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(54) Flared tip fan blade and method of manufacturing same

(57) A fan blade assembly is provided. The fan blade assembly (10) may include: a fan blade (36) having an airfoil shaped section, formed by being run lengthwise though a die and a flap portion integral with the airfoil section also run lengthwise through the die, the fan blade having a hub end and a tip end, a tapering trailing edge on a trailing edge of the fan blade defined by removing a portion of the trailing edge of the fan blade after it has been run through the die, the tapering trailing edge defining the fan blade (36) to be narrower moving from the hub end toward the tip end, and a flared portion interrupting the tapering trailing edge near the tip end, the flared portion defining the fan blade to become wider from the beginning of the flared portion to the tip end. A method for making a fan blade may also be provided.

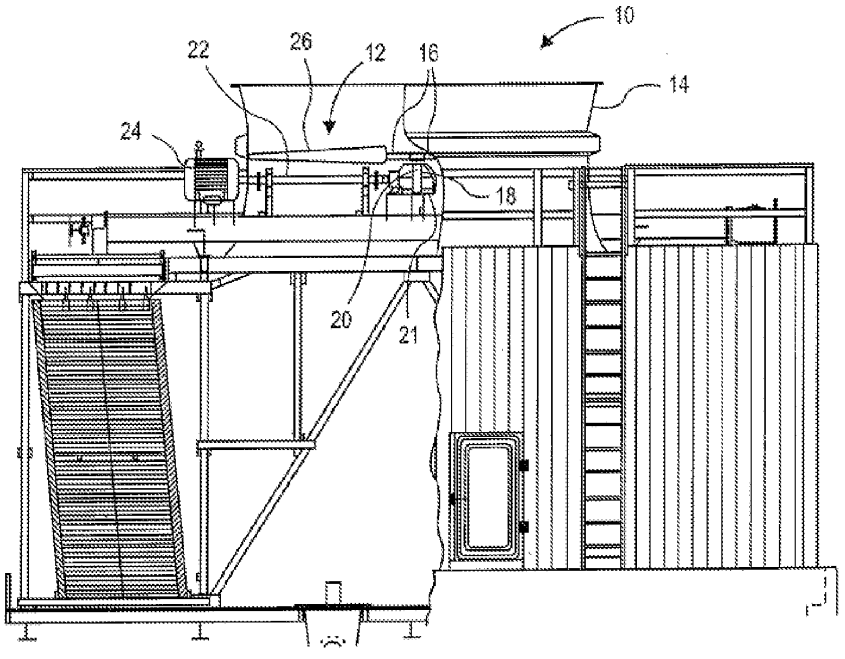

FIG. 1

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Description

FIELD OF THE INVENTION

[0001] The present invention relates generally to a fan blade. More particularly, the present invention relates to a protruded or extruded fan blade having a geometry to achieve high efficiency.

BACKGROUND OF THE INVENTION

[0002] It is generally understood in axial fan design, that a factor relevant to high efficiency operation is to distribute the exiting air velocity as evenly as possible over the entire length of the fan blade. This is typically accomplished in fan blade design by variation of the airfoil chord and angle along the length of the blade, with the widest chords and highest angles near the slower moving hub end of the blade, and narrower chords and lower angles near the faster moving tip of the blade.

[0003] Fans used in cooling towers and air-cooled heat exchangers are generally placed inside of a shroud to improve their efficiency. While the use of a shroud does improve fan performance there are still losses due to aerodynamic drag along the surface of the shroud and air recirculation between the end of the blade and the surface of the shroud. Overcoming these losses through careful design of the fan blade can further improve the operating efficiency of the fan. Fast and inexpensive fabrication of such a fan blade would be a welcome development.

[0004] Accordingly, it is desirable to provide a method and apparatus that in some embodiments provide a relatively inexpensive fan blade that is capable of efficient operation.

SUMMARY OF THE INVENTION

[0005] The foregoing needs are met, to a great extent, by the present invention, wherein in one aspect an apparatus is provided that in some embodiments a relatively efficient fan blade that can be economically produced.

[0006] In accordance with one embodiment of the present invention, a fan blade assembly is provided. The fan blade assembly may include; a fan blade having an airfoil shaped section, formed by being run lengthwise though a die and a flap portion integral with the airfoil section also run lengthwise through the die, the fan blade having a hub end and a tip end, a tapering trailing edge on a trailing edge of the fan blade defined by removing a portion of the trailing edge of the fan blade after it has been run through the die, the tapering trailing edge defining the fan blade to be narrower moving from the hub end toward the tip end, and a flared portion interrupting the tapering trailing edge near the tip end, the flared portion defining the fan blade to become wider from the beginning of the flared portion to the tip end,

[0007] In accordance with another embodiment of the present invention, a method of manufacturing a fan blade assembly is provided. The method may include extruding a metal through a die forming the metal in the shape of fan blade having an airfoil portion and a flap portion, removing material from the extruded metal on a trailing edge fan blade to be narrower moving from a hub end of the fan blade toward a tip end of the fan blade, and shaping the trailing edge of the fan blade to interrupt the tapering trailing edge near the tip end, and forming a flared portion defining the fan blade to become wider from the beginning of the flared portion to the tip end.

[0008] In accordance with yet another embodiment of the present invention, a method of manufacturing a fan blade assembly is provided. The method may include pultruding fiberglass wetted with resin through a die forming the fiberglass in the shape of fan blade having an airfoil portion and a flap portion, removing material from the pultruded fiberglass on a trailing edge fan blade to be narrower moving from a hub end of the fan blade toward a tip end of the fan blade, and shaping the trailing edge of the fan blade to interrupt the tapering trailing edge near the tip end, and forming a flared portion defining the fan blade to become wider from the beginning of the flared portion to the tip end.

[0009] There has thus been outlined, rather broadly, certain embodiments of the invention in order that the detailed description thereof herein may be better understood, and in order that the present contribution to the art may be better appreciated. There are, of course, additional embodiments of the invention that will be described below and which will form the subject matter of the claims appended hereto.

[0010] In this respect, before explaining at least one embodiment of the invention in detail, it is to be understood that the invention is not limited in its application to the details of construction and to the arrangements of the components set forth in the following description or illustrated in the drawings. The invention is capable of embodiments in addition to those described and of being practiced and carried out in various ways. Also, it is to be understood that the phraseology and terminology employed herein, as well as the abstract, are for the purpose of description and should not be regarded as limiting.

[0011] As such, those skilled in the art will appreciate that the conception upon which this disclosure is based may readily be utilized as a basis for the designing of other structures, methods and systems for carrying out the several purposes of the present invention. It is important, therefore, that the claims be regarded as including such equivalent constructions insofar as they do not depart from the spirit and scope of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] FIG. 1 is a side view illustrating a cooling tower using a fan blade according to a preferred embodiment of the invention.

[0013] FIG. 2 is a cutaway side view of a fan blade in

accordance with the invention.

[0014] FIG. 3 is a side view of a fan in accordance with an embodiment of the invention.

[0015] FIG. 4 is a graph illustrating performance of the fan blade of the fan of FIG. 3.

[0016] FIG. 5 is a side view of another fan in accordance with an embodiment of the invention.

[0017] FIG. 6 is a graph illustrating performance of the fan blade of the fan of FIG. 5.

[0018] FIG. 7 is a side view of another fan in accordance with an embodiment of the invention.

[0019] FIG. 8 is a graph illustrating performance of the fan blade of the fan of FIG. 7.

[0020] FIG. 9 is a side view of another fan in accordance with an embodiment of the invention.

[0021] FIG. 10 is a graph illustrating performance of the fan blade of the fan of FIG. 9.

[0022] FIG. 11 is a top view of a fan blade according to the fan shown in FIG. 9.

[0023] FIG. 12 is a cross-section view of the fan blade shown in FIG. 11.

[0024] FIG. 13 is an exploded view of a fan blade according to an embodiment of the invention.

[0025] FIG. 14 is a side, cross-section view of a fan blade according to the fan of FIG. 13.

[0026] FIG. 15 is a top view of a fan blade in accordance with the fan blade of FIG. 13.

[0027] FIG. 16. is an exploded view of a fan blade and a hub assembly.

[0028] FIG. 17 is a front view of a fan blade and hub assembly.

DETAILED DESCRIPTION

[0029] An economical, corrosion resistant, lightweight, hollow fan blade for use in cooling towers and air-cooled heat exchangers can be produced by means of extruding a metal, such as aluminum, through a die. Similar hollow profiles may be produced using composite materials by pultruding fiberglass wetted with resin through a die. Fan blades produced by either the extrusion or pultrusion method will initially have a constant chord and constant angle over their entire length. To improve the static pressure capability of these fan blades, it is common to form these blades with an integral trailing edge extension, or flap, that may be flat or upwardly curved.

[0030] For fan blades without a trailing edge flap, or for blades with a trailing edge flap that is not modified after extrusion, the chord and angle of the blade will likely remain constant. The exit air velocity for constant chord, untwisted blades often have a highly uneven distribution with very low air velocity near the fan hub, and much higher air velocity near the tip of the blade. As is common for fans operating within a shroud, there are significant losses due to drag and recirculation near the shroud,

[0031] A method used to simulate twisted and tapered fan blades with an extruded or pultruded profile is to cut a portion of the trailing edge flap diagonally, leaving the widest chord near the hub and the narrowest chord at the tip end of the blade. The amount of taper can have a dramatic effect on the exiting air velocity distribution, and therefore, the efficiency of the fan in operation. As was seen with the constant chord blades, however, there is still a significant reduction in velocity near the tip end due to drag and recirculation losses at the shroud.

[0032] To overcome many of the losses at the tip end of the blade, a new variation in fan blade design has been developed. A "flare-tip" is created by tapering the trailing edge flap over most of the length of the blade, but increasing the chord width near the tip. The flare tip design overcomes drag and recirculation losses at the tip of the blade, providing a more even velocity distribution and, thus, higher operating efficiencies. Various embodiments of the invention will now be described with reference to the drawing figures, in which like reference numerals refer to like parts throughout. Various spacial terms such as front, back, top, bottom, upward, rearward, and other relative terms are intended to provide a reference with respect to the views shown in the drawings and are not intended to be limiting.

[0033] An embodiment in accordance with the present invention provides a fan having multiple fan blades having some of the features described herein.

[0034] FIG. 1 shows a partly cut away side view of a cooling tower 10. The cooling tower 10 includes a fan 12 located in a shroud 14. The fan 12 is comprised of fan blades 26 supported by blade shanks 16 that attach to a hub 18. The hub 18 is attached to a vertical shaft 20 of gear box 21 that is mechanically attached to a drive shaft 22. The drive shaft 22 is operatively connected to a motor 24. The motor 24 turns the drive shaft 22, which turns the vertical shaft 20 of gear box 21, which turns the hub 18, which turns the blade shanks 16, which turn the fan blades 26.

[0035] FIG. 2 shows a cross-section of a fan blade 26 in accordance with an embodiment of the invention. The fan blade 26 has a hollow air foil section 28 and a trailing edge extension 30. The geometry of the trailing edge extension 30 (also referred to as flap 30) in combination with the other features of the fan blade 26 provides some of the benefits in terms of efficiency.

[0036] The fan blade 26 is supported and attached to the hub 18 by a blade shank 16 extending through at least part of the hollow section 28. Struts 32 and 34 extend vertically through the hollow section 28 between the upper surface 36 and lower surface 38 to provide support and rigidity to the fan blade 12.

[0037] FIGS. 3, 5, 7, and 9 show fans 12 having four fan blades 26 having various geometries. Other embodiments may use more or fewer blades 26. FIGS. 4, 6, 8, and 10 show graphs indicating the performance of the fan blade 26 shown in the FIG. immediately preceding the graph. One of ordinary skill in the art may select a fan blade 26 with a geometry having a performance desired for a particular installation. After reviewing this dis-

closure, one of ordinarily skill in the art may modify and interpolate the data shown in the graphs to arrive at a geometry that will provide an estimated desired performance.

[0038] FIGS. 3, 5, 7, and 9 show fans 12 having fan blades 26 attached to a hub 18. The fan blade 26 includes an upper surface 36 and lower surface 38 and a trailing edge profile 40. As shown in the trailing edge profiles 40 and the corresponding performance graphs of FIGS. 3-10, varying the trailing edge profile 40 may significantly alter performance.

[0039] FIG. 9 shows a fan blade 26 having a tip extension 46 that interrupts the narrowing of the fan blade 26 defined by the sloping of the trailing edge profile 40. The tip extension 46 causes the width of the fan blade 26 to become longer as the trailing edge profile extends toward the end of the fan blade 26.

[0040] FIG. 11 shows a fan blade 26 in accordance with an embodiment of the invention. The fan blade 26 has a hub end 42 that is near the hub 18 (not shown in FIG. 11) when the fan blade 26 is attached to a hub 18. The fan blade 26 has a tip end 44 that is on an opposite end than the hub end 42. A tip extension 46 may be attached to the tip end 44 of the fan blade 26.

[0041] The tip end of the fan blade 26 may be equipped with an end cap 47. The end cap 47 may be made of an injection molded plastic or any other suitable material. The end cap 47 may be attached to the fan blade 26 by rivets 48. Other suitable attaching means or fasteners may also be used. The end cap 47 may be formed to have a desired geometry for the tip of the fan blade 26 that may be difficult to achieve by extrusion or protrusion of the fan blade 26.

[0042] A hub cap 50 may be located on the hub end 42 of the fan blade 26. The hub cap 50 may be attached to the fan blade 26 by rivets 52 or any other suitable means or fasteners. The hub cap 50 may serve to close the hollow airfoil portion 28 of the fan blade 26 and reduce the likelihood of foreign matter from entering the fan blade 26. Removal of the hubcap 50 may provide access to the interior of the fan blade 26 for inspection and/or maintenance.

[0043] The holes 54 in the fan blade are to allow bolts or other fasteners to attach the fan blade 26 to the blade shanks 16 (not shown in FIG. 11).

[0044] Point 56 represents where the rotational center of the fan 12 to which the fan blade 26 is associated with. FIG. 11 shows various dimension lines expressing example lengths and locations of various features expressed as functions of R (the radius of the assembled fan as measured from the rotational center 56 as shown in FIG. 11) and C (the chord or the width of the fan blade as shown in FIG. 12).

[0045] FIG. 12 shows a cross-section of a fan blade 26 having a hollow airfoil section 28 and a trailing edge extension or flap 30. Dimension lines are shown expressing example lengths and locations of various features expressed as functions of C (the cord or the width of the fan blade 26 as shown in FIG. 12).

[0046] FIG. 13, shows an exploded view of a fan blade 26 in accordance with an embodiment of the invention. FIG. 13 shows how the fan blade 26 attaches to the blade shank 16 via bolts 58 having threads 59. The fan blade 26 attaches using bolts 58, washers 60 and nuts 62. The bolts 58 extend through the holes 54. The blade shank 16 extends through the hub cap 50 into the hollow airfoil section 28. Rivets 52 connect the hubcap 50 to the fan blade 26. The tip cap 47 attaches to the fan blade 26 via rivets 48. There are weights 64 attached inside the tip of the blade 26 using bolts 58, washers 60 and nuts 62 to balance the assembly.

[0047] FIG. 14 shows a cross-section of a fan blade 26 taken along the line 14-14 of FIG. 15. The fan blade 26 shown in FIG. 14 is shown attached to the blade shank 16.

[0048] FIG. 15 shows the fan blade 26 assembly of FIG. 13 in an assembled form. FIG 15 is partially cut away to show part of the connection 61 between the weights 64 and the fan blade 26.

[0049] FIG. 16 is a partially exploded view of the fan blade 26 and hub 18. The fan blade 26 attaches to the hub 18 with U bolts 66 engaging the blade shank 16 of the fan blade 26 and the hub 18. The U bolts 66 attach to the hub 18 with washers 60 and nuts 62. The blade shank 16 is seated in a cradle 68. The U bolts 66 extend through holes 70 in the hub 18.

[0050] FIG. 17 shows the fan blade 26 attached to the hub 18 in the manner described above.

[0051] According to some embodiments of the invention, the fan blade 26 may be fabricated by being extruding a metal such as aluminum through a die. Alternatively, a material such as fiberglass and resin may be protruded through a die to fabricate the fan blade. Once the fan blade has been extruded or protruded, the specific shape may be further refined by trimming or machining the fan blade. For example, the trailing edge profile may be cut into the fan blade by milling the fan blade. Other machining or cutting techniques may also be used. Other features such as holes and the like may be cut or punched into the fan blade. Other components such as the hub cap, the blade shank and the tip end cap may be attached to the fan blade.

[0052] It should be understood that specific hardware and methods used to assemble and attach the various components are provides as examples only and are not limiting the invention to the specific examples set forth.

[0053] The many features and advantages of the invention are apparent from the detailed specification, and thus, it is intended by the appended claims to cover all such features and advantages of the invention which fall within the true spirit and scope of the invention. Further, since numerous modifications and variations will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and operation illustrated and described, and accordingly, all suitable modifications and equivalents may be resorted to, falling

within the scope of the invention.

Claims

1. A fan blade assembly comprising:

a fan blade having an airfoil shaped section, formed by being run lengthwise though a die and a flap portion integral with the airfoil section also run lengthwise through the die, the fan blade having a hub end and a tip end;
a tapering trailing edge on a trailing edge of the fan blade defined by removing a portion of the trailing edge of the fan blade after it has been run through the die, the tapering trailing edge defining the fan blade to be narrower moving from the hub end toward the tip end; and
a flared portion interrupting the tapering trailing edge near the tip end, the flared portion defining the fan blade to become wider from the beginning of the flared portion to the tip end.

2. The fan blade assembly of claim 1, wherein the flap portion slopes upward when viewed from the side of the fan blade.

3. The fan blade assembly of claim 1, further comprising plastic insert attached to the fan blade at the tip end.

4. The fan blade assembly of claim 1, further comprising a shroud containing the fan blade and a hub.

5. The fan blade assembly of claim 1, further comprising a cooling tower having the fan blade attached to a hub and figured to provide airflow through the cooling tower.

6. A method of manufacturing a fan blade assembly comprising:

one of (a) extruding a metal through a die forming the metal in the shape of fan blade having an airfoil portion and a flap portion, and (b) pultruding fiberglass wetted with resin through a die forming the fiberglass in the shape of fan blade having an airfoil portion and a flap portion;
(c) removing material from the extruded metal on a trailing edge fan blade to be narrower moving from a hub end of the fan blade toward a tip end of the fan blade and
(d) shaping the trailing edge of the fan blade to interrupt the tapering trailing edge near the tip end, and forming a flared portion defining the fan blade to become wider from the beginning of the flared portion to the tip end.

7. The method of claim 6, comprising step (a) and further comprising attaching an injection molded plastic cap on the tip end of the blade.

8. The method of claim 6, comprising step (a) and further wherein the die forms the flap to extend in an upward direction.

9. The method of claim 6, comprising step (a) and further comprising installing the fan blade in a cooling tower.

10. The method of claim 6 comprising step (a) and further comprising operating a fan comprised of the fan blades.

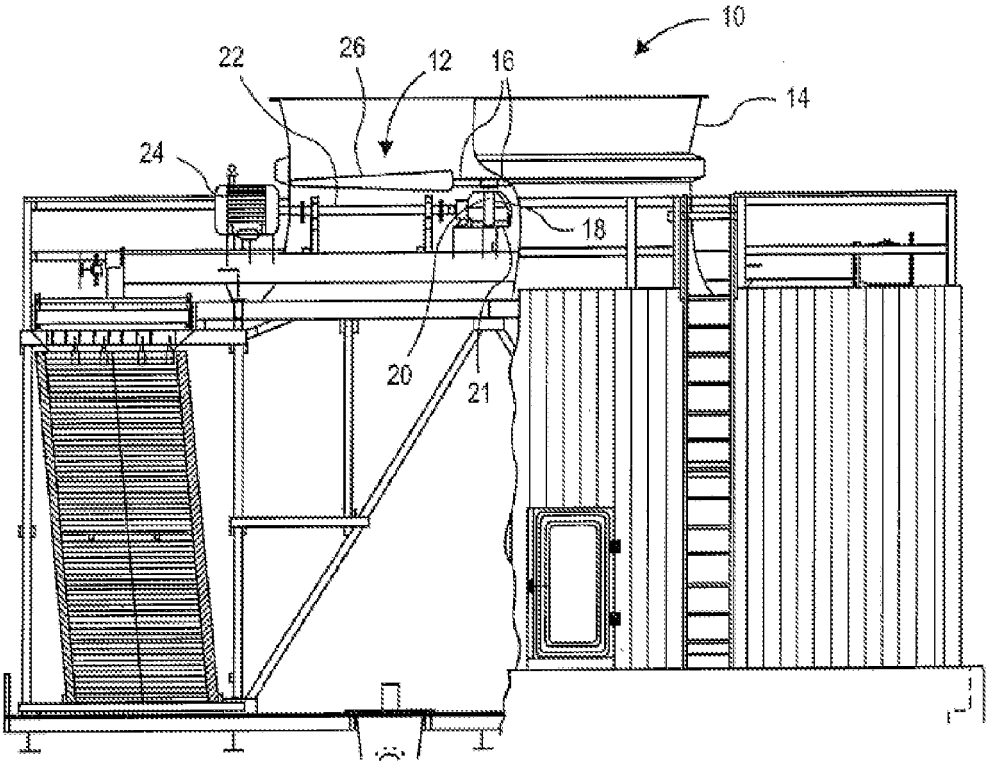

FIG. 1

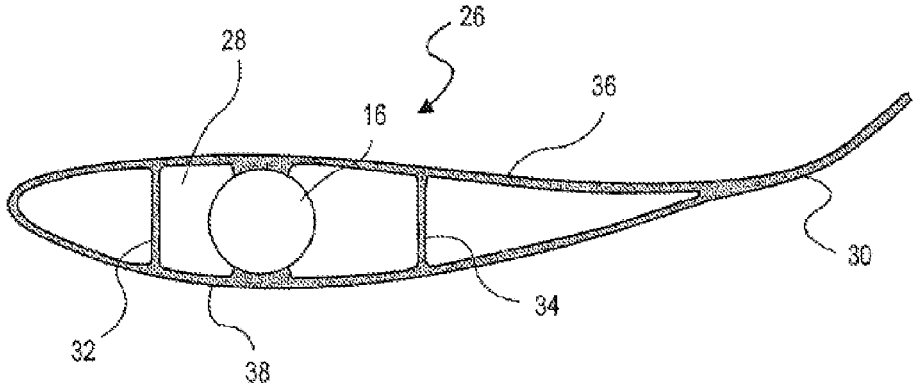

FIG. 2

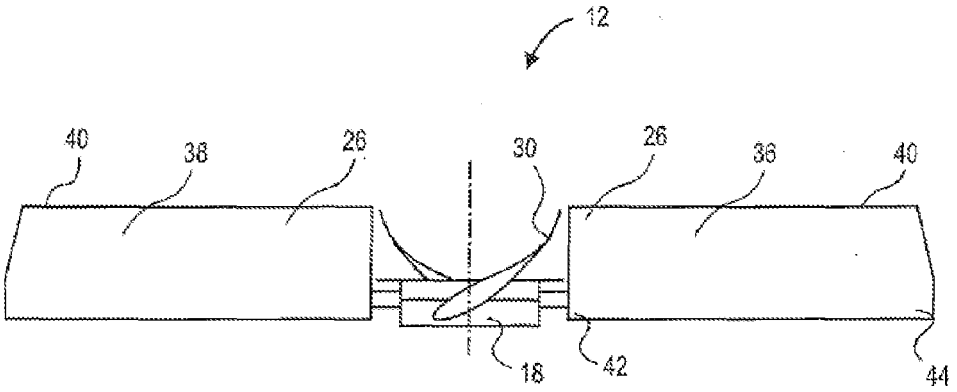
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FIG. 3

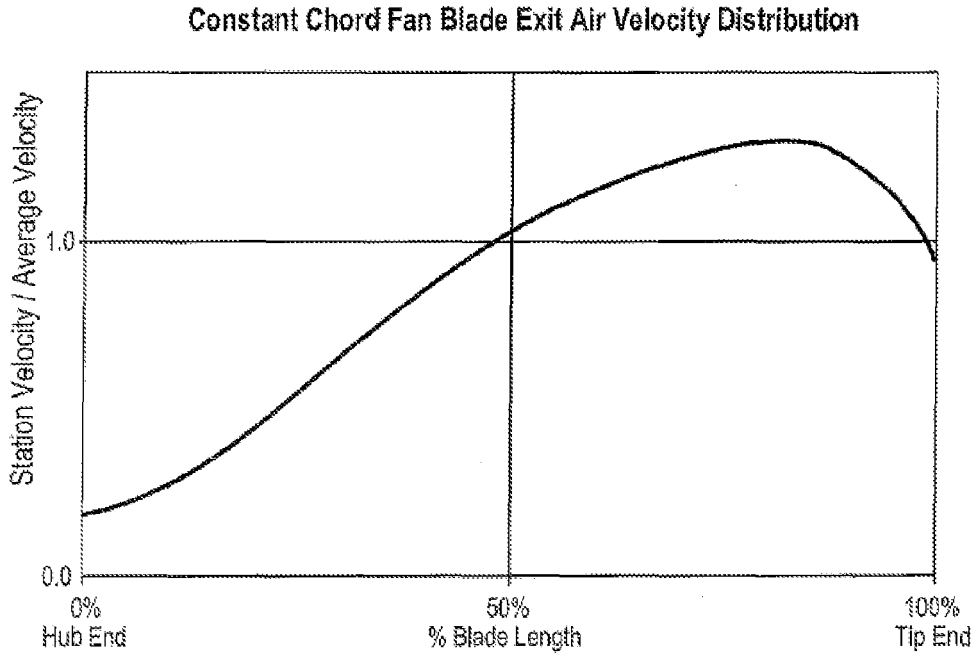
Constant Chord Fan Blade Exit Air Velocity Distribution
Station Velocity / Average Velocity
1.0
0.0
0%
Hub End
50%
% Blade Length
100%
Tip End

FIG. 4

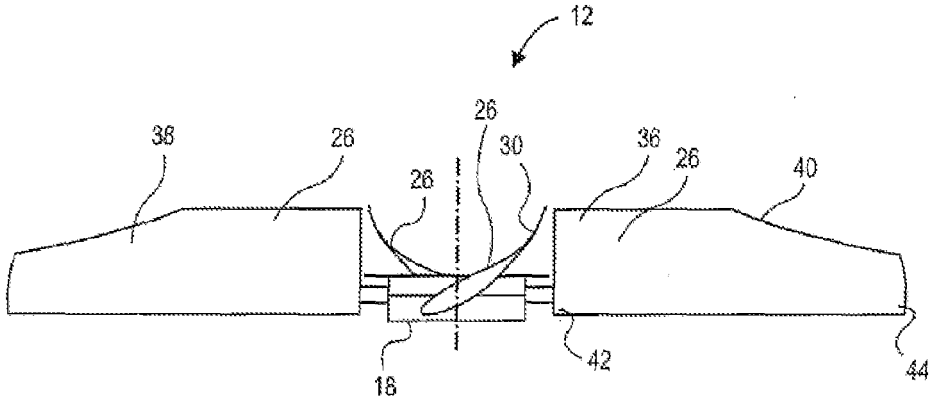
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FIG. 5

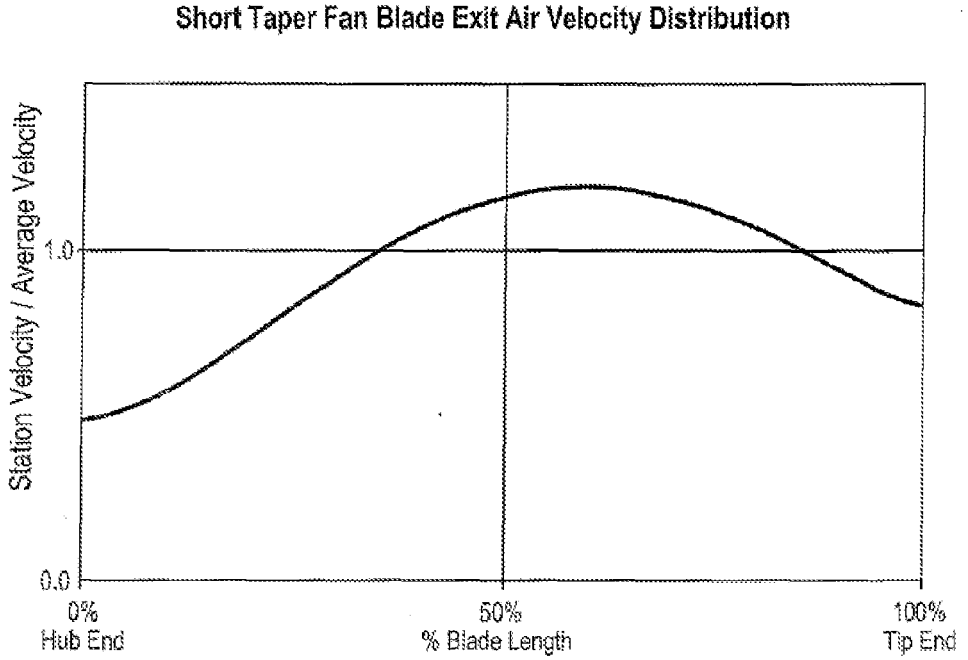
Short Taper Fan Blade Exit Air Velocity Distribution
Station Velocity / Average Velocity
1.0
0.0
0%
Hub End
50%
% Blade Length
100%
Tip End

FIG. 6

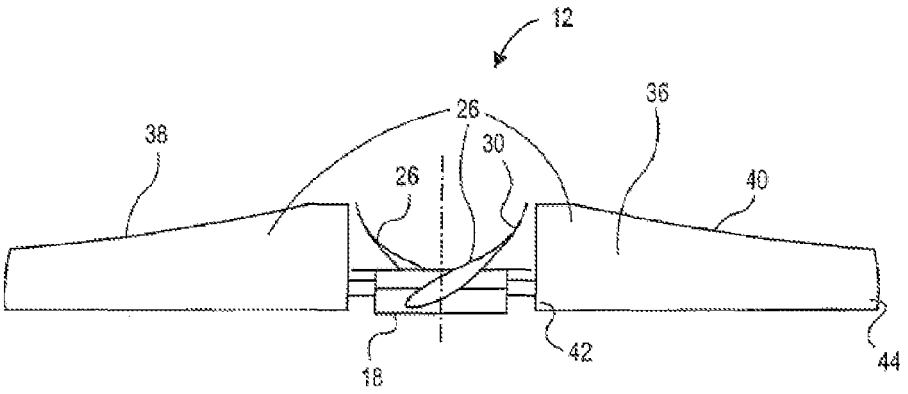
12
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FIG. 7

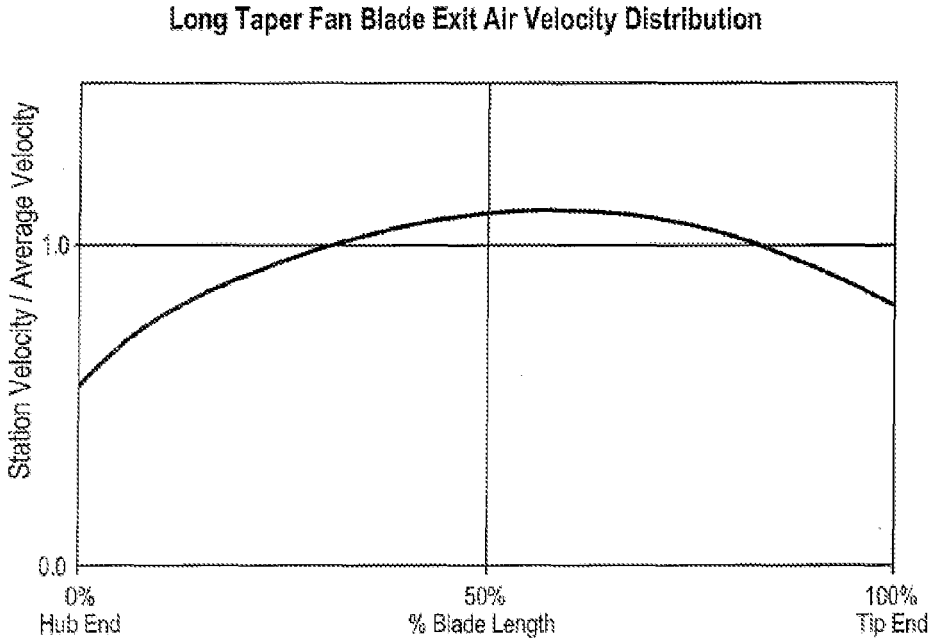
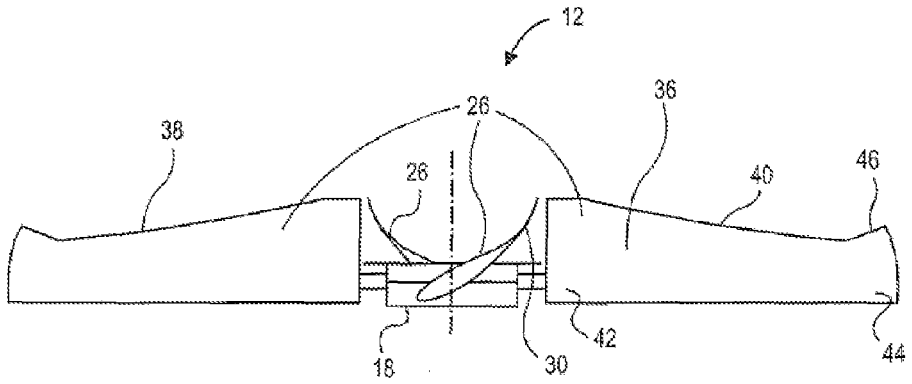

Long Taper Fan Blade Exit Air Velocity Distribution
Station Velocity / Average Velocity
1.0
0.0
0%
Hub End
50%
% Blade Length
100%
Tip End

FIG. 8


12
36
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46
18
30
42
44

FIG. 9

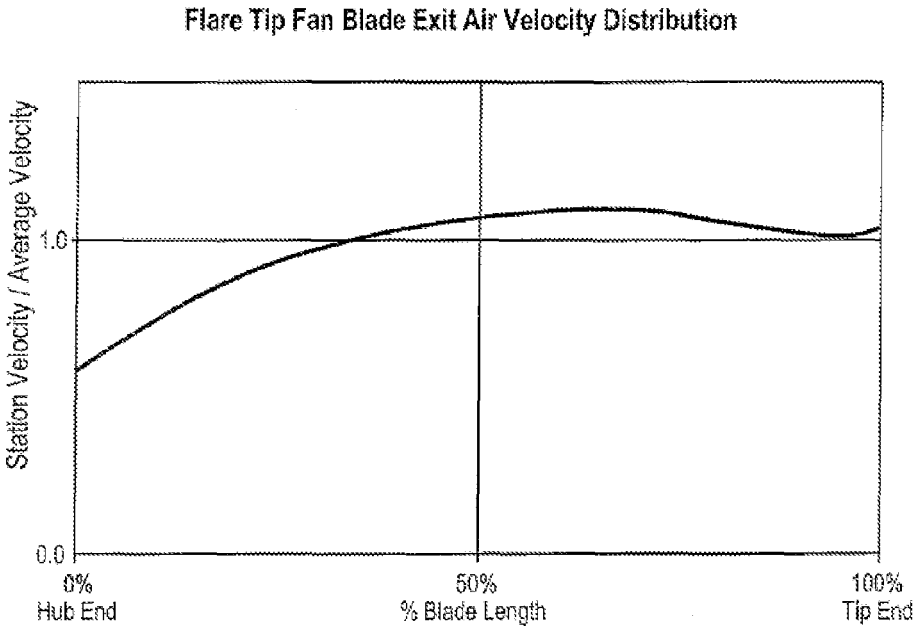
Flare Tip Fan Blade Exit Air Velocity Distribution
Station Velocity / Average Velocity
1.0
0.0
0%
Hub End
50%
% Blade Length
100%
Tip End

FIG. 10

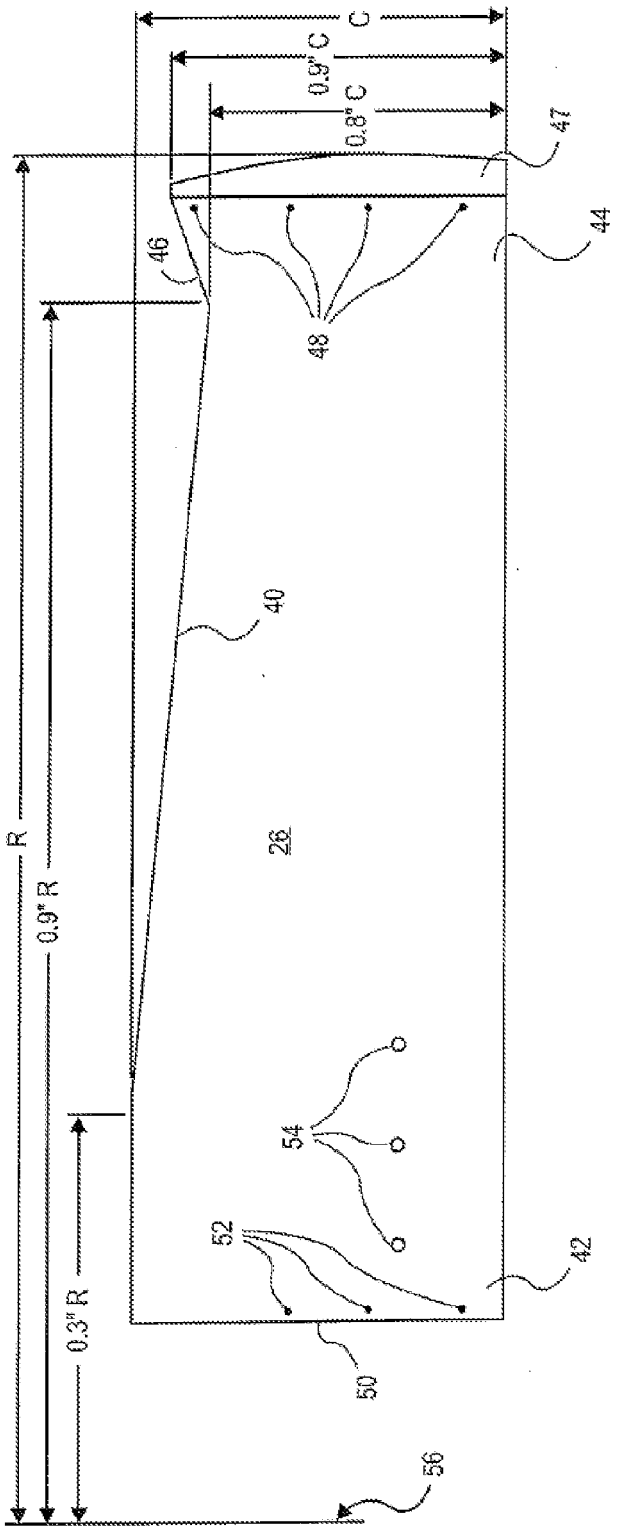

FIG. 11

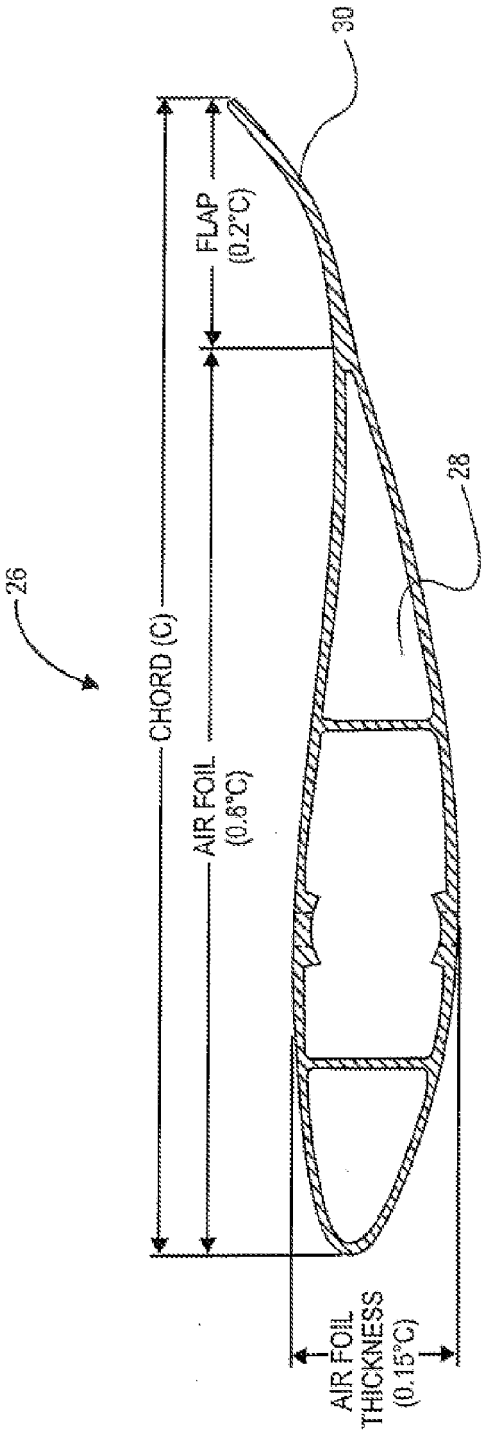

FIG. 12

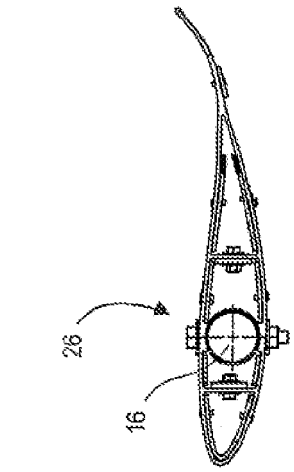

FIG. 14

FIG. 13

FIG. 15

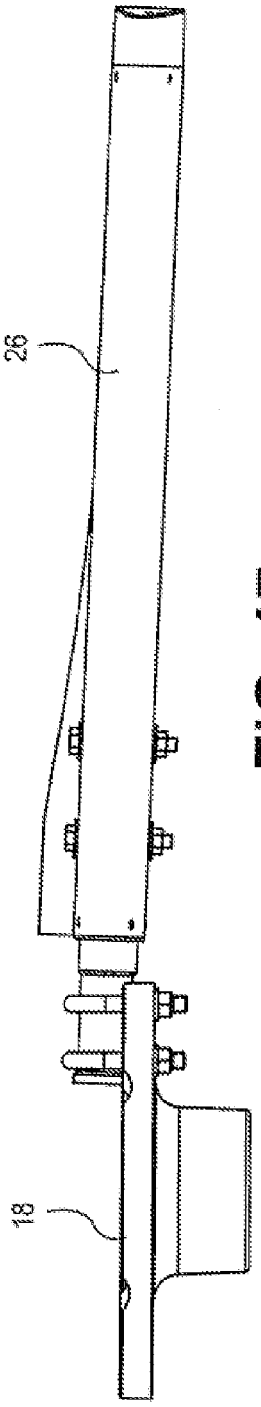

FIG. 17

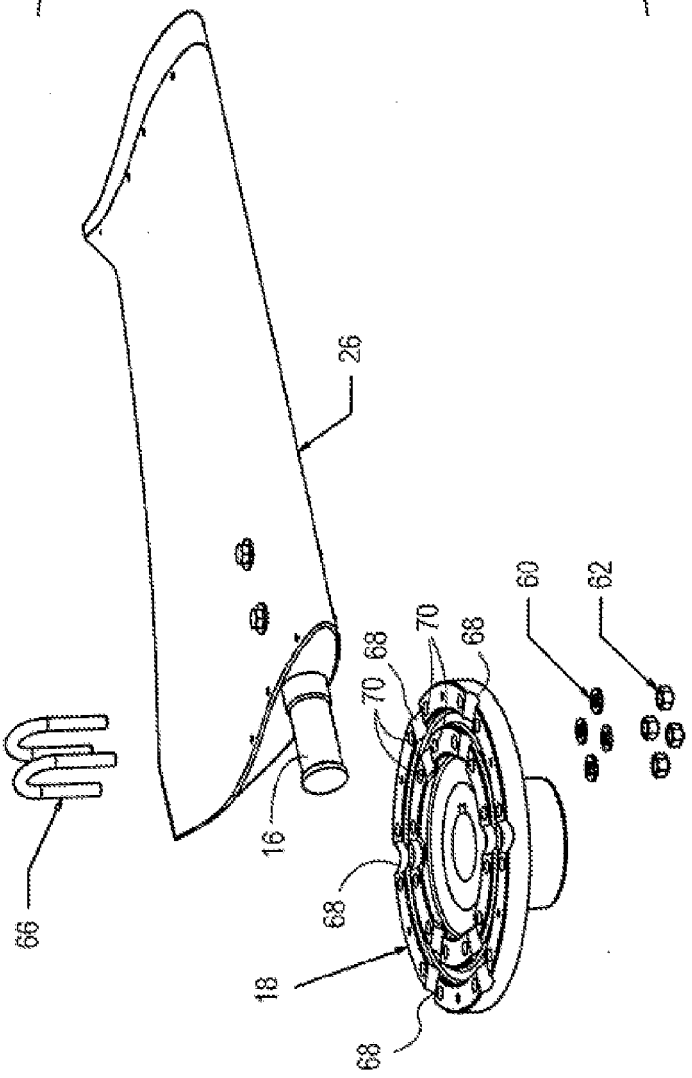

FIG. 16