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(54) **FAN FOR COOLING TOWER**

(71) Applicant: **GEA BATIGNOLLES TECHNOLOGIES THERMIQUES**, Nantes (FR)

(72) Inventors: **Jacques ARNOLD**, Nantes (FR); **Aurelien DERUELLE**, Pargny Les Reims (FR)

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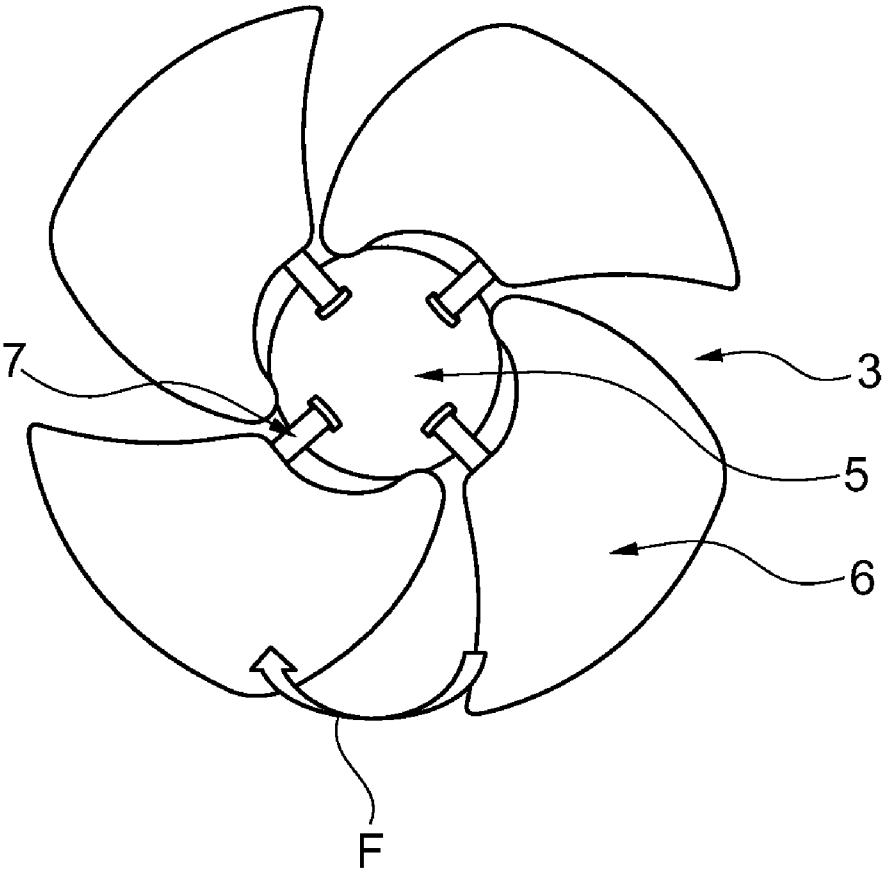
(57) **ABSTRACT**

An industrial fan for a cooling tower comprises a disc-shaped hub and a plurality of blades radially connected to the disc of the hub by means of a stud, provided on one end of each said blade, and a flange provided on one face of the hub and into which the stud of the blade is inserted with a blade angle for generating an axial air flow, each blade has such an aerodynamic profile that the pressure difference between pressure and suction faces is lower at the blade foot than at the middle of the blade chord and is higher at the blade head than at the middle of the blade chord, and it is provided a junction means for blocking the air recirculation between the pressure and suction faces at the blade foot.



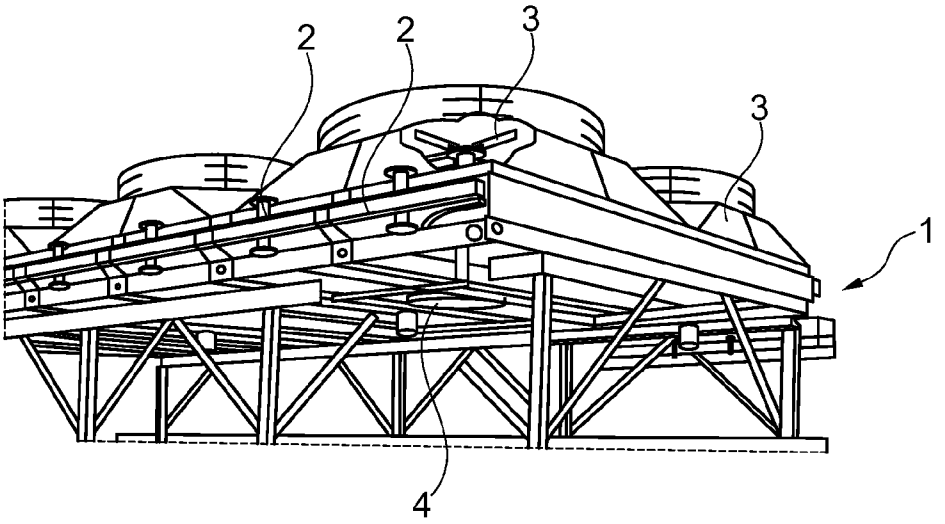


Fig. 1

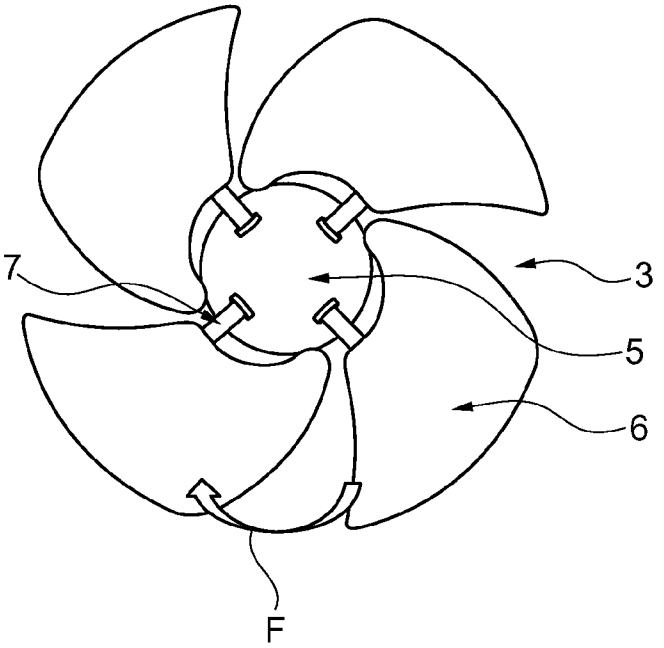


Fig. 2

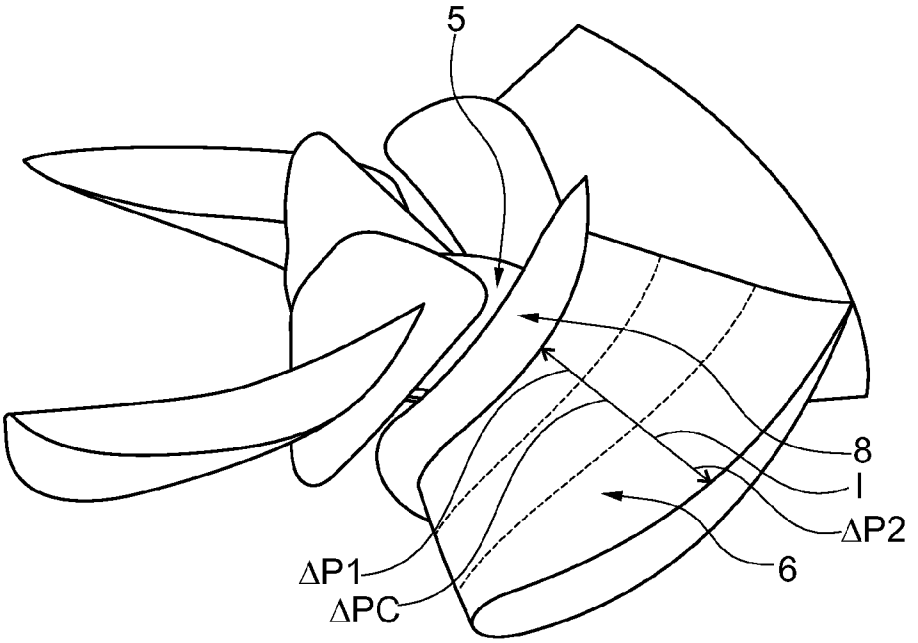


Fig. 3

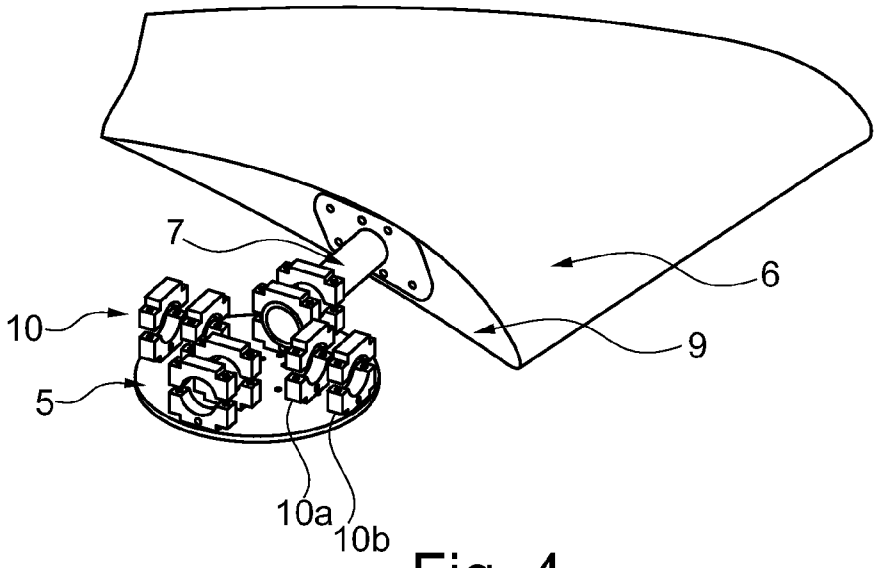


Fig. 4

FAN FOR COOLING TOWER

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims benefit of French patent application number 1458534, filed Sep. 11, 2014, which is herein incorporated by reference.

FIELD OF THE INVENTION

[0002] The invention relates to an industrial fan for cooling tower, comprising a disc-shaped hub and a plurality of blades radially connected to the hub disc by means of a stud provided on one end of each blade and a flange provided on a face of the hub and into which the stud of the blade is inserted.

[0003] Such a fan is used for example in oil, gas and chemical industries. For example, it can be used in an air heat exchanger for condensing and cooling liquids, such as liquefied natural gas, circulating in finned tube bundles. The finned tube bundles are installed on a structure and they are blown by at least one fan of this type operated by electric motors.

BACKGROUND OF THE INVENTION

Description of the Related Art

[0004] Such an industrial fan is notably disclosed in Patent Document WO-2011/126568. It can have large dimensions, the rotor diameter often exceeding 2 meters so that the blades are in practice assembled on site on the disc-shaped hub. During assembly, the blade angle for each blade is set to a value between 25° and 45° when designing the heat exchanger, with a tolerance of +/−1°.

[0005] It is also known that the effectiveness of a fan can be impaired by an air recirculation phenomenon that can occur at the base of each blade when there is sufficient space between the hub and the base of the blades to allow air circulation from the pressure face of the blade to the suction surface of the blade. The overall efficiency of the fan is thus reduced because the air velocity profile is not homogeneous. Because of this air recirculation phenomenon, about one third of the surface of the blade cannot be charged with air and is made useless.

[0006] It is also known that the fans generate a lot of noise. A source of noise in fans is due to the production of air vortices at the tip of the blades. Patent Publication US 2003/0077172 describes a fan in which the fins are placed at the ends of the blades and enable to eliminate such vortices by forming a barrier between the low pressure and the high pressure on the sides of the end of a blade. Giving a complex geometry to the blades can be a solution for reducing the noise generated by the fan. The blades can thus have a complex structure, such as a curvature at the leading and trailing edges, in particular with edges having a sweep forward angle of the blade ends relative to the radial direction. The forward curvature of the leading edges are used to desynchronize noise sources along the blade but do not reduce the source of noise itself. In addition, the air flow around the blade is made unstable, thereby reducing the effectiveness thereof.

[0007] Document WO 2011/126568 discloses a fan provided with blades each having substantially straight leading and trailing edges. This simplified blade shape has surprisingly shown that it helps to reduce the noise due to the fan operation. Nevertheless, this fan does not limit the recirculation of the air flow around the hub and thus does not have an optimum efficiency.

[0008] In order to limit the air recirculation phenomenon that can occur at the base of each blade, the gap between the hub and the blade base must be filled. Thus, Patent Document U.S. Pat. No. 6,086,330 partially gives a solution to this by disclosing an integrally molded fan in which the blades are connected to a cylindrical hub, from the trailing edge to the leading edge, over the entire length from their base. However, disadvantageously, an industrial fan of large diameter, obtained by a molding process, would be very bulky, thus making its transport to the installation site difficult and its installation laborious because of the use of lifting cranes. Moreover, after the molding process, it is not possible to adjust the angle of inclination of the blades. But, when installing industrial fans on site, adjusting the blade angle relative to a theoretic blade angle would enable to minimize the blade tip deviation and to compensate for the load losses at the air circuit.

[0009] Finally, it can be advantageous to change the blades of industrial fans directly on site during maintenance or upgrade procedures.

[0010] Document U.S. Pat. No. 3,647,317 discloses an example of an industrial fan including a part of the features of the preamble of claim **1**.

SUMMARY OF THE INVENTION

[0011] The objective of the invention is to overcome these drawbacks by proposing an industrial fan having good mechanical strength together with improved flow efficiency and making no noise.

[0012] The objective of the invention is reached by a fan for a industrial cooling tower, comprising a disc-shaped hub and a plurality of blades radially connected to the hub disc by means of a stud provided on one end of each blade and a flange provided on a face of the hub and into which the stud of the blade is inserted with a blade angle for generating an axial air flow, characterized in that each blade has such an aerodynamic profile that, over a region corresponding to 30% of the length of the blade from the blade foot, the pressure difference between pressure and suction faces is comprised between 65% and 75% of the pressure difference between pressure and suction faces at the middle of the blade chord and that, over a region corresponding to 30% of the length of the blade from the blade tip, the pressure difference between pressure and suction faces is comprises between 125% and 135% of the pressure difference between pressure and suction faces at the middle of the blade chord, and in that it is provided a junction system for blocking air recirculation between the pressure and suctions faces at the blade foot.

[0013] The fan according to the invention has a blade profile which is much more machined at the blade foot, which gives the blades an aerodynamic profile improving the performance of the industrial fan. In addition, with this stud/flange arrangement, it is possible to easily and independently adjust the radial position and the blade angle relative to the hub. The junction means fills the gap between the hub and the blade base, thereby increasing the efficiency of the fan while limiting the air recirculation at the blade foot.

[0014] The fan according to the invention can include the following features:

[0015] the junction means is a fin which extends along the pressure and suction faces perpendicularly to the surface of

the blade at the blade foot. This fin enables to use the surface at the blade base for blocking the recirculation of the air flow at the blade foot, from the pressure face to the suction face, while ensuring good aerodynamic performance.

[0016] the flange comprises at least one jaw;

[0017] the fan comprises at least three blades;

[0018] the envelope of the blades is made out of composite materials;

[0019] the envelope of the blades is in the form of a pre-shapeable fabric having reinforcing fibers;

[0020] the fiber reinforcement is made out of glass fabric;

[0021] the envelope of the blades is impregnated with a two-component material such as polyester, vinyl esters, epoxies or equivalents;

[0022] its coating can be injection molded;

[0023] the blades are hollow and stiffened by filling their cavity with a light material

[0024] such as polyurethane foam;

[0025] the blades have a pressure face having a flat surface region for receiving an inclinometer and the pitch between the angles of inclination of the blades can be adjusted with an accuracy of + or −0.1°;

[0026] each blade has an blade angle adjustable between 25° and 45°;

[0027] the position of each blade radially connected to the hub disc is adjustable by means of a screw; and

[0028] the junction means has a rotational shape in combination with sealing elements such as elastomeric or silicone seals.

[0029] The invention applies to an air heat exchanger having finned tubes characterized in that it comprises a fan according to the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0030] The present invention will be better understood and other advantages will appear from the detailed description of an embodiment given as a non-limiting example and illustrated in the annexed drawings, in which:

[0031] FIG. **1** represents a cooling tower.

[0032] FIG. **2** represents a fan according to the prior art.

[0033] FIG. **3** is a perspective view of a finned fan according to the invention.

[0034] FIG. **4** is a schematic view of the connection between the hub and a blade.

DETAILED DESCRIPTION

[0035] In FIG. **1**, it is illustrated an example of a cooling tower used in oil, gas and chemical industries. In this Figure, an air heat exchanger **1** condenses and cools liquids circulating in finned tube bundles **2**. The finned tube bundles **2** are installed on a structure and they are blown by at least one fan **3** actuated by electric motors **4**.

[0036] FIG. **2** illustrates an industrial fan **3** for a cooling tower according to the prior art. This fan **3** includes a disc-shaped hub **5** and a plurality of blades **6** radially connected to the hub disc **5** by means of a stud **7** provided on one end of each blade **6** and a flange (not shown) provided on one side of the hub disc **5** and into which the stud **7** of the blade **6** is inserted with a blade angle for generating an axial air flow.

[0037] The arrow F indicates the direction of rotation of the blades **6**.

[0038] The blades **6** have a curvature at the leading and trailing edges, particularly the leading edges have a sweep forward angle of the front ends of the blades relative to the radial direction.

[0039] Gaps are visible between the hub **5** and the base of the blades **6**. These gaps induce a recirculation of the air flow at the base of the blade **6**, from the pressure face to the suction face. This recirculation contributes to decrease the pressure on the blade **6** and to decrease of the air velocity in the region at the base of the blade **6**. Without junction means between the hub **5** and the base of the blades **6**, about a third of the surface of the blade **6** cannot be charged with air and is made useless. As the air velocity profile is not homogeneous, the overall efficiency of the fan **3** is reduced.

[0040] FIG. **3** is a perspective view of a fan according to the invention, which comprises a finned junction means arranged at the base of the blades **6** for blocking the air recirculation between the pressure face and the suction face at the blade foot. On each blade, the fin extends along the pressure face and the suction face perpendicularly to the surface of the blade **6** at the foot of the blade **6**.

[0041] The junction means **8** has a rotational shape.

[0042] In order to improve the air blocking at the blade base, the junction means can be combined with sealing elements such as elastomeric or silicone seals.

[0043] The fan **1** comprises in the example case a flat disc-shaped hub **5** supporting four blades **6** on its underside in the direction of air. The blades **6** radially extend between a blade base at the hub **5** and a blade head. They have a simplified shape. Indeed, each blade has a leading edge opposite a trailing edge, which are both straight. The centers of gravity of all the sections along the blade **6** are perfectly aligned with one another. Because of their simplified shape, the manufacturing costs for the blades **6** are reduced.

[0044] The fans **3** of the invention comprise at least three blades **6**.

[0045] As shown on one of the blades **6** in FIG. **3**, the length I of the blade **6** is divided by broken lines into three regions including a region corresponding to 30% of the length of the blade from the blade foot, a region corresponding to 30% of the length of the blade from the blade head, and a region at the middle of the blade chord. On each of these regions and at different points, pressure measurements are made between pressure and suction faces. Thus, according to the invention, each of the blades **6** shows such an aerodynamic profile that, over a region corresponding to 30% of the length of the blade from the blade foot, the pressure difference ($\Delta P1$) between pressure and suction faces is comprised between 65% and 75% of the difference pressure (ΔPC) between pressure and suction faces at the middle of the blade chord and that, over a region corresponding to 30% of the length of the blade from the blade head, the pressure difference ($\Delta P2$) between pressure and suction faces is comprised between 125% and 135% of the pressure difference (ΔPC) between pressure and suction faces at the middle of the blade chord.

[0046] According to the invention, each blade **6** has an aerodynamic profile as shown in FIG. **3** with a greater blade angle at the blade foot than at the blade head, which provides a more uniform pressure along the chord of the blade **6**.

[0047] According to the invention, each blade **6** has an aerodynamic profile as shown in FIG. **3** with a greater blade angle at the blade foot than at the blade head, which provides a more uniform pressure along the chord of the blade **6**.

[0048] According to the invention, the flange **10** includes at least one jaw.

[0049] In FIG. **4**, this flange **10** includes two jaws **10***a*, **10***b* fixed to the underside of the hub **5**. As shown in FIG. **4**, the stud **7** of a blade **6** is housed in the two jaws **10***a*, **10***b*.

[0050] According to the invention, it is possible to adjust the radial position of each blade **6** relative to the disc of the hub **5** by sliding the stud **7** in a flange **10** by means of an adjusting screw.

[0051] Still according to the invention, the blade angle of the blades **6** relative to the hub **5**, which defines the incidence of the blade relative to the air flow, forms a nominal blade angle of 36° relative to the surface of the hub **5**. According to the invention, the blade angle is adjustable between 25° and 45°. The calculated optimum blade angle is about 36°. It can be adjusted by means of an inclinometer. This inclinometer can be arranged on a perfectly flat region of the pressure face of the blade. The pitch between the angles of inclination of the blades **6** can thus be adjusted with an accuracy of + or −0.1°.

[0052] When installing a cooling tower on-site, it is advantageous to be able to adjust on site the radial position of the blades and the blade angle of the fan blades. The fan can then be brought in pieces and assembled on site. It is then no longer necessary to manufacture a fan in only one piece, for example by molding a hub **5** with the blades **6**, which can be cumbersome to transport and which also cannot be adjusted on site. It is often necessary to adjust the blade angle in order to adjust the air flow on site or to increase the performance of the heat exchanger in the future.

[0053] According to the invention, the envelope of the blades can be made out of composite materials, in the form of a pre-shapeable fabric provided with reinforcing fibers. This fiber reinforcement can be glass fabric. Advantageously, this envelope is impregnated with a curable two-component material as polyester, vinyl esters, epoxies or the like. It is also possible to injection-mold the coating.

[0054] On the other hand, the blades **6** can be hollow. They can be stiffened by filling the cavity with a lightweight material such as polyurethane foam. Because of their lightweight construction, the blades can be more easily installed.

[0055] A fan according to the invention, of at least 4 meters in diameter, has been produced and tested. It has been shown that this fan has better performance and lower noise than a so-called "Super Low Noise" fan. In addition, due to the high aerodynamic efficiency of the fan according to the invention, a low operating speed is required and thus the noise generation is limited.

[0056] The fan according to the invention even provide better performance while emitting as much sound as a prior art device. It has been shown that such a fan also has better performance while consuming less energy than a prior art fan.

[0057] The invention applies to an air heat exchanger **1** provided with finned tubes **2** comprising a fan **3** according to the invention.

1. Industrial fan for a cooling tower, comprising a disc-shaped hub and a plurality of blades radially connected to the disc of said hub by means of a stud, provided on one end of each said blade, and a flange provided on one face of the hub and into which said stud of said blade is inserted with a blade angle for generating an axial air flow, characterized in that each said blade has such an aerodynamic profile that, over a region corresponding to 30% of the length of said blade from the blade foot, the pressure difference Δ(P**1**) between pressure and suction sides edges is comprised between 65% and 75% of the pressure difference (ΔPC) between the pressure and suction faces at the middle of the blade chord and that, over a region corresponding to 30% of the length of said blade from the blade head, the pressure difference (ΔP**2**) between the pressure and suction edges is comprised between 125% and 135% of the pressure difference (ΔPC) between the pressure and suction faces at the middle of the blade chord, and in that it is provided a junction means for blocking the air recirculation between the pressure and suction faces at the blade foot.

2. Fan according to claim **1**, characterized in that said junction means is a fin which extends along the pressure and suction faces perpendicularly to the surface of said blade at the foot of said blade.

3. Fan according to claim **1**, characterized in that said flange comprises at least one jaw.

4. Fan according to claim **1**, characterized in that it comprises at least three blades.

5. Fan according to claim **1**, characterized in that the envelope of said blades is made out of composite materials.

6. Fan according to claim **1**, characterized in that the envelope of said blades is in the form of a pre-shapeable fabric with reinforcing fibers.

7. Fan according to claim **6**, characterized in that said reinforcing fiber is made out of glass fabric.

8. Fan according to claim **5**, characterized in that the envelope of said blades is impregnated with a two-component material such as polyester, vinyl esters, epoxies or the like.

9. Fan according to claim **5**, characterized in that its coating is injection molded.

10. Fan according to claim **1**, characterized in that said blades are hollow and stiffened by filling their cavity with a lightweight material such as polyurethane foam.

11. Fan according to claim **1**, characterized in that said blades have a pressure face which has a flat surface region for receiving an inclinometer and in that the pitch between the angles of inclination of said blades is adjusted with an accuracy of + or −0.1°.

12. Fan according to claim **1**, characterized in that each of said blades (**6**) has a blade angle which is adjustable between 25° and 45°.

13. Fan according to claim **1**, characterized in that the position of each of said blades radially connected to said hub disc is adjustable by means of a screw.

14. Fan according to claim **1**, characterized in that said junction means has a rotational shape and is combined with sealing elements such as elastomeric or silicone seals.

15. Air heat exchanger provided with finned tubes characterized in that it comprises a fan according to claim **1**.

* * * * *