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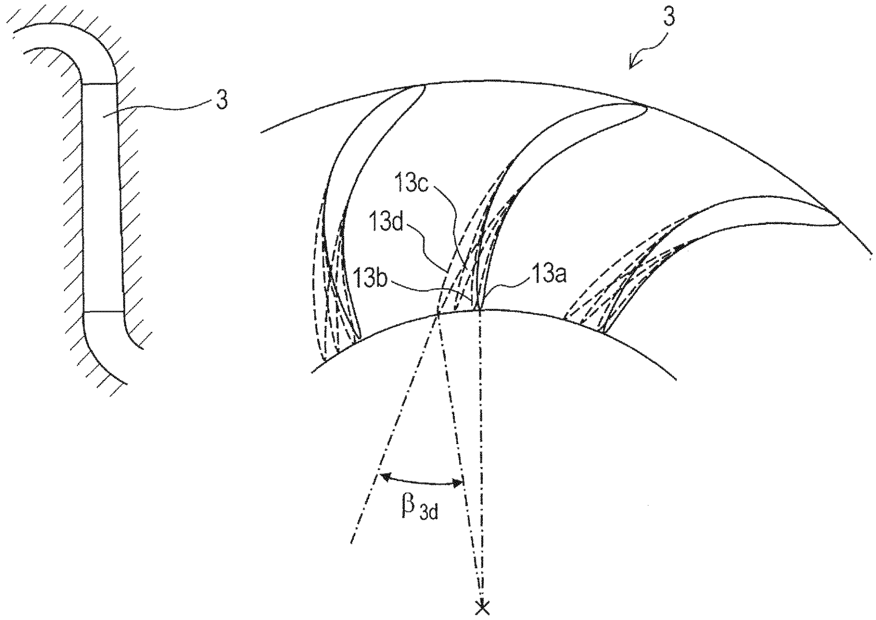
(54) **MULTI-STAGE CENTRIFUGAL COMPRESSOR AND RETURN CHANNELS THEREFOR**

(57) A multi-stage impeller is configured in a multi-stage centrifugal compressor by fixing and attaching a plurality of centrifugal impellers to one rotating shaft. Diffusers and return channels are provided in order downstream from each impeller. The centrifugal impellers, the diffusers and the return channel are housed within a compressor casing. The return channels have a plurality of vanes positioned at intervals from one another in a circumferential direction, and at least two stages are provided. The vane exit angles monotonically increase toward the downstream stage.

FIG. 2



EP 2 631 492 A1

Description

[Technical Field]

[0001] The present invention relates to a multi-stage centrifugal compressor and a return channel thereof. More particularly, the invention relates to a uniaxial multi-stage centrifugal compressor having a plurality of impellers fixedly attached to one shaft as well as a return channel thereof.

[Background Art]

[0002] An example of a conventional multi-stage fluid machine is set forth in Patent Literature 1. The multi-stage pump disclosed in this patent publication has such a structure as to attain high efficiency but not for a partial discharge range and attain a good H-Q characteristic at the partial discharge range. That is, a return channel is provided with a return guide vane, a trailing edge of which is located outwardly of a leading edge of an impeller blade in a radial direction of a rotating shaft. Further, flow guide plates that extends from the trailing edge of the return guide vane toward the rotating shaft are formed within a part of the return channel.

[0003] Examples of the conventional multi-stage centrifugal compressor improved in the performance of the return channel are set forth in Patent Literatures 2 and 3. A multi-stage centrifugal compressor disclosed in Patent Literature 2 has a structure in which a return vane has a leading edge portion and a trailing edge portion configured to conform to the flow. That is, a central portion of the return vane in a width direction (axial direction) is configured such that a leading edge thereof stands up while a trailing edge thereof is inclined in a direction opposite to the rotation of the impeller. A multi-stage centrifugal compressor disclosed in Patent Literature 3 has a structure in which the return channel is provided with movable return vanes on an upstream side thereof and stationary return vanes on a downstream side thereof.

[Citation List]

[Patent Literature]

[0004]

JP-A No.2005-330878
JP-A No.1997-203394
JP-A No.1996-200289

[Summary of the Invention]

[Technical Problem]

[0005] The centrifugal compressors such as a process centrifugal compressor are often required of high efficiency and wide operating range. In a case where the centrifugal compressor includes multiple stages of centrifugal compressors to meet the requirements, the individual stages are so designed as to achieve the highest efficiency at a flow rate at a specified point. Therefore, if the compressors are operated at flow rate other than that at the specified point, the individual stages may encounter flow mismatching.

[0006] This flow mismatching is explained as below with reference to characteristic curves of a multi-stage compressor shown in Fig.3 and Fig.4. Fig.3 shows a characteristic of the first-stage compressor of the multi-stage compressor. Fig.4 shows a characteristic of the last-stage compressor of the multi-stage compressor. The low flow operation limit of the compressor is dependent upon the occurrence of surging. On the other hand, the high flow operation limit is dependent on the occurrence of choking.

[0007] In actual operation, the compressor is operated with an operating range (WR) defined by a flow rate range between (Qs) and (Qc). It is noted that a surge point (Ps) means a point at which the surging occurs; (Qs) means a flow rate at which the surging occurs; (Pc) means a point at which the choking occurs; and (Qc) means a flow rate at which the choking occurs. A specified point (P_{Des}) as a design point is at the intermediate point of the operating range. With a flow rate (Q_{Des}) at this specified point (P_{Des}) as the boundary, a flow rate range between the surge flow rate (Qs) and the specified point flow rate (Q_{Des}) is referred to as "surge margin SM" and a flow rate range between the choke flow rate (Qc) and the specified point flow rate (Q_{Des}) is referred to as "choke margin CM". In a case where the first-stage compressor is operated at the specified point flow rate (Q_{Des}) (volume flow ratio=1.0), the last-stage compressor is also operated at the specified point flow rate (Q_{Des}).

[0008] On the other hand, if the flow rate for the first-stage compressor is increased to a high flow point (A) so as to increase the flow rate, the head (H) of the first-stage compressor decreases to (H_A), which is lower than the head (H_{Des}) corresponding to the specified point (P_{Des}). Namely, the working gas is less compressed than when the first-stage compressor is operated at the flow rate of the specified point (P_{Des}). Therefore, the downstream impellers are operated at point of higher volume flow ratio. Consequently, the last-stage compressor is operated at a higher flow operation point (A') in terms of volume flow ratio. Namely, the last-stage compressor is operated at a point significantly deviated from the specified point flow rate (Q_{Des}).

[0009] Conversely if the first-stage compressor is operated at a lower flow operation point (B) than the specified point (P_{Des}), the head (H_B) thereof is higher than the head (H_{Des}) corresponding to the specified point (P_{Des}). Therefore, the working gas is more compressed so that the downstream compressors are operated at a lower flow operation point in terms of volume flow ratio. The last-stage compressor, for example, is operated at a lower flow operation point (B') close to the surge point (Ps).

[0010] As described above, the operating range of the multi-stage compressor strongly depends upon the operating range of the downstream compressors or more particularly, upon the operating range of the last-stage compressor. In order to construct the multi-stage compressor featuring the wide operating range, therefore, it is necessary that the more downstream compressor is configured to have the wider operating range. However, the impellers alone can only achieve limited expansion of the operating range, which limits the operation of the multi-stage compressor.

[0011] The above fluid machine disclosed in Patent Literature 1 suggests improvement in the return channel of the multi-stage pump, achieving improved stability at the partial discharge range. However, this machine is not the multi-stage centrifugal compressor and hence, the fluid passes through the individual stages at substantially the same volume flow rate. That is, difference in working flow rate of the individual impellers forming the individual stages is not considered.

[0012] The above multi-stage centrifugal compressors disclosed in Patent Literatures 2 and 3 can be improved in efficiency because the return vanes in the return channels are so configured as to conform to the gas flow moving through the return channels. However, enormous amounts of labor and knowledge are necessary for forming the return vanes in conformity to the flow of gas into the return channels. What is more, the individual stages have complicated structures, resulting in an increased number of manufacture steps and complicated control.

[0013] In view of the above-described problems of the related art, the invention seeks to provide a multi-stage centrifugal compressor that can achieve, on the whole, higher efficiency and wider operating range than the conventional machines without sacrifice of the efficiency. Another object of the invention is to achieve the above object in a simple construction.

[Solution to Problem]

[0014] According to an aspect of the invention for achieving the above objects, a multi-stage centrifugal compressor including: a multi-stage impeller configured by fixing and attaching a plurality of centrifugal impellers to one rotating shaft, diffusers and return channels formed in order downstream from each impeller, and a casing housing the centrifugal impellers, the diffusers and the return channels is characterized in that the return channels have a plurality of vanes circumferentially arranged with spacing, and that the vanes have exit angles monotonically increased toward the downstream stage. It is preferred in the above characteristics that the more downstream impeller has the larger blade angle with respect to a radial direction at an exit of the impeller.

[0015] According to another aspect of the invention for achieving the above objects, a multi-stage centrifugal compressor including: a multi-stage impeller configured by fixing and attaching a plurality of centrifugal impellers to one rotating shaft, diffusers and return channels provided in order downstream from each impeller, and a casing which houses the centrifugal impellers, the diffusers and the return channels and in which a plurality of compressor groups are configured by forming a plurality of inlet channels is characterized in that in at least one of the plural compressor groups, the return channels have a plurality of vanes circumferentially arranged with spacing and are provided at least in two stages, and that the vanes have exit angles monotonically increased toward the downstream stage. It is preferred in the above characteristics that in each group, the more downstream impeller has the larger blade angle with respect to a radial direction at an exit of the impeller.

[0016] According to still another aspect of the invention for achieving the above objects, a return channel for use in a multi-stage centrifugal compressor which is used in at least more than one stage of the multi-stage centrifugal compressor having a plurality of impellers attached to one shaft and which includes a plurality of vanes circumferentially arranged with spacing and attached in a channel formed between opposite flat plates is characterized in that of the plural vane exit angles with respect to a radial direction, an exit angle of the vane used in an upstream stage is equal to or less than an exit angle of the vane used in a downstream stage. In the above characteristics, the vane of the uppermost return channel may have an exit angle substantially equal to zero.

[Advantageous Effects of the Invention]

[0017] According to the invention, the multi-stage centrifugal compressor can achieve, on the whole, the high efficiency and the wider operating range than the conventional machines because the vane exit angles of the return channels of the multi-stage centrifugal compressor are progressively increased toward the downstream stage. The invention only needs the setting of the vane exit angles. Hence, the compressor having the simple structure can achieve the high efficiency on the whole and provides the wider operating range than the conventional machines.

Brief Description of the Drawings

[0018]

[Fig.1]
Fig.1 is a vertical sectional view showing a multi-stage centrifugal compressor according to one embodiment of the invention;
[Fig.2]
Fig.2 is a view showing return channels of the multi-stage centrifugal compressor of Fig.1 in an overlapping relation as seen in P-direction;
[Fig.3]
Fig.3 is a graph illustrating a characteristic of a first stage of the multi-stage compressor;

[Fig.4]
Fig.4 is a graph illustrating a characteristic of the last stage of the multi-stage compressor;
[Fig.5]
Fig.5 is a graph showing one example of exit angles of vanes of the return channel according to the invention;
[Fig.6]
Fig.6 is a graph showing another example of the exit angles of the vanes of the return channel according to the invention;
[Fig.7]
Fig.7 is a graph showing still another example of the exit angles of the vanes of the return channel according to the invention;
and
[Fig.8]
Fig.8 is a set of graphs showing still another example of the exit angles of the vanes of the return channel according to the invention.

Best Mode for Carrying Out the Invention

[0019] A multi-stage centrifugal compressor and a return channel for use therein according to the invention will be described as below with reference to the accompanying drawings. Fig. 1 is a vertical sectional view showing a multi-stage centrifugal compressor 10 according to one embodiment of the invention. Further, return channels 3 of the multi-stage centrifugal compressor 10 shown in Fig.1 are illustrated in Fig.2 in an overlapping relation as seen in P-direction.

[0020] The multi-stage centrifugal compressor 10 includes a plurality of impellers (1a to 1e) fixedly attached to one rotating shaft (8) and diffusers (2a to 2e) disposed downstream from the impellers (1a to 1e) respectively. Return channels (3a to 3d) interconnecting the diffusers (2a to 2e) and the subsequent impellers (1b to 1e) are disposed downstream from the respective diffusers (2a to 2d except the last one. The impellers (1a to 1e), the diffusers (2a to 2e) and the return channels (3a to 3e) are housed in a compressor housing (6), where an inlet casing (4) is disposed upstream of the first impeller 1a and an outlet casing (5) is disposed downstream from the last diffuser (2e).

[0021] The multi-stage compressor (10) shown in Fig. 1 is a 5-stage compressor. A working gas from outside the multi-stage compressor (10) is first introduced into the machine through the inlet casing (4) as a flow (9) moving radially inwardly. The flow enters the first impeller (1a) and is increased in pressure while passing through the respective impellers (1a to 1e), diffusers (2a to 2e) and return channels (3a to 3d). After flowing through the last diffuser (2e), the flow is discharged from the machine through the outlet casing (5).

[0022] In a case where the multi-stage compressor (10) includes five stages, four return channels (3a to 3d) are provided. The return channels (3a to 3d) each include a portion disposed downstream from the diffuser (2a to 2d) and having a U-turn bend in section, and a ring-like portion having a plurality of vanes (13a to 13d) circumferentially arranged with spacing (see Fig.2) and between opposite planes defined by wall surfaces of the compressor casing (6). According to this embodiment, the more downstream is the compressor, the larger exit angles (β_{3a} to β_{3d}) have the vanes (13a to 13d) of the return channels. As shown in Fig.5, for example, the vanes (13a to 13d) of the individual stages exhibit an angle distribution such that the vane exit angles increase by a given angle for each addition of stage. It is noted here that the vane exit angle (β) is an angle formed between the radial line and the vane surface at vane exit.

[0023] In the return channels (3a to 3d) of the embodiment configured in this manner, the following merits occur if the return channels (3a to 3d) are increased in the vane exit angles (β_{3a} to β_{3d}). Namely, the return channels (3a to 3d) having the vanes (13a to 13d) increased in the exit angles (β_{3a} to β_{3d}) thereof and the subsequent impellers (1b to 1e) connected to the return channels (3a to 3d) via the flow paths obtain the following merits.

[0024] Specifically, pre-rotation remains in the flow entering the subsequent impellers (1b to 1e) and hence, the flow into the impellers (1b to 1e) is decreased in relative inlet velocity. It is therefore expected that the flow in the impellers (1b to 1e) is decreased in relative velocity of diffusion and an increased surge margin (SM) results. If the return channels are progressively increased in the vane exit angle (β) toward the downstream stage, the impellers (2) connected to the flow path of their corresponding return channels are relatively increased in surge margin (SM). This suggests that the magnitude of surge margin (SM) of the entire compressor machine depends upon the impellers on the downstream side. Accordingly, the surge margin (SM) of the entire compressor machine can be increased by increasing the surge margin (SM) of the downstream impeller.

[0025] The second merit is that the vanes (13a to 13d) of the return channels (3a to 3d) reduce the turning angle of the flow so that the vanes (13a to 13d) themselves are decreased in loss. The vanes (13a to 13d) normally work to turn swirl flow in an axial direction (reducing the exit angle to (β=0°)), the swirl flow formed at exits of the diffusers (2a to 2d). As a result, the flow along the vanes (13a to 13d) is turned greatly so that the vanes (13a to 13d) encounter significant flow loss, which is difficult to reduce.

[0026] The embodiment is adapted to allow the swirl component to remain in an exit flow from the vanes (13a to 13d) of the return channels (3a to 3d) or particularly the exit flow from the downstream vanes (13a to 13d) and to enter the subsequent impellers (1b to 1e) as the pre-rotation. Hence, the vanes (13a to 13d) have smaller turning angles. Thus, the load on the vanes (13a to 13d) can be reduced so that the flow loss at the vanes (13a to 13d) is reduced.

[0027] The third merit is a uniformalized flow distribution. If the load on the vanes (13a to 13d) of the return channels (3a to 3d) is reduced, as described above, the flow distribution of the exit flow from the return channels (3a to 3d) is reduced in flow non-uniformity so as to be more prone to uniformalization. This leads to improved performance of the impellers that are connected to the return channels and designed based on receiving uniform inlet flow.

[0028] This embodiment is configured to allow the swirl component to remain in the exit flow from the return channels (3a to 3d) or particularly the exit flow from the downstream return channels and to allow the exit flow to enter the subsequent impellers. Therefore, the head is lowered as compared with a case where the flow without containing the swirl component or the pre-rotation is allowed to enter the subsequent impellers. In the design of the downstream impellers, rotation speed and outside diameter of the impellers are designed to recover this head decrease into consideration.

[0029] In a case where the characteristics of the downmost stage or the stage just prior to the downmost stage significantly affect the overall surge margin, it is preferred to increase the exit angles of the vanes (13b to 13d) of only the stages having the significant influence, as shown in Fig.6. In the example shown in Fig.6, the vanes (13a, 13b) of the first and second stages have such exit angles (β_{3a}, β_{3b}) as not to allow the swirl to remain in the flow, while the vane (13c) of the stage just prior to the downmost stage and the vane (13d) of the downmost stage have such exit angles (β_{3c}, β_{3d}) as to allow the swirl to remain in the flow. In this configuration, the exit angle (β_{3d}) of the downmost vane (13d) more affecting the surge margin has a larger increment than the exit angle (β_{3c}) of the vane (13c) just prior to the downmost vane (13d). The downmost stage and/or the stage just prior to the downmost stage exhibit a noticeable head decrease but the head decrease is insignificant at the other stages. Hence, the head decrease of the entire compressor can be reduced and besides, the compressor can ensure a required surge margin.

[0030] The above are the examples of the 5-stage centrifugal compressor. An example of a multi-stage centrifugal compressor (10) having a larger number of stages is illustrated in Fig. 7. The multi-stage centrifugal compressor (10) shown in Fig. 7 is a 9-stage machine in which the stages are divided into pairs and the exit angle (β) for each pair is changed incrementally. The preceding stage of the pair has the same vane exit angle (β) as that of the subsequent stage of the preceding pair. At the subsequent stage, the vane exit angle (β) is increased by a predetermined amount.

[0031] For example, the second stage is paired with the third stage. The exit angle (β_{3b}) of the second vane (13b) is equal to the exit angle (β_{3a}) of the first vane (13a), while the exit angle (β_{3c}) of the third vane (13c) is increased by a predetermined increment from the exit angle (β_{3b}) of the second vane (13b). If the vane exit angle (β) is thus changed incrementally and the amount of pre-rotation entering the subsequent impeller is previously determined from the flow at the vane exit angle (β), it is easy to grasp performance and make design decision.

[0032] Fig.8 shows vane angle distributions of the return channels of a multi-stage centrifugal compressor according to still another embodiment of the invention. In this embodiment, two inlet channels are provided in one compressor casing. The machine is adapted for a case where, for example, the compressed working gas flows out of the machine in midstream for intercooling purpose and after cooled, flows back into the compressor again. The compressor is divided into two groups by the inlet channel. The first group includes five return channels while the second group includes four return channels.

[0033] The return channels of the compressor stages constituting each group have the exit angles (β) progressively decreased toward the inlet side, or progressively increased toward the outlet side. Namely, the return channels are configured such that the vane exit angles progressively or monotonically increase in order from the inlet side. If the return channels provided at the respective stages have the exit angles (β) set this way, the working gas flows through the respective groups the same way as in the above embodiments. Therefore, the operating range and performance of the machine is changed or improved as described above. As for a pattern of changing the exit angles of the return channels toward the downstream stage, the patterns shown in Fig.6 and Fig. 7 are also applicable to this embodiment.

[0034] An alternative structure, the illustration of which is omitted, may also be made in which the return channels are configured as described above and the impeller is configured to include impeller units progressively decreased in the impeller exit angle toward the downstream stage. That is, the more downstream impeller unit has the wider surge margin (SM). Having such a structure, the multi-stage compressor as a whole can attain a wider surge margin (SM).

[0035] While the above embodiments have been described by way of examples of the 5-stage machine and 9-stage machine, it is needless to say that the invention is not limited to these stage numbers. The invention is applicable to any multi-stage centrifugal compressors that include two or more return channels. The setting of the vane exit angle is exemplified by the case where the exit angle is proportionally increased, the case where only the two downstream stages are increased in the exit angle and the case where every other stage is increased in the exit angle. The setting of the vane exit angle is not limited to these examples and various setting methods are applicable. However, it is preferred that the vane exit angle monotonically increases toward the downstream stage.

[Reference Signs List]

[0036]

1a-1e: Impeller
2a-2e: Diffuser
3, 3a-3h: Return channel
13a-13h: Vane
4: Inlet casing
5: Outlet casing
6: Compressor casing
7: Bearing
8: Rotating shaft
9: Inlet flow
10: Multi-stage centrifugal compressor
A, A': High flow operation point
B, B': Low flow operation point
CM: Choke margin
H: Head
Ps: Surge point
Q: Volume flow ratio
Qc: Choke flow rate
Qs: Surge flow rate
SM: Surge margin
WR: Operating range
β_{3a} to β_{3a}: Vane exit angle

Claims

1. A multi-stage centrifugal compressor comprising:

a multi-stage impeller configured by fixing and attaching a plurality of centrifugal impellers to one rotating shaft, diffusers and return channels formed in order downstream from each impeller, and a casing housing the centrifugal impellers, the diffusers and the return channels,
wherein the return channels have a plurality of vanes circumferentially arranged with spacing, and wherein the vanes have exit angles monotonically increased toward the downstream stage.

2. The multi-stage centrifugal compressor according to Claim 1, wherein the more downstream impeller has the larger or equal blade angle with respect to a radial direction at an exit of the impeller.

3. A multi-stage centrifugal compressor comprising:

a multi-stage impeller configured by fixing and attaching a plurality of centrifugal impellers to one rotating shaft, diffusers and return channels provided in order downstream from each impeller, and a casing which houses the centrifugal impellers, the diffusers and the return channels and in which a plurality of compressor groups are configured by forming a plurality of inlet channels,
wherein in at least one of the plural compressor groups, the return channels have a plurality of vanes circumferentially arranged with spacing and are provided at least in two stages, and wherein the vanes have exit angles monotonically increased toward the downstream stage.

4. The multi-stage centrifugal compressor according to Claim 3, wherein in each group, the more downstream impeller has the larger or equal blade angle with respect to a radial direction at an exit of the impeller.

5. A return channel for use in multi-stage centrifugal compressor which is used in at least more than one stage of the multi-stage centrifugal compressor having a plurality of impellers attached to one shaft and which includes a plurality of vanes circumferentially arranged with spacing and attached in a channel formed between opposite flat plates, wherein of the plural vane exit angles with respect to a radial direction, an exit angle of the vane used in an upstream stage is equal to or less than an exit angle of the vane used in a downstream stage.

6. The return channel according to Claim 5, wherein the vane of the uppermost return channel has an exit angle substantially equal to zero.

FIG. 1

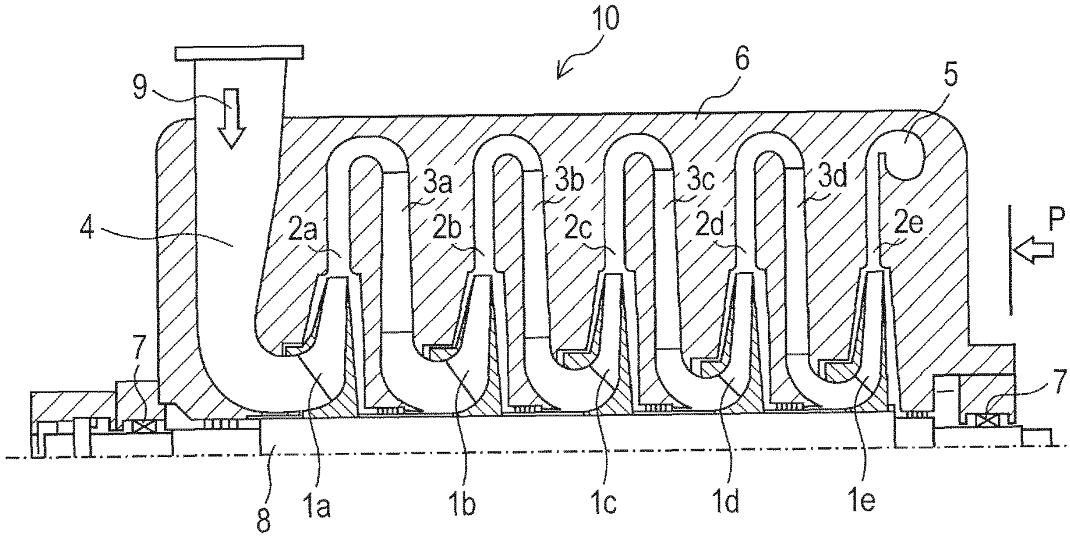

10
6
5
9
3a
3b
3c
3d
4
2a
2b
2c
2d
2e
P
7
7
8
1a
1b
1c
1d
1e

FIG. 2

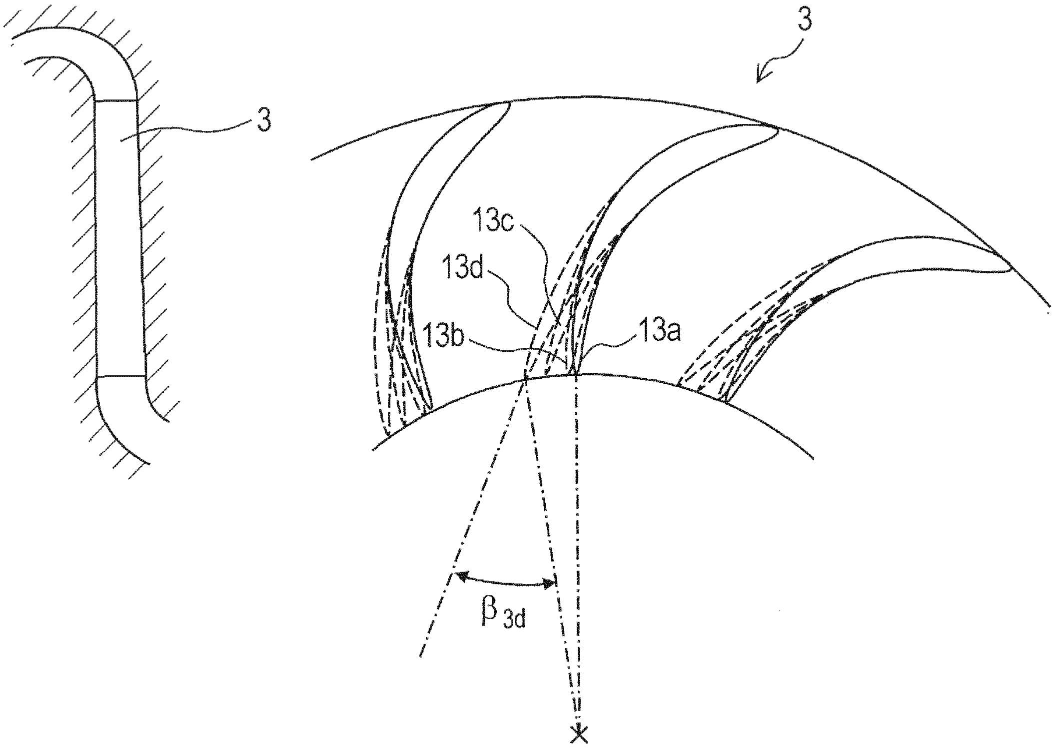

3
3
13c
13d
13b
13a
β_{3d}

FIG. 3

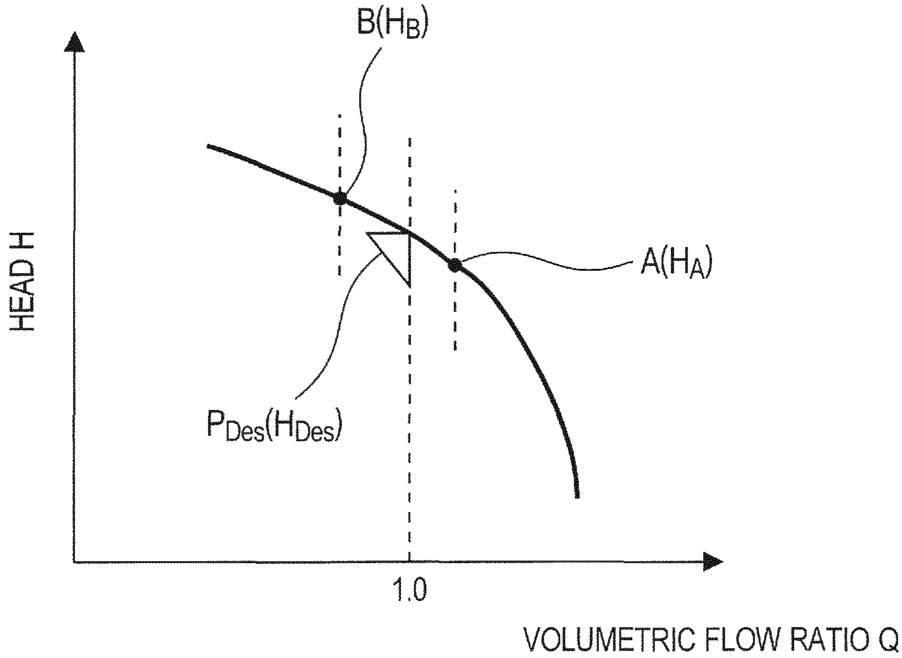

B(H_B)
HEAD H
A(H_A)
P_Des(H_Des)
1.0
VOLUMETRIC FLOW RATIO Q

FIG. 4

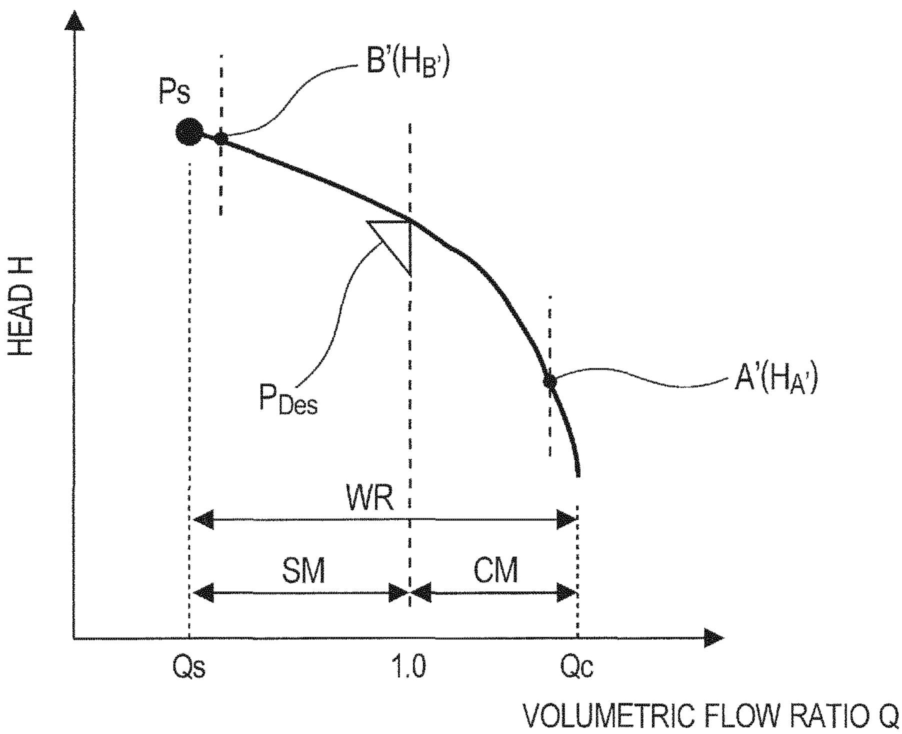

B'(H_B')
Ps
HEAD H
P_Des
A'(H_A')
WR
SM
CM
Qs
1.0
Qc
VOLUMETRIC FLOW RATIO Q

FIG. 5

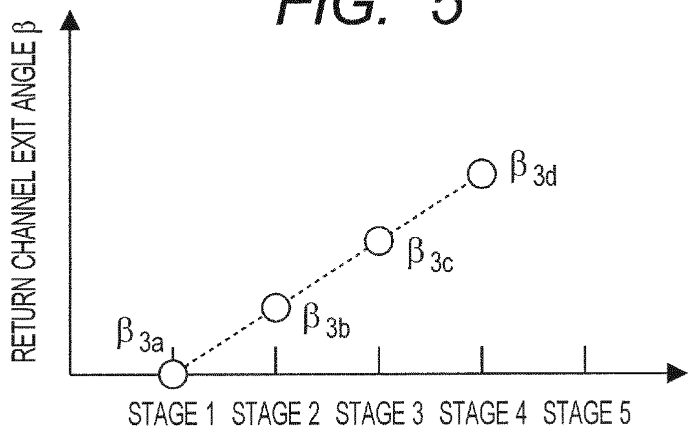


FIG. 6

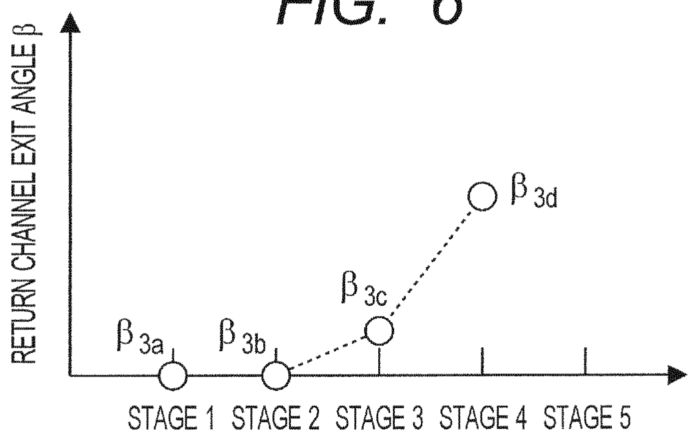


FIG. 7

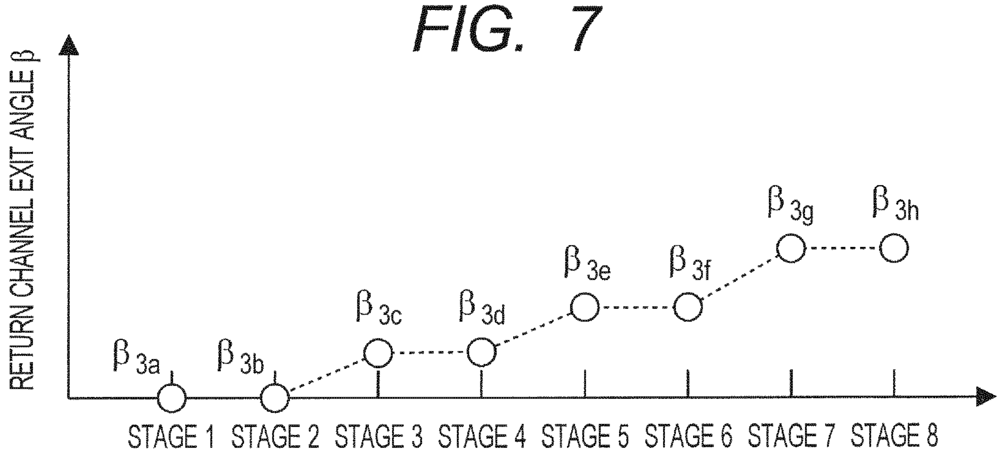
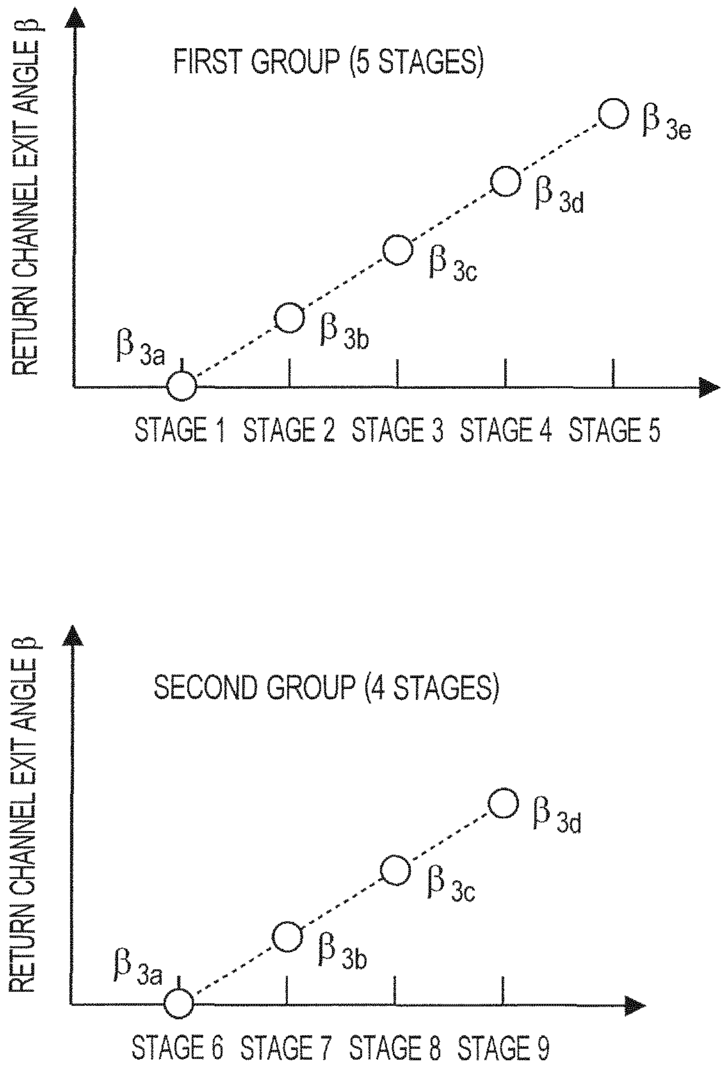


FIG. 8


RETURN CHANNEL EXIT ANGLE β
FIRST GROUP (5 STAGES)
β 3a
β 3b
β 3c
β 3d
β 3e
STAGE 1
STAGE 2
STAGE 3
STAGE 4
STAGE 5
RETURN CHANNEL EXIT ANGLE β
SECOND GROUP (4 STAGES)
β 3a
β 3b
β 3c
β 3d
STAGE 6
STAGE 7
STAGE 8
STAGE 9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2011/073876

A. CLASSIFICATION OF SUBJECT MATTER
F04D29/44(2006.01)i, *F04D17/12*(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, F04D17/12

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	1996-2011
Kokai Jitsuyo Shinan Koho	1971-2011	Toroku Jitsuyo Shinan Koho	1994-2011

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 8-200296 A (Hitachi, Ltd.), 06 August 1996 (06.08.1996), fig. 1 to 3 (Family: none)	1-6
A	JP 2001-200797 A (Hitachi, Ltd.), 27 July 2001 (27.07.2001), fig. 1 to 4 (Family: none)	1-6
A	JP 60-36702 A (Ebara Corp.), 25 February 1985 (25.02.1985), fig. 7, 11 (Family: none)	1-6

☐ 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 01 December, 2011 (01.12.11)	Date of mailing of the international search report 13 December, 2011 (13.12.11)
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Patent documents cited in the description

- JP 2005330878 A **[0004]**
- JP 9203394 A **[0004]**
- JP 8200289 A **[0004]**