1, 2, 5 (Family: none)	1-4

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REFERENCES CITED IN THE DESCRIPTION

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