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Decker et al.(10) **Pub. No.: US 2008/0219836 A1**(43) **Pub. Date: Sep. 11, 2008**(54) **FAN WITH HEAT DISSIPATING OUTLET
GUIDE VANES****Publication Classification**(51) **Int. Cl.****F04D 29/64**

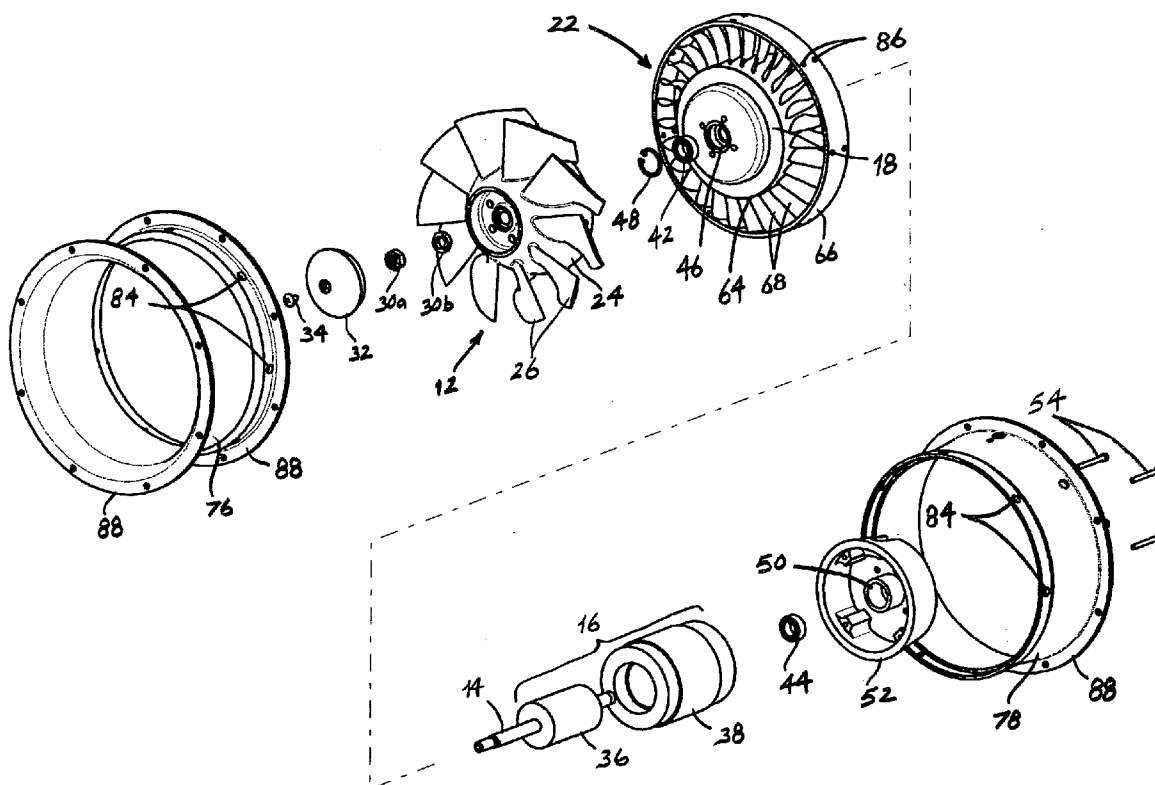
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ABSTRACT

A method for designing a fan having a motor which drives an impeller comprises providing an outlet guide vane assembly which includes a hub and a plurality of guide vanes that extend radially outwardly from the hub, attaching the hub to the motor, determining an approximate amount of heat which is generated by the motor during operation of the fan, determining an approximate surface area which is required to dissipate the heat into a surrounding air stream, and configuring the guide vanes to comprise a total surface area which is approximately equal to the required surface area. In this manner, the heat generated by the motor during operation of the fan can be dissipated by the guide vanes.

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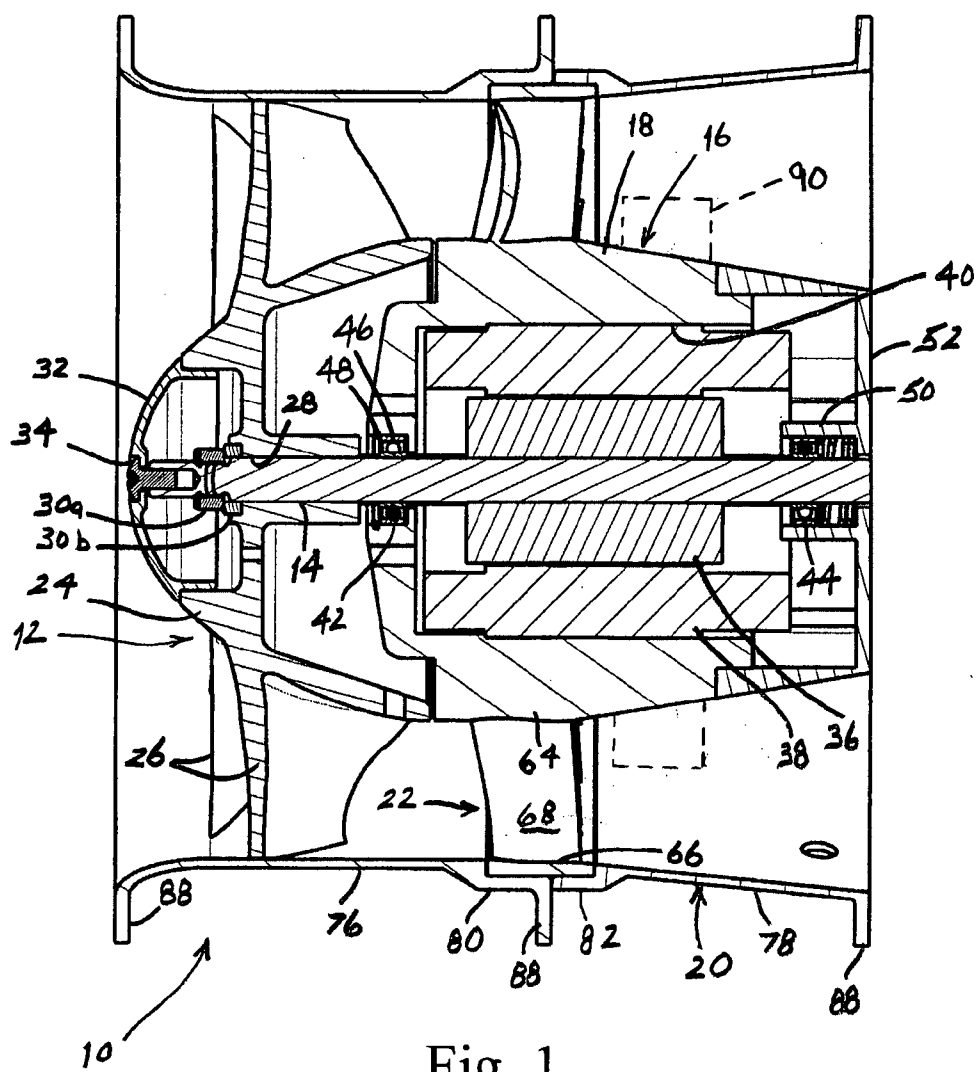


Fig. 1

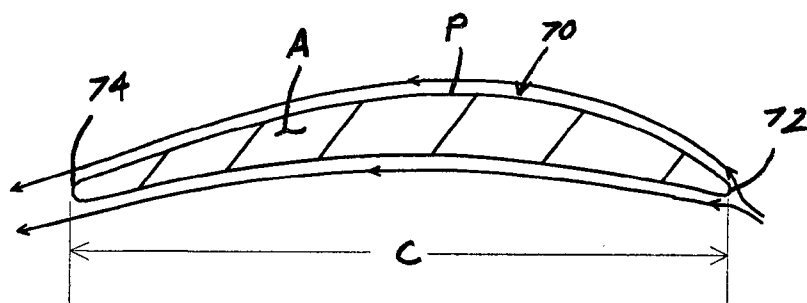


Fig. 3

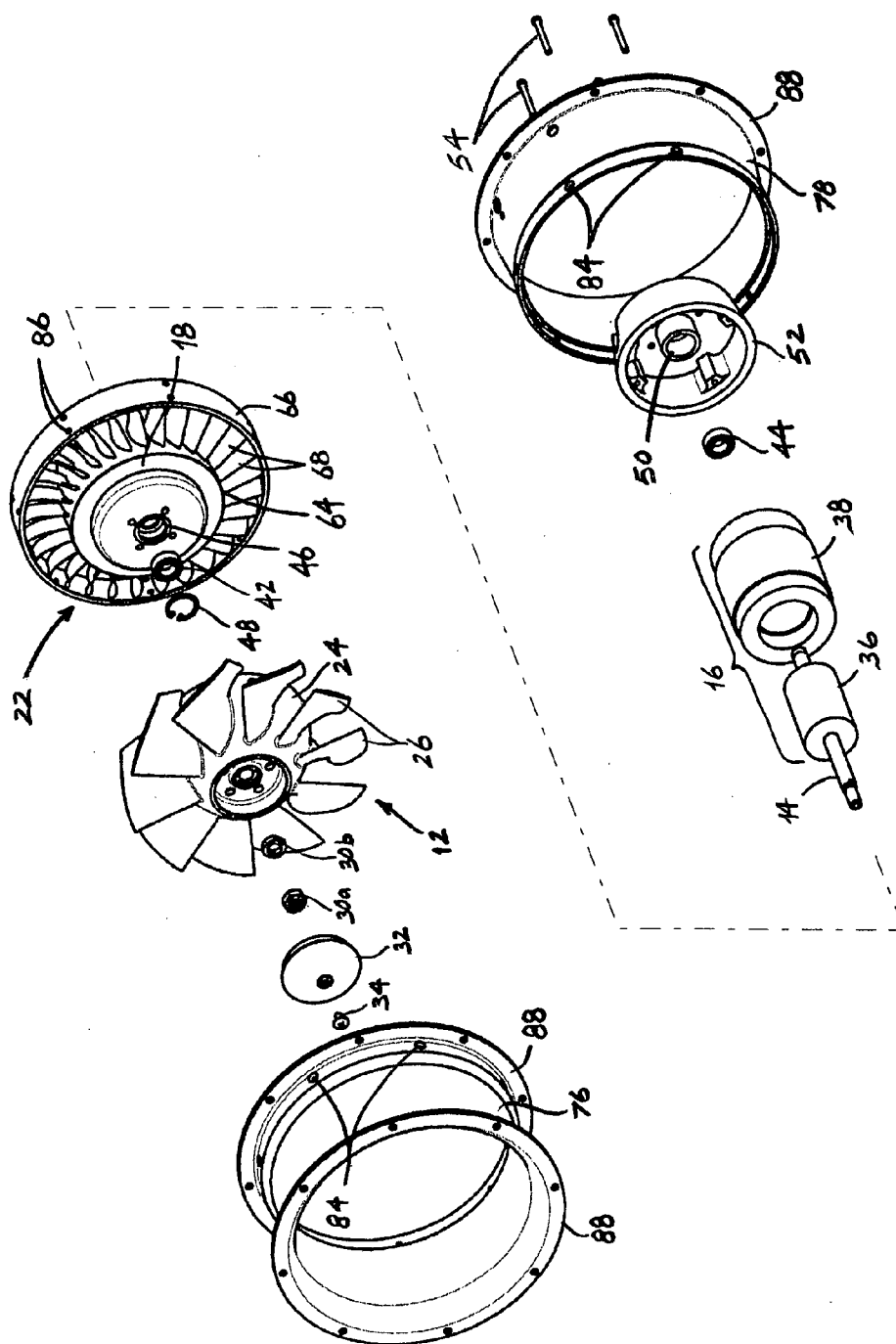
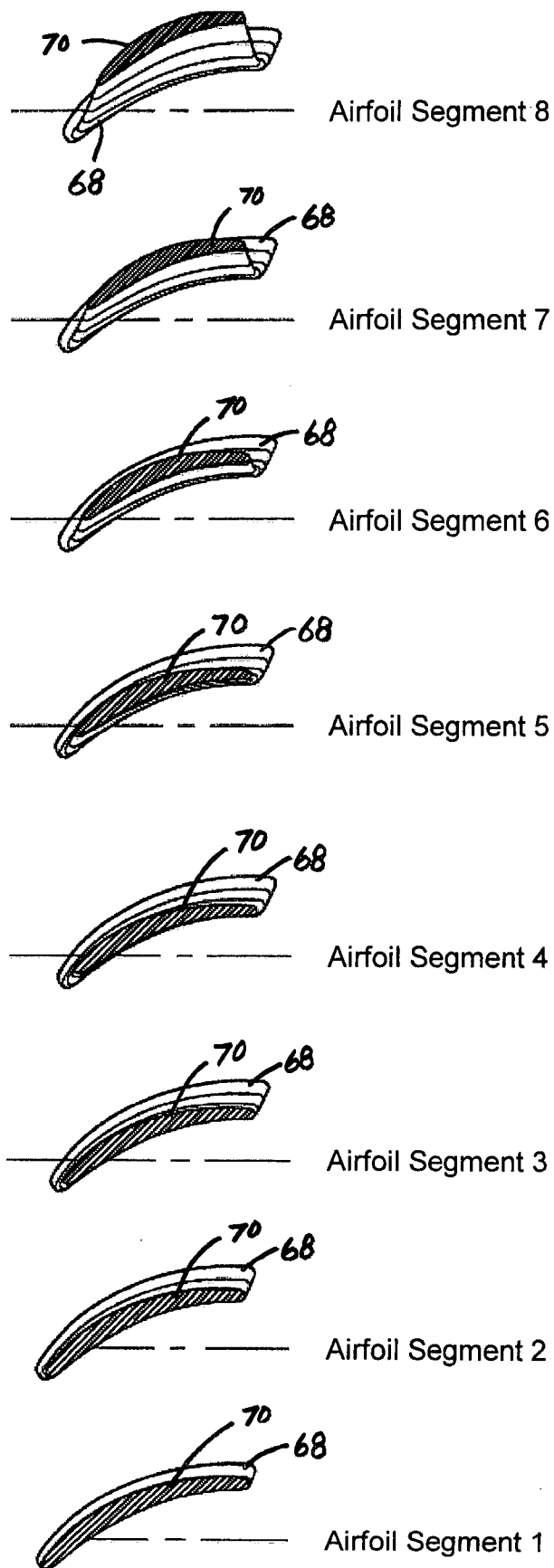


Fig. 2

Fig. 4



FAN WITH HEAT DISSIPATING OUTLET GUIDE VANES

BACKGROUND OF THE INVENTION

[0001] The present invention relates to an air mover which comprises a motor-driven impeller and an outlet guide vane assembly for de-swirling the air stream generated by the impeller. More particularly, the invention relates to such an air mover which comprises an outlet guide vane assembly that is designed to dissipate the heat generated by the motor.

[0002] Typical air movers, such as fans, include an impeller which is driven by a motor. This motor, be it electrically or otherwise powered, will necessarily produce heat during operation of the air mover. Moreover, the size, weight and life of the air mover is determined to a large extent by its operating temperature. Therefore, the desirability exists to dissipate the heat generated by the motor.

[0003] In high flow axial fans, the motor is often positioned in the core of the fan. In addition, many of these fans require the motor to be closed to the external environment. Therefore, the only path through which the heat generated by the motor may be dissipated is typically through the air stream which flows over the motor. Moreover, although motors may be liquid cooled, fans which include such motors are relatively more complex and intrinsically less reliable than air cooled fans.

SUMMARY OF THE INVENTION

[0004] In accordance with the present invention, these and other disadvantages in the prior art are addressed by providing a method for designing a fan which is capable of dissipating the heat generated by the motor into the surrounding air stream. The method comprises the steps of providing an outlet guide vane assembly which includes a hub and a plurality of guide vanes which extend radially outwardly from the hub, attaching the hub to the motor, determining an approximate amount of heat which is generated by the motor during operation of the fan, determining an approximate surface area which is required to dissipate the heat into the surrounding air stream, and configuring the guide vanes to comprise a total surface area which is approximately equal to the required surface area. In this manner, the heat generated by the motor during operation of the fan can be dissipated by the guide vanes into the surrounding air stream.

[0005] In one embodiment of the invention, the step of configuring the guide vanes comprises designating a plurality of radially spaced airfoil segments for each guide vane, each of which comprises a chord, an area and a perimeter length, and then determining the chord, area and perimeter length of each airfoil segment which will result in the guide vanes comprising a total surface area which is approximately equal to the surface area required to dissipate the heat. The method may also comprise the step of adjusting the chord, area and perimeter length of each airfoil segment to decrease the effective thermal resistance of the heat transfer path through the guide vanes. In addition, the method may comprise the step of adjusting the chord, area and perimeter length of each airfoil segment to decrease the effective thermal resistance of the heat transfer path between the guide vanes and a surrounding air stream.

[0006] In accordance with another aspect of the invention, the plurality of airfoil segments comprises a first airfoil segment which is located closest to the hub, an n^{th} airfoil segment

which is located farthest from the hub and a number of additional airfoil segments which are located between the first and the n^{th} airfoil segments. In addition, the method further comprises the step of making at least one of the chord, the area and the perimeter length of the first airfoil segment greater than the chord, the area or the perimeter length of the n^{th} airfoil segment. Moreover, the method may comprise the step of making at least one of the chord, the area and the perimeter length of the first airfoil segment greater than the chord, the area or the perimeter length of the remaining airfoil segments.

[0007] In accordance with yet another aspect of the invention, the step of attaching the hub to the motor comprises providing a housing for the motor and forming the hub integrally with the housing. The method may further comprise the step of forming the motor housing and the outlet guide vane assembly as an integral unit from a single piece of a heat conducting material.

[0008] The present invention also provides a fan which is adapted to dissipate the heat which is generated by its motor during operation of the fan. The fan comprises an outlet guide vane assembly which includes a hub and a plurality of guide vanes which extend radially outwardly from the hub. In addition, the motor includes a housing which is connected to or formed integrally with the hub. Moreover, the guide vanes together comprise a total surface area which is approximately equal to the surface area which is required to dissipate a substantial amount of the heat generated by the motor into the surrounding air stream.

[0009] In accordance with one aspect of this invention, each of the guide vanes comprises a plurality of radially spaced airfoil segments, each of which includes a chord, an area and a perimeter length. Additionally, the plurality of airfoil segments comprises a first airfoil segment which is located closest to the hub, an n^{th} airfoil segment which is located farthest from the hub and a number of additional airfoil segments which are located between the first and the n^{th} airfoil segments. Furthermore, at least one of the chord, the area and the perimeter length of the first airfoil segment may be greater than the chord, the area or the perimeter length of the n^{th} airfoil segment. In addition, at least one of the chord, the area and the perimeter length of the first airfoil segment may be greater than the chord, the area or the perimeter length of the remaining airfoil segments.

[0010] Thus, the present invention provides an effective means for dissipating the heat generated by the motor during operation of the fan. Consequently, the fan can be equipped with a smaller and more efficient motor. Moreover, since the heat generated by the motor is dissipated through the pre-existing outlet guide vane assembly, the fan does not need to be equipped with additional cooling components.

[0011] These and other objects and advantages of the present invention will be made apparent from the following detailed description, with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] FIG. 1 is a cross sectional view of an exemplary embodiment of the fan of the present invention;

[0013] FIG. 2 is an exploded perspective view of the fan shown in FIG. 1;

[0014] FIG. 3 is a schematic representation of an exemplary airfoil which is used to illustrate certain features of the present invention; and

[0015] FIG. 4 is a representation of a succession of radially spaced airfoil segments of a guide vane component of the fan of FIG. 1, with Airfoil Segment 1 being closest to the root of the guide vane and Airfoil Segment 8 being closest to the tip of the guide vane;

DETAILED DESCRIPTION OF THE INVENTION

[0016] The present invention is applicable to a variety of air movers. However, for purposes of brevity it will be described in the context of an exemplary vane-axial cooling fan. Nevertheless, the person of ordinary skill in the art will readily appreciate how the teachings of the present invention can be applied to other types of air movers. Therefore, the following description should not be construed to limit the scope of the present invention in any manner.

[0017] Referring to FIGS. 1 and 2, the cooling fan of the present invention, which is indicated generally by reference number 10, includes an impeller 12 which is mounted on a shaft 14 that is driven by a motor 16. The motor 16 includes a motor housing 18 which is connected to a fan housing 20 by an outlet guide vane assembly 22.

[0018] The impeller 12 comprises an impeller hub 24 and a number of fan blades 26 which are connected to or formed integrally with the impeller hub. The impeller hub 24 includes an axial bore 28 through which the shaft 14 extends, and the shaft is secured to the impeller hub 12 by a pair of counter-acting nuts 30a, 30b. The impeller hub 12 may include a nose cone 32, which in this case is connected to the shaft 14 by a screw 34.

[0019] The motor 16 may comprise a totally enclosed air-over cooled ("TEAOC") brushless DC motor which includes a rotor 36 and a stator 38. The rotor 36 is attached to or formed integrally with the shaft 14, and the stator 38 is mounted in a cylindrical recess 40 that is formed in the motor housing 18. As is known in the art, the stator 38 includes a stack of laminations and a number of windings which, when energized by an electric current, create a magnetic field which causes the rotor 36 to spin.

[0020] The shaft 14 is rotationally supported in a front bearing 42 and a rear bearing 44, both of which may be, e.g., metal ball bearings. The front bearing 42 is mounted in an aperture 46 in the motor housing 18 and is held in place by a retaining ring 48. The rear bearing 44 is mounted in a collar 50 which is attached to or formed integrally with a tail cone 52 that is connected to the motor housing by, e.g., a number of screws 54. The shaft 14 is retained axially relative to the motor housing 18 by the front bearing 42.

[0021] Referring still to FIGS. 1 and 2, the outlet guide vane assembly 22 comprises a hub 64 which is attached to or formed integrally with the motor housing 18, an outer ring 66 which is secured to the fan housing 20, and a plurality of guide vanes 68 which extend radially between the hub and the outer ring. Each guide vane 68 comprises a root, which is the radially innermost portion of the guide vane, and a tip, which is the radially outermost portion of the guide vane. In addition, each guide vane 68 may comprises a radial stack of a number of individual airfoil segments, each of which represents a cross section of the guide vane at a specific radial distance from its root.

[0022] Referring to FIG. 3, an exemplary airfoil segment 70 includes a leading edge 72 and a trailing edge 74. Each airfoil segment 70 is oriented such that the air stream, which is represented by the lines with multiple arrowheads, meets the airfoil segment 70 at the leading edge 72 and departs the

airfoil segment at the trailing edge 74. Each airfoil segment 70 also comprises a chord C, an area A and a perimeter P. The chord C is the straight line distance between the leading and trailing edges 72, 74, and the area A is the cross sectional area of the guide vane 68 at the radial location of the airfoil segment 70.

[0023] Referring again to FIGS. 1 and 2, the fan housing 20 includes an inlet shroud 76 and an outlet shroud 78. The inlet and outlet shrouds 76, 78 comprise respective first and second annular rims 80, 82 which together define a cylindrical recess within which the outer ring 66 of the outlet guide vane assembly 22 is positioned. The inlet and outlet shrouds 76, 78 are secured to the outlet guide vane assembly 22 by a number of screws (not shown), which extend through corresponding bores 84 in the first and second rims 80, 82 and into matching holes 86 in the outer ring 66. The inlet and outlet shrouds 76, 78 may also comprise one or more radial lips 88 to enable the fan housing 20, and thus the cooling fan 10, to be mounted to an associated structure.

[0024] In operation of the cooling fan 10, the motor 16 spins the impeller 12 to draw air into the inlet shroud 76 and through the fan housing 20. The spinning impeller 12 imparts a significant degree of swirl to the air stream. As the air stream passes through the outlet guide vane assembly 22, however, the guide vanes 68 remove this swirl by reorienting the air stream into a substantially axial direction. Thus, an important function of the outlet guide vane assembly 22 is to de-swirl, or straighten, the air stream prior to its exiting the outlet shroud 78. Another function of the outlet guide vane assembly 22 is to physically support the motor 16 within the fan housing 20.

[0025] However, in accordance with the present invention, the outlet guide vane assembly 22 is designed to not only de-swirl the air stream generated by the impeller 12 and support the motor 16 within the fan housing 20, but also to dissipate the heat produced by the motor 16. This is accomplished in an effective manner by conducting the heat through the motor housing 18 to the guide vanes 68, where it can then be readily dissipated into the air stream flowing through the cooling fan 10.

[0026] In accordance with one aspect of the invention, the cooling fan 10 is designed to minimize the effective thermal resistance of the heat transfer path between the motor 16 and the guide vanes 68. In this embodiment, the stator 38 is ideally mounted in the recess 40 in the motor housing 18 using an interference fit, such as a press fit. Also, both the motor housing 18 and the outlet guide vane assembly 22 are made from a heat conductive material, such as aluminum. Optimally, the motor housing 18 and the outlet guide vane assembly 22 are constructed from a single block of material using known techniques, such as machining, casting or pressing. Consequently, the heat generated by the motor 16 during operation of the cooling fan 10 will be readily conducted through the motor housing 18 and into the guide vanes 68.

[0027] In accordance with another aspect of the invention, the guide vanes 68 are designed to minimize the effective thermal resistance of the heat transfer path between the guide vanes 68 and the air stream flowing through the cooling fan 10. In particular, the present invention defines a process to determine the optimum number and configuration of guide vanes 68 which will achieve these functions without interfering with the ability of the guide vanes to de-swirl the air stream generated by the impeller 12 or support the motor 16 within the fan housing 20.

[0028] The design of the outlet guide vane assembly 22 is largely dependent upon the velocity and pressure of the air stream which the cooling fan 10 is required to deliver for a particular cooling application. These factors will define the inside and outside boundaries of the flow path through the cooling fan 10, which in turn will define the inner and outer radial extents of the guide vanes 68.

[0029] In accordance with the present invention, the design of the outlet guide vane assembly 22 is also dependent upon the amount of heat generated by the motor 16. The amount of heat generated by the motor 16 is determined by first calculating the amount of power which the motor will need to generate in order to deliver the required air stream. The rated efficiency of the motor 16 is then applied to this power value to compute the total motor losses, which are a fairly reasonable estimate of the heat generated by the motor during operation of the cooling fan 10.

[0030] Once the amount of heat generated by the motor 16 is determined, the total surface area of the guide vanes 68 required to dissipate a substantial amount of this heat into the surrounding air stream may be determined. In the context of the present invention, a "substantial amount" of the heat may comprise greater than about 50% of the heat, more preferably greater than about 60% of the heat, and most preferably greater than about 70% of the heat. First, based on the velocity and temperature of the air stream, an estimate can be made of the film coefficient for the guide vanes 68. This film coefficient is then used to estimate the total surface area of the guide vanes 68 which is required to dissipate the heat generated by the motor 16. In this regard, both the film coefficient and the total surface area of the guide vanes 68 may be determined using known heat transfer equations applicable to the process of forced convection.

[0031] The length and total surface area of the guide vanes 68 will provide a basis for an initial determination of the number of guide vanes and the chord C, area A and perimeter length L of each of a pre-selected number of airfoil segments 70 for each guide vane. Other factors which may be considered in determining these values may include the desired or required vane-blade ratio for the cooling fan 10 (i.e., the ratio of the number of guide vanes to the number of impeller blades, which has important acoustic implications), the desired or required chord solidity for the outlet guide vane assembly (i.e., the chord of the guide vanes multiplied by the number of guide vanes divided by the outer circumference of the circle joining the tips of the guide vanes), the desired or required aspect ratio for the outlet guide vane assembly (i.e., the ratio of the height of the guide vanes to the chord of the guide vanes), the desired or required static pressure rise of the air flowing through the outlet guide vane assembly, the desired or required Reynolds number of the air flowing over the guide vanes, and the ability of the guide vanes to support the motor 16.

[0032] After the number of guide vanes 68 and the chord C, area A and perimeter length L of the airfoil segments 70 are determined, the configuration of the airfoil segments 70 may be adjusted to minimize the effective thermal resistance of the heat transfer paths through the guide vanes 68 and between the guide vanes and the surrounding air. For example, since the heat flux through the outlet guide vane assembly 22 is greatest at the hub 64, increasing the area A of the airfoil segment 70 closest to the hub will decrease the effective thermal resistance of the heat transfer path from the motor housing 18 into the hub and from the hub into the guide vane

68. In addition, increasing the area A of all the airfoil segments 70 will increase the perimeter P of the airfoils segments and, consequently, the entire surface area of the guide vanes 68, which will accordingly decrease the effective thermal resistance of the heat transfer path between the guide vanes and the surrounding air stream. However, since the total surface area of the guide vanes 68 should be minimized in order to minimize frictional losses, increasing the area A of the airfoil segment 70 closest to the hub 64 will require that the area A of the other airfoil segments be reduced.

[0033] Once these adjustments are made, the number and configuration of the guide vanes 68 may be further modified to both optimize the heat dissipation capacity of the guide vanes and provide a desired degree of de-swirling of the air stream generated by the impeller 12. Factors to consider in making these modifications may include the desired or required values for the vane-blade ratio, chord solidity, aspect ratio, static pressure rise and Reynolds number. Moreover, further changes in the number and configuration of the guide vanes 68 may be made by modeling the cooling fan using available computer modeling programs and noting the effects which these changes have on the ability of the guide vanes 68 to dissipate the heat generated by the motor 16 and de-swirl the air stream generated by the impeller 12.

[0034] Several iterations of the above-described process may be required to achieve an optimum number and configuration of guide vanes 68. For example, while increasing the area A of the airfoil segments 70 will improve both the conduction of heat through the guide vanes 68 and the convection of this heat from the guide vanes to the surrounding air stream, at some point the airfoil segments may become so thick that the air flow may separate from the guide vanes. To avoid this problem, the chords C of the airfoil segments 70 can be made longer to increase both the perimeter P and the area A without increasing the thickness of the airfoil. Unfortunately, increasing the chord C also increases the drag coefficient of the airfoil. Thus, the longer the chord C, the less efficient the cooling fan 10 will become and the more power the motor 16 will have to generate to produce the required air stream. Moreover, more motor power implies more motor losses, which results in additional heat that must be dissipated. Therefore, an optimal chord length C exists which is sufficiently long to enable the heat to be dissipated through convection, but not so long as to create excessive drag losses.

[0035] The principles of the present invention will be further elucidated in the context of an exemplary cooling fan 10. In this example, the inlet temperature of the cooling fan 10 is taken to be 15° C., and the cooling fan comprises a 28 kW motor 16 with an efficiency of 96%. Thus, during operation of the cooling fan 10 the motor 16 will generate about 1.12 kW of heat. Also, the outlet guide vane assembly 22 was chosen to include 31 guide vanes 68, and the outer radius of the motor housing 18 and the inner radius of the fan housing 20 are assumed to be about 5.2 inches and 8 inches, respectively. Therefore, the radial length of each guide vane 68 will be approximately 2.8 inches.

[0036] In determining the optimum configuration of the guide vanes 68 for dissipating the maximum amount of heat from the motor 16, each guide vane was selected to comprise eight airfoil segments 70. Referring to FIG. 4, the airfoil segments 70 for a single guide vane 68 are shown successively from bottom to top, with the first airfoil segment 70 being closest to the root of the guide vane and the eighth airfoil segment being closest to the tip of the guide vane. Table

1 below sets forth the radial location of each airfoil **70**, as measured from the axial centerline of the cooling fan **10**, and the optimum perimeter length *L*, area *A* and chord *C* of each airfoil which were determined to dissipate a maximum amount of heat generated by the motor **16**.

TABLE 1

Airfoil No.	Radial Height (in.)	Perimeter Length <i>L</i> (in.)	Area <i>A</i> (in ²)	Chord <i>C</i> (in.)
1	5.51	7.47	0.84	3.30
2	5.82	7.13	0.75	3.10
3	6.13	6.67	0.66	2.90
4	6.44	6.18	0.60	2.80
5	6.76	5.75	0.56	2.70
6	7.07	5.43	0.53	2.60
7	7.38	5.17	0.51	2.40
8	7.69	4.94	0.47	2.30

[0037] From Table 1 we can see that the optimum configuration for the guide vanes **68** exists when the perimeter length *L*, area *A* and chord *C* of the first air foil **70** are each greater than the values for any other airfoil, and when the perimeter length *L*, area *A* and chord *C* for the eighth air foil are each smaller than the values for any other airfoil. More specifically, as the height of each airfoil **70** from the root of the guide vane **68** increases, the perimeter length *L*, area *A* and chord *C* all decrease. Moreover, although the increase in height from the first airfoil to the eighth airfoil is generally linear, the decrease in the perimeter length *L*, area *A* and chord *C* from the first airfoil to the eighth airfoil are all non-linear. However, the amounts by which the perimeter length *L*, area *A* and chord *C* increase from the first airfoil to the eighth airfoil are not necessarily equal.

[0038] It should be noted, however, that while the configuration represented by Table 1 optimizes the amount of heat which the guide vanes **68** are able to dissipate in this particular cooling fan **10**, other fan designs comprising different parameters may require that the guide vanes be configured differently. Therefore, the above example and the conclusions drawn therefrom should not be considered as limiting the scope of the present invention.

[0039] Referring again to FIG. 1, the cooling fan **10** may optionally comprise a number of radially extending cooling fins **90** to provide an additional means for dissipating the heat generated by the motor **16**. The cooling fins **90** may be made of a suitable heat conductive material, such as aluminum, and may be attached to or formed integrally with the motor housing **18**. In this manner, the heat generated by the motor will be conducted through the motor housing **18** and into the cooling fins **90**, and then dissipated into the air stream flowing through the fan housing **20**.

[0040] It should be recognized that, while the present invention has been described in relation to the preferred embodiments thereof, those skilled in the art may develop a wide variation of structural and operational details without departing from the principles of the invention. Therefore, the appended claims are to be construed to cover all equivalents falling within the true scope and spirit of the invention.

What is claimed is:

1. A method for designing a fan which includes a motor that drives an impeller, the method comprising:

providing an outlet guide vane assembly which includes a hub and a plurality of guide vanes which extend radially outwardly from the hub;

attaching the hub to the motor;

determining an approximate amount of heat which is generated by the motor during operation of the fan;

determining an approximate surface area which is required to dissipate a substantial amount of the heat into a surrounding air stream; and

configuring the guide vanes to comprise a total surface area which is approximately equal to the required surface area;

wherein the heat generated by the motor during operation of the fan can be dissipated by the guide vanes into the surrounding air stream.

2. The method of claim 1, wherein the step of determining the required surface area comprises determining a film coefficient for the guide vanes.

3. The method of claim 1, wherein the step of configuring the guide vanes comprises:

designating a plurality a radially spaced airfoil segments for each guide vane, each of which comprises a chord, an area and a perimeter length;

determining the chord, area and perimeter length of each airfoil segment which will result in the guide vanes comprising a total surface area which is approximately equal to the surface area required to dissipate the heat.

4. The method of claim 3, further comprising adjusting the chord, area and perimeter length of each airfoil segment to decrease the effective thermal resistance of the heat transfer path through the guide vanes.

5. The method of claim 3, further comprising adjusting the chord, area and perimeter length of each airfoil segment to decrease the effective thermal resistance of the heat transfer path between the guide vanes and a surrounding air stream.

6. The method of claim 3, wherein the plurality of airfoil segments comprises a first airfoil segment which is located closest to the hub, an *n*th airfoil segment which is located farthest from the hub and a number of additional airfoil segments which are located between the first and the *n*th airfoil segments, and wherein the method further comprises making at least one of the chord, the area and the perimeter length of the first airfoil segment greater than the chord, the area or the perimeter length of the *n*th airfoil.

7. The method of claim 6, further comprising making the chord, the area and the perimeter length of the first airfoil segment greater than the chord, the area and the perimeter length of the *n*th airfoil segment.

8. The method of claim 6, further comprising making at least one of the chord, the area and the perimeter length of the first airfoil segment greater than the chord, the area or the perimeter length of the remaining airfoil segments.

9. The method of claim 6, further comprising making the chord, the area and the perimeter length of the first airfoil segment greater than the chord, the area and the perimeter length of the remaining airfoil segments.

10. The method of claim 1, wherein the step of attaching the hub to the motor comprises:

providing a housing for the motor; and

forming the hub integrally with the housing.

11. The method of claim 10, further comprising forming the motor housing and the outlet guide vane assembly as an integral unit from a single piece of a heat conducting material.

12. A fan which comprises:

an outlet guide vane assembly which includes a hub and a plurality of guide vanes which extend radially outwardly from the hub; and

a motor which includes a housing that is connected to or formed integrally with the hub and which during operation of the fan generates heat;

wherein the guide vanes together comprise a total surface area which is approximately equal to a surface area which is required to dissipate a substantial amount of the heat into a surrounding air stream.

13. The fan of claim **12**, wherein each of the guide vanes comprises a plurality a radially spaced airfoil segments, each of which includes a chord, an area and a perimeter length.

14. The fan of claim **13**, wherein the plurality airfoil segments comprises a first airfoil segment which is located closest to the hub, an n^{th} airfoil segment which is located farthest from the hub and a number of additional airfoil segments which are located between the first and the n^{th} airfoil segments.

15. The fan of claim **14**, wherein at least one of the chord, the area and the perimeter length of the first airfoil segment is greater than the chord, the area or the perimeter length of the n^{th} airfoil segment.

16. The fan of claim **14**, wherein the chord, the area and the perimeter length of the first airfoil segment are greater than the chord, the area and the perimeter length of the n^{th} airfoil segment.

17. The fan of claim **14**, wherein at least one of the chord, the area and the perimeter length of the first airfoil segment is greater than the chord, the area or the perimeter length of the remaining airfoil segments.

18. The fan of claim **14**, wherein the chord, the area and the perimeter length of the first airfoil segment is greater than the chord, the area and the perimeter length of the remaining airfoil segments.

19. The fan of claim **14**, wherein the distance between successive segments is generally constant.

20. The fan of claim **19**, wherein relationship between at least one of the chords, the areas and the perimeter lengths of the airfoil segments is non-linear.

21. The fan of claim **19**, wherein the relationships between the chords, the areas and the perimeter lengths of the airfoils segments are non-linear.

22. The fan of claim **12**, wherein the motor comprises a stator which forms an interference fit with the housing.

23. The fan of claim **12**, further comprising a number of radially extending cooling fins which are attached to or formed integrally with the motor housing.

24. A fan which comprises:

an outlet guide vane assembly which includes a hub and a plurality of guide vanes which extend radially outwardly from the hub; and

a motor which includes a housing that is connected to or formed integrally with the hub and which during operation of the fan generates heat;

wherein each of the guide vanes comprises a plurality a radially spaced airfoil segments, each of which includes a chord, an area and a perimeter length.

wherein the plurality airfoil segments comprises a first airfoil segment which is located closest to the hub, an n^{th} airfoil segment which is located farthest from the hub and a number of additional airfoil segments which are located between the first and the n^{th} airfoil segments.

wherein at least one of the chord, the area and the perimeter length of the first airfoil segment is greater than the chord, the area or the perimeter length of the n^{th} airfoil segment.

25. The fan of claim **24**, wherein the chord, the area and the perimeter length of the first airfoil segment are greater than the chord, the area and the perimeter length of the n^{th} airfoil segment.

26. The fan of claim **24**, wherein at least one of the chord, the area and the perimeter length of the first airfoil segment is greater than the chord, the area or the perimeter length of the remaining airfoil segments.

27. The fan of claim **24**, wherein the chord, the area and the perimeter length of the first airfoil segment is greater than the chord, the area and the perimeter length of the remaining airfoil segments.

28. The fan of claim **24**, wherein the distance between successive segments is generally constant.

29. The fan of claim **28**, wherein relationship between at least one of the chords, the areas and the perimeter lengths of the airfoil segments is non-linear.

30. The fan of claim **19**, wherein the relationships between the chords, the areas and the perimeter lengths of the airfoils segments are non-linear.

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