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(54) **WIND WHEEL, FAN, AND AIR CONDITIONER**

(57) A wind wheel (10), a fan (100) and an air conditioner (200). The wind wheel (10) comprises a hub (11). The wind wheel (10) further comprises a blade (12), the blade (12) having a blade root (121), an outer edge (122) and a suction surface (126), wherein the blade root (121) is connected to the hub (11), the outer edge (122) is arranged away from the hub (11) relative to the blade root (121), and the suction surface (126) is separately connected to the blade root (121) and the outer edge (122). The wind wheel (10) further comprises at least two first notches (13), wherein the at least two first notches (13) are arranged in the suction surface (126) and close to the outer edge (122), and the at least two first notches (13) are sequentially distributed at an interval in the extending direction of the outer edge (122).

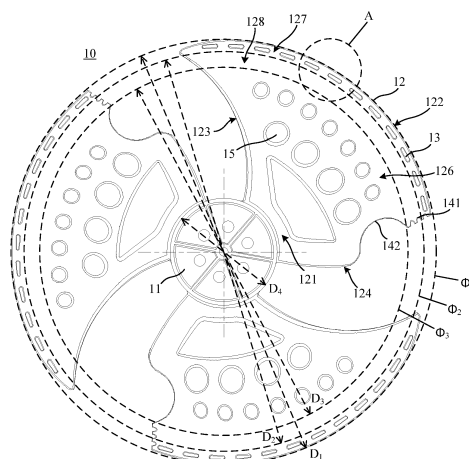


FIG. 1

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Description

[0001] The present disclosure claims priorities to Chinese Patent Application No. 202023086217.9 filed on December 18, 2020 and titled "WIND TURBINE, FAN, AND AIR CONDITIONER" and Chinese Patent Application No. 202023083750.X filed on December 18, 2020 and titled "WIND TURBINE, FAN, AND AIR CONDITIONER", the contents of which are herein incorporated by reference in their entireties.

TECHNICAL FIELD

[0002] The present disclosure relates to the technical field of fans, in particular to a wind turbine, a fan, and an air conditioner.

BACKGROUND

[0003] At present, a suction surface of a blade of a wind turbine of an axial flow fan used in an outdoor unit of an air conditioner is generally a smooth surface. Moreover, the axial flow fan of the outdoor unit of the air conditioner is generally required to have excellent aerodynamic performance and small noise. Thus, a chord length of a middle part and a chord length of an outer edge of the wind turbine blade are relative long in most cases, which results in airflow separation on the suction surface of the blade of the wind turbine, thereby reducing the aerodynamic efficiency of the axial flow fan and increasing noise generated during operation of the axial flow fan.

SUMMARY

[0004] In view of above problems, the present disclosure provides a wind turbine, a fan, and an air conditioner, which reduce airflow separation on a suction surface of a blade.

[0005] In order to solve above problems, a wind turbine is provided in a solution of the present disclosure. The wind turbine includes a hub, a blade, and at least two first grooves. The blade includes a blade root, an outer edge, and a suction surface. The blade root is connected to the hub, the outer edge is farther away from the hub than the blade root, and the suction surface is connected to the blade root and the outer edge. The first grooves are provided on the suction surface at positions close to the outer edge and spaced sequentially apart from each other along an extension direction of the outer edge.

[0006] In some embodiments, the blade includes a pressure surface, the pressure surface is arranged opposite to the suction surface, a bottom of at least one of the first grooves is disposed closer to the pressure surface than the suction surface.

[0007] In some embodiments, a relationship between a length L1 of at least one of the first grooves and a distance L2 between two adjacent of the first grooves meets the following condition: $0.1 < L1/L2 < 2$.

[0008] In some embodiments, the relationship between the length L1 and the distance L2 meets the following condition: $L1/L2 = 1.7$ or $L1/L2 = 0.23$.

[0009] In some embodiments, the suction surface includes a first region, and the first grooves are provided in the first region; and the wind turbine defines a first circumference and a second circumference, the first circumference is centered on a center of the hub, a radius of the first circumference is a maximum distance from the blade to the center, the second circumference is centered on the center, a radius of the second circumference is a minimum distance from an edge of the first region close to the hub to the center, and a relationship between a diameter D1 of the first circumference and a diameter D2 of the second circumference meets the following condition: $0.9 < D2/D1 < 0.99$.

[0010] In some embodiments, the relationship between the diameter D1 of the first circumference and the diameter D2 of the second circumference meets the following condition: $D2/D1 = 0.93$.

[0011] In some embodiments, the wind turbine includes at least two first-groove sets, each of the first-groove sets includes the first grooves, and the first-groove sets are spaced sequentially apart from each other along a direction from the blade root toward the outer edge.

[0012] In some embodiments, the blade includes a front edge and a rear edge, the front edge and the rear edge are arranged opposite to each other, the front edge is connected to the blade root and the outer edge, and the rear edge is connected to the blade root and the outer edge; and the rear edge has a recess recessed toward the front edge, and the recess extends through the blade along a direction of thickness of the blade.

[0013] In some embodiments, the suction surface includes a second region, and the recess is provided in the second region; and the wind turbine defines a first circumference and a third circumference, the first circumference is centered on a center of the hub, a radius of the first circumference is a maximum distance from the blade to the center, the third circumference is centered on the center, a radius of the third circumference is a minimum distance from an edge of the second region close to the hub to the center, and a relationship between a diameter D1 of the first circumference and a diameter D3 of the third circumference meets the following condition: $0.5 < D3/D1 < 0.95$.

[0014] In some embodiments, the relationship between the diameter D1 of the first circumference and the diameter D3 of the third circumference meets the following condition: $D3/D1 = 0.78$.

[0015] In some embodiments, the wind turbine includes a plurality of second grooves, the second grooves are provided on the suction surface, the second grooves are disposed closer to the blade root than the first grooves.

[0016] In some embodiments, the blade includes a front edge, and two ends of the front edge are connected

to the blade root and the outer edge; and the wind turbine includes a protrusion arranged on the suction surface and close to the outer edge and the front edge, and the first grooves are disposed closer to the outer edge than the protrusion.

[0017] In some embodiments, the number of the protrusions is at least two, and the protrusions are spaced apart from each other along a direction close to the outer edge.

[0018] In some embodiments, the protrusion extends away from the front edge.

[0019] In some embodiments, the wind turbine includes one or more feature layers, arranged on the suction surface and including at least two features distributed sequentially along a direction from the blade root towards the outer edge.

[0020] In some embodiments, the number of the feature layers is at least two, the feature layers are distributed layer by layer in a direction away from the front edge, and a thickness of the blade at a position where each of the feature layers is located decreases layer by layer in the direction away from the front edge.

[0021] In some embodiments, a relationship between a diameter D1 of the wind turbine and a diameter D4 of the hub meets the following condition: $0.2 < D4/D1 < 0.4$.

[0022] In order to solve above problems, a fan is provided in another solution of the present disclosure. The fan includes a wind turbine. The wind turbine includes a hub, a blade, and at least two first grooves. The blade includes a blade root, an outer edge, and a suction surface. The blade root is connected to the hub, the outer edge is farther away from the hub than the blade root, and the suction surface is connected to the blade root and the outer edge. The first grooves are provided on the suction surface at positions close to the outer edge and sequentially spaced apart from each other along an extension direction of the outer edge.

[0023] In order to solve above problems, an air conditioner is provided in still another solution of the present disclosure. The air conditioner includes a fan. The fan includes a wind turbine. The wind turbine includes a hub, a blade, and at least two first grooves. The blade includes a blade root, an outer edge, and a suction surface. The blade root is connected to the hub, the outer edge is farther away from the hub than the blade root, and the suction surface is connected to the blade root and the outer edge. The first grooves are provided on the suction surface at positions close to the outer edge and sequentially spaced apart from each other along an extension direction of the outer edge.

[0024] Technical effect of the present disclosure including following. Different from the related art, the present disclosure provides a wind turbine, a fan, and an air conditioner. The wind turbine has at least two first grooves provided on the suction surface at positions close to the outer edge and spaced sequentially apart from each other along an extension direction of the outer edge. In this way, the suction surface of the blade

presents an uneven surface appearance, thereby reducing the airflow separation on the suction surface of the blade.

[0025] In addition, the airflow separation on the suction surface of the blade at the position close to the outer edge is always serious in most cases in the related art. However, in the present disclosure, the first grooves are provided on the suction surface at the positions close to the outer edge, thereby further reducing the airflow separation on the suction surface of the blade.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] Drawings herein are incorporated into the description and form a part of the description, illustrate embodiments in accordance with the present disclosure, and are used in conjunction with the description to explain principles of the present disclosure. Furthermore, the drawings and descriptions are not intended to limit a scope of the present disclosure in any way, but to illustrate concepts in the present disclosure to those skilled in the art by reference to specific embodiments.

FIG. 1 is a structural schematic view of a first embodiment of a wind turbine according to the present disclosure.

FIG. 2 is a structural schematic side view of the wind turbine shown in FIG. 1.

FIG. 3 is an enlarged structural schematic view of a region A of the wind turbine shown in FIG. 1.

FIG. 4 is a structural schematic view of a second embodiment of a wind turbine according to the present disclosure.

FIG. 5 is a structural schematic view of a third embodiment of a wind turbine according to the present disclosure.

FIG. 6 is a structural schematic view of a fourth embodiment of a wind turbine according to the present disclosure.

FIG. 7 is a cross-sectional structural schematic view of the wind turbine along a B-B direction shown in FIG. 6.

FIG. 8 is an enlarged structural schematic view of a region C of the wind turbine shown in FIG. 6.

FIG. 9 is a schematic diagram illustrating a relationship between distances and noise of adjacent feature layers according to the present disclosure.

FIG. 10 is a schematic diagram illustrating a relationship between distances and noise at corresponding positions of any two adjacent features in each feature layer of the present disclosure.

FIG. 11 is a structural schematic view of a fifth embodiment of a wind turbine according to the present disclosure.

FIG. 12 is structural schematic view of an embodiment of a fan according to the present disclosure.

FIG. 13 is a schematic diagram illustrating comparison between a fan according to the present disclosure

sure and a traditional fan with respect to relationships between airflow volumes and noises.

FIG. 14 is a schematic diagram illustrating comparison between a fan according to the present disclosure and a traditional fan with respect to relationships between the airflow volumes and powers.

FIG. 15 is a schematic diagram illustrating comparison between a fan according to the present disclosure and a traditional fan with respect to noise levels at various frequency points.

FIG. 16 is a structural schematic view of an embodiment of an air conditioner according to the present disclosure.

DETAILED DESCRIPTION

[0027] In order to make a purpose, technical solutions and technical effect of the present disclosure clear, the technical solutions in some embodiments of the present disclosure are clearly and completely described in conjunction with the drawings in the embodiments of the present disclosure. It is obvious that the described embodiments are only a part of embodiments of the present disclosure, and not all embodiments. All other embodiments acquired by those skilled in the art based on the embodiments in the present disclosure without the creative work are all within the scope of the present disclosure. Without conflict, following embodiments and features in the embodiments may be combined with each other.

[0028] In order to solve a technical problem in related art that an airflow separation phenomenon is easy to occur on a suction surface of a blade of a wind turbine used in an axial flow fan, some embodiments of the present disclosure provide a wind turbine. The wind turbine includes a hub and a blade. The blade includes a blade root, an outer edge, and a suction surface. The blade root is connected to the hub. The outer edge is farther away from the hub than the blade root, and the suction surface is connected to the blade root and the outer edge. The wind turbine further includes at least two first grooves. The first grooves are provided on the suction surface at a position close to the outer edge and distributed sequentially and spaced apart from each other along an extension direction of the outer edge. Following are described in detail.

[0029] As shown in FIGS. 1 and 2, FIG. 1 is a structural schematic view of a first embodiment of a wind turbine according to the present disclosure, and FIG. 2 is a structural schematic side view of the wind turbine shown in FIG. 1.

[0030] In some embodiments, a wind turbine 10 includes a hub 11 and a blade 12 connected to the hub 11. The number of the blades 12 is one or more, and the one or more blades 12 are spaced sequentially apart from each other along a circumferential direction of the hub 11. The hub 11 is configured to be connected to a driving apparatus a transmission way such as a motor, such that

the hub 11 is driven by the driving apparatus to rotate around a center axis of the hub 11, and then the blade 12 connected to the hub 11 is driven to rotate around the center axis of the hub 11, thereby generating airflow.

[0031] The blade 12 has a blade root 121, an outer edge 122, a front edge 123, a rear edge 124, a pressure surface 125, and a suction surface 126. The blade root 121 of the blade 12 is connected to the hub 11. An edge of the blade 12 arranged opposite to or facing or away from the blade root 121 is the outer edge 122. The front edge 123 and the rear edge 124 of the blade 12 are arranged opposite to or facing each other. Both ends of the front edge 123 are connected to the blade root 121 and the outer edge 122, respectively. Both ends of the rear edge 124 are connected to the blade root 121 and the outer edge 122, respectively. Circumferential airflow caused by movement of the blade 12 flows from the front edge 123 to the rear edge 124. The pressure surface 125 and the suction surface 126 of the blade 12 are arranged opposite to each other, and axial airflow caused by movement of the blade 12 flows from a side where the suction surface 126 is located to a side where the pressure surface 125 is located.

[0032] As further shown in FIG. 1, a relationship between a diameter D1 of the wind turbine 10 and a diameter D4 of the hub 11 meets the following condition: $0.2 < D4/D1 < 0.4$. In some embodiments, the relationship between the diameter D1 of the wind turbine 10 and the diameter D4 of the hub 11 meets the following condition: $D4/D1 = 0.3$. In this way, a size of the hub 11 may be minimized to ensure air outlet efficiency of the wind turbine 10. In addition, a connection strength between the hub 11 and the blade 12 is high, so that stability problems such as the blade 12 breaking are not easy to occur.

[0033] The wind turbine 10 in some embodiments of the present disclosure may be an axial flow wind turbine. The axial flow wind turbine is widely used in air conditioners and various ventilation and heat dissipation scenes since it has a large airflow volume, a low noise level, and a low pressure. A design of the axial flow wind turbine has a great impact on an efficiency and noise of an axial flow fan. With an increasing requirement for an energy efficiency of the air conditioner, a requirement for an efficiency of the axial flow fan is also increasing day by day. Generally, the axial flow fan is required to have a low noise level and a high efficiency. The axial flow fan is a key component in an outdoor unit of the air conditioner. Performance of the axial flow fan has a great impact on performance of the air conditioner. In addition, the axial flow fan is usually used in conjunction with a motor. Therefore, an optimal working speed and a load capability of the motor need to be fully considered to ensure that the designed axial flow fan has a high efficiency.

[0034] Considering factors such as aerodynamic efficiency, noise, and the like of the wind turbine, a suction surface of a blade of a traditional axial flow wind turbine is generally a smooth surface, and keeping the suction surface smooth helps to reduce a friction loss caused by

the blade and reduce unnecessary aerodynamic noise. However, since the wind turbine is generally required to have good aerodynamic performance and low noise, a chord length of a middle part and a chord length of an outer edge of the blade is relative long in most cases. Since the suction surface of the blade of the traditional axial flow wind turbine is usually smooth, so that a boundary layer is formed on a surface of the blade due to an impact of a viscous force when the airflow flows through the surface of the blade, and a thickness of the boundary layer increases gradually along a direction of flow of the airflow, thereby forming an adverse pressure gradient in the boundary layer. When the adverse pressure gradient causes a flow speed of the airflow in the boundary layer to be close to zero, a boundary layer separation phenomenon, i.e., an airflow separation, occurs. Therefore, a relatively smooth suction surface with a long chord length tends to cause the airflow separation phenomenon to occur at a region of the blade close the rear edge. The airflow separation not only reduces the aerodynamic efficiency of the wind turbine, but also increases the aerodynamic noise of the wind turbine.

[0035] In order to improve the airflow separation on the suction surface of the blade, for the traditional axial flow wind turbine, a mounting angle of the blade is usually adjusted. This method is simple and convenient, and may also have a good effect under some particular circumstances. However, after the mounting angle of the blade is adjusted to match an airflow angle, readjustment of the mounting angle will reduce the aerodynamic performance of the wind turbine or cause the aerodynamic performance of the wind turbine to deteriorate seriously. In addition, adjusting the mounting angle of the blade is easy to cause an axial size of the wind turbine to obviously change, so that the wind turbine cannot meet actual application requirements of air conditioner products.

[0036] In order to reduce the weight of the wind turbine and a load of the wind turbine, the blade of the traditional axial flow fan is usually designed as a single-circular-arc structure with the same thickness, and a section of the blade is no longer adopts a wing-shape design. In this way, although the weight of the wind turbine and the load of the fan are reduced, however, the noise of the fan is increased, and the strength of the fan is weakened. Therefore, the blade of the wind turbine is easy to have stability problems such as breaking due to the weakened strength.

[0037] In view of this, as shown in FIG. 1, the wind turbine 10 in some embodiments further includes at least two first grooves 13. The first grooves 13 are provided on the suction surface 126 at positions close to the outer edge 122 and are spaced sequentially apart from each other along an extension direction of the outer edge 122.

[0038] It may be seen that the first grooves 13 enable the suction surface 126 of the blade 12 to present an uneven surface appearance, which helps to introduce high-energy fluid into the boundary layer, so that a flow field of the boundary layer in the adverse pressure gra-

dient may continue to attach to the suction surface 126 of the blade 12 after obtaining additional energy, thereby achieving the effect of delaying the airflow separation of the suction surface 126, reducing the airflow separation on the suction surface 126 of the blade 12, improving the aerodynamic efficiency of the wind turbine 10, and reducing the noise of the wind turbine 10.

[0039] In addition, since at a position of the suction surface 126 of the blade 12 close to the outer edge 122, the airflow speed is fast and the airflow separation is serious, the first grooves 13 in some embodiments of the present disclosure are provided on the suction surface 126 at the positions close to the outer edge 122, so that the position of the suction surface 126 close to the outer edge 122 presents the uneven surface appearance, which facilitates reducing the airflow separation on the suction surface 126 of the blade 12.

[0040] As further shown in FIGS. 1 and 2, a bottom of at least one of the first grooves 13 is disposed closer to the pressure surface 125 than the suction surface 126, that is, each of the first grooves 13 is formed by recessing the suction surface 126 toward the pressure surface 125, or a part of the blade 12 at a position of the suction surface 126 where each of the first grooves 13 is located is missing to form the corresponding one of the first grooves 13. In this way, by defining the first grooves 13, the weight of the blade 12 may be reduced, which in turn reduces the load of the fan configured with the wind turbine 10 in some embodiments of the present disclosure, thereby improving the efficiency of the fan.

[0041] As shown in FIG. 3, FIG. 3 is an enlarged structural schematic view of a region A of the wind turbine shown in FIG. 1.

[0042] In some embodiments, a length of each of the first grooves 13 is defined as a chord length corresponding to a position where the first groove 13 is located, and a distance between two adjacent first grooves 13 of the first grooves 13 is defined as a minimum distance between two adjacent ends, which are adjacent to each other, of two adjacent first grooves 13, respectively. A relationship between the length L1 of at least one of the first grooves 13 and the distance L2 between two adjacent first grooves 13 meets the following condition: $0.1 < L1/L2 < 2$, as shown in FIG. 3. In this way, the first grooves 13 have a reasonable distribution density on the suction surface 126 of the blade 12, which facilitates ensuring the effect of dispersing a vortex at the outer edge 122 by the first grooves 13, and the airflow separation phenomenon on the suction surface 126 of the blade 12 may be suppressed, thereby facilitating improving the aerodynamic efficiency of the wind turbine 10 and reducing the noise of the wind turbine 10.

[0043] Further, in some embodiments, the relationship between the length L1 of at least one of the first grooves 13 and the distance L2 between two adjacent first grooves 13 meets the following condition: $L1/L2 = 1.7$. In some embodiments, the relationship between the length L1 of at least one of the first grooves 13 and the distance

L2 between two adjacent first grooves 13 meets the following condition: $L1/L2=0.23$. In this way, it is possible to ensure that the first grooves 13 have a reasonable distribution density on the suction surface 126 of the blade 12 as far as possible, ensure the effect of dispersing the vortex at the outer edge 122 by the first grooves 13 as far as possible, and further suppress the airflow separation phenomenon on the suction surface 126 of the blade 12 as far as possible. Thus, the aerodynamic efficiency of the wind turbine 10 may be further improved, and the noise of the wind turbine 10 may be reduced. Moreover, size relationships described above may be reasonably selected according to a specific design of the wind turbine 10.

[0044] As shown in FIG. 1, in some embodiments, the suction surface 126 of the blade 12 includes a first region 127 in which the first grooves 13 are provided. Furthermore, the wind turbine 10 defines a first circumference (such as the circumference $\Phi 1$ shown in FIG. 1, similarly hereinafter) and a second circumference (such as the circumference $\Phi 2$ shown in FIG. 1, similarly hereinafter). A region located between the first circumference and the second circumference of the suction surface 126 is the first region 127.

[0045] In some embodiments, the first circumference and the second circumference are concentric circles centered on a center of the hub 11. A plane where the first circumference is located and a plane where the second circumference is located are perpendicular to a central axis of the hub 11. The central axis of the hub 11 passes through the center of the hub 11. The first circumference is centered on the center of the hub 11, and a radius of the first circumference is a maximum distance from the blade 12 to the center of the hub 11. The maximum distance is a distance from a position on the blade 12 farthest from the center of the hub 11 to the center of the hub 11. The second circumference is centered on the center of the hub 11, and a radius of the second circumference is a minimum distance from an edge of the first region 127 close to the hub 11 to the center of the hub 11. A diameter of the first circumference is a diameter of the wind turbine 10.

[0046] As shown in FIG. 1, a relationship between the diameter D1 of the first circumference and a diameter D2 of the second circumference meets the following condition: $0.9 < D2/D1 < 0.99$. In this way, the first grooves 13 may be provided as close as possible to the outer edge 122 of the blade 12, so as to reduce the airflow separation on a position of the suction surface 126 of the blade 12 close to the outer edge 122.

[0047] Further, as shown in FIG. 1, the relationship between the diameter D1 of the first circumference and the diameter D2 of the second circumference meets the following condition: $D2/D1=0.93$, so that the first grooves 13 may be provided close but not too close to the outer edge 122 of the blade 12, thereby facilitating forming the first groove 13 and ensuring a structural reliability of the wind turbine 10.

[0048] As shown in FIG. 4, FIG. 4 is a structural schematic view of a second embodiment of a wind turbine according to the present disclosure.

[0049] In some embodiments, the wind turbine 10 includes at least two first-groove sets 131. Each of the first-groove sets 131 includes the first grooves 13 as described above. The first-groove sets 131 are spaced sequentially apart from each other along a direction from the blade root 121 towards the outer edge 122. In this way, the first-groove sets 131 are provided on the suction surface 126 at positions close to the outer edge 122, such that the suction surface 126 of the blade 12 may further presents an uneven surface appearance, and the effect of dispersing the vortex at the outer edge 122 may be improved, thereby improving the airflow separation on the suction surface 126.

[0050] As shown in FIG. 1, in some embodiments, the rear edge 124 of the blade 12 includes a recess recessed towards the front edge 123, and the recess is extended through the blade 12 along a direction of thickness of the blade 12. The direction of thickness of the blade 12 may be understood as a direction perpendicular to the suction surface 126 and the pressure surface 125 of the blade 12. The recess may not only reduce the weight of the blade 12 to reduce the load of the fan configured with the wind turbine 10 in some embodiments of the present disclosure, but also reduce the vortex loss at the rear edge 124 of the blade 12, thereby reducing vibration and the noise of the wind turbine 10 during operation.

[0051] In some embodiments, the recess includes at least one of a first recess 141 and a second recess 142. The number of first recess 141 is at least two, and the first recesses 141 are provided side by side in a zigzag shape along an extension direction of the rear edge 124. The second recess 142 is recessed deeper toward the front edge 123 than the first recess 141, i.e., an end of the second recess 142 toward the front edge 123 is closer to the front edge 123 than an end of the first recess 141 toward the front edge 123. FIG. 1 shows that the first recess 141 is closer to the outer edge 122 of the blade 12 than the second recess 142. A relative positional relationship between the first recess 141 and the second recess 142 is only provided for discussion purposes but not for limitation.

[0052] For example, as shown in FIG. 1, the suction surface 126 of the blade 12 includes a second region 128 having a recess. In some embodiments, the first recess 141 is provided in the second region 128 of the suction surface 126. The wind turbine 10 includes the first circumference and a third circumference (such as the circumference $\Phi 3$ shown in FIG. 1, similarly hereinafter), and a region of the suction surface 126 located between the first circumference and the third circumference is the second region 128. That is, the first recess 141 is provided in the region of the suction surface 126 located between the first circumference and the third circumference, and the second recess 142 is provided in a region of the suction surface 126 located between the third cir-

cumference and the hub 11. It may be seen from FIG. 1 that the first region 127 is located in the second region 128.

[0053] The first and third circumferences are concentric circles centered on the center of the hub 11. The plane where the first circumference is located and a plane where the third circumference is located are perpendicular to the central axis of the hub 11. The first circumference is centered on the center of the hub 11, and the radius of the first circumference is the maximum distance from the blade 12 to the center of the hub 11. The third circumference is centered on the center of the hub 11, and a radius of the third circumference is a minimum distance from an edge of the second region 128 close to the hub 11 to the center of the hub 11.

[0054] As shown in FIG. 1, a relationship between the diameter D1 of the first circumference and a diameter D3 of the third circumference meets the following condition: $0.5 < D3/D1 < 0.95$. In this way, a position of the first recess 141 on the suction surface 126 of the blade 12 may be reasonably selected, which ensures that the first recess 141 reduces the vortex loss at the rear edge 124 of the blade 12, thereby reducing the vibration and the noise of the wind turbine 10 during operation. As further shown in FIG. 1, the relationship between the diameter D1 of the first circumference and the diameter D3 of the third circumference meets the following condition: $D3/D1 = 0.78$.

[0055] As shown in FIG. 1, in some embodiments, the wind turbine 10 further includes a plurality of second grooves 15 provided on the suction surface 126 of the blade 12. Moreover, the plurality of second grooves 15 are arranged closer to the blade root 121 of the blade 12 than the first grooves 13 described above. The plurality of second grooves 15 are formed by recessing the suction surface 126 toward the pressure surface 125, or a part of the blade 12 at a position of the suction surface 126 where the plurality of second grooves 15 are located is missing to form the plurality of second grooves 15. In this way, by defining the plurality of second grooves 15, the weight of the wind turbine 10 may be reduced, which in turn reduces the load of the fan configured with the wind turbine 10 in some embodiments of the present disclosure. Thus, the cost of material of the fan may be reduced and the efficiency of the fan may be improved. The plurality of second grooves 15 may further reduce the airflow separation on the suction surface 126 of the blade 12, reduce the vortex loss of the suction surface 126, thereby reducing the vibration and the noise of the wind turbine 10 during operation.

[0056] It should be noted that the number of second grooves 15 is one, two, or more than two, and is not limited here.

[0057] In conclusion, the wind turbine in some embodiments of the present disclosure includes the first grooves provided on the suction surface at positions close to the outer edge, and the first grooves are spaced sequentially apart from each other along the extension direction of

the outer edge, so that the suction surface of the blade presents the uneven surface appearance, thereby reducing the airflow separation on the suction surface of the blade.

[0058] Besides, since the airflow separation on the suction surface of the blade close to the outer edge is always serious, the first grooves in some embodiments of the present disclosure are provided on the suction surface at the positions close to the outer edge, which may further reduce the airflow separation on the suction surface of the blade.

[0059] As shown in FIG. 5, FIG. 5 is a structural schematic view of a third embodiment of a wind turbine according to the present disclosure.

[0060] In some embodiments, different from the above embodiments, the wind turbine 10 in some embodiments of the present disclosure further includes a protrusion 16 arranged on and protrudes from the suction surface 126 and disposed close to the outer edge 122 and the front edge 123. A blade tip of the blade 12 is formed at an intersection of the outer edge 122 and the front edge 123 of the blade 12, and the protrusion 16 is arranged at the blade tip formed by the outer edge 122 and the front edge 123, which may disperse the vortex at the blade tip, and enable the suction surface 126 of the blade 12 to present an uneven surface appearance, thereby reducing the airflow separation on the suction surface 126 of the blade 12.

[0061] Since a position of the suction surface 126 of the blade 12 close to the outer edge 122 has a high efficiency in doing work on the airflow, and a relative linear speed of the airflow at the position is fast, the protrusion 16 in some embodiments is arranged close to the outer edge 122, which facilitates improving the effect of the protrusion 16 in dispersing the vortex and suppressing the airflow separation, thereby reducing the airflow separation on the suction surface 126 of the blade 12.

[0062] The protrusion 16 is arranged on the second region 128 on the suction surface 126 described in the above embodiments. In this way, the protrusion 16 is arranged as close as possible to the outer edge 122 of the blade 12, so as to ensure the effect of the protrusion 16 in dispersing the vortex and suppressing the airflow separation, thereby further reducing the airflow separation on the suction surface 126 of the blade 12. The second region 128 has been described in the above embodiments and is not repeated here.

[0063] It should be noted that, the wind turbine 10 described in some embodiments may further include the first groove 13 described in the above embodiments, in addition to the protrusion 16, so as to reduce the airflow separation on the suction surface 126 of the blade 12 by the cooperation of the protrusion 16 and the first groove 13. FIG. 5 shows that the protrusion 16 and the first grooves 13 are arranged on the suction surface 126 of the blade 12, and the first grooves 13 are disposed closer to the outer edge 122 of the blade 12 than the protrusion 16.

[0064] In some embodiments, the number of protrusions 16 is at least two, and the protrusions 16 are spaced apart from each other along a direction close to or towards the outer edge 122, so that the airflow generated at the front edge 123 of the blade 12 is affected by a greater number of protrusions 16 to further improve the effect of the protrusions 16 in dispersing the vortex at a position where the protrusions are located.

[0065] In some embodiments, the protrusion 16 extends along a direction away from the front edge 123 of the blade 12. In this way, the effect of the protrusion 16 in dispersing the vortex and suppressing the airflow separation is ensured, the protrusion 16 with this design facilitates optimizing the airflow, which further facilitates reducing the vortex loss on the suction surface 126 and reducing the vibration and the noise of the wind turbine 10 during operation.

[0066] As shown in FIG. 5, in some embodiments, the wind turbine 10 further includes one or more feature layers 17 arranged on the suction surface 126 of the blade 12. The one or more feature layers 17 include features 171 distributed sequentially in a direction from the blade root 121 of the blade 12 to the outer edge 122. In some embodiments, the number of the feature layers 17 is at least two, the feature layers 17 are distributed layer by layer along a direction away from the front edge 123 of the blade 12.

[0067] FIG. 5 shows that the protrusion 16, the first grooves 13, and the one or more feature layers 17 are arranged on the suction surface 126 of the blade 12. The first grooves 13 are disposed closer to the outer edge 122 of the blade 12 than the protrusion 16 and the one or more feature layers 17. The one or more feature layers 17 are disposed closer to the rear edge 124 of the blade 12 than the protrusion 16. The first recess 141 as described in the above embodiments may be further provided on the rear edge 124 of the blade 12.

[0068] It may be seen that the design of the above-mentioned feature layers 17 are similar to a feather of a bird or a fish scale, etc., so that the suction surface 126 of the blade 12 presents an uneven surface appearance, which facilitates introducing high-energy fluid into the boundary layer, so that the flow field of boundary layer in the adverse pressure gradient may continue to attach to the suction surface 126 of the blade 12 after obtaining additional energy, and thus the effect of delaying the airflow separation on the suction surface 126 may be achieved. In this way, the airflow separation on the suction surface 126 of the blade 12 may be reduced, thereby improving the aerodynamic efficiency of the fan configured with the wind turbine 10 in some embodiments of the present disclosure and reducing the noise of the fan configured with the wind turbine 10 in some embodiments of the present disclosure.

[0069] As shown in FIGS. 6 and 7, FIG. 6 is a structural schematic view of a fourth embodiment of a wind turbine according to the present disclosure, and FIG. 7 is a cross-sectional structural schematic view of the wind turbine

along a B-B direction in FIG. 6. FIG. 6 shows one blade 12 of the whole wind turbine 10 and a part of the hub 11 connected to the one blade 12.

[0070] In some embodiments, a thickness of the blade 12 (the thickness H as shown in FIG. 7) at a position where the one or more feature layers 17 are located is reduced layer by layer along a direction close to the rear edge 124 of the blade 12, so that the thickness of the blade 12 is reduced and the weight of the blade 12 may be reduced, thereby improving the aerodynamic performance of the wind turbine 10. Besides, the thickness of the blade 12 being reduced layer by layer also facilitates introducing the high-energy fluid into the boundary layer, so that the flow field of the boundary layer in the adverse pressure gradient may continue to attach to the suction surface 126 of the blade 12 after obtaining the additional energy, thereby achieving the effect of delaying the airflow separation on the suction surface 126.

[0071] In some embodiments, thicknesses of the feature layers 17 (the thickness h as shown in FIG. 7) are set differently from each other, so that the thickness of the blade 12 may be reduced to different degrees. In this way, a reduced degree of the thickness of the blade 12 may be reasonably selected according to requirements for the aerodynamic performance of the wind turbine 10. In this way, the weight of the blade 12 may be reduced, the strength of the blade 12 is not significantly affected and may also meet the requirements for the aerodynamic performance of the wind turbine 10.

[0072] In some embodiments, as shown in FIGS. 6 and 7, the thickness h of each of the feature layers 17 is reduced layer by layer along the direction close to the rear edge 124 of the blade 12, so that the thickness of the blade 12 may be minimized, that is, the weight of the blade 12 may be minimized. Of course, in other embodiments of the present disclosure, the thicknesses of the feature layers 17 are increased layer by layer in the direction close to the rear edge 124 of the blade 12, which is not limited here.

[0073] It should be noted that, the thickness of one of the feature layers 17 is a reduced thickness of the blade 12 by subtracting a thickness of the blade 12 at a position where another one of the feature layers 17 adjacent to the one of the feature layers 17 and located closer to the rear edge 124 than the one of the feature layers 17 is located from a thickness of the blade 12 at a position where the one of the feature layers 17 is located. As shown in FIG. 7, a feature layer α is adjacent a feature layer β , and the feature layer β is disposed closer to the rear edge 124 of the blade 12 than the feature layer α . Thus, the thickness of the feature layer α is a reduced thickness of the blade 12 by subtracting a thickness of the blade 12 at a position where the feature layer β is located from the thickness of the blade 12 at a position where the feature layer α is located. That is, the thickness of the blade 12 at a position where the feature layer β is located is a thickness acquired by subtracting the thickness h of the feature layer α from the thickness of the

blade 12 at the position where the feature layer α is located.

[0074] As shown in FIGS. 5 and 6, in some embodiments, since regions in the blade 12 on which the airflow separation is easy to occur are mostly located at positions of the suction surface 126 of the blade 12 close to the rear edge 124, the feature layers 17 described above are arranged at the positions of the suction surface 126 of the blade 12 close to the rear edge 124, so that the positions of the suction surface 126 of the blade 12 close to the rear edge 124 have a non-smooth shape. In this way, the airflow separation on the suction surface 126 of the blade 12 may be delayed, thereby further reducing the airflow separation on the suction surface 126.

[0075] As shown in FIGS. 6 and 8, FIG. 8 is an enlarged structural schematic view of a region C of the wind turbine shown in FIG. 6.

[0076] In some embodiments, a distance between adjacent feature layers 17 (a distance W as shown in FIG. 8, similarly hereinafter) is from 0.5 mm to 100 mm. The distance between the adjacent feature layers 17 may be a distance between corresponding positions of the adjacent feature layers 17. For example, as shown in FIG. 8, the distance between the adjacent feature layers may be a minimum distance between ends of the features 171 of the adjacent feature layers facing the rear edge 124.

[0077] In this way, it may be ensured that there is a sufficient distance between the adjacent feature layers 17 to facilitate a design and a manufacture of the features 171 of each of the feature layers 17, and that the distance between adjacent feature layers is not too long or too great to ensure the effect of the feature layers 17 in reducing the airflow separation, and avoid poor suppression of the airflow separation on the suction surface 126 of the blade 12 due to sparse distribution of feature layers 17.

[0078] As shown in FIGS. 5 and 6, in some embodiments, a distance between ends of the adjacent feature layers close to the blade root 121 is less than a distance between ends of adjacent feature layers close to the outer edge 122. In some embodiments, the distance between the adjacent feature layers increases gradually along a direction from the blade root 121 to the outer edge 122 of the blade 12 to match a trend that the chord length of the blade 12 increases gradually along the direction from the blade root 121 to the outer edge 122 of the blade 12, so that the distance between the adjacent feature layers 17 better matches the variation of the chord length of the blade 12, thereby improving the effect of the one or more feature layers 17 in suppressing the airflow separation on the suction surface 126 of the blade 12. In addition, the above design enables the blade 12 in some embodiments of the present disclosure to have a better product appearance, which is more consistent with an industrial design and application, and which improves a product competitiveness of the wind turbine 10 in some embodiments of the present disclosure.

[0079] The distance between the adjacent feature lay-

ers 17 as described in the above embodiments is from 0.5 mm to 100 mm. In some embodiments, the distance between the ends of the adjacent feature layers 17 close to the blade root 121 is 30 mm, while the distance between the ends of the adjacent feature layers 17 close to the outer edge 122 is 50 mm. In other words, the distance between adjacent feature layers 17 in some embodiments gradually increases from 30 mm to 50 mm along the direction from the blade root 121 of the blade 12 to the outer edge 122. In this way, it may be further ensured that the distance between adjacent feature layers 17 better matches the variation of the chord length of the blade 12, which facilitates improving the effect of the one or more feature layers 17 in suppressing the airflow separation on the suction surface 126 of the blade 12, and further guaranteeing the product appearance effect of the blade 12.

[0080] FIG. 9 is a schematic diagram illustrating a relationship between distances and noise of adjacent feature layers according to the present disclosure. It may be seen that the distance between the adjacent feature layers 17 in some embodiments of the present disclosure is between 30 mm and 50 mm, which may ensure that the wind turbine 10 in some embodiments of the present disclosure has low noise.

[0081] Of course, in other embodiments of the present disclosure, the distance between the adjacent feature layers 17 may also gradually decrease, remain unchanged, or be arranged in an irregular manner along the direction from the blade root 121 of the blade 12 to the outer edge 122. Provided that the effect of the one or more feature layers 17 in suppressing the airflow separation on the suction surface 126 of the blade 12 may be improved, the distance between the adjacent feature layers 17 is not limited.

[0082] As further shown in FIGS. 6 and 8, in some embodiments, in each of the feature layers 17, the distance between corresponding positions of any two adjacent features 171 (the distance W as shown in FIG. 8, similarly hereinafter) is from 5 mm to 80 mm. The distance between the corresponding positions of any two adjacent features 171 may be a distance between ends of any two adjacent features 171 facing the rear edge 124. In this way, a distribution form of the features 171 in each of the feature layers 17 may meet requirements, thereby ensuring the effect of the one or more feature layers 17 in suppressing the airflow separation on the suction surface 126 of the blade 12.

[0083] In some embodiments, a distance between corresponding positions of any two adjacent features 171 in each of the feature layers 17 is 22 mm. In this way, the effect of the one or more feature layers 17 in suppressing the airflow separation on the suction surface 126 of the blade 12 may be maximized.

[0084] FIG. 10 is a schematic diagram illustrating a relationship between distances and noise of corresponding positions of any two adjacent features in each feature layer of the present disclosure. It may be seen that the

distance between the corresponding positions of any two adjacent features 171 in each of the feature layers 17 of the above embodiment is 22 mm, which may ensure that the fan configured with the wind turbine 10 in some embodiments of the present disclosure has small noise.

[0085] In some embodiments, in each of the feature layers 17, the distances between corresponding positions of any two adjacent features 171 may be equal to each other. In this way, provided that the one or more feature layers 17 may suppress the airflow separation on the suction surface 126 of the blade 12, the blade 12 has a good product appearance and is more consistent with an industrial design and application, and a product competitiveness of the wind turbine 10 in some embodiments of the present disclosure may be improved.

[0086] Of course, in other embodiments of the present disclosure, in each of the feature layers 17, the distances between corresponding positions of any two adjacent features 171 may be different from each other and irregular. Provided that the effect of the one or more feature layers 17 in suppressing the airflow separation on the suction surface 126 of the blade 12 is improved, the distance between the corresponding positions of any two adjacent features 171 is not limited.

[0087] As shown in FIGS. 6 and 11, FIG. 11 is a structural schematic view of a fifth embodiment of a wind turbine according to the present disclosure.

[0088] In some embodiments, an orthographic projection of each of the features 171 on a reference plane is in shape of at least one selected from the group consisting of an arc, a curve, and a zigzag line. The reference plane (plane γ as shown in FIGS. 6 and 11, similarly hereinafter) is perpendicular to the central axis of the hub 11 (the axis O perpendicular to a paper direction as shown FIG. 6). In this way, the blade 12 has a good product appearance and is more consistent with an industrial design and application, and facilitates improving a product competitiveness of the wind turbine 10 in some embodiments of the present disclosure.

[0089] FIG. 6 shows that the orthographic projection of each of the features 171 on the reference plane γ is in an arc shape, and the arc shape may be a circular arc or the like. The orthographic projection of each of the features 171 shown in FIG. 6 on the reference plane γ is in a semicircular-arc shape. The orthographic projection of each of the features 171 shown in FIG. 11 on the reference plane γ is in a zigzag-line shape. Of course, in other embodiments of the present disclosure, the orthographic projection of each of the features 171 on the reference plane may be in other shapes, and the orthographic projections of the features 171 included in each of the feature layers 17 on the reference plane may be in shape of a combination of an arc, a zigzag line, and any other shapes, which is not limited.

[0090] In conclusion, the wind turbine in some embodiments of the present disclosure includes the protrusion protruding from the suction surface and close to the outer edge and the front edge, the protrusion is capable of dis-

persing the vortex formed at the blade tip by the outer edge and the front edge, and enables the suction surface of the blade to present an uneven surface appearance, thereby reducing the airflow separation on the suction surface of the blade.

[0091] Besides, the wind turbine further includes the feature layer arranged on the suction surface. The feature layer includes the features, and the features are distributed sequentially along the direction from the blade root towards the outer edge, which enables the suction surface of the blade to present an uneven surface appearance, and further reduces the airflow separation on the suction surface of the blade.

[0092] As shown in FIG. 12, FIG. 12 is structural schematic view of an embodiment of a fan according to the present disclosure.

[0093] In some embodiments, the fan 100 includes the wind turbine 10. The wind turbine 10 has been described in detail in the above embodiments and is not repeated here. In some embodiments, the fan 100 further includes a driving apparatus 20 connected to the wind turbine 10 in a transmission way to drive the wind turbine 10 to rotate, thereby generating airflow. In some embodiments, the driving apparatus 20 may be a motor or the like, which is not limited.

[0094] In some embodiments, the fan 100 may be an axial flow fan, and a concept and a working principle of the axial flow fan can be understood by those skilled in the art, and are not repeated here. The fan 100 in some embodiments may be applied to an outdoor unit of an air conditioner system or the like, especially an outdoor unit of a multi-split air conditioner system or the like, which is not limited.

[0095] As shown in FIG. 13, FIG. 13 is a schematic diagram illustrating comparison between a fan according to the present disclosure and a traditional fan with respect to relationships between airflow volumes and noises. A line I1 shows a relationship between the airflow volume and the noise of the fan in some embodiments of the present disclosure, and a line I2 shows a relationship between the airflow volume and the noise of the traditional fan. It may be seen from FIG. 13 that the fan in some embodiments of the present disclosure has smaller noise than the traditional fan when the fan in some embodiments of the present disclosure has the same airflow volume as the traditional fan.

[0096] As shown in FIG. 14, FIG. 14 is a schematic diagram illustrating comparison between a fan according to the present disclosure and a traditional fan with respect to relationships between the airflow volumes and powers. A line I3 shows a relationship between the airflow volume and a power of the fan in some embodiments of the present disclosure, and a line I4 shows a relationship between the airflow volume and a power of the traditional fan. It may be seen from FIG. 14 that the power of the fan in some embodiments of the present disclosure is lower than that of the traditional fan when the fan in some embodiments of the present disclosure has the same air-

flow volume as the traditional fan, which means that the fan in some embodiments of the present disclosure has a lower power consumption and a greater efficiency than the traditional fan.

[0097] As shown in FIG. 15, FIG. 15 is a schematic diagram illustrating comparison between a fan according to the present disclosure and a traditional fan with respect to noise levels at various frequency points. A line 15 shows noise levels at various frequency points of the wind turbine in some embodiments of the present disclosure, and a line 16 shows noise levels at various frequency point of a traditional wind turbine. It may be seen from FIG. 15 that the wind turbine in some embodiments of the present disclosure has smaller noise in the whole frequency band than the traditional fan.

[0098] As shown in FIG. 16, FIG. 16 is a structural schematic view of an embodiment of an air conditioner according to the present disclosure.

[0099] In some embodiments, the air conditioner 200 includes the fan 100. The fan 100 has been described in detail in the above embodiments and is not repeated here. The air conditioner 200 is configured in an air conditioner system. In some embodiments, the air conditioner 200 may be an outdoor unit of an air conditioner or the like, such as a multi-split outdoor unit of an air conditioner or the like, which is not limited.

[0100] In addition, in some embodiments of the present disclosure, unless otherwise expressly limited and defined, terms "connected", "coupled", "laminated", and the like should be understood in broad sense. For example, these terms may be interpreted as the two components being fixedly connected to each other, detachably connected to each other, or integrated with each other; or may be interpreted as the two components being directly connected to each other or indirectly connected to each other through an intermediate medium; or may be interpreted as the two components being communicated with each other or interacted with each other. For those skilled in the art, a specific meaning of the above terms in the present disclosure may be understood according to a specific circumstance.

[0101] It should be noted that the above embodiments are only used to explain the technical solutions of the present disclosure but not to limit it. Although the present disclosure is described in detail with reference to the aforementioned embodiments, those skilled in the art should understand that the technical solutions described in the aforementioned embodiments may be modified, or some or all of the technical features therein may be equivalently replaced. However, these modifications or substitutions do not make the essence of corresponding technical solutions out of the scope of the technical solutions of the embodiments of the present disclosure.

Claims

1. A wind turbine, comprising:

a hub;
a blade, comprising a blade root, an outer edge, and a suction surface; the blade root being connected to the hub, the outer edge being farther away from the hub than the blade root, and the suction surface being connected to the blade root and the outer edge; and
at least two first grooves, provided on the suction surface at positions close to the outer edge, the first grooves being spaced sequentially apart from each other along an extension direction of the outer edge.

2. The wind turbine as claimed in claim 1, wherein the blade comprises a pressure surface, the pressure surface is arranged opposite to the suction surface, a bottom of at least one of the first grooves is disposed closer to the pressure surface than the suction surface.

3. The wind turbine as claimed in claim 1, wherein a relationship between a length L1 of at least one of the first grooves and a distance L2 between two adjacent of the first grooves meets the following condition: $0.1 < L1/L2 < 2$.

4. The wind turbine as claimed in claim 3, wherein the relationship between the length L1 and the distance L2 meets the following condition: $L1/L2 = 1.7$ or $L1/L2 = 0.23$.

5. The wind turbine as claimed in claim 1, wherein

the suction surface comprises a first region, and the first grooves are provided in the first region; and

wherein the wind turbine defines a first circumference and a second circumference, the first circumference is centered on a center of the hub, a radius of the first circumference is a maximum distance from the blade to the center, the second circumference is centered on the center, a radius of the second circumference is a minimum distance from an edge of the first region close to the hub to the center, and a relationship between a diameter D1 of the first circumference and a diameter D2 of the second circumference meets the following condition:

$$0.9 < D2/D1 < 0.99.$$

6. The wind turbine as claimed in claim 5, wherein the relationship between the diameter D1 of the first circumference and the diameter D2 of the second circumference meets the following condition: $D2/D1 = 0.93$.

7. The wind turbine as claimed in claim 1, wherein the wind turbine comprises at least two first-groove sets, each of the first-groove sets comprises the first grooves, and the first-groove sets are spaced sequentially apart from each other along a direction from the blade root toward the outer edge.

8. The wind turbine as claimed in claim 1, wherein

the blade comprises a front edge and a rear edge, the front edge and the rear edge are arranged opposite to each other, the front edge is connected to the blade root and the outer edge, and the rear edge is connected to the blade root and the outer edge; and wherein the rear edge has a recess recessed toward the front edge, and the recess extends through the blade along a direction of thickness of the blade.

9. The wind turbine as claimed in claim 8, wherein

the suction surface comprises a second region, and the recess is provided in the second region; and wherein the wind turbine defines a first circumference and a third circumference, the first circumference is centered on a center of the hub, a radius of the first circumference is a maximum distance from the blade to the center, the third circumference is centered on the center, a radius of the third circumference is a minimum distance from an edge of the second region close to the hub to the center, and a relationship between a diameter D1 of the first circumference and a diameter D3 of the third circumference meets the following condition:

$$0.5 < D3/D1 < 0.95.$$

10. The wind turbine as claimed in claim 9, wherein the relationship between the diameter D1 of the first circumference and the diameter D3 of the third circumference meets the following condition: $D3/D1=0.78$.

11. The wind turbine as claimed in claim 1, further comprising: a plurality of second grooves, the second grooves being provided on the suction surface, the second grooves being disposed closer to the blade root than the first grooves.

12. The wind turbine as claimed in claim 1, wherein

the blade comprises a front edge, and two ends of the front edge are connected to the blade root and the outer edge; and

wherein the wind turbine comprises a protrusion arranged on the suction surface and close to the outer edge and the front edge, and the first grooves are disposed closer to the outer edge than the protrusion.

13. The wind turbine as claimed in claim 12, wherein the number of the protrusions is at least two, and the protrusions are spaced apart from each other along a direction close to the outer edge.

14. The wind turbine as claimed in claim 12, wherein the protrusion extends away from the front edge.

15. The wind turbine as claimed in claim 1, further comprising: one or more feature layers, arranged on the suction surface and comprising at least two features distributed sequentially along a direction from the blade root towards the outer edge.

16. The wind turbine as claimed in claim 15, wherein the number of the feature layers is at least two, the feature layers are distributed layer by layer in a direction away from the front edge, and a thickness of the blade at a position where each of the feature layers is located decreases layer by layer in the direction away from the front edge.

17. The wind turbine as claimed in claim 1, wherein a relationship between a diameter D1 of the wind turbine and a diameter D4 of the hub meets the following condition: $0.2 < D4/D1 < 0.4$.

18. A fan, comprising: a wind turbine, comprising:

a hub;
a blade, comprising a blade root, an outer edge, and a suction surface; the blade root being connected to the hub, the outer edge being farther away from the hub than the blade root, and the suction surface being connected to the blade root and the outer edge; and
at least two first grooves, provided on the suction surface at positions close to the outer edge and sequentially spaced apart from each other along an extension direction of the outer edge.

19. An air conditioner, comprising: the fan, comprising: a wind turbine, comprising:

a hub;
a blade, comprising a blade root, an outer edge, and a suction surface; the blade root being connected to the hub, the outer edge being farther away from the hub than the blade root, and the

suction surface being connected to the blade root and the outer edge; and
at least two first grooves, provided on the suction surface at positions close to the outer edge and sequentially spaced apart from each other along an extension direction of the outer edge.

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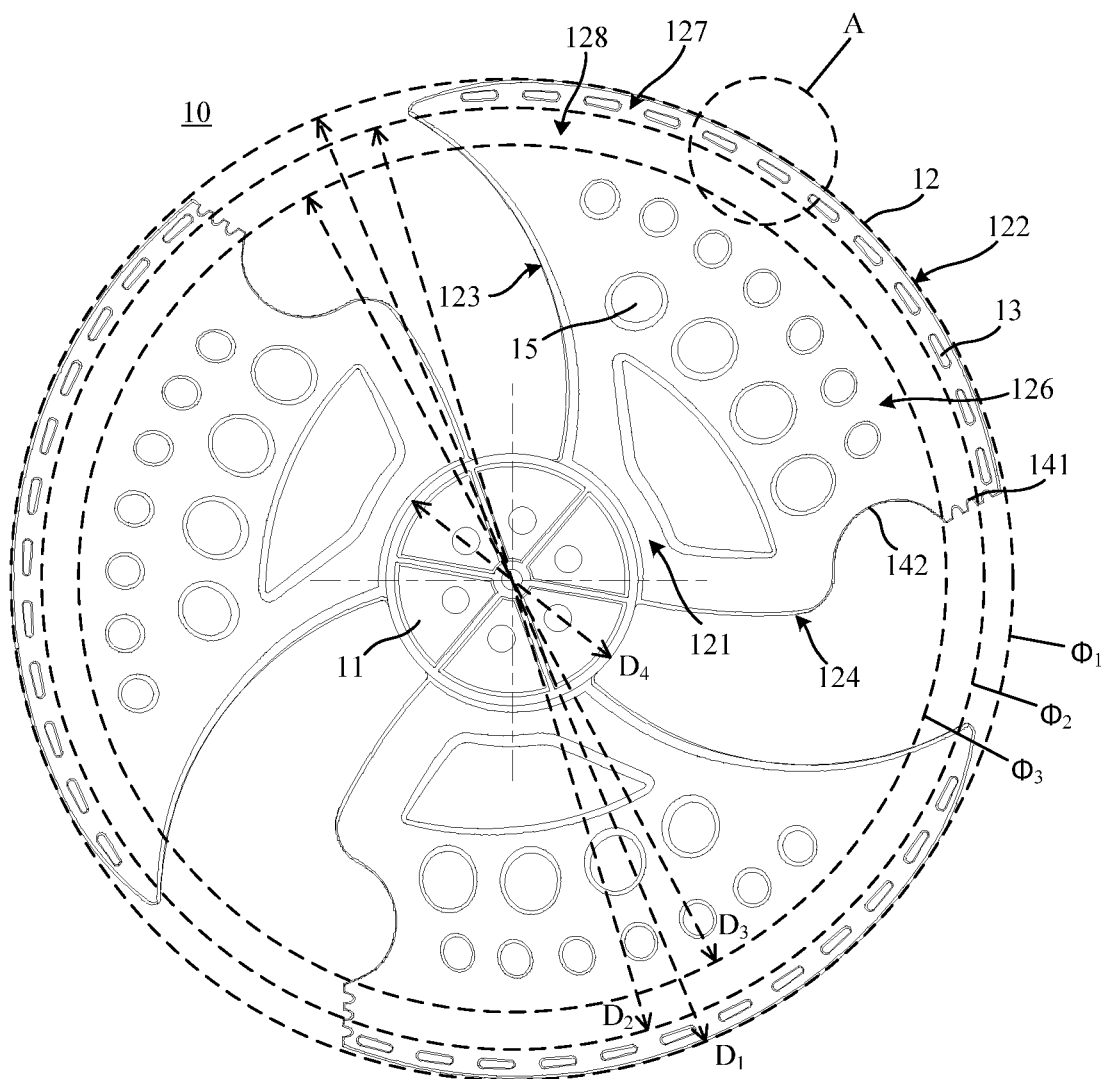


FIG. 1

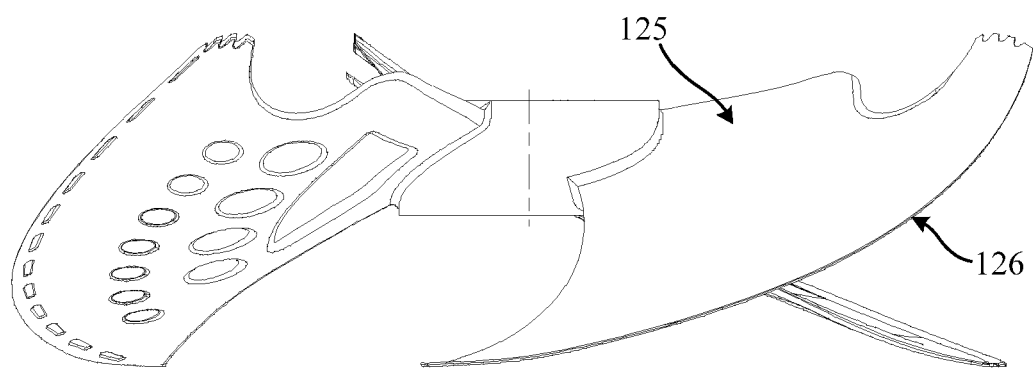


FIG. 2

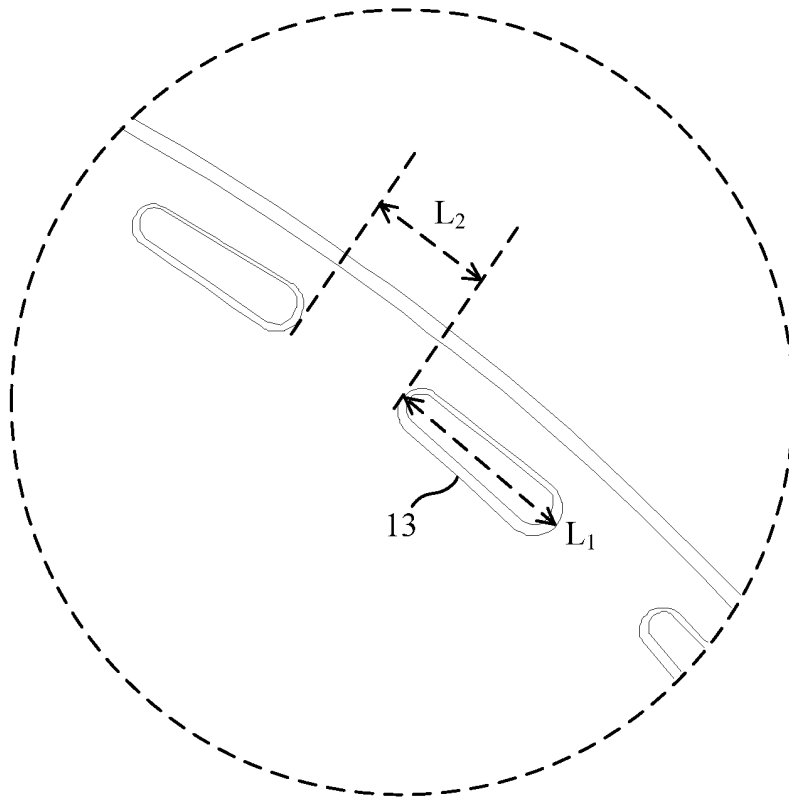


FIG. 3

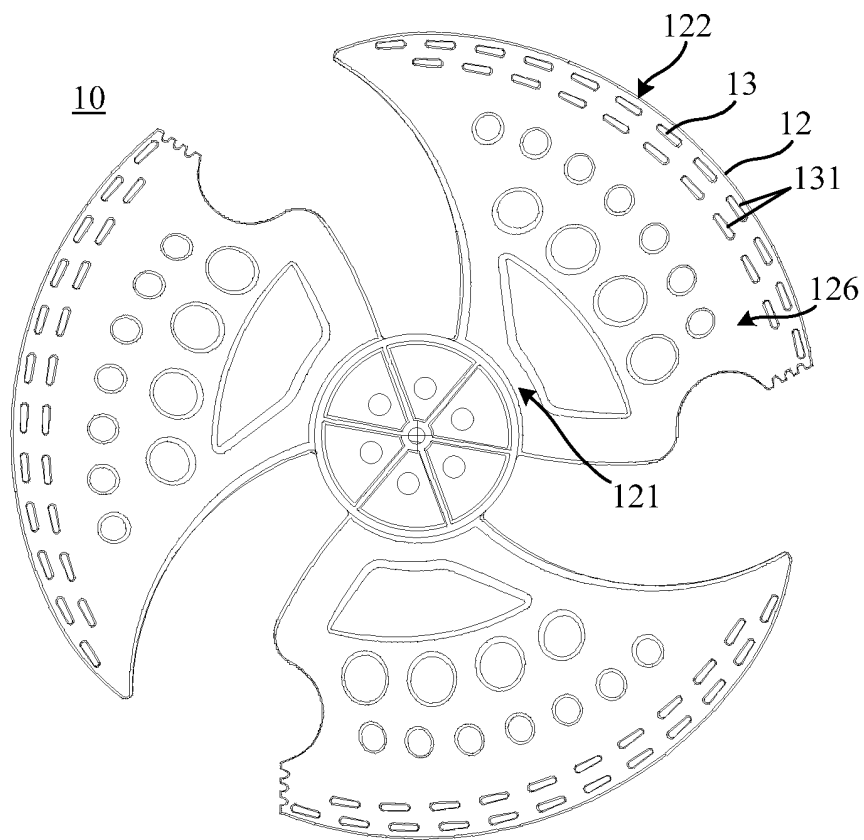


FIG. 4

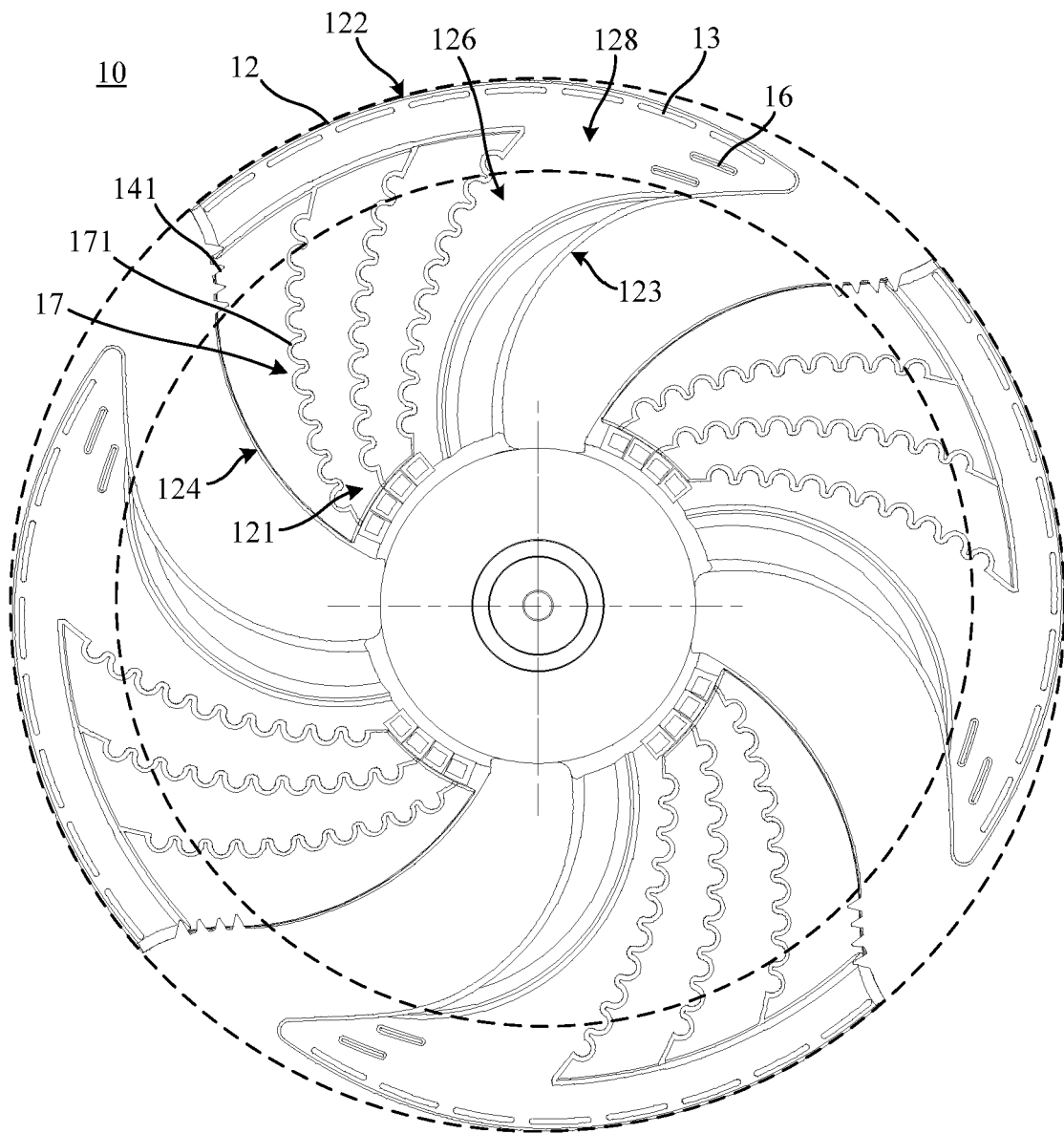


FIG. 5

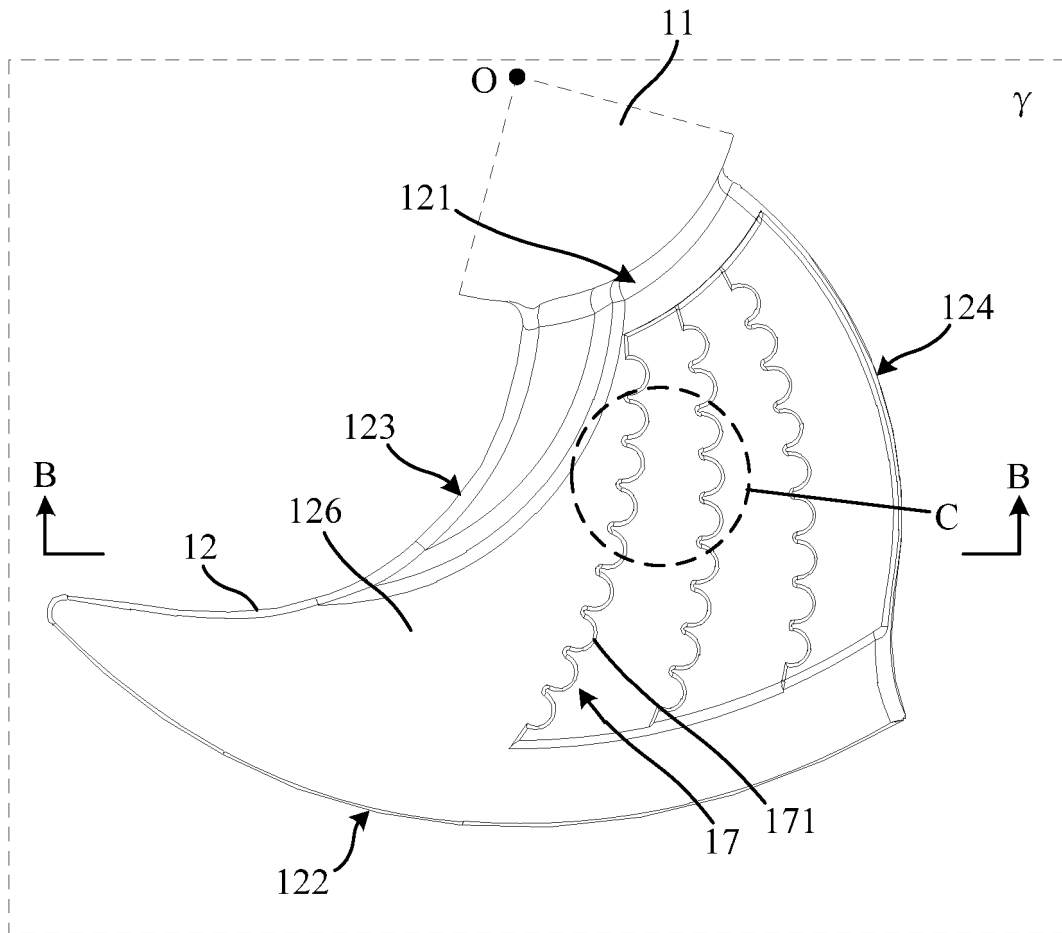


FIG. 6

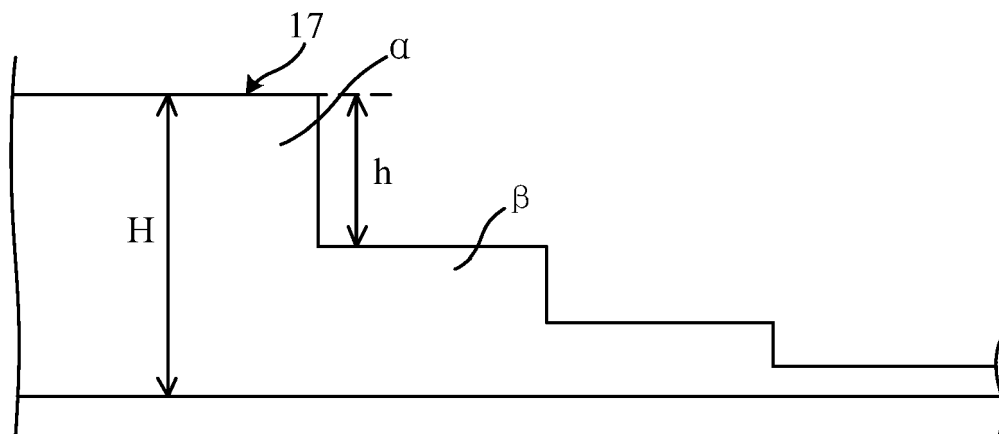


FIG. 7

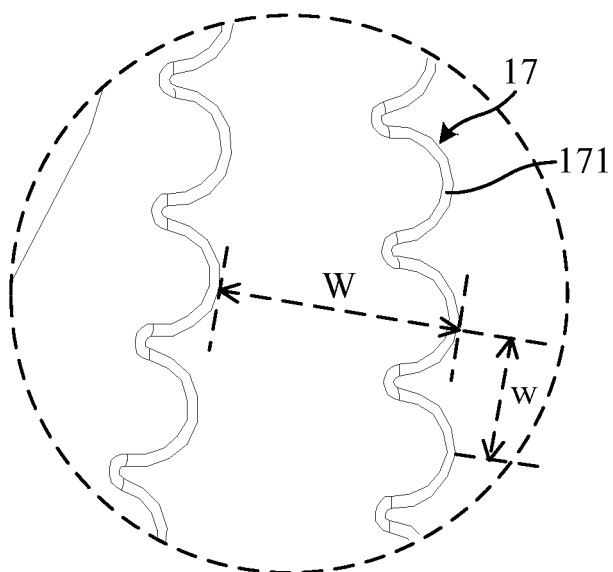


FIG. 8

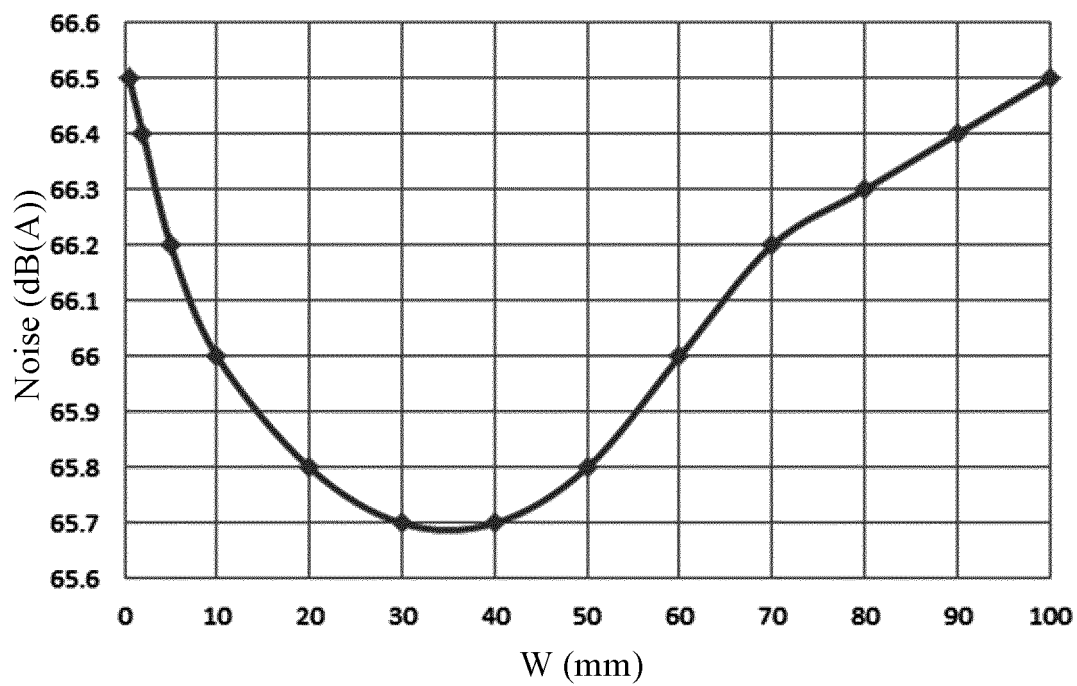


FIG. 9

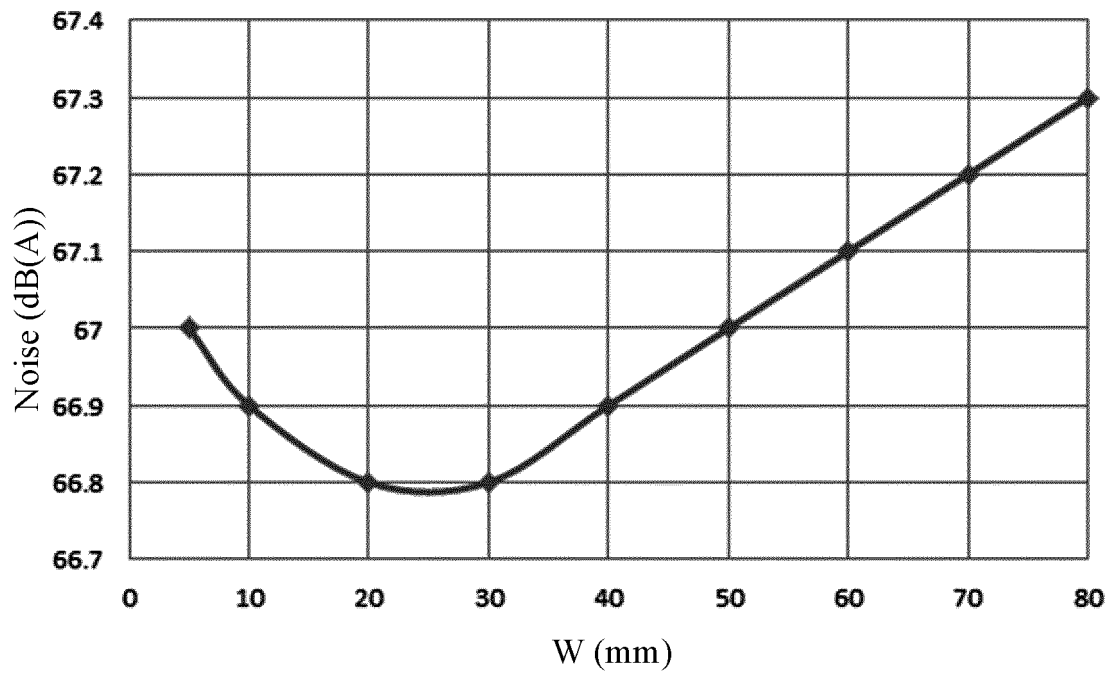


FIG. 10

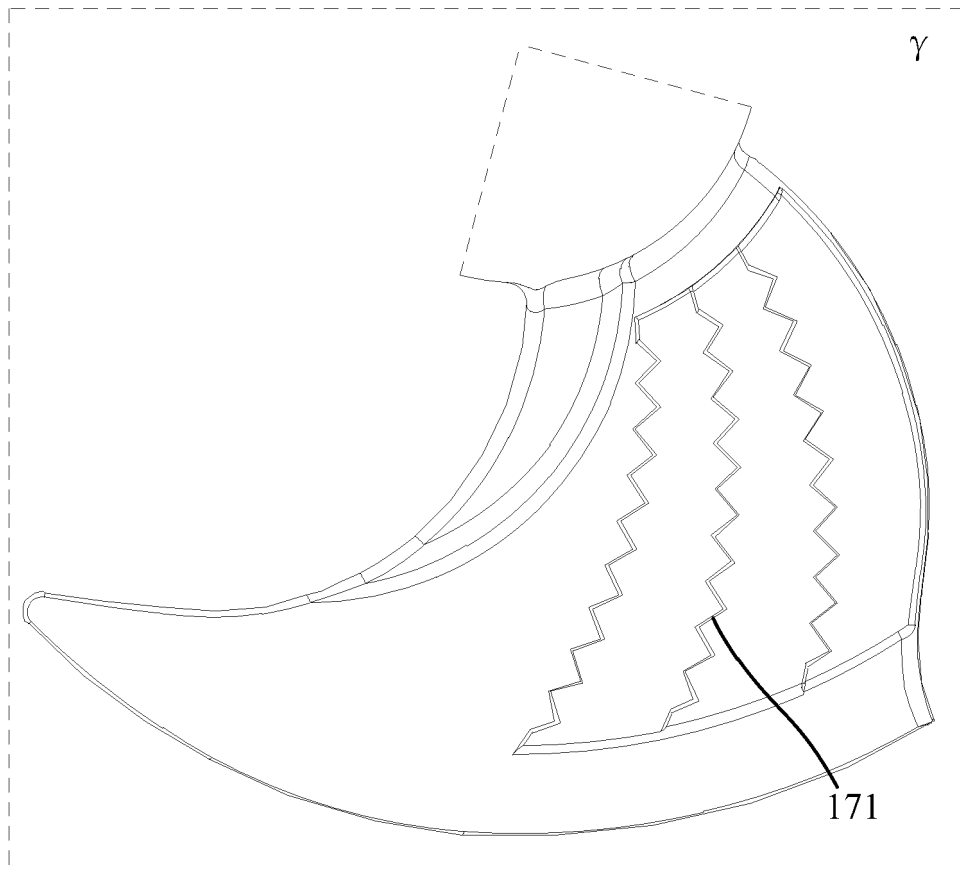


FIG. 11

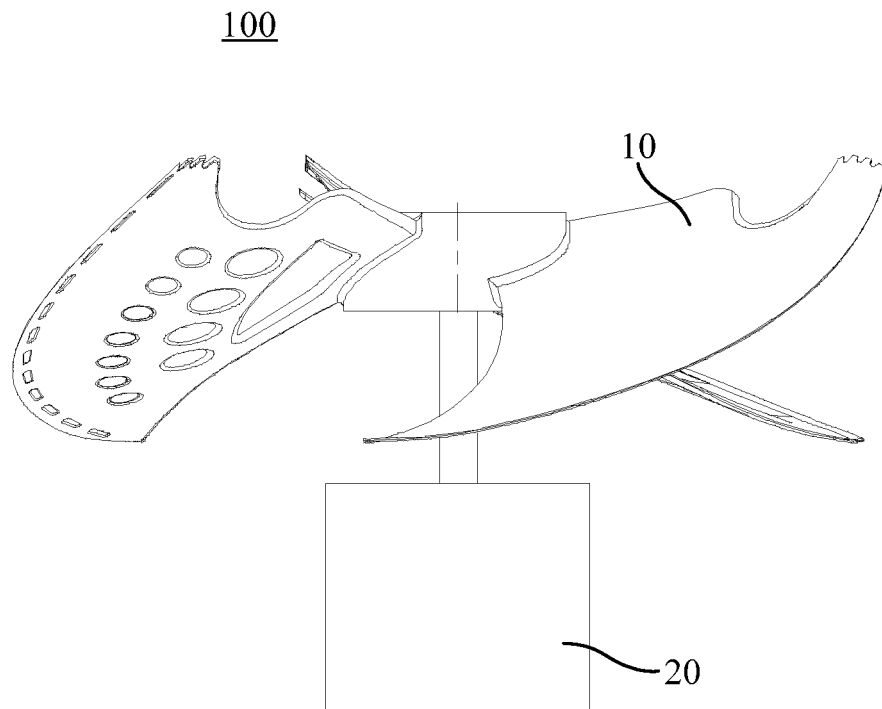


FIG. 12

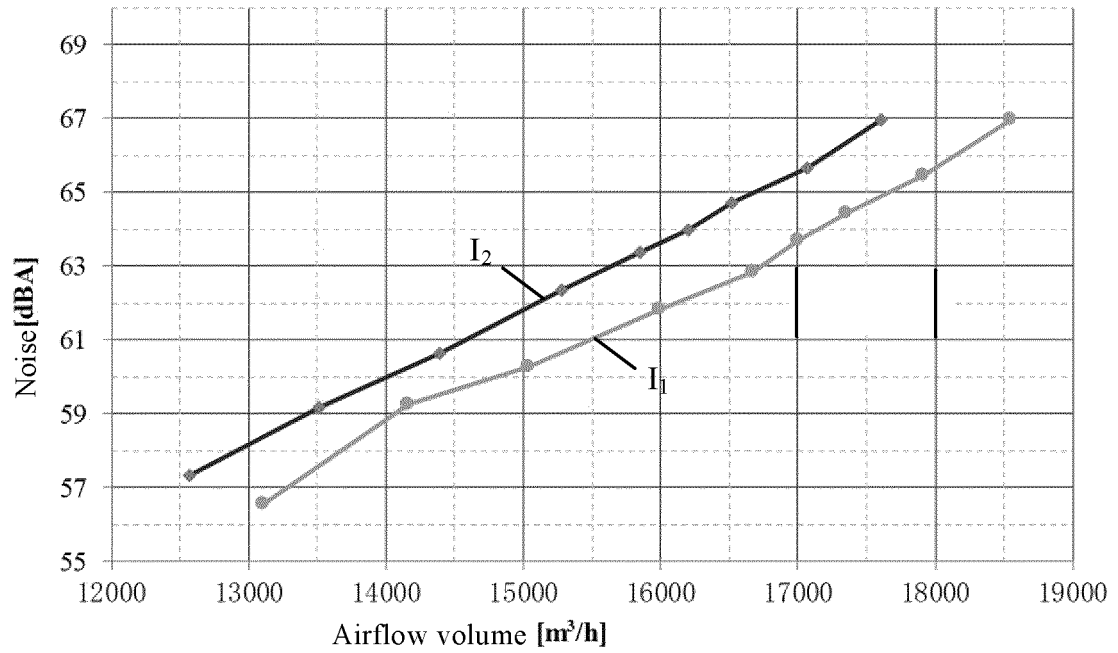


FIG. 13

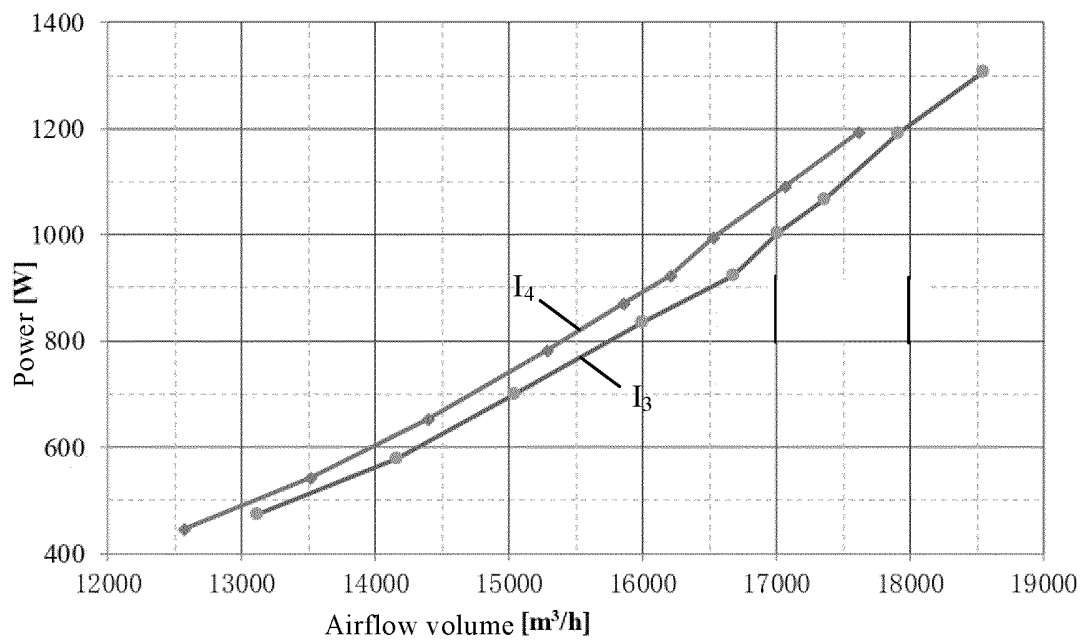


FIG. 14

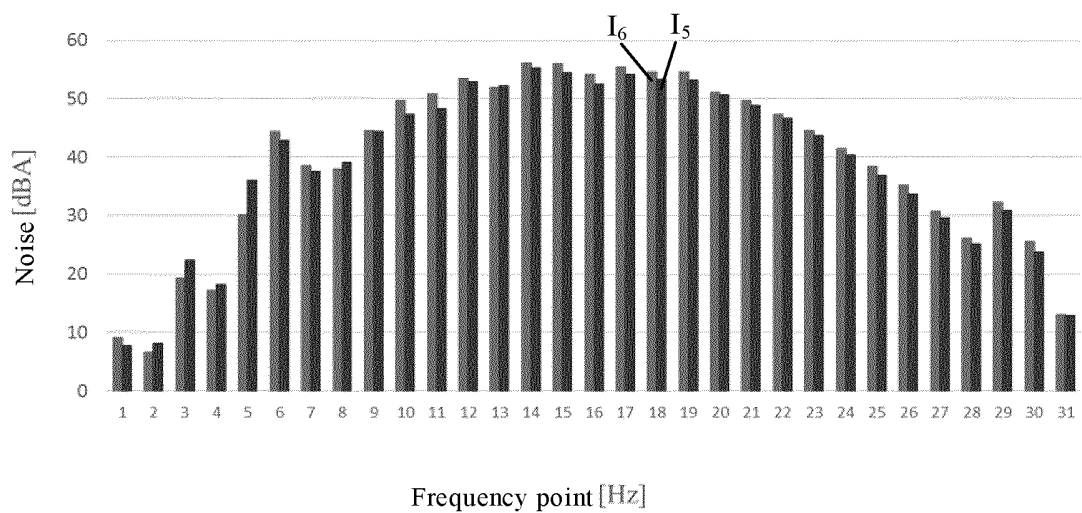


FIG. 15

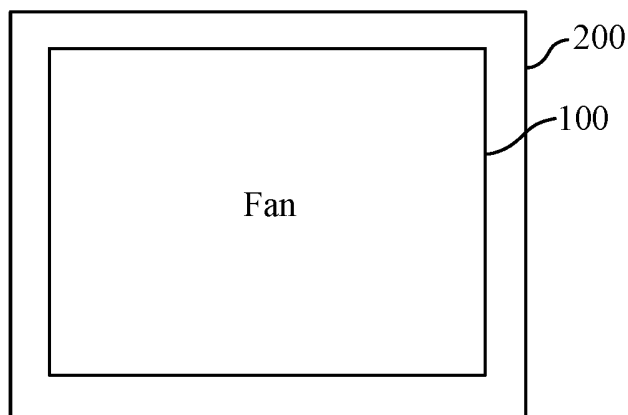


FIG. 16

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2021/121842

A. CLASSIFICATION OF SUBJECT MATTER F04D 29/32(2006.01)i; F04D 29/38(2006.01)i; F04D 29/66(2006.01)i; F04D 29/68(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 Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched																		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) CNABS; CNTXT; VEN; USTXT; EPTXT; WOTXT; CNKI: 美的暖通, 美的集团, 风轮, 叶轮, 轮毂, 叶片, 叶根, 外缘, 吸力面, 负压面, 背风面, 凹, 槽, 坑, 压力面, 长度, 间距, 半径, 直径, 前缘, 后缘, 凸, 风机, 空调器, impeller, hub, vane, blade, pressure, positive, suction, negative, surface, face, side, concave, trough, groove, slot, pit, length, space, radii, radius, semidiameter, diameter, lead+, fillet+, front+, trail+, tail+, back+, edge, end, protruding, fan, blower, air, condition																		
C. DOCUMENTS CONSIDERED TO BE RELEVANT <table border="1"> <thead> <tr> <th>Category*</th> <th>Citation of document, with indication, where appropriate, of the relevant passages</th> <th>Relevant to claim No.</th> </tr> </thead> <tbody> <tr> <td>PX</td> <td>CN 213928874 U (GUANGDONG MIDEA HEATING & VENTILATION EQUIPMENT CO., LTD. et al.) 10 August 2021 (2021-08-10) claims 1-13, description paragraphs [0003]-[0109] and figures 1-16</td> <td>1-19</td> </tr> <tr> <td>PX</td> <td>CN 112283154 A (GREE ELECTRIC APPLIANCES, INC. OF ZHUHAI) 29 January 2021 (2021-01-29) claims 1-16, description paragraphs [0008]-[0083] and figures 1-6</td> <td>1-19</td> </tr> <tr> <td>X</td> <td>CN 2451783 Y (ENGINEERING PLASTIC FACTORY, TIANDA (GROUP) CO., LTD., ANHUI et al.) 03 October 2001 (2001-10-03) description, page 1, line 1 to page 2, line 5 and figure 1</td> <td>1-7, 17-19</td> </tr> <tr> <td>Y</td> <td>CN 2451783 Y (ENGINEERING PLASTIC FACTORY, TIANDA (GROUP) CO., LTD., ANHUI et al.) 03 October 2001 (2001-10-03) description, page 1, line 1 to page 2, line 5 and figure 1</td> <td>8-16,</td> </tr> <tr> <td>Y</td> <td>CN 206221361 U (GUANGDONG MIDEA HEATING & VENTILATION EQUIPMENT CO., LTD. et al.) 06 June 2017 (2017-06-06) description, paragraphs [0031]-[0055] and figures 1-6</td> <td>8-11</td> </tr> </tbody> </table>	Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.	PX	CN 213928874 U (GUANGDONG MIDEA HEATING & VENTILATION EQUIPMENT CO., LTD. et al.) 10 August 2021 (2021-08-10) claims 1-13, description paragraphs [0003]-[0109] and figures 1-16	1-19	PX	CN 112283154 A (GREE ELECTRIC APPLIANCES, INC. OF ZHUHAI) 29 January 2021 (2021-01-29) claims 1-16, description paragraphs [0008]-[0083] and figures 1-6	1-19	X	CN 2451783 Y (ENGINEERING PLASTIC FACTORY, TIANDA (GROUP) CO., LTD., ANHUI et al.) 03 October 2001 (2001-10-03) description, page 1, line 1 to page 2, line 5 and figure 1	1-7, 17-19	Y	CN 2451783 Y (ENGINEERING PLASTIC FACTORY, TIANDA (GROUP) CO., LTD., ANHUI et al.) 03 October 2001 (2001-10-03) description, page 1, line 1 to page 2, line 5 and figure 1	8-16,	Y	CN 206221361 U (GUANGDONG MIDEA HEATING & VENTILATION EQUIPMENT CO., LTD. et al.) 06 June 2017 (2017-06-06) description, paragraphs [0031]-[0055] and figures 1-6	8-11
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Date of the actual completion of the international search 06 November 2021	Date of mailing of the international search report 29 November 2021																	
Name and mailing address of the ISA/CN China National Intellectual Property Administration (ISA/CN) No. 6, Xitucheng Road, Jimenqiao, Haidian District, Beijing 100088, China Facsimile No. (86-10)62019451	Authorized officer Telephone No.																	

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2021/121842

C. DOCUMENTS CONSIDERED TO BE RELEVANT		
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Y	CN 201671881 U (GREE ELECTRIC APPLIANCES, INC. OF ZHUHAI) 15 December 2010 (2010-12-15) description, paragraphs [0037]-[0041] and figure 2	12-14
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Information on patent family members

International application No.

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CN 213928874 U	10 August 2021	None	
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REFERENCES CITED IN THE DESCRIPTION

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- CN 202023086217 [0001]
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