



US 20130189109A1

(19) **United States**

(12) **Patent Application Publication**  
Noble

(10) **Pub. No.: US 2013/0189109 A1**

(43) **Pub. Date: Jul. 25, 2013**

(54) **THIN AIRFOIL CEILING FAN BLADE**

**Publication Classification**

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(51) **Int. Cl.**  
**F01D 5/02** (2006.01)

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(52) **U.S. Cl.**  
CPC ..... **F01D 5/02** (2013.01)  
USPC ..... **416/219 R**

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(57) **ABSTRACT**

(21) Appl. No.: **13/743,456**

(22) Filed: **Jan. 17, 2013**

A fan blade comprising a root end, a blade region, and a transition region. Wherein each of the root end and blade region comprise a unique profile, and wherein the transition region comprises a profile which transitions the root end profile to the blade region profile. The root end profile comprises a substantially convex top surface, a substantially concave domed sector, and reliefs to allow for the root end to be coupled with a similarly shaped fan hub extrusion. The blade region profile comprises a substantially convex top surface and bottom surface which terminate at a leading edge and trailing edge. The blade region slopes upward along a length of the blade region and terminates at a curved tip.

**Related U.S. Application Data**

(60) Provisional application No. 61/588,932, filed on Jan. 20, 2012.

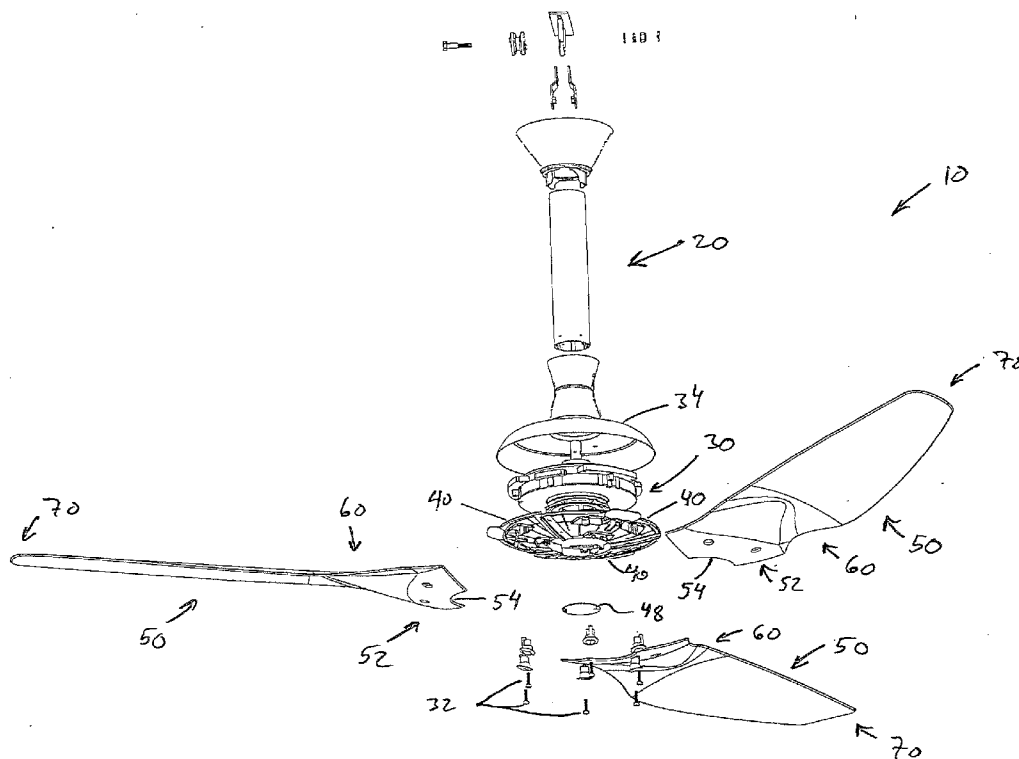
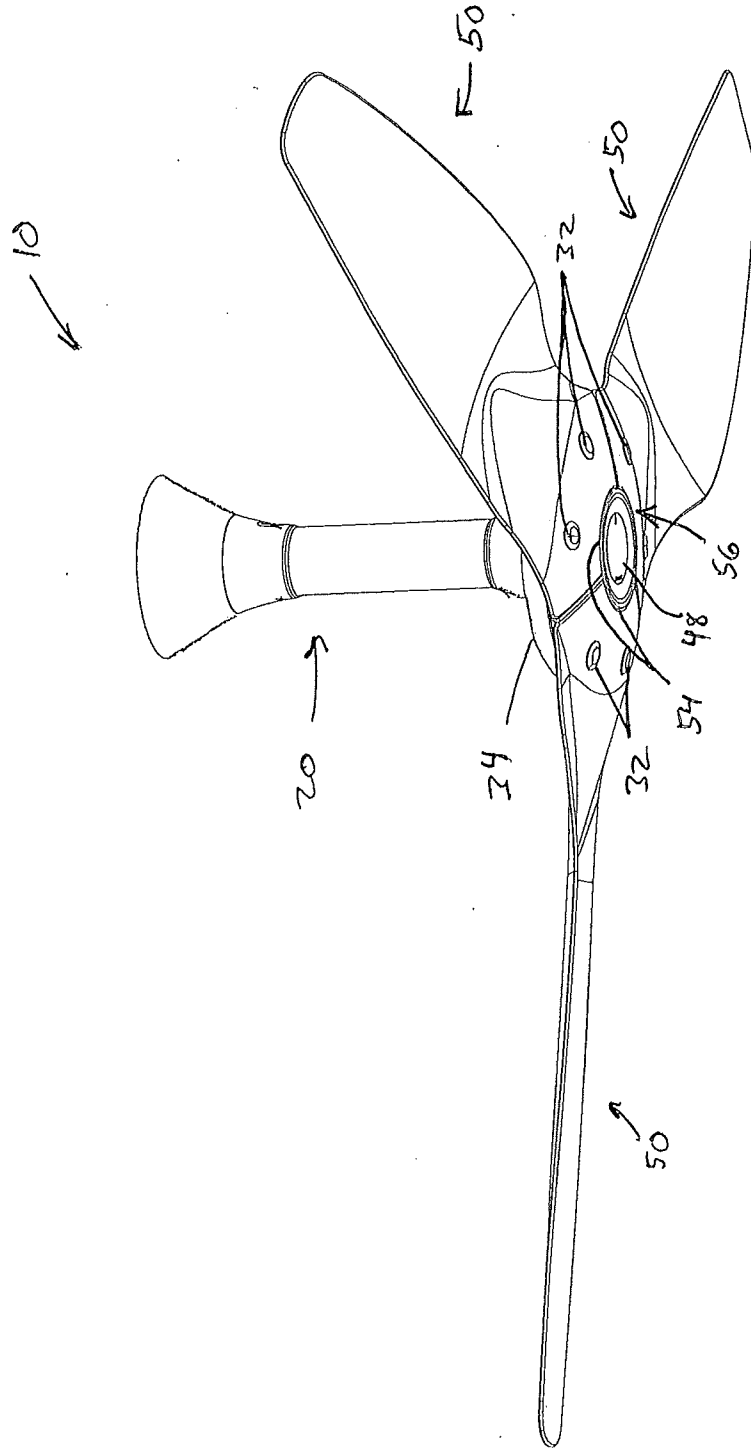


FIG. 1



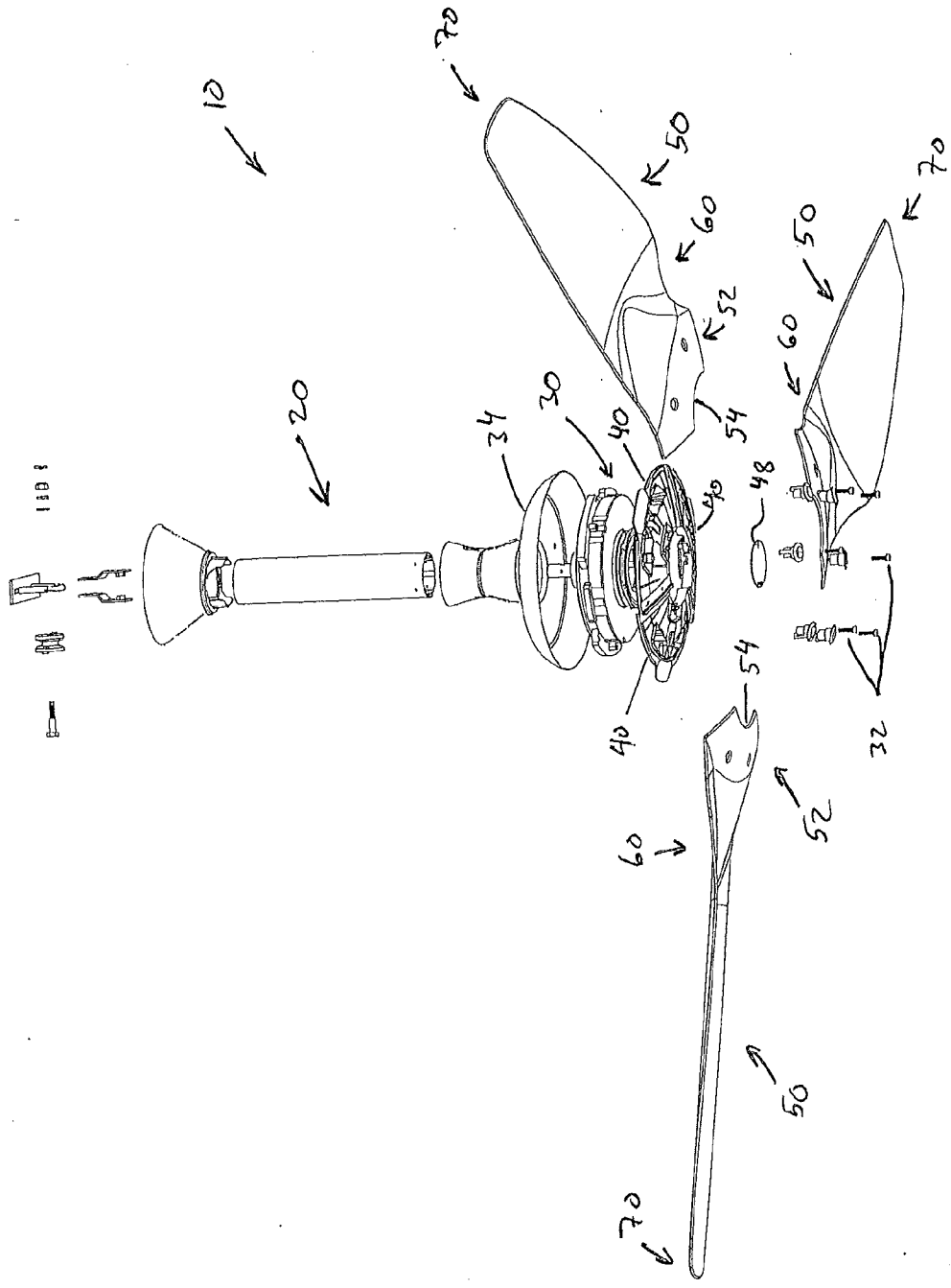


FIG. 2



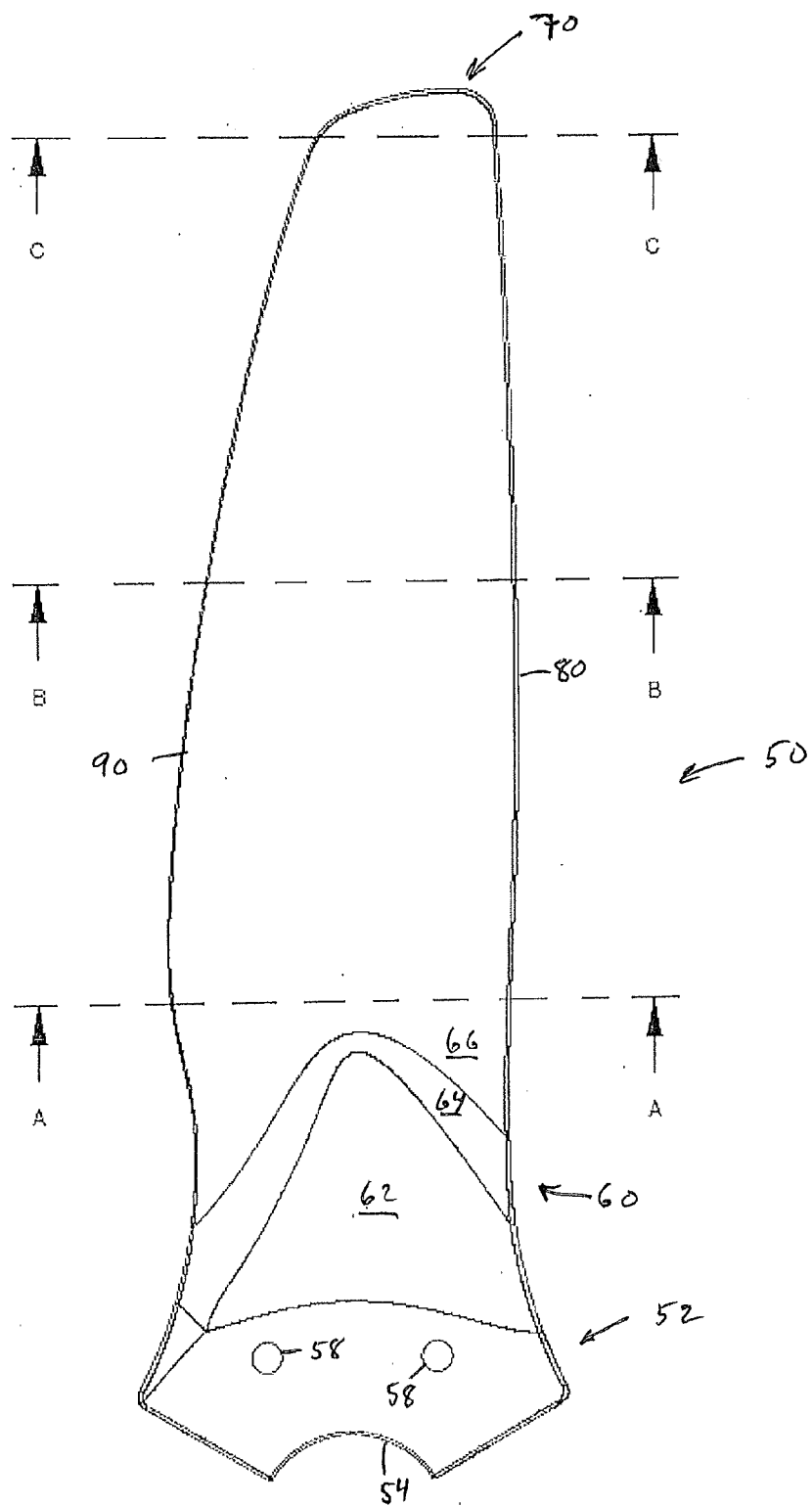


FIG 4

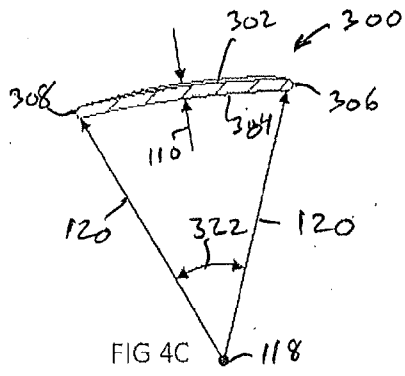


FIG 4C

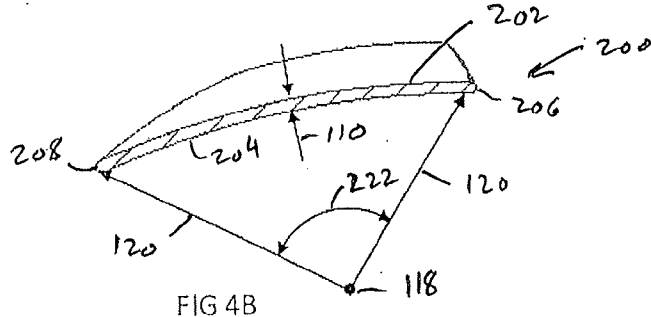


FIG 4B

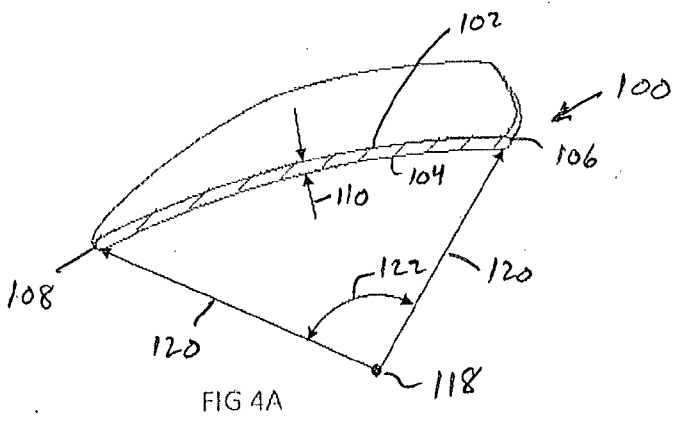


FIG 4A

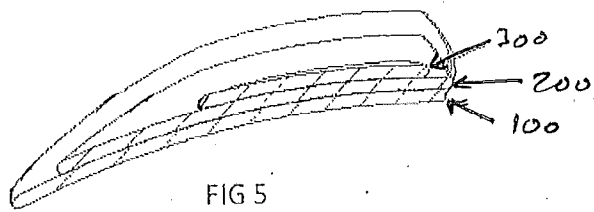


FIG 5

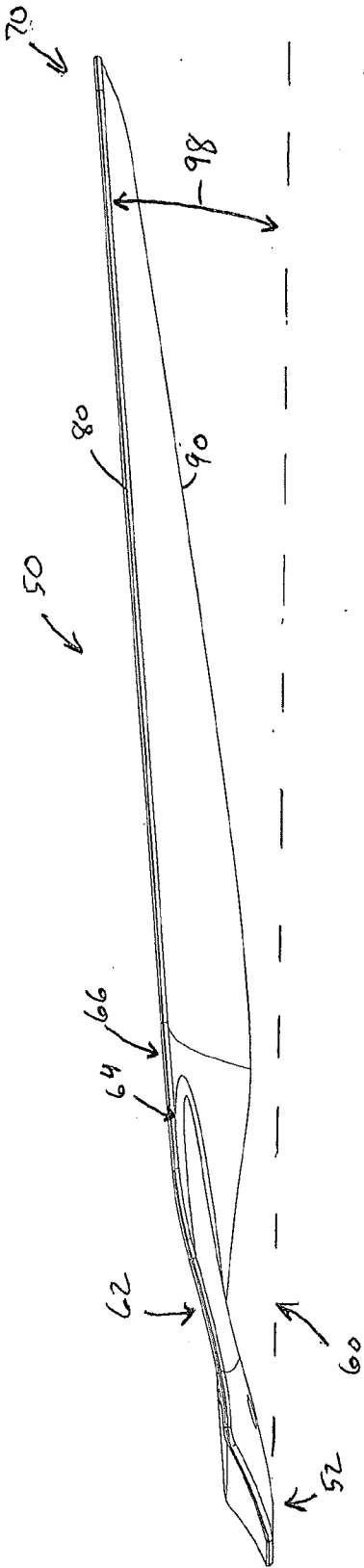


FIG. 6

FIG. 7

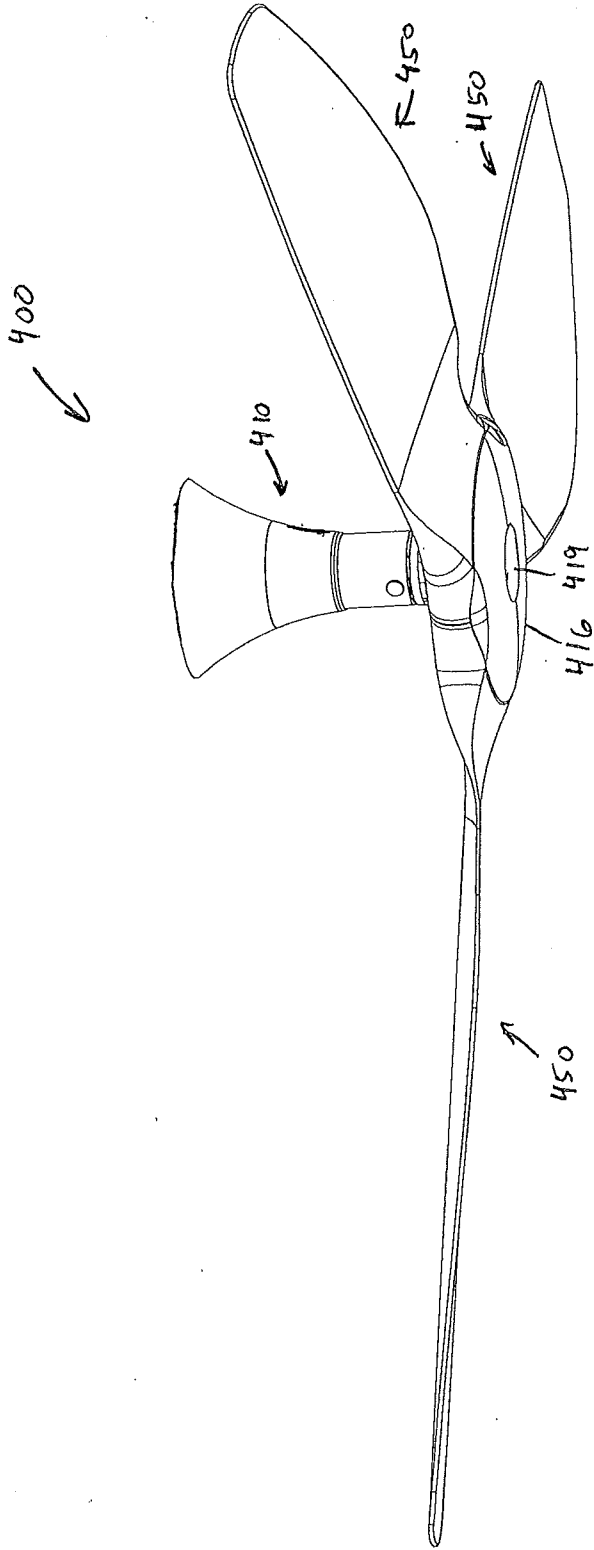
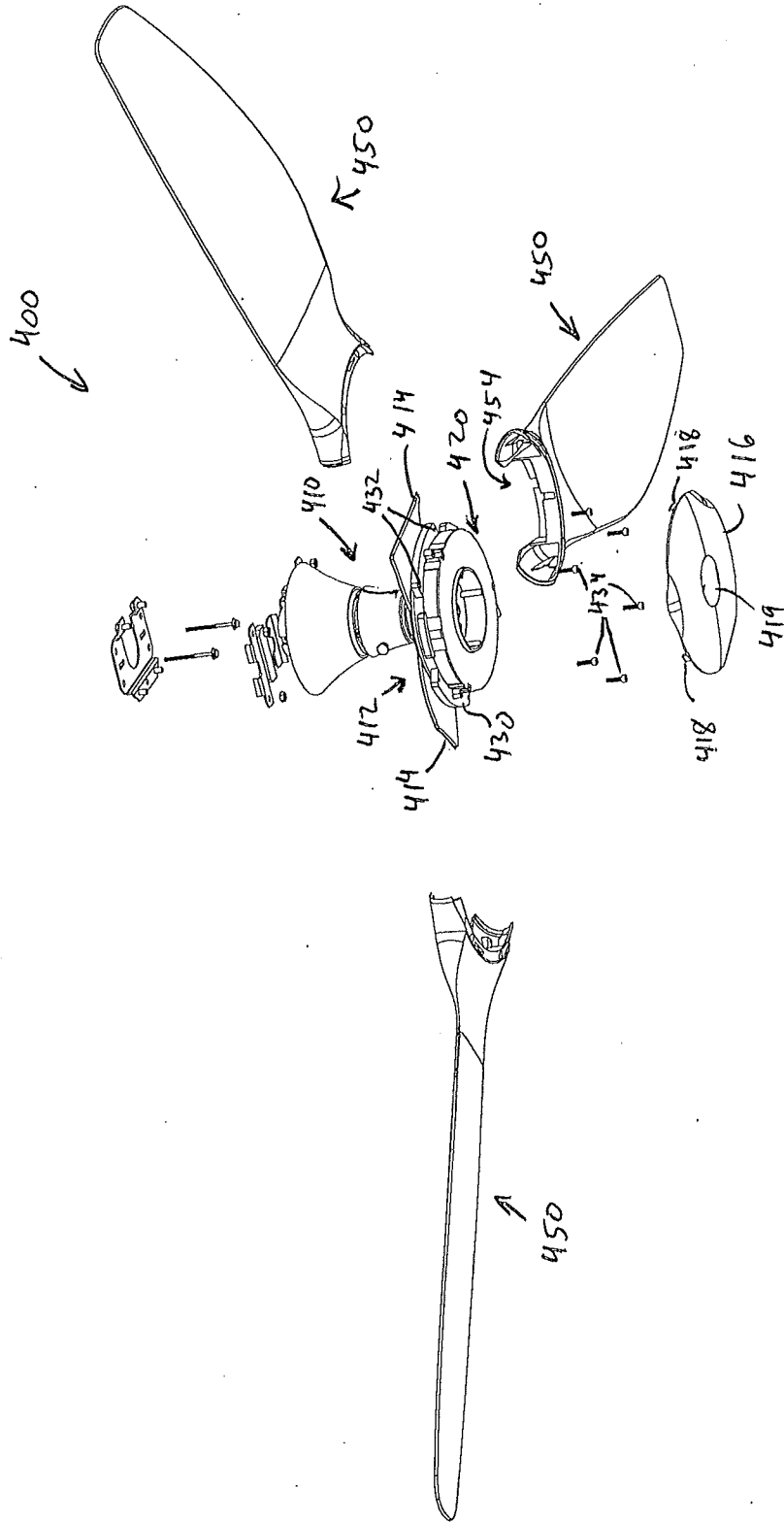


FIG. 8



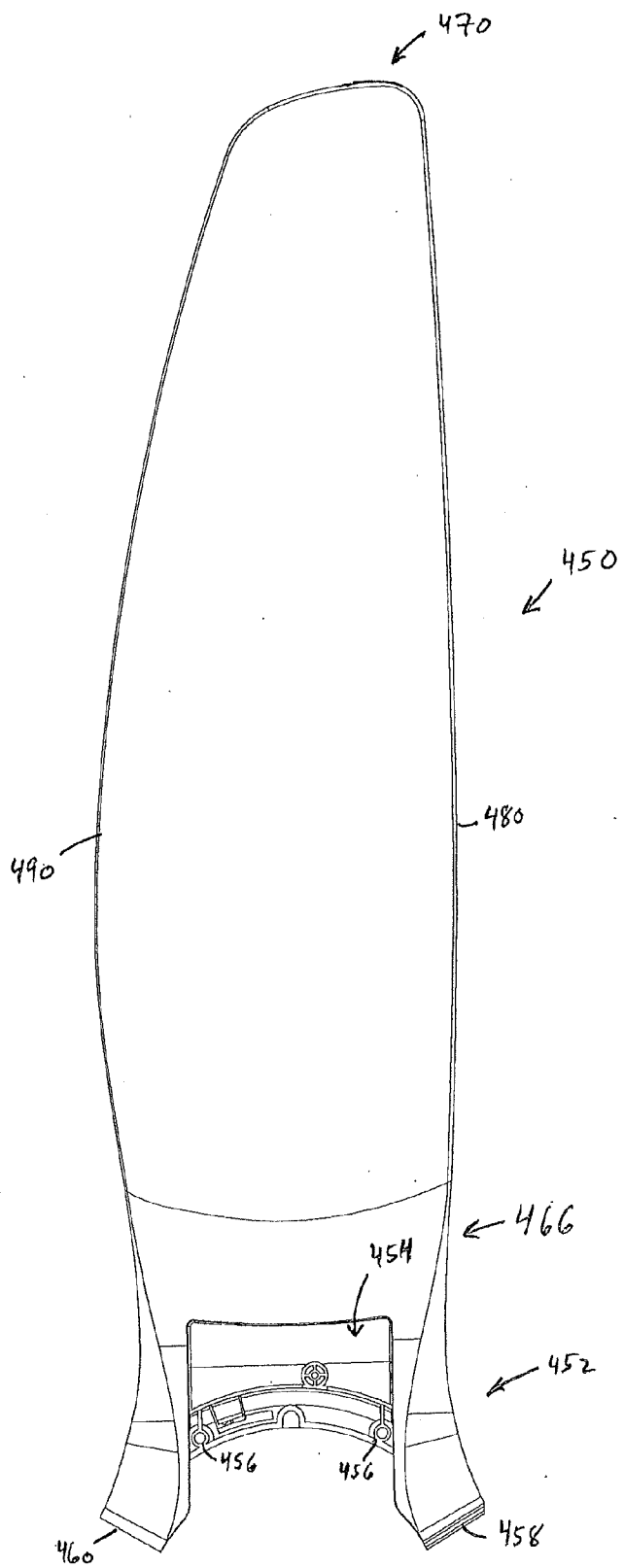


FIG. 9

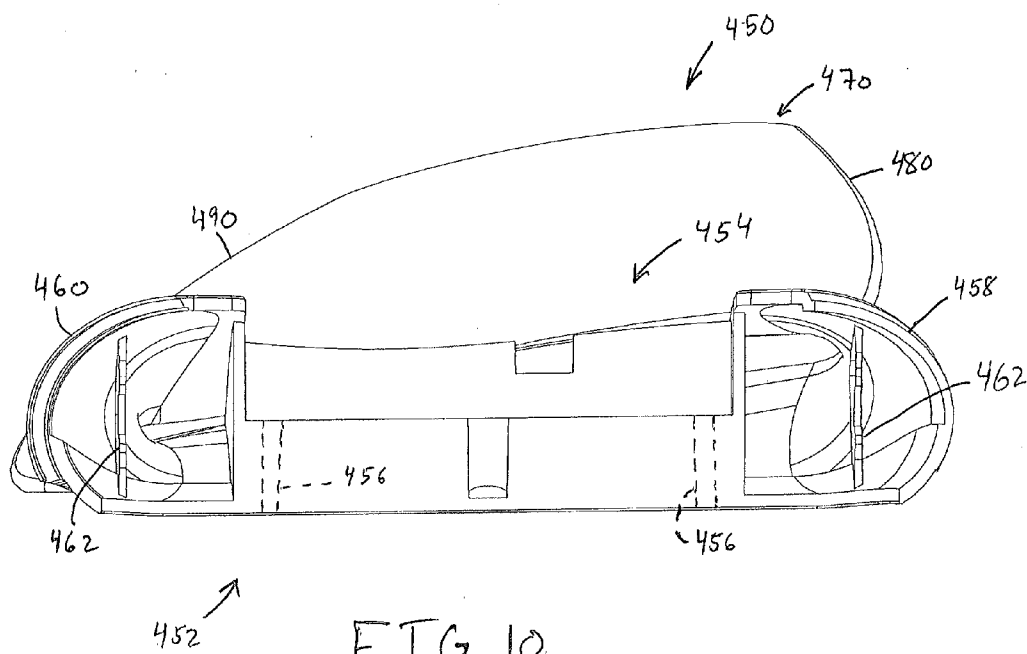


FIG. 10

**THIN AIRFOIL CEILING FAN BLADE****PRIORITY**

**[0001]** This application claims priority to U.S. Provisional Patent Application Ser. No. 61/588,932, filed Jan. 20, 2012, entitled “Thin Airfoil Ceiling Fan Blade,” the disclosure of which is incorporated by reference herein.

**BACKGROUND**

**[0002]** A variety of fan systems have been made and used over the years in a variety of contexts. For instance, various ceiling fans are disclosed in U.S. Pat. No. 7,284,960, entitled “Fan Blades,” issued Oct. 23, 2007; U.S. Pat. No. 6,244,821, entitled “Low Speed Cooling Fan,” issued Jun. 12, 2001; U.S. Pat. No. 6,939,108, entitled “Cooling Fan with Reinforced Blade,” issued Sep. 6, 2005; and U.S. Pat. No. D607,988, entitled “Ceiling Fan,” issued Jan. 12, 2010. The disclosures of each of those U.S. patents are incorporated by reference herein. Additional exemplary fans are disclosed in U.S. Pat. No. 8,079,823, entitled “Fan Blades,” issued Dec. 20, 2011; U.S. Pat. Pub. No. 2009/0208333, entitled “Ceiling Fan System with Brushless Motor,” published Aug. 20, 2009; and U.S. Pat. Pub. No. 2010/0278637, entitled “Ceiling Fan with Variable Blade Pitch and Variable Speed Control,” published Nov. 4, 2010, the disclosures of which are also incorporated by reference herein. It should be understood that teachings herein may be incorporated into any of the fans described in any of the above-referenced patents, publications, or patent applications.

**[0003]** A fan blade or airfoil may include one or more upper air fences and/or one or more lower air fences at any suitable position(s) along the length of the fan blade or airfoil. Merely exemplary air fences are described in U.S. Pat. Pub. No. 2011/0081246, entitled “Air Fence for Fan Blade,” published Apr. 7, 2011, the disclosure of which is incorporated by reference herein. Alternatively, any other suitable type of component or feature may be positioned along the length of a fan blade or airfoil; or such components or features may simply be omitted.

**[0004]** The outer tip of a fan blade or airfoil may be finished by the addition of an aerodynamic tip or winglet. Merely exemplary winglets are described in U.S. Pat. No. 7,252,478, entitled “Fan Blade Modifications,” issued Aug. 7, 2007, the disclosure of which is incorporated by reference herein. Additional winglets are described in U.S. Pat. No. 7,934,907, entitled “Cuffed Fan Blade Modifications,” issued May 3, 2011, the disclosure of which is incorporated by reference herein. Still other exemplary winglets are described in U.S. Pat. No. D587,799, entitled “Winglet for a Fan Blade,” issued Mar. 3, 2009, the disclosure of which is incorporated by reference herein. In some settings, such winglets may interrupt the outward flow of air at the tip of a fan blade, redirecting the flow to cause the air to pass over the fan blade in a perpendicular direction, and also ensuring that the entire air stream exits over the trailing edge of the fan blade and reducing tip vortex formation. In some settings, this may result in increased efficiency in operation in the region of the tip of the fan blade. In other variations, an angled extension may be added to a fan blade or airfoil, such as the angled airfoil extensions described in U.S. Pat. No. 8,162,613, entitled “Angled Airfoil Extension for Fan Blade,” issued Apr. 24, 2012, the disclosure of which is incorporated by reference herein. Other suitable structures that may be associated with

an outer tip of an airfoil or fan blade will be apparent to those of ordinary skill in the art. Alternatively, the outer tip of an airfoil or fan blade may be simply closed (e.g., with a cap or otherwise, etc.), or may lack any similar structure at all.

**[0005]** The interface of a fan blade and a fan hub may also be provided in a variety of ways. For instance, an interface component is described in U.S. Pat. No. 8,147,204, entitled “Aerodynamic Interface Component for Fan Blade,” issued Apr. 3, 2012, the disclosure of which is incorporated by reference herein. In addition, or in the alternative, the fan blade may include a retention system that couples the tip of a fan blade to an attachment point on the fan hub via a cable running through the fan blade, such as that disclosed in U.S. Pat. Pub. No. 2011/0262278, published Oct. 27, 2011. Alternatively, the interface of a fan blade and a fan hub may include any other component or components, or may lack any similar structure at all.

**[0006]** Fans may also include a variety of mounting structures. For instance, a fan mounting structure is disclosed in U.S. Pat. No. 8,152,453, entitled “Ceiling Fan with Angled Mounting,” issued Apr. 10, 2012, the disclosure of which is incorporated herein. Of course, a fan need not be mounted to a ceiling or other overhead structure, and instead may be mounted to a wall or to the ground. For instance, a fan may be supported on the top of a post that extends upwardly from the ground. Examples of such mounting structures are shown in U.S. Design Pat. No. D635,237, entitled “Fan with Ground Support,” issued Mar. 29, 2011, the disclosure of which is incorporated by reference herein; U.S. Design Pat. No. D641,075, entitled “Fan with Ground Support and Winglets,” issued Jul. 5, 2011, the disclosure of which is incorporated by reference herein; and U.S. Pat. App. No. 61/720,077, entitled “Fan Mounting System,” filed Oct. 30, 2012, the disclosure of which is incorporated by reference herein. Alternatively, any other suitable mounting structures and/or mounting techniques may be used in conjunction with embodiments described herein.

**[0007]** It should also be understood that a fan may include sensors or other features that are used to control, at least in part, operation of a fan system. For instance, such fan systems are disclosed in U.S. Pat. No. 8,147,182, entitled “Ceiling Fan with Concentric Stationary Tube and Power-Down Features,” issued Apr. 3, 2012, the disclosure of which is incorporated by reference herein; U.S. Pat. No. 8,123,479, entitled “Automatic Control System and Method to Minimize Oscillation in Ceiling Fans,” issued Feb. 28, 2012, the disclosure of which is incorporated by reference herein; U.S. Pat. Pub. No. 2010/0291858, entitled “Automatic Control System for Ceiling Fan Based on Temperature Differentials,” published Nov. 18, 2010, the disclosure of which is incorporated by reference herein; U.S. Provisional Patent App. No. 61/165,582, entitled “Fan with Impact Avoidance System Using Infrared,” filed Apr. 1, 2009, the disclosure of which is incorporated by reference herein; and U.S. Pat. App. No. 61/720,679, entitled “Integrated Thermal Comfort Control System Utilizing Circulating Fans,” filed Oct. 31, 2012, the disclosure of which is incorporated by reference herein. Alternatively, any other suitable control systems/features may be used in conjunction with embodiments described herein.

**[0008]** In some settings, it may be desirable to replicate or approximate the function of a winglet in a component that may be located at a position on a fan blade other than at the free end of the fan blade. For instance, such components are disclosed in U.S. Pat. Pub. No. 2011/0081246, entitled “Air

Fence For Fan Blade,” published Apr. 7, 2011, the disclosure of which is incorporated by reference herein. Such a component may provide an effect on fan efficiency similar to the effect provide by a winglet, albeit at one or more additional regions of the fan blade. In particular, such a component or accessory may serve as an aerodynamic guide or air fence, interrupting slippage of air along the length or longitudinal axis of the fan blade; and redirecting the air flow to a direction perpendicular to the longitudinal axis of the fan blade, above and/or below the fan blade.

[0009] In some ceiling fans, flat planar blades are used by inclining the blades at an angle of approximately ten to twenty degrees from the horizontal to displace airflow in a downward direction. These flat blades might not be aerodynamically efficient in some settings. Accordingly, to move a given volume of air, the fan must operate at a higher speed, thereby consuming more electricity. In addition, these flat blades might be manufactured from wood or fiberboard, harvested from trees, such as Monterey Pine, which typically take 25-30 years to reach maturity. Since the regrowth time of the raw materials may exceed the lifespan of the ceiling fan, continued production in this manner is not an environmentally sustainable practice.

[0010] While flat planar blades have been used, attempts have been made to improve upon ceiling fan blade designs. For example, Parker, et al, U.S. Pat. No. 6,039,541, issued Mar. 21, 2000, describes a ceiling fan blade that includes the SD7032, GM15, MA409, and Hibbs 504 airfoils. Airfoils of this type may operate with higher coefficients of lift versus angle of attack at Reynolds numbers greater than 100,000. In the instance of a fan blade with a chord length of 10.16 centimeters (4 inches) and blade span with the root located 22.5 centimeters (9 inches) from the center of rotation and a tip located 76.2 centimeters (30 inches) from the center of rotation, operating at 50 rotations per minute may experience Reynolds numbers ranging from 8,000 at the root to 28,000 at the tip. While at 200 rotations per minute, the fan blade may experience Reynolds numbers ranging from 33,000 at the root to 110,000 at the tip. At speeds below 180 rotations per minute, the entire blade may experience Reynolds numbers less than 100,000. Accordingly, the airfoils described by Parker, et al. may operate below their optimal performance under the majority of operating conditions for the ceiling fan. Furthermore, airfoil blades of the types disclosed in Parker, et al. may increase manufacturing complexity since the airfoil thickness has a teardrop profile and varies substantially from leading edge to trailing edge. In some instances, to create this teardrop profile the blade must be manufactured by plastic injection molding or, alternatively, machined from a flat sheet material, which may result in significant wastage. Thus, a need exists for an improved blade design that offers optimal airflow performance at the low Reynolds numbers experienced by a ceiling fan and is capable of being manufactured by simple techniques using sustainable materials.

[0011] While several systems and methods have been made and used for ceiling fan blades, it is believed that no one prior to the inventors has made or used the invention described in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] While the specification concludes with claims which particularly point out and distinctly claim this technology, it is believed this technology will be better understood from the following description of certain examples taken in

conjunction with the accompanying drawings, in which like reference numerals identify the same elements and in which:

[0013] FIG. 1 depicts a front perspective view of an exemplary fan having a plurality of exemplary ceiling fan blades attached thereto;

[0014] FIG. 2 depicts an exploded perspective view of the fan of FIG. 1;

[0015] FIG. 3 depicts a side elevation view of the fan of FIG. 1;

[0016] FIG. 4 depicts a plan view of the exemplary ceiling fan blade of FIGS. 1-3;

[0017] FIG. 4A depicts a cross-sectional view of the ceiling fan blade of FIG. 4 taken along section line A-A of FIG. 4;

[0018] FIG. 4B depicts a cross-sectional view of the ceiling fan blade of FIG. 4 taken along section line B-B of FIG. 4;

[0019] FIG. 4C depicts a cross-sectional view of the ceiling fan blade of FIG. 4 taken along section line C-C of FIG. 4;

[0020] FIG. 5 depicts a combination cross-sectional view of the blade sections shown in FIGS. 4A-4C, showing the relative curvature of each section;

[0021] FIG. 6 depicts a front elevation view of the fan blade of FIGS. 1-5;

[0022] FIG. 7 depicts a perspective view of an alternative fan having a plurality of exemplary ceiling fan blades attached thereto;

[0023] FIG. 8 depicts an exploded perspective view of the fan of FIG. 7;

[0024] FIG. 9 depicts a plan view of the exemplary fan blade of FIG. 7; and

[0025] FIG. 10 depicts an elevation view taken from a root end of the fan blade of FIG. 9.

[0026] The drawings are not intended to be limiting in any way, and it is contemplated that various embodiments of the technology may be carried out in a variety of other ways, including those not necessarily depicted in the drawings. The accompanying drawings incorporated in and forming a part of the specification illustrate several aspects of the present technology, and together with the description serve to explain the principles of the technology; it being understood, however, that this technology is not limited to the precise arrangements shown.

DETAILED DESCRIPTION

[0027] The following description of certain examples of the technology should not be used to limit its scope. Other examples, features, aspects, embodiments, and advantages of the technology will become apparent to those skilled in the art from the following description, which is by way of illustration, one of the best modes contemplated for carrying out the technology. As will be realized, the technology described herein is capable of other different and obvious aspects, all without departing from the technology. Accordingly, the drawings and descriptions should be regarded as illustrative in nature and not restrictive.

[0028] I. Exemplary Fan Overview

[0029] Referring to FIG. 1, a fan (10) of the present example comprises a support (20), a motor (30) (shown in FIG. 2), and a plurality of fan blades (50). While three fan blades (50) are shown, it should be understood that any other suitable number of fan blades (50) may be used. Fan blades (50) of the present example may define a fan diameter ranging from approximately 0.5 meters (1.64 feet), inclusive, to approximately 5 meters (16.4 feet), inclusive. In the present example, fan blades (50) define a fan diameter of approxi-

mately 1.5 meters (4.92 feet). Alternatively, fan (10) and/or fan blades (50) may have any other suitable dimensions.

**[0030]** Support (20) is configured to be coupled to a surface or other structure at a first end such that fan (10) is substantially attached to the surface or other structure. Support (20) of the present example comprises an elongate metal tube-like structure that couples fan (10) to a ceiling, though it should be understood that support (20) may be constructed and/or configured in a variety of other suitable ways as will be apparent to one of ordinary skill in the art in view of the teachings herein. In one merely exemplary version, support (20) is configured to couple to an electrical junction box (not shown) located within or on a ceiling. With support (20) comprising an elongate metal tube, wires or other power supply or control members are extended through support (20) to motor (30). By way of example only, support (20) need not be coupled to a ceiling or other overhead structure, and instead may be coupled to a wall or to the ground. For instance, support (20) may be positioned on the top of a post that extends upwardly from the ground. Alternatively, support (20) may be mounted in any other suitable fashion at any other suitable location. This includes, but is not limited to, the teachings of the patents, patent publications, or patent applications cited herein. By way of example only, support (20) may be configured in accordance with the teachings of U.S. Pat. Pub. No. 2009/0072108, entitled “Ceiling Fan with Angled Mounting,” published Mar. 19, 2009, the disclosure of which is incorporated by reference herein. As yet another alternative, support (20) may have any other suitable configuration.

**[0031]** As shown in FIG. 2, fan (10) of the present example includes a motor (30) that is coupled to fan blades (50). Motor (30) of the present example is coupled to fan blades (50) via fasteners (32). Fasteners (32) may include screws, bolts, clips, clamps, and/or any other suitable fastener (32) for coupling fan blades (50) to motor (30). Alternatively, fasteners (32) may be omitted and fan blades (50) may be adhesively attached or integrally formed with a portion of motor (30) such that fan blades (50) rotate when motor (30) is operated. In the present example, a blade shoe (40) is interposed between motor (30) and each fan blade (50). In some versions, blade shoe (40) may comprise a rubber, synthetic rubber, or other vibratory buffering material such that fan blades (50) are substantially isolated from vibrations of motor (30) and/or other portions of fan (10). Alternatively, blade shoe (40) may comprise a plastic, metal, wood, composite, and/or any other material. Of course it should be understood that blade shoe (40) is merely optional and may be omitted.

**[0032]** In some versions, motor (30) comprises an AC induction motor having a drive shaft, though it should be understood that motor (30) may alternatively comprise any other suitable type of motor (e.g., a permanent magnet brushless DC motor, a brushed motor, an inside-out motor, etc.). In the present example, motor (30) is fixedly coupled to support (20) and is configured to rotate fan blades (50) relative to support (20) such that air is propelled by fan (10) away from the structure to which support (20) is coupled. In an alternative version, shown in FIGS. 7-10, a hub (430) may be included in addition to, or instead of, blade shoes (40). In the version shown in FIGS. 7-10, hub (430) comprises an annular member having a plurality of holes (432) disposed about the circumference to which fan blades (50) may be coupled. Hub (430) is coupled to motor (30) such that rotation of hub (430) by motor (30) rotates fan blades (50). Of course motor (30) may be constructed in accordance with at least some of the

teachings of U.S. Pat. Pub. No. 2009/0208333, entitled “Ceiling Fan System with Brushless Motor,” published Aug. 20, 2009, the disclosure of which is incorporated by reference herein. Furthermore, fan (10) may include control electronics that are configured in accordance with at least some of the teachings of U.S. Pat. Pub. No. 2010/0278637, entitled “Ceiling Fan with Variable Blade Pitch and Variable Speed Control,” published Nov. 4, 2010, the disclosure of which is incorporated by reference herein. Of course, motor (30), blade shoe (40), and/or hub (430) may have any other suitable components, configurations, functionalities, and operability, as will be apparent to those of ordinary skill in the art in view of the teachings herein.

**[0033]** In the present example, fan (10) further includes a top cover (34). Top cover (34) comprises a dome-shaped component configured to enclose the top of motor (30). Top cover (34) of the present example is attached to support (20) to form a dome over the top of motor (30) when motor (30) is coupled to support (20). In some versions, top cover (34) is threadably coupled to support (20). In other versions, top cover (34) may be integrally formed with support (20), coupled via fasteners (not shown), or otherwise attached to support (20) and/or motor (30). When fan blades (50) of the example shown in FIGS. 1-3 are coupled to motor (30), fan blades (50) and top cover (34) substantially enclose motor (30), as seen best in FIG. 1.

**[0034]** Fan blades (50) of the example shown in FIGS. 1-6 each include an arcuate cutout (54) at a root end (52) of each fan blade (50). When fan blades (50) are coupled to motor (30), arcuate cutouts (54) form a cylindrical aperture (56). A semi-transparent lens (48) is inserted into aperture (56). A sensor (not shown) is mounted within aperture (56) and is configured to receive infrared signals from a remote control (not shown) or other source. The sensor is coupled to a motor control module that is operable to control fan (10). Fan (10) may be further configured in accordance with at least some of the teachings of the fan systems disclosed in U.S. Pat. Pub. No. 2009/0097975, entitled “Ceiling Fan with Concentric Stationary Tube and Power-Down Features,” published Apr. 16, 2009, the disclosure of which is incorporated by reference herein; U.S. Pat. Pub. No. 2009/0162197, entitled “Automatic Control System and Method to Minimize Oscillation in Ceiling Fans,” published Jun. 25, 2009, the disclosure of which is incorporated by reference herein; U.S. Pat. Pub. No. 2010/0291858, entitled “Automatic Control System for Ceiling Fan Based on Temperature Differentials,” published Nov. 18, 2010, the disclosure of which is incorporated by reference herein; and U.S. Provisional Patent App. No. 61/165,582, entitled “Fan with Impact Avoidance System Using Infrared,” filed Apr. 1, 2009, the disclosure of which is incorporated by reference herein. Still further configurations for lens (48), arcuate cutouts (54), aperture (56), and the sensor will be apparent to one of ordinary skill in the art in view of the teachings herein. Of course, it should be understood that lens (48), arcuate cutouts (54) and aperture (56) are merely optional and may be omitted.

**[0035]** While some merely exemplary features of fan (10) have been described herein, it should be understood that fan (10) may have other features, components, and/or configurations as will be apparent to one of ordinary skill in the art in view of the teachings herein.

**[0036]** II. Exemplary Fan Blades

**[0037]** A single fan blade (50) is shown plan form in FIG. 4 having a root end (52), a tip (70), a leading edge (80) and a

trailing edge (90). Sections A-A, B-B, and C-C are shown in FIG. 4 and correspond to cross-sectional FIGS. 4A, 4B, and 4C, respectively. Sections A-A, B-B, and C-C will be discussed in greater detail below. As noted above, root end (52) of the present example comprises an arcuate cutout (54) configured to permit lens (48) be inserted in a central aperture (56) formed when fan blades (50) are mounted. Root end (52) further includes a pair of openings (58) that permit fasteners (32) to extend therethrough to couple fan blade (50) to motor (30) and/or hub (42). As shown in FIGS. 1-3, root end (52) of the present exemplary fan blade (50) comprises a domed sector that corresponds to an approximately 120 degree sector of a dome for the present fan (10) having three fan blades (50). The domed sector of root end (52) is substantially flat, or parallel, relative to the plane of rotation for fan blades (50) at or near arcuate cutout (54). The domed sector curves upwardly toward motor (30) and/or support (20). Root end (52) may of course include an approximately 180 degree, 90 degree, 60 degree, 45 degree and/or any other sector portion of a dome or may omit a domed sector end. Of course other root ends (52) will be apparent to one of ordinary skill in the art in view of the teachings herein.

[0038] Fan blade (50) also includes a transition region (60) extending from root end (52), shown best in FIGS. 4 and 6. In the present example, transition region (60) comprises a first portion (62), an inflection portion (64), and a second portion (66). First portion (62) comprises an extension of the domed sector of root end (52) that terminates at inflection portion (64). Inflection portion (64) of the present example comprises a quasi-parabolic shaped portion that extends from leading edge (80) to trailing edge (90) and transitions fan blade (50) from the upwardly extending domed shape of first portion to a planar portion. Second portion (66) extends from inflection portion (64) and transitions fan blade (50) from the planar inflection portion (64) to the downwardly curved root airfoil profile (100), shown in FIG. 4A. By way of example only, a non-dimensional matrix of coordinates in Table 1 below generally describes the surface formed by transition region (60) and airfoil profile (100). It should be understood that the domed sector of root end (52) is omitted from the coordinates in Table 1. In addition, the Z coordinate corresponds to the vertical height of the point at the transition point from root end (52) (e.g., a height of 0 corresponds to where root end (52) ends and transition region (60) begins), the X coordinate corresponds to the longitudinal distance from a central point about which blade (50) rotates, and the Y coordinate corresponds to the chord-wise position, where negative coordinates approach trailing edge (90) and positive coordinates approach leading edge (80).

TABLE 1-continued

Z	X	Y
0	0.1351	0.002
0	0.1327	0.003
0	0.1294	0.004
0	0.1252	0.005
0	0.1201	0.006
0	0.1141	0.007
0	0.1071	0.008
0	0.0989	0.009
0	0.0888	0.01
0.005	0.0986	-0.01
0.005	0.1273	-0.009
0.005	0.1897	-0.008
0.005	0.1452	-0.007
0.005	0.1471	-0.006
0.005	0.1521	-0.005
0.005	0.1564	-0.004
0.005	0.1595	-0.003
0.005	0.1614	-0.002
0.005	0.1621	-0.001
0.005	0.1617	0
0.005	0.1602	0.001
0.005	0.1578	0.002
0.005	0.1544	0.003
0.005	0.1501	0.004
0.005	0.145	0.005
0.005	0.139	0.006
0.005	0.1322	0.007
0.005	0.1248	0.008
0.005	0.1166	0.009
0.01	0.4002	-0.007
0.01	0.3408	-0.006
0.01	0.286	-0.005
0.01	0.1931	-0.004
0.01	0.1902	-0.003
0.01	0.1913	-0.002
0.01	0.1909	-0.001
0.01	0.1892	0
0.01	0.1863	0.001
0.01	0.1824	0.002
0.01	0.1776	0.003
0.01	0.1718	0.004
0.01	0.1653	0.005
0.01	0.1581	0.006
0.01	0.1503	0.007
0.01	0.1421	0.008
0.015	0.4724	-0.007
0.015	0.4133	-0.006
0.015	0.3586	-0.005
0.015	0.3085	-0.004
0.015	0.2616	-0.003
0.015	0.2246	-0.002
0.015	0.2212	-0.001
0.015	0.2175	0
0.015	0.2126	0.001
0.015	0.2067	0.002
0.015	0.2	0.003
0.015	0.1926	0.004
0.015	0.1846	0.005
0.015	0.1762	0.006
0.015	0.1675	0.007
0.015	0.1585	0.008
0.02	0.5299	-0.007
0.02	0.4852	-0.006
0.02	0.4308	-0.005
0.02	0.3807	-0.004
0.02	0.3352	-0.003
0.02	0.2942	-0.002
0.02	0.2551	-0.001
0.02	0.2442	0
0.02	0.2369	0.001
0.02	0.2289	0.002
0.02	0.2204	0.003
0.02	0.2115	0.004
0.02	0.2023	0.005
0.02	0.1929	0.006

TABLE 1

Z	X	Y
0	0.0892	-0.01
0	0.0991	-0.009
0	0.1072	-0.008
0	0.1145	-0.007
0	0.1209	-0.006
0	0.1263	-0.005
0	0.1305	-0.004
0	0.1337	-0.003
0	0.1358	-0.002
0	0.137	-0.001
0	0.1373	0
0	0.1366	0.001

TABLE 1-continued

Z	X	Y
0.02	0.1834	0.007
0.02	0.1745	0.008
0.025	0.5627	-0.006
0.025	0.5024	-0.005
0.025	0.4526	-0.004
0.025	0.4072	-0.003
0.025	0.3662	-0.002
0.025	0.3296	-0.001
0.025	0.2975	0
0.025	0.2696	0.001
0.025	0.2502	0.002
0.025	0.2395	0.003
0.025	0.2297	0.004
0.025	0.2203	0.005
0.025	0.2117	0.006
0.025	0.2042	0.007
0.025	0.1988	0.008
0.03	0.5734	-0.005
0.03	0.5241	-0.004
0.03	0.4789	-0.003
0.03	0.438	-0.002
0.03	0.4014	-0.001
0.03	0.3692	0
0.03	0.3412	0.001
0.03	0.3175	0.002
0.03	0.2977	0.003
0.03	0.2818	0.004
0.03	0.2696	0.005
0.03	0.2614	0.006
0.03	0.2566	0.007
0.03	0.2548	0.008
0.035	0.595	-0.004
0.035	0.5502	-0.003
0.035	0.5095	-0.002
0.035	0.473	-0.001
0.035	0.4408	0
0.035	0.4128	0.001
0.035	0.3891	0.002
0.035	0.3693	0.003
0.035	0.3535	0.004
0.035	0.3414	0.005
0.035	0.333	0.006
0.035	0.328	0.007
0.035	0.3264	0.008
0.04	0.6211	-0.003
0.04	0.5808	-0.002
0.04	0.5445	-0.001
0.04	0.5124	0
0.04	0.4844	0.001
0.04	0.4606	0.002
0.04	0.4409	0.003
0.04	0.4252	0.004
0.04	0.4133	0.005
0.04	0.4051	0.006
0.04	0.4005	0.007
0.04	0.3994	0.008

[0039] Of course, it should be understood that other configurations for transition region (60) and/or other regions of fan blade (50) may be used. For instance, if root end (52) omits a domed sector, then fan blade (50) may omit first portion (62) and, in some versions, inflection portion (64), having only second portion (66) transition to root airfoil profile (100) directly. Still further constructions for transition region (60), etc., will be apparent to one of ordinary skill in the art in view of the teachings herein.

[0040] Referring now to FIG. 4A, a cross-sectional root airfoil profile (100) is shown taken along section A-A of FIG. 4. Root airfoil profile (100) comprises a top surface (102), a bottom surface (104), a leading edge (106), and a trailing edge (108). Root airfoil profile (100) of the present example com-

prises a curved airfoil having a substantially constant thickness (110) and a substantially constant radius of curvature (120). By way of example only, thickness (110) may range from approximately 1 millimeter (0.03937 inches), inclusive, to approximately 5 millimeters (0.19685 inches), inclusive. In the example shown, thickness (110) is approximately 4 millimeters (0.15748 inches) though this is merely one embodiment. Still further values for thickness (110) will be apparent to one of ordinary skill in the art in view of the teachings herein. Also by way of example only, radius of curvature (120) is measured from a center point (118) and may range from approximately 2 meters (6.56167 feet), inclusive, to approximately 5 meters (16.4042 feet), inclusive. In the example shown, radius of curvature (120) is approximately 3.7 meters (12.1391 feet). Still further values for radius of curvature (120) will be apparent to one of ordinary skill in the art in view of the teachings herein. In the example shown in FIG. 4A, root airfoil profile (100) is defined when radius of curvature (120) is swept through a root angle (122). Root angle (122) of the present example is approximately 14 degrees, though it should be understood that this is merely exemplary and other smaller and/or larger root angles (122) will be apparent to one of ordinary skill in the art in view of the teachings herein. Furthermore, leading edge (106) and trailing edge (108) comprise rounded surfaces connecting top surface (102) to bottom surface (104), though this is merely optional. Leading edge (102) and trailing edge (104) of the present example form rounded surfaces having a radius of curvature substantially equal to thickness (110). Thus, as shown in FIG. 4A, a substantially constant thickness root airfoil profile (100) is formed.

[0041] FIG. 4B depicts a cross-sectional intermediate airfoil profile (200) taken along section B-B of FIG. 4 at an approximate midpoint between root airfoil profile (100) and tip airfoil profile (300), discussed in greater detail below. It should be understood that while the term intermediate is used, it does not necessarily connote that the shape, size, or values defining intermediate airfoil profile (200) are in between those of root airfoil profile (100) and tip airfoil profile (300). Intermediate airfoil profile (200) of the present example comprises a top surface (202), a bottom surface (204), a leading edge (206), and a trailing edge (208). Intermediate airfoil profile (200) of the present example is substantially identical to root airfoil profile (100) and has a substantially identical thickness (110) and is defined by a substantially identical radius of curvature (120) with the exception that radius of curvature (120) is swept through an intermediate angle (222). By way of example only, intermediate angle (222) is approximately 12.5 degrees, though of course other smaller and/or larger intermediate angles (222) will be apparent to one of ordinary skill in the art in view of the teachings herein.

[0042] FIG. 4C shows a cross-sectional tip airfoil profile (300) taken along section C-C of FIG. 4 at an approximate tip (70) of fan blade (50). Tip airfoil profile (300) of the present example comprises a top surface (302), a bottom surface (304), a leading edge (306), and a trailing edge (308). Tip airfoil profile (300) of the present example is substantially identical to root airfoil profile (100) and has a substantially identical thickness (110) and is defined by a substantially identical radius of curvature (120) with the exception that radius of curvature (120) is swept through a tip angle (322). By way of example only, tip angle (322) is approximately 7 degrees, though of course other smaller and/or larger tip

angles (322) will be apparent to one of ordinary skill in the art in view of the teachings herein.

[0043] FIG. 5 depicts a composite overlay of the cross-sections of FIGS. 4A-4C. As noted above, root airfoil profile (100), intermediate airfoil profile (200), and tip airfoil profile (300) are substantially identical in shape and thickness with the exception of each being formed by sweeping radius of curvature (120) to various angle (122, 222, 322). In some versions, the tip angle (322) is a minimum value for the angles through which radius of curvature (120) is swept while root angle (122) is a maximum value for fan blade (50). Though, it should be understood that tip angle (322) need not necessarily be the minimum value for the angles through which radius of curvature (120) is swept and/or root angle (122) need not necessarily be the maximum value for the angles through which radius of curvature (120) is swept. In addition, or in the alternative, angles (122, 222, 322) may linearly increase in value from tip angle (322) to root angle (122). In other versions, angles (122, 222, 322) may increase in value logarithmically, parabolically, cubically, and/or in any other manner from tip angle (322) to root angle (122). Referring briefly to FIG. 6, fan blade (50) is also configured to have a blade rise angle (98). In the example shown, blade rise angle (98) corresponds to the angle formed between the plane in which the fan rotates and the top surface of fan blade (50). Thus, the absolute height of each fan blade (50) increases from root end (52) to tip (70). By way of example only, blade rise angle (98) may be an angle of approximately 0 degrees, inclusive, to approximately 20 degrees, inclusive. More specifically, blade rise angle (98) may be from 2.5 degrees, inclusive, to 5 degrees, inclusive. In the example shown, blade rise angle (98) is approximately 3.8 degrees. Still further configurations for airfoil profiles (100, 200, 300) and/or fan blade (50) will be apparent to one of ordinary skill in the art in view of the teachings herein. By way of example only, flaps, slats, extensions, electrical or mechanical actuators, and/or other features may be added to fan blades (50).

[0044] Fan blade (50) of the present example is manufactured from thin sheets of material laminated together. For instance, fan blade (50) may be constructed by combining individual sheets with adhesive between each layer and forcing the sheets together under pressure in a shaped mold to form fan blade (50) shown in FIGS. 1-6. By way of example only, fan blade (50) may be manufactured using 7 layers of 0.5 millimeter (0.019685 inches) thick bamboo veneer that are compressed together as described above. Of course other thicknesses and/or number of layers may be used. Alternatively, other types of wooden veneer may be used or may be combined with other woods to form composite fan blades (50). In yet a further alternative, fan blade (50) may be formed from of a thermoplastic resin that is injected into a mold for fan blade (50) to achieve the desired profile. Further still, fan blade (50) may be formed from a single layer of plastic that is heated and bent or inserted into a mold to form the profile of fan blade (50). In still a further alternative, fan blade (50) may be formed from layers of fiberglass matting or carbon fiber composite materials combined with epoxy resins. In yet another alternative, layers of wood veneer or other materials (e.g., carbon fiber, fiberglass, etc.) may initially be layered within a mold and plastic or another resin may be injected or otherwise added to form fan blade (50). Of course still further constructions for fan blade (50) will be apparent to one of ordinary skill in the art in view of the teachings herein.

### [0045] III. Exemplary Alternative Fan

[0046] FIGS. 7-10 depict an alternative fan (400) having a support (410), a motor (420), a hub (430), and a plurality of fan blades (450). Support (410) and motor (420) of the present example may be constructed in substantial accordance with support (20) and motor (30) described above. Hub (430), shown best in FIG. 8, comprises an annular member disposed about and coupled to motor (420) such that rotation of motor (420) rotates hub (430). Hub (430) further includes a plurality of holes (432) to which fasteners (434) may be coupled to substantially fixedly coupled fan blades (450) with hub (430). Accordingly, when motor (420) rotates, fan blades (450) and hub (430) also rotate. It should be understood that additional components, such as grommets or other vibratory-reducing members may be included between fan blades (450) and hub (430) and/or between hub (430) and motor (420). In the present example, fan (400) further includes a top cover (412) having a circular center (not shown) and a plurality of rectangular fan extensions (414). In the present example, rectangular fan extensions (414) curve downwardly relative to support (410) and are configured to nest within top recesses (454) formed in fan blades (450), described below, to form a substantially smooth transition between top cover (414) and fan blades (450).

[0047] A circular bottom cover (416) includes a plurality of upwardly projecting L-shaped tabs (418) disposed about the circumference of bottom cover (416) and a central lens (419). Lens (419) may be constructed in accordance with lens (48) described above. Bottom cover (416) is configured to couple to a bottom portion of fan blades (450) via tabs (418) inserting into recesses (not shown) formed in fan blades (450) and then being rotated such that an axial projection from each tab locks into the recesses. Accordingly, when bottom cover (416) is coupled to fan blades (450), a substantially smooth lower surface for fan (400) is formed. Of course it should be understood that bottom cover (416) may couple to fan blades (450) through other attachment members, such as screws, bolts, clips, clamps, straps, resilient tabs, etc. In addition, or in the alternative, bottom cover (416) may be directly coupled to motor (420). Fan (400) may be further configured in accordance with the teachings of fan (10) described above or in any other manner as will be apparent to one of ordinary skill in the art in view of the teachings herein.

[0048] Referring now to FIGS. 9-10, fan blade (450) of the present example comprises a root end (452), a tip (470), a leading edge (480), and a trailing edge (490). Fan blade (450) of the present example comprises airfoil profiles that substantially correspond to airfoil profiles (100, 200, 300) described above. In the present example, however, fan blade (450) comprises an alternative root end (452) and transition region (466). Transition region (466) of the present example comprises a tapered portion of fan blade (450) that transitions from root end (452) to airfoil profiles (100, 200, 300) for fan blade (450). Root end (452) of the present example includes a top recess (454) configured to receive a respective extension (414) therein. Thus, when extensions (414) are nested within respective top recesses (454) a substantially smooth transition is formed from top cover (414) to fan blades (450) for fan (400). In addition, one or more openings (456) are formed through a lower portion of root end (452) to permit fasteners (434) therethrough to substantially fixedly coupled fan blade (450) to hub (430) described above.

[0049] Root end (452) is further includes a recessed ledge (458) and an outer lip (460) disposed on opposing ends of root

end (452). As shown in FIGS. 8-9, recessed ledge (458) corresponds to the side of fan blade (450) with leading edge (480) while outer lip (460) corresponds to the side of fan blade (450) with trailing edge (490). Accordingly, when fan blades (450) are assembled for fan (400), recessed ledge (458) nests with and below outer lip (460) of the fan blade (450) to form a substantially smooth and continuous surface from one fan blade (450) to the next. In the present example, fan blades (450) have root ends (452) with recessed ledges (458) and outer lips (460) disposed approximately 120 degrees from each other such that three fan blades (450) may be combined to form a substantially continuous fan blade structure (as shown in FIG. 7). Of course it should be understood that other angular relationships may be used as well (e.g., 180 degrees for a dual fan blade (450) assembly, 90 degrees for a four fan blade (450) assembly, 60 degrees for a five fan blade (450) assembly, etc.). In addition, or in the alternative, fasteners (not shown) may be used to couple corresponding recessed ledges (458) and outer lips (460) together for fan blades (450). Further still, rubber grommets (not shown) or other vibratory-reducing members may be interposed between corresponding recessed ledges (458) and outer lips (460) to vibrationally isolate fan blades (450) from one another. In the present example, a pair of rib members (462) are provided within root end (452) to reinforce or otherwise provide additional rigidity to root end (452), though these are merely optional. Still further constructions for root end (452) and/or fan blade (450) will be apparent to one of ordinary skill in the art in view of the teachings herein.

**[0050]** Fan blade (450) of the present example is manufactured by a thermoplastic resin that is injected into a mold for fan blade (450) to achieve the desired profile. Alternatively, fan blade (450) may be formed from thin sheets of material laminated together and anchored to a thermoplastic or other material root end (452). For instance, fan blade (450) may be constructed by combining individual sheets with adhesive between each layer and forcing the sheets together under pressure in a shaped mold to form fan blade (450) shown in FIGS. 9-10 and anchored to root end (452). In one version, fan blade (450) may be manufactured using 7 layers of 0.5 millimeter (0.019685 inches) thick bamboo veneer that are compressed together as described above. Of course other thicknesses and/or number of layers may be used. Alternatively, other types of wooden veneer may be used or may be combined with other woods to form composite fan blades (450). Further still, fan blade (450) may be formed from a single layer of plastic that is heated and bent or inserted into a mold to form the profile of fan blade (450) which is subsequently joined to root end (452). In still a further alternative, fan blade (450) may be formed from layers of fiberglass matting or carbon fiber composite materials combined with epoxy resins. In yet another alternative, layers of wood veneer or other materials (e.g., carbon fiber, fiberglass, etc.) may initially be layered within a mold and plastic or another resin may be injected or otherwise added to form fan blade (450). Of course still further constructions for fan blade (450) will be apparent to one of ordinary skill in the art in view of the teachings herein.

**[0051]** It should be appreciated that any patent, publication, or other disclosure material, in whole or in part, that is said to be incorporated by reference herein is incorporated herein only to the extent that the incorporated material does not conflict with existing definitions, statements, or other disclosure material set forth in this disclosure. As such, and to the

extent necessary, the disclosure as explicitly set forth herein supersedes any conflicting material incorporated herein by reference. Any material, or portion thereof, that is said to be incorporated by reference herein, but which conflicts with existing definitions, statements, or other disclosure material set forth herein will only be incorporated to the extent that no conflict arises between that incorporated material and the existing disclosure material.

**[0052]** Having shown and described various embodiments of the present invention, further adaptations of the methods and systems described herein may be accomplished by appropriate modifications by one of ordinary skill in the art without departing from the scope of the present invention. Several of such potential modifications have been mentioned, and others will be apparent to those skilled in the art. For instance, the examples, embodiments, geometrics, materials, dimensions, ratios, steps, and the like discussed above are illustrative and are not necessarily required. Accordingly, the scope of the present invention should be considered in terms of the following claims and is understood not to be limited to the details of structure and operation shown and described in the specification and drawings.

What is claimed is:

1. A fan blade configured to mount to a rotating fan hub, the fan blade comprising:
  - a. a root end configured to couple with the rotating fan hub, wherein a profile of the root end comprises a substantially convex top surface and a substantially concave domed sector;
  - b. a blade region, wherein a profile of the blade region comprises a substantially convex top surface and bottom surface;
  - c. a transition region extending between the root end and the blade region, wherein the transition region comprises a profile which transitions the root end profile to the blade region profile;
  - d. a leading edge;
  - e. a trailing edge; and
  - f. a tip, wherein the leading edge and trailing edge terminate into the tip.
2. The fan blade of claim 1, wherein the root end comprises an arcuate cutout.
3. The fan blade of claim 2, wherein the domed sector is configured to terminate into a region which is parallel to a plane of rotation of the fan blade at a position proximal to the arcuate cutout.
4. The fan blade of claim 3, wherein the transition portion comprises a first portion, an inflection portion, and a second portion.
5. The fan blade of claim 4, wherein the first portion comprises an extension of the concave domed sector of the root end which terminates at the inflection portion.
6. The fan blade of claim 5, wherein the inflection portion comprises a quasi-parabolic shaped portion that extends from the leading edge to the trailing edge and transitions the fan blade from the extension of the concave domed sector of the first portion to a planar portion.
7. The fan blade of claim 6, wherein the second portion extends from the inflection portion and the planar portion to the profile of the blade region.
8. The fan blade of claim 7, wherein the top surface of the profile of the blade region comprises:

a first top convex curvature proximal to the second portion of the transition region, and a second top convex curvature proximal to the tip.

9. The fan blade of claim 8, wherein the bottom surface of the profile of the blade region comprises a first bottom convex curvature proximal to the second portion of the transition region, and a second bottom convex curvature proximal to the tip.

10. The fan blade of claim 9, wherein the top surface of the blade region transitions from the first top convex curvature to the second top convex curvature along a length of the blade region.

11. The fan blade of claim 10, wherein the bottom surface of the blade region transitions from the first bottom convex curvature to the second bottom convex curvature along the length of the blade region.

12. The fan blade of claim 11, wherein the bottom surface of the blade region slopes upward along the length of the blade region.

13. The fan blade of claim 12, wherein the top surface of the blade region slopes upward along the length of the blade region.

14. The fan blade of claim 13, wherein the leading edge is located at a position higher than a position of the trailing edge.

15. The fan blade of claim 14, wherein the tip is curved.

16. A fan assembly comprising:

- a. a fan motor;
- b. a fan hub, wherein the fan hub is attached to the fan motor; and
- c. the fan blade of claim 14, wherein the fan blade is one of a plurality of similar fan blades mounted to the fan hub.

17. A fan blade configured to mount to a rotating fan hub, the fan blade comprising:

- a. a root end, wherein the root end comprises:
  - i. a root end profile comprising a concave bottom surface and a convex top surface,

- ii. a cutout on the bottom surface configured to receive a bottom surface of the fan hub,
  - iii. a plurality of holes configured to allow the root end to be coupled to the rotating fan hub, and
  - iv. a cutout on the top surface configured to receive a top surface of the fan hub;
- b. a blade region, wherein a profile of the blade region comprises a substantially convex top surface and bottom surface; and
- c. a transition region located between the root end and the blade region, wherein a profile of the transition region transitions the profile of the root end into the profile of the blade region.

18. The fan blade of claim 17, wherein the relief on the top surface of the root end is substantially square in shape.

19. The fan blade of claim 18, wherein the bottom surface of the root end is configured to terminate into a region which is parallel to a plane of rotation of the fan blade at a position proximal to the cutout.

20. A fan assembly, wherein the fan assembly comprises:

- a. a fan motor;
- b. a fan hub, wherein the fan hub is coupled to the fan motor; and
- c. a plurality of fan blades, wherein each one of the fan blades of the plurality of fan blades comprises:
  - i. a root end capable of being coupled to the rotating fan hub, wherein a profile of the root end comprises a substantially convex top surface and a substantially concave domed sector,
  - ii. a blade region, wherein a profile of the blade region comprises a substantially convex top surface and bottom surface, and
  - iii. a transition region extending between the root end and the blade region, wherein the transition region comprises a profile which transitions the root end profile to the blade region profile.

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