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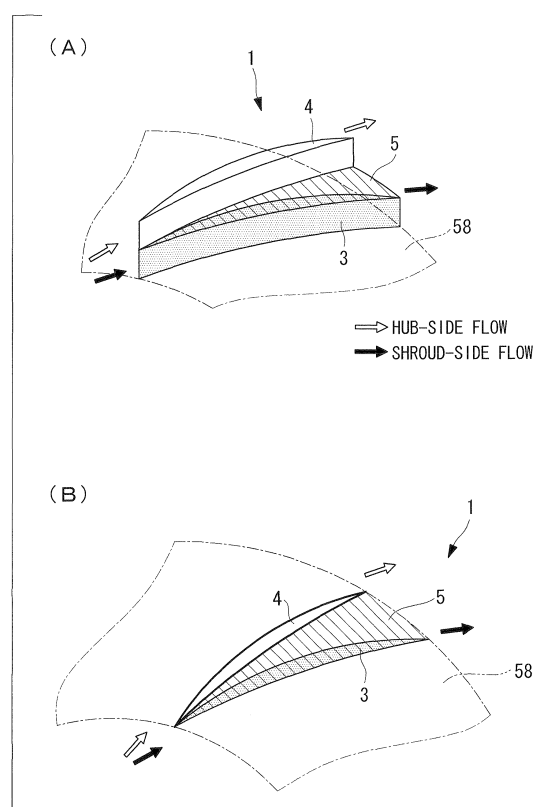
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(54) **CENTRIFUGAL COMPRESSOR DIFFUSER AND CENTRIFUGAL COMPRESSOR PROVIDED WITH THE SAME**

(57) A centrifugal compressor diffuser includes a shroud-side wall (58) provided downstream of a centrifugal impeller; a hub-side wall provided so as to face the shroud-side wall (58); a plurality of shroud-side blades (3) fixed at base ends thereof to the shroud-side wall (58) and hub-side blades (4) fixed at base ends thereof to the hub-side wall. The shroud-side blades (3) and the hub-side blades (4) are combined in such a state that inlet angles thereof differ from one another and that at least portions of top ends thereof in a blade height direction are abutted onto one another. In gaps where the top ends of the combined shroud-side blades (3) and hub-side blades (4) are not abutted onto one another, a connecting member (5) that connects the top ends is provided so as to fill at least portions of the gaps.

FIG. 1



Description

{Citation List}

{Technical Field}

{Patent Literature}

[0001] The present invention relates to a diffuser and a centrifugal compressor provided with the same, and more specifically, it relates to a diffuser in which blades having different inlet angles are combined in a blade height direction.

5 **[0007]**

{PTL 1} The Publication of Japanese Patent No. 3746740 {Summary of Invention}

{Background Art}

10 {Technical Problem}

[0002] FIG. 14 shows the relevant part of a centrifugal compressor disclosed in PTL 1, which is a known centrifugal compressor. FIG. 14(A) is a vertical cross-sectional view, FIG. 14(B) is a side view, FIG. 14(C) is an enlarged perspective view of a shroud-side blade and a hub-side blade, and FIG. 14 (D) is a top view of FIG. 14 (C).

[0008] However, in the centrifugal compressor disclosed in PTL 1, when the shroud-side blades 3 and the hub-side blades 4 having different blade inlet angles are combined, the combined shroud-side blades 3 and hub-side blades 4 may not overlap one another downstream of the leading edges of the diffuser blades 60, and thus, gaps 63 may be formed. If the gaps 63 are formed between the shroud-side blades 3 and the hub-side blades 4, as in this case, airflow separation and generation of vortices (represented by spiral arrows in FIGS. 14(C) and 14(D)) occur due to the influence of the airflow passing through the gaps 63, leading to a problem in that the performance of the diffuser 55 is lowered.

[0003] A centrifugal compressor 50 shown in FIG. 14 compresses fluid, such as gas or air, introduced from the outside of a housing 51 by rotating an impeller 53 having multiple blades 52 in the housing 51. The thus-formed flow of fluid (airflow) is directed outside through an impeller outlet 54 (also referred to as a "diffuser inlet"), which constitutes an outer circumferential edge of the impeller 53; a diffuser 55; and a volute 56. Note that the reference numeral 57 in the figure represents the axis of rotation of the impeller 53.

[0009] The present invention has been made in view of these circumstances, and an object thereof is to provide a centrifugal compressor diffuser that can be improved in performance by combining blades having different inlet angles in the blade height direction and a centrifugal compressor provided with the same.

[0004] The above-mentioned diffuser 55 is an airflow path provided between the impeller outlet 54 and the volute 56 and has a function of converting dynamic pressure to static pressure by decelerating the airflow discharged from the impeller outlet 54. Typically, this diffuser 55 is formed of a pair of opposing walls. In the description below, one of the pair of opposing walls is referred to as a shroud-side wall 58 and the other as a hub-side wall 2.

{Solution to Problem}

[0005] In the diffuser 51, a plurality of diffuser blades 60 are provided between the shroud-side wall 58 and the hub-side wall 2. These diffuser blades 60 include a plurality of shroud-side blades 3 provided on the shroud-side wall 58 and a plurality of hub-side blades 4 provided on the hub-side wall 2. The shroud-side blades 3 and the hub-side blades 4 are two-dimensional blades having different blade inlet angles and combined in the blade height direction.

[0010] To achieve the above object, the present invention provides the following solutions.
A centrifugal compressor diffuser according to a first aspect of the present invention includes a shroud-side wall provided downstream of a centrifugal impeller; a hub-side wall provided so as to face the shroud-side wall; a plurality of shroud-side blades fixed at base ends thereof to the shroud-side wall; and a plurality of hub-side blades fixed at base ends thereof to the hub-side wall. The shroud-side blades and the hub-side blades are combined in such a state that inlet angles thereof differ from one another and that at least portions of top ends thereof in a blade height direction are abutted onto one another. In gaps where the top ends of the combined shroud-side blades and hub-side blades are not abutted onto one another, a connecting member that connects the top ends so as to fill at least portions of the gaps is provided.

[0006] As described above, by combining the shroud-side blades 3 and the hub-side blades 4 having different blade inlet angles to make the flow angle of the airflow at an outlet of the blades 52 (the angle formed between the streamlines of the airflow and the cascade axis) close to the inlet angle of the diffuser blades 60 to prevent flow separation at the leading edges of the diffuser blades 60, it is possible to increase the efficiency of the diffuser 55 and to expand the operating range thereof.

[0011] In a centrifugal compressor diffuser including shroud-side blades and hub-side blades combined in such a state that inlet angles thereof differ from one another and that at least portions of top ends thereof in a blade height direction are abutted onto one another, gaps where the top ends of the combined shroud-side blades and hub-side blades are not abutted onto one another are sometimes formed. When such gaps where the top

ends of the shroud-side blades and hub-side blades are not abutted onto one another are formed, the performance of the diffuser is lowered due to separation of flow passing through the gap portions and generation of vortices.

[0012] Hence, a connecting member is provided, which connects the top ends so as to fill at least portions of the gaps formed due to the top ends of the combined shroud-side blades and hub-side blades not being abutted onto one another. As a result, the gaps formed between the top ends of the shroud-side blades and the top ends of the hub-side blades are covered by the connecting member. Thus, it is possible to eliminate a flow in the gaps and to suppress flow separation and generation of vortices caused by the flow in the gaps. Accordingly, it is possible to improve the performance of the diffuser. Furthermore, because the gaps formed between the top ends of the shroud-side blades and hub-side blades are connected by the connecting member, the rigidity of the blades can be increased. Accordingly, it is possible to improve the vibration strength of the blades.

[0013] In the centrifugal compressor diffuser according to the first aspect of the present invention, the connecting member may have a ring-like shape that continuously connects all of the top ends of the plurality of shroud-side blades and hub-side blades in a circumferential direction.

[0014] The connecting member may have a ring-like shape and may continuously connect all of the top ends of the shroud-side blades and hub-side wall blades. Thus, the gaps formed between the top ends of the shroud-side blades and hub-side blades when combined together are covered by the connecting member, whereby the flow in the gaps can be eliminated. As a result, it is possible to suppress flow separation and generation of vortices caused by the flow in the gaps. Accordingly, it is possible to improve the performance of the diffuser. Furthermore, because the connecting member has a simple, ring-like shape, the performance of the diffuser can be improved at low cost.

[0015] In the centrifugal compressor diffuser according to the first aspect of the present invention, the inside diameter of the ring-like connecting member may be smaller than the inside diameter of the shroud-side wall and hub-side wall.

[0016] As a result of studies, the inventors found that, also in the case where the inside diameter of the ring-like connecting member is smaller than the inside diameter of the shroud-side wall and hub-side wall, similarly to the case where the inside diameter of the ring-like connecting member is equal to the inside diameter of the shroud-side wall and hub-side wall, it is possible to eliminate a flow passing through the gaps formed between the top ends of the shroud-side blades and hub-side blades when combined and to improve the performance of the diffuser.

[0017] In the centrifugal compressor diffuser according to the first aspect of the present invention, the connecting member may be provided so as to fill an area from leading

edges of the top ends of at least one of the combined shroud-side blades and hub-side blades to 60% positions in the length of the blades on the downstream side.

[0018] As a result of studies, the inventors found that the gaps formed from the leading edges of the top ends of at least one of the shroud-side blades and the hub-side blades to 60% positions in the length of the blades on the downstream side cause a notable deterioration in performance due to flow separation and generation of vortices caused by the flow in the gaps.

[0019] Hence, the connecting member is provided in the circumferential direction so as to fill the gaps between the tip ends from the leading edges of the top ends of at least one of the shroud-side blades and the hub-side blades to 60% positions in the length of the blades on the downstream side. Thus, similarly to the case where the connecting member is provided in the circumferential direction so as to fill the gaps over the entire blade length from the leading edges to the trailing edges, it is possible to suppress flow separation and generation of vortices caused by the flow in the gaps. Accordingly, it is possible to improve the performance of the diffuser.

[0020] In the centrifugal compressor diffuser according to the first aspect of the present invention, the combined shroud-side blades and hub-side blades may be arranged such that their leading edges are shifted from one another in the circumferential direction.

[0021] The shroud-side blades and the hub-side blades combined therewith may be provided such that their leading edges are shifted from one another in the circumferential direction. Thus, when the shroud-side blades and the hub-side blades are combined, gaps are not formed between the leading edges of the top ends of the shroud-side blades and hub-side blades. Accordingly, it is possible to prevent flow separation and generation of vortices caused by the flow in the gaps and to improve the performance of the diffuser.

[0022] In the centrifugal compressor diffuser according to the first aspect of the present invention, the combined shroud-side blades and hub-side blades may be arranged so as to be shifted from one another in the circumferential direction such that they do not overlap one another from the leading edges to 60% positions in the entire length of the blades.

[0023] The shroud-side blades and the hub-side blades combined therewith may be provided so as to be shifted from one another in the circumferential direction such that they do not overlap one another from the leading edges to 60% positions in the entire length of the blades. Thus, gaps are not formed from the leading edges of the shroud-side blades and hub-side blades to 60% positions in the entire length of the blades. Accordingly, it is possible to suppress flow separation and generation of vortices caused by the flow in the gaps and to improve the performance of the diffuser.

[0024] A centrifugal compressor diffuser according to a second aspect of the present invention includes a shroud-side wall provided downstream of a centrifugal

impeller; a hub-side wall provided so as to face the shroud-side wall; a plurality of shroud-side blades fixed at base ends thereof to the shroud-side wall; and a plurality of hub-side blades fixed at base ends thereof to the hub-side wall. The shroud-side blades and the hub-side blades are combined in such a state that inlet angles thereof differ from one another and that top ends thereof in a blade height direction are abutted onto one another, with portions thereof in a thickness direction overlapping one another over the blade lengths.

[0025] The shroud-side blades and the hub-side blades have different inlet angles and their top ends in the blade height direction are abutted onto one another such that portions thereof in the thickness direction overlap one another over the blade lengths. Thus, gaps are not formed between the top ends of the shroud-side blades and hub-side blades when the shroud-side blades and the hub-side blades are combined. Accordingly, it is possible to prevent flow separation and generation of vortices caused by the flow in the gaps and to improve the performance of the diffuser.

Furthermore, because the top ends, in the blade height direction, of the shroud-side blades and hub-side blades are abutted onto one another such that portions thereof in the thickness direction overlap one another over the blade lengths, the rigidity of the blades can be increased. Accordingly, it is possible to improve the vibration strength of the blades.

[0026] In the centrifugal compressor diffuser according to the second aspect of the present invention, the thicknesses of the shroud-side blades and hub-side blades are smaller at the trailing edges than at middle portions in the length direction.

[0027] The thicknesses of the shroud-side blades and hub-side blades may be smaller at the trailing edges than at the middle portions in the length direction. Thus, it is possible to reduce the wake of the shroud-side blades and hub-side blades. Accordingly, it is possible to improve the performance of the diffuser.

[0028] In the centrifugal compressor diffuser according to the second aspect of the present invention, either the shroud-side blades or the hub-side blades may be thick blades and the other may be thin blades.

[0029] Either the shroud-side blades or the hub-side blades may be thick blades (for example, blades having a wedge shape or a channel shape in cross-section perpendicular to the blade height direction) and the other may be thin blades. As a result, when the shroud-side blades and the hub-side blades are abutted onto one another, the top ends of the thin blades overlap portions of the top ends of the thick blades. Thus, gaps are not formed between the top ends of the shroud-side blades and the top ends of the hub-side blades. Accordingly, it is possible to prevent flow separation and generation of vortices caused by the flow in the gaps and to improve the performance of the diffuser.

Note that it is preferable that the width of the thick blades in cross-section perpendicular to the blade height direc-

tion be about two or more times greater than that of the thin blades.

[0030] A centrifugal compressor diffuser according to a third aspect of the present invention includes the centrifugal compressor diffuser according to any one of the above-described aspects.

[0031] A diffuser whose performance can be improved by suppressing flow separation and generation of vortices in the gaps where the top ends of the combined shroud-side blades and hub-side blades are not abutted onto one another is used. Thus, it is possible to efficiently convert the speed energy of the flow passing through the diffuser into pressure. Accordingly, it is possible to improve the efficiency of the centrifugal compressor and to expand the operability thereof.

{Advantageous Effects of Invention}

[0032] In the centrifugal compressor diffuser according to the present invention, a connecting member is provided, which connects the top ends so as to fill at least portions of gaps formed due to the top ends of the combined shroud-side blades and hub-side blades not being abutted onto one another. As a result, the gaps formed between the top ends of the shroud-side blades and the top ends of the hub-side blades are covered by the connecting member. Thus, it is possible to eliminate the flow in the gaps and to suppress flow separation and generation of vortices caused by the flow in the gaps. Accordingly, it is possible to improve the performance of the diffuser. Furthermore, because the top ends of the shroud-side blades and hub-side blades are connected by the connecting member, the rigidity of the blades can be increased. Accordingly, it is possible to improve the vibration strength of the blades.

{Brief Description of Drawings}

[0033]

{FIG. 1} FIG. 1 shows a shroud-side blade and a hub-side blade provided in a centrifugal compressor diffuser according to a first embodiment of the present invention, in which (A) is a perspective view thereof, and (B) is a top view of (A).

{FIG. 2} FIG. 2 shows a second modification of the blades shown in FIG. 1, in which (A) is a perspective view thereof, and (B) is a top view of (A).

{FIG. 3} FIG. 3 shows a shroud-side blade and a hub-side blade provided in a centrifugal compressor diffuser according to a second embodiment of the present invention, in which (A) is a perspective view thereof, and (B) is a top view of (A).

{FIG. 4} FIG. 4 is a top view of a first modification of the blades shown in FIG. 3.

{FIG. 5} FIG. 5 is a top view of a second modification of the blades shown in FIG. 3.

{FIG. 6} FIG. 6 shows a shroud-side blade and a

hub-side blade of a centrifugal compressor diffuser according to a fourth embodiment of the present invention, in which (A) is a perspective view thereof, (B) is a top view of (A), and (C) is a cross-sectional view taken along line A-A in (A) and (B).

{FIG. 7} FIG. 7 shows a shroud-side blade and a hub-side blade provided in a centrifugal compressor diffuser according to a fifth embodiment of the present invention, in which (A) is a perspective view thereof, and (B) is a top view of (A).

{FIG. 8} FIG. 8 shows a shroud-side blade and a hub-side blade provided in a centrifugal compressor diffuser according to a sixth embodiment of the present invention, in which (A) is a perspective view thereof, and (B) is a top view of (A).

{FIG. 9} FIG. 9 shows a modification of the blades shown in FIG. 8, in which (A) is a perspective view thereof, and (B) is a top view of (A).

{FIG. 10} FIG. 10 shows a shroud-side blade and a hub-side blade provided in a centrifugal compressor diffuser according to a seventh embodiment of the present invention, in which (A) is a perspective view thereof, and (B) is a top view of (A).

{FIG. 11} FIG. 11 shows a modification of the blades shown in FIG. 10, in which (A) is a perspective view thereof, and (B) is a top view of (A).

{FIG. 12} FIG. 12 shows a shroud-side blade and a hub-side blade provided in a centrifugal compressor diffuser according to an eighth embodiment of the present invention, in which (A) is a perspective view thereof, and (B) is a top view of (A).

{FIG. 13} FIG. 13 shows a modification of the blades shown in FIG. 12, in which (A) is a perspective view thereof, and (B) is a top view of (A).

{FIG. 14} FIG. 14 shows the relevant part of a known centrifugal compressor, in which (A) is a vertical cross-sectional view, (B) is a side view, (C) is an enlarged perspective view of the shroud-side blade and the hub-side blade, and (D) is a top view of (C).

{Description of Embodiments}

First Embodiment

[0034] Shroud-side blades and hub-side blades provided in a centrifugal compressor diffuser according to a first embodiment of the present invention will be described with reference to FIGS. 1 and 14.

A diffuser 1 shown in FIG. 1 converts dynamic pressure of an airflow to static pressure by decelerating the airflow (flow) discharged from an outer circumferential edge of an impeller 53 (see FIG. 14) rotating inside a housing 51 (see FIG. 14) of a centrifugal compressor 50 (see FIG. 14). This diffuser 1 includes a shroud-side wall 58 provided downstream of the impeller (centrifugal impeller) 53, a hub-side wall 2 provided so as to face the shroud-side wall 58, a plurality of shroud-side blades 3 (FIG. 1 shows only one of them) fixed at base ends thereof to

the shroud-side wall 58, and a plurality of hub-side blades 4 (FIG. 1 shows only one of them) fixed at base ends thereof to the hub-side wall 2.

[0035] In the first embodiment, the shroud-side blades 3 and the hub-side blades 4 are two-dimensional thin blades provided with the same length. The shroud-side blades 3 and the hub-side blades 4 are combined in such a state that inlet angles thereof differ from one another and that the leading edges (at least portions thereof) of their top ends in the blade height direction are abutted onto one another. Their trailing edges are separated in the circumferential direction.

[0036] In gaps 63 (see FIG. 14) where the top ends of the combined shroud-side blades 3 and hub-side blades 4 are not abutted onto one another, connecting walls (connecting members) 5 connecting the top ends are provided so as to fill the gaps 63. The connecting walls 5 are provided along the entire length, from the leading edges to the trailing edges, of the shroud-side blades 3 and hub-side blades 4.

[0037] By providing the connecting walls 5 in the gaps 63 between the shroud-side blades 3 and the hub-side blades 4, the airflow guided from the leading edges of the shroud-side blades 3 flows along the top surfaces of the connecting walls 5 (upper side in FIG. 1(A)). Thus, it is possible to suppress airflow separation and generation of vortices caused by the flow in the gaps.

[0038] As has been described above, the diffuser 1 of a centrifugal compressor and the centrifugal compressor provided with the same according to the first embodiment provide the following advantages.

The connecting walls (connecting members) 5 connecting the top ends of the shroud-side blades 3 and hub-side blades 4 are provided so as to fill the gaps 63 (see FIG. 14) where the top ends of the combined shroud-side blades 3 and hub-side blades 4 are not abutted onto one another. As a result, the gaps 63 formed between the top ends of the shroud-side blades 3 and hub-side blades 4 are covered by the connecting walls 5. Thus, it is possible to eliminate a flow in the gaps and to suppress flow separation and generation of vortices caused by the flow in the gaps. Accordingly, it is possible to improve the performance of the diffuser 1.

Furthermore, because the top ends of the shroud-side blades 3 and hub-side blades 4 are connected by the connecting walls 5, the rigidity of the shroud-side blades 3 and hub-side blades 4 can be increased. Accordingly, it is possible to improve the vibration strength of the shroud-side blades 3 and hub-side blades 4.

[0039] Although it has been described that the connecting walls 5 are provided over the entire blade length, from the leading edges to the trailing edges, of the shroud-side blades 3 and hub-side blades 4 in the first embodiment, the present invention is not limited thereto. In a first modification of the first embodiment, the connecting walls 5 may cover the gaps 63 from the leading edges of the shroud-side blades 3 and hub-side blades 4 to some midpoint (for example, 60% of the blade length)

in the length of the blades.

[0040] As a result of studies, the inventors found that the gaps 63 formed from the leading edges of at least one of the shroud-side blades 3 and the hub-side blades 4 to 60% positions in the length of the blades cause a notable deterioration in performance due to flow separation and generation of vortices caused by the flow in the gaps. Thus, also in the case where the gaps 63 between the tips from the leading edges of the shroud-side blades 3 and hub-side blades 4 to 60% positions in the length of the blades are connected by the connecting walls 5, similarly to the case where the connecting walls 5 are provided so as to fill the gaps 63 over the entire blade length from the leading edges to the trailing edges, it is possible to suppress flow separation and generation of vortices caused by the flow in the gaps. Accordingly, it is possible to improve the performance of the diffuser 1.

[0041] Although it has been described that the shroud-side blades 3 and the hub-side blades 4 have the same length in the first embodiment, the present invention is not limited thereto. In a second modification of the first embodiment, hub-side blades 6 may have a smaller length than the shroud-side blades 3, as shown in FIG. 2.

[0042] FIG. 2(A) shows a perspective view of the second modification of the first embodiment, and (B) shows a top view of (A).

The hub-side blades 6 have a smaller length than the shroud-side blades 3. The leading edges of the hub-side blades 6 are located at some midpoint, on the downstream side, in the length of the shroud-side blades 3.

[0043] In the gaps where the top ends of the combined shroud-side blades 3 and hub-side blades 4 are not abutted onto one another, connecting walls (connecting members) 7 substantially parallel to the shroud-side wall 58 and the hub-side wall are provided. Because the leading edges of the hub-side blades 6 are located at some midpoint, on the downstream side, in the shroud-side blades 3, the connecting walls 7 are provided over the entire length of the hub-side blades 6 from the leading edges to the trailing edges of the hub-side blades 6.

[0044] In addition, the connecting walls 7 according to the second modification may cover the gaps from the leading edges of the hub-side blades 6 to some midpoint (for example, 60% of the blade length) in the length of the hub-side blades 6.

Second Embodiment

[0045] A diffuser according to a second embodiment differs from that according to the first embodiment in that a disc connecting all of the top ends of the shroud-side blades and hub-side blades is provided; the other configurations are the same. Therefore, the same structures will be denoted by the same reference numerals, and descriptions thereof will be omitted.

The second embodiment of the present invention will be described below using FIG. 3.

A disc (connecting member) 8 continuously connects top

ends of a plurality of (only one in FIG. 3) shroud-side blades 3 and hub-side blades 4 in a circumferential direction. The disc 8 has a ring-like shape and is provided substantially parallel to the shroud-side wall 58 and the hub-side wall (not shown).

[0046] The disc 8 has a ring-like shape similarly to the shroud-side wall 58 and the hub-side wall. The ring-like disc 8 is provided from the leading edges to the trailing edges of the shroud-side blades 3 and hub-side blades 4.

[0047] By providing the disc 8 so as to be sandwiched between all of the top ends of the plurality of shroud-side blades 3 and hub-side blades 4 in this manner, it is possible to separate the flow path of the airflow guided from the leading edges of the shroud-side blades 3 to the shroud-side blades 3 (indicated by black arrows) from the flow path of the airflow guided from the leading edges of the hub-side blades 4 to the hub-side blades 4 (indicated by white arrows). Thus, the airflow does not pass through the gaps where the top ends of the combined shroud-side blades 3 and hub-side blades 4 are not abutted onto one another, and hence, it is possible to suppress airflow separation and generation of vortices caused by the flow in the gaps.

[0048] As has been described above, the diffuser 1 of a centrifugal compressor and the centrifugal compressor provided with the same according to the second embodiment provide the following advantages.

The disc (connecting member) 8 has a ring-like shape and continuously connects all of the top ends of the shroud-side blades 3 and hub-side blades 4. Thus, the gaps formed between the shroud-side blades 3 and the hub-side blades 4 are covered by the disc 8, whereby the flow in the gaps can be eliminated. As a result, it is possible to suppress flow separation and generation of vortices caused by the flow in the gaps. Accordingly, it is possible to improve the performance of the diffuser 1. Furthermore, because the disc 8 has a simple, ring-like shape, the performance of the diffuser 1 can be improved at low cost.

[0049] Although it has been described that the shroud-side blades 3 and the hub-side blades 4 have the same length in the second embodiment, the present invention is not limited thereto. In a first modification of the second embodiment, the hub-side blades 6 may have a smaller length than the shroud-side blades 3, as shown in FIG. 4.

[0050] Furthermore, in a second modification of the second embodiment, the hub-side blades 6 may have a smaller length than the shroud-side blades 3, and the circumferential phases of the hub-side blades 3 and shroud-side blades 6 may be differentiated, as shown in FIG. 5.

[0051] More specifically, the shroud-side blades 3 and the hub-side blades 6 having a smaller length than the shroud-side blades 3 are provided such that their leading edges and trailing edges are located at different positions in the circumferential direction, and hence, they do not overlap one another.

Third Embodiment

[0052] A diffuser according to a third embodiment differs from that according to the second embodiment in the inside diameter of the disc connecting all of the top ends of the shroud-side blades and hub-side blades; the other configurations are the same. Accordingly, descriptions of the same structures will be omitted.

[0053] The ring-like disc (connecting member) continuously connecting all of the top ends of the plurality of shroud-side blades and hub-side blades in the circumferential direction has a smaller inside radius than a radius defined by the leading edges of the shroud-side blades and hub-side blades.

[0054] More specifically, the inner circumferential edge of the ring-like disc extends in the inside diameter direction beyond the leading edges of the shroud-side blades and hub-side blades; that is, the leading edges of the shroud-side blades and hub-side blades are provided at some midpoint in the disc in the radial direction.

[0055] As has been described above, the centrifugal compressor diffuser and the centrifugal compressor provided with the same according to the third embodiment provide the following advantages.

As a result of studies, the inventors found that, also in the case where the inside diameter of the ring-like disc (connecting member) is smaller than the radius defined by the leading edges of the shroud-side blades and hub-side blades, it is possible to eliminate a flow passing through the gaps formed between the shroud-side blades and the hub-side blades and to improve the performance of the diffuser, similarly to the case where the inside diameter of the ring-like disc is the same as the radius defined by the leading edges of the shroud-side blades and hub-side blades.

Fourth Embodiment

[0056] A diffuser according to a fourth embodiment differs from that according to the first embodiment in that the leading edges of the shroud-side blades and hub-side blades are located at positions shifted from one another in the circumferential direction; the other configurations are the same. Therefore, the same structures will be denoted by the same reference numerals, and descriptions thereof will be omitted.

A fourth embodiment of the present invention will be described below using FIG. 6.

[0057] As shown in FIG. 6, the combined shroud-side blades 3 and hub-side blades 4 are arranged such that their leading edges are shifted from one another in the circumferential direction, and such that their trailing edges are shifted from one another in the circumferential direction. The shroud-side blades 3 and the hub-side blades 4 are shifted from one another in the circumferential direction such that they do not overlap one another at least from the leading edges to 60% positions in the length of the blades.

[0058] More specifically, in FIG. 6(C), which is the cross-section taken along line A-A in FIG. 6(B), the shroud-side blades 3 and the hub-side blades 4 are separated over the entire blade length from the leading edges to the trailing edges of the shroud-side blades 3 and hub-side blades 4. Note that the shroud-side blades 3 and the hub-side blades 4 may overlap one another beyond the 60% positions in the length of the blades from the leading edges.

[0059] In this manner, because the shroud-side blades 3 and the hub-side blades 4 are separated from the leading edges to the trailing edges of the shroud-side blades 3 and hub-side blades 4, gaps where the top ends of the combined shroud-side blades 3 and hub-side blades 4 are not abutted onto one another, which are formed in the first embodiment, are not formed. Thus, the airflow guided from the leading edges of the shroud-side blades 3 and the airflow guided from the leading edges of the hub-side blades 4 flow along the shroud-side blades 3 and the hub-side blades 4, respectively, whereby it is possible to suppress flow separation and generation of vortices caused by the flow in the gaps.

[0060] There is a description "the shroud-side blades 3 and the hub-side blades 4 may overlap one another beyond the 60% positions in the length of the blades from the leading edges", which allows gaps to be formed after those positions. This is led by findings reached by the inventors, as a result of studies, that the gaps 63 formed from the leading edges of at least one of the shroud-side blades 3 and the hub-side blades 4 to 60% positions in the length of the blades cause a notable deterioration in performance of the diffuser 1 due to flow separation and generation of vortices caused by the flow in the gaps.

[0061] As has been described above, the diffuser 1 of a centrifugal compressor and the centrifugal compressor provided with the same according to the fourth embodiment provide the following advantages.

The leading edges and the trailing edges of the combined shroud-side blades 3 and hub-side blades 4 are provided at positions shifted from one another in the circumferential direction. Thus, gaps are not formed between the top ends of the leading edges of the shroud-side blades 3 and hub-side blades 4 when the shroud-side blades 3 and the hub-side blades 4 are combined. Accordingly, it is possible to prevent flow separation and generation of vortices caused by the flow in the gaps, improving the performance of the diffuser 1.

Fifth Embodiment

[0062] A diffuser according to a fifth embodiment differs from that according to the fourth embodiment in that a disc connecting top ends of the shroud-side blades and hub-side blades is provided; the other configurations are the same. Therefore, the same structures will be denoted by the same reference numerals, and descriptions thereof will be omitted.

The fifth embodiment of the present invention will be de-

scribed below using FIG. 7.

The disc (connecting member) 8 has a ring-like shape similarly to the shroud-side wall 58 and the hub-side wall (not shown), and is provided substantially parallel to the shroud-side wall 58 and the hub-side wall. The ring-like disc 8 is provided from the leading edges to the trailing edges of the shroud-side blades 3 and hub-side blades 4.

[0063] In this manner, by providing the disc 8 so as to be sandwiched between all of the top ends of the plurality of shroud-side blades 3 and hub-side blades 4, it is possible to separate the flow path of the airflow guided from the leading edges of the shroud-side blades 3 to the shroud-side blades 3 from the flow path of the airflow guided from the leading edges of the hub-side blades 4 to the hub-side blades 4. Thus, it is possible to suppress airflow separation and generation of vortices caused by a flow in the gaps.

[0064] As has been described above, the diffuser 1 of a centrifugal compressor and the centrifugal compressor provided with the same according to the fifth embodiment provide the following advantages.

The disc (connecting member) 8 has a ring-like shape and continuously connects all of the top ends of the shroud-side blades 3 and hub-side blades 4. Thus, the gaps formed between the top ends of the shroud-side blades 3 and hub-side blades 4 are covered by the disc 8, whereby a flow in the gaps can be eliminated. As a result, it is possible to suppress flow separation and generation of vortices caused by the flow in the gaps. Accordingly, it is possible to improve the performance of the diffuser 1.

Furthermore, because the disc 8 has a simple shape, i.e., a ring-like shape, the performance of the diffuser 1 can be improved at low cost.

Sixth Embodiment

[0065] A diffuser according to a sixth embodiment differs from that according to the first embodiment in that the top ends of the shroud-side blades and hub-side blades are abutted onto one another such that portions of their thicknesses overlap one another over the blade lengths; the other configurations are the same. Therefore, the same structures will be denoted by the same reference numerals, and descriptions thereof will be omitted.

The sixth embodiment of the present invention will be described below using FIG. 8.

[0066] Shroud-side blades 11 and hub-side blades 12 are thick blades having a wedge shape in cross-section perpendicular to the blade height direction. The shroud-side blades 11 and the hub-side blades 12, which are wedge-shaped thick blades, have substantially triangular shapes in cross-section perpendicular to the blade height direction and gradually widen from their leading edges toward their trailing edges.

[0067] The wedge-shaped shroud-side blades 11 and hub-side blades 12 are combined in such a state that

inlet angles thereof differ from one another and that top ends thereof in the blade height direction are abutted onto one another, with portions thereof in a thickness direction overlapping one another over the blade lengths.

Thus, these top ends have overlapping portions 13 (see FIG. 8(B)) where portions thereof in the thickness direction overlap one another over the blade length.

[0068] In this manner, if the wedge-shaped shroud-side blades 11 and the thick-blade hub-side blades 12 are abutted such that they overlap one another, forming the overlapping portions 13, gaps are not formed between the top ends of the combined shroud-side blades 11 and hub-side blades 12. Thus, the airflow guided from the leading edges of the shroud-side blades 11 and the airflow guided from the leading edges of the hub-side blades 12 flow along the shroud-side blades 11 and the hub-side blades 12, respectively. Thus, it is possible to suppress airflow separation and generation of vortices.

[0069] As has been described above, the diffuser 1 of a centrifugal compressor and the centrifugal compressor provided with the same according to the sixth embodiment provide the following advantages.

The shroud-side blades 11 and the hub-side blades 12 are abutted onto one another such that their inlet angles differ from one another and such that portions, in the thickness direction, of their top ends in the blade height direction overlap one another over the blade lengths. Thus, gaps are not formed between the top ends of the shroud-side blades 11 and hub-side blades 12 when the shroud-side blades 11 and the hub-side blades 12 are combined. Accordingly, it is possible to prevent flow separation and generation of vortices caused by the flow in the gaps and to improve the performance of the diffuser 1. Furthermore, because the shroud-side blades 11 and the hub-side blades 12 are abutted onto one another such that portions, in the thickness direction, of their top ends in the blade height direction overlap one another over the blade lengths, it is possible to increase the rigidity of the shroud-side blades 11 and hub-side blades 12. Accordingly, it is possible to improve the vibration strength of the shroud-side blades 11 and hub-side blades 12.

[0070] Although it has been described that the shroud-side blades 11 and the hub-side blades 12 have the same length in the sixth embodiment, the present invention is not limited thereto. In a modification of the sixth embodiment, hub-side blades 14 may have a smaller length than the shroud-side blades 11, as shown in FIG. 9.

[0071] The hub-side blades 14 have a smaller length than the shroud-side blades 11, and the shroud-side blades 11 and the hub-side blades 14 are combined such that portions in the thickness direction have the overlapping portions 13 along the blade lengths and such that the leading edges of the hub-side blades 14 are located at some midpoint in the length of the shroud-side blades 11.

Seventh Embodiment

[0072] A diffuser according to a seventh embodiment differs from that according to the sixth embodiment in that the thicknesses of the trailing edges of the combined shroud-side blades and hub-side blades are small; the other configurations are the same. Therefore, the same structures will be denoted by the same reference numerals, and descriptions thereof will be omitted.

The seventh embodiment of the present invention will be described below using FIG. 10.

[0073] Shroud-side blades 15 and hub-side blades 16 are thick blades having substantially wedge shapes in cross-section perpendicular to the blade height direction. The substantially wedge-shaped shroud-side blades 15 and hub-side blades 16 are shaped such that they gradually widen from the leading edges toward the trailing edges and such that they gradually decrease in thickness from certain points downstream of the middle portions in the blade length toward the trailing edges.

[0074] The shroud-side blades 15 and the hub-side blades 16 that decrease in thickness toward the trailing edges are combined in such a state that inlet angles thereof differ from one another and that top ends thereof in the blade height direction are abutted onto one another, with portions thereof in a thickness direction overlapping one another over the blade lengths. Thus, these top ends have overlapping portions 17 (see FIG. 10(B)) where portions thereof in the thickness direction overlap one another over the blade length. The blade length of the hub-side blades 16 on the suction pressure surface side is substantially the same as the blade length of the shroud-side blades 15 on the pressure surface side, and the hub-side blades 16 and the shroud-side blades 15 form the overlapping portions 17.

[0075] As has been described above, the diffuser 1 of a centrifugal compressor and the centrifugal compressor provided with the same according to the seventh embodiment provide the following advantages.

The thicknesses of the shroud-side blades 15 and hub-side blades 16 are smaller at the trailing edges than at the middle portions in the length direction. Thus, it is possible to reduce the wake of the shroud-side blades 15 and hub-side blades 16. Accordingly, it is possible to improve the performance of the diffuser 1.

[0076] Although it has been described that the shroud-side blades 15 and the hub-side blades 16 have the same length in the seventh embodiment, the present invention is not limited thereto. In a modification of the seventh embodiment, hub-side blades 18 may have a smaller length than the shroud-side blades 15, as shown in FIG. 11.

Eighth Embodiment

[0077] A diffuser according to an eighth embodiment differs from that according to the sixth embodiment in that thick shroud-side blades and thin hub-side blades

are combined; the other configurations are the same. Therefore, the same structures will be denoted by the same reference numerals, and descriptions thereof will be omitted.

5 The eighth embodiment of the present invention will be described below using FIG. 12.

[0078] The shroud-side blades 11 are thick blades having a wedge shape in cross-section perpendicular to the blade height direction. The wedge-shaped shroud-side blades 11 have a substantially triangular shape and gradually widen from the leading edges toward the trailing edges. The hub-side blades 4 are thin blades. The width of the shroud-side blades 11 in cross-section perpendicular to the blade height direction is about two or more times greater than that of the thin hub-side blades 4.

[0079] The thick shroud-side blades 11 and the thin hub-side blades 4 are combined such that their inlet angles differ from one another. Furthermore, they are combined in such a state that the top ends, in the blade height direction, of the thick shroud-side blades 11 and the top ends, in the blade height direction, of the thin hub-side blades 4 are abutted onto one another. Thus, as shown in FIG. 12(B), in top view, the entire top ends of the thin hub-side blades 4 overlap portions of the top ends of the thick shroud-side blades 11.

[0080] As has been described above, the diffuser 1 of a centrifugal compressor and the centrifugal compressor provided with the same according to the eighth embodiment provide the following advantages.

30 The thick shroud-side blades 11 and the thin hub-side blades 4 are abutted onto one another such that their inlet angles differ from one another and such that the entire top ends, in the blade height direction, of the hub-side blades 4 overlap portions, in the thickness direction, of the shroud-side blades 11 over the blade lengths. Thus, when the shroud-side blades 11 and the hub-side blades 4 are combined, gaps are not formed between the shroud-side blades 11 and the hub-side blades 4. Accordingly, it is possible to prevent flow separation and generation of vortices caused by the flow in the gaps and to improve the performance of the diffuser 1.

[0081] Although it has been described that the shroud-side blades 11 and the hub-side blades 4 have the same length in the eighth embodiment, the present invention is not limited thereto. In a modification of the eighth embodiment, as shown in FIG. 13, the hub-side blades 6 may have a smaller length than the shroud-side blades 11.

[0082] Although it has been described that the cross-section of the thick shroud-side blades 11 perpendicular to the blade height direction is wedge-shaped in the eighth embodiment, the cross-section thereof may be channel-shaped.

[0083]

55

{Reference Signs List}

1

diffuser

(continued)

- 3 shroud-side blade
- 4 hub-side blade
- 5 connecting wall (connecting member)
- 58 shroud-side wall

Claims**1.** A centrifugal compressor diffuser comprising:

a shroud-side wall provided downstream of a centrifugal impeller;
 a hub-side wall provided so as to face the shroud-side wall;
 a plurality of shroud-side blades fixed at base ends thereof to the shroud-side wall; and
 a plurality of hub-side blades fixed at base ends thereof to the hub-side wall, wherein the shroud-side blades and the hub-side blades are combined in such a state that inlet angles thereof differ from one another and that at least portions of top ends thereof in a blade height direction are abutted onto one another, and in gaps where the top ends of the combined shroud-side blades and hub-side blades are not abutted onto one another, a connecting member that connects the top ends so as to fill at least portions of the gaps is provided.

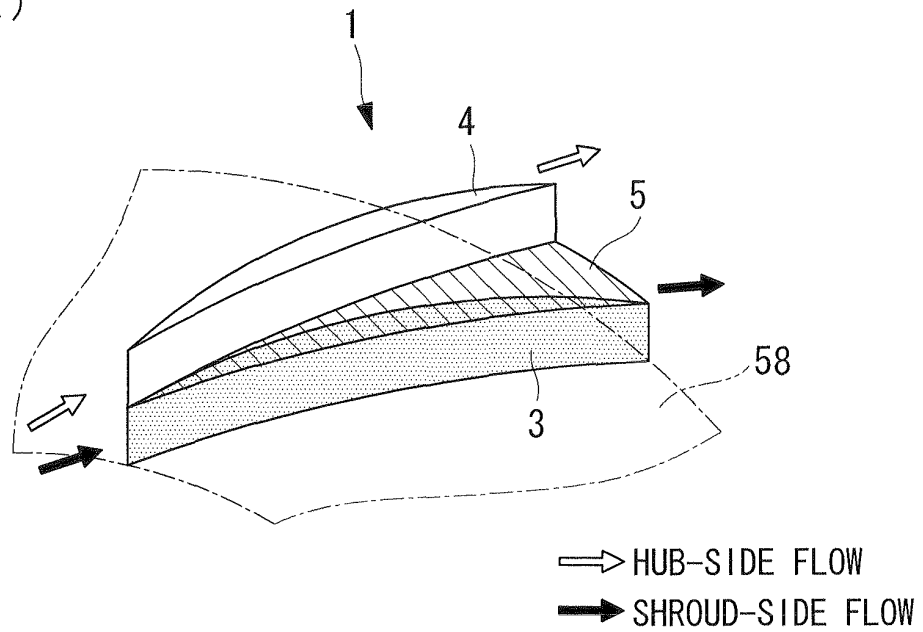
2. The centrifugal compressor diffuser according to Claim 1, wherein the connecting member has a ring-like shape that continuously connects the top ends of the plurality of shroud-side blades and hub-side blades in a circumferential direction.**3.** The centrifugal compressor diffuser according to Claim 2, wherein the inside diameter of the ring-like connecting member is smaller than a radius defined by leading edges of the shroud-side blades and hub-side blades.**4.** The centrifugal compressor diffuser according to any one of Claims 1 to 3, wherein the connecting member is provided so as to fill an area from leading edges of the top ends of at least one of the combined shroud-side blades and hub-side blades to 60% positions in the length of the blades on the downstream side.**5.** The centrifugal compressor diffuser according to any one of Claims 1 to 4, wherein the combined shroud-side blades and hub-side blades are arranged such that their leading edges are shifted from one another in the circumferential direction.**6.** The centrifugal compressor diffuser according to any one of Claims 1 to 4, wherein the combined shroud-side blades and hub-side blades are arranged so as to be shifted from one another in the circumferential direction such that they do not overlap one another from the leading edges to 60% positions in the length of the blades.**7.** A centrifugal compressor diffuser comprising:

a shroud-side wall provided downstream of a centrifugal impeller;
 a hub-side wall provided so as to face the shroud-side wall;
 a plurality of shroud-side blades fixed at base ends thereof to the shroud-side wall; and
 a plurality of hub-side blades fixed at base ends thereof to the hub-side wall, wherein the shroud-side blades and the hub-side blades are combined in such a state that inlet angles thereof differ from one another and that top ends thereof in a blade height direction are abutted onto one another, with portions thereof in a thickness direction overlapping one another over the blade lengths.

8. The centrifugal compressor diffuser according to Claim 7, wherein the thicknesses of the shroud-side blades and hub-side blades are smaller at the trailing edges than at middle portions in the length direction.**9.** The centrifugal compressor diffuser according to Claim 7 or Claim 8, wherein either the shroud-side blades or the hub-side blades are thick blades and the other are thin blades.**10.** A centrifugal compressor comprising the centrifugal compressor diffuser according to any one of Claims 1 to 9.

FIG. 1

(A)



(B)

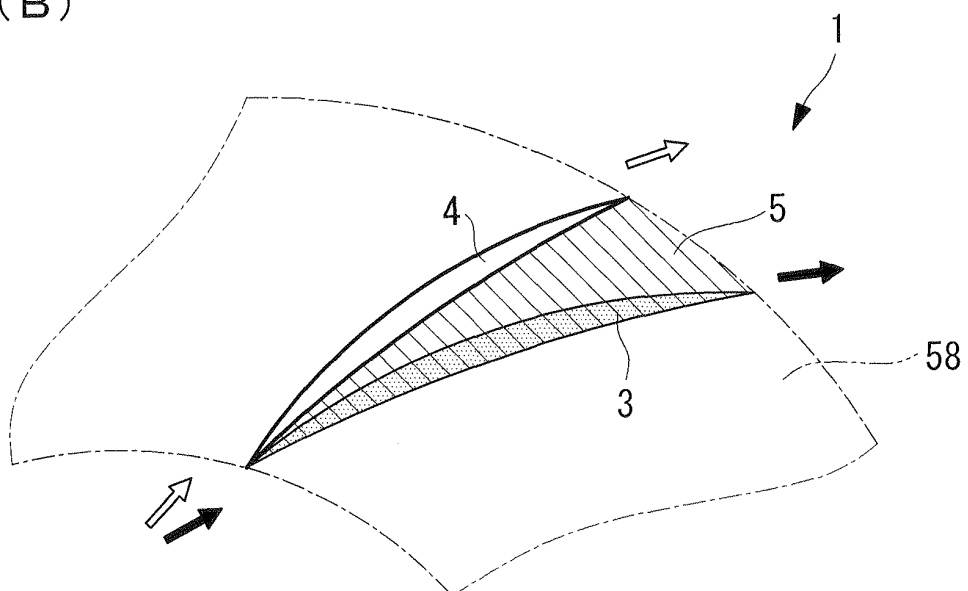
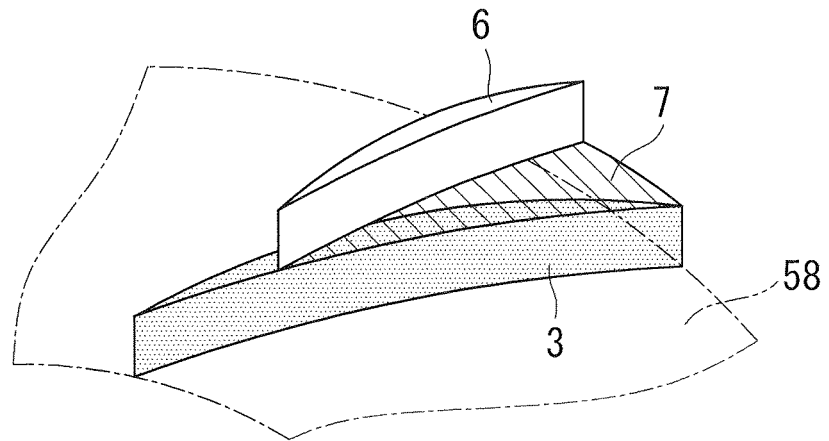


FIG. 2

(A)



(B)

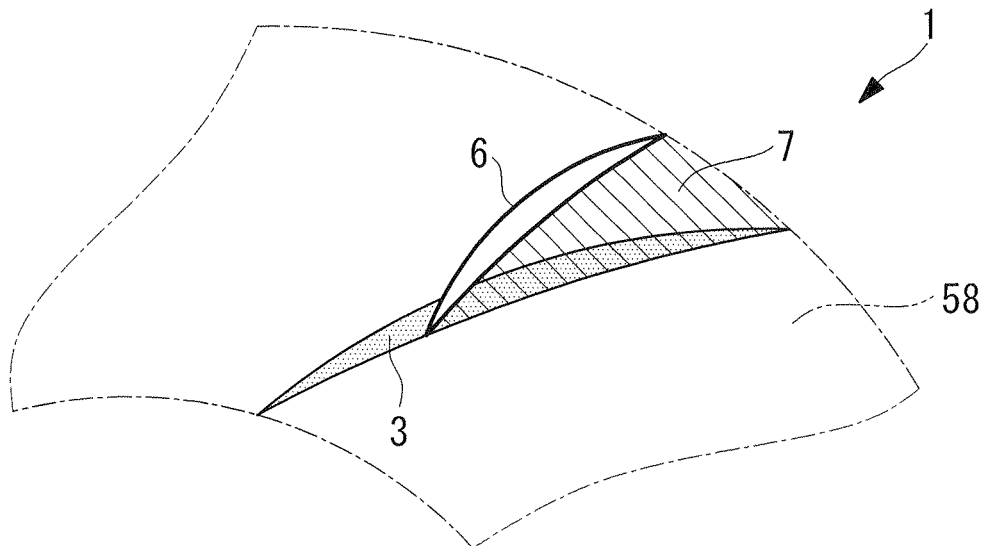
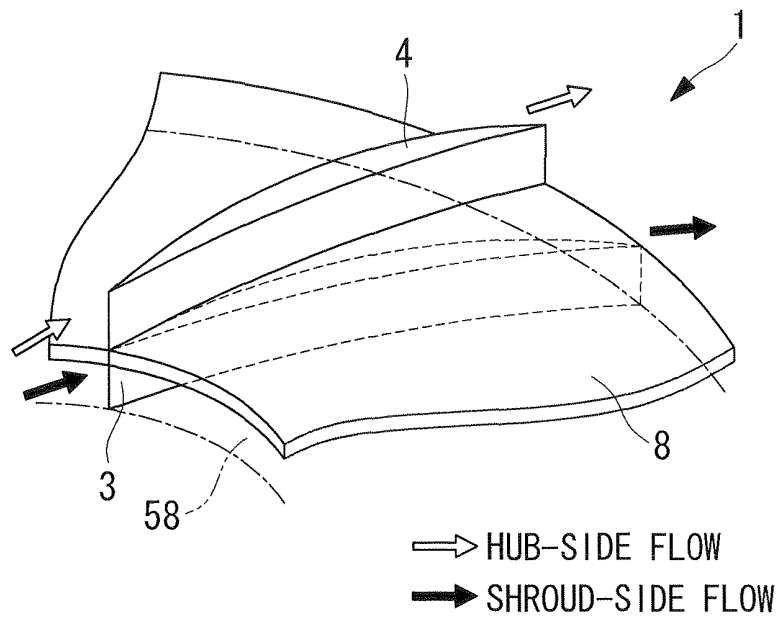


FIG. 3

(A)



(B)

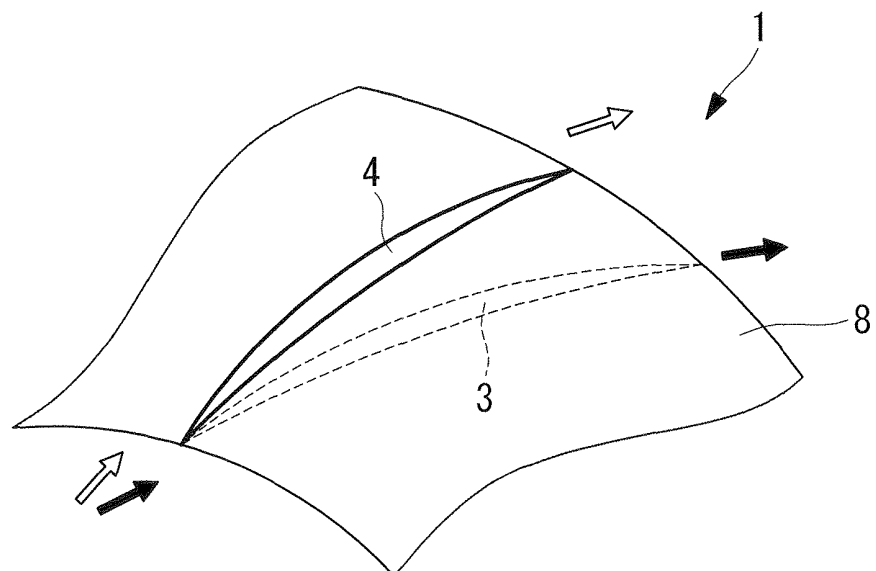


FIG. 4

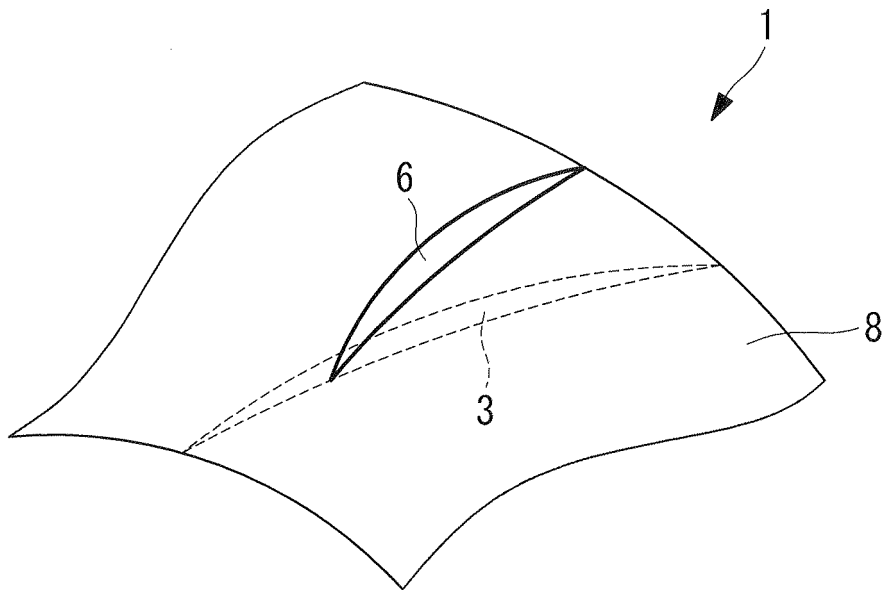


FIG. 5

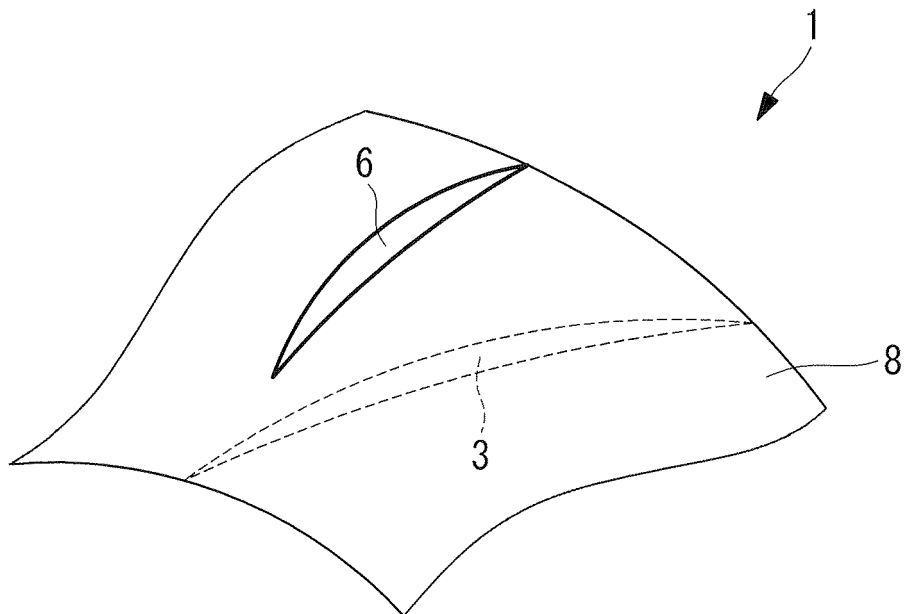


FIG. 6

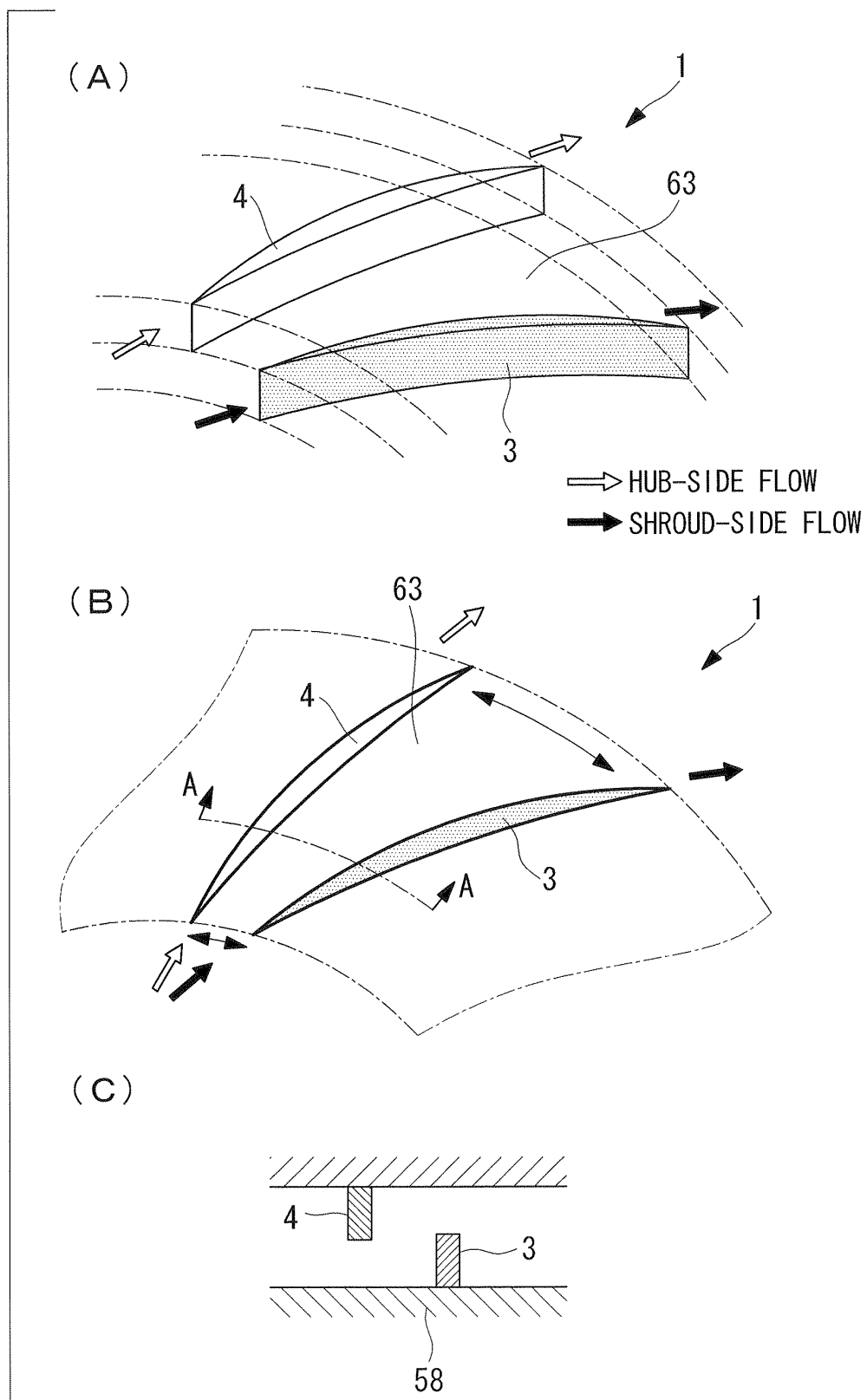


FIG. 7

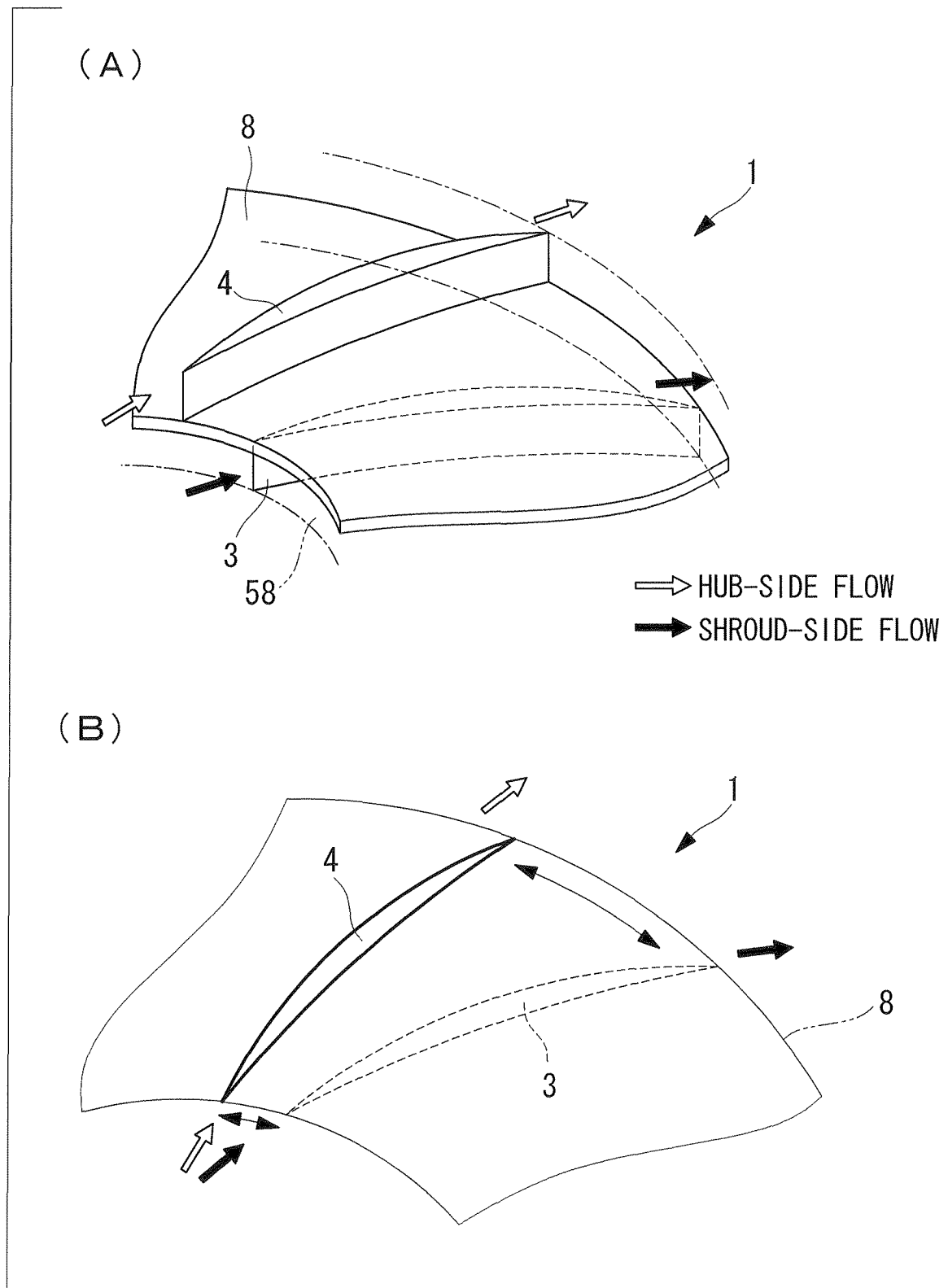
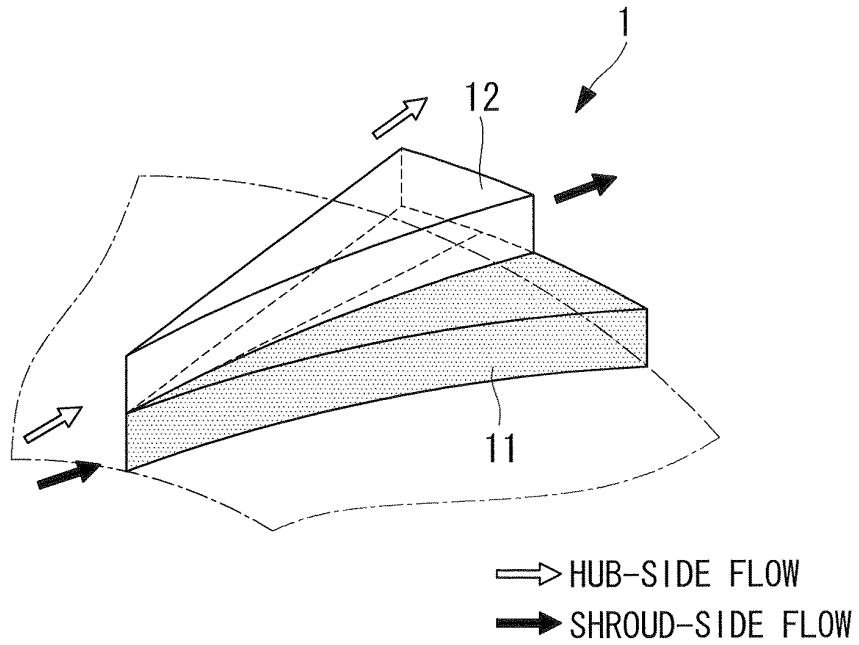


FIG. 8

(A)



(B)

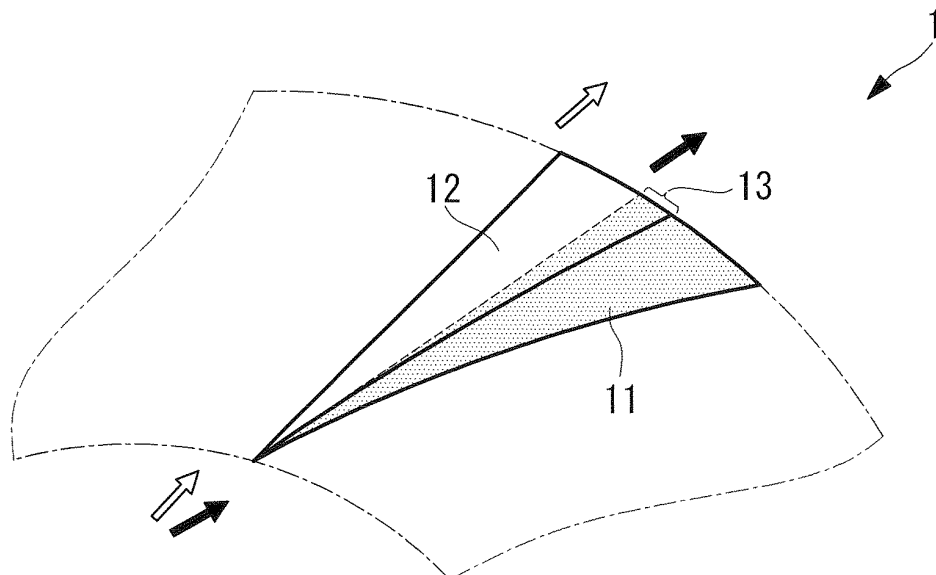
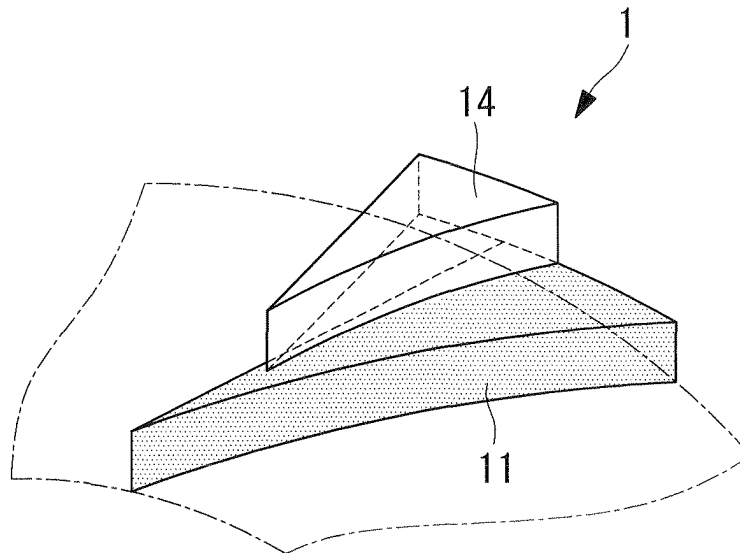


FIG. 9

(A)



(B)

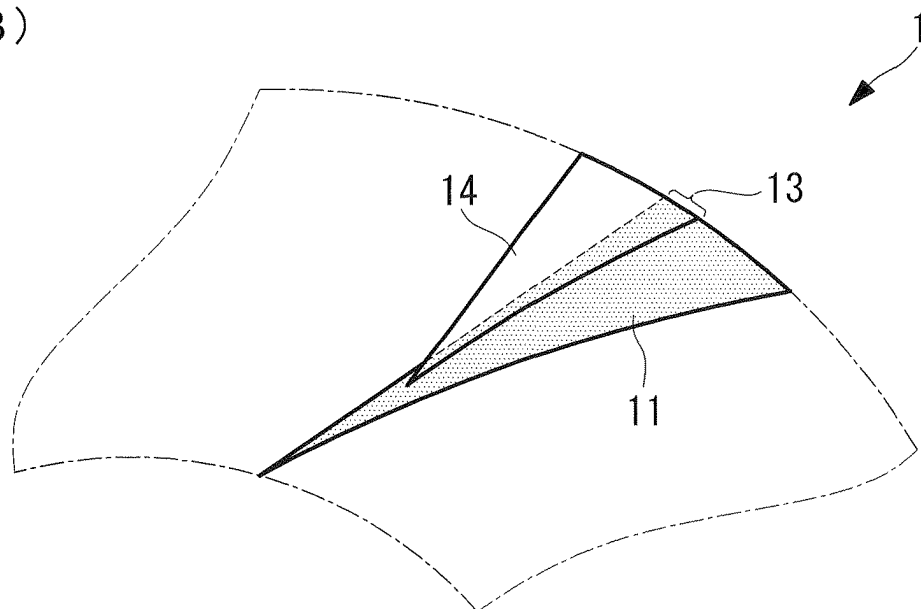
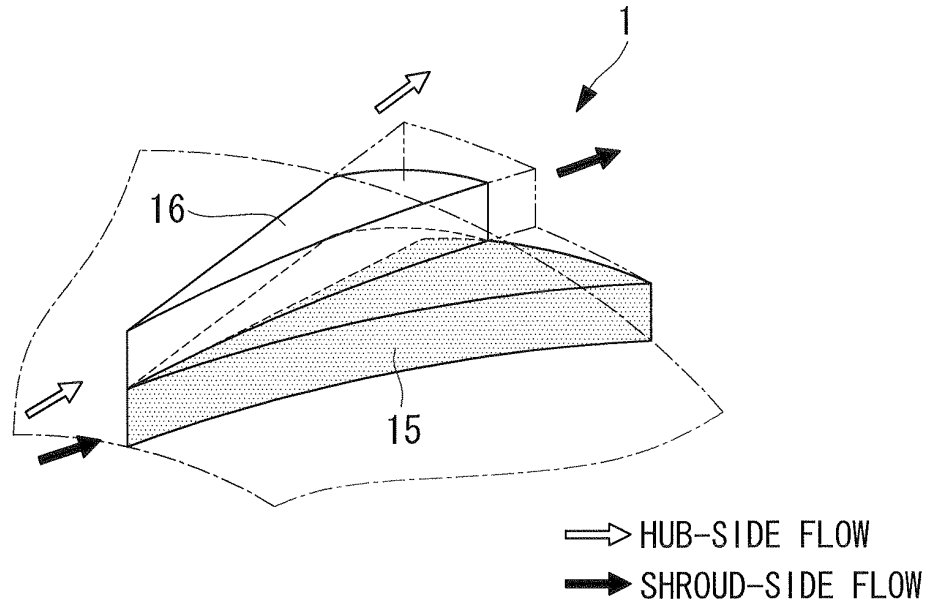


FIG. 10

(A)



(B)

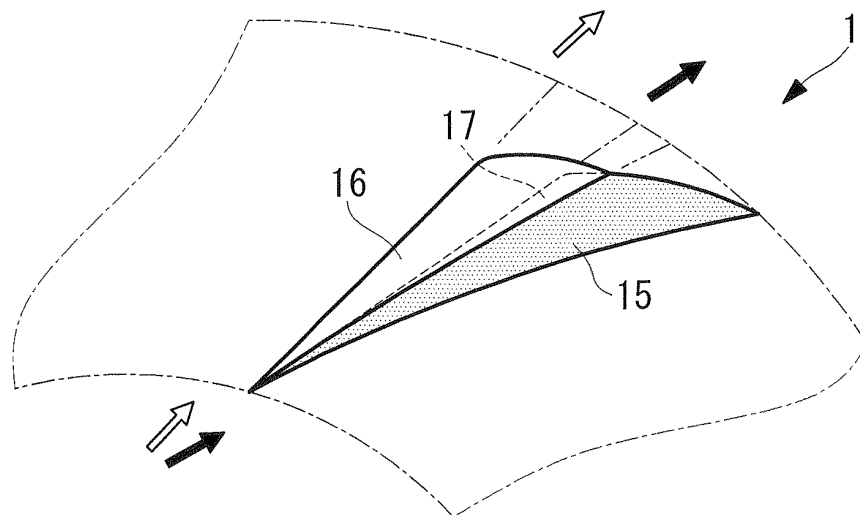
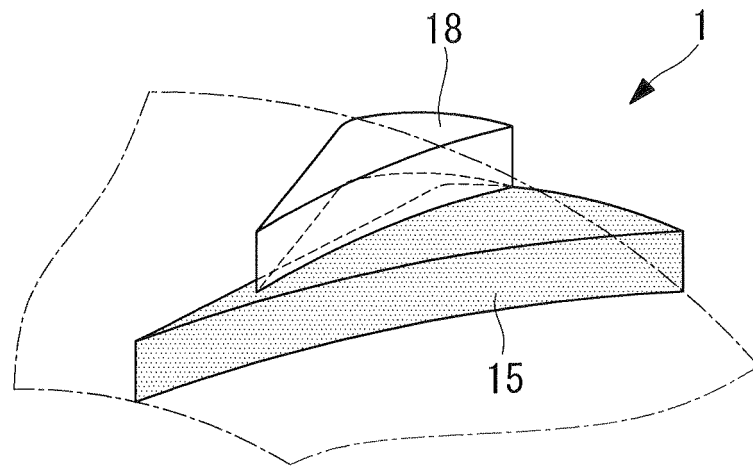


FIG. 11

(A)



(B)

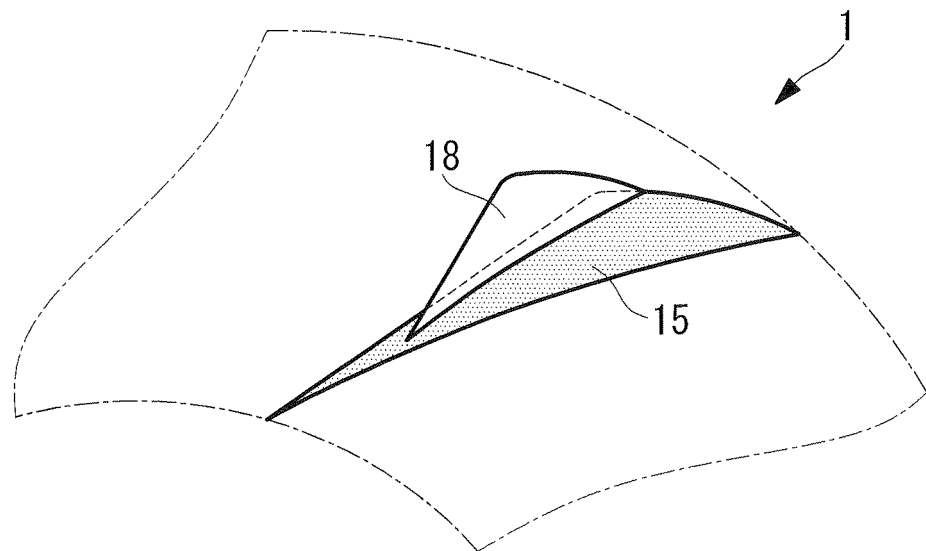
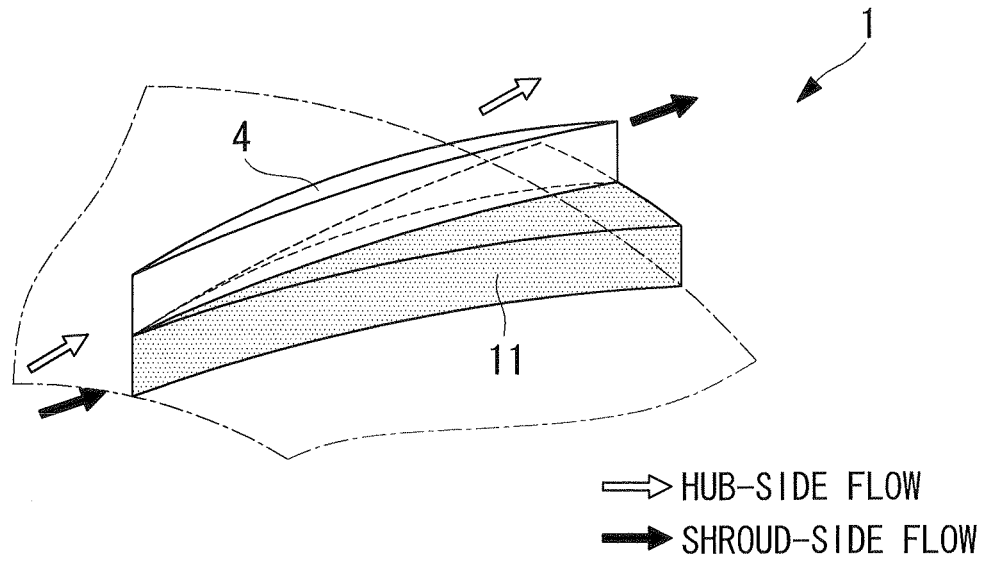


FIG. 12

(A)



(B)

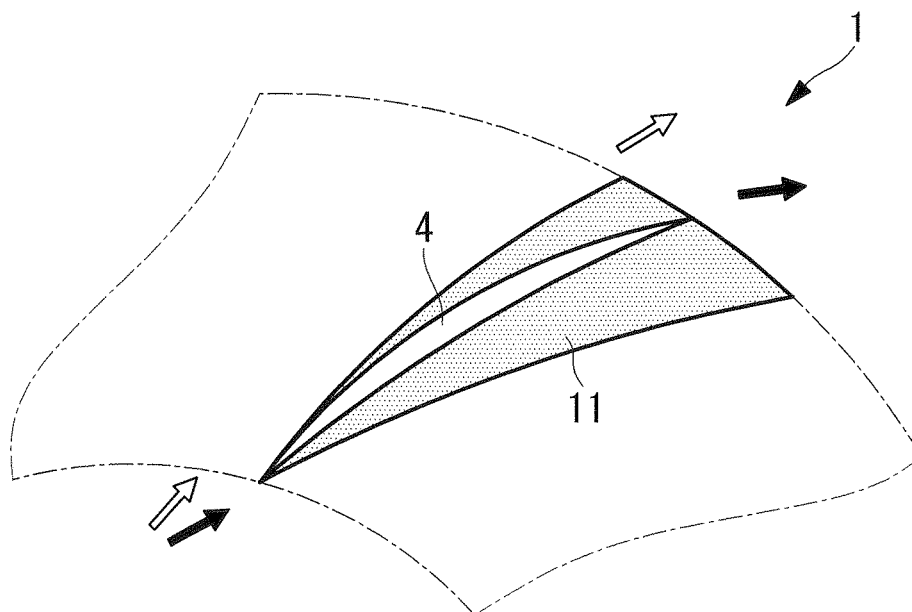
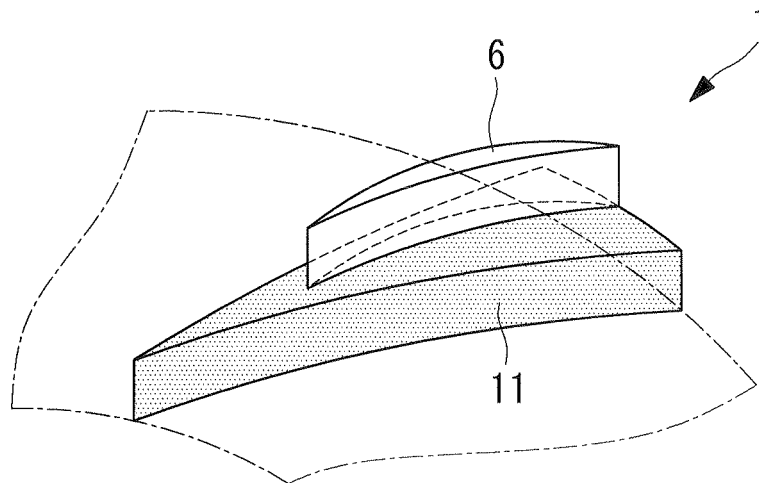


FIG. 13

(A)



(B)

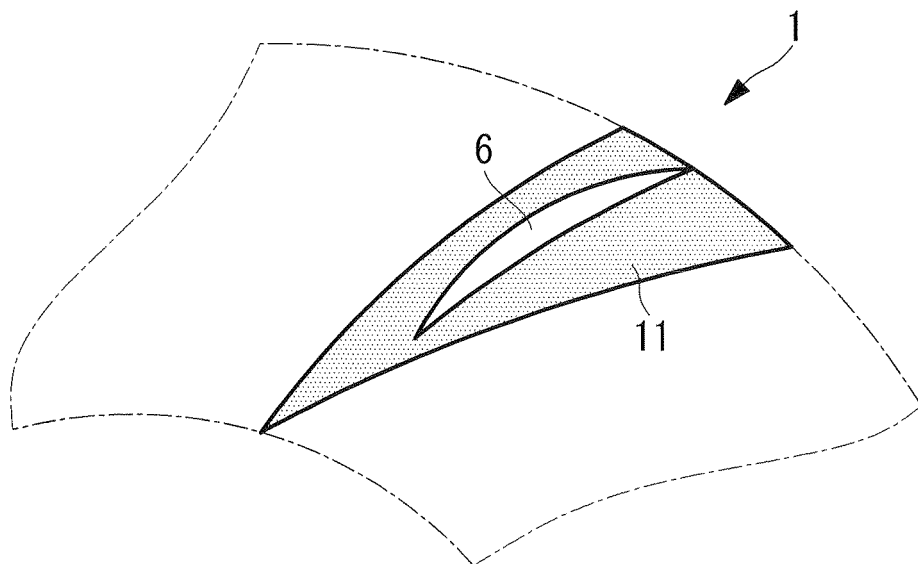
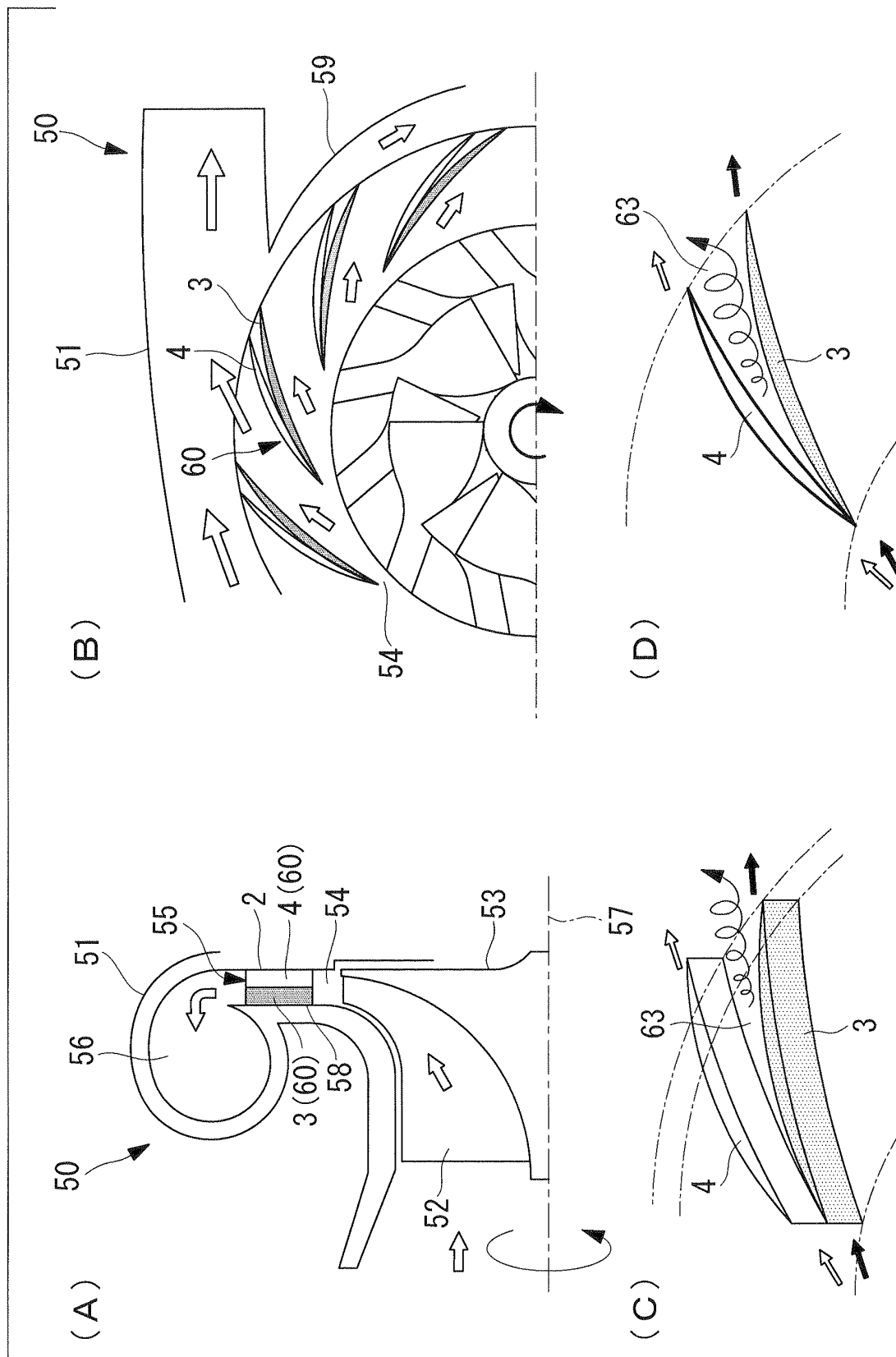


FIG. 14



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2011/068611

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, F04D29/46

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2011
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.
X A	JP 60-184999 A (Hitachi, Ltd.), 20 September 1985 (20.09.1985), page 3, upper left column, line 13 to lower left column, line 5; fig. 6 to 8 (Family: none)	1-2, 10 3-6
X	JP 3746740 B2 (Mitsubishi Heavy Industries, Ltd.), 15 February 2006 (15.02.2006), claim 1; paragraph [0026]; fig. 4 (Family: none)	7-10



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

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"I" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

07 November, 2011 (07.11.11)

Date of mailing of the international search report

22 November, 2011 (22.11.11)

Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

Facsimile No.

Telephone No.

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

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2011/068611

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P, A	JP 2011-89460 A (Hitachi Plant Technologies, Ltd.), 06 May 2011 (06.05.2011), paragraphs [0026], [0032]; fig. 1 to 3 & US 2011/0097203 A1 & EP 2314876 A2 & CN 102042266 A	5-6

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

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2011/068611

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

The inventions in claims 1-2 cannot be considered to be novel in the light of the invention disclosed in the document 1, and have no special technical feature. Therefore, it is considered that this international application involves the following two inventions.

(Invention 1) the inventions in claims 1-6, 10

(Invention 2) the inventions in claims 7-10

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

Form PCT/ISA/210 (continuation of first sheet (2)) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 3746740 B [0007]