

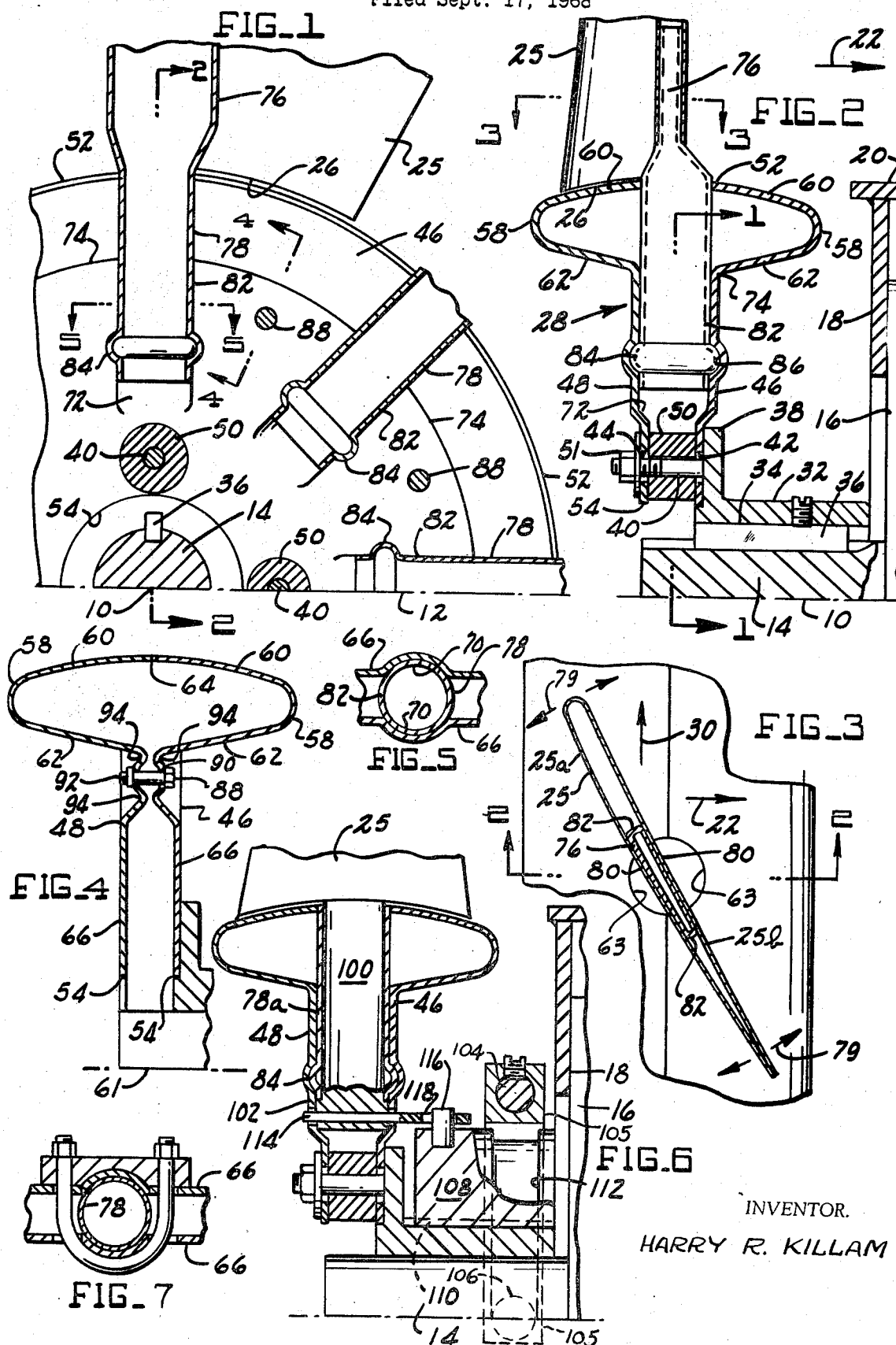
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# FAN BLADE SECUREMENTS

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## FAN BLADE SECUREMENTS

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6 Claims

### ABSTRACT OF THE DISCLOSURE

A vane-axial fan wherein the blades are mounted on a sheet metal hub structure formed by two metal discs. The discs are clamped together to retain certain blade-retention struts in radial sockets formed by channels in the facing surfaces of the discs. Peripheral portions of the discs are bulged or deformed to define a strengthening rib for the discs; the outer peripheral surface of the rib has a spherical contour which conforms to the inner edge contours on the blades, thus preventing air leakage or turbulence. Blades can be adjusted to provide different pitch angles without disturbing the rib-blade inner edge relationship.

### THE DRAWINGS

FIG. 1 is a sectional view illustrating one form of the invention, and taken on line 1—1 in FIG. 2.

FIG. 2 is a sectional view on line 2—2 in FIG. 1.

FIG. 3 is a sectional view on line 3—3 in FIG. 2.

FIG. 4 is a sectional view on line 4—4 in FIG. 1.

FIG. 5 is a sectional view on line 5—5 in FIG. 1.

FIG. 6 is a sectional view illustrating a second form of the invention.

FIG. 7 shows a disc clamping mechanism usable as an alternate to the arrangement in FIG. 4.

### THE DRAWINGS IN MORE DETAIL

FIGS. 1 and 2 show a vane axial fan having a rotational axis 10 and a transverse horizontal centerline 12. Shaft 14 is thus shown sectioned on its centerline so that only half of the fan diameter is visible in FIGS. 1 and 2. As shown in FIG. 2, shaft 14 is actually the shaft of an electric motor 16 which is disposed behind a mounting plate 18. The fan is a direct-drive unit as opposed to a belt-driven arrangement; the invention is however applicable to directly driven units or belt-driven arrangements. A peripheral annular sleeve or shroud 20 overlies at least part of the motor length to channel gas around the motor exterior as it flows in the arrow 22 direction.

Shroud 20 is disposed within a cylindrical gas duct (not shown), and carries fluid straightener vanes similar to vanes 4 in U.S. Pat. 2,664,961. As shown in FIG. 2 of that patent, the straightener vanes act on the gas after it has been acted upon by the airfoil blades 25. The outer tips of blades 25 (not shown) conform with the contour of the cylindrical gas duct to minimize turbulence and pressure loss at the blade tips. Similarly the inner edge areas 26 of the blades conform with the peripheral contour of the rotary hub structure 28 to minimize turbulence and ineffective recirculation at the blade-hub joint.

Motor 16 provides power which is transmitted through shaft 10 and hub structure 28 to accomplish rotation of blades 25 in the arrow 30 direction (FIG. 3). Such blade rotation produces gas flow vectors circumferentially and in the arrow 22 direction; the aforementioned straightened vanes on shroud 20 turn the issuing gas stream into the arrow 22 direction. The illustrated fan has eight hollow airfoil blades. However, the invention is applicable to fans having different numbers of blades and different blade contours (single sheet blades of arcuate or essentially flat contour).

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### HUB STRUCTURE 28

Hub structure 28 comprises a cylindrical sleeve 32 having a keyway 34 registering with a second keyway in shaft 14; a key 36 is retained within the keyways so that the shaft and sleeve are locked together for conjoint rotation. Circular flange 38 on the sleeve is provided with four or more weld-on studs 40 which go through aligned holes 42 and 44 in sheet metal discs 46 and 48. A collar 50 encircles each stud so that when the respective nut 51 is tightened on the stud the respective collar acts as a spacer to retain the discs spaced apart at their inner peripheral edges.

Discs 46 and 48 are preferably identical with one another so that each may be stamp-formed in the same die. The discs are arranged in mirror-image relation to act as clamping devices for certain radial struts, to be described later. Each disc is of circular annular outline defined by a circular outer edge area 52 and circular inner edge 54. Edge area 52 is formed by an endless peripheral channel 56 having the FIG. 2 cross section. As there shown, the channel wall structure includes an arcuate web 58 and two slightly divergent legs 60 and 62. Legs 60 of the discs meet to form a joint 64; in the final assembly a seam weld may be formed along this joint, or if the discs are manufactured to sufficient precision the weld may be omitted.

Inner peripheral face areas 66 of the discs are for the most part flat and parallel as shown in FIG. 4. However eight radial channels or grooves 70 are formed in the surface of each disc. FIG. 5 shows the cross section of each groove (arcuate), and FIGS. 2 and 4 illustrate to a certain degree the radial length of each groove. As seen in FIG. 2, each groove extends outwardly from a point 72 to the point 74 where the flat disc area 66 meets the diverging wall 62. The two outer walls 60 are formed with circular cut-outs 63 in their meeting edges 64; these cut-outs are located in radial registry with channels 70 so that certain tubular struts (to be described later) can be locked in the channels with portions thereof projecting through the cut-outs into the circumjacent blades 25.

### BLADE RETENTION

Each airfoil blade 25 encircles or is otherwise attached to the flat spade-like portion 76 of a tubular strut 78. As seen in FIG. 3, spade portion 76 is of essentially rectangular cross section, providing two major surface wall areas 80 and two connecting minor surface wall areas 82. The sheet areas which form blade 25 are not absolutely flat, nor are they exactly parallel. Thus the leading face area 25a is slightly convex, and the trailing face area 25b is slightly concave. Accordingly, the spade portion 76 of the strut is preformed to preserve the airfoil blade shape. Attachment of the strut portion 76 to the blade may be accomplished by two or more welds along the strut length, or by rivets or possibly by adhesives; welding is preferred.

Each strut 78 includes a circular cross-sectioned portion 82 which has the same diameter as the aforementioned cut-outs 63 (FIG. 3) and the socket defined by the mating channels 70. Thus, strut portion 82 is adapted to fit within the socket in facial contact with the channel 70 surfaces. Suitable tension bolts (FIG. 4) clamp the opposed discs together so that channels 70 grip the strut portions 82 and thus prevent the attached blades 25 from turning about the strut axes under aerodynamic force.

During fan operation the high centrifugal forces produce outward radial stresses tending to blow the blade-strut assemblies out from the hub structure. To resist such stresses each strut is formed with a peripheral rib 84. Companion grooves 86 are formed in the mating surfaces of discs 28. The rib 84-groove 86 relation locks

the struts against radial displacement out of the sockets, and thus retains the blades against blow-out forces.

#### BLADE PITCH ADJUSTMENT

FIG. 4 shows a tension bolt 88 going through aligned openings in the hub discs 46 and 48. The disc areas 90 immediately surrounding the bolt openings are spaced apart so that bolt tightening force by nut 92 causes the two areas 90 to deflect toward one another for indirectly applying a clamping action on the struts 78. As shown in FIG. 1, there is one bolt 88 between each strut 78. Thus, with an eight bladed fan (eight struts) there could be eight bolts. These bolts are preferably evenly spaced between the adjacent struts 78 so that each bolt produces a clamping force on two struts; also each bolt is preferably located radially outwardly beyond the imaginary circle defined by the inner ends of the struts so that each bolt exerts maximum clamping force along the entire length of each radial channel 70. In lieu of the illustrated straight bolts 88 it is possible to utilize U-bolts going through disc openings along the side areas of channels as shown in FIG. 7.

Referring again to FIG. 4, each disc area 90 is circumscribed by an embossed ring-like groove 94. The ridges defined by these grooves do not quite touch one another so that the nut-bolt force can be increased to desired torque values. Embossments 94 give the disc areas 90 some axial stiffness so that these areas do not oil-can together at low bolt forces; this insures satisfactory anti-rotation clamping action on the blade struts 78.

Adjustment of the blade pitch is sometimes required to enable the fan to meet unanticipated system pressure requirements, due for example to original system miscalculations, or alterations in the system after original installation. In the illustrated fan pitch adjustment is accomplished by loosening bolts 88 and nuts 51 (FIG. 2). The blades 25 can then be manually turned about the strut 78 axes to desired positions; arrows 79 in FIG. 3 illustrate the directional movements taken by the blade leading and trailing edges during this adjusting operation. Location of each blade at the same pitch setting can be insured by suitable reference lines on the outer face of disc wall 60.

#### AERODYNAMIC CONSIDERATIONS

It will be noted from FIG. 4 that the surface formed by disc walls 60 is spherical about the imaginary centerpoint 61. This centerpoint lies along the axes of the blade struts 78. Thus, blade pitch adjustment operations do not appreciably enlarge the clearances between surface 60 and the blade inner edges 26. As a result aerodynamic performance is maintained at all blade pitch angles; i.e. there is minimum recirculation or inefficient turbulence at the blade inner edges. Some minor turbulence may be generated in the area where circular strut section 82 merges into the flat spade section 76; in this area the blade sheets are preferably cut away to minimize blade thickness. The blade surface is at this point formed by the exposed portions of strut 78, and the thickness of the strut somewhat interferes with most efficient gas flow. The effect is minor since in an illustrative fan each blade may be on the order of twenty five inches long, and the transitional portion of the strut only about one and one half inches long. The spade portion 76 of the strut may extend into its blade about three or four inches to provide a considerable twist resistance to the blade-strut joint. The strut may be initially manufactured from high strength round tubing, die-formed to provide spade portion 76 and rib 84. Blades 25 can be formed of steel, aluminum, or other material suited to specific environments (temperature, erosion conditions, etc.).

As seen in FIG. 4, the various walls 60, 58 and 62 form a box section offering considerable resistance to disc deformation against aerodynamic stress. During service the

gas exerts considerable force against each blade trailing face 25b; the blades transmit this force onto the hub structure. Unless counteracted this force would tend to tilt the peripheral areas of the disc structure forwardly about centerpoint 61. However the box-like character of the disc peripheral rib effectively counteracts this tendency since the box cannot tilt without causing one of the wall areas 58 to move inward and the other wall area 58 to move outward; the nature of the box precludes such action.

It will be noted that the disc, strut, and blade structure are of hollow character. This is advantageous in reducing the mass of the rotating assembly and thus reducing the magnitude of the centrifugal forces tending to cause wheel blow-up. By thus lightening the rotating portions of the fan it is possible to safely run the fan at higher tip speeds than correspondingly sized heavier structures.

It has been the practice to form these type fans with precision cast hubs and blades. These are heavier structures and are therefore disadvantageous as noted above. Additionally such structures are quite costly to produce. The present design is intended to utilize stampings in lieu of castings for cost reduction and lightness. Use of stampings also offer a wider choice of materials since precision castings have heretofore been obtainable for the most part only in aluminum, not steel. Steel stamped parts are of course better suited to high temperature or high erosion environments than parts formed of aluminum.

FIG. 6

FIG. 6 illustrates a fan wherein the blade pitch can be adjusted while the fan is operating. This is sometimes referred to as a controllable pitch fan whereas the fan of FIG. 1 is often termed an adjustable pitch fan. In the FIG. 6 arrangement the tubular strut 78a is clamped between the two discs 46 and 48, as by the bolt arrangements of FIGS. 4 or 7. Strut 78a forms a sleeve-type bearing. Rotatably journaled within this bearing is a cylindrical spindle 100 having a suitable fixed attachment with the blade 25; the spindle and blade form one unitary structure. Bearing 78a extends to the outer periphery of the disc assembly for adequate radial spindle support (i.e. about the spindle axis). End thrust loadings on the spindle are absorbed by an enlarged end portion 102 on the spindle engaged with the inner end of the bearing sleeve. In actual practice the end of the sleeve may not have sufficient anti-friction or wear characteristics; therefore some additional thrust bearings may be needed.

It will be appreciated that rotation of each spindle 100 about its axis produces the desired change in pitch adjustment. In the FIG. 6 arrangement this is accomplished by a control rod 104 which extends outwardly through the tubular fan housing (not shown) to connection with a suitable manual or motor operator. Rod is mounted for rotation about its axis, as by means of two radial bearings, located inside or outside the fan housing. The control rod has a yoke 105 affixed thereto so that the arm portions of the yoke extend adjacent the side surface of a collar 108. A roller 106 carried by each arm of the yoke extends into a peripheral groove 112 in the collar.

Sleeve 32 (affixed to shaft 14) has a collar 108 keyed thereto, as at 110, whereby the collar rotates with the sleeve but is free for axial motion along the sleeve surface. Rollers 106 ride in a peripheral groove 112 in collar 108. Therefore, with the fan running, rotation of rod 104 from a point external to the fan casing is effective to shift collar 108 a limited distance back and forth on sleeve 32.

Each blade spindle 100 carries an arm 114 which extends through a slot in disc 48 to overlie the side surface of collar 108. A pin 116 carried collar 108 projects through a cam slot 118 in arm 114. With this arrangement the back-and-forth movement of collar 108 produces a corresponding component of motion in each pin 116, which is translated into an arcuate motion of each arm

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114 about the axis of its spindle 100. The spindle and its blade 25 are thus rotated or adjusted about the spindle axis. It will be understood that each spindle must be equipped with an arm 114, and that collar 108 must be equipped with a pin 116 for each arm 114, whereby all of the blades are rotated in unison.

The control structure shown in FIG. 6 may in practice not be the most practical from the standpoint of precision requirements, wear requirements control force requirements, etc. Hence the showing should be considered illustrative of what can be used. The invention is believed to relate principally to the above-discussed disc-strut-blade features. FIG. 6 merely illustrates that the invention is applicable to both adjustable pitch fans and controllable pitch fans. Similar tooling can be used to produce both type fans. This is a material advantage since it cuts tooling costs in half. When a range of fan sizes is being produced (different hub diameters) the tool cost savings may be appreciable.

I claim:

1. An axial fan comprising a rotary hub structure which includes two circular stamp-formed sheet material discs of substantially uniform wall thickness throughout; each disc having an inner face area and an outer rim area stamp-formed into an endless reinforcement channel projecting axially away from the disc face area; each disc further having series of stamp-formed radial channels extending inwardly from the endless rim channel; said discs being pancaked together so that the inner face areas are spaced from one another and so that the respective channels open toward one another; the radial channels combining to define split sockets, and the rim channels combining to form an endless reinforcement box section having an axial dimension many times the disc wall thickness; radial blades positioned around the disc periphery; struts affixed to the blades and projecting into the split sockets; and a number of clamps operable to draw the discs toward but not against one another at various points around the disc, whereby the discs are caused to clamp the struts in the sockets.

2. The fan of claim 1 wherein the disc clamp means comprises tension bolts going through the discs in the areas between adjacent ones of the sockets; the facing disc areas immediately surrounding each bolt being spaced from one another but being circumscribed by ring-like embossments projecting toward one another, whereby bolt pressure deforms said surrounding wall areas toward one another for increased clamping force on the struts.

3. The fan of claim 1 wherein each strut is formed with a locking rib; said discs having embossed locking grooves

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in the areas which define the radial channels; said struts being inserted into the sockets so that the locking ribs lie within the locking grooves to resist radial blow-out of the struts from the sockets; said discs being spaced from one another in the disc areas radially inward from the peripheral reinforcement rib, the radially innermost areas of the discs having spacer means interposed between the facing disc surfaces for maintaining the discs in such spaced positions as will cause the discs to cooperatively resist disc deformation due to aerodynamic stress.

4. The fan of claim 3 wherein the hub structure further comprises a flanged shaft-encircling sleeve having a number of studs projecting axially from the flange area; said studs going through aligned holes in the inner peripheral areas of the discs whereby to secure the discs to the sleeve; the aforementioned spacer means comprising spacer collars surrounding the studs.

5. The fan of claim 1 wherein each fan blade is an airfoil blade having a leading face and a trailing face; each strut being formed as a one piece hollow tubular element having a circular cross-sectioned portion within the confining split socket, and a flat spade portion extending an appreciable distance into the blade between its leading and trailing edges, said strut thereby reinforcing the blade against aerodynamic deflection forces.

6. The fan of claim 1 wherein each endless rim channel is of generally V-shaped cross section, comprising an arcuate web wall 58, an outer leg wall 60, and an inner leg wall 62; said leg walls diverging slightly with respect to one another as they proceed away from the web wall; the outer leg walls 60 on adjacent discs abutting against one another to form a continuous outer face area, and the inner leg areas 62 on adjacent discs terminating short of one another so as not to interfere with deflection of the discs by the aforementioned clamps.

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