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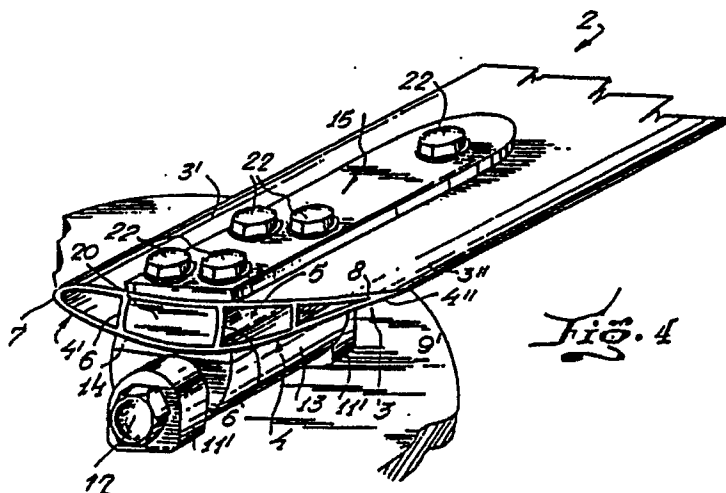
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(54) Industrial axial-flow fan having offset airfoil-to-hub mounting system for improved aerodynamic performance.

(57) An industrial fan having a plurality of blades attached to a common hub, wherein each blade has a substantially uniform aerodynamic shape the length thereof including its root, by virtue of novel attachment means which do not require added strengthening of the root deforming its aerodynamic shape, thereby improving overall performance. The attachment means include an intermediate member of each blade coupled to the hub and clamped

against one of the faces of the associated blade. Radial pivot means are provided between each intermediate member and the hub according to feathering axes offset from the blade longitudinal axes, for manually adjusting the pitch (angle of incidence) of the blades according to a required flow. The invention also includes a pneumatic system for varying the position (pitch) of the fan blades in motion.



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INDUSTRIAL AXIAL-FLOW FAN HAVING OFFSET AIRFOIL-TO-HUB MOUNTING SYSTEM FOR IMPROVED AERODYNAMIC PERFORMANCE.

Field of the Invention:

The present invention is related to fluid-flow propelling or propelled machines embodied with rotary blades or blade-like means and particularly refers to industrial fans and the like. More specifically, the invention concerns improvements in axial-flow fans having diameters ranging from less than one metre to over ten metres, which improvements are focussed on the structure, shape and mounting of the blades to the hub of the fan.

Background of the Invention:

Industrial fans of various sizes and structures are well known already. They have a number of blades or blades linked to a rotary hub which in turn is driven by a motor. Although the link between the hub and each blade is done in several different ways, it generally consists of each blade having a stud or the like either embedded in or integrated with the root of the blade and projecting longitudinally inwardly therefrom to be directly fixed at a position on the hub. For this reason the blades are subjected to loads requiring that the shape of the blade be adapted to provide additional structural strength, resulting in a deformation of the blade shape or section which downgrades the general performance of the fan. These studs must be dimensioned and the root of the blade wherein they are fitted must have an adequate section in order to bear the aerodynamic load of the blade and the fluid-flow drag, as well as dynamic, centrifugal and vibratory loads that the fan is subjected to in operation. Hence the cross-sections towards the root of the blade must forfeit a desired aerodynamic contour to increase the thickness sufficiently to fit and support the stem of each of the aforementioned studs therein. That is, axial-flow fans manufactured nowadays for industrial use must have a substantially overengrossed blade section at the root (i.e. the end of the blade fixed to the driving hub) to sustain the stud linking it to the hub. Thus the blade section is not uniform from the root to the outermost end and the changing resistance section brings about as a result a noticeable loss of aerodynamic performance and a weakened blade structure.

In addition to enabling the blade to be placed in a fixed position on the hub, the stud may also be used to adjust the pitch (angle of incidence) of the blade to enhance the performance of the assembly for a given application.

The Argentine Patent no. 206.444 for example discloses improvements in fans with adjustable pitch which include a pair of blade fastening elements placed opposite and axially separated one another. At least one of these fastening elements is engaged to a sleeve forming the hub and both the fastening elements are provided with a number of radially arranged cylindrical seats. Each seat of an element has a corresponding seat in the other element and between them they form a housing for a cylindrical portion which is fixed to the root of the blade and which has an orifice arranged coaxially relative to the respective orifices in the fixing seats.

The Argentine Patent no. 217.289 discloses a new adjustable fan blade structure comprising a plate provided with a hub with means for connecting it to the shaft of the motor. One of the faces of this plate has a number of radial concave cavities for receiving ends projecting from the root of the respective blades. A number of segments cooperating with the plate are removably fixed against that side of the plate for adjusting and fastening said ends in the corresponding cavities.

From this we may see that in both instances the blades must be provided with means capable of resisting the loads present at the roots, which means adversely affect performance although they make allowance for the blade to be turned about its shaft to adjust the pitch to flow requirements. That is to say, although the blades may be rotated and adapted to the fan's specific requirements, this is done by means coaxial with the longitudinal geometric axis of the blade to which they are a part of. The important drawback of this is that all these loads are transmitted to the structure, weakening it and upsetting its performance as a whole.

Summary of the Invention:

The object of this invention is to precisely find a solution to these drawbacks. More particularly, an object of the present invention is to provide an improved blade-to-hub mounting system and method enabling the use of blades having continuous aerodynamic cross-sections all along from the root up to the outermost tip section. Another object of the invention is a system satisfying the previous object and which further includes means for changing or adjusting the blade pitch in order to match the flow requirements to the best performance.

The novel improvements afforded by the present invention reside in that the blade maintains a constant resistant cross-section in its root where

it is affixed to the hub and where the highest aerodynamic, dynamic and centrifugal loads appear. This is achieved by attaching the blade to the hub by means of a support member which is external of the profile of the blade. This support has a longitudinal orifice for passage of a bolt or shaft about which the blade may hinge to change its pitch (angle of incidence), instead of fastening a blade stud directly to the hub as in the prior art. This bolt embodies the feathering axis of the blade about which the blade hinges each time it is necessary to change its angle of incidence to the fluid-flow direction (pitch); according to the invention, the feathering axis is offset, i.e. it does not coincide with the longitudinal axis of the blade. As a result the contour, profile or shape of the blade need not be distorted at the root, but may be shaped with its most favourable profile thus noticeably increasing the overall efficiency and output.

In fact, the blade is subjected to the same loads as heretofore, however the internal stresses and strains in its structure are much lower as a result of the design of the system of the invention for mounting the same to the hub. The only structural disturbance is given by the shear load in the blade section corresponding to the external face of the intermediate support, however this disturbance is much less than the that produced by the change in resistant section suffered by prior systems.

And, this new mounting and fastening system easily provides for the inclusion of means for changing and adjusting the pitch of the blade.

Broadly stated, according to the invention, each blade or blade of the fan is associated with a respective intermediate member linking it to the hub which is turn is driven by the electric motor. Each intermediate member is in engagement contact with one of the faces of its corresponding blade at the root thereof by means of bolts, bonding, welding or any other suitable joining means. Besides, the contact area between the intermediate member and the blade root face by no means has to be situated in the transverse middle of the root face, but within the many possibilities afforded by the present invention the connection may be situated on or near one of the edges.

From the foregoing it may be said that the fan of the present invention differs from the traditional anchorage system in that it avoids a direct connection between each blade and the hub by a stud projecting along the longitudinal axis passing by the centre of gravity of the associated blade structure. Instead, an intermediate member specially adapted to fit against the blade is provided for this purpose and which, for good measure, allows for the blade to be rotated easily about its feathering axis, although fixed-pitch blades may be provided if a specific application requires it.

The improvements set forth are just some of those outstanding in the present invention; however other remarkable features will be apparent from the following description carried out together with the appended drawings.

Brief description of the drawings:

Figures 1 and 2 are general perspective views of an axial-flow fan according to the present invention, seen from the back-pressure and pressure sides respectively.

Figure 3 is an exploded view in perspective showing the components of an blade and its mounting system to the hub according to an embodiment of the fan in figures 1 and 2.

Figure 4 is a detailed view in perspective of the anchorage means of figure 3 assembled according to the present invention.

Figure 5A is a partial cross-section view of the anchor between blade and hub of figure 4.

Figure 5B illustrates how the blade may be rotated about its feathering axis for changing the angle of incidence (pitch) in the flow direction.

Figures 6A to 6D illustrate perspective views of different positions in which the anchor means may be clamped to the blade surface.

Figure 7 shows a perspective view of the hub and the blade anchor system according to another embodiment of the invention.

Figure 8 is a cross-section view of the embodiment of figure 7.

Figure 9 is a side view in elevation showing yet another embodiment including a pitch setting mechanism.

Figure 10 shows an embodiment of a disassembled mechanism for varying the blade angle of incidence with the fan of the invention in motion.

Like reference numbers in the different drawings identify the same or like parts in the different figures.

Detailed Description of the Drawings:

Figures 1 and 2 show opposite sides of an axial-flow fan 1 which may embody the present invention. The fan 1 comprises a number of blades or blades 2 extruded in aluminum to a shape designed specially for optimum performance and efficiency of the assembly 1.

Each blade 2 is anchored to a common hub 21 by a mounting system shown in disassembled and assembled detail in figures 3 and 4 respectively. Each blade 2 has a profile, contour or shape which resembles an airplane wing design. This holds true for the entire length of the blade 2 including a root

portion 2' which is where the blade 2 is fixed to the hub 9. That is to say, as a result of an improvement devised by the invention it is unnecessary to deform this aerodynamic shape of the root portion 2' of the blade to maintain a good connection with the hub 9. Consequently the blade profile is formed by two wide curved surfaces 3 and 4 that define the pressure and backpressure sides or faces, respectively, of the blade 2. The curved faces 3 and 4 are joined together at two opposite terminal edges 7 and 8, viz. a leading edge 7 and a trailing edge 8. The leading edge of the blade 2 is a bluntly curved section 7 joining the respective edges 3', 4' of each side face 3, 4 whilst the opposite face edges 3'', 4'' meet to form a sharp trailing edge 8. The different radii of curvature of the pair of side faces 3 and 4 forms an internal space 5 therebetween which may be partitioned by ribs 6 joining the faces 3 and 4 and extending longitudinally along the length of the blade.

Of course, notwithstanding the extruded metal blade profile preferred above, other kinds may be used within the purview of the present invention. That is, the blade 2 may be of aluminum or any other suitable metallic or non-metallic material, including plastics such as reinforced resin, cast metal, steel, etc., and in shapes and sizes different from the blade 2 disclosed.

The hub 9 of the fan assembly 1 includes a solid metal disc 9 having a number of perforations 10 on its surface at equal angles which define locations for the blade 2. These perforations 10 are traversed by eyebolts 11, each of which has an eyelet 11' for a transverse hinging bolt 12 which passes through an intermediate member 13 to lock or clamp it in the place. The member 13 supports and anchors the root 2' of the blade 2 using a set of bolts 22 to fasten it. In figures 4 and 5A it may be seen that the blade 2 is engaged via its back-pressure face 4, which is just one of the different linking positions which may be adopted according to the present invention. Conversely, the bolts 22 may be done away with and the blade root 2' may be anchored using solder, adhesive or the like.

In figure 3 the intermediate member 13 is formed by a generally solid semicylindrical metal body traversed by a longitudinal orifice for the shaft of the bolt 12. In order to facilitate manufacture of the member 13 and make it simpler to conform it to different blade contours, i.e. curvatures of the rear face 4, the intermediate semicylindrical member 13 is provided with a longitudinal flat face which is associated with a complementary intermediate plate 14 provided with a companion flat face clamped in close contact therewith and an opposite, curved face which copies the surface of the blade face 4.

The member 13 not only serves for the con-

nection between the blades 2 and the hub disc 9' but also forms part of a regulator device for changing the blade pitch, i.e. for adjusting the tilt angle of the blade 2 relative to the disc 9'. Once the blade 2 is assembled by means of this member 13, its pitch may be changed by loosening the bolt 12 enough to rotate the member 13 round to the desired pitch angle. Thereafter the bolt 12 is tightened again to lock the attachment means 13 back in place. Thus it may be seen that the blade pitch may be quickly and easily adjusted with the system of the invention.

This straightforward and ingenious assembly for anchoring the blade 2 to the hub disc 9' essentially comprises the intermediate member 13 held in place by the bolt 12 engaging the disc 9' in the fan's radial direction. The simple bolt 12 serves several different purposes since, in addition to securing the blade 2 in its proper position on the hub equidistant from the adjacent blades of the fan 1, it provides the hinge for rotating the attachment member 13 to adjust the blade pitch, thereby defining the feathering axis of the blade, and in its normally tight condition it clamps the member 13 to lock the blade 2 with a desired fixed pitch.

The coupling between the intermediate member 13 and each blade 12 may be embodied in different positions. For example, in figure 6A the mounting means 13-14 make contact at the breadth centre of the back-pressure side 4 of the blade 2. In the embodiment of figure 6B this contact is established in a similar position on the opposite pressure face 3, although other positions are possible within the scope of the present invention on any other point on the blade surface provided that it is eccentric of the blades longitudinal axis. Such are the positions shown in figures 6C and 6D in which the intermediate means 13 is integrated or fixed into the edges 7 and 8 respectively of the root portion 2' of the blade 2. That is to say, the mounting system of the invention essentially resides in the intermediate member 13 defining the feathering axis generally parallel to and spaced from the longitudinal axis of the blade 2, although its axial position may vary according to different embodiments so long as it is eccentric, this feathering axis offset requirement being another essential condition of the invention.

A condition resulting from the forementioned and that the blades 2 are located in a plane parallel to the hub disc 9', either in front or behind the latter, is that the feathering axis is generally placed external of the blade's contour so that the blades' resistant section corresponds to the maximum bending moment.

The position of the rest of the components 11, 11', 12, 14, 15, 22, etc., must be carefully selected according to the actual link point of the intermedi-

ate member 13 on the blade 2 in order to reduce as much as possible the stresses which appear in operation at the root 2', thus optimizing the design of the assembly 1. When the ratio of the length of the blade 2, that is the diameter of the fan 1, to the diameter of the hub 21 is small, such as in an industrial fan in the forementioned range of between 1 and 10 metres, the blade 2 may be considered as formed of relatively quite slender blades.

In this case, the intermediate plate 14 may be lengthened to project radially outwards in relation to the semicylindrical member 14 so as to provide a larger contact surface area on the surface of the face 4. Furthermore and additionally, a supplementary plate 15 (figure 4) may be placed on the face 3 to increase the resistant moment of the section. Although this may cause some aerodynamic disturbance, it will hardly be significant by virtue of the small thickness of the plates 14 and 15, and also considering the fact that with a small hub diameter the tangential velocity of the root section 2' or the blade 2 is very slow, hence the overall effect of this disturbance on the performance is negligible. In actual fact the plate sections scarcely cause any disturbance whatsoever.

In fans 1 having long blades 2, in addition to plates 14 and 15, a solid filler substance 20 may be provided inside and between the central partitions 6. This filler 20, together with the plates 14 and 15, may help to increase the blade's resistant and inertia moments. The filler 20 is design to a convenient length and located to be traversed by the bolts 22 fastening the plates 14 and 15 to the blade and the intermediate member 13.

Although the holes for the bolts 22 may structurally interfere with the blade 2 and the filler 20, the presence of the complementary and supplementary plates 14 and 15 more than compensate for any weakening in these sections so that, if the blade 2 is properly designed, there is no danger of fatigue in an blade section containing bolts 22. In actual fact the risk of fatigue appear to be greater in the sections of the blade 2 not covered by the blade 14 and 15.

As previously remarked different alternatives to the embodiment set forth in figures 3, 4 and 5A may be considered within the pervue of the invention. Another possibility is to replace the eyebolts 11 with integral projections 16 either stamped, cast or moulded on the structure of the hub disc 9' itself. This is shown in figures 7 and 8 wherein a given blade 2 is associated with a pair of radially-spaced projections 16 traversed by the hinge bolt 12. This bolt 12 may be identical in form and function to the feathering bolt 12 of figure 3 such that it engages the intermediate member 13 in the same way and defines the blade pitch adjustment

axis. This alternative is simply shown as an example of the many different embodiments that may be bred in linea with the principles of the present invention which, to be emphatic, consists in connecting the blade 2 to the hub 21 through means different in place and shape from the prior art stud which is coaxial with the longitudinal axis of the blade and therefore longitudinally inside the contour of the root.

Figure 7 also shows how a corner 24 of the trailing edge 8 may be cut out from the root portion 2' of each blade 2 to make room for adjacent blades in fans requiring, for instance, a large number of blades 2, a small hub 21 or broad blades 2. Except in the connection position suggested in figure 6C which should not be adapted in this instance, this will not be detrimental to the mechanical properties of the blade because this trailing-edge corner 24 does not transmit any forces to the hub 21 and therefore does not lessen the resistance of the blade structure 2.

Figures 5A and 8 also show how the intermediate member 13 (any consequently the blade 2 also) is clamped in place by the pressure of the nut 12' on the bolt 12. In figure 8, this pressure is exerted by the nut 12' and a locknut 2'', the former pressing against a bushing 26 which pushes the coupling member 13 against the outer surface 16' of the hub projection 16 such that the member 13 is held in place by friction between its surface 13' and the hub surface 16'. Here again the hub 21 and blades 2 are held by stud-bolts; if a securer lock is required washers of a material having a high friction coefficient may be inserted between the parts clamped together.

In figure 5B it is shown how the coupler member 13, the bolt 12 and the rest of the attachment means described hereinbefore let each blade 2 be positioned in a selected pitch-angle according to the flow requirements of the fan 1. Thus it can be seen that with the means of the invention a large range of pitch angles is afforded, such that the position of the blade 2 may be chosen from as snug up to the disc 9' as possible up to rather large pitches (such as the position indicated by dashed lines 28), by rotating the blade about the feathering axis defined by the shaft of the bolt 12 such that the trailing edge 8 describes an arc 17.

Airfoils 2 of industrial fans are sometimes subjected to considerable torsion and stress magnitudes in certain applications. In these instances, additional pitch locking means 18-19 may be arranged between the hub 21 and each blade 2 to maintain the blade at a fixed pitch angle. Figure 9 shows a suitable locking arrangement which comprises a pair of anchor ears 19, one fitted to the back-pressure face 4 of the blades 2 at a point near the trailing edge 8 while the other anchor ear

19 is fitted to an opposite point of the hub disc 9'. Such ears 19 may be embodied by means of respective eyebolts. One or more connecting rods 18 join the pair of anchor ears 19 to hold the blade 2 at the desired pitch angle. The pitch may be varied in steps by inserting or removing connecting rods 18 as desired.

The fan of the invention may include an accessory device by virtue of which the blade pitch may be changed with the fan in motion. Figure 10 shows two embodiments for a novel control mechanism 30 for this purpose suited to the fan 1 of the present invention. Differed control systems may be used such as mechanical, electrical, hydraulic, etc. or pneumatic as is the case disclosed in figure 10. The latter system is specially suitable in petrochemical and siderurgical plants and those already having a central compressed air installation available.

The pneumatic system 30 of figure 10 comprises a 2-way rotary distributor 31 which is used to transport the air from a stationary pipeline to the rotary fan system 1. One line 32 carries air at a pressure of between 3 and 7 atmospheres to a pneumatic piston 33, while the remaining line 34 supplies a standard positioning device 35 for controlling the position of the piston 33. The air reaching the piston 33 under pressure compresses a recovery spring 36 and urges a lever assembly 37 joining the piston 33 to each fan blade 2 to displace the latter. The spring 36 urges the blades 2 of the fan back to a preset reference position should the control mechanism 30 break down. The reference position may be set to either minimum or maximum pitch.

According to one alternative shown on the left-hand side of figure 10, bearings means 40, 41 are mounted inside the intermediate member 13, including bearings 40 to bear the bending moment and bearings 41 which bear the axial compression force. The bolt 12 joins and transmits the bearing load to the hub 21. A different alternative is shown on the right-hand side whereby the bearings 41, 40 are mounted to the eyebolts 11 to transmit the bending moments and the centrifugal forces to the hub 21.

From all the foregoing it may be seen that the invention, by means of a rather straightforward and practical construction, substantially improves the performance of industrial fans, and in particular the aerodynamic contour is enhanced to its utmost along the length of the blade 2, since there is no significant aerodynamic distortion near the root caused by the anchors on the driving hub 21. At the same time, not only is the best aerodynamic contour maintained and the structure protected, but the fan 1 is also less prone to fatigue than traditional fans.

Although the essential features of the invention have been brought out by means of preferred embodiments disclosed herein, other alternative forms may be considered within the purview of the appended claims. For instance, the hub end of the blade 2 may be left open as shown in figure 4, or else conveniently covered with any suitable substance like rubber foam to avoid whistling at certain speeds. Either alternative has scarcely and negative effect on the fan performance.

Claims

1. In a fan apparatus including a driving hub and a set of driven blades, an attachment device fixed to each hub for mounting and anchoring an associated one of said blades thereto, said attachment device engaging said associated blade at a point eccentric of the longitudinal axis extending radially of the fan and through the centre of gravity of said blade.
2. The attachment device of claim 1, and including means for changing the pitch of said associated blade.
3. The attachment device of claim 2, wherein said pitch changing means includes means for locking said associated blade in a selected position defining a pitch angle relative to said hub.
4. The attachment device of claim 2, and comprising an intermediate member which includes means for joining said member in contact with a root portion of said blade such that both are integrated with one another, and means for coupling said member to said hub at a certain angular position thereof.
5. The attachment device of claim 4, wherein said coupling means comprises a bolt extending in a radial position relative said hub, and said intermediate member further includes means for pivoting about said bolt to change the pitch of said associated blade.
6. The attachment device of claim 5, wherein said pitch changing means and said locking means further include rod means connecting a point of said hub with a second point of said blade separate from the first point of said blade where the attachment device is engaged, said rod means including means for adjusting the distance between said hub point and said second blade point.
7. The attachment device of claim 5, wherein said intermediate member is a substantially semi-cylindrical body provided with a longitudinal orifice for passage of said bolt.
8. The attachment device of claim 4, further including plate means fixed to both faces of the blade, one of said plate means having a surface in close contact with said intermediate member and an op-

posite surface in close contact with said root portion.

9. The attachment device of claim 8, wherein said plate means are relatively slender and longer than said intermediate member, whereby when mounted to said associated blade the plate means project radially outwards relative to said intermediate member.

10. A method for assembling a fan, the fan including a driving hub and a plurality of blades for causing a flow of surrounding fluid when rotated, each blade comprising a pressure side face and a backpressure side face joined together at a pair of opposite longitudinal edges, all shaped to form substantially aerodynamic cross-sections the length of the blade, the improvement whereby said each blade is attached to said hub through at least one of said faces and said edges to define a feathering axis extending substantially radially of the hub and offset from a longitudinal axis passing through the centre of gravity of the associated blade.

11. The method of claim 10, wherein said associated blade may be pivoted about said feathering axis to change the pitch of the blade.

12. The method of claim 11, wherein said each blade is clamped in place at a desired fixed pitch.

13. The method of claim 10, wherein said each blade is anchored by means of a member having a substantial contact surface clamped against one of said faces of said associated blade, said member surface having a substantial area in close contact with said one blade face and a shape which is complementary to the shape of said blade face.

14. A fan comprising a hub, motor means for rotatably driving said hub, a plurality of rotary blades for causing a fluid to flow in an axial direction of the fan, each blade comprising a pressure side face, a back-pressure side face and leading and trailing edges joining said faces, and attachment means for anchoring each of said blades at a predetermined position on said hub to be rotatably driven thereby, the improvement whereby said blades have a substantially aerodynamic shape which is substantially uniform along the length of the blade, said attachment means comprising a plurality of intermediate members, one for each of said blades, each of said intermediate members being linked to said hub according to said predetermined position of the associated blade, and each intermediate members fixedly engages the associated blade at a point or area on at least one of said faces and edges and spaced from all longitudinal axes internal of said associated blade.

15. The fan of claim 14, wherein said attachment means further include means for changing the angle of incidence of said blades and locking the blades to a desired fixed pitch position.

16. The fan of claim 15, wherein each of said

intermediate members includes means for clamping it against one of said faces of the associated blade and means which in normal operation of the fan are locked in place for pivotably coupling the intermediate member to said hub, whereby said coupling means may be unlocked for pivoting the intermediate member about a feathering axis substantially parallel to the longitudinal axis of said associated blade and then locked back in place to maintain the associated blade at said fixed pitch position.

17. The fan of claim 16, wherein said intermediate member comprises a generally semicylindrical body including a longitudinal flat face and a longitudinal orifice parallel to said flat face, said clamping means are adapted to match said flat face of said semicylindrical body to said one airfoil face, and said coupling means further includes a bolt engaging said hub in an approximately radial direction and passing through said orifice of the semicylindrical body, whereby said bolt may be manually loosened to allow the pitch of said associated blade to be changed and then manually retightened to lock the semicylindrical body in a fixed position on said hub.

18. The fan of claim 17, wherein said body is locked in position by friction between a flat surface fixed to said hub and a flat surface corresponding to one of the semicircular end faces of said body under contact pressure caused by the tightening of said bolt.

19. The fan of claim 17, wherein said clamping means comprise a pair of elongated plates each having a differently curved face which complements the shape of a respective one of said blade faces with which it is clamped in close contact, one of said plates having a flat face opposite its curved face and clamped against said flat face of said semicylindrical body.

20. The fan of claim 19, wherein said plates are relatively slender and longer than said body such that they project radially outwards along part of the length of said associated blade.

21. The fan of claim 15, wherein said means for changing and locking the angle of incidence of said blades to a desired position are operative with the fan in motion, and comprise means for moving said blades and intermediate members under control of a fluid under pressure and means for transporting said control fluid from a supply external of the fan to said fluid-controlled moving means.

22. The fan of claim 21, wherein said transporting means includes a rotary distributor, and said fluid-controlled moving means comprise piston means the position of which is governed by said control fluid and lever means connecting said piston means to said blades whereby the angle of incidence of said blades in the flow direction de-

pende on said piston position.

23. The fan of claim 14, wherein said aerodynamic shape of the blades comprises substantially constant cross-sections down the length thereof.

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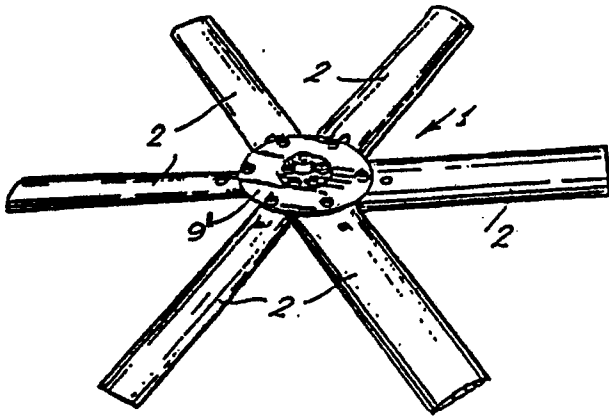


Fig. 1

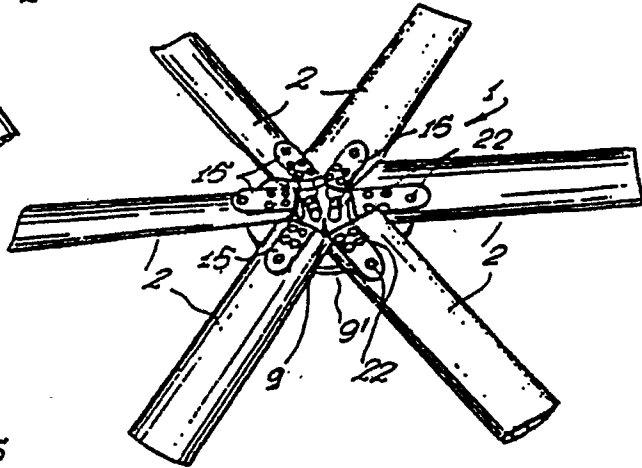


Fig. 2

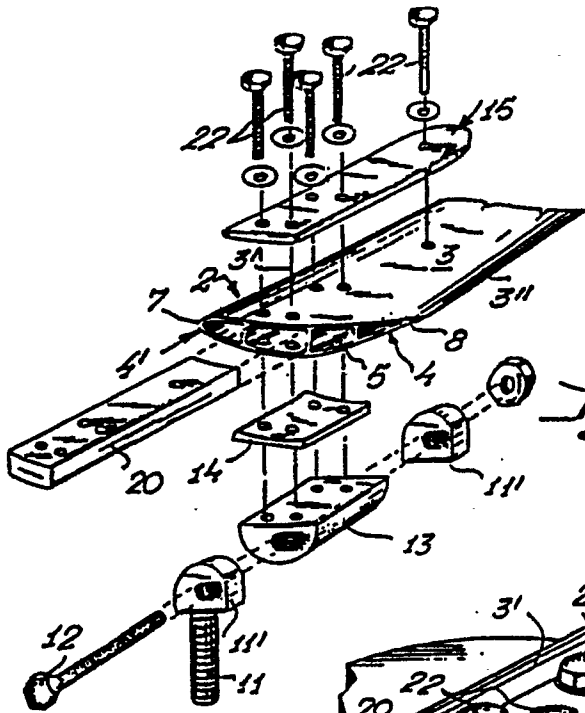


Fig. 3

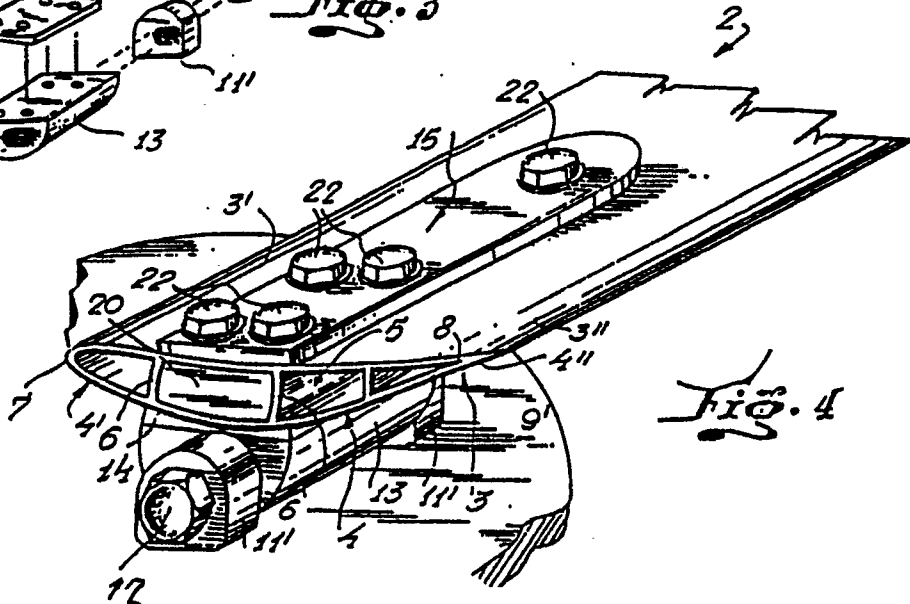


Fig. 4

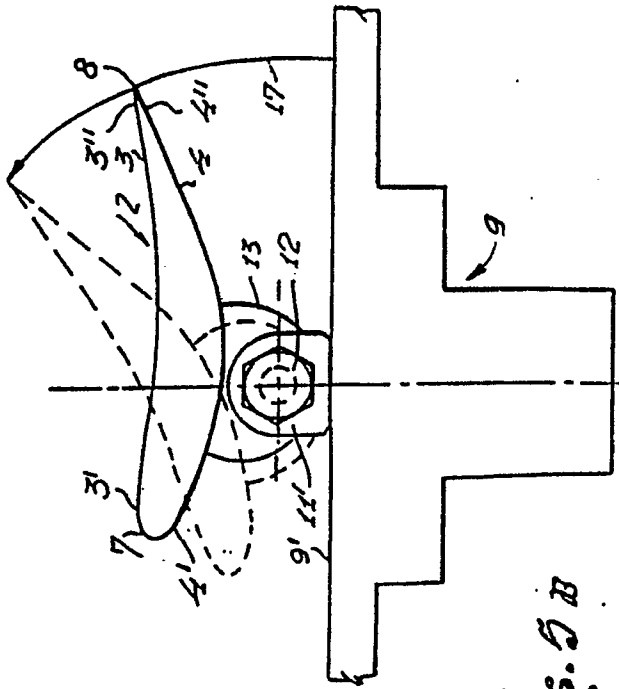


FIG. 5 B

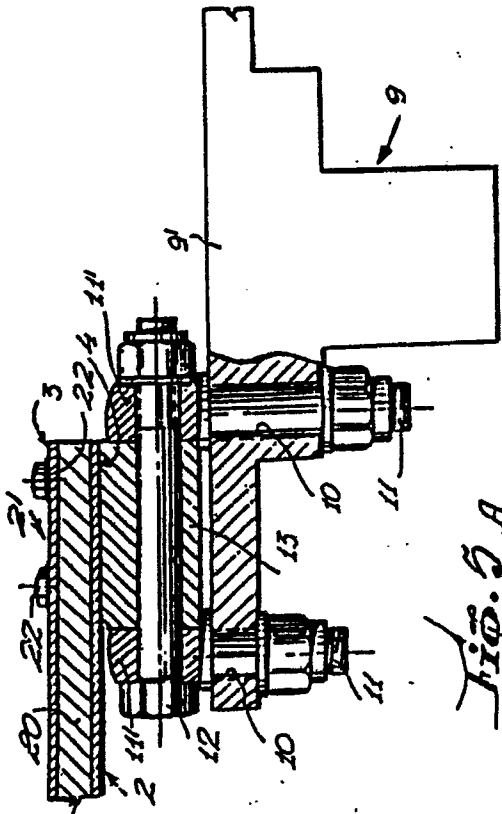


FIG. 5 A

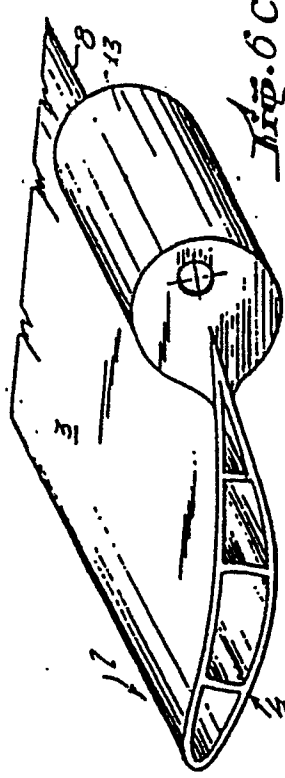


FIG. 6 C



FIG. 6 D



FIG. 6 A

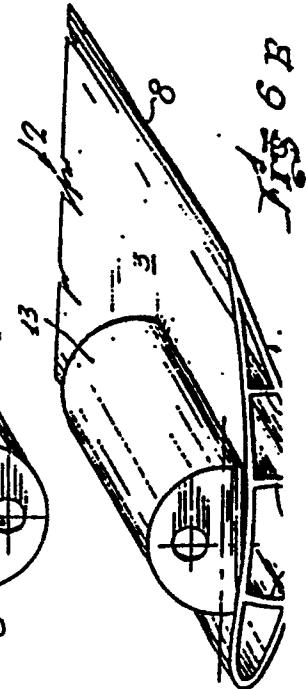


FIG. 6 B

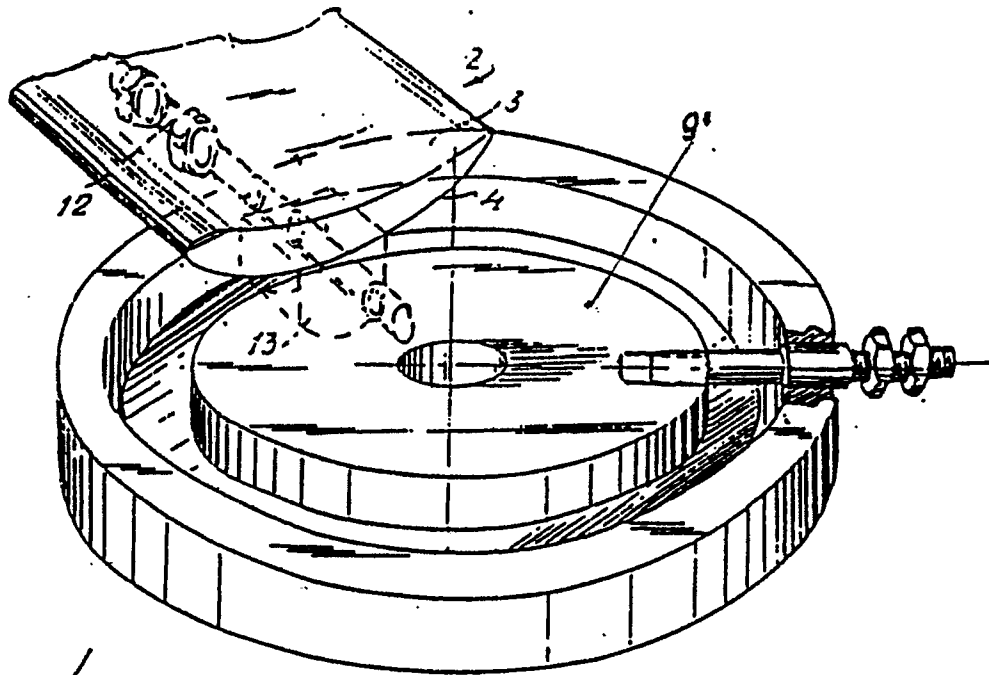


Fig. 7

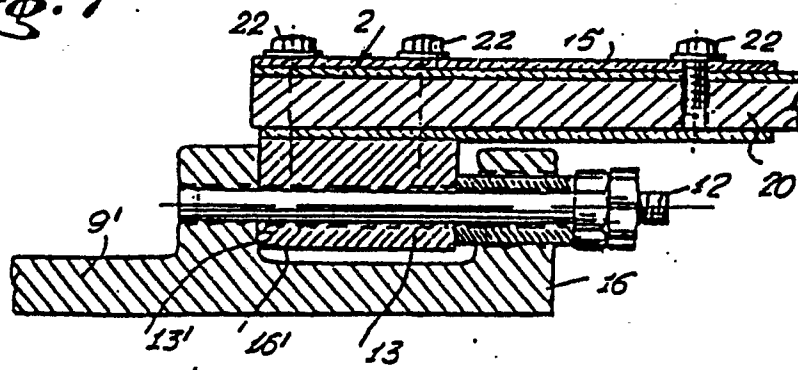


Fig. 8

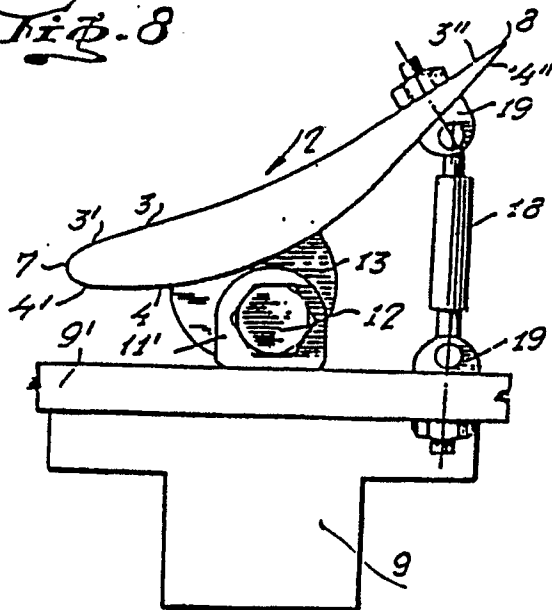


Fig. 9

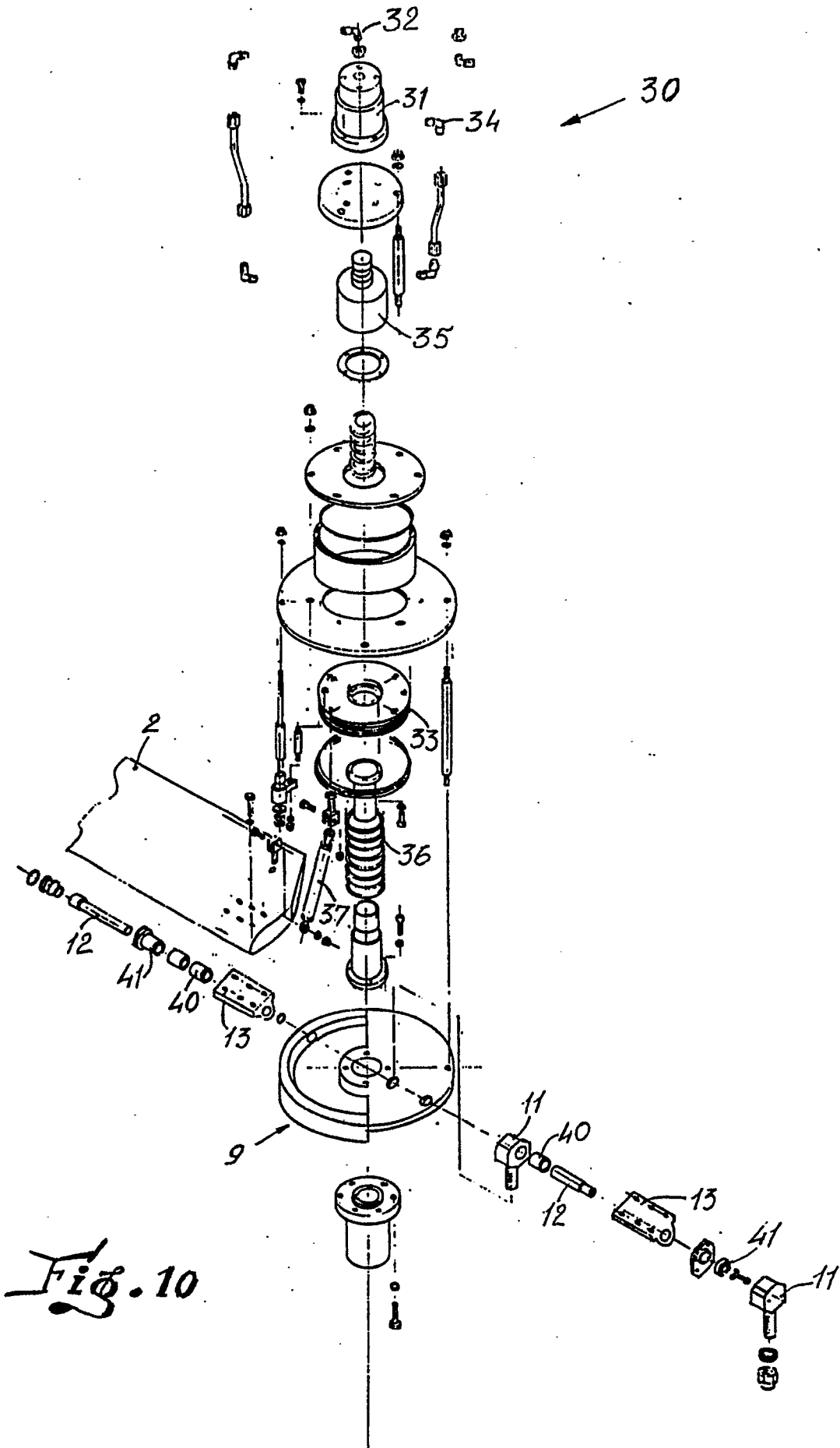


Fig. 10