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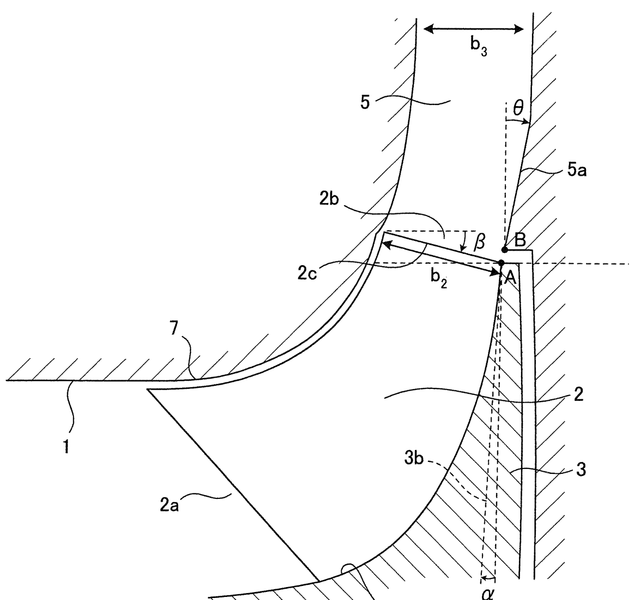
(54) **CENTRIFUGAL COMPRESSOR**

(57) A centrifugal compressor for which θ-α>0° and 0°<θ<34°, when the angle formed by a diffuser inlet hub-side line (5a) and the radial direction at a point B in the meridian plane is θ, and the angle formed by a tangent line (3b) and the radial direction at a point A of an impeller hub-side line (3a) nearest the inlet of the diffuser (5) is α. Thus, skewing of the velocity distribution of a gas within the diffuser of the centrifugal compressor is eliminated.

Fig. 1



EP 2 806 170 A1

Description

TECHNICAL FIELD

[0001] The present invention relates to a centrifugal compressor, and particularly to a centrifugal compressor with a large flow rate.

BACKGROUND ART

[0002] For improving the performances of products such as superchargers, gas turbines, and industrial compressors, it is a critical issue to increase the flow rate. Increasing the flow rate of a centrifugal compressor means to increase the discharge flow rate of a compressor with the same shell size, and further of an impeller with the same outer diameter.

[0003] One of the problems associated with the increase in flow rate is a decrease in efficiency. For this reason, a technique of increasing the flow rate while suppressing the decrease in efficiency is industrially very significant.

[0004] A conventional centrifugal compressor will be described by using FIG. 6. The centrifugal compressor mainly includes a suction inlet 1, an impeller 2, a hub 3, a rotary shaft 4, a diffuser 5, and a scroll 6.

[0005] The impeller 2 is connected to the rotary shaft 4 via the hub 3. The diffuser 5 is provided downstream of the impeller 2, has a flow passage extending in a direction away from the rotary shaft 4, and has an outlet directed in a radial direction in a meridian plane. Moreover, the scroll 6 is provided downstream of the diffuser 5 and communicates with the outlet of the diffuser 5.

[0006] The suction inlet 1 plays a roll of guiding a gas to the impeller 2. The centrifugal compressor is configured such that the gas guided to the impeller 2 is sucked into the centrifugal compressor by the impeller 2 being rotated by the rotary shaft 4. The velocity of the gas having passed through the impeller 2 is decreased, and the pressure of the gas is increased, in the diffuser 5. The gas having passed through the diffuser 5 flows into the scroll 6, and thereafter flows into a discharge port, which is not shown. In this way, the centrifugal compressor converts the kinetic energy of the gas to a pressure.

[0007] FIG. 7 is a cross-sectional view of the diffuser 5 and the impeller 2 of the conventional centrifugal compressor. The more the velocity vector of the gas (the arrow in the figure) is directed in a radial direction in the meridian plane, the less the energy loss is. However, a large flow rate causes the velocity distribution of the gas sacked through an impeller inlet 2a to be skewed to the hub 3 side at an impeller outlet 2b. As a result, the velocity vector is inclined toward an axial direction from the radial direction. In addition, if the gas flows further inside the diffuser 5 in this state, the velocity distribution is further skewed to become a cause of occurrence of shear stress, reducing the amount of static pressure recovery, and in turn leading to a decrease in efficiency of the entire compressor.

[0008] To solve the above-described problem, there is a method of bringing the velocity distribution of the gas into a more uniform distribution by providing the inside of the diffuser with a guide blade (see Patent Document 1) or a guide flow passage to the impeller inlet (see Patent Document 2).

PRIOR ART DOCUMENTS

PATENT DOCUMENTS

[0009]

PATENT DOCUMENT 1: Japanese Patent No. 2569143
PATENT DOCUMENT 2: Japanese Patent No. 2703055

SUMMARY OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0010] However, the above-described apparatuses require that new mechanisms should be provided in the diffuser, and have a possibility that the production costs and working hours are wasted.

[0011] In view of this, an object of the present invention is to solve the problems of the conventional techniques and to achieve higher efficiency in a centrifugal compressor with a large flow rate, not by providing a new mechanism, but by changing a shape of a diffuser.

MEANS FOR SOLVING THE PROBLEMS

[0012] A centrifugal compressor according to a first invention for solving the above-described problems is a centrifugal compressor comprising:

an impeller connected to a rotary shaft via a hub; and a diffuser provided downstream of the impeller, the diffuser having a flow passage which extends in a direction away from the rotary shaft and an outlet which is directed in a radial direction in a meridian plane, characterized in that
the centrifugal compressor satisfies $\theta-\alpha>0°$
where
θ is an angle formed by a diffuser inlet hub-side line with the radial direction in the meridian plane at a point closest to an outlet of the impeller in the diffuser inlet hub-side line, the diffuser inlet hub-side line being a line on the hub side in an inlet of the diffuser, and
α is an angle formed by a tangent line of an impeller hub-side line with the radial direction in the meridian plane at a point closest to the inlet of the diffuser in the impeller hub-side line, the impeller hub-side line being a line on the hub side in the impeller.

[0013] A centrifugal compressor according to a second invention for solving the above-described problems is the centrifugal compressor according to the first invention, characterized in that the 9 is such that 0°<θ<34°.

[0014] A centrifugal compressor according to a third invention for solving the above-described problems is the centrifugal compressor according to the first or second invention, characterized in that
the diffuser inlet hub-side line is a concave curved line.

EFFECT OF THE INVENTION

[0015] According to the centrifugal compressor of the first invention, since θ-α>0°, skewing of the velocity distribution of the gas is eliminated, and accordingly a decrease in amount of static pressure recovery is suppressed. Therefore, a higher efficiency of the entire compressor can be achieved.

[0016] According to the centrifugal compressor of the second invention, since 0°<θ<34°, the skewing of the velocity distribution of the gas can be further eliminated.

[0017] According to the centrifugal compressor of the third invention, since the diffuser inlet hub-side line is a concave curved line, a stagnation region inside the diffuser is reduced. Therefore, a further higher efficiency can be achieved.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018]

[FIG. 1] FIG. 1 is a cross-sectional view of a diffuser and an impeller of a centrifugal compressor according to Embodiment 1 of the present invention.
[FIG. 2] FIG. 2 is a graph showing a relationship between θ and an efficiency improvement rate of the centrifugal compressor according to Embodiment 1 of the present invention.
[FIG. 3] FIG. 3 is a cross-sectional view of a diffuser and an impeller of a centrifugal compressor according to Embodiment 2 of the present invention.
[FIG. 4] FIG. 4 is a schematic view showing differences between the centrifugal compressor according to Embodiment 1 of the present invention and the centrifugal compressor according to Embodiment 2 of the present invention.
[FIG. 5] FIG. 5 is a schematic diagram showing a relationship between 8 and α of the centrifugal compressor according to Embodiment 1 or 2 of the present invention.
[FIG. 6] FIG. 6 is a cross-sectional view of a conventional centrifugal compressor.
[FIG. 7] FIG. 7 is a cross-sectional view of a diffuser and an impeller of the conventional centrifugal compressor.

MODES FOR CARRYING OUT THE INVENTION

[0019] Hereinafter, a centrifugal compressor according to the present invention will be described referring to embodiments by use of the drawings.

Embodiment 1

[0020] An apparatus according to Embodiment 1 of the present invention will be described by use of FIG. 1. The apparatus mainly includes a suction inlet 1, an impeller 2, a hub 3, a rotary shaft 4, a diffuser 5, and a scroll 6, as in the case of the conventional centrifugal compressor. The impeller 2 is connected to the rotary shaft 4 via the hub 3. In addition, the diffuser 5 is provided downstream of the impeller 2, has a flow passage directed in a direction away from the rotary shaft 4, and has an outlet directed in a radial direction in a meridian plane. Moreover, the scroll 6 is provided downstream of the diffuser 5, and communicates with an outlet of the diffuser 5. Note that the rotary shaft 4 and the scroll 6 are not shown in FIG. 1, but are assumed to be the same as those of the conventional technical.

[0021] Furthermore, like the conventional technique, the suction inlet 1 plays a role of guiding a gas to the impeller 2. The centrifugal compressor is configured such that the gas guided to the impeller 2 is sucked into the centrifugal compressor by the impeller 2 being rotated by the rotary shaft 4. The velocity of the gas having passed through the impeller 2 is decreased, and the pressure of the gas is increased, in the diffuser 5. The gas having passed through the diffuser 5 flows into the scroll 6, and thereafter flows into a discharge port.

[0022] Here, a line on the hub 3 side in the inlet of the diffuser 5 (hereinafter, stated as a diffuser inlet hub-side line 5a) is inclined toward an axial direction from the radial direction in the meridian plane. At this time, an angle formed by the diffuser inlet hub-side line 5a with the radial direction at a point B closest to the impeller outlet 2b in the diffuser inlet hub-side line 5a is represented by θ.

[0023] Next, an angle formed by a tangent line 3b of a line on the hub 3 side in the impeller 2 (hereinafter, stated as an impeller hub-side line 3a) with the radial direction at a point A closest to an inlet of the diffuser 5 in the impeller hub-side line 3a is represented by α.

[0024] The conventional technique is set such that θ=α in order to smoothly connect the impeller hub-side line 3a and the diffuser inlet hub-side line 5a. On the other hand, the present apparatus is set such that θ-α>0° as shown in FIG. 5, and further θ is set such that 0°<θ<34°.

[0025] In addition, an angle formed by the impeller rear edge 2c with the axial direction is represented by β. Here, β has not necessary to be limited, but is set such that 0 °≤β≤35°, which is a value used in a general centrifugal compressor.

[0026] Note that a line of the shroud 7 is also inclined in conjunction with the inclination of θ to confirm with a diffuser width ratio of the conventional shape. The diffuser width ratio is b_3/b_2 (see FIG. 1), and has a value set for each impeller. In general, the value of the diffuser width ratio is set such that b_3/b_2=0.6 to 1.0.

[0027] With the above-described structure, while the velocity vector of the gas at the time when the gas has flowed from the impeller outlet 2b to the diffuser 5 is not changed from that of the conventional one, the skewing of the velocity distribution can be suppressed.

[0028] FIG. 2 shows a result of simulation of the compressor efficiency of the present apparatus, conducted under conditions that α and β are certain constant values and only θ is a variable. In a graph of FIG. 2, the horizontal axis represents θ and the vertical axis represents a compressor efficiency improvement rate. The compressor efficiency improvement rate represents a difference, expressed in percentage, between the compressor efficiency of the present apparatus and the compressor efficiency of the conventional technique. As becoming higher in the graph, the compressor efficiency improvement rate indicates that the compressor efficiency of the present apparatus is higher. It can be understood from the graph that the compressor efficiency is improved when $0° < \theta < 34°$.

[0029] Accordingly, in the present apparatus, the skewing of the velocity distribution of the gas in the diffuser, which has conventionally occurred, is eliminated, and accordingly a decrease in the amount of static pressure recovery in the diffuser is suppressed. Therefore, a higher efficiency of the entire compressor can be achieved.

Embodiment 2

[0030] An apparatus according to Embodiment 2 of the present invention is one obtained by improving the apparatus according to Embodiment 1. FIG. 4 shows differences between the apparatus according to Embodiment 1 and the present apparatus. In the apparatus according to Embodiment 1, since the diffuser inlet hub-side line 5a is a straight line, directing the outlet of the diffuser 5 in the radial direction requires that the angle of the diffuser 5 has to be changed at a certain portion. As a result, as shown in FIG. 4, a stagnation region 11 where the flow of the gas stagnates is formed. Shear stress acts between the gas stagnating in the stagnation region 11 and the flowing gas, leading to a possibility of occurrence of an energy loss. The present apparatus reduces the stagnation region 11.

[0031] As in the case of the apparatus according to Embodiment 1, as shown in FIG. 3, the present apparatus mainly includes a suction inlet 1, an impeller 2, a hub 3, a rotary shaft 4, a diffuser 5, and a scroll 6. The impeller 2 is connected to the rotary shaft 4 via the hub 3. The diffuser 5 is provided downstream of the impeller 2, has a flow passage extending in a direction away from the rotary shaft 4, and has an outlet directed in a radial direction in a meridian plane. Moreover, the scroll 6 is provided downstream of the diffuser 5 and communicates with the outlet of the diffuser 5. Note that the rotary shaft 4 and the scroll 6 are not shown in FIG. 3, but are assumed to be the same as those of the conventional technique. Furthermore, the operation of the present apparatus is also the same as those of the apparatus according to Embodiment 1 and of the conventional technique, and is accordingly omitted.

[0032] Here, in the present apparatus, the diffuser inlet hub-side line 5b is made to be a concave curved line. An angle formed by a tangent line 5c of the diffuser inlet hub-side line 5b with a radial direction at a point B closest to an impeller outlet 2b in the diffuser inlet hub-side line 5b is represented by θ. The line of the shroud 7, α, and β are set such that $\theta - \alpha > 0°$ as shown in FIG. 5, and further θ is set such that $0° < \theta < 34°$ as in the case of the apparatus according to Embodiment 1. Note that the diffuser inlet hub-side line 5b may be a single arc, or may be a line obtained by smoothly combining a plurality of arcs or ovals, as long as it is a curved line.

[0033] With the above-described structure, as shown in FIG. 4, the present apparatus can reduce the stagnation region 11, which exists in the case of the apparatus according to Embodiment 1. Therefore, the present apparatus can reduce shear stress and makes it possible to achieve higher efficiency.

INDUSTRIAL APPLICABILITY

[0034] The present invention is favorable as a centrifugal compressor, and in particular a centrifugal compressor with a large flow rate.

EXPLANATION OF REFERENCE NUMERALS

[0035]

1 suction inlet
2 impeller
2a impeller inlet
2b impeller outlet
2c impeller rear edge
3 hub
3a impeller hub-side line
3b tangent line
4 rotary shaft
5 diffuser
5a diffuser inlet hub-side line (in the apparatus according to Embodiment 1 of the present invention)
5b diffuser inlet hub-side line (in the apparatus according to Embodiment 2 of the present invention)
5c tangent line
6 scroll
7 shroud
11 stagnation region

Claims

1. A centrifugal compressor comprising:

an impeller connected to a rotary shaft via a hub; and
a diffuser provided downstream of the impeller, the diffuser having a flow passage which extends in a direction away from the rotary shaft and an outlet which is directed in a radial direction in a meridian plane, **characterized in that** the centrifugal compressor satisfies $\theta-\alpha>0°$ where

θ is an angle formed by a diffuser inlet hub-side line with the radial direction in the meridian plane at a point closest to an outlet of the impeller in the diffuser inlet hub-side line, the diffuser inlet hub-side line being a line on the hub side in an inlet of the diffuser, and
α is an angle formed by a tangent line of an impeller hub-side line with the radial direction in the meridian plane at a point closest to the inlet of the diffuser in the impeller hub-side line, the impeller hub-side line being a line on the hub side in the impeller.

2. The centrifugal compressor according to claim 1, **characterized in that**
the θ is such that $0°<\theta<34°$.

3. The centrifugal compressor according to claim 1 or 2, **characterized in that**
the diffuser inlet hub-side line is a concave curved line.

Fig. 1

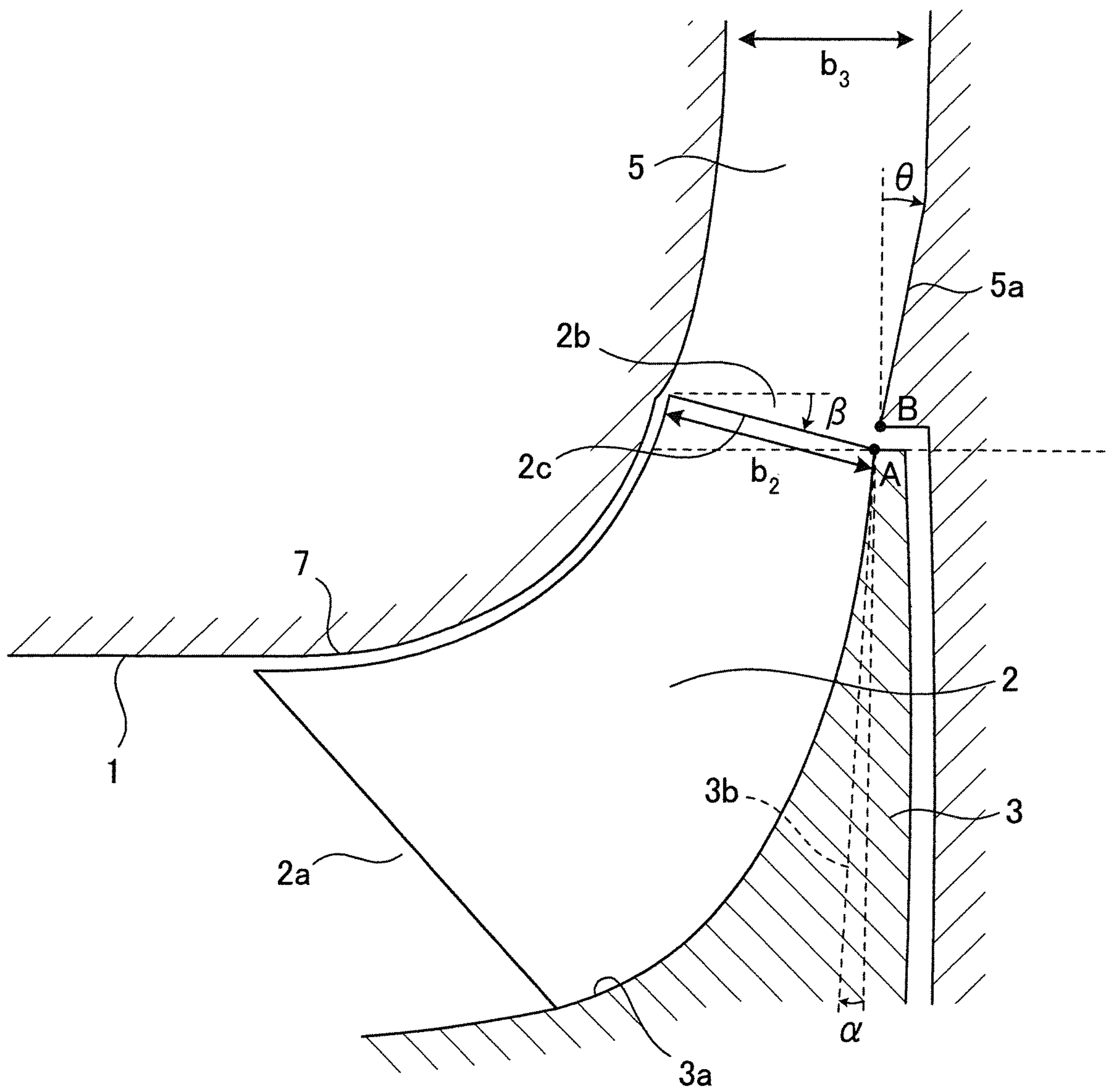


Fig.2

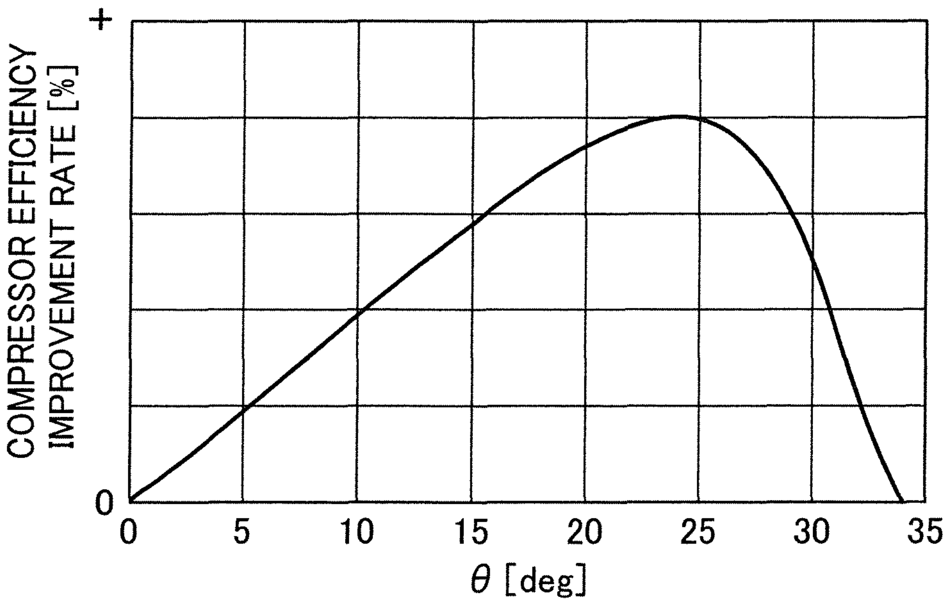

+
0
COMPRESSOR EFFICIENCY
IMPROVEMENT RATE [%]
0
5
10
15
20
25
30
35
θ [deg]

Fig. 3

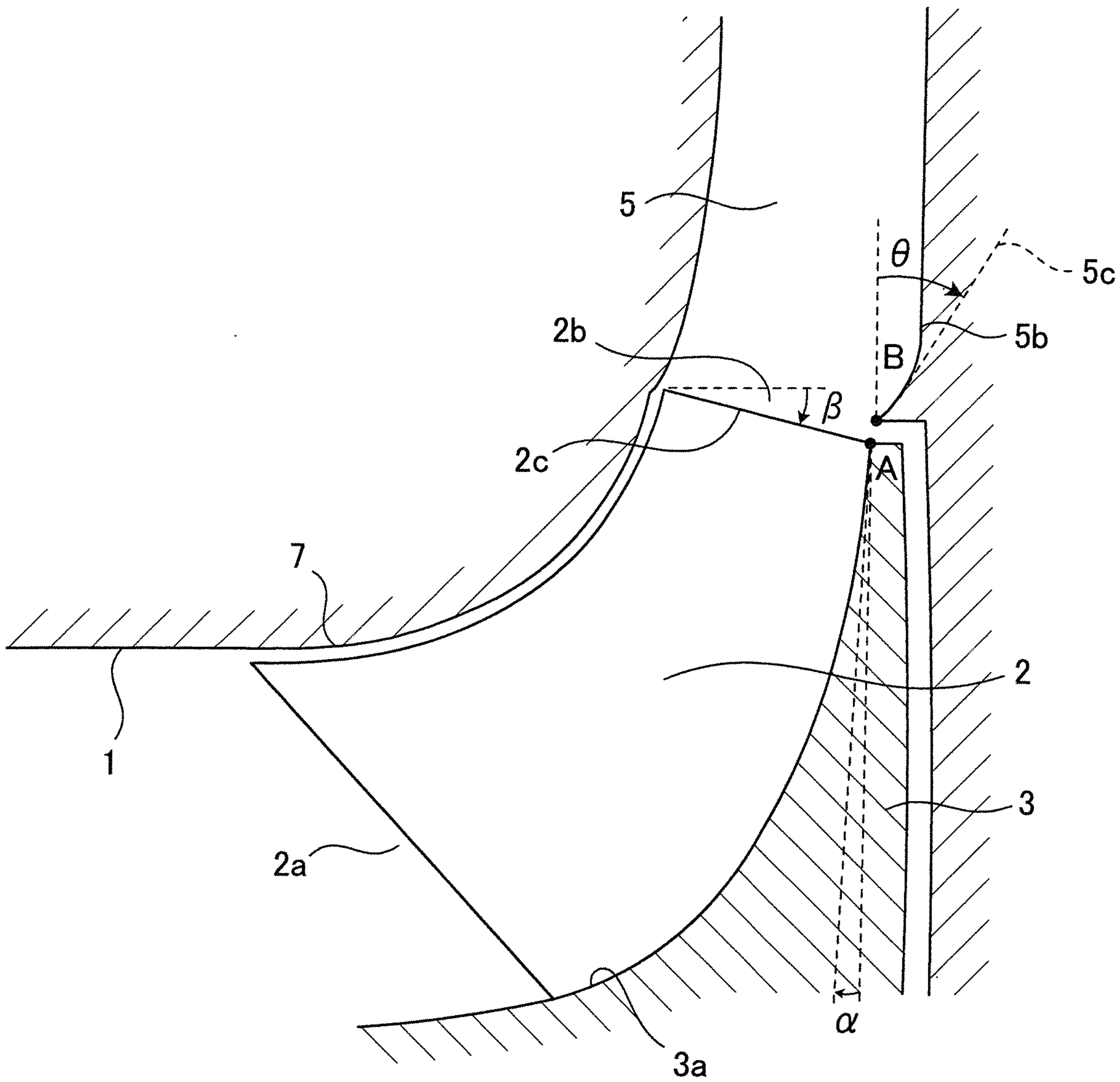


Fig.4

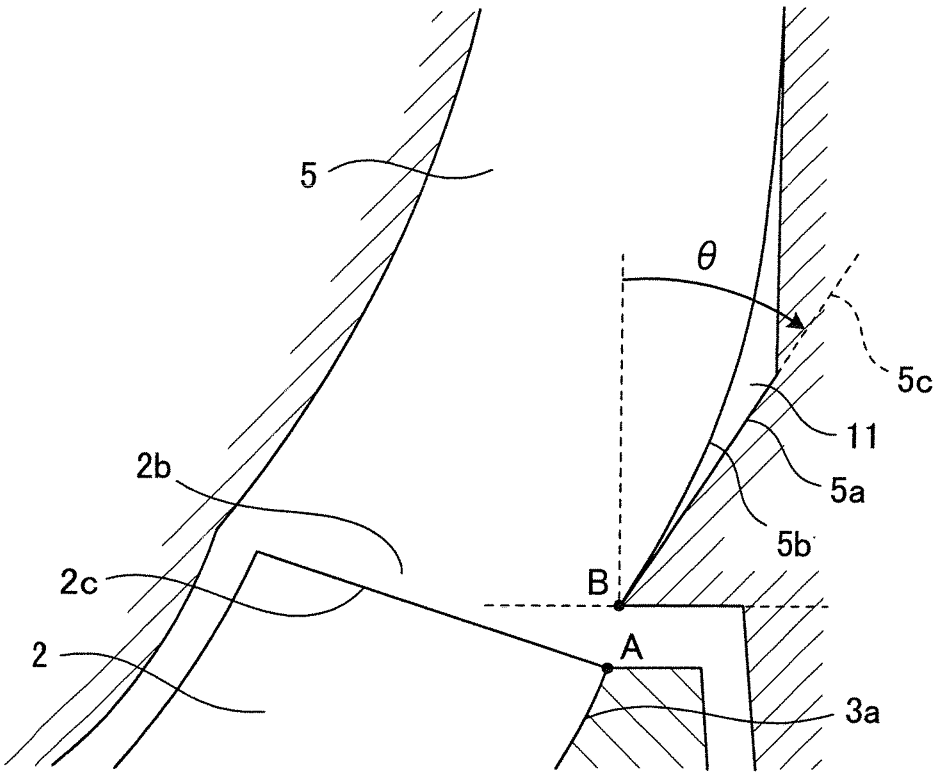


Fig.5

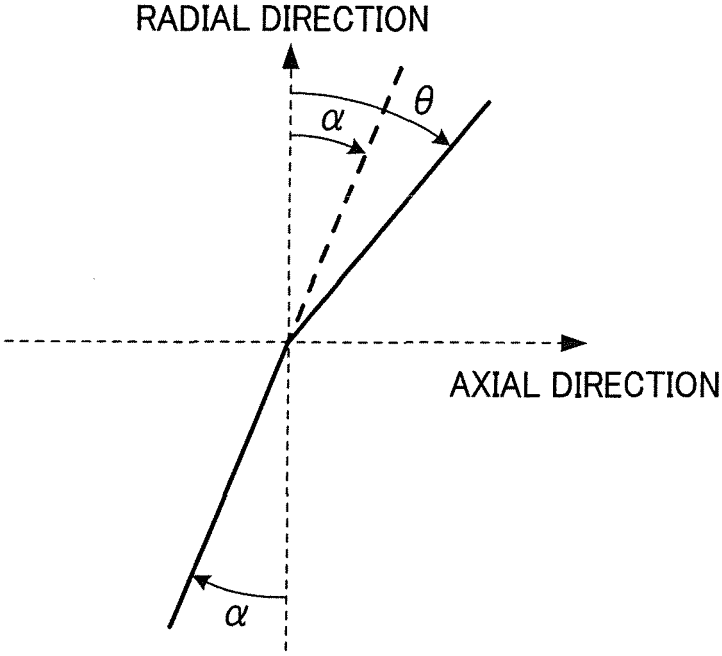


Fig. 6

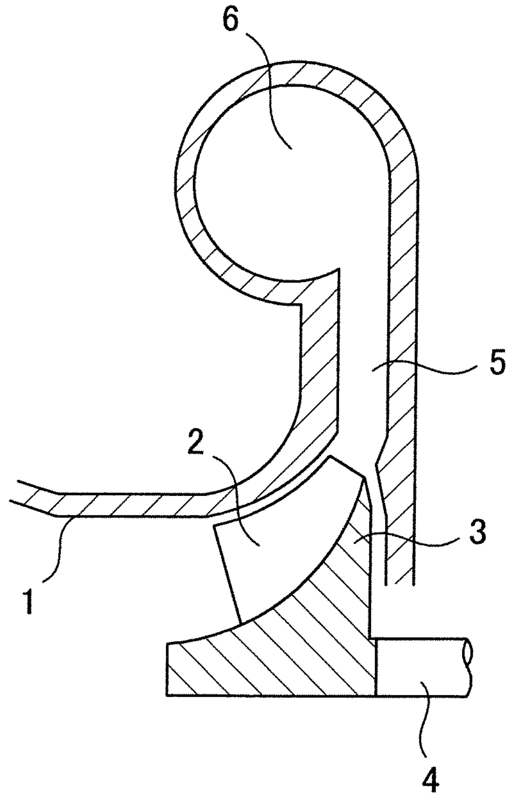
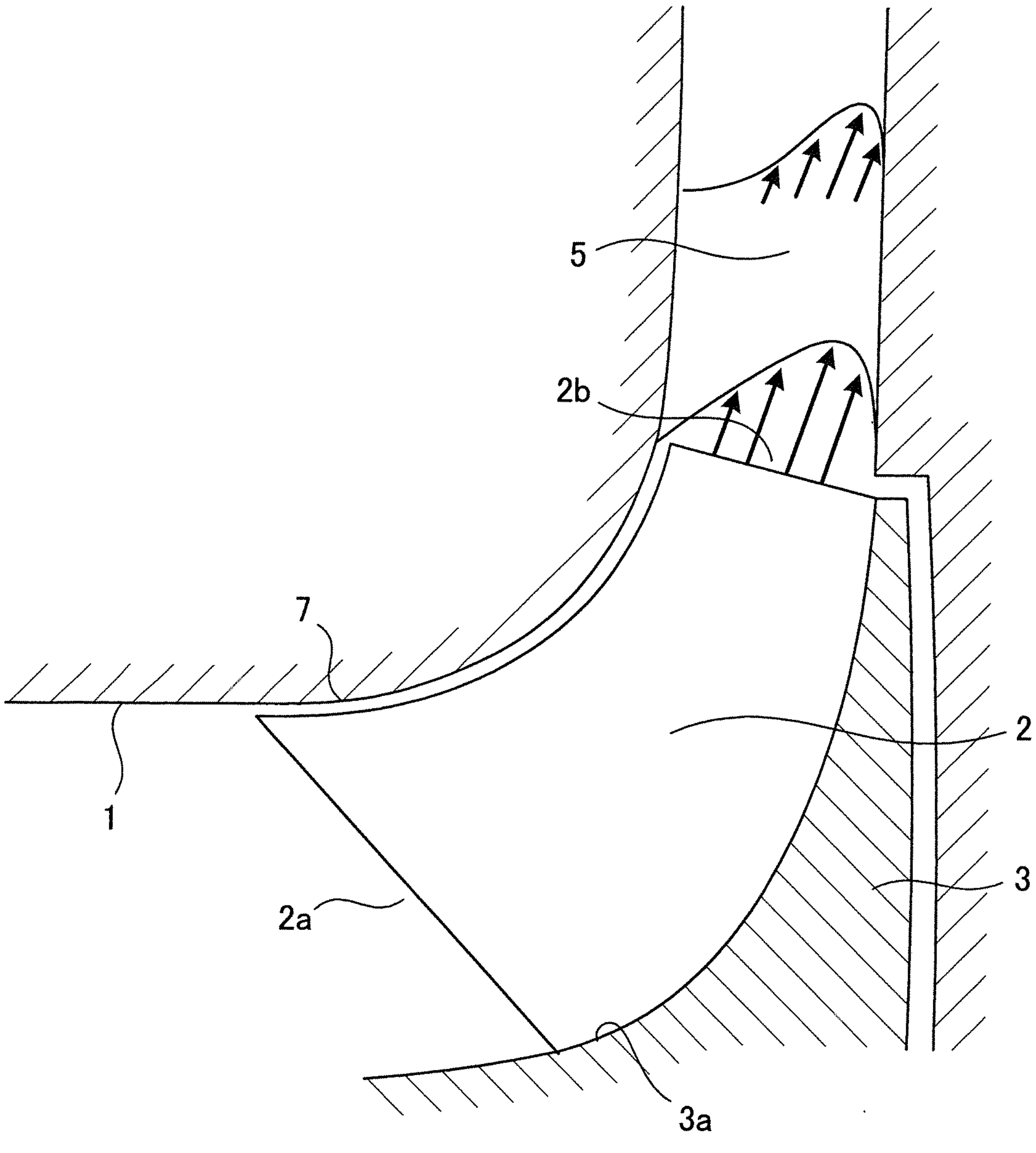


Fig. 7



INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2013/050360

A. CLASSIFICATION OF SUBJECT MATTER
F04D29/44(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)
F04D29/44

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	1996-2013
Kokai Jitsuyo Shinan Koho	1971-2013	Toroku Jitsuyo Shinan Koho	1994-2013

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP 2008-75536 A (Mitsubishi Heavy Industries, Ltd.), 03 April 2008 (03.04.2008), entire text; all drawings & US 2010/0129209 A1 & EP 2072834 A1 & WO 2008/035465 A1	1-2 3
X Y	JP 2002-5089 A (Mitsubishi Heavy Industries, Ltd.), 09 January 2002 (09.01.2002), entire text; all drawings & US 2002/0106278 A1 & WO 2001/098669 A1	1-2 3

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

* Special categories of cited documents:
- "A" document defining the general state of the art which is not considered to be of particular relevance
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- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
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Date of the actual completion of the international search	Date of mailing of the international search report
18 March, 2013 (18.03.13)	02 April, 2013 (02.04.13)

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

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2013/050360

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP 2011-89460 A (Hitachi Plant Technologies, Ltd.), 06 May 2011 (06.05.2011), entire text; all drawings & US 2011/0097203 A1 & EP 2314876 A2	1-2 3
X Y	JP 2008-175124 A (IHI Corp.), 31 July 2008 (31.07.2008), entire text; all drawings (Family: none)	1-2 3
Y	JP 2002-31094 A (Mitsubishi Heavy Industries, Ltd.), 31 January 2002 (31.01.2002), entire text; all drawings (Family: none)	3

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

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 2569143 B **[0009]**
- JP 2703055 B **[0009]**