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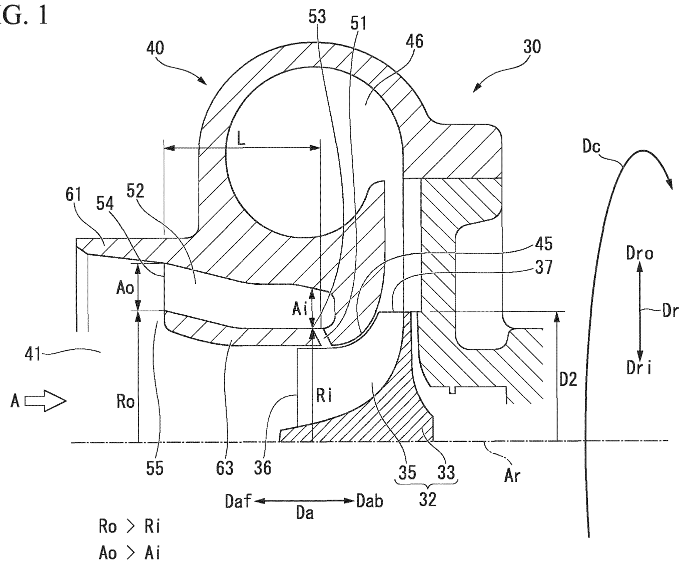
(54) **CENTRIFUGAL COMPRESSOR AND SUPERCHARGER COMPRISING SAME**

(57) A housing (40) is formed with an impeller side communicating passage (51) extending from an impeller chamber (45) in a direction including a component of an outer side (Dro) in a radial direction, circulating channels (52) extending from the impeller side communicating passage (51) in a direction including a component of a front side (Daf) in the axial direction, and a suction side communicating passage (55) communicating with the circulating channel (52) and a suction channel (41) that guides a gas into the impeller chamber (45). A radial dimension (Ri) from an axis (Ar) to a communicating position at which each of the circulating channels (52) communicates with the suction side communicating path (55) is larger than a radial dimension (Ro) from the axis (Ar) to a communication position with the impeller side communicating path (51) in the circulating channel (52). A channel area (Ao) of the circulating passage (52) at a communicating position for the suction side communicating passage (55) is larger than a channel area (Ai) of the circulating channel (52) at a communicating position for the impeller side communicating passage (51).

FIG. 1



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Description

[Technical Field]

[0001] The present invention relates to a centrifugal compressor and a supercharger having the same.

[Background Art]

[0002] A centrifugal compressor includes a rotary shaft, an impeller mounted around the rotary shaft, and a housing covering the impeller. The impeller of the centrifugal compressor guides a gas, which flows from a front side in an axial direction, to an outside in a radial direction. The housing is formed with a suction channel that guides the gas to the front side of the impeller in the axial direction, an impeller chamber which communicates with the suction channel and in which the impeller is housed, and a discharge channel which communicates with the impeller chamber and into which the gas sent from the impeller to the outside in the radial direction flows.

[0003] In this centrifugal compressor, when a flow rate of a gas flowing in the housing is reduced, a phenomenon called surging in which the gas violently vibrates in a flow direction of the gas occurs. For this reason, a various methods of suppressing this surging are being studied in the centrifugal compressor.

[0004] Thus, a centrifugal compressor, in which a working area is widened by moving a surge limit at which surging occurs to a lower flow side, is disclosed, for example, in Patent Literature 1 below. A housing of the centrifugal compressor is formed with either a chamber that spatially connects an impeller chamber and a suction channel of the housing or a chamber that spatially connects the impeller chamber of the housing and a suction pipe connected to the suction channel side of the housing. In this way, when the chamber is formed in the housing, even when a flow rate of a gas flowing from the suction channel to a discharge channel via the impeller chamber is low, part of the gas in the impeller chamber returns to the impeller chamber via the chamber and the suction channel. Thereby, the flow rate of the gas is increased at an upstream portion of the impeller chamber so that the surging can be suppressed.

[Citation List]

[Patent Literature]

[0005]

[Patent Literature 1]
Japanese Patent No. 3006215

[Summary of Invention]

[Technical Problem]

[0006] In the technique described in Patent Literature 1 above, the working area of the centrifugal compressor can be widened. However, in the centrifugal compressor, further widening the working area is required.

[0007] Thus, an object of the present invention is to provide a centrifugal compressor in which a working area can be widened, and a supercharger having the same.

[Solution to Problem]

[0008] To achieve the above object, a centrifugal compressor as an aspect according to the present invention includes: a rotary shaft configured to rotate about an axis; an impeller mounted on an outer circumference of the rotary shaft; and a housing configured to cover the impeller. The impeller has a hub mounted on the rotary shaft and a plurality of blades that are provided on the hub at intervals in a circumferential direction centered on the axis and are rotated integrally with the hub to guide a gas, which flows from a front side in an axial direction which is one side in an axial direction in which the axis extends, to an outer side in a radial direction relative to the axis. The housing is formed with a suction channel that guides the gas to the front side in the axial direction of the impeller, an impeller chamber which communicates with the suction channel and in which the impeller is housed, a discharge channel which communicates with the impeller chamber and into which the gas sent from the impeller to the outer side in the radial direction flows, an impeller side communication passage that communicates with the impeller chamber and extends from the impeller chamber in a direction including a component of the outer side in the radial direction, circulating channels that communicate with the impeller side communication passage and extend from the impeller side communication passage in a direction including a component of the front side in the axial direction, and a suction side communication passage that communicates with the circulating channels and the suction channel, and a suction side diameter dimension, which is a radial dimension in the radial direction from the axis to a communicating position at which each of the circulating channels communicates with the suction side communication passage, is greater than an impeller side diameter dimension, which is a radial dimension in the radial direction from the axis to a communicating position at which each of the circulating channels communicates with the impeller side communication passage, and a channel area of each of the circulating channels at the communicating position for the suction side communication passage is greater than that of each of the circulating channels at the communicating position for the impeller side communication passage.

[0009] In the centrifugal compressor, when a flow rate of the gas flowing into the suction channel is small, a pressure in the impeller chamber is higher than that in the suction channel. For this reason, when the circulating channels or the like are formed in the compressor housing like the centrifugal compressor, a part of the gas in the impeller chamber returns to the suction channel via the circulating channels or the like. As a result, the flow rate of a portion in the impeller chamber at the front side in the axial direction relative to the impeller side communication passage is increased. For this reason, in the centrifugal compressor, surging can be suppressed. That is, in the centrifugal compressor, a surge limit line can be set to a small flow rate side, and a working range can be widened.

[0010] A component of the gas flowing from the impeller chamber into the circulating channels via the impeller side communication passage in a flow direction includes a component that is a swirl component centered on the axis and is a component in the same direction as a rotational direction of the impeller. If the gas having the swirl component as a component of a flow returns to the impeller chamber via the circulating channels, the suction side communication passage, and the suction channel, an angle of attack of each blade is reduced, and thus a discharge pressure is reduced, that is, the pressure ratio is reduced.

[0011] In the centrifugal compressor, the suction side diameter dimension of each of the circulating channels is greater than the impeller side diameter dimension of each of the circulating channels. For this reason, in the centrifugal compressor, a flow velocity of the swirl component of the gas at the communicating position at which each of the circulating channels communicates with the suction side communication passage can be slower than that of the swirl component of the gas at the communicating position at which each of the circulating channels communicates with the impeller side communication passage.

[0012] In the centrifugal compressor, the channel are of each of the circulating channels at the communicating position for the suction side communication passage is greater than that of each of the circulating channels at the communicating position for the impeller side communication passage. For this reason, in the centrifugal compressor, a flow velocity of an axial component as well as the swirl component of the gas at the communicating position at which each of the circulating channels communicates with the suction side communication passage can be reduced.

[0013] As decribed above, in the centrifugal compressor, the flow velocity of the swirl component of the air flowing into the impeller chamber can be reduced. As a result, in the centrifugal compressor, the angle of attack of each blade is increased, so that a pressure ratio can be increased. Therefore, in the centrifugal compressor, the surge limit line can be set to a high pressure ratio side. For this reason, in the centrifugal compressor, the working range can be further widened.

[0014] Here, in the centrifugal compressor, the housing may be formed with the plurality of circulating channels that are arranged in the circumferential direction centered on the axis, and partition parts which divide circulating channels adjacent to each other in the circumferential direction.

[0015] In the centrifugal compressor, due to the presence of the partition parts, the flow velocity of the swirl component of the gas in the circulating channel can be suppressed.

[0016] In one of the above centrifugal compressors, the suction channel may be formed in a shape that is rotationally symmetric around the axis and has a diameter-reduced part in which a channel area thereof is gradually reduced toward a back side in the axial direction which is the other side in the axial direction, and a communication port of the suction side communication passage for the suction channel is formed in a face defining a channel at the diameter-reduced part.

[0017] In the centrifugal compressor, since the suction channel has the diameter-reduced part in which the channel area is gradually reduced toward the back side in the axial direction, the air from the outside easily flows into the impeller chamber via the suction channel. Further, in the centrifugal compressor, since the communication port of the suction side communication passage is formed in the face defining the channel at the diameter-reduced part, the gas in the suction side communication passage can be efficiently guided into the suction channel due to an effect of reducting a static pressure on this face.

[0018] As a result, in the centrifugal compressor, the flow rate of the gas flowing into the impeller chamber via the suction channel can be increased. For this reason, in the centrifugal compressor, the surge limit line can be set to a smaller flow rate side, and the working range can be further widened.

[0019] In the centrifugal compressor having the diameter-reduced part, the face defining the channel at the diameter-reduced part may form a curved surface protruding to a side close to the axis.

[0020] In the centrifugal compressor, since a part of the face defining the suction channel forms the curved surface protruding to the side close to the axis, that is, a bell mouth face, the air from the outside easily flows into the impeller chamber via the suction channel. Further, in the centrifugal compressor, since the communication port of the suction side communication passage is formed in the bell mouth face, the gas in the suction side communication passage can be efficiently guided into the suction channel due to an effect of reducting a static pressure on the bell mouth face.

[0021] In one of the centrifugal compressors having the diameter-reduced part, a radial dimension in the radial direction from the axis to an edge of the communication port of the suction side communication passage at the front side in the axial direction may be smaller than the suction side diameter dimension and may be greater than the impeller side diameter dimension.

[0022] In one of the above centrifugal compressors, the suction side communication passage may be folded back from a boundary between the circulating channel and the suction side communication passage and then extend toward a back side in the axial direction which is the other side in the axial direction to communicate with the suction channel while being directed to an inner side in the radial direction relative to the axis.

[0023] In the centrifugal compressor, the axial dimension of the housing can be prolonged, and the chennel length of the gas can be prolonged until a part of the gas of the impeller chamber returns to the suction channel via the impeller side communication passage, the circulating channels, and the suction side communication passage. When the chennel length in the axial direction is prolonged, the gas easily flows along a wall of the channel extending in the axial direction, and the swirl component of the gas is reduced. Therefore, in the centrifugal compressor, the angle of attack of each blade is increased, so that the pressure ration can be increased. For this reason, in the centrifugal compressor, the working range can be further widened.

[0024] In one of the above centrifugal compressors, when L is defined as an axial dimension in the axial direction from the communicating position at which each of the circulating channels communicates with the suction side communication passage to the communicating position at which each of the circulating channels communicates with the impeller side communication passage, when do is defined as an equivalent diameter related to the channel area of each of the circulating channels at the communicating position for the suction side communication passage, and when di is defined as an equivalent diameter related to the channel area of each of the circulating channels at the communicating position for the impeller side communication passage, a spread angle (2θ) defined by a formular below is less than 20°.

$$2\theta = 2 \times \tan((do - di)/2L) < 20°$$

[0025] Sharp reduction of the flow velocity in each of the circulating channels causes development of a boundary layer on a wall defining each of the circulating channels. For this reason, a loss of pressure of the gas flowing through each of the circulating channels increases, and the flow rate of the gas flowing through each of the circulating channels is reduced. Thus, in the centrifugal compressor, the spread angle (2θ) is set to be less than 20°, and a reduction in the flow rate of the gas flowing through each of the circulating channels is suppressed.

[0026] In one of the above centrifugal compressors, an axial dimension in the axial direction from the communicating position at which each of the circulating channels communicates with the suction side communication passage to the communicating position at which each of the circulating channels communicates with the impeller side communication passage may be greater than or equal to 0.25 times an impeller outer diameter that is a maximum outer diameter of the impeller.

[0027] When the chennel length in the axial direction is prolonged, the gas easily flows along the wall of the channel extending in the axial direction, and the swirl component of the gas is reduced. Therefore, in the centrifugal compressor, the axial dimension is prolonged from the communicating position at which each of the circulating channels communicates with the suction side communication passage to the communicating position at which each of the circulating channels communicates with the impeller side communication passage, and the swirl component of the gas is reduced.

[0028] To achieve the object, a supercharger as an aspect according to the present invention includes: one of the above centrifugal compressors, and a turbine. The turbine has a turbine rotary shaft configured to rotate about the axis, a turbine impeller mounted on an outer circumference of the turbine rotary shaft, and a turbine housing configured to conver the turbine impeller. The turbine rotary shaft and the rotary shaft of the centrifugal compressor are located on the same axis, are mutually coupled, are integrally rotated, and form a supercharger rotary shaft.

[Advantageous Effects of Invention]

[0029] In the aspect of the present invention, a working range of the centrifugal compressor can be widened.

[Brief Description of Drawings]

[0030]

Fig. 1 is a typical sectional view illustrating key parts of a centrifugal compressor in a first embodiment of the present invention.
Fig. 2 is a full section view of a supercharger in the first embodiment of the present invention.
Fig. 3 is an explanatory view for explaining a spread angle.
Fig. 4 is a typical sectional view illustrating key parts of a centrifugal compressor in a second comparative example.
Fig. 5 is a graph illustrating characteristics of each centrifugal compressor.
Fig. 6 is a typical sectional view illustrating key parts of a centrifugal compressor in a second embodiment of the present invention.
Fig. 7 is a typical sectional view illustrating key parts of a centrifugal compressor in a third embodiment of the present invention.
Fig. 8 is a typical sectional view illustrating key parts of a centrifugal compressor in a fourth embodiment of the present invention.

[Description of Embodiments]

[0031] Hereinafter, each embodiment according to the present invention will be described using the drawings.

[First embodiments of centrifugal compressor and supercharger]

[0032] First embodiments of a centrifugal compressor and a supercharger will be described using Figs. 1 to 5.
[0033] As illustrated in Fig. 2, a supercharger of the present embodiment includes a turbine 10 that is driven with exhaust gas EX from an engine, a centrifugal compressor 30 that compresses air A and feeds the compressed air A into the engine, and a coupler 20 that couples the centrifugal compressor 30 and the turbine 10.
[0034] The turbine 10 has a columnar turbine rotary shaft 11 that rotates about an axis Ar, a turbine impeller 12 that is mounted on an outer circumference of the turbine rotary shaft 11, and a turbine housing 19 that covers the turbine impeller 12.
[0035] The centrifugal compressor 30 has a columnar compressor rotary shaft 31 that rotates about the axis Ar, a compressor impeller 32 that is mounted on an outer circumference of the compressor rotary shaft 31, and a compressor housing 40 that covers the compressor impeller 32.
[0036] The coupler 20 has a columnar coupling rotary shaft 21 that rotates about the axis Ar, a central housing 29 that covers the coupling rotary shaft 21, and bearings 28 that rotatably support the coupling rotary shaft 21. The bearings 28 are fixed at an inner circumference side of the central housing 29.
[0037] The compressor rotary shaft 31, the coupling rotary shaft 21, and the turbine rotary shaft 11 have axes located on the same axis Ar, are coupled to one another in that order, rotate integrally, and constitute a supercharger rotary shaft. The compressor housing 40, the central housing 29, and the turbine housing 19 are coupled to one another and constitute a supercharger housing.
[0038] Here, a direction in which the axis Ar extends is defined as an axial direction Da which has one side defined as a front side Daf in the axial direction Daf, and the other side defined as a back side Dab in the axial direction. In the present embodiment, the centrifugal compressor 30 is provided at the front side Daf in the axial directionrelative to the coupler 20, and the turbine 10 is provided at the back side Dab in the axial direction relative to the coupler 20. In addition, a radial direction of the axis Ar is simply defined as a radial direction Dr; a side away from the axis Ar in the radial direction Dr is defined as an outer side Dro in the radial direction; and a side moving toward the axis Ar in the radial direction Dr is defined as an inner side Dri in the radial direction. A circumferential direction centered on the axis Ar is simply defined as a circumferential direction Dc.
[0039] The compressor impeller 32 is an open impeller. The compressor impeller 32 has a hub 33 that is mounted on the outer circumference of the compressor rotary shaft 31, and a plurality of blades 35 that are provided for the hub 33 at intervals in the circumferential direction Dc.
[0040] The hub 33 is formed in a circular shape having a shape centered on the axis Ar when viewed in the axial direction Da, and an outer diameter thereof gradually increases from the front side Daf in the axial direction toward the back side Dab in the axial direction. Further, the hub 33 has a shape having a tangent at each position, which is on a boundary between a hub face 34, which is a surface at the outer side Dro in the radial direction, and a meridian plane, that is gradually directed from a direction that is nearly parallel to the axis Ar toward the radial direction Dr as each of the positions is directed from the front side Daf in the axial direction toward the back side Dab in the axial direction.
[0041] The plurality of blades 35 are all provided on the hub face 34. The blades 35 protrude in a direction including

a directional component perpendicular to the hub face 34, and extend from the front side Daf in the axial direction of the hub face 34 to an edge of the hub face 34 at the back side Dab in the axial direction along the hub face 34. An edge of each of the blades 35 at the front side Daf in the axial direction forms a leading edge 36, and an edge of each of the blades 35 which is located at the back side Dab in the axial direction and is directed to the outer side Dro in the radial direction forms a trailing edge 37. A tip of each of the blades 35 in a direction in which each of the blades 35 protrudes from the hub face 34 forms a tip 38. The tip 38 of each of the blades 35 faces an inner circumferential surface of the compressor housing 40.

[0042] The compressor housing 40 is formed with a suction channel 41 that guides the air A to the compressor impeller 32 at the front side Daf in the axial direction, an impeller chamber 45 which communicates with the suction channel 41 and in which the compressor impeller 32 is housed, and a discharge channel 46 which communicates with the impeller chamber 45 and into which a gas, which is sent from the compressor impeller 32 to the outer side Dro in the radial direction flows. The suction channel 41 is formed in a shape that is rotationally symmetric around the axis Ar. The air A from the suction channel 41 flows from a space between the leading edges 36 of the plurality of blades 35 in the compressor impeller 32 into a space between the plurality of blades 35. The discharge channel 46 has a diffuser part 47 that spreads from the trailing edges 37 of the plurality of blades 35 to the outer side Dro in the radial direction, and a scroll part 48 that extends from an edge of the diffuser part 47 at the outer side Dro in the radial direction in the circumferential direction Dc. The air A from the discharge channel 46 flows from an intake manifold of the engine into cylinders of the engine.

[0043] The compressor housing 40 is further formed with an impeller side communication passage 51 that communicates with the impeller chamber 45 and extends from the impeller chamber 45 in a direction including a component of the outer side Dro in the radial direction, a plurality of circulating channels 52 that communicate with the impeller side communication passage 51 and extend from the impeller side communication passage 51 in a direction including a component of the front side Daf in the axial direction, and suction side communication passage 55 that communicate with the plurality of circulating channels 52 and the suction channel 41.

[0044] The impeller side communication passage 51 is open to the inner side Dri in the radial direction on an impeller chamber inner surface 45ip, which is a surface facing the tips 38 of the compressor impeller 32, within a surface defining the impeller chamber 45 of the compressor housing 40. The opening is the impeller chamber inner surface 45ip and is formed at a position that is between the back side Dab in the axial direction relative to the leading edges 36 of the compressor impeller 32 and at the front side Daf in the axial direction relative to the trailing edges 37 of the compressor impeller 32. In the present embodiment, the impeller side communication passage 51 is formed in an annular shape centered on the axis Ar. That is, the impeller side communication passage 51 extends from the impeller chamber 45 in the direction including the component of the outer side Dro in the radial direction, and is spread at an angle of 360° in the circumferential direction Dc centered on the axis Ar. For this reason, an opening formed in the impeller chamber inner surface 45ip of a passage adjacent to the compressor impeller 32 is open in 360° in the circumferential direction Dc centered on the axis Ar.

[0045] All of the plurality of circulating channels 52 extend from an end of the impeller side communication passage 51 at the outer side Dro in the radial direction in the direction including the component of the front side Daf in the axial direction, and are spread in the circumferential direction Dc. The plurality of circulating channels 52 are arranged in the circumferential direction Dc and center on the axis Ar. The circulating channels 52 adjacent to each other in the circumferential direction Dc are divided by struts (partition parts) 62 of the compressor housing 40.

[0046] The suction side communication passage 55 extends from ends of the plurality of circulating channels 52 at the front side Daf in the axial direction in the direction including the component of the inner side Dri in the radial direction, and communicates with the suction channel 41. In the present embodiment, like the impeller side communication passage 51, the suction side communication passage 55 is also formed in an annular shape centered on the axis Ar.

[0047] A portion of the compressor housing 40 which is at the inner side Dri in the radial direction of the plurality of circulating channels 52 and at the outer side Dro in the radial direction of the suction channel 41 forms a treatment tube 63. The treatment tube 63 is formed in a tubular shape centered on the axis Ar. An edge of the treatment tube 63 at the front side Daf in the axial direction forms an edge of the suction side communication passage 55 at the back side Dab in the axial direction. An edge of the treatment tube 63 at the back side Dab in the axial direction forms an edge of the impeller side communication passage 51 at the front side Daf in the axial direction. The treatment tube 63 is coupled to a housing main body 61, which forms a portion of the compressor housing 40 at the outer side Dro in the radial direction of the plurality of circulating channels 52, by the plurality of struts (partition parts) 62.

[0048] Next, dimensions of each part of the compressor housing 40 in the present embodiment will be described using Fig. 1.

[0049] Here, communicating positions of the circulating channels 52, which communicate with the impeller side communication passage 51, are defined as inlets 53 of the circulating channels 52, and communicating positions of the circulating channels 52, which communicate with the suction side communication passage 55, are defined as outlets 54 of the circulating channels 52. In the present embodiment, as shown in Formula (1) below, a suction side diameter dimension (hereinafter referred to as an outlet inner diameter) Ro, which is a dimension in the radical direction from the axis Ar to each of edges of the outlets 54 of the circulating channels 52 at the inner side Dri in the radial direction is greater than an impeller side diameter dimension (hereinafter referred to as an inlet inner diameter) Ri, which is a dimension in the radical direction from the axis Ar to each of edges of the inlets 53 of the circulating channels 52 at the inner side Dri in the radial direction.

$$Ro > Ri \ldots\ldots\ldots\ldots\ldots (1)$$

[0050] In the present embodiment, as shown in Formula (2) below, a channel area (hereinafter referred to as an outlet channel area) Ao of each of the outlets 54 of the circulating channels 52 is greater than a channel area (hereinafter referred to as an inlet channel area) Ai of each of the inlets 53 of the circulating channels 52.

$$Ao > Ai \ldots\ldots\ldots\ldots\ldots (2)$$

[0051] In the present embodiment, as shown in Formula (3) below, a channel length L of each of the circulating channels 52, which is a dimension from the inlet 53 to the outlet 54 in of each of the circulating channels 52 in the axial direction Da, is greater than or equal to 0.25 times an impeller outer diameter D2, which is the largest diameter of the compressor impeller 32.

$$L \geq 0.25 \times D2 \ldots\ldots\ldots\ldots\ldots (3)$$

[0052] In the present embodiment, a spread angle 2θ of each of the circulating channels 52, which is indicated by Formula (4) below, is less than 20°.

$$2\theta = 2 \times \tan((do-di)/2L) < 20° \ldots\ldots\ldots\ldots\ldots (4)$$

[0053] As described above, L in Formula (4) is the channel length of each of the circulating channels 52 in the axial direction Da. As illustrated in Fig. 3, do indicates an equivalent diameter of an area related to an outlet channel area Ao, and di indicates an equivalent diameter of an area related to an inlet channel area Ai. The spread angle 2θ refers to a doubled angle of an angle θ formed by a conical axis and a segment that connects an edge of the channel at an inlet position and an edge of the channel at an outlet position in a case in which it is assumed that a channel is a simple conical diffuser. An equivalent diameter related to a channel area refers to a diameter of a circle of the channel area.

[0054] Next, to set forth effects of the present embodiment, first and second comparative examples of the centrifugal compressor will be described.

[0055] Like the compressor housing 40 in the centrifugal compressor 30 of the present embodiment, a compressor housing in the centrifugal compressor of the first comparative example is formed with a suction channel, an impeller chamber, and a discharge channel. However, the impeller side communication passage 51, the circulating channels 52, and the suction side communication passage 55 of the compressor housing 40 in the centrifugal compressor 30 of the present embodiment are not formed in the centrifugal compressor of the first comparative example.

[0056] As illustrated in Fig. 4, like the compressor housing 40 in the centrifugal compressor 30 of the present embodiment, a compressor housing 40x in a centrifugal compressor 30x of the second comparative example is formed with a suction channel 41, an impeller chamber 45, and a discharge channel 46, and is further formed with an impeller side communication passage 51, circulating channels 52x, and a suction side communication passage 55.

[0057] However, in the second comparative example, an outlet inner diameter Ro of each of the circulating channels 52x and an impeller side diameter dimension Ri of each of the circulating channels 52x are identical to each other. In the second comparative example, an outlet channel area Ao of each of the circulating channels 52x and an inlet channel area Ai of each of the circulating channels 52x are identical to each other.

[0058] In the centrifugal compressor, when a flow rate of a gas flowing into the suction channel is low, a pressure in the suction channel is lower than that in the impeller chamber. For this reason, as in the present embodiment or the second comparative example, when the circulating channels 52 or 52x are formed in the compressor housing 40 or 40x, a part of the gas in the impeller chamber 45 returns to the suction channel 41 via the circulating channels 52 or 52x. As a result, a portion inside the impeller chamber 45 at the front side Daf in the axial direction relative to the impeller side communication passage 51 has a higher flow rate.

[0059] In the present embodiment or the second comparative example, when the flow rate of the gas flowing into the suction channel 41 is low, the flow rate of the gas flowing into the discharge channel 46 is also low, but the flow rate of the portion inside the impeller chamber 45 at the front side Daf in the axial direction relative to the impeller side communication passage 51 is higher than that of the gas flowing into the suction channel 41 so that surging can be suppressed. As illustrated in Fig. 5, surge limit lines S1 to S4 and Sx2 of first to fourth examples, which are various examples of the present embodiment, and the second comparative example become lower flow rate sides than a surge limit line Sx1 of the first comparative example. For this reason, in the first to fourth examples, which are various examples of the present embodiment, and the second comparative example, a working range of the centrifugal compressor 30 can be set to be wider than in the first comparative example. The centrifugal compressors of the first to fourth examples are centrifugal compressors that satisfy Formulae (1) to (4) above. However, as will be described below, a channel length L of each circulating channel is different in the centrifugal compressors of the first to fourth examples. A plurality of curves drawn by a solid line in Fig. 5 are characteristic curves showing a relation between a flow rate and a pressure ratio when the number of rotations are different from each other.

[0060] Meanwhile, a flow of the air A flowing into the circulating channels 52 or 52x from the impeller chamber 45 via the impeller side communication passage 51 is a swirl component centered on the axis Ar, and includes a component in the same direction as a rotational direction of the compressor impeller 32. If the air A having the swirl component as a component of the flow returns to the impeller chamber 45 via the circulating channel 52x, the suction side communication passage 55, and the suction channel 41 in the second comparative example, an angle of attack of each blade 35 is reduced, and thus a discharge pressure is reduced, that is, the pressure ratio is reduced.

[0061] When no external force is applied to a gas swirling about the axis Ar, Formula (5) below is established.

$$ci \times Ri = co \times Ro \quad \ldots\ldots\ldots\ldots\ldots (5)$$

[0062] In Formula (5), ci indicates a flow velocity of the swirl component of the air A in the inlet 53 of the circulating channel, and co indicates a flow velocity of the swirl component of the air A in the outlet 54 of the circulating channel. In Formula (5), Ri indicates the inlet inner diameter of the circulating channel, and Ro indicates the outlet inner diameter of the circulating channel 52.

[0063] For this reason, as in the present embodiment, when the outlet inner diameter Ro of the circulating channel 52 is greater than the inlet inner diameter Ri of the circulating channel 52, the flow velocity co of the swirl component of the air A in the outlet 54 of the circulating channel 52 becomes less than the flow velocity ci of the swirl component of the air A in the inlet 53 of the circulating channel 52.

[0064] In the present embodiment, the outlet channel area Ao of the circulating channel 52 is great than the inlet channel area Ai of the circulating channel 52. For this reason, in the present embodiment, the flow velocity co of the swirl component of the air A in the outlet 54 of the circulating channel 52 becomes still less than the flow velocity ci of the swirl component of the air A in the inlet 53 of the circulating channel 52.

[0065] Therefore, in the centrifugal compressor 30 of the present embodiment, the flow velocity of the swirl component of the air A flowing into the impeller chamber 45 can become less than in the centrifugal compressor 30x of the second comparative example.

[0066] Among the first to fourth examples, which are various examples of the present embodiment, the first example is the centrifugal compressor 30 in which the channel length L of the circulating channel 52 is 0.25×D. The second example is the centrifugal compressor 30 in which the channel length L of the circulating channel 52 is 0.50×D. The third example is the centrifugal compressor 30 in which the channel length L of the circulating channel 52 is 0.64×D. The fourth example is the centrifugal compressor 30 in which the channel length L of the circulating channel 52 is 0.89×D. That is, among the first to fourth examples, the channel length L of the first example is shortest, and is set to be longer in the order of the second example, the third example, and the fourth example.

[0067] As illustrated in Fig. 5, among the first to fourth examples, the surge limit line S1 of the first example is at the highest flow rate side, and the surge limit line moves to a low flow rate side in the order of the second example, the third example, and the fourth example. That is, as the channel length L of the circulating channel 52 lengthens, the surge limit line becomes the low flow rate side and the working range of the centrifugal compressor 30 can be widened. This is because, as the channel length L of the circulating channel 52 lengthens due to an influence of, for instance, friction between the circulating channel 52 and the air A, a velocity component as well as a swirl component of the flow of the air A in the axial direction Da is reduced. Thus, in the present embodiment, the channel length L of the circulating channel 52 is set to 0.25×D or more.

[0068] Meanwhile, in the present embodiment, as described above, the outlet channel area Ao of the circulating channel 52 is set to be larger than the inlet channel area Ai of the circulating channel 52, and the flow velocity of the air A in the circulating channel 52 is set to be slow. However, sharp deceleration in the circulating channel 52 causes development of a boundary layer at a wall surface defining the circulating channel 52. For this reason, a loss of pressure of the gas flowing through the circulating channel 52 increases, and the flow rate of the gas flowing through the circulating channel 52 is reduced. Thus, in the present embodiment, as described above, the spread angle 2θ is set to be smaller than 20° using Formula (5), and a reduction in the flow rate of the air A flowing through the circulating channel 52 is suppressed. As can be understood from Formula (5), to reduce the spread angle 2θ, the channel length of the circulating channel 52 is preferably prolonged.

[0069] That is, the channel length L of the circulating channel 52 is preferably prolonged in the view of reducing the swirl component as well as the spread angle 2θ. For this viewpoint, the channel length of the circulating channel 52 is greater than or equal to 0.25×D, and is preferably greater than or equal to 0.50×D if possible. However, when the channel length L of the circulating channel 52 is prolonged, an increase in the length of the compressor housing 40 in the axial direction Da is caused. For this reason, the channel length L of the circulating channel 52 is preferably decided after weighing the viewpoint of reducing the spread angle while reducing the swirl component against the viewpoint of increasing the length of the compressor housing 40.

[Second embodiment of centrifugal compressor]

[0070] A second embodiment of the centrifugal compressor will be described using Fig. 6.

[0071] Like the centrifugal compressor 30 of the first embodiment, a centrifugal compressor 30a of the present embodiment has a compressor impeller 32 and a compressor housing 40a. A constitution of the compressor impeller 32 is the same as in the first embodiment.

[0072] Like the compressor housing 40 in the centrifugal compressor 30 of the first embodiment, the compressor housing 40a of the present embodiment is also formed with a suction channel 41a, an impeller chamber 45, a discharge channel 46, an impeller side communication passage 51, a plurality of circulating channels 52, and a suction side communication passage 55a. However, shapes of the suction channel 41a and the suction side communication passage 55a in the compressor housing 40a of the present embodiment are different from those in the first embodiment.

[0073] The suction channel 41a of the present embodiment is formed in a shape that is rotationally symmetric around an axis Ar, and has a diameter-reduced part 42 in which a channel area is gradually reduced from a front side Daf in an axial direction toward a back side Dab in the axial direction. The diameter-reduced part 42 is formed in the shape of a bell mouth centered on the axis Ar. For this reason, a face defining a channel at the diameter-reduced part 42 forms a convex bell mouth face 42f that is smooth toward an inner side Dri in the radial direction which is a side close to the axis Ar.

[0074] A communication port 550 of the suction side communication passage 55a for the suction channel 41a is formed in the bell mouth face 42f defining the channel at the diameter-reduced part 42. Like the first embodiment, a portion of the suction side communication passage 55a at the back side Dab in the axial direction relative to the suction side communication passage 55a is formed by a treatment tube 63a. A portion of the suction side communication passage 55a at the front side Daf in the axial direction relative to the suction side communication passage 55a is formed by a housing main body 61 and a bell mouth cap 65.

[0075] An inner circumferential surface of the treatment tube 63a of the present embodiment forms a portion of the bell mouth face 42f at the back side Dab in the axial direction. For this reason, a channel defined by the inner circumferential surface of the treatment tube 63a is configured such that the channel area is gradually reduced from the front side Daf in the axial direction toward the back side Dab in the axial direction.

[0076] The bell mouth cap 65 is formed in a shape that is rotationally symmetric around the axis Ar. The bell mouth cap 65 is at the front side Daf in the axial direction of the housing main body 61 and is fixed at the inner side Dri in the radial direction. The bell mouth cap 65 is fixed to the housing main body 61 at an interval from the treatment tube 63a at the front side Daf in the axial direction. A space between the treatment tube 63a and the bell mouth cap 65 becomes the suction side communication passage 55a. The inner circumferential surface of the treatment tube 63a forms the portion of the bell mouth face 42f at the back side Dab in the axial direction. For this reason, a channel defined by an inner circumferential surface of the bell mouth cap 65 is configured such that the channel area is gradually reduced from the front side Daf in the axial direction toward the back side Dab in the axial direction.

[0077] Like the compressor housing 40 of the first embodiment, the compressor housing 40a of the present embodiment also satisfies Formulae (1) to (4). In the present embodiment, as shown in Formula (6) below, a dimension in the radical direction from the axis Ar to an edge of the communication port 550 of the suction side communication passage 55a at the front side Daf in the axial direction, that is, a dimension Rc in the radical direction from the axis Ar to an edge of the bell mouth cap 65, which is at the inner side Dri in the radial direction and at the front side Daf in the axial direction is smaller than an outlet inner diameter Ro and is greater than an inlet inner diameter Ri.

$$Ro>Rc>Ri \quad \ldots\ldots\ldots\ldots\ldots (6)$$

[0078] For this reason, in the present embodiment, to satisfy Formula (6), a channel, which is defined by the bell mouth face 42f, around the communication port 55o of the suction side communication passage 55a is smoothly reduced in diameter toward the back side Dab in the axial direction.

[0079] Like the compressor housing 40 of the first embodiment, the compressor housing 40a of the present embodiment also satisfies the relations shown in Formulae (1) to (4). Thus, a flow velocity of a swirl component of air A flowing into the impeller chamber 45 can be reduced, and a working range of the centrifugal compressor 30a can be widened.

[0080] Since part of a surface defining the suction channel 41a of the present embodiment forms the bell mouth face 42f, the air A easily flows from the outside into the impeller chamber 45 via the suction channel 41a. Further, in the present embodiment, since the communication port 55o of the suction side communication passage 55a for the suction channel 41a is formed in the bell mouth face 42f, the air A in the suction side communication passage 55a can be efficiently guided into the suction channel 41a due to an effect of reducing a static pressure at the bell mouth face 42f.

[0081] As a result, in the present embodiment, a flow rate of the air A flowing into the impeller chamber 45 via the suction channel 41a can be increased more than in the first embodiment. For this reason, in the present embodiment, a surge limit line can be set to a lower flow rate side than in the first embodiment, and the working range of the centrifugal compressor 30a can be further widened.

[Third embodiment of centrifugal compressor]

[0082] A third embodiment of the centrifugal compressor will be described using Fig. 7.

[0083] Like the centrifugal compressors 30 and 30a of the first and second embodiments, a centrifugal compressor 30b of the present embodiment has a compressor impeller 32 and a compressor housing 40b. A constitution of the compressor impeller 32 is the same as in the first and second embodiments.

[0084] Like the compressor housings 40 and 40a in the centrifugal compressors 30 and 30a of the first and second embodiments, the compressor housing 40b of the present embodiment is also formed with a suction channel 41b, an impeller chamber 45, a discharge channel 46, an impeller side communication passage 51, a plurality of circulating channels 52, and a suction side communication passage 55b. However, shapes of the suction channel 41b and the suction side communication passage 55b in the compressor housing 40b of the present embodiment are different from those in the first embodiment.

[0085] The suction channel 41b of the present embodiment has a diameter-reduced part 42b and a straight barrel part 43b that are formed in a shape that is rotationally symmetric around an axis Ar. The diameter-reduced part 42b is configured such that a channel area thereof is gradually reduced from a front side Daf in an axial direction toward a back side Dab in the axial direction. The diameter-reduced part 42b is formed in a shape of a bell mouth centered on the axis Ar. For this reason, a face defining a channel at the diameter-reduced part 42b forms a convex bell mouth face 42bf that is smooth toward an inner side Dri in the radial direction which is a side close to the axis Ar. The straight barrel part 43b has the same channel area at each position in an axial direction Da. For this reason, a face defining a channel at the straight barrel part 43b forms a cylindrical inner circumferential surface 43bg centered on the axis Ar.

[0086] A communication port 55oof the suction side communication passage 55b for the suction channel 41b is formed in the cylindrical inner circumferential surface 43bg defining the channel at the straight barrel part 43b. Like the first and second embodiments, a portion of the suction side communication passage 55b at the back side Dab in the axial direction relative to the suction side communication passage 55b is formed by a treatment tube 63b. A portion of the suction side communication passage 55b at the front side Daf in the axial direction relative to the suction side communication passage 55b is formed by a housing main body 61 and a bell mouth cap 65b. Like the second embodiment, the bell mouth cap 65b is at the front side Daf in the axial direction of the housing main body 61, and is fixed at the inner side Dri in the radial direction. The bell mouth cap 65b is also fixed to the housing main body 61 at an interval from the treatment tube 63b at the front side Daf in the axial direction. A space between the treatment tube 63b and the bell mouth cap 65b becomes the suction side communication passage 55b.

[0087] The suction side communication passage 55b is folded back from a boundary between the circulating channel 52 and the suction side communication passage 55b and then extends toward the back side Dab in the axial direction while being directed to the inner side Dri in the radial direction relative to the axis Ar to communicate with the suction channel 41b.

[0088] The treatment tube 63b of the present embodiment is formed with a diameter-reduced inner circumferential surface 63bf in which an inner diameter thereof is gradually reduced toward the back side Dab in the axial direction, and a cylindrical inner circumferential surface 63bg in which an inner diameter thereof is constant in the axial direction Da. The cylindrical inner circumferential surface 63bg is formed from an edge of the diameter-reduced inner circumferential surface 63bf at the back side Dab in the axial direction. The bell mouth cap 65b is formed with a bell mouth face 65bf in which an inner diameter is gradually reduced toward the back side Dab in the axial direction, and a cylindrical inner circumferential surface 65bg in which an inner diameter thereof is constant in the axial direction Da. The cylindrical inner circumferential surface 65bg is formed from an edge of the bell mouth face 65bf at the back side Dab in the axial direction.

Further, the bell mouth cap 65b is formed with a diameter-reduced outer circumferential surface 65bh in which an outer diameter thereof is gradually reduced toward the back side Dab in the axial direction.

[0089] The suction side communication passage 55b is formed between the diameter-reduced inner circumferential surface 63bf of the treatment tube 63b and the diameter-reduced outer circumferential surface 65bh of the bell mouth cap 65b. The cylindrical inner circumferential surface 43bg defining the channel at the straight barrel part 43b is formed by the cylindrical inner circumferential surface 63bg of the treatment tube 63b and the cylindrical inner circumferential surface 65bg of the bell mouth cap 65b.

[0090] Like the compressor housings 40 and 40a of the above embodiments, the compressor housing 40b of the present embodiment also satisfies the relations shown in Formulae (1) to (4). Like the compressor housing 40 of the first embodiment, the compressor housing 40b of the present embodiment can also reduce a flow velocity of a swirl component of air A flowing into the impeller chamber 45 and widen a working range of the centrifugal compressor 30a.

[0091] In the present embodiment, since the suction side communication passage 55b is folded back from the boundary between the circulating channel 52 and the suction side communication passage 55b and then extends toward the back side Dab in the axial direction to communicate with the suction channel 41b, a channel length required until a part of the air A in the impeller chamber 45 returns to the suction channel 41b is prolonged. For this reason, like the case in which the channel length L of the circulating channel 52 is prolonged, the flow velocity of the swirl component of the air A flowing into the impeller chamber 45 can be reduced. However, in the present embodiment, since the suction side communication passage 55b is folded back from the boundary between the circulating channel 52 and the suction side communication passage 55b and then extends toward the back side Dab in the axial direction, the channel length required until a part of the air A in the impeller chamber 45 returns to the suction channel 41b can be prolonged while inhibiting enlargement of the compressor housing 40b in the axial direction Da.

[Fourth embodiment of centrifugal compressor]

[0092] A fourth embodiment of the centrifugal compressor will be described using Fig. 8.

[0093] A centrifugal compressor 30c of the present embodiment is a combination of a structure of the centrifugal compressor 30a of the second embodiment and a structure of the centrifugal compressor 30b of the third embodiment. That is, the present embodiment is configured to form a communication port for a suction channel in suction side communication in a bell mouth face of a suction side channel as in the second embodiment while adopting the constitution of the suction side communication passage in the third embodiment.

[0094] Like the third embodiment, a suction channel 41c of the present embodiment also has a diameter-reduced part 42c and a straight barrel part 43c that are formed in a shape that is rotationally symmetric around an axis Ar. The diameter-reduced part 42c is configured such that a channel area thereof is gradually reduced from a front side Daf in an axial direction toward a back side Dab in the axial direction. The diameter-reduced part 42c is formed in a shape of a bell mouth centered on the axis Ar. For this reason, a face defining a channel at the diameter-reduced part 42c forms a convex bell mouth face 42cf that is smooth toward an inner side Dri in the radial direction. The straight barrel part 43c has the same channel area at each position in the axial direction Da. For this reason, a face defining a channel at the straight barrel part 43c forms a cylindrical inner circumferential surface 43cg centered on the axis Ar.

[0095] A communication port 55o of the suction side communication passage 55c for the suction channel 41c is formed in the bell mouth face 42cf at the diameter-reduced part 42c. Like each of the above embodiments, a portion of the suction side communication passage 55c at the back side Dab in the axial direction based on the suction side communication passage 55c is formed by a treatment tube 63c. A portion of the suction side communication passage 55c at the front side Daf in the axial direction relative to the suction side communication passage 55c is defined by a housing main body 61 and a bell mouth cap 65c. Like the second and third embodiments, the bell mouth cap 65c is at the front side Daf in the axial direction of the housing main body 61, and is fixed at the inner side Dri in the radial direction. The bell mouth cap 65c is also fixed to the housing main body 61 at an interval from the treatment tube 63c at the front side Daf in the axial direction. A space between the treatment tube 63c and the bell mouth cap 65c becomes the suction side communication passage 55c.

[0096] Like the third embodiment, the suction side communication passage 55c is folded back from a boundary between a circulating channel 52 and the suction side communication passage 55c, and then extends toward the back side Dab in the axial direction while being directed to the inner side Dri in the radial direction relative to the axis Ar, thereby communicating with the suction channel 41c.

[0097] The treatment tube 63c of the present embodiment is formed with a diameter-reduced inner circumferential surface 63cf in which an inner diameter thereof is gradually reduced toward the back side Dab in the axial direction, and a cylindrical inner circumferential surface 63cg in which an inner diameter thereof is constant in the axial direction Da. The cylindrical inner circumferential surface 63cg is formed from an edge of the diameter-reduced inner circumferential surface 63cf at the back side Dab in the axial direction. The bell mouth cap 65c is formed with a bell mouth face 65cf in which an inner diameter thereof is gradually reduced toward the back side Dab in the axial direction. Further, the bell mouth cap 65c is formed with a diameter-reduced outer circumferential surface 65ch in which an outer diameter thereof is gradually reduced toward the back side Dab in the axial direction. A portion of the treatment tube 63c in the diameter-reduced inner circumferential surface 63cf at the back side Dab in the axial direction forms a bell mouth face 63cff. The bell mouth face 63cff of the treatment tube 63c is located on a virtual bell mouth face in which the bell mouth face 65cf of the bell mouth cap 65c extends to the back side Dab in the axial direction.

[0098] The suction side communication passage 55c is formed between a portion excluding the bell mouth face 63cff from the diameter-reduced inner circumferential surface 63cf of the treatment tube 63c and the diameter-reduced outer circumferential surface 65ch of the bell mouth cap 65c. The bell mouth face 42cf at the diameter-reduced part 42c of the suction channel 41c is defined by the bell mouth face 65cf of the bell mouth cap 65c and the bell mouth face 63cff of the treatment tube 63c.

[0099] Like the compressor housings 40, 40a, and 40b of the above embodiments, the compressor housing 40c of the present embodiment also satisfies the relations shown in Formulae (1) to (4). Further, like the second embodiment, in the present embodiment, a dimension Rc in the radical direction from the axis Ar to an edge of the bell mouth cap 65c, which is at the inner side Dri in the radial direction and at the front side Daf in the axial direction is smaller than an outlet inner diameter Ro and is greater than an inlet inner diameter Ri.

[0100] Like the third embodiment, the suction side communication passage 55c of the present embodiment is folded back from the boundary between the circulating channel 52 and the suction side communication passage 55c and then extends toward the back side Dab in the axial direction to communicate with the suction channel 41c. For this reason, like the third embodiment, in the present embodiment, a channel length required until a part of air A in an impeller chamber 45 returns to the suction channel 41c can be prolonged while inhibiting enlargement of the compressor housing 40c in the axial direction Da.

[0101] Like the second embodiment, a communication port 55o of the suction side communication passage 55c of the present embodiment for the suction channel 41c is formed in the bell mouth face 42cf at the diameter-reduced part 42c. For this reason, in the present embodiment, like the second embodiment, the air A from the outside easily flows into the impeller chamber 45 via the suction channel 41c, and then the air A in the suction side communication passage 55a can be efficiently guided into the suction channel 41c due to an effect of reducing a static pressure at the bell mouth face 42cf.

[0102] Both the compressor housing 40b of the third embodiment and the compressor housing 40c of the present embodiment satisfy the relation shown in Formula (3). However, in the compressor housing 40b of the third embodiment and the compressor housing 40c of the present embodiment, the relation shown in Formula (3) may not be satisfied.

[0103] The centrifugal compressor of each of the above embodiments is a centrifugal compressor provided in a supercharger, but the centrifugal compressor according to the present invention may not be provided in a supercharger.

[Industrial Applicability]

[0104] In an aspect of the present invention, a working range of a centrifugal compressor can be widened.

[Reference Signs List]

[0105]

10 Turbine
11 Turbine rotary shaft
12 Turbine impeller
19 Turbine housing
20 Coupler
21 Coupling rotary shaft
29 Center housing
30, 30a, 30b, 30c, 30x Centrifugal compressor
31 Compressor rotary shaft
32 Compressor impeller
33 Hub
35 Blade
40, 40a, 40b, 40c, 40x Compressor housing
41, 41a, 41b, 41c Suction channel
42, 42b, 42c Diameter-reduced part
42f, 42bf, 42cf Bell mouth face
43b, 43c Straight barrel part

43bg Cylindrical inner circumferential surface
45 Impeller chamber
46 Discharge channel
51 Impeller side communication passage
52 Circulating channel
55, 55a, 55b, 55c Suction side communication passage
550 Communication port
61 Housing main body
62 Strut (partition part)
63, 63a, 63b, 63c Treatment tube
65, 65b, 65c Bell mouth cap
Ar Axis
Da Axial direction
Dab Back side in the axial direction
Daf Front side in the axial direction
Dc Circumferential direction
Dr Radial direction
Dri Inner side in the radial direction
Dro Outer side in the radial direction

Claims

1. A centrifugal compressor comprising
a rotary shaft configured to rotate about an axis;
an impeller mounted on an outer circumference of the rotary shaft; and
a housing configured to cover the impeller,
wherein the impeller has a hub mounted on the rotary shaft and a plurality of blades that are provided on the hub at intervals in a circumferential direction centered on the axis and are rotated integrally with the hub to guide a gas, which flows from a front side in an axial direction which is one side in an axial direction in which the axis extends, to an outer side in a radial direction relative to the axis,
the housing is formed with a suction channel that guides the gas to the front side in the axial direction of the impeller, an impeller chamber which communicates with the suction channel and in which the impeller is housed, a discharge channel which communicates with the impeller chamber and into which the gas sent from the impeller to the outer side in the radial direction flows, an impeller side communication passage that communicates with the impeller chamber and extends from the impeller chamber in a direction including a component of the outer side in the radial direction, circulating channels that communicate with the impeller side communication passage and extend from the impeller side communication passage in a direction including a component of the front side in the axial direction, and a suction side communication passage that communicates with the circulating channels and the suction channel, and
a suction side diameter dimension, which is a radial dimension in the radial direction from the axis to a communicating position at which each of the circulating channels communicates with the suction side communication passage, is greater than an impeller side diameter dimension, which is a radial dimension in the radial direction from the axis to a communicating position at which each of the circulating channels communicates with the impeller side communication passage, and a channel area of each of the circulating channels at the communicating position for the suction side communication passage is greater than that of each of the circulating channels at the communicating position for the impeller side communication passage.

2. The centrifugal compressor according to claim 1, wherein the housing is formed with the plurality of circulating channels that are arranged in the circumferential direction centered on the axis, and partition parts which divide circulating channels adjacent to each other in the circumferential direction.

3. The centrifugal compressor according to claim 1 or 2, wherein:

   the suction channel is formed in a shape that is rotationally symmetric around the axis and has a diameter-reduced part in which a channel area thereof is gradually reduced toward a back side in the axial direction which is the other side in the axial direction; and
   a communication port of the suction side communication passage for the suction channel is formed in a face

defining a channel at the diameter-reduced part.

4. The centrifugal compressor according to claim 3, wherein the face defining the channel at the diameter-reduced part forms a curved surface protruding to a side close to the axis.

5. The centrifugal compressor according to claim 3 or 4, wherein a radial dimension in the radial direction from the axis to an edge of the communication port of the suction side communication passage at the front side in the axial direction is smaller than the suction side diameter dimension and is greater than the impeller side diameter dimension.

6. The centrifugal compressor according to any one of claims 1 to 5, wherein the suction side communication passage is folded back from a boundary between the circulating channel and the suction side communication passage and then extends toward a back side in the axial direction which is the other side in the axial direction, to communicate with the suction channel while being directed to an inner side in the radial direction relative to the axis.

7. The centrifugal compressor according to any one of claims 1 to 6, wherein, when
L is defined as an axial dimension in the axial direction from the communicating position at which each of the circulating channels communicates with the suction side communication passage to the communicating position at which each of the circulating channels communicates with the impeller side communication passage,
do is defined as an equivalent diameter related to the channel area of each of the circulating channels at the communicating position for the suction side communication passage, and
di is defined as an equivalent diameter related to the channel area of each of the circulating channels at the communicating position for the impeller side communication passage,
a spread angle (2θ) defined by a formular below is less than 20°.

$$2\theta = 2 \times \tan((do - di)/2L) < 20^\circ$$

8. The centrifugal compressor according to any one of claims 1 to 7, wherein an axial dimension in the axial direction from the communicating position at which each of the circulating channels communicates with the suction side communication passage to the communicating position at which each of the circulating channels communicates with the impeller side communication passage is greater than or equal to 0.25 times an impeller outer diameter that is a maximum outer diameter of the impeller.

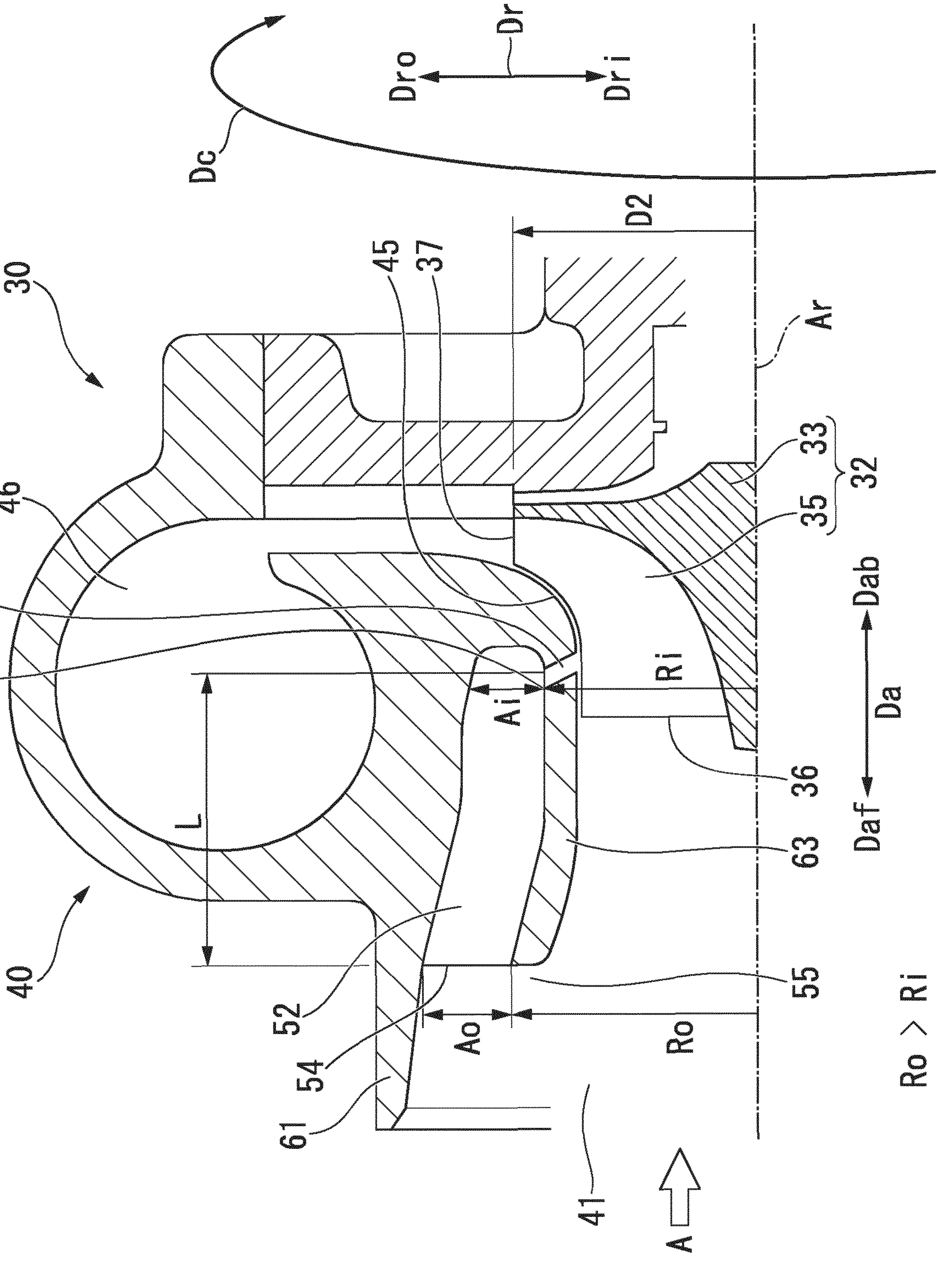
9. A supercharger comprising:

the centrifugal compressor according to any one of claims 1 to 8; and
a turbine,
the turbine has

a turbine rotary shaft configured to rotate about the axis,
a turbine impeller mounted on an outer circumference of the turbine rotary shaft, and
a turbine housing configured to conver the turbine impeller,

the turbine rotary shaft and the rotary shaft of the centrifugal compressor are located on the same axis, are mutually coupled, are integrally rotated, and form a supercharger rotary shaft.

FIG. 1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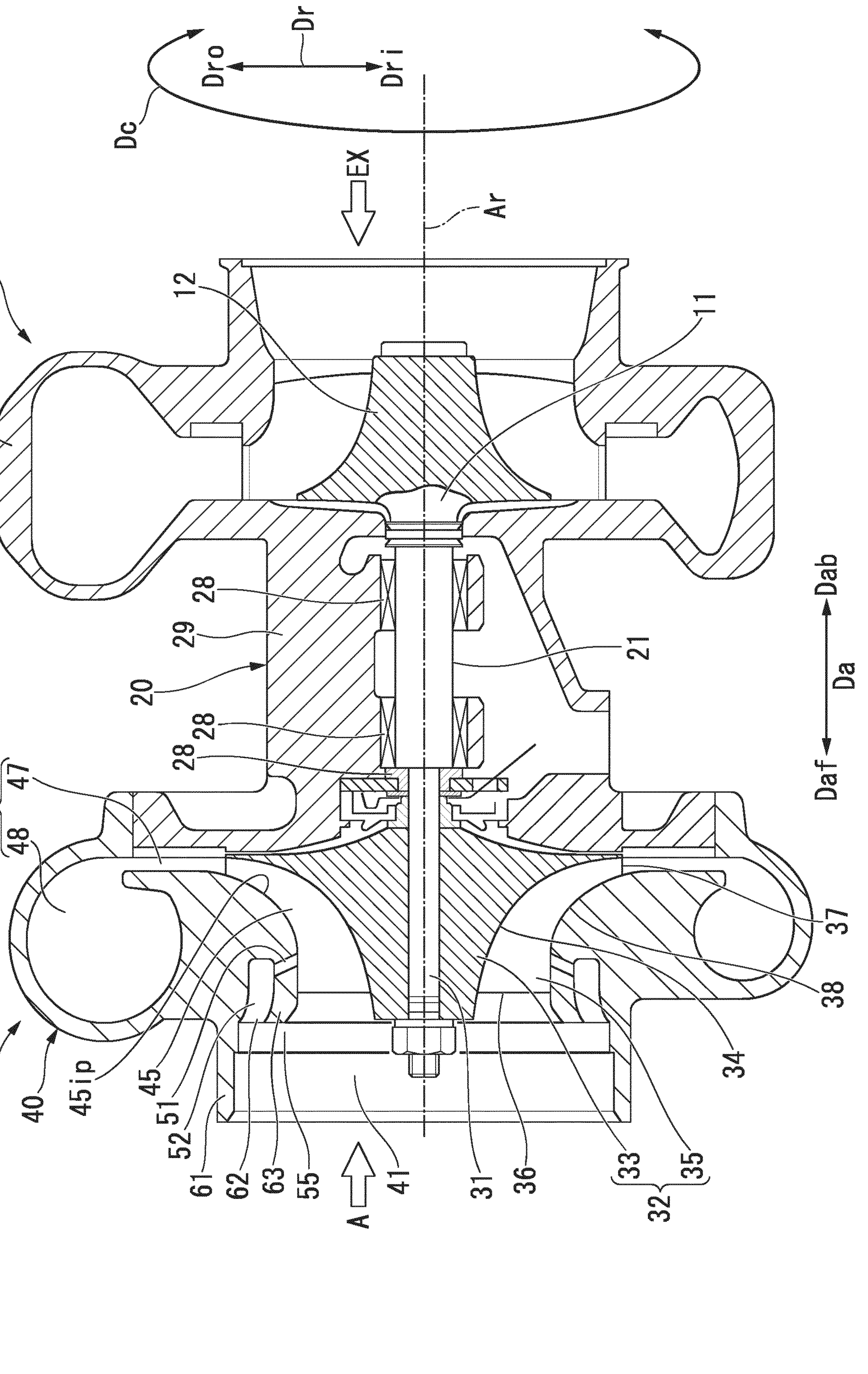
Dro
Dr
Dri
D2
30
Ar
45
37
33
32
35
46
51
53
Dab
Ri
Da
Ai
L
36
Daf
63
40
55
52
54
Ao
Ro
61
41
A
Ro > Ri
Ao > Ai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Dri
Dc
EX
Ar
10
12
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29
20
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Dab
Da
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46
48
37
38
34
30
40
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61
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63
55
A
41
31
36
33
35
32

FIG. 2

FIG. 3

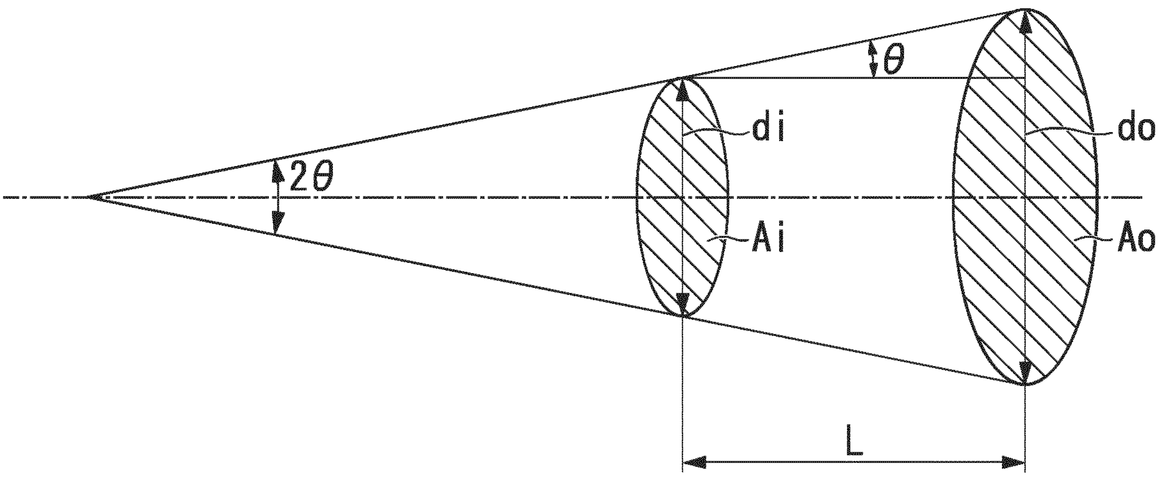
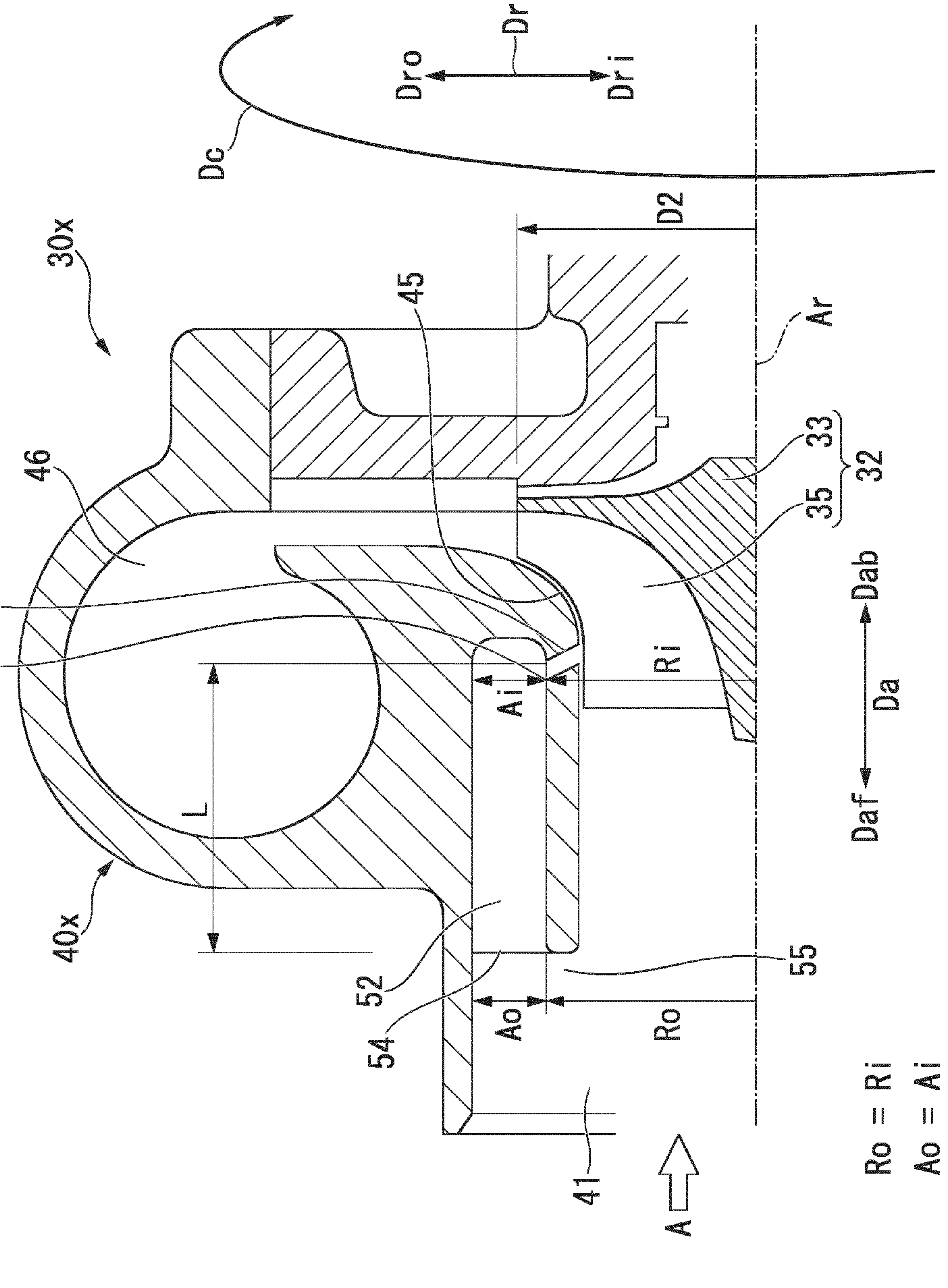
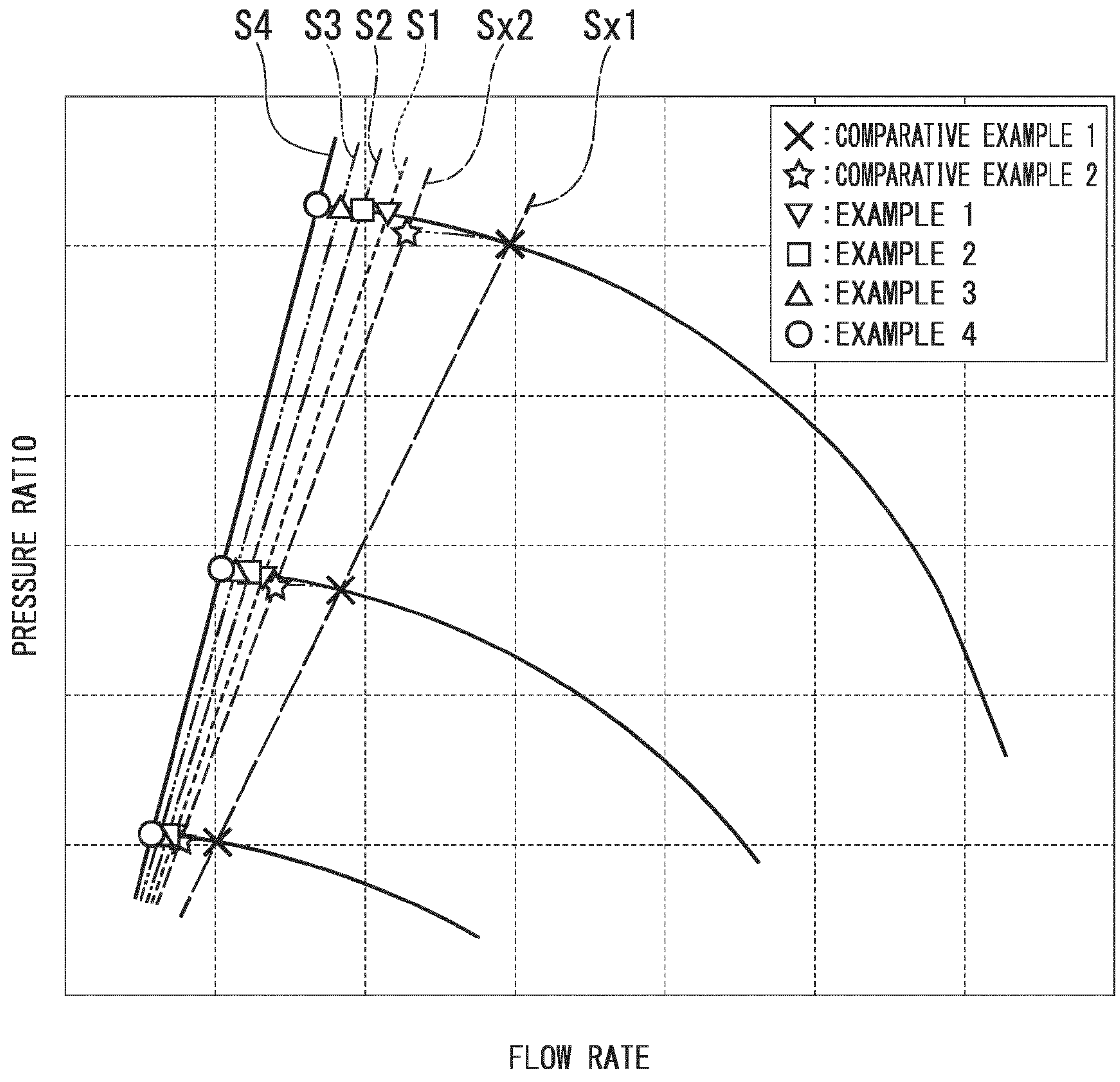


FIG. 4



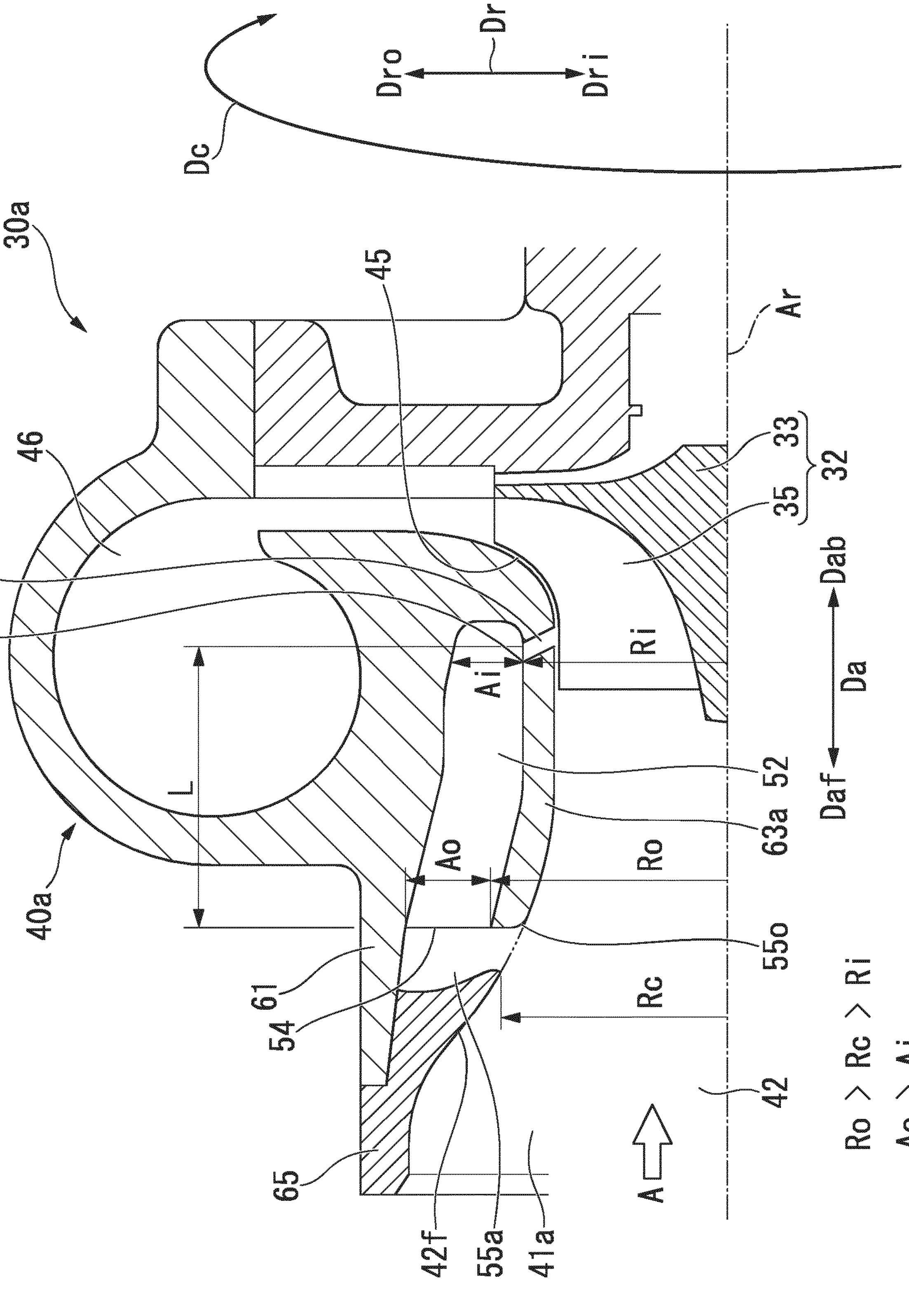
Dr
Dro
Dri
Dc
30x
D2
45
Ar
46
33
32
35
51
53
Dab
Ri
Ai
Da
L
Daf
40x
52
55
54
Ao
Ro
41
A
Ro = Ri
Ao = Ai

FIG. 5

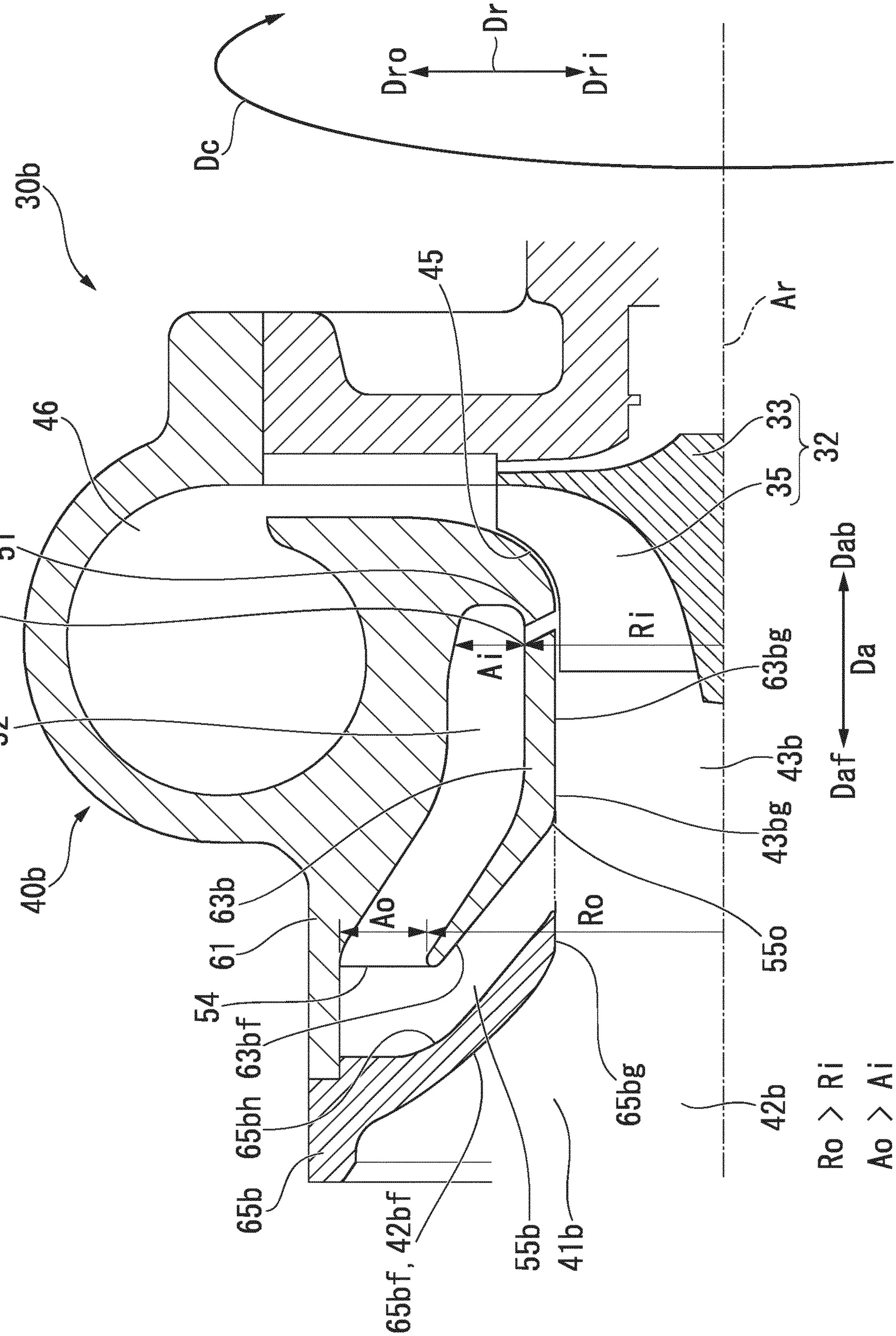


S4
S3
S2
S1
Sx2
Sx1
PRESSURE RATIO
FLOW RATE
: COMPARATIVE EXAMPLE 1
: COMPARATIVE EXAMPLE 2
: EXAMPLE 1
: EXAMPLE 2
: EXAMPLE 3
: EXAMPLE 4

FIG. 6



Dr
Dro
Dri
Dc
30a
45
Ar
46
33
32
35
Dab
51
53
Ri
Da
Ai
L
52
Daf
63a
Ro
Ao
40a
55o
61
Rc
54
42
Ro > Rc > Ri
Ao > Ai
65
A
42f
55a
41a


30b
Dc
Dr
Dro
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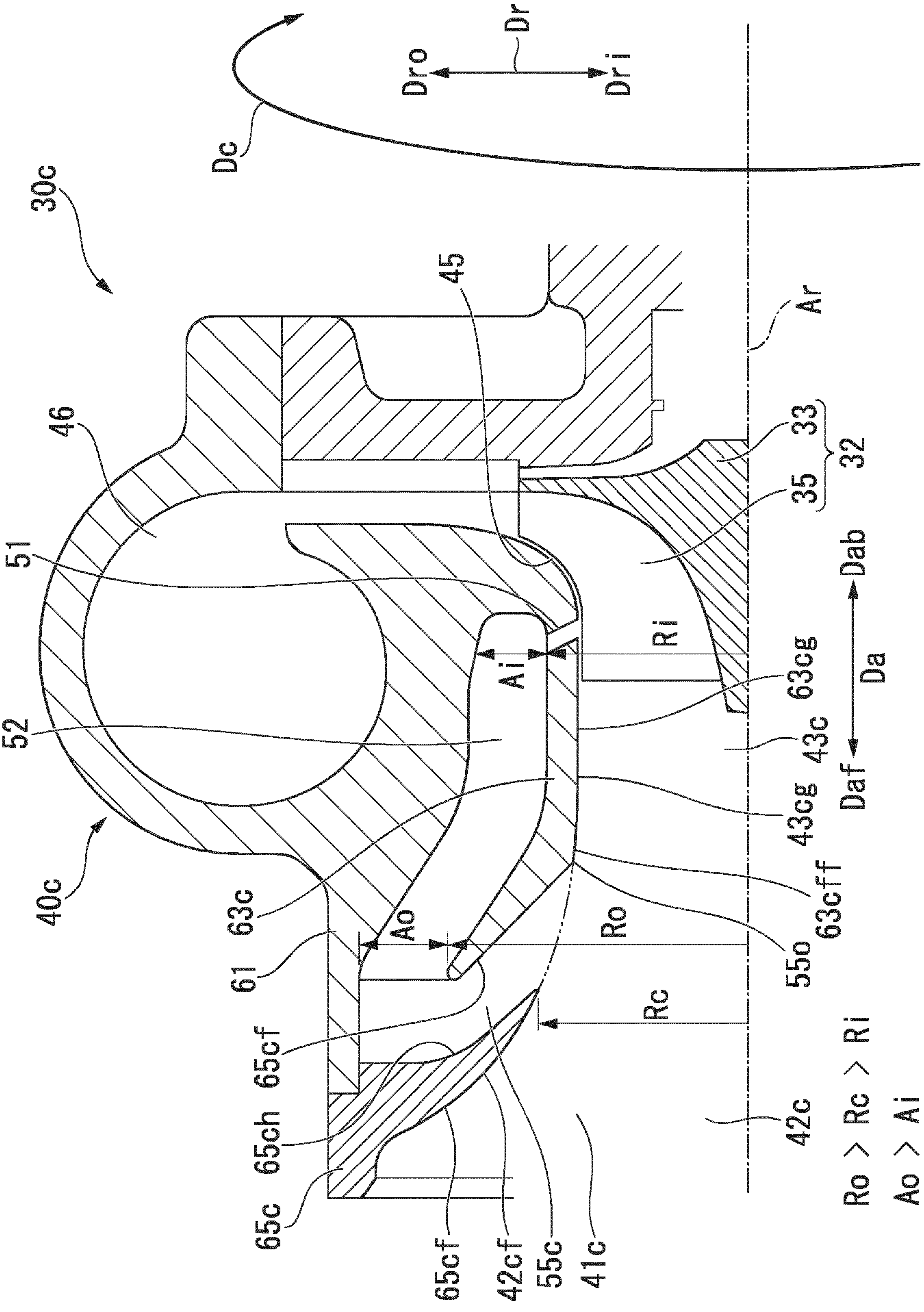
45
Ar
46
33
32
35
51
Dab
53
Ri
63bg
Da
Ai
52
43b
Daf
40b
63b
61
43bg
Ao
Ro
55o
54
63bf
65bh
65bg
42b
65b
65bf, 42bf
55b
41b
Ro > Ri
Ao > Ai

FIG. 7

FIG. 8



30c
Dc
Dro
Dr
Dri
45
Ar
46
33
32
35
51
Dab
Ri
Da
Daf
63cg
52
Ai
43c
43cg
63cff
40c
63c
Ao
Ro
55o
61
Rc
65cf
65ch
65c
42c
65cf
42cf
55c
41c
Ro > Rc > Ri
Ao > Ai

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2015/058538

A. CLASSIFICATION OF SUBJECT MATTER
F04D29/42(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)
F04D29/42

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	1996-2015
Kokai Jitsuyo Shinan Koho	1971-2015	Toroku Jitsuyo Shinan Koho	1994-2015

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	US 2007/0269308 A1 (Terry G.WOOD), 22 November 2007 (22.11.2007), paragraphs [0029] to [0034]; fig. 4 to 7B (Family: none)	1,9 2-8
A	US 2014/0093354 A1 (Aleksandar SEKULARAC et al.), 03 April 2014 (03.04.2014), entire text; all drawings & WO 2012/154414 A2	1-9
A	JP 2012-154200 A (IHI Corp.), 16 August 2012 (16.08.2012), entire text; all drawings & US 2013/0302155 A1 & WO 2012/102146 A1 & EP 2669526 A1	1-9

☒ 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
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"P" document published prior to the international filing date but later than the priority date claimed
"T" 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
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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
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
04 June 2015 (04.06.15)	16 June 2015 (16.06.15)

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3,Kasumigaseki,Chiyoda-ku, Tokyo 100-8915,Japan	Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2015/058538

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2009-68372 A (IHI Corp.), 02 April 2009 (02.04.2009), entire text; all drawings (Family: none)	1-9

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

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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