International Journal of Mechanical, Industrial and Aerospace Sciences
ISSN: 2517-9950
Vol:7, No:5, 2013

Selection and Design of an Axial Flow Fan

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***Abstract*—**This work presents a methodology for the selection and design of propeller oriented to the experimental verification of theoretical results. The problem of propeller selection and design usually present itself in the following manner: a certain air volume and static pressure are required for a certain system. Once the necessity of fan design on a theoretical basis has been recognized, it is possible to determinate the dimensions for a fan unit so that it will perform in accordance with a certain set of specifications. The same procedures in this work then can be applied in other propeller selection.

***Keywords*—**airfoil, axial flow, blade, fan, hub, mathematical algorithm, propeller design, simulation, wheel.

I. Introduction

THE term axial flow fan indicates that the air flows through the fan in an approximately axial direction. On the inlet side, as the flow approaches the fan blades, the direction of the flow is axial, in other words, parallel to the axis of rotation, provided there are no inlet vanes or other restrictions ahead of the fan wheel. The fan blade then deflects the airflow, as show in the fig. 1:

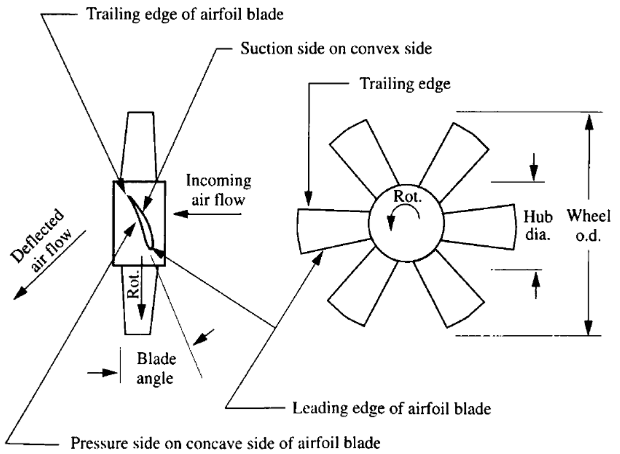

Fig. 1 Airfoil as used in an axial flow fan blade [1]

A propeller is a mechanism designed to produce a tractive force or push, when submerged in a fluid medium. The propellers are aerodynamic elements that are composed of a hub or central core and a number of blades.

The operating principle of axial-flow fans is simply deflection of airflow [2]. Past the blade, therefore, the pattern of the deflected airflow is of helical shape, like a spiral staircase. This is true for all three types of axial-flow fans: propeller fans, tubeaxial fans, and vaneaxial fans. Accordingly, the design procedures and the design calculations are similar for all three types.

The helical pattern of the airflow past the blade of an axial flow fan the air velocity the can be resolved into two components: an axial velocity a tangential velocity. The axial velocity is the useful component. It moves the air to the location where we need it.

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II. Airfoil

An airfoil is a streamline shape. Its main application is as the cross section of an airplane wing. Another application is as the cross section of a fan blade.

There are symmetric and asymmetric airfoils. The airfoils used in fan blade are asymmetric. Fig. 2 shows an asymmetric airfoil that has been developed by the National Advisory Committee for aeronautics (NACA); it is the NACA airfoil no.6512.

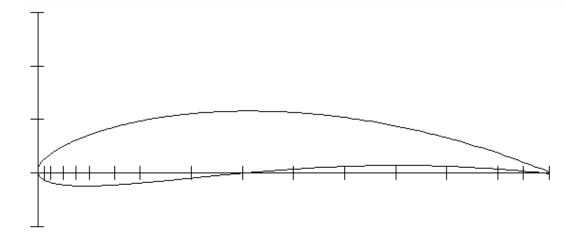

Fig. 2 NACA 6512 airfoil obtained from Matlab

As an airfoil moves through the air, it normally produces positive pressure on the lower surface of the airfoil and negative pressure or suction on the upper surface [3]. The suction pressure on the top surface are about twice as large as the positive pressures on the lower surface, but all these positive and negative pressures push and pull in approximately the same direction and reinforce each other. The combination of these positive and negative pressures results in a force F. This force F can be resolved into two components: a lift force L, perpendicular to the relative air velocity; and a drag force D, parallel to the relative air velocity. The lift force L is the useful component.

III. BLADE TWIST

For good efficiency, the airflow of an axial flow fan should be evenly distributed over the working face of the fan wheel. The axial air velocity should be the same from hub to tip. The velocity of the rotating blade is far from evenly distributed: it is low near the centre and increases toward the tip. This gradient should be compensated by a twist in the blade, resulting in larger blade angles near the center and smaller blade angles toward the tip. Fig. 3 shows an asymmetric airfoil as the cross section of a fan blade.

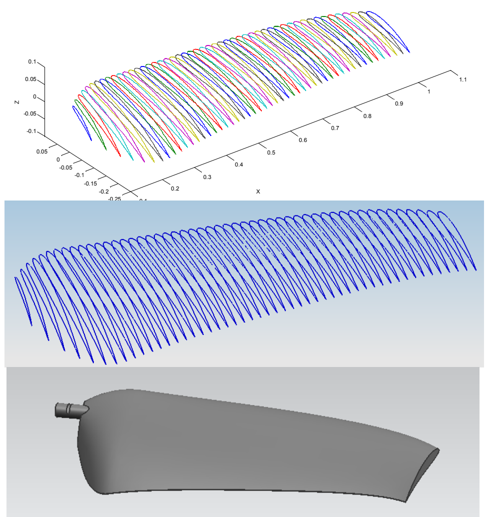

Fig. 3 An asymmetric NACA 6512 airfoil as the cross section of a fan blade

IV. NUMBER OF BLADES

Turbulence and noise are mostly produced by the edges, both leading and trailing edges and not by the blade surface [4]. Therefore, fewer and wider blades will result in a better fan efficiency and a lower noise level. But if the number of blades becomes too small and the blade width too large, the fan cub becomes axially too wide and thus heavy, bulky, expensive, and hard to balance.

Aerodynamically, the optimal number of blades would be one very wide blade, draped around the entry hub, but it would be an impractical and costly fan wheel. As a compromise between efficiency and cost, five to twelve blades are good practical solution [5]. Fig. 4 shows a propeller fan.

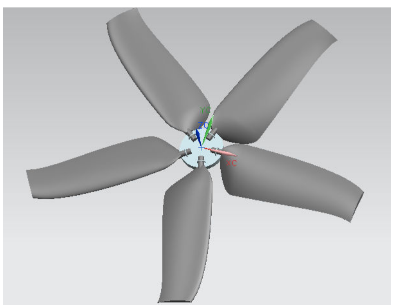

Fig. 4 A 1.618m propeller fan wheel

As far as the point of design is concerned, the designer has a certain amount of freedom in selecting the blade width at each radius can be compensated by corresponding variations in the lift coefficient C_L [6].of the profile used in that section.

V. THE DIMENSIONS FOR AN AXIAL FLOW FAN

Let us consider a duct area $A = 1.392m^2$ .The requirements call for $60\frac{m^3}{s}$ (127133cfm) at a static pressure of 495 Pascal (2inWC) to be produced by an axial fan at 2000rpm from an 84.438Kw motor:

We can calculate the outlet velocity OV or q as:

$$OV = q = \frac{1}{2}\rho V^2$$

where:

OV=q= dynamic pressure or outlet velocity

ρ= at 2240m density altitude above Sea level

V= local velocity

So

$$Q = AV$$

$$V = \frac{60\frac{m^3}{s}}{1.392m^2} = 43.103\frac{m}{s}$$

where:

Q=Volume of air

A= duct area

V= local velocity

The outlet velocity OV will be:

$$OV = q = \frac{1}{2}\rho V^2 =$$

$$\left(\frac{1}{2}\right)\left(0.982\,\frac{\text{Kg}}{\text{m}^3}\right)\left(43.103\,\frac{m}{s}\right)^2 = 912\,Pascal\,(3.661\,inWC)$$

The total pressure will be:

$$TP = SP + VP = 495 + 912 = 1407\,Pascal\,(5.661\,inWC)$$

The air power will be:

P=Air Volume x Total Pressure

$$P = \left(60\frac{m^3}{s}\right)(1407Pa) = 84.438Kw$$

with an 84.438Kw motor this fan would have to have an 85 percent mechanical efficiency, which is more than can be expected. This means that an 84.438Kw motor would be overloaded. A 100.711Kw motor will be needed in order to get $60\frac{m^3}{s}$ at a static pressure of 495 Pascal.

Let us calculate the minimum hub diameter d_{min} and the minimum wheel diameter D_{min} for these requirements. The minimum hub diameter d_{min} will be

$$d_{\min} = \frac{19.000}{rpm}\sqrt{SP} = 13.435in(0.341m)$$

Fig. 5 shows a hub for a propeller fan.

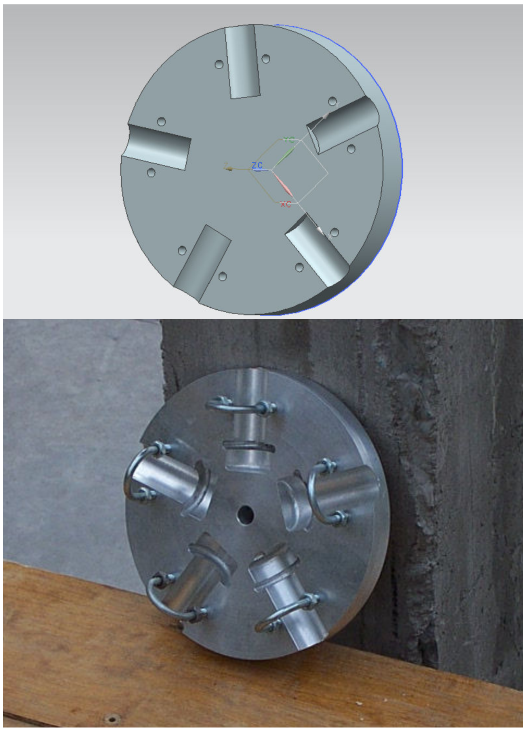

Fig. 5 A 0.34m hub diameter for a propeller fan

We calculate the minimum wheel diameter D_{min}. It will be:

$$D_{\min} = \sqrt{d^2 + 61(\frac{AirVolume}{\text{rpm}})} = 63.703in(1.618m)$$

Fig. 6 shows a propeller fan wheel with 5 blades.

Fig. 6 A 1.618m Propeller fan wheel with 5 blades

VI. Conclusion

Once the necessity of fan design on a theoretical basis has been recognized, it is possible to determinate the dimensions for a fan unit so that it will perform in accordance with a certain set of specifications. The requirements for air volume and static pressure often determine what type of fan should be used for a specific application. The axial flow fan has the following advantages: compactness, low first cost, straight line installation, little sound level at high tip speed.

VII. Results

From the aerodynamic point of view, it is a method for the selection and design of an axial flow fan. The same procedures in this work then can be applied in other fan selection.

Acknowledgment

I would like to thank COMECyT, ICyTDF, and IPN for providing the funding which allowed attending this conference.

The authors would like to acknowledge COMECyT, ICyTDF, IPN, and CONACyT for the financial support of this work.

Nomenclature

Lift Coefficient	C_L
Drag Coefficient	C_D
Chord	c
Magnitude of the relative wind	V_0
Speed of the propeller revolutions per second	n
Angle of attack	α
Blade width	σ
Radius	r
Force	F
Lift force	L
Drag force	D
Efficiency	η
Outlet velocity or dynamic pressure	OV
Static pressure	SP
Dynamic pressure or outlet velocity	q
Local velocity	V
Duct area	A
Volume of air	Q
At 2240m density altitude above Sea level	ρ
Total pressure	TP
Air power	P
Pascal	Pa
Inch water column	$inWC$
Cubic Feet per Minute	cfm
Revolutions per minute	rpm
Minimum hub diameter	d_{min}
Minimum wheel diameter	D_{min}
Kilowatts	Kw
Meter	m
Second	s

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