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(71) Applicant: **LG Electronics Inc.**
Yeongdeungpo-gu, Seoul 150-721 (KR)

(72) Inventor: **SON, Sang Yuk**
Gyeongsangnam-do 642-711 (KR)

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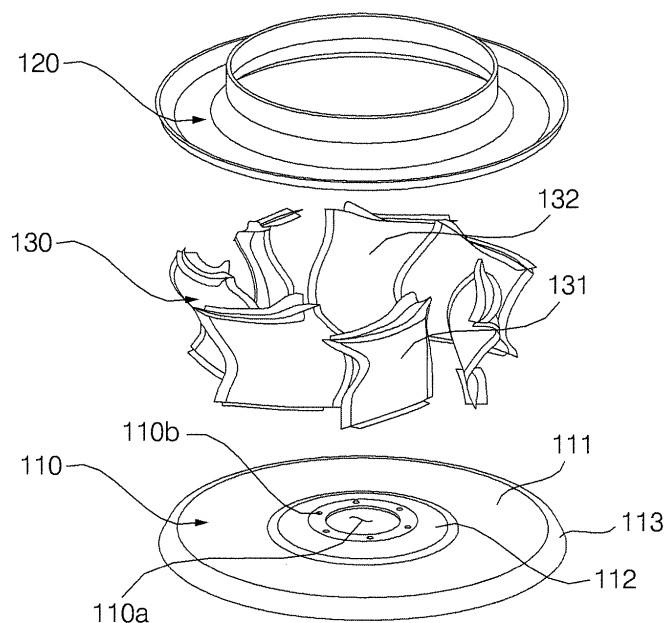
(74) Representative: **Vossius & Partner**
Siebertstrasse 4
81675 München (DE)

(54) **CENTRIFUGAL FAN AND METHOD FOR MANUFACTURING SAME**

(57) Disclosed is a centrifugal fan having a blade configured by bonding two members having plasticity to each other. The centrifugal fan has high durability and permits easy formation of a positive pressure surface or a neg-

ative pressure surface of the blade having a complicated shape, which advantageously results in enhancement in performance of the fan.

FIG. 3



Description

[Technical Field]

[0001] The present invention relates to a centrifugal fan and a method of manufacturing the same.

[Background Art]

[0002] A centrifugal fan is a fan that accelerates air introduced in an axial direction through a shroud and discharges the air in a radial direction through gaps between blades. Performance of the centrifugal fan is affected by various shape factors as well as friction loss, shock loss and the like. Representative examples of factors having an effect on the performance of the centrifugal fan include a speed of the centrifugal fan, the shape, angle or number of blades and the shape of a shroud.

[0003] Among the aforementioned factors, in particular, the shape of blades is important because it may contribute to enhancement in the performance of the centrifugal fan without a great change in the entire size or standard of the centrifugal fan. In recent years, studies to acquire desired performance by changing the shape of blades in various ways have been actively conducted.

[0004] With regard to manufacture of blades having a complicated shape, a constituent material thereof must be considered as an important factor. The easiest method to manufacture blades having a desired shape is injection molding using a resin material. In this case, a main plate and a shroud, which are coupled to blades, are also generally formed of the same resin material as the blades. Although a centrifugal fan formed of a resin material may achieve required strength when the centrifugal fan is small, increase in the size of the centrifugal fan is difficult in terms of rigidity and durability of the resin.

[0005] Alternatively, a scheme in which a main plate, to which torque of a motor is transmitted, is formed of a metal having sufficient strength and blades are formed of a resin material may be considered. However, in this case, due to the fact that the blades and the main plate formed of heterogeneous materials are coupled to each other, acquisition of required coupling strength or durability may be difficult. In addition, when fasteners are added to increase coupling strength, the fasteners may cause friction loss, which makes it difficult to enhance the performance of a centrifugal fan.

[0006] Meanwhile, when a centrifugal fan applied to large products is formed of a resin material, there is a risk that the centrifugal fan cannot withstand pressure and breaks because considerably great external static pressure is applied to the centrifugal fan. Therefore, although the centrifugal fan applied to large products is appropriately formed of a metal, the metal centrifugal fan has difficulty in achieving various shapes of blades as compared to a resin centrifugal fan and, thus, conventional metal blades have a considerably simplified shape.

[0007] Considering conventional metal blades in more

detail, first, the case in which blades are formed of a single metal sheet may be considered. In this case, to acquire rigidity, a thickness of the blades must be at least 2 mm and, according to materials, must be 2.7 mm or more. Increase in the thickness of the blades, however, may increase material costs and deteriorate efficiency of a centrifugal fan. As well known, the shape of blades has a great effect on the performance of a centrifugal fan (more particularly, efficiency of a centrifugal fan). In conclusion, conventional metal centrifugal fans are heavier than conventional resin centrifugal fans and are not beneficial in terms of efficiency.

[0008] Japanese Patent Laid-open Publication No. 2000-45997 discloses a blade formed by bending a single metal sheet. In the above patent, the blade formed by bending a single metal sheet has an airfoil cross section. More particularly, the blade has a three dimensional shape in which a leading edge 1af of the blade has a prescribed inclination relative to a rotation axis of a centrifugal fan and a trailing edge 1ab of the blade is parallel to the rotation axis. However, as exemplarily shown in (b) of FIG. 6 included in the above patent, respective airfoil cross sections of the blade taken at arbitrary layers perpendicular to the rotation axis have a common camber line. For example, although a lower edge of the blade bonded to a main plate 3 has the longest camber line and an upper edge of the blade coming into contact with a shroud has the shortest camber line, the camber line at the upper edge completely overlaps the camber line at the lower edge. The blade having the above-described shape is an inevitable consequence of bending a single metal sheet using a mold 5c2 that defines a single camber line as exemplarily shown in (a) of FIG. 7 included in the above patent. As described above, although Japanese Patent Laid-open Publication No. 2000-045997 discloses the metal blade, the blade has a limit in terms of shape, thus having difficulty in having a complicated three dimensional shape, such as, for example, a shape in which the attack angle β varies in a vertical direction of the blade or a shape in which camber lines of respective cross sections of the blade are angled with each other.

[0009] Japanese Patent Laid-open Publication No. 2003-396522 discloses a centrifugal fan in which a blade having a thickness decreasing from a leading edge to a trailing edge thereof is constructed by coupling two resin parts (i.e. a first surface part 51 and a second surface part 61). In this case, since the thickness of the blade is considerably reduced toward the trailing edge of the blade, a trailing edge portion of the blade cannot be constructed by coupling two parts due to a limit in terms of injection molding thickness. Therefore, a whole trailing edge is formed at the first surface part forming a positive pressure surface and a negative pressure surface is formed by a trailing edge portion of the first surface part as well as the second surface part. Here, although coupling of the second surface part and the first surface part at the negative pressure surface is achieved by fitting, to solve weakness of coupling strength, the second surface

part is provided with fitting protrusions 62a protruding toward the first surface part and the first surface part is provided with protruding rings 52a into which the fitting protrusions are inserted. The fitting protrusions and the protruding rings may be easily processed because the first surface part and the second surface part are formed of a resin material. Since coupling of the fitting protrusions and the protruding rings is achieved by fitting, to maintain coupling thereof without a risk of separation, it is necessary to use a resin material that is somewhat deformable.

[Disclosure]

[Technical Problem]

[0010] It is one object of the present invention to provide a centrifugal fan having a blade comprised of two metal members.

[0011] It is another object of the present invention to provide a centrifugal fan capable of achieving enhanced performance via improvement in the shape of a blade.

[0012] It is another object of the present invention to provide a centrifugal fan having a blade of a complicated three dimensional shape that has not been easily achieved using a metal in the related art.

[0013] It is another object of the present invention to provide a centrifugal fan capable of achieving reduced material cost and enhanced rigidity.

[0014] It is another object of the present invention to provide a centrifugal fan capable of being applied to larger products than in the related art.

[0015] It is another object of the present invention to provide a centrifugal fan having a blade in which a positive pressure surface and a negative pressure surface are curved surfaces having different curvature variations.

[0016] It is another object of the present invention to provide a centrifugal fan capable of achieving reduced flow resistance, more particularly, enhanced efficiency via improvement in the shape of a blade.

[0017] It is another object of the present invention to provide a centrifugal fan capable of allowing a blade having a three dimensional shape to be easily coupled to a shroud or a main plate.

[0018] It is another object of the present invention to provide a centrifugal fan capable of minimizing welding beads between members, thereby restricting increase in flow resistance and minimizing a negative effect on balancing of the fan due to the welding beads.

[0019] It is another object of the present invention to provide a centrifugal fan in which no bonding portion or coupling portion between constituent members of a blade is present at a positive pressure surface or a negative pressure surface.

[0020] It is another object of the present invention to provide a centrifugal fan capable of restricting generation of an eddy at the outer circumference of a shroud or at the outer circumference of a main plate.

[0021] It is another object of the present invention to

provide a centrifugal fan capable of increasing the flow rate of air discharged from a main plate via improvement in the shape of a blade.

[0022] It is another object of the present invention to provide a centrifugal fan capable of improving rigidity of a blade via processing of a metal sheet.

[0023] It is another object of the present invention to provide a method of manufacturing a centrifugal fan having a blade comprised of two metal members.

[0024] It is another object of the present invention to provide a method of manufacturing a centrifugal fan which includes a method of bonding two constituent members of a blade to each other.

[0025] It is a further object of the present invention to provide a method of manufacturing a centrifugal fan which includes a method of bonding a blade to a main plate or a shroud.

[Technical Solution]

[0026] In accordance with one embodiment of the present invention, the above and other objects can be accomplished by the provision of a centrifugal fan including a main plate configured to be rotated about a rotation axis, a shroud having a suction opening through which air is sucked, and a plurality of blades arranged in a circumferential direction between the main plate and the shroud to allow the air sucked through the suction opening to flow from a front edge to a rear edge of each blade. Each of the blades is formed by bonding a pair of members to each other, each member being formed of a metal sheet having a curved surface, and any one of the members is a positive pressure surface forming member defining a positive pressure surface of the blade and the other member is a negative pressure surface forming member defining a negative pressure surface of the blade. The positive pressure surface forming member and the negative pressure surface forming member are bonded to each other with a space therebetween such that a cross section of the blade taken at a layer crossing the rotation axis has an enclosed shape.

[0027] When cross sections of the blade taken at planar layers perpendicular to the rotation axis are projected onto a prescribed projection plane in a direction of the rotation axis, two or more lines among lines interconnecting front edges and rear edges of the respective cross sections in the projection plane may do not overlap each other.

[0028] Bonding between the positive pressure surface forming member and the negative pressure surface forming member may be implemented at the front edge and the rear edge and the space is located between the front edge and the rear edge. Bonding between the positive pressure surface forming member and the negative pressure surface forming member may be implemented between a surface of the member opposite to the positive pressure surface and a surface of the member opposite to the negative pressure surface.

[0029] The positive pressure surface forming member and the negative pressure surface forming member may be formed of steel.

[0030] Each of the positive pressure surface forming member and the negative pressure surface forming member may be formed of a metal sheet having an even thickness.

[0031] The shroud, the blades and the main plate may be formed of the same material.

[0032] At least one of the positive pressure surface forming member and the negative pressure surface forming member may include a shroud bonding surface portion to be bonded to the shroud. The shroud bonding surface portion may be formed by bending an upper edge of each of the positive pressure surface forming member and the negative pressure surface forming member in a direction opposite to the other member.

[0033] The shroud may have an inner circumferential surface along which the air sucked through the suction opening is guided, the inner circumferential surface being a curved surface expanding in a direction opposite to the rotation axis with decreasing distance to the main plate along the rotation axis, and the shroud bonding surface portion may have a shape corresponding to a shape of the curved surface so as to come into close contact with the curved surface.

[0034] The curved surface may be formed by pressing.

[0035] The cross section of the blade taken at an arbitrary layer crossing the rotation axis may configure an airfoil having an upper surface and a lower surface in the form of curved surfaces extending respectively between a leading edge and a trailing edge, the upper surface belonging to the positive pressure surface and the lower surface belonging to the negative pressure surface. The airfoil may have a camber line connecting equidistant points from the upper surface and the lower surface to one another and a chord line straightly connecting the leading edge and the trailing edge to each other, the camber line being located between the chord line and the upper surface. The blade may include a section in which an angle between a tangent at a prescribed point on the camber line in relation to a circle, at which the point is located, among concentric circles about the rotation axis and a tangent at the point in relation to the camber line is gradually increased along a stream line on the positive pressure surface.

[0036] A height from the main plate to a point where the front edge of the blade meets the shroud may be greater than a height from the main plate to a point where the rear edge of the blade meets the shroud.

[0037] At least one of the positive pressure surface forming member and the negative pressure surface forming member may include a main plate bonding surface portion to be bonded to the main plate. The main plate bonding surface portion may be formed by bending a lower edge of each of the positive pressure surface forming member and the negative pressure surface forming member in a direction opposite to the other member.

[0038] The space may be defined by a surface of the member opposite to the positive pressure surface, a surface of the member opposite to the negative pressure surface, the shroud and the main plate.

[0039] The entire region of the positive pressure surface may be defined by the positive pressure surface forming member, and the entire region of the negative pressure surface may be defined by the negative pressure surface forming member.

[0040] In accordance with another embodiment of the present invention, there is provided a centrifugal fan including a main plate configured to be rotated about a rotation axis, a shroud having a suction opening through which air is sucked, and a plurality of blades arranged in a circumferential direction between the main plate and the shroud to allow the air sucked through the suction opening to flow from a front edge to a rear edge of each blade. Each of the blades is formed by bonding a pair of members to each other, each member being formed of a metal sheet, any one of the members is a positive pressure surface forming member defining a positive pressure surface of the blade and the other member is a negative pressure surface forming member defining a negative pressure surface of the blade. Bonding between the positive pressure surface forming member and the negative pressure surface forming member is implemented at the front edge and the rear edge.

[0041] Bonding between the positive pressure surface forming member and the negative pressure surface forming member may be implemented between a surface of the member opposite to the positive pressure surface and a surface of the member opposite to the negative pressure surface. Bonding between the positive pressure surface forming member and the negative pressure surface forming member may be implemented by projection welding between a protrusion formed at the surface of the member opposite to any one of the positive pressure surface and the negative pressure surface and the other one of the positive pressure surface and the negative pressure surface.

[0042] Bonding between the positive pressure surface forming member and the negative pressure surface forming member may be implemented by spot welding.

[0043] Bonding between the positive pressure surface forming member and the negative pressure surface forming member may be implemented by laser welding.

[0044] The positive pressure surface forming member and the negative pressure surface forming member may be formed of steel.

[0045] The shroud, the blades and the main plate may be formed of the same material.

[0046] At least one of the positive pressure surface forming member and the negative pressure surface forming member may include a shroud bonding surface portion to be bonded to the shroud. The shroud bonding surface portion may be formed by bending an upper edge of each of the positive pressure surface forming member and the negative pressure surface forming member in a

direction opposite to the other member.

[0047] At least one of an upper end of the front edge and an upper end of the rear edge may come into contact with the shroud. The shroud bonding surface portion may be formed at a section of an upper edge of at least one of the positive pressure surface forming member and the negative pressure surface forming member except for portions constituting the front edge and the rear edge.

[0048] Bonding between the shroud bonding surface portion and the shroud may be implemented by projection welding between a protrusion formed at any one of the shroud bonding surface portion and the shroud and a prescribed surface of the other one of the shroud bonding surface portion and the shroud.

[0049] Bonding between the shroud bonding surface portion and the shroud may be implemented by spot welding. At least one of the shroud bonding surface portion and the shroud may have welding beads indented from a peripheral portion at a prescribed interval in a line by spot welding.

[0050] Bonding between the shroud bonding surface portion and the shroud may be implemented by laser welding.

[0051] At least one of the positive pressure surface forming member and the negative pressure surface forming member may include a main plate bonding surface portion to be bonded to the main plate. The main plate bonding surface portion may be formed by bending a lower edge of each of the positive pressure surface forming member and the negative pressure surface forming member in a direction opposite to the other member.

[0052] At least one of an upper end of the front edge and a lower end of the rear edge may come into contact with the main plate. The main plate bonding surface portion may be formed at a section of a lower edge of at least one of the positive pressure surface forming member and the negative pressure surface forming member except for portions constituting the front edge and the rear edge.

[0053] At least one of the positive pressure surface forming member and the negative pressure surface forming member may have a curved surface formed by pressing.

[0054] The shroud may have an inner circumferential surface along which the air sucked through the suction opening is guided, the inner circumferential surface being a curved surface expanding in a direction opposite to the rotation axis with decreasing distance to the main plate along the rotation axis, and the shroud bonding surface portion may have a shape corresponding to a shape of the curved surface so as to come into close contact with the curved surface.

[0055] A height from the main plate to a point where the front edge of the blade meets the shroud may be greater than a height from the main plate to a point where the rear edge of the blade meets the shroud.

[0056] The entire positive pressure surface of the blade may be defined by the positive pressure surface forming

member, and the entire negative pressure surface of the blade may be defined by the negative pressure surface forming member.

[0057] In accordance with another embodiment of the present invention, there is provided a centrifugal fan including a main plate configured to be rotated about a rotation axis, a shroud having a suction opening through which air is sucked, and a plurality of blades arranged in a circumferential direction between the main plate and the shroud to allow the air sucked through the suction opening to flow from a front edge to a rear edge of each blade. Each of the blades is formed by bonding a pair of members to each other, each member being formed of a metal sheet and having a curved surface, and, when cross sections of the blade taken at planar layers perpendicular to the rotation axis are projected onto a prescribed projection plane in a direction of the rotation axis, two or more lines among lines interconnecting front edges and rear edges of the respective cross sections in the projection plane do not overlap each other.

[0058] The rear edge of the blade may be located farther from the rotation axis than the front edge and may be deviated in a direction opposite to a rotation direction of the centrifugal fan.

[0059] The cross section of the blade taken at an arbitrary layer crossing the rotation axis may configure an airfoil having an upper surface and a lower surface in the form of curved surfaces extending respectively between a leading edge and a trailing edge, the upper surface belonging to a positive pressure surface of the blade and the lower surface belonging to a negative pressure surface of the blade.

[0060] The airfoil may have a camber line connecting equidistant points from the upper surface and the lower surface to one another and a chord line straightly connecting the leading edge and the trailing edge to each other, the camber line being located between the chord line and the upper surface. An angle between a tangent at a prescribed point on the camber line in relation to a circle, at which the point is located, among concentric circles about the rotation axis and a tangent at the point in relation to the camber line may be gradually increased along a stream line on a positive pressure surface.

[0061] The members constituting the blade may include a positive pressure surface forming member defining the entire region of a positive pressure surface of the blade; and a negative pressure surface forming member defining the entire region of a negative pressure surface of the blade.

[0062] A positive pressure surface forming member and a negative pressure surface forming member may be formed of steel.

[0063] The shroud, the blades and the main plate may be formed of the same material.

[0064] At least one of the members may have a curved surface.

[0065] The members may be bonded to each other with a space therebetween.

[0066] A portion of the blade near the shroud may be convex in a facing direction of a positive pressure surface and a portion of the blade near the main plate may be convex in a facing direction of a negative pressure surface. The convex portion of the blade in the facing direction of the positive pressure surface may have a maximum distance from the rotation axis.

[0067] The convex portion of the blade in the facing direction of the negative pressure surface may have a minimum distance from the rotation axis.

[0068] The blade may include a convex portion in a facing direction of a positive pressure surface. The convex portion of the blade in the facing direction of the positive pressure surface may have a maximum distance from the rotation axis.

[0069] In accordance with another embodiment of the present invention, there is provided a centrifugal fan including a main plate configured to be rotated about a rotation axis, a shroud having a suction opening through which air is sucked, and a plurality of blades arranged in a circumferential direction between the main plate and the shroud. Each of the blades is formed by bonding a pair of members to each other, each member being formed of a metal sheet, any one of the members being a positive pressure surface forming member defining a positive pressure surface of the blade and the other member being a negative pressure surface forming member defining a negative pressure surface of the blade. The positive pressure surface forming member includes a first curved surface portion having a curved surface and a first front edge bonding surface portion and a first rear edge bonding surface portion at opposite sides of the first curved surface portion. The negative pressure surface forming member includes a second curved surface portion having a curved surface, the second curved surface portion and the first curved surface portion defining a space therebetween, and a second front edge bonding surface portion and a second rear edge bonding surface portion at opposite sides of the second curved surface portion, the second front edge bonding surface portion being bonded to the first front edge bonding surface portion and the second rear edge bonding surface portion being bonded to the first rear edge bonding surface portion.

[0070] The first curved surface portion and the second curved surface portion may define different curves in a longitudinal cross section of the blade parallel to the rotation axis.

[0071] A curve defined by the first curved surface portion in a longitudinal cross section parallel to the rotation axis may be convex near the shroud in a facing direction of the positive pressure surface and may be convex near the main plate in a facing direction of the negative pressure surface.

[0072] The blade may be convex near the shroud in a facing direction of the positive pressure surface and may be convex near the main plate in a facing direction of the negative pressure surface in a longitudinal cross section

parallel to the rotation axis.

[0073] The blade may be convex in a facing direction of the positive pressure surface.

[0074] The first front edge bonding surface portion and the second front edge bonding surface portion may have a corresponding shape.

[0075] The first curved surface portion and the second curved surface portion may configure an airfoil in a layer crossing the rotation axis. The first curved surface portion may define an upper surface of the airfoil, and the second curved surface portion may define a lower surface of the airfoil.

[0076] At least one of the positive pressure surface forming member and the negative pressure surface forming member may include a shroud bonding surface portion to be bonded to the shroud. The shroud may have an inner circumferential surface along which the air sucked through the suction opening is guided, the inner circumferential surface being a curved surface expanding in a direction opposite to the rotation axis with increasing distance from the shroud along the rotation axis, and the shroud bonding surface portion may have a curved surface corresponding to a shape of the shroud.

[0077] The shroud bonding surface portion may be formed at a section of an upper edge of at least one of the positive pressure surface forming member and the negative pressure surface forming member except for portions constituting a front edge bonding portion and a rear edge bonding portion.

[0078] At least one of the positive pressure surface forming member and the negative pressure surface forming member may include a main plate bonding surface portion to come into contact with the main plate. The main plate bonding surface portion may be formed at a section of a lower edge of at least one of the positive pressure surface forming member and the negative pressure surface forming member except for portions constituting a front edge bonding portion and a rear edge bonding portion.

[0079] In accordance with a further embodiment of the present invention, there is provided a method of manufacturing a centrifugal fan, the method including forming a first member and a second member using a metal sheet, each member having a curved surface, bonding front edges of the first member and the second member to each other and bonding rear edges of the first member and the second member to each other to form a blade, bonding at least one of the first member and the second member to a shroud, and bonding at least one of the first member and the second member to a main plate.

[0080] The bonding of the members may include implementing resistance welding of the first member and the second member.

[0081] The method may further include positioning the blade on the main plate, and the bonding of the main plate may be implemented in a state in which the blade is positioned on the main plate.

[0082] The method may further include positioning the

blade on the shroud, and the bonding of the shroud may be implemented in a state in which the blade is positioned on the shroud.

[0083] The method may further include implementing painting in a state in which the blade, the shroud and the main plate are integrally coupled to each other.

[Advantageous Effects]

[0084] According to the present invention, a centrifugal fan and a method of manufacturing the same have the effects of achieving higher rigidity than that of a conventional centrifugal fan formed of a resin material and of enhancing performance of the fan owing to a three dimensional shape of blades.

[0085] In addition, as a result of processing two thin metal sheets respectively and bonding the same to each other, the present invention has the effect of enabling formation of a blade having a complicated three dimensional shape that has not been easily achieved in the related art. The blade comprised of the two sheets, moreover, has the effect of achieving less material cost, higher efficiency of the fan owing to weight reduction and reduced power consumption than in the related art. Furthermore, the metal blade has enhanced rigidity, thus having the effect of being applied to large products.

[0086] In addition, since two members are first processed as curved members respectively and then bonded to each other to construct a blade, the members have independent shapes of curved surfaces, which has the effect of enabling formation of a blade having a complicated three dimensional shape (for example, a positive pressure surface and a negative pressure surface of the blade are curved surfaces having different curvature variations).

[0087] In addition, the metal blade having a complicated shape has the effect of reducing flow resistance and enhancing performance of the fan, more particularly, efficiency of the fan.

[0088] In addition, the present invention has the effect of easily coupling the blade having a three dimensional surface to a shroud or a main plate.

[0089] In addition, welding beads between members may be minimized, which has the effect of restricting increase in flow resistance and minimizing a negative effect on balancing of the fan due to the welding beads.

[0090] In addition, no bonding portion or coupling portion between constituent members of the blade is present at the positive pressure surface or the negative pressure surface, which has the effect of reducing flow resistance.

[0091] In addition, the present invention has the effect of restricting generation of an eddy at the outer circumference of the shroud or at the outer circumference of the main plate.

[0092] In addition, by increasing the flow rate of air discharged from the main plate via improvement in the shape of the blade, the present invention has the effect of providing more uniform distribution of flow rate or flow

velocity from an upper edge of the blade coming into contact with the shroud to a lower edge of the blade coming into contact with the main plate than in the related art.

[0093] In addition, when the blade is formed by plastic working of metal sheets, the present invention has the effect of achieving increased strength and reduced ductility due to characteristics of plastic working.

[Description of Drawings]

[0094]

FIG. 1 is a view showing one example of a plug fan module usable with a centrifugal fan.

FIG. 2 is a perspective view showing a centrifugal fan according to one embodiment of the present invention.

FIG. 3 is an exploded perspective view of the centrifugal fan shown in FIG. 2.

FIG. 4 is a longitudinal cut-away view of the centrifugal fan shown in FIG. 2.

FIG. 5 is an enlarged view showing a hub in (a) and a coupling structure of the hub and a main plate in (b).

FIG. 6 is a view showing a positive pressure surface forming member in (a), a negative pressure surface forming member in (b) and a coupled state of the positive pressure surface forming member and the negative pressure surface forming member in (c).

FIG. 7 is a view showing a height from a front edge to a rear edge of a blade included in the centrifugal fan.

FIG. 8 is a view showing holes for insertion of rivets used to install the blade.

FIGs. 9 and 10 are partial views of the centrifugal fan, particularly, showing rivets and welding beads.

FIG. 11 is a transverse cut-away view of the blade.

FIG. 12 is a transverse sectional view of the blade.

FIG. 13 is a view showing main factors to define a cross sectional shape and an attachment structure of the blade.

FIG. 14 is a view showing factors defined at a point P on a camber line with reference to FIG. 13.

FIG. 15 is a view showing positions of layers marked at the blade in (a) and cross sections of the blade taken at the layers in (b).

FIG. 16 is a view showing the cross sections of FIG. 15 projected onto a single plane in a direction of a rotation axis.

FIG. 17 is a longitudinal sectional view of the blade.

FIG. 18 is a comparative graph showing efficiency depending on air volume Q of the centrifugal fan according to one embodiment of the present invention and a conventional centrifugal fan.

FIG. 19 is a perspective view showing a centrifugal fan according to another embodiment of the present invention.

FIGs. 20 and 21 are longitudinal cut-away views of the centrifugal fan shown in FIG. 19.

FIG. 22 is a view showing layers referenced for explanation of the shape of a blade.

FIG. 23 is a view showing cross sections of the blade taken at the layers shown in FIG. 22.

FIG. 24 is a view showing the cross sections of FIG. 23 projected onto a single plane in a direction of a rotation axis.

[Best Mode]

[0095] Advantages and features of the present invention and a method of achieving the same will be more clearly understood from embodiments described below in detail with reference to the accompanying drawings. However, the present invention is not limited to the following embodiments and may be implemented in various different forms. The embodiments are provided merely to complete disclosure of the present invention and to provide those skilled in the art of the present invention with the category of the invention. The invention is defined only by the claims. Wherever possible, the same reference numbers will be used throughout the specification to refer to the same or like parts.

[0096] FIG. 1 is a view showing one example of a plug fan module usable with a centrifugal fan. The centrifugal fan according to the embodiments that will be described hereinafter may be applied to refrigerators, air conditioners, cleaners and the like. The centrifugal fan may be installed without a duct because it provides natural introduction and discharge of air into and from a fan. In particular, the centrifugal fan may be applied to a plug fan module for use in an air conditioner which is installed at an outdoor place as exemplarily shown in FIG. 1 and serves to cool or heat air directed from an indoor space and then resupply the air into the indoor space. The fan module 1 as described above includes a motor 2 having a rotating shaft, a support frame 3 supporting the motor 2 and a centrifugal fan 4 coupled to the rotating shaft of the motor 2. In addition, a front panel 5 coupled to a front surface of the support frame 3 has an opening through which air can be introduced into the centrifugal fan 4. The air introduced in a longitudinal direction of the rotating shaft through the opening is discharged in a radial direction from a rear region of the front panel 5 as the centrifugal fan 4 is rotated.

[0097] FIG. 2 is a perspective view showing a centrifugal fan according to one embodiment of the present invention. FIG. 3 is an exploded perspective view of the centrifugal fan shown in FIG. 2. FIG. 4 is a longitudinal cut-away view of the centrifugal fan shown in FIG. 2. FIG. 5 is an enlarged view showing a hub in (a) and a coupling structure of the hub and a main plate in (b). FIG. 6 is a view showing a positive pressure surface forming member in (a), a negative pressure surface forming member in (b) and a coupled state of the positive pressure surface forming member and the negative pressure surface forming member in (c). FIG. 7 is a view showing a height from a front edge to a rear edge of a blade included in the

centrifugal fan. FIG. 8 is a view showing holes for insertion of rivets used to install the blade. FIGs. 9 and 10 are partial views of the centrifugal fan, particularly, showing rivets and welding beads. FIG. 11 is a transverse cut-away view of the blade. FIG. 12 is a transverse sectional view of the blade. FIG. 13 is a view showing main factors to define a cross sectional shape and an attachment structure of the blade. FIG. 14 is a view showing factors defined at a point P on a camber line with reference to FIG. 13. FIG. 15 is a view showing positions of layers marked at the blade in (a) and cross sections of the blade taken at the layers in (b). FIG. 16 is a view showing the cross sections of FIG. 15 projected onto a single plane in a direction of a rotation axis.

[0098] Referring to FIGs. 2 to 4, the centrifugal fan 100 according to one embodiment of the present invention includes a main plate 110, a shroud 120 and a plurality of blades 130. The main plate 110, the shroud 120 and the blades 130 may be formed of a metal having plasticity, preferably, steel.

[0099] The main plate 110 is rotated about a rotation axis O by a motor (2, see FIG. 1). Although the main plate 110 may be directly coupled to the rotating shaft of the motor according to an embodiment, the centrifugal fan 100 may further include a hub 160 configured to couple the main plate 110 and the rotating shaft of the motor to each other.

[0100] The shroud 120 is spaced apart from the main plate 110 and has a suction opening 121 through which air is introduced in a direction of the rotation axis O. The shroud 120 takes the form of a ring centrally defining the suction opening 121. A diameter of the shroud 120 is gradually increased in a radial direction from an inner circumference of the shroud 120 defining the suction opening 121 and has a maximum value at an outer circumference of the shroud from which an air stream pumped by the blades 130 is discharged. The shroud 120 may have a curved inner surface along which air is guided, the curved inner surface of the shroud being convex toward the main plate 110.

[0101] The plural blades 130 are arranged in a circumferential direction between the main plate 110 and the shroud 120. Air sucked through the suction opening 121 of the shroud 120 is moved from a front edge to a rear edge of the respective blades 130 to thereby be discharged outward. The centrifugal fan 100 may include seven blades 130 although this is not essential.

[0102] In the following description, a portion of the blade 130 at which an air stream sucked through the shroud 120 begins to come into contact with the blade 130 is referred to as a front edge FE and a portion of the blade 130 at which the air stream is separated from the blade 130 is referred to as a rear edge RE. Considering arbitrary layers (or planes) perpendicular to the rotation axis O, cross sections of the blade 130 taken at the respective layers have front edges FE located on a prescribed common inner circumference and rear edges RE located on a prescribed common outer circumference,

the common outer circumference having a greater diameter than that of the common inner circumference. Assuming that one surface of the blade 130 facing the outer side of the centrifugal fan 100 is referred to as a positive pressure surface 131 and the other surface of the blade facing the inner side of the centrifugal fan 100 opposite to the positive pressure surface 131 is a negative pressure surface 132, the front edge FE of the blade 130 is located in front of the rear edge RE in a facing direction of the positive pressure surface 131 (or in a rotation direction of the centrifugal fan 100).

[0103] Referring to FIGs. 3 to 5, the main plate 110 includes a blade support plate portion 111 supporting lower edges of the blades 130 and a center hub mounting portion 112 raised from the blade support plate portion 111 toward the shroud 120. The hub mounting portion 112 extending from the blade support plate portion 111 is curved by a prescribed curvature. The hub mounting portion 112 is centrally provided with a mounting opening 110a for installation of the hub 160 and a plurality of first fastening holes 110b arranged at a constant interval in a circumferential direction around the mounting opening 110a.

[0104] The hub 160 includes a hub body 161 having a center insertion opening 160a for insertion of the rotating shaft (not shown) of the motor, the hub body being seated on the hub mounting portion 112 and a tubular first protrusion 162 protruding from the hub body 161 around the insertion opening 160a.

[0105] The hub body 161 is provided with second fastening holes 161a corresponding to the first fastening holes 110b. As fastening members, such as screws, bolts or the like, are fastened through the first fastening holes 110b and the second fastening holes 161a, the hub 160 and the main plate 110 are coupled to each other.

[0106] The first protrusion 162 is provided at an inner circumferential surface thereof with a key insertion recess 162a, into which a key formed at the rotating shaft of the motor is inserted, and also provided with a key fastening hole 162b, through which a fastening member, which will be fastened into a fastening hole (not shown) formed in the key, penetrates in a radial direction. The key fastening hole 162b may have screw threads.

[0107] In addition, the hub 160 may further include a tubular second protrusion 163 formed around the insertion opening 160a to protrude from the hub body 161 in a direction opposite to the first protrusion 162. The second protrusion 163 is inserted into the mounting opening 110a of the hub mounting portion 112 and has substantially the same diameter as that of the mounting opening 110a.

[0108] Meanwhile, a height HH of the hub mounting portion 112 raised from the blade support plate portion 111 and a curvature of the hub mounting portion 112 are main factors with regard to efficiency of the fan and interact with each other. Although increase in the height of the hub mounting portion 112 causes reduction in flow rate because the increased height resists an introduced

air stream, an appropriate height determined in consideration of interaction with the curvature of the hub mounting portion 112 improves the flow of air, resulting in increased efficiency.

[0109] Although a region of the hub mounting portion 112 coming into contact with a rear surface of the hub body 161 defines a horizontal plane, the hub mounting portion 112 begins to be curved by a first curvature $1/HR1$ from an outer end of the horizontal plane and a region of the hub mounting portion 112 connected to the blade support plate portion 111 is curved by a second curvature $1/HR2$ in a direction opposite to that of the first curvature $1/HR1$. For reference, "BD/2" designates a radius of the hub mounting portion 112.

[0110] The main plate 110 includes a discharge guide portion 113 at an outer circumference thereof. More specifically, the blade support plate portion 111 has a flat surface region for coupling with the blades 130 and the discharge guide portion 113 extending from the flat surface region to the outer circumference of the main plate 110 is curved downward (away from the shroud 120) by a third curvature $1/HR3$. When air is discharged via rotation of the centrifugal fan 100, the air is smoothly guided along the discharge guide portion 113, which has the effects of restricting generation of an eddy at the outer circumference of the main plate 110 from which an air stream is separated and of reducing flow resistance.

[0111] "BD/2" designates a blowing radius of the main plate 110 and corresponds to a distance from the center O of the main plate 110 to the rear edge RE of the blade 130 measured at a boundary of the blade 130 and the main plate 110. "BDL" designates a length of a region where an air stream separated from the rear edge of the blade 130 is guided along the main plate 110 and is a radial distance from the rear edge RE of the blade 130 to the outer circumference of the main plate 110.

[0112] The shroud 120 has a curved surface, a diameter of which is gradually increased from the suction opening 121 to the outer circumference of the shroud. Although the curved surface may have a constant curvature, preferably, the curvature of the curved surface is changed plural times. In the present embodiment, starting from the suction opening 121, the curved surface has a first curvature $1/SR1$, a second curvature $1/SR2$ and a third curvature $1/SR3$ in this sequence. Here, in particular, the third curvature $1/SR3$ is a curvature at the outer circumference of the shroud 120 and is preferably substantially equal to the third curvature $1/HR3$ of the main plate 110. It has been experimentally found that the above-described configuration contributes to enhancement in the efficiency of the fan.

[0113] "SD1/2" designates a radius of the suction opening 121 (i.e. "SD1" designates a diameter of the suction opening), and "SD2/2" designates a distance from the center O of the shroud 120 to the rear edge RE of the blade 130 measured at a boundary of the blade 130 and the shroud 120.

[0114] Considering a configuration of the shroud 120

having a curved inner circumferential surface, a vertical distance from an upper edge of the blade 130 coming into contact with the shroud 120 to the main plate 110 has a maximum value B1 at the front edge FE of the blade 130 and has a minimum value B2 at the rear edge RE of the blade 130.

[0115] A ratio of the suction diameter SD1 of the shroud 120 to the blowing diameter BD of the main plate 110 ($SD1/BD$) and a ratio of a minimum value B2 to a maximum value B1 of the vertical distance between the upper edge of the blade 130 and the main plate 110 ($B2/B1$) are factors that may contribute to enhancement in static pressure and efficiency of the fan. In particular, in the case of the aforementioned plug fan module having no duct, it is important to optimize these factors for increase in static pressure.

[0116] Although increase in the ratio $SD1/BD$ advantageously increases static pressure, increasing the ratio beyond a predetermined level is limited due to a limited size of the entire device to which the centrifugal fan is installed. In addition, although increase in the ratio $B2/B1$ advantageously increases static pressure, this may cause flow separation at the outer circumference of the shroud 120, resulting in performance deterioration.

[0117] Referring to FIGs. 6 to 8, the blade 130 includes a positive pressure surface forming member 140 that forms the positive pressure surface (131, see FIG. 2) and a negative pressure surface forming member 150 that forms the negative pressure surface (132 see FIG. 2). The positive pressure surface forming member 140 and the negative pressure surface forming member 150 may be coupled to each other with a space S therebetween. Preferably, the entire region of the positive pressure surface 131 is defined by the positive pressure surface forming member 140 and the entire region of the negative pressure surface 132 is defined by the negative pressure surface forming member 150. The positive pressure surface forming member 140 and the negative pressure surface forming member 150 may be formed by processing a metal sheet. Preferably, the positive pressure surface forming member 140 (or the negative pressure surface forming member 150) is formed by processing a metal sheet having an even thickness. In particular, the positive pressure surface forming member 140 or the negative pressure surface forming member 150 may achieve sufficient rigidity with a thickness of approximately 1 mm that is half or more of a conventional blade formed of a metal sheet having a thickness of 2 mm or more.

[0118] More specifically, the positive pressure surface forming member 140 and the negative pressure surface forming member 150 may be fabricated by pressing a metal sheet having plasticity. More particularly, a steel sheet has high plasticity and is easily formed in various shapes and may achieve sufficient corrosion resistance, heat resistance, rigidity and the like according to the content ratio of carbon (C), chrome (Cr), Nickel (Ni) and the like. In particular, a steel centrifugal fan may achieve enhanced rigidity and thus is rotatable at a higher rpm than

a conventional resin centrifugal fan. The conventional resin centrifugal fan ensures easy formation of a blade having a complicated shape, but has low rigidity. In particular, when the resin centrifugal fan is applied to a large product, the fan may be problematic in terms of stability because of a high risk of damage to blades due to high external static pressure. On the contrary, according to the present invention, as the blade is constructed using the two metal members 140 and 150, it is possible to achieve sufficient rigidity and to provide the blade with a complicated shape for enhancement in the performance of the fan.

[0119] The positive pressure surface forming member 140 and the negative pressure surface forming member 150 may be bonded to each other at the front edge and the rear edge of the blade 130. Bonding between the positive pressure surface forming member 140 and the negative pressure surface forming member 150 may be implemented at rear surfaces of the respective members. In the following description, a portion of the front edge of the blade 130 where bonding between the positive pressure surface forming member 140 and the negative pressure surface forming member 150 is implemented is referred to as a front edge bonding portion 133 and a portion of the rear edge of the blade 130 where bonding between the positive pressure surface forming member 140 and the negative pressure surface forming member 150 is implemented is referred to as a rear edge bonding portion 134. In addition, the blade 130 has a main body portion 135 between the front edge bonding portion 133 and the rear edge bonding portion 134 and the main body portion 135 inwardly defines a space S. In particular, the main body portion 135 may have an enclosed cross section surrounding the space S.

[0120] The positive pressure surface forming member 140 is provided at a front edge thereof with a first front edge bonding surface portion 141 and at a rear edge thereof with a first rear edge bonding surface portion 142. The positive pressure surface forming member is further provided with a first curved surface portion 145 between the first front edge bonding surface portion 141 and the second rear edge bonding surface portion 142. Similarly, the negative pressure surface forming member 150 is provided at a front edge thereof with a second front edge bonding surface portion 151 and at a rear edge thereof with a second rear edge bonding surface portion 152. The negative pressure surface forming member 150 is further provided with a second curved surface portion 155 between the second front edge bonding surface portion 151 and the second rear edge bonding surface portion 152.

[0121] Bonding between the first front edge bonding surface portion 141 and the second front edge bonding surface portion 151 is implemented at the front edge bonding portion 133 of the blade 130 and bonding between the first rear edge bonding surface portion 142 and the second rear edge bonding surface portion 152 is implemented at the rear edge bonding portion 134.

[0122] Preferably, a rear surface of the first front edge bonding surface portion 141 (hereinafter referred to as a first front edge bonding surface) and a rear surface of the second front edge bonding surface portion 151 (hereinafter referred to as a second front edge bonding surface) may come into surface contact with each other. The first front edge bonding surface portion 141 and the second front edge bonding surface portion 151 may include bonding surfaces having a corresponding shape. That is, the first front edge bonding surface and the second front edge bonding surface may have substantially the same shape so as to be bonded to each other in close contact.

[0123] Likewise, a rear surface of the first rear edge bonding surface portion 142 (hereinafter referred to as a first rear edge bonding surface) and a rear surface of the second rear edge bonding surface portion 152 (hereinafter referred to as a second rear edge bonding surface) may come into surface contact with each other. The first rear edge bonding surface portion 142 and the second rear edge bonding surface portion 152 may include bonding surfaces having a corresponding shape. That is, the first rear edge bonding surface and the second rear edge bonding surface may have substantially the same shape so as to be bonded to each other in close contact.

[0124] The main body portion 135 includes the first curved surface portion 145 and the second curved surface portion 155 and the space S is defined between the first curved surface portion 145 and the second curved surface portion 155. The space S has a transverse cross sectional shape defined by a rear surface of the first curved surface portion 145 and a rear surface of the second curved surface portion 155 and the top and bottom of the space is respectively defined by the shroud 120 and the main plate 110. The positive pressure surface forming member 140 and the negative pressure surface forming member 150 are independent of each other until they are bonded to each other and, therefore, may be freely processed into different shapes. Accordingly, the first curved surface portion 145 and the second curved surface portion 155 may be shaped to exhibit different curvature variations. In particular, since the shapes of the first curved surface portion 145 and the second curved surface portion 155 determine a shape of the positive pressure surface 131 and a shape of the negative pressure surface 132 respectively, the fact that the shapes of the curved surface portions 145 and 155 are freely determined is very advantageous in terms of enhancement in the performance of the fan. In particular, it is possible to form a positive pressure surface or negative pressure surface including more complicated curved surfaces than that in a case in which a positive pressure surface and a negative pressure surface are formed by bending a single metal sheet (see Japanese Patent Laid-open Publication No. 2000-45997).

[0125] Bonding between the positive pressure surface forming member 140 and the negative pressure surface forming member 150 at the front edge bonding portion

133 or at the rear edge bonding portion 134 may be implemented by welding, more particularly, resistance welding or laser welding.

[0126] Resistance welding is welding that confines generation of resistance heat to a relative small specific portion by applying pressure to a welding position of a base metal and thereafter passing current therethrough. An example of resistance welding may include spot welding or projection welding. Although welding using a welding rod leaves a strip of corrugated fusion beads caused by melting a base metal and the welding rod, projection welding or spot welding has less formation of beads, thus having a less effect on balancing of the fan.

[0127] Laser welding exhibits considerably low heat input to a weld and a narrow heat influence range and leaves behind substantially no welding beads, although it requires relatively great cost and, therefore, enables very precise bonding between members. When the blade 130 is formed using laser welding, areas of the front edge bonding portion 133 and the rear edge bonding portion 134 may be remarkably reduced.

[0128] The blade 130 may include a shroud connection portion 136 connected to the shroud 120. The shroud connection portion 136 may include a shroud bonding surface portion 143 and/or a shroud bonding surface portion 153 bent from an upper edge of at least one of the positive pressure surface forming member 140 and the negative pressure surface forming member 150.

[0129] Preferably, the positive pressure surface forming member 140 and the negative pressure surface forming member 150 are respectively provided with the first shroud bonding surface portion 143 and the second shroud bonding surface portion 153. In a state in which the positive pressure surface forming member 140 and the negative pressure surface forming member 150 are bonded to each other, the first shroud bonding surface portion 143 and the second shroud bonding surface portion 153 are bent in opposite directions. The first shroud bonding surface portion 143 and the second shroud bonding surface portion 153 may be bonded to an inner circumferential surface of the shroud 120 by welding. Bonding surfaces of the first shroud bonding surface portion 143 and the second shroud bonding surface portion 153 to be bonded to the shroud 120 (hereinafter referred to as a first shroud bonding surface and a second shroud bonding surface) are preferably curved to correspond to the shape of the inner circumferential surface of the shroud 120 so as to come into close contact with the inner circumferential surface.

[0130] The blade 130 may include a main plate connection portion 137 connected to the main plate 110. The main plate connection portion 137 may include a main plate bonding surface portion 144 and/or a main plate bonding surface portion 154 bent from a lower edge of at least one of the positive pressure surface forming member 140 and the negative pressure surface forming member 150.

[0131] Preferably, the positive pressure surface form-

ing member 140 and the negative pressure surface forming member 150 are respectively provided with the first main plate bonding surface portion 144 and the second main plate bonding surface portion 154. In a state in which the positive pressure surface forming member 140 and the negative pressure surface forming member 150 are bonded to each other, the first main plate bonding surface portion 144 and the second main plate bonding surface portion 154 are bent in opposite directions. The first main plate bonding surface portion 144 and the second main plate bonding surface portion 154 may be bonded to the main plate 110 by welding. Bonding surfaces of the first main plate bonding surface portion 144 and the second main plate bonding surface portion 154 to be bonded to the main plate 110 (hereinafter referred to as a first main plate bonding surface and a second main plate bonding surface) come into close contact with the main plate 110.

[0132] Bonding between the shroud bonding surface portions 143 and 153 and the shroud 120 or bonding between the main plate bonding surface portions 144 and 154 and the main plate 110 may be implemented by welding, more particularly resistance welding or laser welding. Resistance welding and laser welding have been described above and thus a further description thereof will be omitted hereinafter.

[0133] Referring to FIG. 6, the positive pressure surface forming member 140 and the negative pressure surface forming member 150 may be fabricated by the following procedure.

(1) Member Forming Step: A first member and a second member, each having a curved surface, are formed by pressing a metal sheet having plasticity (more particularly, steel sheet). The first member and the second member may respectively be the positive pressure surface forming member 140 and the negative pressure surface forming member 150. This step may include bending an upper edge of any one of the first member 140 and the second member 150 to form the shroud bonding surface portion 143 and/or the shroud bonding surface portion 153 and bending a lower edge of any one of the first member 140 and the second member 150 to form the main plate bonding surface portion 144 and/or the main plate bonding surface portion 154.

(2) Blade Forming Step: Front edges of the first member 140 and the second member 150 are bonded to each other and rear edges of the first member 140 and the second member 150 are bonded to each other to form the blade 130. The front edges of the respective members 140 and 150 may be bonded to each other by projection welding to form the front edge bonding portion 133, and the rear edges of the respective members 140 and 150 may be bonded to each other by projection welding to form the rear edge bonding portion 134.

(3) Provisional Assembly Step: The integrated blade

130 acquired by bonding the members 140 and 150 to each other is positioned on the main plate 110. The blade 130 may be fixed based on a predetermined inlet angle and a predetermined outlet angle.

(4) Shroud Bonding Step: At least one of the first member 140 and the second member 150 is bonded to the shroud 120 in a state in which the blade 130 is positioned on the main plate 110. In particular, bonding may be implemented by resistance welding (spot welding or projection welding) between the shroud bonding surface portions 143 and/or 153 and the shroud 120.

(5) Main Plate Bonding Step: At least one of the first member 140 and the second member 150 is bonded to the main plate 110 in a state in which the blade 130 is positioned on the main plate 110. Bonding may be implemented by resistance welding (more particularly, spot welding or projection welding) between the main plate bonding surface portions 144 and/or 154 and the main plate 110.

(6) Painting Step: Painting is implemented in a state in which assembly of the main plate 110, the shroud 120 and the blade 130 is completed. A paint layer may improve corrosion resistance and seal a coupling region between the members.

[0134] In particular, in (1) Step, in (4) Step or in (5) Step, holes 172 for insertion of rivets 171 may be processed in the shroud bonding surface portions 143 and 153 and the main plate bonding surface portions 144 and 154. In (4) Step or in (5) Step, prior to implementation of resistance welding, the rivets 171 may be aligned with and fastened through the holes 172 to couple the shroud 120 and the shroud bonding surface portions 143 and 153 to each other. The main plate 110 and the main plate bonding surface portions 144 and 154 may be coupled to each other in the same manner. As exemplarily shown in FIG. 8, processing positions of the holes 172 may include at least two positions of a front end and a rear end of the main plate bonding surface portion 144 or 154 and at least one position of a rear end of the shroud bonding surface portion 143 or 153. Here, note that the hole 172 for insertion of the rivet 171 may further be processed in a front end of the shroud bonding surface portion 143 or 153 based on the size of the centrifugal fan 100. Each bonding surface portion 143, 153, 144 or 154 may be spot welded to an object (the shroud 120 or the main plate 110) at a prescribed interval in a portion thereof between the front end and the rear end thereof except for the fastening positions of the rivets 171. FIGs. 9 and 10 show the centrifugal fan after completion of coupling using the rivets 171 and spot welding. As will be appreciated from the drawings, the rivets 171 are fastened at two positions of the rear end of the shroud bonding surface portion 143 or 153 and the rivets 171 are respectively fastened at the front end and the rear end of the main plate bonding surface portion 144 or 154. In addition, these drawings show beads caused by spot welding. As

exemplarily shown, spot welding leaves indentations or welding beads 173 in a surface of a base metal. Since the welding beads 173 are formed in a significantly confined range due to the characteristics of spot welding and, thus, cause less flow resistance and no increase in the weight of a base metal, the welding beads have substantially no negative effect on balancing of the fan. In the case of projection welding, a smooth surface having no welding beads may be acquired. However, fine welding beads 173 may be formed when a base metal is thick.

[0135] Meanwhile, the shroud bonding surface portions 143 and 153 or the main plate bonding surface portions 144 and 154 are not necessary to extend from the front edge to the rear edge of the blade 130. Preferably, the blade 130 is provided at the front edge thereof with the front edge bonding portion 133 throughout a region extending from the upper edge of the blade connected to the shroud 120 to the lower edge of the blade connected to the main plate 110, and an upper end and a lower end of the front edge bonding portion 133 are respectively bonded to the shroud 120 and the main plate 110. Likewise, the blade 130 is provided at the rear edge thereof with the rear edge bonding portion 134 throughout a region extending from the upper edge of the blade connected to the shroud 120 to the lower edge of the blade connected to the main plate 110, and an upper end and a lower end of the rear edge bonding portion 134 are respectively bonded to the shroud 120 and the main plate 110. In this case, the shroud connection portion 136 is formed between the upper end of the front edge bonding portion 133 and the upper end of the rear edge bonding portion 134 and the main plate connection portion 137 is formed between the lower end of the front edge bonding portion 133 and the lower end of the rear edge bonding portion 134. Bonding between the positive pressure surface forming member 140 and the negative pressure surface forming member 150 is implemented by projection welding at each of the front edge bonding portion 133 and the rear edge bonding portion 134. In particular, this bonding is preferably maintained even at the upper end and the lower end of each bonding portion 133 or 134 at which the shroud bonding surface portion 143 or 153 or the main plate bonding surface portion 144 or 154 is not formed.

[0136] Meanwhile, the blade 130 may have a three dimensional (3D) shape. In the following description, the 3D shape of the blade is defined as a shape in which, when cross sections of the blade taken at prescribed layers corresponding to prescribed planes perpendicular to the rotation axis O are projected onto a prescribed projection plane in a direction of the rotation axis O, two or more lines among lines interconnecting the front edges FE and the rear edges RE of the respective cross sections in the projection plane do not overlap each other. Here, the lines interconnecting the front edges and the rear edges are defined according to given rules. For example, the lines may be straight lines interconnecting the front edges FE and the rear edges RE. Alternatively, the

lines may be lines connecting equidistant points from the positive pressure surface 131 and the negative pressure surface 132.

[0137] Referring to FIGs. 11 and 12, in a region of the blade 130 defining the space S, a cross section of the blade may have an airfoil shape. The main body portion 135 defines an airfoil. The entire cross section of an inner circumferential surface of the blade defining the space S has an airfoil shape, but a front edge of the cross section may have a cusp due to bonding between the positive pressure surface forming member 140 and the negative pressure surface forming member 150. Therefore, "airfoil" is defined based on the shape of an outer circumferential surface of the blade 130 and a leading edge LE is defined as being located on a virtual curve that interconnects an outer circumferential surface of the positive pressure surface forming member 140 and an outer circumferential surface of the negative pressure surface forming member 150. In the drawings, "r" designates a radius of curvature at the leading edge LE and a radius of curvature at an upper surface or a lower surface of the airfoil has a minimum value at the leading edge LE.

[0138] Hereinafter, the main body portion 135 will be described in more detail. The main body portion 135 may have an airfoil or streamlined shape inwardly defining the space S. According to the definition proposed by the National Advisory Committee for Aeronautics (NACA), "airfoil" is configured by a leading edge, a trailing edge and an upper surface 145a and a lower surface 155a which connect the leading edge and the trailing edge to each other and a shape of the airfoil is determined by various factors. Examples of the factors include a chord line CRL that is a straight line connecting the leading edge and the trailing edge to each other and a camber line CBL that is acquired by connecting equidistant points from the upper surface and the lower surface between the leading edge and the trailing edge. Referring to FIGs. 13 and 14, factors required to define the cross sectional shape of the main body portion 135 and arrangement of the main body portion 135 on the main plate 110 are as follows:

Xc: vector drawn along the chord line CRL from the leading edge LE;

Yc: vector perpendicular to the vector Xc at the leading edge LE;

α : angle between the leading edge LE and the trailing edge TE at the rotation axis O;

C(P): circumference passing a point P on the camber line CBL about the rotation axis O;

TC(P): tangent in relation to the circumference C(P) at the point P (FIG. 13 shows the case in which the point P is the leading edge);

TCB(P): tangent in relation to the camber line CBL at the point P (FIG. 13 shows the case in which the point P is the leading edge);

β (P): angle between the tangent TC(P) and the tangent TCB(P);

θ (P): angle between the tangent TCB(P) and the

chord line CRL;

γ : angle between the chord line CRL and a line TC at the leading edge LE;

OT: line connecting the center axis O and the trailing edge TE to each other; and

Φ : angle between the chord line CRL and the line OT at the trailing edge TE.

[0139] In the following description, β (P) is referred to as an attack angle, the attack angle β (LE) at the leading edge LE is referred to as an inlet angle and the attack angle β (TE) at the trailing edge TE is referred to as an outlet angle.

[0140] Meanwhile, four layers perpendicular to the rotation axis O are shown in (a) of FIG. 15. Cross sections S(L1), S(L2), S(L3) and S(L4) of the blade 130 are respectively taken at a first layer Layer 1, a second layer Layer 2, a third layer Layer 3 and a fourth layer Layer 4. The first layer Layer 1, the second layer Layer 2, the third layer Layer 3 and the fourth layer Layer 4, which are required to define the shape of the blade 130, may be freely selected so long as they are taken from the top to the bottom along the rotation axis O in this sequence.

[0141] Referring to FIGs. 15 and 16, in the arbitrary cross sections S(L1), S(L2), S(L3) and S(L4) of the blade 130, a camber line may be located between the upper surface 145a of the airfoil and a chord line. The upper surface 145a configuring the positive pressure surface 131 is convex outward of the centrifugal fan 1 and, therefore, air velocity is increased at the positive pressure surface 131.

[0142] In the first blade cross section S(L1), a rear edge RE(L1) is taken at a portion of the blade 130 coming into contact with the shroud 120. In the second blade cross section S(L2), a rear edge RE(L2) is located on a circle C(L2) having a maximum radius Rmax among concentric circles C(P) about the rotation axis O. In the third blade cross section S(L3) taken at the layer Layer 3, a rear edge RE(L3) is located on a circle C(L4) having a minimum radius Rmin.

[0143] That is, the rear edge RE of the blade 130, which extends from a portion of the blade coming into contact with the shroud 120 to the main plate 110, gradually becomes farther away from the rotation axis O in a given section so as to be at a maximum distance Rmax from the rotation axis O in the second layer Layer 2 and, thereafter, gradually approaches the rotation axis O so as to be at a minimum distance Rmin from the rotation axis O in the third layer Layer 3. Then, the rear edge of the blade gradually becomes farther away from the rotation axis O until it again meets the shroud 120 (see RE(L4)).

[0144] The rear edge RE of the blade 130 is a curve connecting points RE(L1), RE(L2), RE(L3) and RE(L4) to one another. Considering geometrical arrangement relationship of these points, an inflection point is present between the point RE(L2) and the point RE(L3). In particular, in a section between the inflection point and the

point RE(L4), the positive pressure surface 131 is concave toward the rotation axis O, which may advantageously realize increased static pressure and guidance of airflow to the main plate 110.

[0145] Meanwhile, considering positions of front edges FE(L1), FE(L2), FE(L3) and FE(L4) of the respective cross sections of the blade, the front edge FE(L1) at the first layer Layer 1 is located farther from the rotation axis O than the other front edges FE(L2), FE(L3) and FE(L4) and the front edge FE(L3) at the third layer Layer 3 is located closer to the rotation axis O than the other front edges FE(L1), FE(L2) and FE(L4) shown in the drawing. Accordingly, characteristic points of the blade 130 to indicate variation of distance from the rotation axis O to the front edge FE (for example, an inflection point and points having a maximum or minimum distance from the rotation axis O) may not be present at the same layer as characteristic points with regard to the rear edge RE (for example, the points RE(L3) and RE(L2) respectively having a minimum distance and a maximum distance from the rotation axis O). This is because the blade 130 has a complicated 3D shape and a metal sheet may be easily processed into the complicated shape.

[0146] Meanwhile, in the cross sections S(L1), S(L2), S(L3) and S(L4) of the blade, considering the attack angle β defined with reference to FIGs. 13 and 14, the attack angle β of the cross section S(L1) taken at the first layer Layer 1 is increased from the leading edge LE(L1) to the trailing edge TE(L1), and, likewise, the attack angle β of the cross section S(L4) taken at the fourth layer Layer 4 is increased from the leading edge LE(L4) to the trailing edge TE(L4). In the first cross section S(L1), an inlet angle β LE(L1) is approximately 16 degrees and an outlet angle β TE(L1) is approximately 24 degrees. In addition, in the fourth cross section S(L4), an inlet angle β LE(L4) is approximately 10 degrees and an outlet angle β TE(L4) is approximately 38 degrees.

[0147] Since the velocity of air discharged along the main plate 110 differs from the velocity of air passing through the shroud 120, variation of the attack angle β from the upper edge of the blade 130 connected to the shroud 120 to the lower edge of the blade connected to the main plate 110 has a great effect on the efficiency of the fan. Accordingly, when air moves in the shortest path or in an airflow direction along the positive pressure surface 131 of the blade 130 from the leading edge LE(L1) of the cross section S(L1) taken at the first layer Layer 1 to the trailing edge TE(L4) of the cross section S(L4) taken at the fourth layer Layer 4, the attack angle is gradually increased and the outlet angle β TE(L4) of the cross section S(L4) taken at the fourth layer Layer 4 has a maximum value. This may result in increase in the velocity of air discharged from the main plate 110.

[0148] FIG. 17 is a longitudinal sectional view of the blade. Referring to FIG. 17, in a longitudinal cross section of the blade 130 parallel to the rotation axis O, a curve defined by the first curved surface portion 145 is convex near the shroud 120 in a facing direction of the positive

pressure surface 131 (see RC) and is convex near the main plate 110 in a facing direction of the negative pressure surface 132 (see CRC). In particular, since the longitudinal cross section is convex near the main plate 110 in a facing direction of the negative pressure surface 132, this has the effect of guiding airflow to the main plate 110 and, thus, a relatively uniform volume of air may be discharged throughout a section from the upper edge to the lower edge of the blade 130.

[0149] In addition, considering the shape of the blade 130 based on longitudinal cross sections parallel to the rotation axis O, at least one of the longitudinal cross sections may be convex near the shroud 120 in a facing direction of the positive pressure surface 131 and may be convex near the main plate 110 in a facing direction of the negative pressure surface 132.

[0150] FIG. 18 is a comparative graph showing efficiency depending on air volume Q of the centrifugal fan according to one embodiment of the present invention and a conventional centrifugal fan. As exemplarily shown in FIG. 18, it was found from experiments that the centrifugal fan 100 according to one embodiment of the present invention is increased in efficiency depending on the same air volume beyond that in the conventional centrifugal fan and, more particularly, the centrifugal fan 100 has maximum efficiency up to 82% that is rapidly improved than efficiency of approximately 70% based on the same air volume of the related art.

[0151] FIG. 19 is a perspective view showing a centrifugal fan according to another embodiment of the present invention. FIGs. 20 and 21 are longitudinal cut-away views of the centrifugal fan shown in FIG. 19. FIG. 22 is a view showing layers referenced for explanation of the shape of a blade. FIG. 23 is a view showing cross sections of the blade taken at layers of FIG. 22. FIG. 24 is a view showing the cross sections of FIG. 23 projected onto a single plane in a direction of a rotation axis.

[0152] Referring to FIGs. 19 to 24, the centrifugal fan 200 according to another embodiment of the present invention includes a main plate 210 to which a hub 260 is coupled, a shroud 220 and blades 230.

[0153] Referring to FIG. 21, although a curved surface of the shroud 220 extending from a suction opening 221 undergoes sequential curvature variation from the first curvature 1/SR1 to the second curvature 1/SR2 in the same manner as in the shroud 120 of the embodiment as described above, the shroud of the present embodiment has a difference in that it is provided at an outer circumference thereof with a horizontal portion 223 and a discharge guide portion SDL having a prescribed angle DA with the horizontal portion 223. This configuration advantageously ensures easy processing of the discharge guide portion SDL that serves to diffuse airflow.

[0154] The main plate 210 may include a discharge guide portion 213 at an outer circumference thereof and the discharge guide portion 213 may have the same shape as the discharge guide portion SDL of the shroud 220.

[0155] Meanwhile, as exemplarily shown in FIGs. 19 and 20, the blade 230 may be constructed by bonding a positive pressure surface forming member 240 and a negative pressure surface forming member 250 to each other, and bonding of these members 240 and 250 may be implemented in substantially the same manner as that of the embodiment as described above with reference to FIGs. 1 to 18. For example, a front edge bonding surface portion of the positive pressure surface forming member 240 and a front edge bonding surface portion of the negative pressure surface forming member 250 may be bonded to each other at a front edge portion 233 of the blade 230 and a rear edge bonding surface portion of the positive pressure surface forming member 240 and a rear edge bonding surface portion of the negative pressure surface forming member 250 may be bonded to each other at a rear edge portion 234 of the blade. At least one of the positive pressure surface forming member 240 and the negative pressure surface forming member 250 may be provided at an upper edge thereof with a shroud bonding surface portion (not designated) to be bonded to the shroud 220. In addition, at least one of the positive pressure surface forming member 240 and the negative pressure surface forming member 250 may be provided at a lower edge thereof with a main plate bonding surface portion (not designated) to be bonded to the main plate 210. The shroud bonding surface portion and the main plate bonding surface portion have substantially the same configuration as that in the blade 130 according to the embodiment as described above.

[0156] In addition, the blade 230 includes the front edge bonding portion 233, a main body portion 235 and the rear edge bonding portion 234. A cross section of the blade 230 that will be described hereinafter has an airfoil shape defined by the main body portion 235.

[0157] FIG. 22 shows a first layer Layer 1, a second layer Layer 2 and a third layer Layer 3 perpendicular to the rotation axis O. Cross sections S(L1), S(L2) and S(L3) of the blade 230 shown in FIGs. 23 and 24 are respectively taken at the first layer Layer 1, the second layer Layer 2 and the third layer Layer 3.

[0158] In the first blade cross section S(L1), a rear edge RE(L1) is taken at a portion of the blade 230 coming into contact with the shroud 220. The third blade cross section S(L3) is taken at a portion of the blade 230 that meets the main plate 210. The second blade cross section S(L2) is taken between the first blade cross section S(L1) and the third blade cross section S(L3). Note that the first layer Layer 1, the second layer Layer 2 and the third layer Layer 3, which are used to define the shape of the blade 230, may be freely selected so long as they are taken from the top to the bottom along the rotation axis O in this sequence, without being limited thereto.

[0159] The second blade cross section S(L2) is located farthest from the rotation axis O. In particular, a positive pressure surface of the blade 230 has the longest distance from the rotation axis O in the second blade cross section S(L2). That is, in the second blade cross section

S(L2), the blade 230 is convex to the maximum extent in a facing direction of the positive pressure surface.

[0160] The blade 230 may have a longitudinal cross section that is parallel to the rotation axis O and is convex in a facing direction of the positive pressure surface. In particular, a front edge or a rear edge of the blade 230 may be convex in a facing direction of the positive pressure surface.

[0161] Meanwhile, referring to FIG. 22, the blade 230 further includes a top extension 239 that extends upward from a convex portion between the first blade cross section S(L1) and the third blade cross section S(L3) and is connected to the shroud 220. The top extension 239 is perpendicular to the main plate 210 and shroud bonding surface portions of the positive pressure surface forming member 240 and the negative pressure surface forming member 250 are formed at an upper end of the top extension 239.

Claims

1. A centrifugal fan comprising:

a main plate configured to be rotated about a rotation axis;

a shroud having a suction opening through which air is suctioned; and

a plurality of blades arranged in a circumferential direction between the main plate and the shroud to allow the air suctioned through the suction opening to flow from a front edge to a rear edge of each blade,

wherein each of the blades is formed by bonding a pair of members to each other, each member being formed of a metal sheet having a curved surface,

wherein any one of the members is a positive pressure surface forming member defining a positive pressure surface of the blade and the other member is a negative pressure surface forming member defining a negative pressure surface of the blade, and

wherein the positive pressure surface forming member and the negative pressure surface forming member are bonded to each other with a space therebetween such that a cross section of the blade taken at a layer crossing the rotation axis has an enclosed shape.

2. The centrifugal fan according to claim 1, wherein, when cross sections of the blade taken at planar layers perpendicular to the rotation axis are projected onto a prescribed projection plane in a direction of the rotation axis, two or more lines among lines interconnecting front edges and rear edges of the respective cross sections in the projection plane do not overlap each other.

3. The centrifugal fan according to claim 1, wherein bonding between the positive pressure surface forming member and the negative pressure surface forming member is implemented at the front edge and the rear edge and the space is located between the front edge and the rear edge.

4. The centrifugal fan according to claim 3, wherein bonding between the positive pressure surface forming member and the negative pressure surface forming member is implemented between a surface of the member opposite to the positive pressure surface and a surface of the member opposite to the negative pressure surface.

5. The centrifugal fan according to claim 1, wherein the positive pressure surface forming member and the negative pressure surface forming member are formed of steel.

6. The centrifugal fan according to claim 1, wherein each of the positive pressure surface forming member and the negative pressure surface forming member is formed of a metal sheet having an even thickness.

7. The centrifugal fan according to claim 1, wherein the shroud, the blades and the main plate are formed of the same material.

8. The centrifugal fan according to claim 1, wherein at least one of the positive pressure surface forming member and the negative pressure surface forming member includes a shroud bonding surface portion to be bonded to the shroud.

9. The centrifugal fan according to claim 8, wherein the shroud bonding surface portion is formed by bending an upper edge of each of the positive pressure surface forming member and the negative pressure surface forming member in a direction opposite to the other member.

10. The centrifugal fan according to claim 8, wherein the shroud has an inner circumferential surface along which the air suctioned through the suction opening is guided, the inner circumferential surface being a curved surface expanding in a direction opposite to the rotation axis with decreasing distance to the main plate along the rotation axis, and wherein the shroud bonding surface portion has a shape corresponding to a shape of the curved surface so as to come into close contact with the curved surface.

11. The centrifugal fan according to claim 1, wherein the curved surface is formed by pressing.

12. The centrifugal fan according to claim 1, wherein the cross section of the blade taken at an arbitrary layer crossing the rotation axis configures an airfoil having an upper surface and a lower surface in the form of curved surfaces extending respectively between a leading edge and a trailing edge, the upper surface belonging to the positive pressure surface and the lower surface belonging to the negative pressure surface.
13. The centrifugal fan according to claim 12, wherein the airfoil has a camber line connecting equidistant points from the upper surface and the lower surface to one another and a chord line straightly connecting the leading edge and the trailing edge to each other, the camber line being located between the chord line and the upper surface.
14. The centrifugal fan according to claim 13, wherein the blade includes a section in which an angle between a tangent at a prescribed point on the camber line in relation to a circle, at which the point is located, among concentric circles about the rotation axis and a tangent at the point in relation to the camber line is gradually increased along a stream line on the positive pressure surface.
15. The centrifugal fan according to claim 1, wherein a height from the main plate to a point where the front edge of the blade meets the shroud is greater than a height from the main plate to a point where the rear edge of the blade meets the shroud.
16. The centrifugal fan according to claim 1, wherein at least one of the positive pressure surface forming member and the negative pressure surface forming member includes a main plate bonding surface portion to be bonded to the main plate.
17. The centrifugal fan according to claim 16, wherein the main plate bonding surface portion is formed by bending a lower edge of each of the positive pressure surface forming member and the negative pressure surface forming member in a direction opposite to the other member.
18. The centrifugal fan according to claim 1, wherein the space is defined by a surface of the member opposite to the positive pressure surface, a surface of the member opposite to the negative pressure surface, the shroud and the main plate.
19. The centrifugal fan according to claim 1, wherein the entire region of the positive pressure surface is defined by the positive pressure surface forming member, and wherein the entire region of the negative pressure surface is defined by the negative pressure surface

forming member.

20. A centrifugal fan comprising:

- a main plate configured to be rotated about a rotation axis;
a shroud having a suction opening through which air is suctioned; and
a plurality of blades arranged in a circumferential direction between the main plate and the shroud to allow the air suctioned through the suction opening to flow from a front edge to a rear edge of each blade,
wherein each of the blades is formed by bonding a pair of members to each other, each member being formed of a metal sheet,
wherein any one of the members is a positive pressure surface forming member defining a positive pressure surface of the blade and the other member is a negative pressure surface forming member defining a negative pressure surface of the blade, and
wherein bonding between the positive pressure surface forming member and the negative pressure surface forming member is implemented at the front edge and the rear edge.
21. The centrifugal fan according to claim 20, wherein bonding between the positive pressure surface forming member and the negative pressure surface forming member is implemented between a surface of the member opposite to the positive pressure surface and a surface of the member opposite to the negative pressure surface.
22. The centrifugal fan according to claim 21, wherein bonding between the positive pressure surface forming member and the negative pressure surface forming member is implemented by projection welding between a protrusion formed at the surface of the member opposite to any one of the positive pressure surface and the negative pressure surface and the other one of the positive pressure surface and the negative pressure surface.
23. The centrifugal fan according to claim 20, wherein bonding between the positive pressure surface forming member and the negative pressure surface forming member is implemented by spot welding.
24. The centrifugal fan according to claim 20, wherein bonding between the positive pressure surface forming member and the negative pressure surface forming member is implemented by laser welding.
25. The centrifugal fan according to claim 20, wherein the positive pressure surface forming member and the negative pressure surface forming member are

formed of steel.

26. The centrifugal fan according to claim 20, wherein the shroud, the blades and the main plate are formed of the same material.

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27. The centrifugal fan according to claim 20, wherein at least one of the positive pressure surface forming member and the negative pressure surface forming member includes a shroud bonding surface portion to be bonded to the shroud.

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28. The centrifugal fan according to claim 27, wherein the shroud bonding surface portion is formed by bending an upper edge of each of the positive pressure surface forming member and the negative pressure surface forming member in a direction opposite to the other member.

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29. The centrifugal fan according to claim 27, wherein at least one of an upper end of the front edge and an upper end of the rear edge comes into contact with the shroud.

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30. The centrifugal fan according to claim 29, wherein the shroud bonding surface portion is formed at a section of an upper edge of at least one of the positive pressure surface forming member and the negative pressure surface forming member except for portions constituting the front edge and the rear edge.

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31. The centrifugal fan according to claim 27, wherein bonding between the shroud bonding surface portion and the shroud is implemented by projection welding between a protrusion formed at any one of the shroud bonding surface portion and the shroud and a prescribed surface of the other one of the shroud bonding surface portion and the shroud.

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32. The centrifugal fan according to claim 27, wherein bonding between the shroud bonding surface portion and the shroud is implemented by spot welding.

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33. The centrifugal fan according to claim 32, wherein at least one of the shroud bonding surface portion and the shroud has welding beads indented from a peripheral portion at a prescribed interval in a line by spot welding.

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34. The centrifugal fan according to claim 27, wherein bonding between the shroud bonding surface portion and the shroud is implemented by laser welding.

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35. The centrifugal fan according to claim 20, wherein at least one of the positive pressure surface forming member and the negative pressure surface forming member includes a main plate bonding surface portion to be bonded to the main plate.

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36. The centrifugal fan according to claim 35, wherein the main plate bonding surface portion is formed by bending a lower edge of each of the positive pressure surface forming member and the negative pressure surface forming member in a direction opposite to the other member.

37. The centrifugal fan according to claim 35, wherein at least one of an lower end of the front edge and a lower end of the rear edge comes into contact with the main plate.

38. The centrifugal fan according to claim 37, wherein the main plate bonding surface portion is formed at a section of a lower edge of at least one of the positive pressure surface forming member and the negative pressure surface forming member except for portions constituting the front edge and the rear edge.

39. The centrifugal fan according to claim 20, wherein at least one of the positive pressure surface forming member and the negative pressure surface forming member has a curved surface formed by pressing.

40. The centrifugal fan according to claim 20, wherein the shroud has an inner circumferential surface along which the air suctioned through the suction opening is guided, the inner circumferential surface being a curved surface expanding in a direction opposite to the rotation axis with decreasing distance to the main plate along the rotation axis, and wherein the shroud bonding surface portion has a shape corresponding to a shape of the curved surface so as to come into close contact with the curved surface.

41. The centrifugal fan according to claim 20, wherein a height from the main plate to a point where the front edge of the blade meets the shroud is greater than a height from the main plate to a point where the rear edge of the blade meets the shroud.

42. The centrifugal fan according to claim 20, wherein the entire positive pressure surface of the blade is defined by the positive pressure surface forming member, and wherein the entire negative pressure surface of the blade is defined by the negative pressure surface forming member.

43. A centrifugal fan comprising:

a main plate configured to be rotated about a rotation axis;
a shroud having a suction opening through which air is suctioned; and
a plurality of blades arranged in a circumferential direction between the main plate and the shroud

- to allow the air suctioned through the suction opening to flow from a front edge to a rear edge of each blade,
 wherein each of the blades is formed by bonding a pair of members to each other, each member being formed of a metal sheet and having a curved surface, and
 wherein, when cross sections of the blade taken at planar layers perpendicular to the rotation axis are projected onto a prescribed projection plane in a direction of the rotation axis, two or more lines among lines interconnecting front edges and rear edges of the respective cross sections in the projection plane do not overlap each other.
44. The centrifugal fan according to claim 43, wherein the rear edge of the blade is located farther from the rotation axis than the front edge and is deviated in a direction opposite to a rotation direction of the centrifugal fan.
45. The centrifugal fan according to claim 43, wherein the cross section of the blade taken at an arbitrary layer crossing the rotation axis configures an airfoil having an upper surface and a lower surface in the form of curved surfaces extending respectively between a leading edge and a trailing edge, the upper surface belonging to a positive pressure surface of the blade and the lower surface belonging to a negative pressure surface of the blade.
46. The centrifugal fan according to claim 43, wherein the airfoil has a camber line connecting equidistant points from the upper surface and the lower surface to one another and a chord line straightly connecting the leading edge and the trailing edge to each other, the camber line being located between the chord line and the upper surface.
47. The centrifugal fan according to claim 46, wherein an angle between a tangent at a prescribed point on the camber line in relation to a circle, at which the point is located, among concentric circles about the rotation axis and a tangent at the point in relation to the camber line is gradually increased along a stream line on a positive pressure surface.
48. The centrifugal fan according to claim 43, wherein the members constituting the blade includes:
 a positive pressure surface forming member defining the entire region of a positive pressure surface of the blade; and
 a negative pressure surface forming member defining the entire region of a negative pressure surface of the blade.
49. The centrifugal fan according to claim 43, wherein a positive pressure surface forming member and a negative pressure surface forming member are formed of steel.
50. The centrifugal fan according to claim 43, wherein the shroud, the blades and the main plate are formed of the same material.
51. The centrifugal fan according to claim 43, wherein at least one of the members has a curved surface.
52. The centrifugal fan according to claim 43, wherein the members are bonded to each other with a space therebetween.
53. The centrifugal fan according to claim 43, wherein a portion of the blade near the shroud is convex in a facing direction of a positive pressure surface and a portion of the blade near the main plate is convex in a facing direction of a negative pressure surface.
54. The centrifugal fan according to claim 53, wherein the convex portion of the blade in the facing direction of the positive pressure surface has a maximum distance from the rotation axis.
55. The centrifugal fan according to claim 53, wherein the convex portion of the blade in the facing direction of the negative pressure surface has a minimum distance from the rotation axis.
56. The centrifugal fan according to claim 43, wherein the blade includes a convex portion in a facing direction of a positive pressure surface.
57. The centrifugal fan according to claim 56, wherein the convex portion of the blade in the facing direction of the positive pressure surface has a maximum distance from the rotation axis.
58. A centrifugal fan comprising:
 a main plate configured to be rotated about a rotation axis;
 a shroud having a suction opening through which air is suctioned; and
 a plurality of blades arranged in a circumferential direction between the main plate and the shroud, wherein each of the blades is formed by bonding a pair of members to each other, each member being formed of a metal sheet, any one of the members being a positive pressure surface forming member defining a positive pressure surface of the blade and the other member being a negative pressure surface forming member defining a negative pressure surface of the blade,
 wherein the positive pressure surface forming

- member includes a first curved surface portion having a curved surface and a first front edge bonding surface portion and a first rear edge bonding surface portion at opposite sides of the first curved surface portion, and
 wherein the negative pressure surface forming member includes a second curved surface portion having a curved surface, the second curved surface portion and the first curved surface portion defining a space therebetween, and a second front edge bonding surface portion and a second rear edge bonding surface portion at opposite sides of the second curved surface portion, the second front edge bonding surface portion being bonded to the first front edge bonding surface portion and the second rear edge bonding surface portion being bonded to the first rear edge bonding surface portion.
59. The centrifugal fan according to claim 58, wherein the first curved surface portion and the second curved surface portion define different curves in a longitudinal cross section of the blade parallel to the rotation axis.
60. The centrifugal fan according to claim 58, wherein a curve defined by the first curved surface portion in a longitudinal cross section parallel to the rotation axis is convex near the shroud in a facing direction of the positive pressure surface and is convex near the main plate in a facing direction of the negative pressure surface.
61. The centrifugal fan according to claim 58, wherein the blade is convex near the shroud in a facing direction of the positive pressure surface and is convex near the main plate in a facing direction of the negative pressure surface in a longitudinal cross section parallel to the rotation axis.
62. The centrifugal fan according to claim 58, wherein the blade is convex in a facing direction of the positive pressure surface.
63. The centrifugal fan according to claim 58, wherein the first front edge bonding surface portion and the second front edge bonding surface portion have a corresponding shape.
64. The centrifugal fan according to claim 58, wherein the first curved surface portion and the second curved surface portion configure an airfoil in a layer crossing the rotation axis.
65. The centrifugal fan according to claim 64, wherein the first curved surface portion defines an upper surface of the airfoil, and
 wherein the second curved surface portion defines
- a lower surface of the airfoil.
66. The centrifugal fan according to claim 58, wherein at least one of the positive pressure surface forming member and the negative pressure surface forming member includes a shroud bonding surface portion to be bonded to the shroud.
67. The centrifugal fan according to claim 66, wherein the shroud has an inner circumferential surface along which the air suctioned through the suction opening is guided, the inner circumferential surface being a curved surface expanding in a direction opposite to the rotation axis with increasing distance from the shroud along the rotation axis, wherein the shroud bonding surface portion has a curved surface corresponding to a shape of the shroud.
68. The centrifugal fan according to claim 66, wherein the shroud bonding surface portion is formed at a section of an upper edge of at least one of the positive pressure surface forming member and the negative pressure surface forming member except for portions constituting a front edge bonding portion and a rear edge bonding portion.
69. The centrifugal fan according to claim 58, wherein at least one of the positive pressure surface forming member and the negative pressure surface forming member includes a main plate bonding surface portion to come into contact with the main plate.
70. The centrifugal fan according to claim 69, wherein the main plate bonding surface portion is formed at a section of a lower edge of at least one of the positive pressure surface forming member and the negative pressure surface forming member except for portions constituting a front edge bonding portion and a rear edge bonding portion.
71. A method of manufacturing a centrifugal fan, the method comprising:
 forming a first member and a second member using a metal sheet, each member having a curved surface;
 bonding front edges of the first member and the second member to each other and bonding rear edges of the first member and the second member to each other to form a blade;
 bonding at least one of the first member and the second member to a shroud; and
 bonding at least one of the first member and the second member to a main plate.
72. The method according to claim 71, wherein the bonding of the members includes implementing resist-

ance welding of the first member and the second member.

73. The method according to claim 71, further comprising positioning the blade on the main plate, wherein the bonding of the main plate is implemented in a state in which the blade is positioned on the main plate. 5
74. The method according to claim 71, further comprising positioning the blade on the shroud, wherein the bonding of the shroud is implemented in a state in which the blade is positioned on the shroud. 10
75. The method according to claim 71, further comprising implementing painting in a state in which the blade, the shroud and the main plate are integrally coupled to each other. 15
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- 45
- 50
- 55

FIG. 1

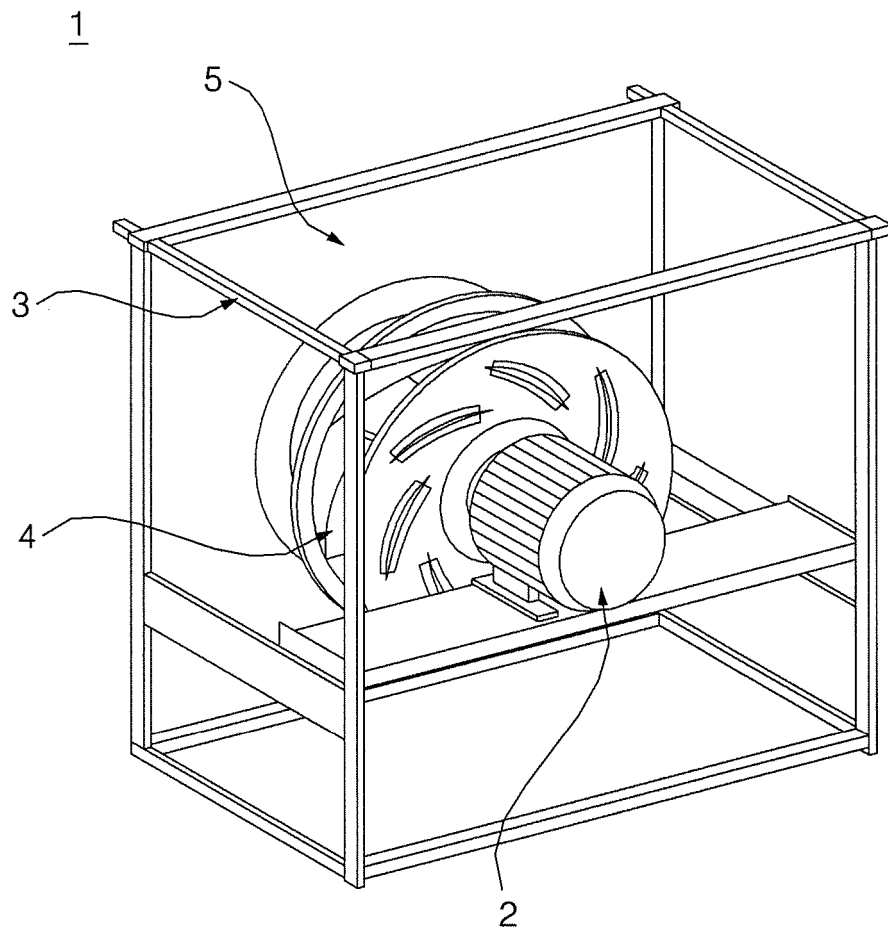


FIG. 2

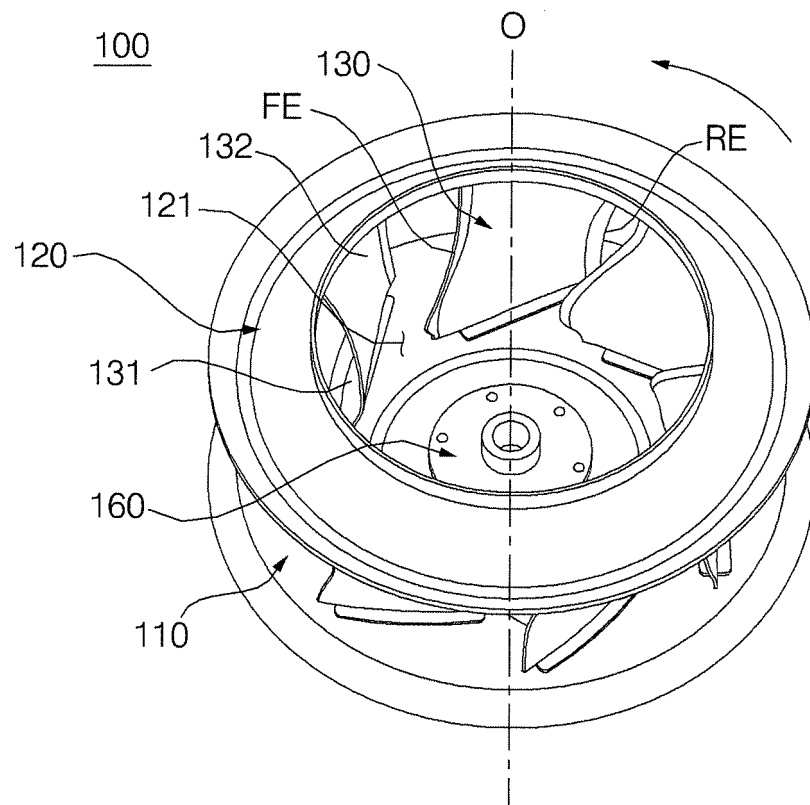


FIG. 3

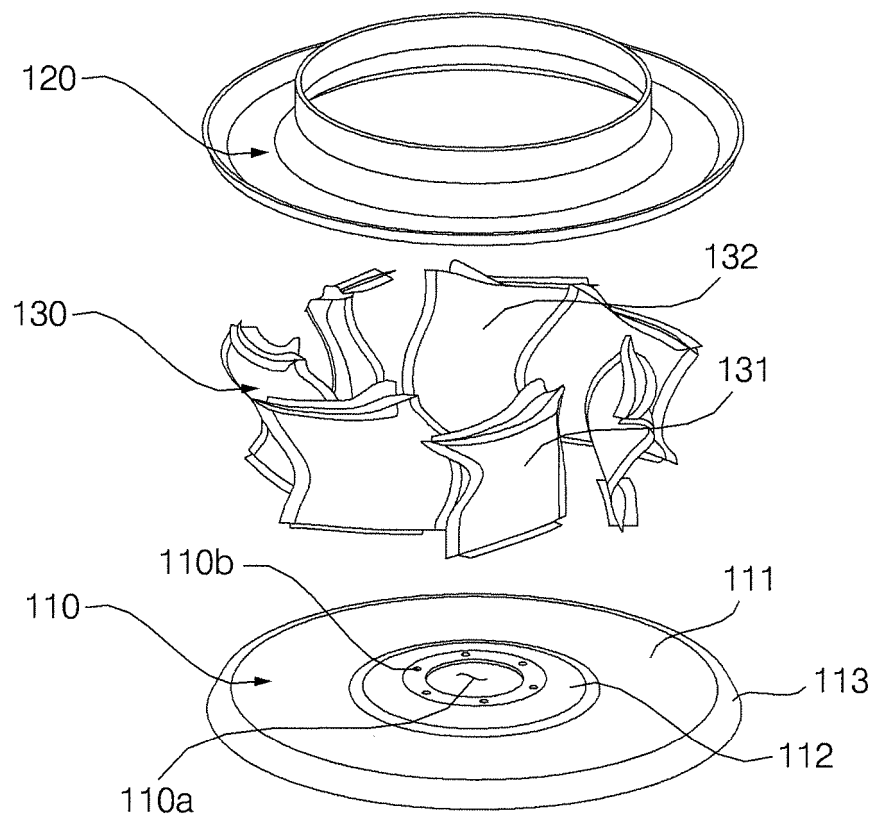


FIG. 4

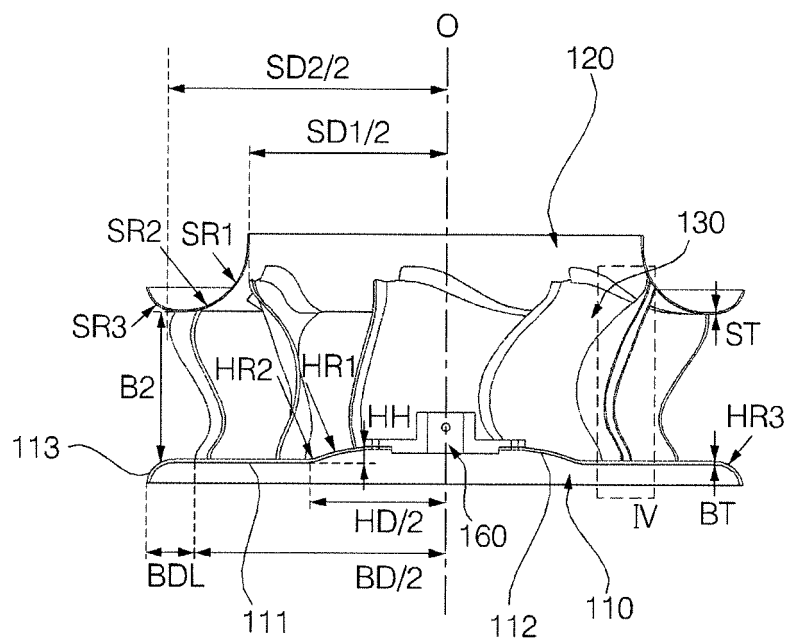


FIG. 5

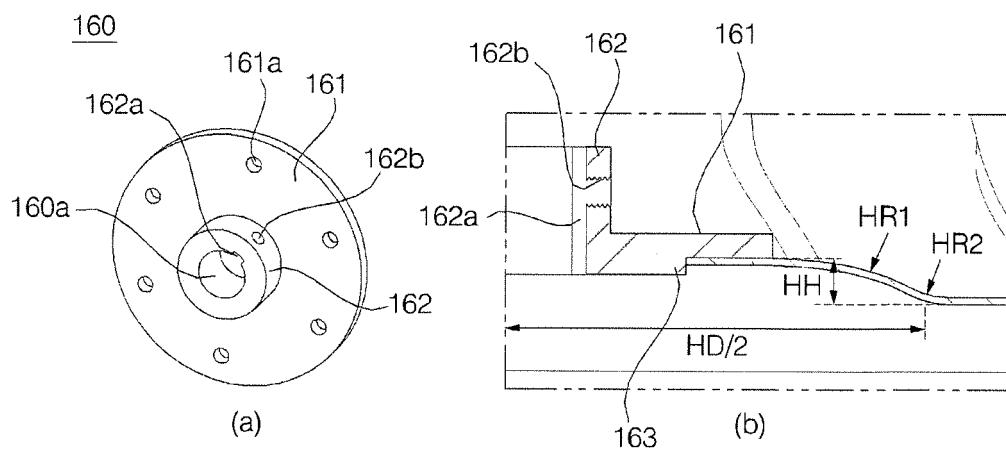


FIG. 6

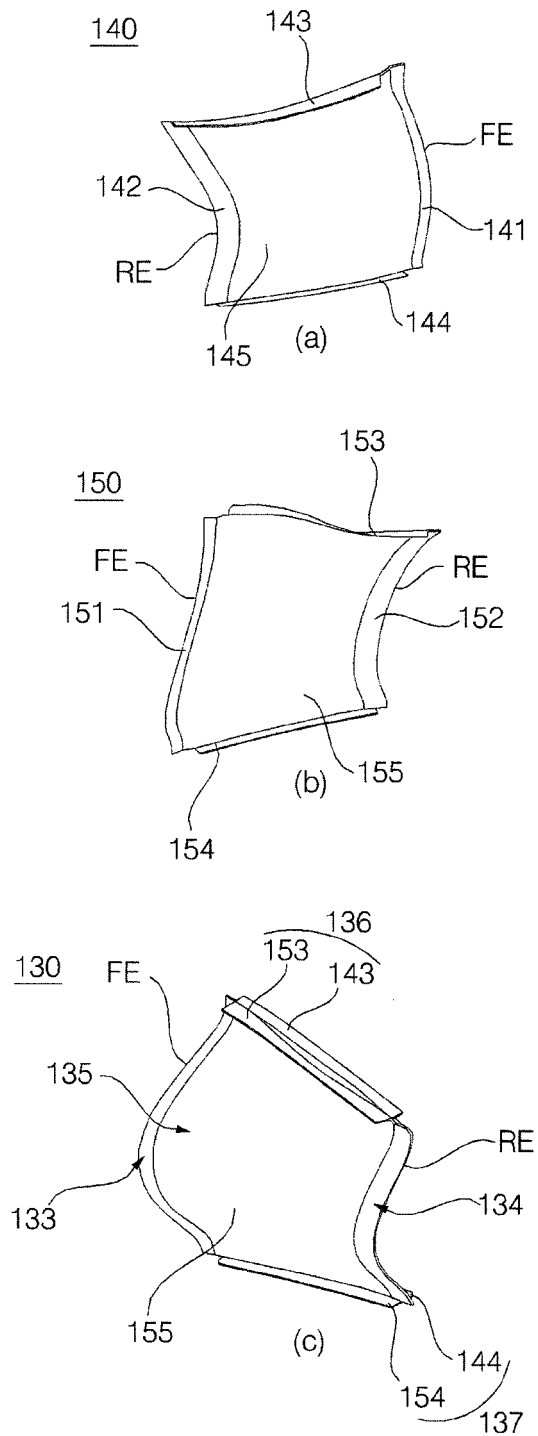


FIG. 7

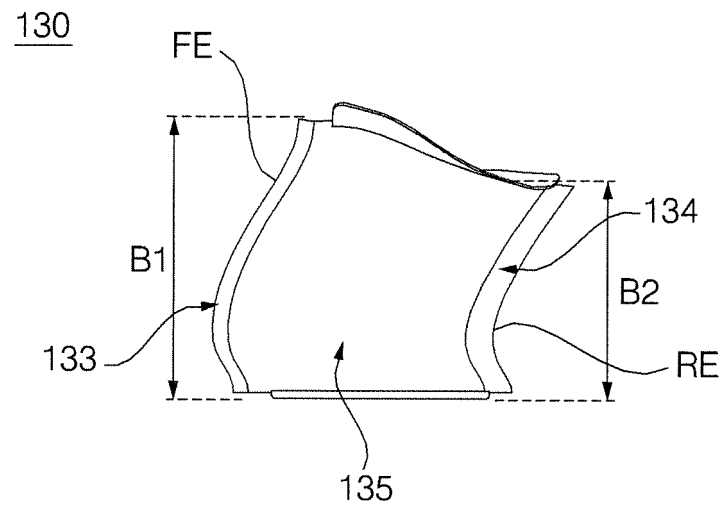


FIG. 8

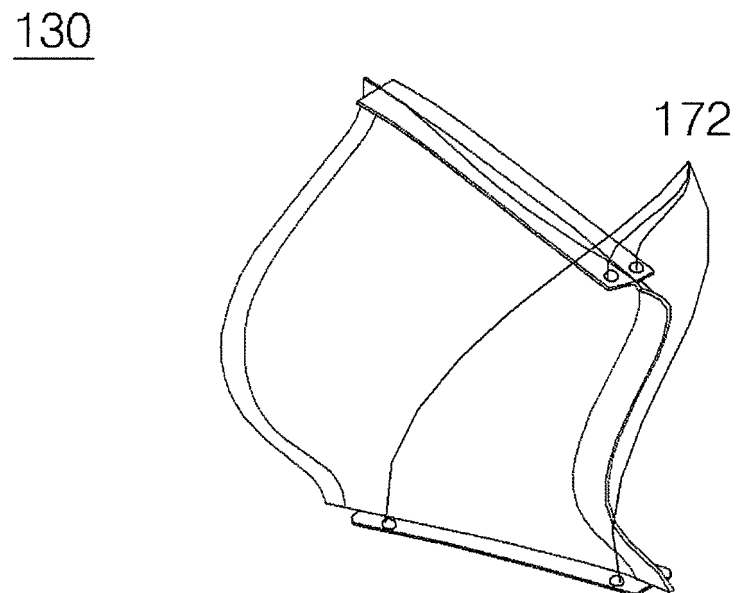


FIG. 9

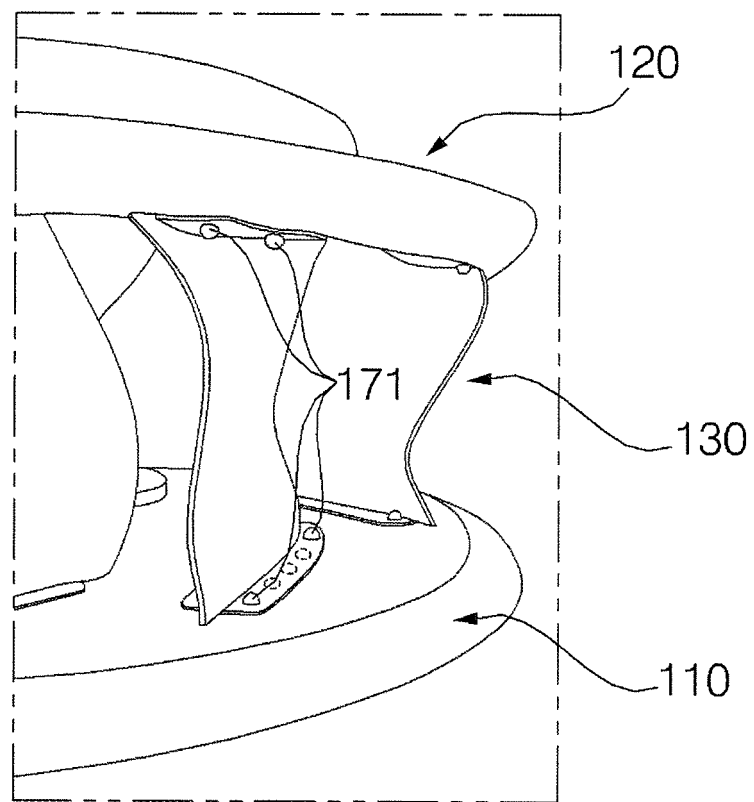


FIG. 10

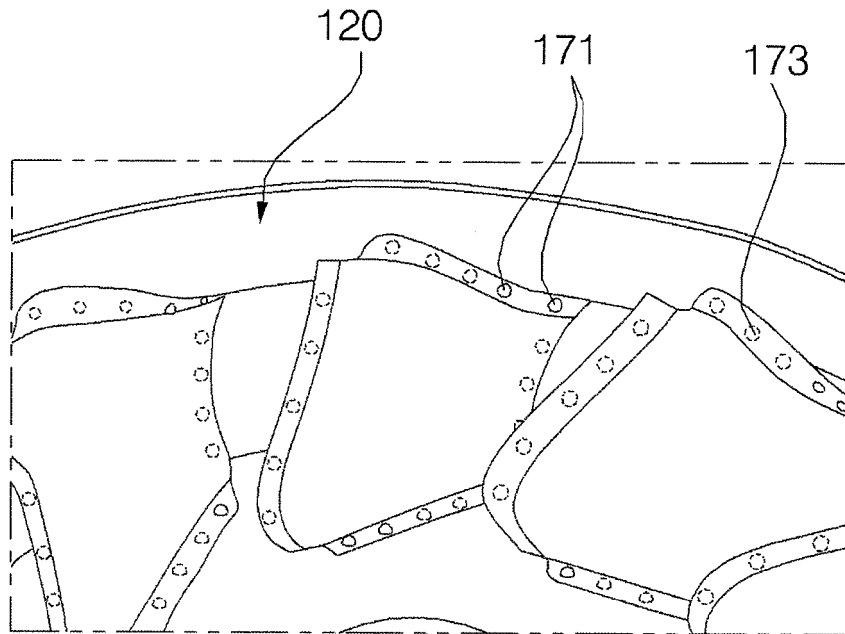


FIG. 11

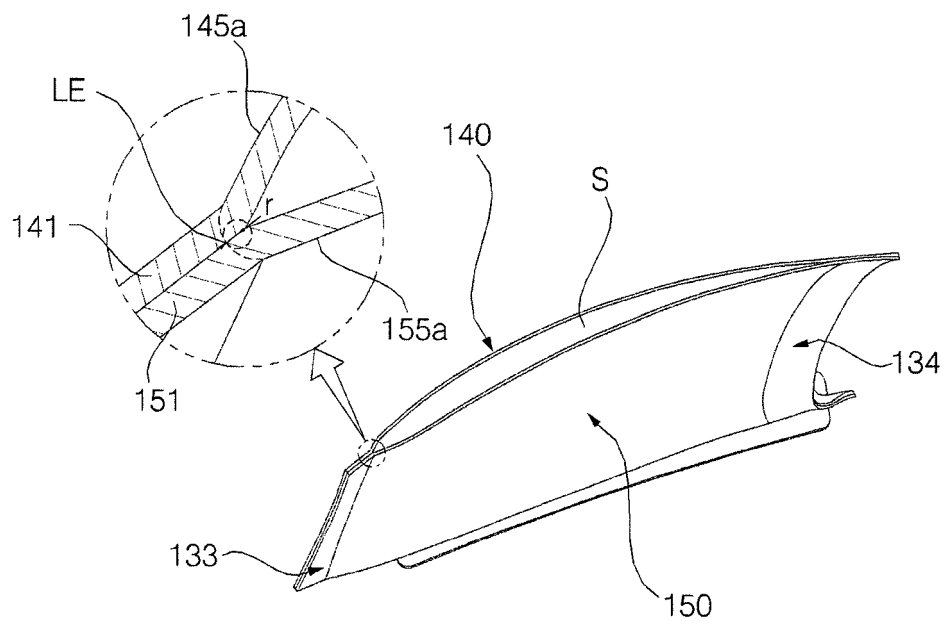


FIG. 12

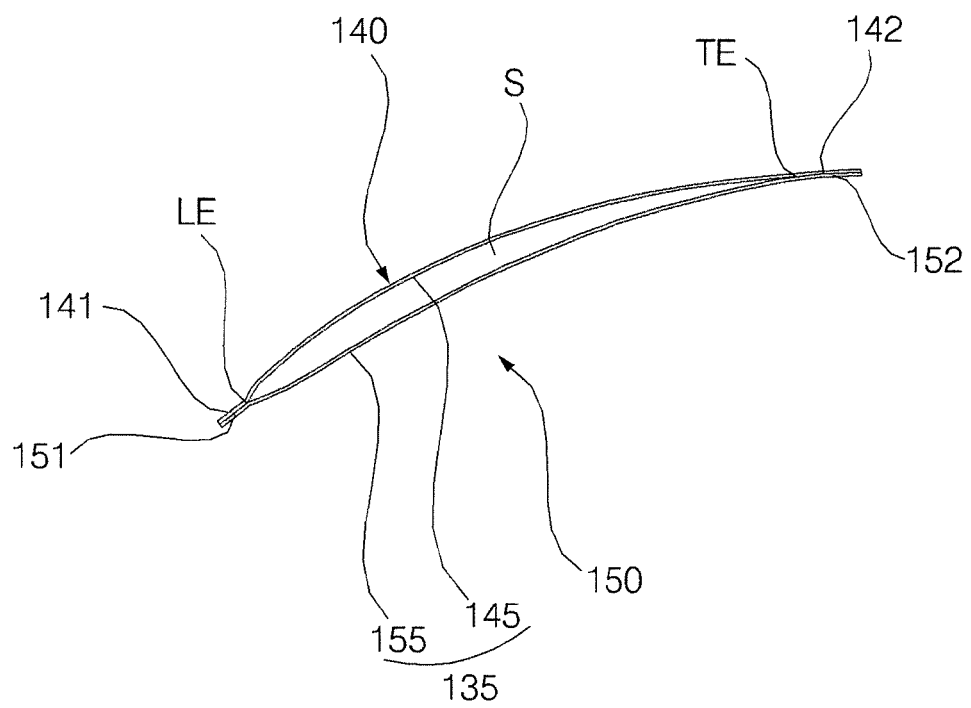


FIG. 13

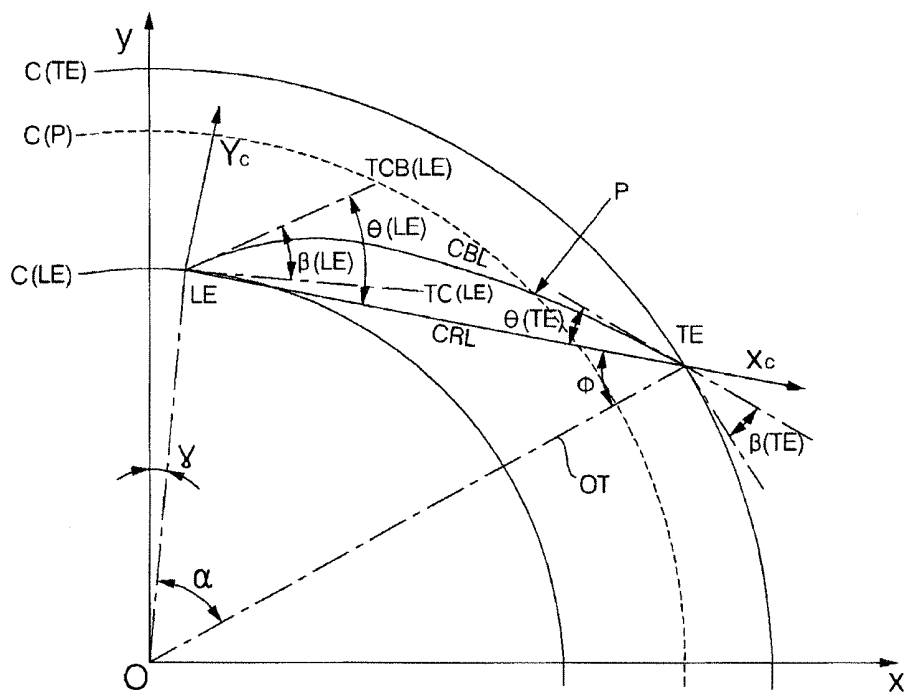


FIG. 14

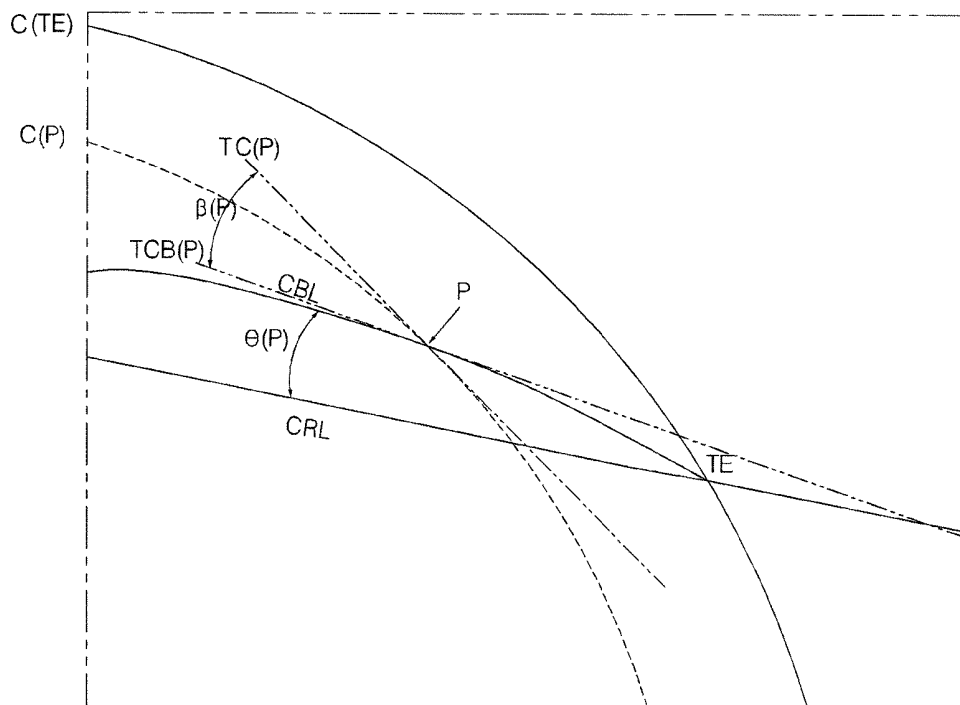


FIG. 15

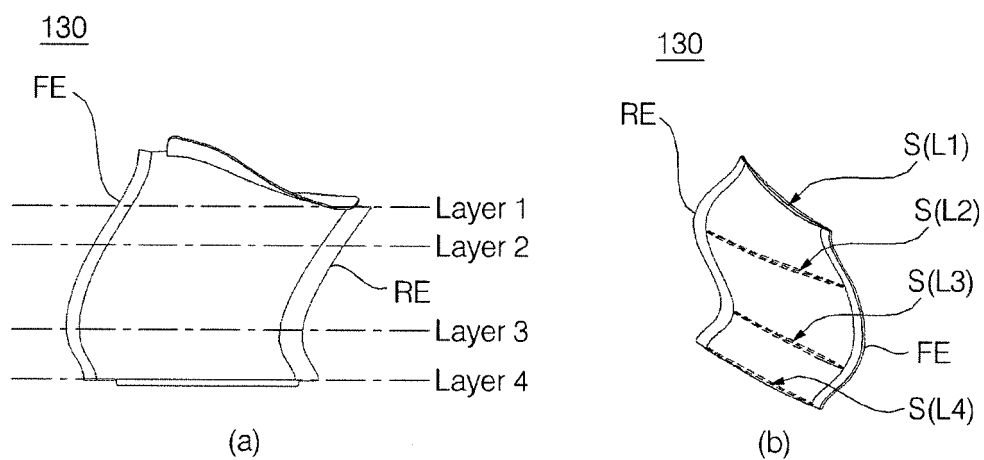


FIG. 16

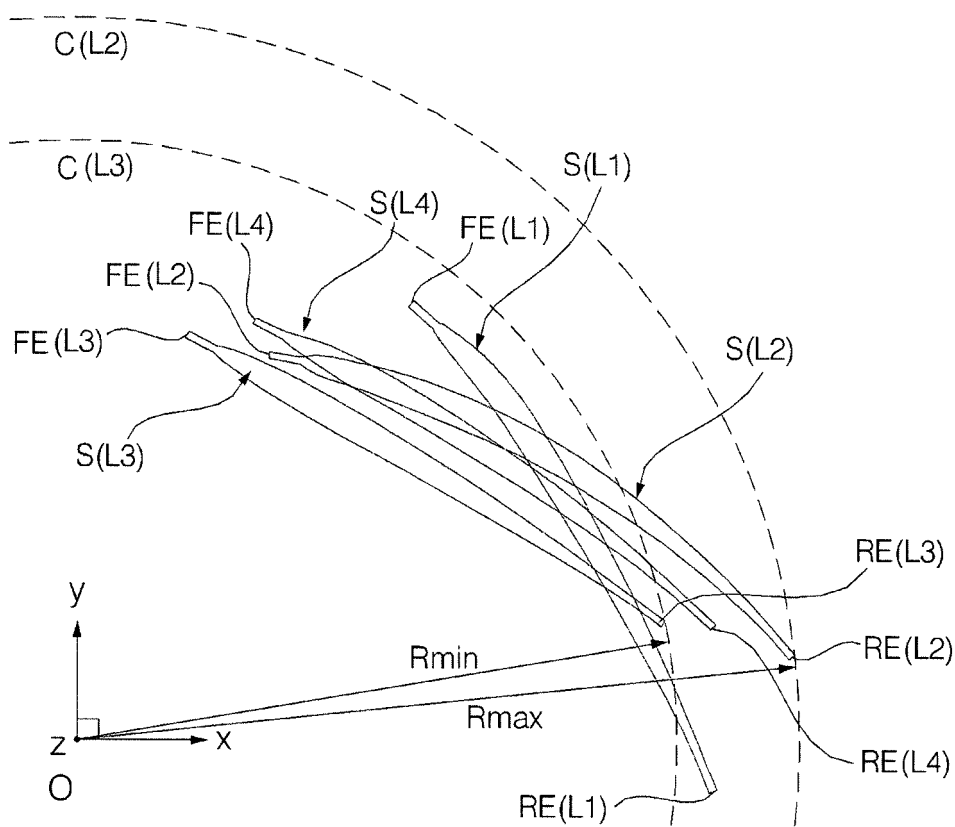


FIG. 17

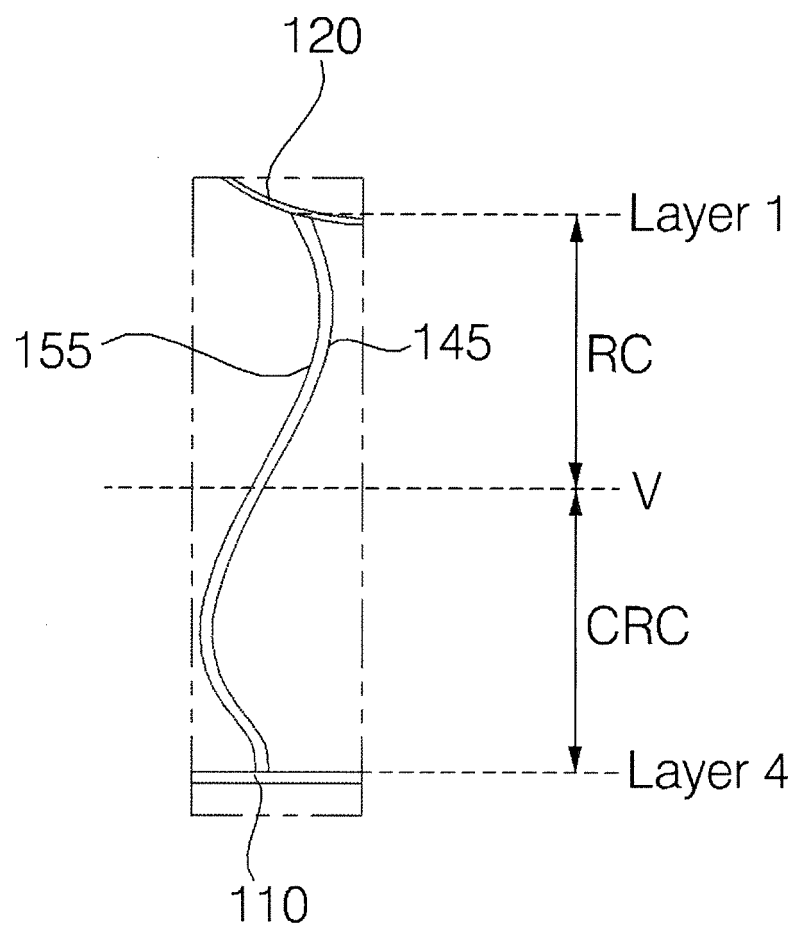


FIG. 18

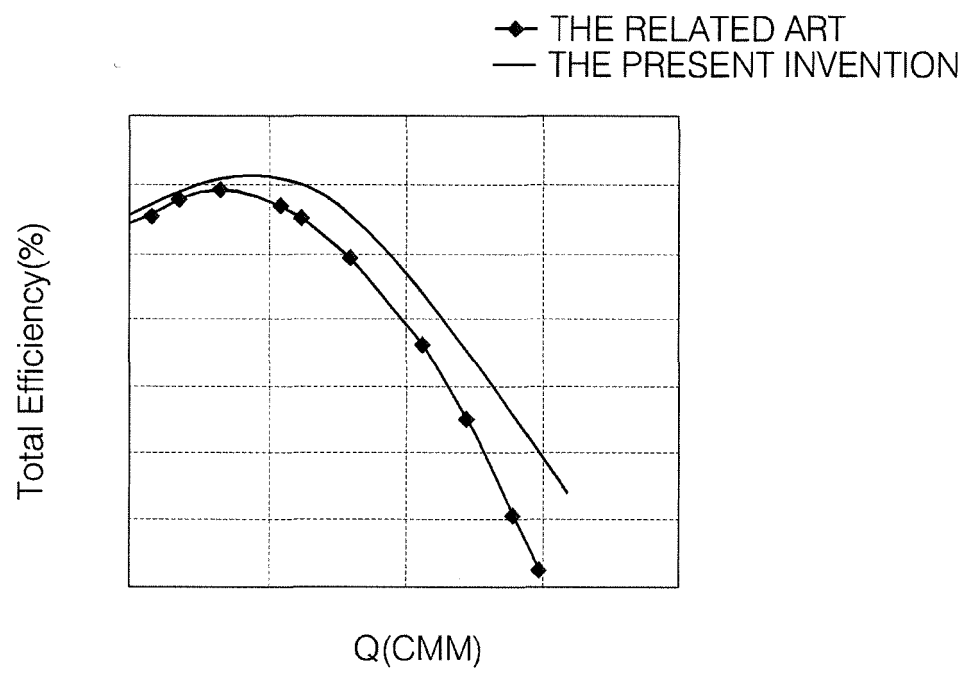


FIG. 19

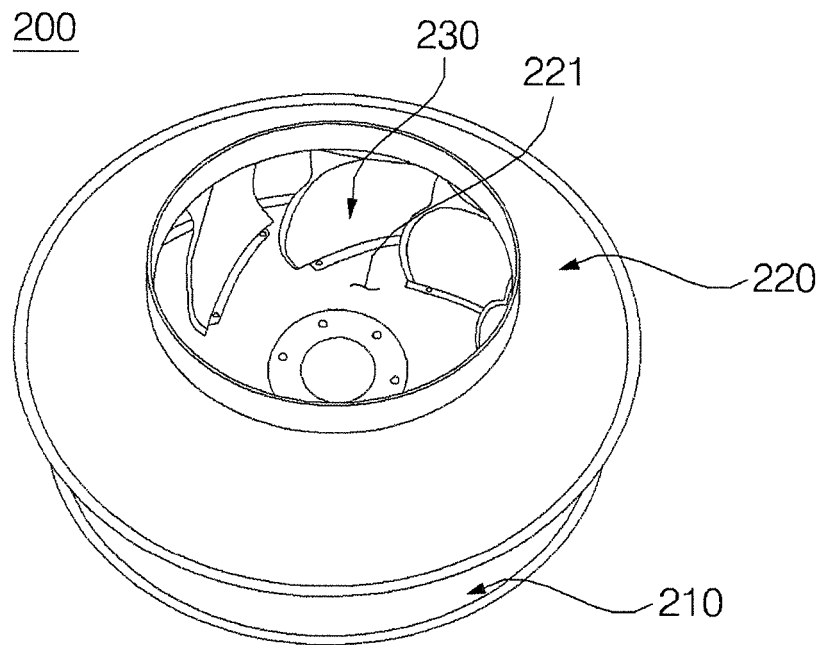


FIG. 20

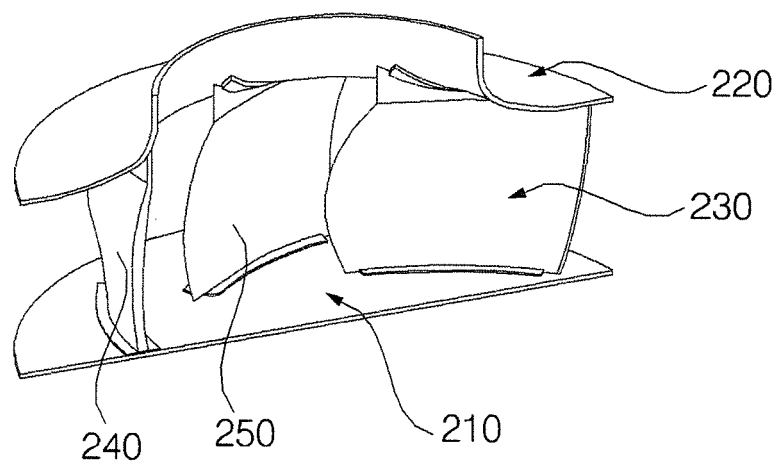


FIG. 21

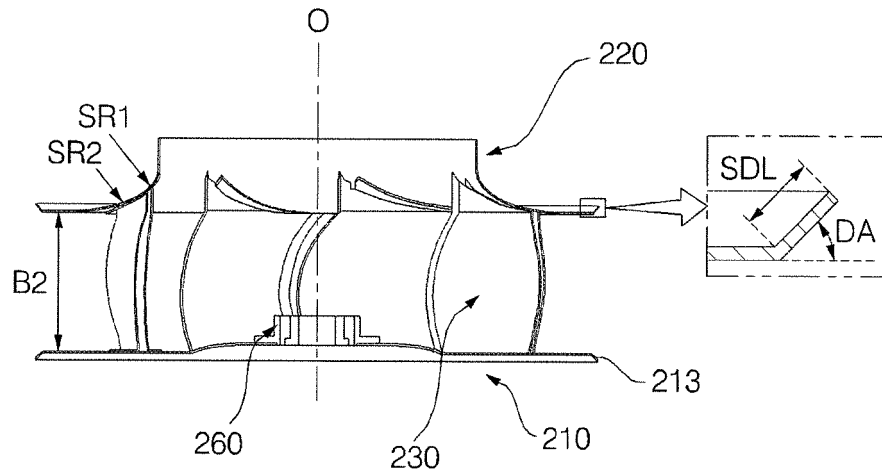


FIG. 22

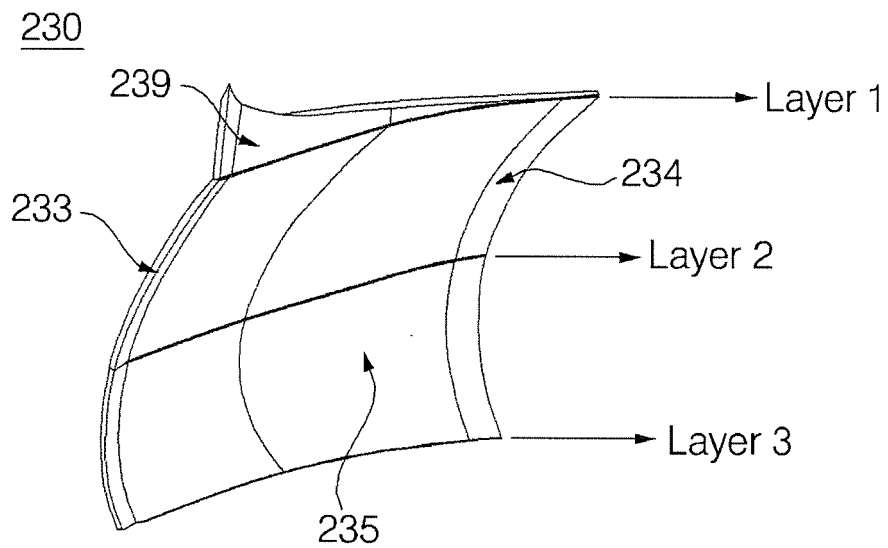


FIG. 23

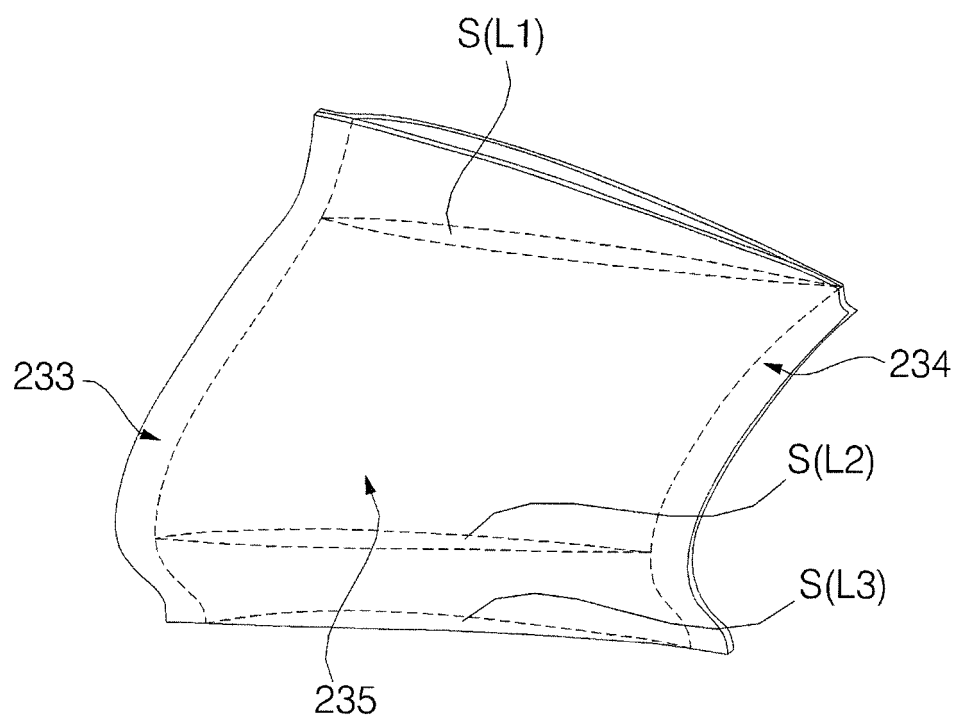
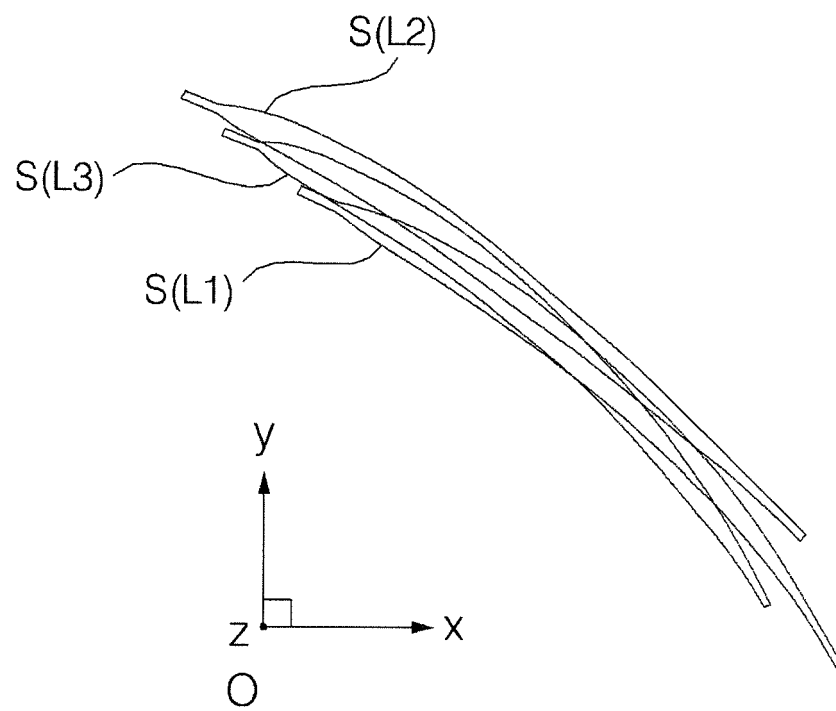


FIG. 24



INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2014/004152

A. CLASSIFICATION OF SUBJECT MATTER

F04D 17/08(2006.01)i, F04D 29/30(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)

F04D 17/08; F24F 1/00; F04D 29/66; F04D 29/38; F04D 29/30; F04D 29/02

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

Korean Utility models and applications for Utility models: IPC as above

Japanese Utility models and applications for Utility models: IPC as above

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

eKOMPASS (KIPO internal) & Keywords: centrifugal fan, shroud, main plate, blade, welding, hallow

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	KR 10-2006-0008988 A (DAIKIN INDUSTRIES, LTD.) 27 January 2006 See abstract, page 7, line 45 - page 8, line 44, page 9, line 1 - page 10, line 15 and figures 3-7.	1-52,56-59,62-75
A		53-55,60-61
Y	US 6368062 B1 (YAGAMI et al.) 09 April 2002 See column 3, lines 10-30, column 4, lines 7-55 and figures 2, 5, 7.	1-52,56-59,62-75
Y	KR 10-2012-0023320 A (LG ELECTRONICS INC.) 13 March 2012 See paragraphs [0019]-[0030] and figures 1, 6.	2,43-52,56-57
A	JP 2002-235695 A (MITSUBISHI ELECTRIC CORP.) 23 August 2002 See paragraphs [0021], [0075] and figures 77, 78.	1-75
A	JP 2008-002379 A (DAIKIN IND. LTD.) 10 January 2008 See abstract, paragraphs [0050]-[0052] and figures 4-6.	1-75

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

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"&" document member of the same patent family

Date of the actual completion of the international search

15 SEPTEMBER 2014 (15.09.2014)

Date of mailing of the international search report

16 SEPTEMBER 2014 (16.09.2014)

Name and mailing address of the ISA/KR


 Korean Intellectual Property Office
 Government Complex-Daejeon, 189 Seonsa-ro, Daejeon 302-701,
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/KR2014/004152

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REFERENCES CITED IN THE DESCRIPTION

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