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(54) STIRRING IMPELLER AND STIRRING DEVICE

(57) An object of the present invention is to provide a stirring impeller and a stirring device capable of reducing power required for stirring. Provided are an axial stirring impeller 1 including a plurality of blades 3 arranged at intervals in a rotational direction with reference to the central axis of rotation, and a stirring device including the stirring impeller 1. Each of the plurality of blades 3 has a front portion with reference to at least the rotational direction R inclined to a plane orthogonal to the central axis of rotation in a cross section in the rotational direction R at an angle θ1 of 20° to 40° toward a front end edge 3a, and each of the plurality of blades 3 includes a tapered portion 31 tapered to have a tip angle of 30° to 50° in the cross section in the rotational direction R, on the front end edge 3a with reference to the rotational direction R.

Fig . 1A

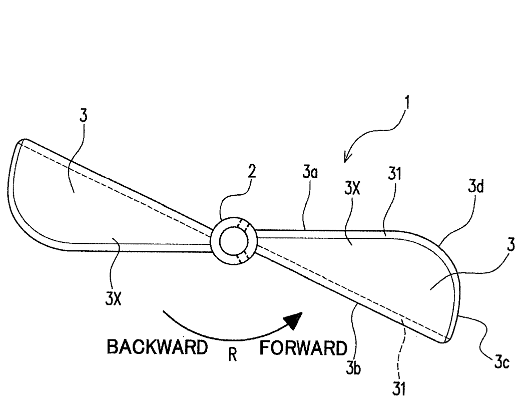

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Fig . 1B

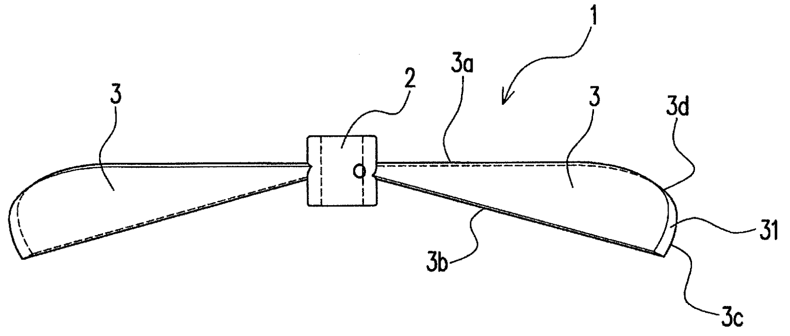
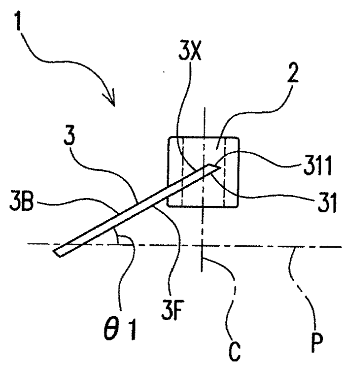


Fig . 1C



Description

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

[0001] The present invention relates to a stirring impeller and a stirring device that are used, for example, for stirring fluid.

BACKGROUND ART

[0002] Various types of stirring impellers to be used, for example, for stirring fluid are employed. Among these types, various examples of shapes of axial stirring impellers are shown in Fig. 9 and Fig. 10 of JP H10-337461A. However, in these stirring impellers, the shapes of blade edges have not been specifically considered.

[0003] Meanwhile, the smaller the power required for stirring, it is more advantageous since it leads to cost reduction. Therefore, in order to reduce the power, the torque acting on a stirring impeller needs to be reduced. However, there is room for improvement in conventional stirring impellers at this point.

SUMMARY OF THE INVENTION

[0004] Therefore, the present invention focuses on the positional relationship of blades to the central axis of rotation and the shapes of blade edges, and it is an object of the present invention to provide a stirring impeller and a stirring device capable of reducing power required for stirring.

[0005] The present invention is an axial stirring impeller including: a plurality of blades arranged at intervals in a rotational direction with reference to the central axis of rotation, wherein each of the plurality of blades has at least a front portion close to a front end edge with reference to the rotational direction, the at least the front portion is inclined to a plane orthogonal to the central axis of rotation in a cross section in the rotational direction at an angle of 20° to 40° toward the front end edge, each of the plurality of blades has a front surface facing forward and a back surface facing backward with reference to the rotational direction that are formed therein, and each of the plurality of blades comprises a tapered portion that is tapered to have a tip angle of 30° to 50° in the cross section in the rotational direction, on the front end edge.

[0006] The present invention is also a stirring device including the stirring impeller.

[0007] According to these configurations, the inclination angle of each of the plurality of blade and the tip angle of the tapered portion are set to the aforementioned ranges, so that the resistance received from the stirring object by each of the plurality of blades can be reduced.

[0008] Further, the tapered portion may have a flat surface located between the front surface and the back surface of each of the plurality of blades.

[0009] According to this configuration, the flow of the stirring object is separated from each of the plurality of blades by the flat surface, so that an increase in negative pressure can be suppressed.

[0010] Further, each of the plurality of blades may be in the form of a flat plate having a constant thickness except the tapered portion.

[0011] According to this configuration, the shape can be simplified as compared with a common axial blade (for example, a propeller blade).

[0012] Further, each of the plurality of blades may have the front end edge and an outer end edge in the radial direction (a radially outer end edge) that are coupled together so as to have a curved contour.

[0013] According to this configuration, a phase difference occurs due to a shift in the rotational direction in the timing at which the blade contacts with the stirring object as the stirring impeller rotates between a radially inward position and a radially outward position of each of the plurality of blades. This can reduce the rotational resistance as compared to the case where there is no phase difference. Therefore, the power to rotate the stirring impeller can be reduced.

[0014] Further, each of the plurality of blades may have a back portion close to a back end edge with reference to the rotational direction, and may include a tapered portion that is tapered to have a tip angle of 30° to 50° in the cross section in the rotational direction, on the back end edge.

[0015] According to this configuration, a sudden change of the cross section at the back end of each of the plurality of blades can be avoided by the tapered portion formed on the back end edge. As a result, the pressure resistance can be reduced, and generation of negative pressure in the stirring object (fluid) can be suppressed.

[0016] Further, each of the plurality of blades may include a rectifier constituted by a projection or a recess formed on the front surface or the back surface along the rotational direction.

[0017] According to this configuration, the rectifier can rectify the stirring object by the rotation of the stirring impeller. This rectification can further reduce the power required for stirring.

[0018] The present invention can reduce the resistance received from the stirring object by the plurality of blades. Therefore, the power required for stirring can be reduced.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019]

Fig. 1A is a plan view showing a stirring impeller according to an embodiment of the present invention.
Fig. 1B is a front view showing the stirring impeller.
Fig. 1C is a right side view showing the stirring impeller when Fig. 1B is taken as a front view (where,

however, only a blade more on the near side of a boss is shown).

Fig. 2 is a vertical sectional view showing an example of a stirring device including the stirring impeller.

Fig. 3A is a plan view showing a piece of blade taken out from the stirring impeller, as viewed with reference to the upper surface of the blade.

Fig. 3B is a sectional view as seen in the direction of the arrow A of Fig. 3A.

Fig. 3C is a sectional view as seen in the direction of the arrow B of Fig. 3A.

Fig. 3D is a sectional view as seen in the direction of the arrow C of Fig. 3A.

Fig. 4A is a graph showing the analysis results for the stirring impeller and showing the relationship between a tip angle (of a tapered portion) and an average force applied to the blades.

Fig. 4B is a graph showing the analysis results for the stirring impeller and showing the relationship between the tip angle (of the tapered portion) and the average force applied to the blades.

Fig. 4C is a graph showing the analysis results for the stirring impeller and showing the relationship between the tip angle (of the tapered portions) and the average force applied to the blades.

Fig. 5 is a graph additionally written for explaining the properties that can be read from Fig. 4C.

Fig. 6 is a graph showing the analysis results for the stirring impeller and showing the relationship between the tip angle (of the tapered portions) and the average force applied to the blades in the case where the blades have different inclination angles.

Fig. 7 is a distribution chart of turbulent kinetic energy generated in the stirring impeller, which also shows the case where the blades have different inclination angles.

Fig. 8A is a plan view showing one piece of blade in the stirring impeller according to another embodiment of the present invention, as viewed with reference to the upper surface of the blade.

Fig. 8B is a schematic cross-sectional view in the circumferential direction showing the shapes of blade edges in a stirring impeller according to still another embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0020] Hereinafter, a stirring impeller 1 according to an embodiment of the present invention will be described. The expressions of "front and back" in the following description refer to directions with reference to a rotational direction R of the stirring impeller 1, and the stirring impeller 1 is supposed to rotate from the back to the front (see Fig. 1A).

[0021] The stirring impeller 1 of this embodiment is an axial stirring impeller having a shape shown in Fig. 1A to Fig. 1C. The stirring impeller 1, for example, can form a flow with a Reynolds number of 1000 or more in a fluid (particularly a liquid) that is a stirring object. The stirring impeller 1 is arranged in a stirred tank 41 capable of storing a liquid, for example, as shown in Fig. 2 so that blades 3 are immersed in the liquid, and is used for stirring the liquid and a solid put in the stirred tank 41 together with the liquid to disperse or suspend particles of the solid in the liquid. Though not shown in the figures, a plurality of stirring impellers 1 can be continuously arranged in the axial direction within the stirred tank in use. Further, a plurality of combined sets of the stirring impeller 1 and a rotation shaft 42 also can be arranged within the stirred tank. At this time, they can be arranged within the stirred tank so as to have rotation shafts 42 parallel to each other.

[0022] Here, an example of a stirring device 4 including the stirring impeller 1 of this embodiment will be described. As shown in Fig. 2, the stirring device 4 shown as an example is a vertical stirring device. The stirring device 4 includes the stirred tank 41 configured to house a stirring object (liquid L), the rotation shaft 42 attached rotatably within the stirred tank 41, the stirring impeller 1 attached to the rotation shaft 42, and a drive unit 43 configured to rotate the rotation shaft 42. The stirring device 4 can further include a feeder configured to feed another stirring object (solid) into the stirred tank 41 (not shown). In this embodiment, the stirring object housed in the stirred tank 41 is a liquid L and a solid. However, the type of the stirring object is not limited to such a combination. Further, the liquid L includes a liquid having comparatively low viscosity and high fluidity. Moreover, it also includes a liquid having comparatively high viscosity and low fluidity.

[0023] The stirred tank 41 is formed into a cylindrical shape elongated in the longitudinal direction. Specifically, the stirred tank 41 includes a cylindrical straight body 411, a bottom 412 that has a semi-ellipsoid or dish-like sectional shape or the like and is attached to the lower end of the straight body 411, and a top 413 that has a semi-ellipsoid or dish-like sectional shape or the like and is attached to the upper end of the straight body 411. Further, the stirred tank 41 holds the rotation shaft 42 so that an axis direction L42 of the rotation shaft 42 coincides with the vertical direction (upward and downward directions in Fig. 2).

[0024] The rotation shaft 42 is arranged at the center in the radial direction of the stirred tank 41. The lower end of the rotation shaft 42 is supported via a bearing (not shown) provided at the bottom 412 of the stirred tank 41. Meanwhile, the upper end of the rotation shaft 42 extends over the top 413 of the stirred tank 41, and is connected to the drive unit 43 (which is, for example, a motor M in this case) arranged above the top 413. The rotation shaft 42 rotates in the rotational direction R42 by receiving the driving force of the drive unit 43. The rotation shaft 42 with a configuration in which the lower end is not supported at all also can be employed. Further, a configuration in which the lower end of the rotation shaft 42 extends below the bottom 412 to be arranged below the bottom 412, and the lower end is connected to the drive unit such as the motor also can be employed.

[0025] As shown in Fig. 1A to Fig. 1C, the stirring impeller 1 of this embodiment includes a boss 2, and a plurality of blades 3 fixed to the boss 2 and extending in a radially outward direction. The plurality of blades 3 are located in rotational symmetry with reference to a central axis of rotation C (an imaginary axis shown in Fig. 1C, passing through the center of the rotation shaft 42 of the stirring device 4) of the stirring impeller 1. The stirring impeller 1 of this embodiment includes two pieces of blades, and the two pieces of blades 3 are fixed to the single boss 2. Therefore, the stirring impeller 1 has a simple configuration. The boss 2 is cylindrical and is connected to the drive unit 43 such as the motor M. In this embodiment, the boss 2 is fixed to the rotation shaft 42 (see Fig. 2) driven by the drive unit 43. The two pieces of blades 3 are fixed to the lateral surface in the radial direction of the boss 2 at intervals at specific angles in the circumferential direction (direction that coincides with the rotational direction R with reference to the central axis of rotation C). In this embodiment, the two pieces of blades 3 are located in rotational symmetry at 180° with reference to the central axis of rotation C of the stirring impeller 1.

[0026] As shown in Fig. 3A, each of the blades 3 is in the form of a flat plate having a constant thickness and a "divergent" or "fan-like" shape in which the blade width dimension (dimension in the circumferential direction) increases radially outward. Of the blade end edges of the blade 3, a front end edge 3a and a back end edge 3b are straight. The blade 3 has a front portion close to the front end edge 3a and a back portion close to the back end edge 3b with reference to the circumferential direction. The front end edge 3a and an outer end edge in the radial direction 3c (a radially outer end edge 3c) are coupled together via a curved continuous part 3d so as to have a curved contour. Meanwhile, the radially outer end edge 3c and the back end edge 3b are coupled together so as to intersect each other at an acute angle. As shown in Fig. 1C, the blade 3 is fixed to the boss 2 while the blade 3 is inclined to the central axis of rotation C like a common paddle-shaped stirring impeller. As shown in Fig. 1A, the two pieces of blades 3 have a positional relationship at 180° in which the end edges of the back end edges 3b pass through the central axis of rotation C of the stirring impeller 1 and have a shape extending in a straight line. Since the blade 3 of this embodiment is in the form of a flat plate, which is a shape that does not exert a rectifying action that a later-described rectifier 32 exerts, a solid content present in the fluid and a substance formed by solidification of the liquid are difficult to remain on the surface (in other words, difficult to adhere thereon), and thus maintenance such as washing is easy, as compared with a shape having a lot of projections and recesses that prevent the flow of fluid along the blade 3.

[0027] As shown in Fig. 1C, the blade 3 is attached to the boss 2 so as to extend along an imaginary line orthogonal to the central axis of rotation C, and has at least a front portion 3X (with reference to the rotational direction R) inclined to an imaginary plane P (shown by a dashed-dotted line in the figure) orthogonal to the central axis of rotation C in a cross section in the circumferential direction at an angle (inclination angle) θ1 of 20° to 40° toward the front end edge 3a. The inclination angle θ1 of the blade 3 shown in the figure is 30°. The drag received by the blade 3 from the stirring object in the stirring impeller 1 during rotation can be reduced as the inclination angle θ1 approximates 0°. However, when the inclination angle θ1 decreases, the flow occurring in the stirring object becomes weak. Therefore, in the case where the stirring object is composed of liquid and solid, it becomes difficult to disperse the solid in the liquid. Therefore, the inclination angle θ1 is set to the range of 20° to 40° in view of solid dispersion. As shown in Fig. 1A and Fig. 1C, the "front portion 3X" is a portion of the blade 3 in the vicinity of the front end (that is, edge located foremost) with reference to the rotational direction R. Further, the "cross section in the circumferential direction" is a cross section cut along the circumferential direction (along the rotational direction R) (longitudinally, in this embodiment). Further, the "imaginary plane P" is shown in Fig. 1C in a shape as viewed directly from the side.

[0028] The stirring impeller 1 rotates in the rotational direction R shown in Fig. 1A. In this embodiment, the side of a front surface 3F facing forward with reference to the rotational direction R of the stirring impeller 1 is located on the lower side, and the side of a back surface 3B facing backward is located on the upper side (see Fig. 1C). Therefore, when the stirring impeller 1 is rotated, a downward flow is generated in the fluid that is the stirring object. This flow can swirl the liquid and solid located at the bottom of the stirred tank to flow upward within the tank, and thus high dispersion performance can be achieved. Contrary to this embodiment, it is also possible to employ a configuration in which the side of the front surface with reference to the rotational direction R of the stirring impeller 1 is located on the upper side and the side of the back surface is located on the lower side. In this case, an upward flow can be generated in the fluid when the stirring impeller 1 is rotated.

[0029] The blade 3 includes a tapered portion 31 on at least the front end edge 3a with reference to the rotational direction R. In this embodiment, the tapered portion 31 is provided on all ends (blade edges) except the end in contact with the boss 2 (that is, the end that does not contact with the fluid), specifically, the front end edge 3a, the radially outer end edge 3c, the back end edge 3b, and the continuous part 3d. The tapered portion 31 has a shape tapered so that the angle (tip angle) θ2 in the cross section in the circumferential direction is 30° to 50°. The tapered portion 31 can be formed, for example, by cutting the blade edges. In Fig. 3B to Fig. 3D, the blade edges of the blade 3 in the form of a flat plate are cut at 45° into a shape such that a flat surface 311 appears between the front surface (in this embodiment, the lower surface) 3F and the back surface (in this embodiment, the upper surface) 3B with reference to the rotational direction R. The flat surface 311 is a surface facing upward on the front end edge 3a and the radially outer end edge 3c, as shown in Fig. 3B and Fig. 3D, and is a surface facing downward on the back end edge 3b, as shown in Fig. 3C.

[0030] Generally, it is said that, when the flow of fluid separates from the blade 3, negative pressure increases, and the power to rotate the stirring impeller 1 increases. As described above, the inclination angle θ1 of the blade 3 is set to 20° to 40°, and the tip angle θ2 of the tapered portion 31 is set to 30° to 50°, thereby making the separation of the flow less likely to occur, particularly, on the front end edge 3a of the blade 3. Therefore, one of the causes (such as vortex generation due to the separation) that increase the power to rotate the stirring impeller 1 can be suppressed. Accordingly, the resistance received by the blade from the stirring object (fluid) can be reduced, and thus the power to rotate the stirring impeller 1 can be reduced.

[0031] Further, the curved continuous part 3d formed at a position on the radially outward of the front portion of the blade 3 causes a phase difference to occur due to the shift or deviation in the rotational direction R in the timing at which the blade 3 contacts with the stirring object (fluid) as the blade 3 rotates due to the rotation of the stirring impeller 1 between a radially inward position and a radially outward position. Thus, the stirring object (fluid) can be rectified as compared with the case where the phase difference does not occur. The rectification can reduce the rotational resistance of the stirring impeller 1. This also can reduce the power to rotate the stirring impeller 1.

[0032] Further, the tapered portion 31 formed on the back end edge 3b of the blade 3 can avoid a sudden change in cross section on the back end edge 3b. As a result, the pressure resistance can be reduced. Accordingly, generation of negative pressure in the stirring object (fluid) can be suppressed.

[0033] Next, the analysis (two-dimensional analysis) of the stirring impeller 1 conducted by the inventors of the subject application will be described. The analysis conditions are as follows.

- Analysis software: CFX (ANSYS Japan K.K.)
- Turbulence model: k-ε model
- Fluid properties/Object liquid: Water (with a density of 1000 kg/m^3 and a viscosity of 0.001 Pa·s)
- Boundary conditions

  Impeller: Slip-free boundary
  Upper side and lower side: Slip boundary
  Near side and far side: Symmetrical boundary
  Inlet and outlet: Inflow and outflow boundary
  Inflow velocity and outflow velocity: 3.896 m/s (equivalent to the blade edge velocity at 600 rpm with impeller diameter d = 124 mm)

[0034] Fig. 4 to Fig. 7 show the analysis results. The boxed legend in each figure shows settings of the shape and arrangement of the stirring impeller 1. For example, the legend "0.3d-9mm" means that the plate thickness of the blade 3 is set to 9 mm ("0.3d" will be described later). The legend "0.3d-9mm-30°" means that the tip angle θ2 of the tapered portion 31 is set to 30° in addition to the aforementioned setting. Further, the legend "0.3d" indicates that, by setting the stirring impeller 1 having an impeller diameter (d) of 124 mm, with reference to a "0.3d-18mm-90°" blade in which the width dimension (constant) of the blade 3 is 0.3 times (37.2 mm) the impeller diameter, that is, a blade in the form of a flat plate having a plate thickness of 18 mm with the tapered portion 31 not having a tapered shape (where the tip angle θ2 of the tapered portion 31 is 90°), the projection area in the rotational direction (horizontal direction) of the blade 3 is set to coincide with "0.3d". In this analysis, the inner diameter (D) of the stirred tank in which the stirring impeller 1 is arranged is set to 310 mm. That is, d = 0.4D is satisfied. In summary, the example of "0.3d-9mm-30°" means that "(inclination is obtained by allowing the projection area to coincide with a 0.3d-18mm-90° blade), (the plate thickness of the blade 3 is 9 mm), and (the tip angle θ2 of the tapered portion 31 is 30°)".

[0035] Fig. 4A to Fig. 4C show the relationships between the tip angle θ2 of the tapered portion 31 (horizontal axis) and the average force applied to the blade 3 (Fav, unit N) (vertical axis) (which is expressed as "tip angle" in Fig. 4And Fig. 5) as the transient analysis results when the tip angle θ2 of the tapered portion 31 is set to 30°, 45°, and 90° (where the tapered portion 31 is not tapered) in this analysis. In Fig. 4A, the projection area is set to 0.3d (with reference to a "0.3d-18mm-90°" blade), and the plate thickness of the blade 3 is set to 3 mm (square points in the figure (the same applies to the following description)), 9 mm (triangle points), and 18 mm (circle points). In Fig. 4B, the projection area is set to 0.5d (with reference to a "0.5d-18mm-90°" blade), and the plate thickness of the blade 3 is set to 3 mm (square points), 9 mm (triangle points), and 18 mm (circle points). In Fig. 4C, the projection area is set to 0.7d (with reference to a "0.7d-18mm-90°" blade), and the plate thickness of the blade 3 is set to 3 mm (square points), 9 mm (triangle points), and 18 mm (circle points). The blade 3 having a plate thickness of 18 mm (circle points) is analyzed also for the tip angle θ2 of other tapered portions 31, and the results are plotted in Fig. 4C. In Fig. 4C, when the tip angle θ2 of the tapered portion 31 is 90°, the triangle points and the circle points almost coincide with each other.

[0036] From Fig. 4A to Fig. 4C, it can be seen that the average force applied to the blade 3 is smallest when the tip angle θ2 of the tapered portion 31 is about 45°.

[0037] Fig. 5 shows a curve connecting a plurality of points obtained in this analysis for "0.7d-18mm" in Fig. 4C. In the equation shown in Fig. 5, the horizontal axis is taken as the x-axis, and the vertical axis is taken as the y-axis. From this curve, it can be seen that the average force applied to the blade 3 is smallest when the tip angle θ2 of the tapered portion 31 is 45°. It can be seen that, as compared with the case where the tapered portion 31 is not provided (the tip angle θ2 of the tapered portion 31 is 90°), the force can be reduced by about 40% when the tip angle θ2 of the tapered portion 31 is about 45°, as shown by the arrow in Fig. 5.

[0038] For the settings other than "0.7d-18mm", the analysis is conducted only in the case where the tip angle θ2 of the tapered portion 31 is 30°, 45°, and 90°, but it can be sufficiently inferred that the relationship shown by the curve in Fig. 5 is established in the settings other than "0.7d-18mm", in the light of the relationship of the square points, the triangle points, and the circle points in each of Fig. 4A to Fig. 4C.

[0039] Next, Fig. 6 shows the relationship between the tip angle θ2 of the tapered portion 31 (horizontal axis) and the average force applied to the blade 3 (Fav) (vertical axis) as the transient analysis results when the inclination angle θ1 of the blade 3 is set to 30° and 45°with "0.7d-18mm", and the tip angle θ2 of the tapered portion 31 is varied. Fig. 6 shows the relationship when the inclination angle θ1 of the blade 3 is 30° by the circle points, and the relationship when the inclination angle θ1 of the blade 3 is about 45° by the triangle points. It can be seen that, on average, the average force applied to the blade 3 is smaller when the inclination angle θ1 of the blade 3 is set to 30° than when the inclination angle θ1 of the blade 3 is set to 45°.

[0040] Further, Fig. 7 shows a distribution chart of turbulent kinetic energy (unit: m^2/s^2) generated in the stirring impeller 1 as the stationary analysis results for the stirring impeller 1 set to "0.7d-18mm-30°" and the stirring impeller 1 set to "0.7d-18mm-45°" when the inclination angle θ1 of the blade 3 is set to 45° and 30°. In the figure, the thick colored region in the periphery of a portion corresponding to the stirring impeller 1 shown in white and having a parallelogram shape is a region with high turbulent kinetic energy. As is obvious from the contents in the figure, in any case where the tip angle θ2 of the tapered portion 31 is 30° or 45°, the turbulent kinetic energy generated in the stirring impeller 1 is lower when the inclination angle θ1 of the blade 3 is set to 30° than when the inclination angle θ1 of the blade 3 is set to 45°. It can be said from this that the power required for stirring can be reduced relatively more when the inclination angle θ1 of the blade 3 is set to 30° than when the inclination angle θ1 of the blade 3 is set to 45°.

[0041] From these analysis results, it has been proved that the stirring impeller 1 of this embodiment can reduce the average force applied to the blade 3. Therefore, the stirring impeller 1 of this embodiment can form a flow field efficiently in the periphery of the blade 3 with low power, as compared with conventional stirring impellers (common paddle-shaped stirring impellers). Therefore, solid particles can be dispersed or suspended in fluid (liquid).

[0042] Further, the stirring impeller 1 of this embodiment mainly has the following three advantageous points, and therefore it helps cost reduction in use of the stirring impeller 1.

(1) Low torque is achieved (this can reduce the initial cost and running cost of the device (such as a stirring device) using the stirring impeller 1).
(2) High local dispersion performance, specifically, high performance capable of dispersing (suspending) solid particles only around the bottom 412 of the stirred tank 41 is achieved by low power (this can improve the productivity, thereby reducing the running cost).
(3) Maintenance time is reduced by simplifying the structure (this can reduce the maintenance cost).

[0043] Hereinbefore, embodiments of the present invention have been described. However, the stirring impeller 1 according to the present invention is not limited to the above described embodiments, and various modifications can be made without departing from the gist of the present invention.

[0044] For example, the outer edge shape of the blade 3 is not limited to the shapes of the aforementioned embodiments. For example, various shapes such as a substantially rectangular shape having a constant blade width dimension (dimension in the circumferential direction), and a "tapered" or "reverse fan-like" shape in which the blade width dimension (dimension in the circumferential direction) decreases radially outward can be employed.

[0045] Further, in the aforementioned embodiments, the front surface (in the aforementioned embodiments, the lower surface) 3F and the back surface (in the aforementioned embodiments, the upper surface) 3B with reference to the rotational direction R of the blade 3 are flat surfaces, but may be curved surfaces. In the case of not being flat surfaces such as curved surfaces, the inclination angle θ1 of the blade 3 is evaluated in the front portion of the blade 3.

[0046] Further, the blade 3 can be formed using various metal materials, or can be formed using materials other than metal (such as hard resin and ceramics). Further, the blade 3 can be formed by cutting a material, or can be formed by molding a raw material having fluidity such as casting. Further, the surface of the blade 3 can be subjected to coating, plating, or roughening that is suitable for the stirring object.

[0047] Further, the stirring impeller 1 in the aforementioned embodiments is constituted by two pieces of blades, but the number of the blade 3 is not limited to two, and three or more pieces can be employed.

[0048] Further, the rectifier 32 constituted by a projection or a recess can be formed on at least one of the upper surface and the lower surface of the blade 3. The concept of the "form of a flat plate" in the present invention includes the shape in which the rectifier 32 is formed.

The rectifier 32 can be formed to have at least a part extending along the circumferential direction, and the shape as shown in Fig. 8A, for example, can be employed. The blade 3 shown in the figure is the same as in Fig. 3A except the rectifier 32, and has a "divergent" or "fan-like" shape in which the blade width dimension (dimension in the circumferential direction) increases radially outward. Accordingly, the rectifier 32 at a radially outward position is formed longer than the rectifier 32 at a radially inward position. In the case where the rectifier 32 is a projection, it can be formed, for example, by welding or adhesion. Further, grinding is performed thereon, as needed. Further, in the case where the rectifier 32 is a recess, it can be formed, for example, by cutting. Further, it can be formed also by pressing.

[0049] The thus formed rectifier 32 can rectify the fluid that is the stirring object with the rotation of the stirring impeller 1. This rectification can further reduce the power required for stirring as compared with the case where the upper and lower surfaces of the blade 3 are smooth surfaces. The rectifier 32, for example, can have a shape extending along the rotational direction R of the stirring impeller 1 (curved projecting ridge or groove), or a shape extending along the tangential direction of the rotational direction R (linear projecting ridge or groove). In Fig. 8A, the blade 3 in which three rectifiers 32 are formed is shown, but the number of rectifiers 32 to be formed per the single blade 3 is not limited. For example, a lot of projections or recesses can be formed on the entire surface of the blade 3.

[0050] In Fig. 8A, the shape of the blade 3 on which the rectifiers 32 are formed is shown as the same as the shape of the blade 3 shown in Fig. 3A, but there is no limitation to this. The rectifiers 32 can be formed on the blade 3 having various outer edge shapes.

[0051] Further, the rectifiers 32 can be formed on the flat surface 311 of the tapered portion 31 instead of the upper or the lower surface of the blade 3.

[0052] Further, the tapered portion 31 can have various shapes. In the aforementioned embodiments, the shape is such that the single flat surface 311 appears between the front surface (the lower surface in the aforementioned embodiments) 3F and the back surface (the upper surface in the aforementioned embodiments) 3B with reference to the rotational direction R, but the shape may be such that two or more flat surfaces 311 appear between the front surface 3F and the back surface 3B, as shown in Fig. 8B.

[0053] Further, the blade 3 of the aforementioned embodiments includes the tapered portion 31 on each of the front end edge 3a, the radially outer end edge 3c, and the back end edge 3b, but there is no limitation to this. The blade 3 needs only to include the tapered portion 31 on at least the front end edge 3a, and specifically, can include the tapered portion 31 only on the front end edge 3a, or can include the tapered portion 31 on each of the front end edge 3a and the radially outer end edge 3c.

[0054] Further, in the analysis of the stirring impeller 1 of the aforementioned embodiments, the stirring object is water, but various types of fluid (liquid) other than water can constitute the stirring object. Further, various types of solid to be mixed with the liquid can constitute the stirring object.

Claims

1. An axial stirring impeller comprising:

    a plurality of blades arranged at intervals in a rotational direction with reference to the central axis of rotation, wherein
    each of the plurality of blades has a front portion close to a front end edge with reference to the rotational direction,
    at least the front portion is inclined to a plane orthogonal to the central axis of rotation in a cross section in the rotational direction at an angle of 20° to 40° toward the front end edge,
    each of the plurality of blades has a front surface facing forward and a back surface facing backward with reference to the rotational direction that are formed therein, and
    each of the plurality of blades comprises a tapered portion that is tapered to have a tip angle of 30° to 50° in the cross section in the rotational direction, on the front end edge.

2. The stirring impeller according to claim 1, wherein the tapered portion has a flat surface located between the front surface and the back surface of each of the plurality of blades.

3. The stirring impeller according to claim 1 or 2, wherein
each of the plurality of blades is in the form of a flat plate having a constant thickness except the tapered portion.

4. The stirring impeller according to any one of claims 1 to 3, wherein
each of the plurality of blades has the front end edge and an outer end edge in the radial direction that are coupled together so as to have a curved contour.

5. The stirring impeller according to any one of claims 1 to 4, wherein
each of the plurality of blades has a back portion close to a back end edge with reference to the rotational direction, and comprises a tapered portion that is tapered to have a tip angle of 30° to 50° in the cross section in the rotational direction, on the back end edge.

6. The stirring impeller according to any one of claims 1 to 5, wherein

each of the plurality of blades comprises a rectifier constituted by a projection or a recess formed on the front surface or the back surface along the rotational direction.

7. A stirring device comprising:

the stirring impeller according to any one of claims 1 to 6.

Fig . 1A

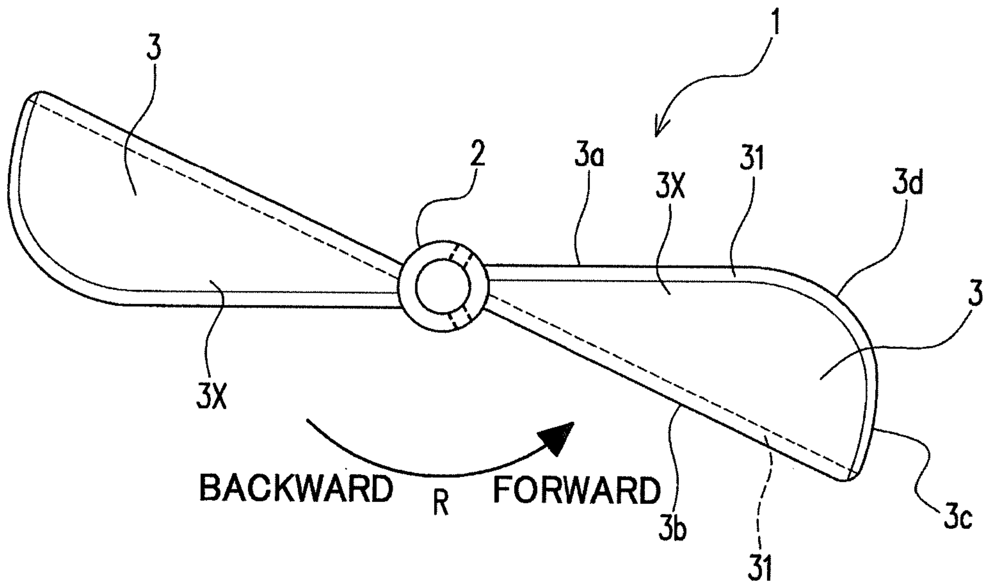


Fig . 1B

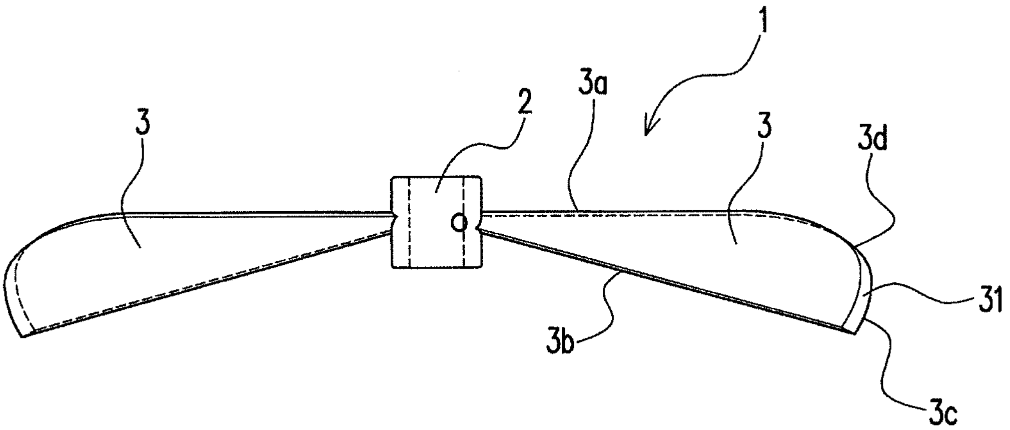


Fig . 1C

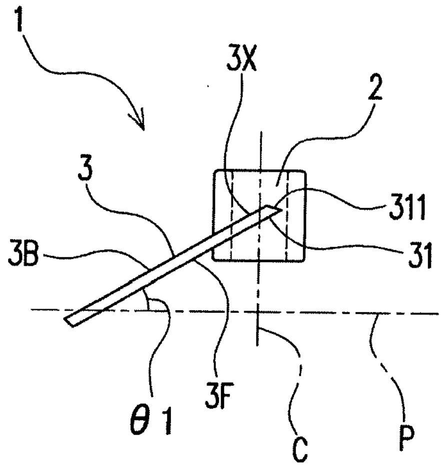


Fig . 2

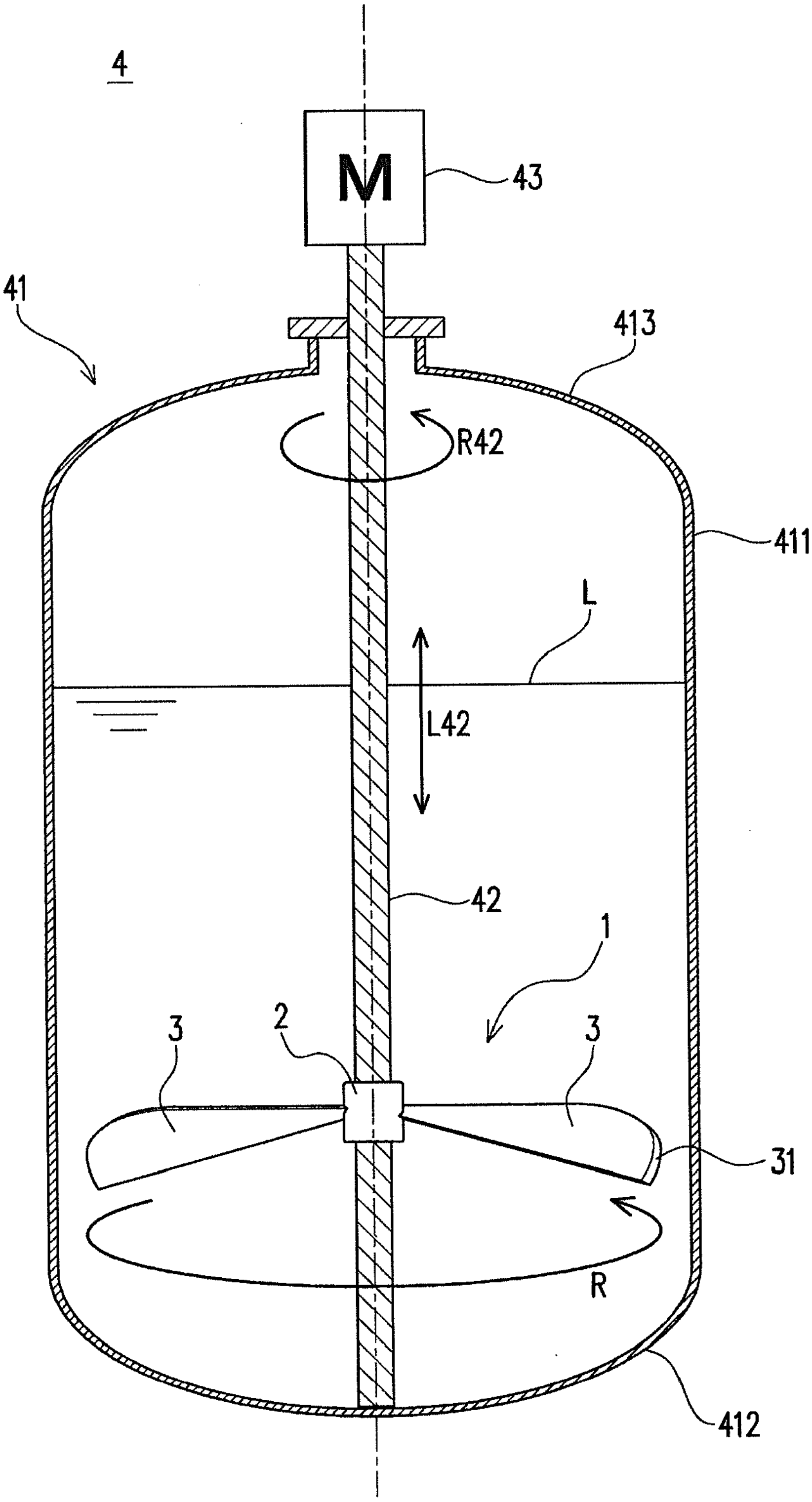


Fig . 3A

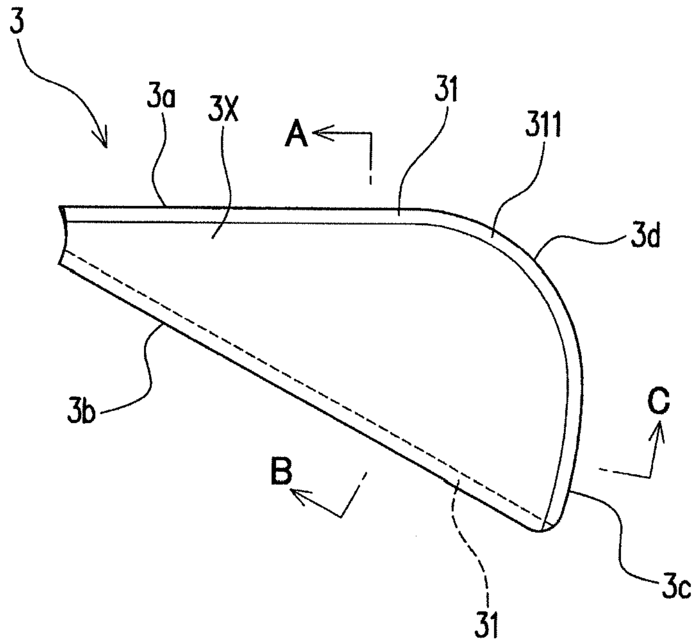


Fig . 3B

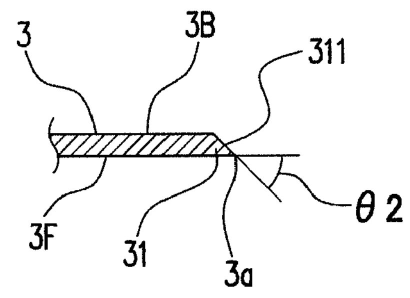


Fig . 3C

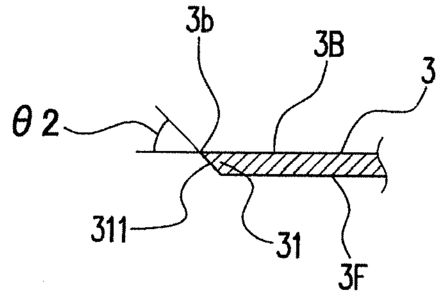


Fig . 3D

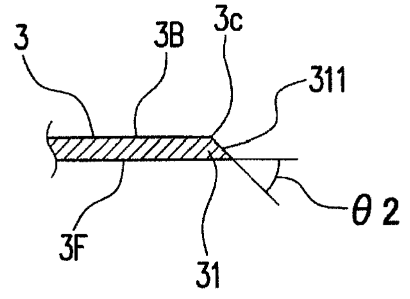


Fig . 4A

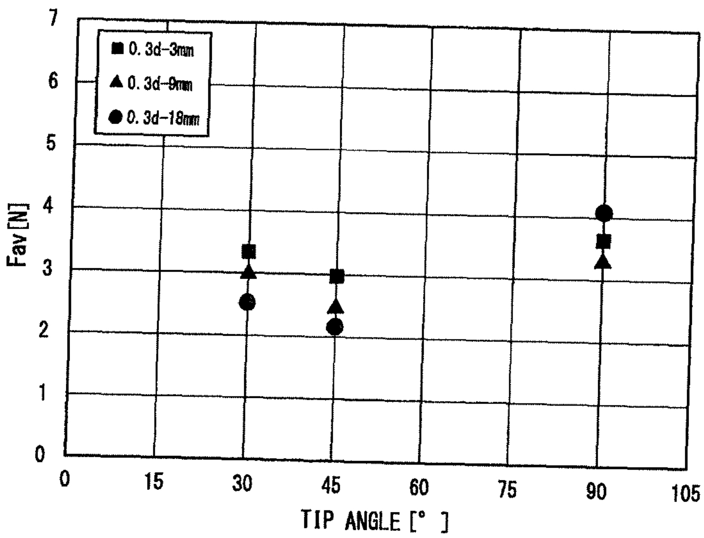
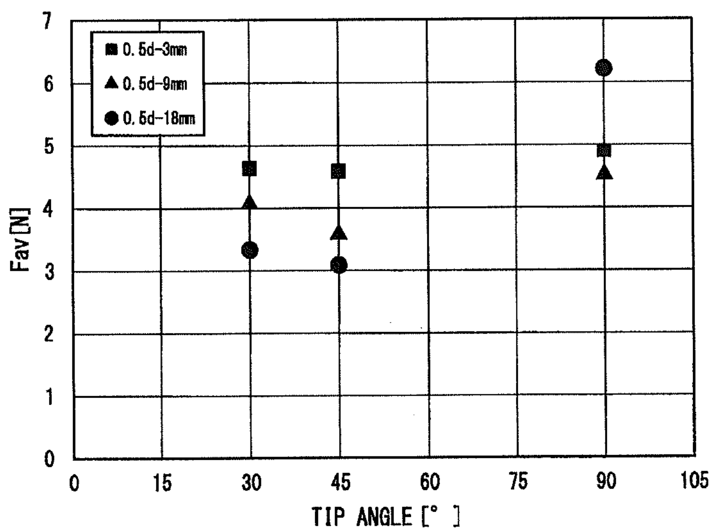

0. 3d-3mm
0. 3d-9mm
0. 3d-18mm
Fav [N]
7
6
5
4
3
2
1
0
0
15
30
45
60
75
90
105
TIP ANGLE [°]

Fig . 4B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Fav[N]
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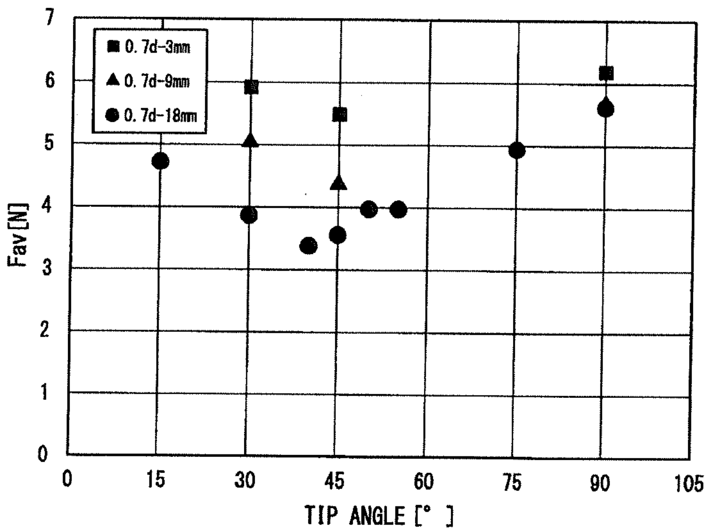
5
4
3
2
1
0
0
15
30
45
60
75
90
105
TIP ANGLE [°]

Fig . 4C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0. 7d-18mm
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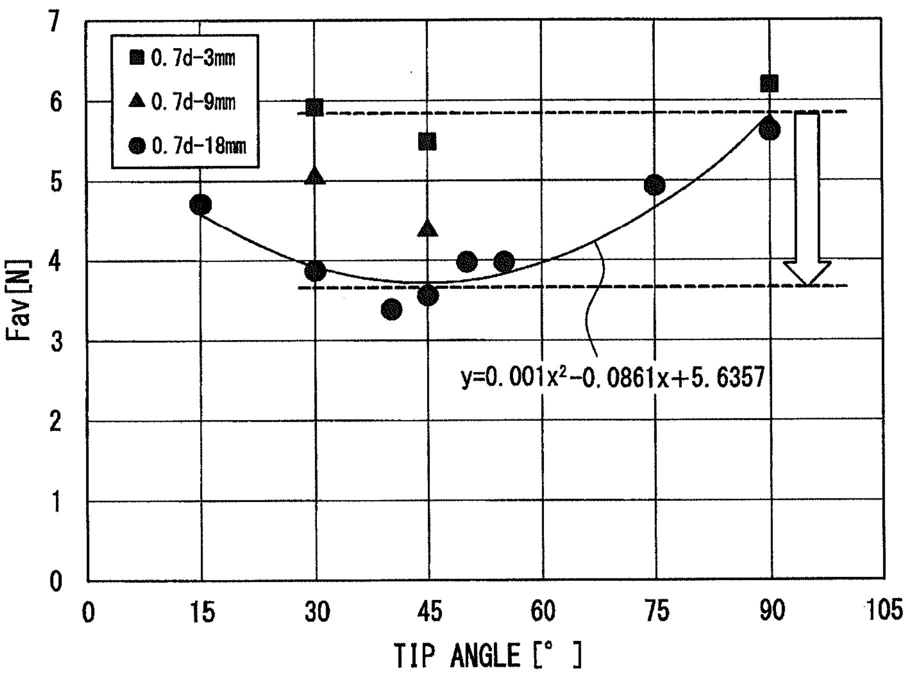
5
6
7
0
15
30
45
60
75
90
105
TIP ANGLE [°]

Fig . 5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y=0. 001x²-0. 0861x+5. 6357
Fav [N]
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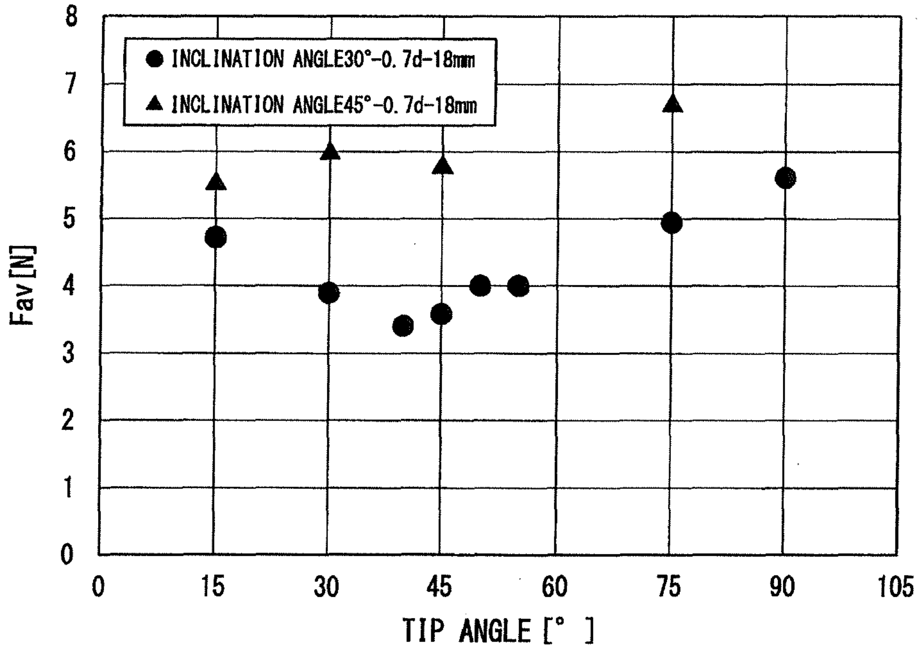
75
90
105

Fig . 6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INCLINATION ANGLE45°-0.7d-18mm
Fav[N]
TIP ANGLE [°]
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1
2
3
4
5
6
7
8
0
15
30
45
60
75
90
105

Fig . 7

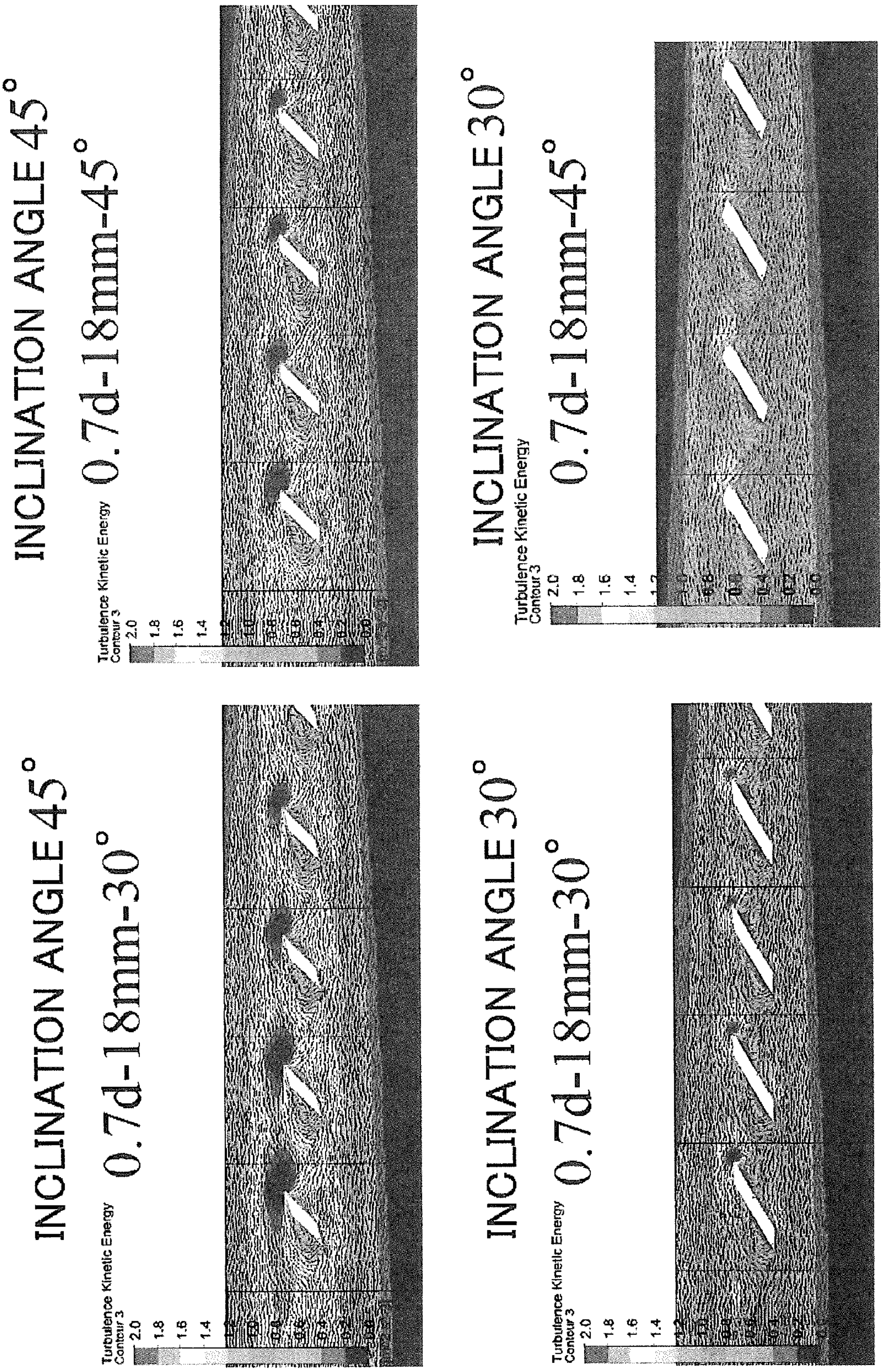

INCLINATION ANGLE 45°
0.7d-18mm-45°
Turbulence Kinetic Energy
Contour 3
2.0
1.8
1.6
1.4
INCLINATION ANGLE 30°
0.7d-18mm-45°
Turbulence Kinetic Energy
Contour 3
2.0
1.8
1.6
1.4
INCLINATION ANGLE 45°
0.7d-18mm-30°
Turbulence Kinetic Energy
Contour 3
2.0
1.8
1.6
1.4
INCLINATION ANGLE 30°
0.7d-18mm-30°
Turbulence Kinetic Energy
Contour 3
2.0
1.8
1.6
1.4

Fig . 8A

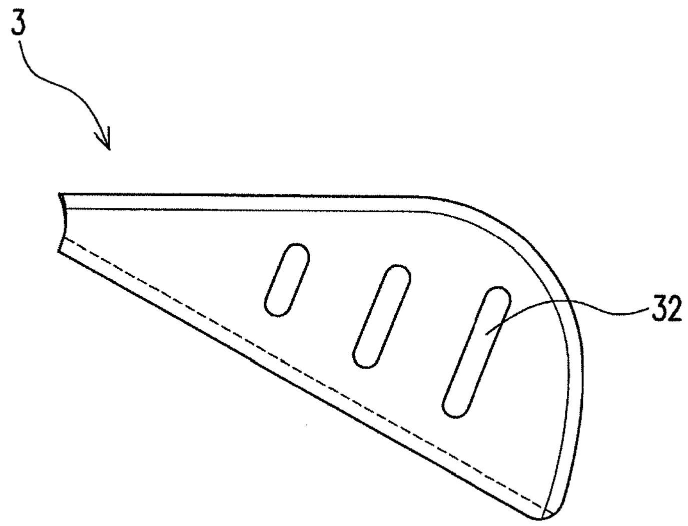
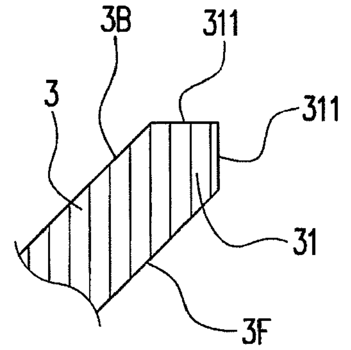


Fig . 8B



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EUROPEAN SEARCH REPORT

Application Number
EP 16 17 2082

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A	US 1 838 453 A (WILLIAM ROSEN) 29 December 1931 (1931-12-29) * page 1, lines 59-80 * * figures 1, 4 * -----	1-7	

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B01F

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	29 November 2016	Posten, Katharina

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