International Journal of Research in Engineering and Applied Sciences(IJREAS)
Available online at http://euroasiapub.org/journals.php
Vol. 7 Issue 2, February-2017, pp. 35~41
ISSN (O): 2249-3905, ISSN(P): 2349-6525 | Impact Factor: 6.573 | Thomson Reuters Researcher ID: L-5236-2015

Experimental Investigation on Aerodynamic Characteristics of an Axial Flow Fan

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Abstract

The prime objective of this work is to determine the relationship between the mechanical and aerodynamic characteristics of the fan when the blade position is default and when it is changed and to find out which position gives optimum output at given power and given working conditions and according to the change of environment. In this experiment, the aerodynamic characteristic of an axial flow fan is going to be determined by measuring the static and total pressures in the suction and discharge sides of the fan for various flow rates. In this experiment, for different blade angle, flow velocity is measured and relationship between the change of blade angles and the flow velocity are plotted

Keywords: Axial Flow Fan, Blade angle, Aerodynamic characteristics

INTRODUCTION

Turbo Machines

Basically all the turbo machines are used for changing the energy level of flowing fluid. The process by which these machines convert the energy from one form to another is momentum exchange. Most turbo machines transfer energy between a rotor and fluid. For example, turbines transfer energy from a fluid to rotor whereas a compressor transfers energy from a rotor to fluid. Centrifugal fans are also a part of the turbo machine family which transfers energy from a rotor to fluid. These turbo machines are used mostly everywhere such as turbines are used for power generation in power plants, fans used for cooling purpose in computers, different industrial and residential sectors, food processing firms etc, pumps used in pumping fluid for residential sectors as well as in elevators, cranes etc.

Axial Flow Fan

An axial flow fan moves air or gas parallel to the axis of rotation. By comparison, a centrifugal or radial flow fan moves air perpendicular to the axis of rotation. Axial flow fans are better suited for low-resistance, high-flow applications, whereas centrifugal flow fans apply to high-pressure resistance, low-flow conditions. Typically, the types of fans discussed in this manual can handle "resistances" up to approximately 1 in. of water. Axial fans can have widely varied operating characteristics depending on blade width and shape, number of blades and tip speed. The most common type of fan for air-cooled heat exchanger (ACHE) is less than 14 ft. diameter and has four blades. The most common type for wet cooling towers is 28 ft diameter and has eight blades.

The axial-flow fan has blades that force air to move parallel to the shaft about which the blades rotate. In an axial-flow fan, with the runner and guide vanes in a cylindrical housing, air passes through the runner essentially without changing its distance from the axis of rotation. There is no centrifugal effect. Guide, or stator, vanes serve to smooth the airflow and improve efficiency. In general, an axial-flow fan is suitable for a relatively large rate of flow with a relatively small pressure gain, and a centrifugal fan for a small rate of flow and a large pressure gain. Actually, the pressure developed in a fan is small compared with the pressure developed in a compressor. Airflow across the plane of the fan is not uniform varying from positive at the tip to negative at the center of the fan. Blade shape and twist of the airfoil along the blade affects the shape of the velocity profile. Velocity profile of a well designed tapered blade with a generous twist compared to a constant chord blade with minimal twist. Work performed by a fan blade is basically a function of three factors at any point or radius: Chord width, Airfoil twist, Tangential velocity squared. Hence the shape of blades varies the efficiency and performance of fan. The flow of fluid in axial flow fans is parallel to the axis of fan. So the pressure, temperature, and velocity of fluid must be moderate.

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LITERATURE REVIEW

1. Lifu Zhu, Yingzi Jin, Yuzhen Jin, Yanping Wang and Li Zhang conducted a numerical study on internal flow of small axial flow fan with splitter blades. The objective of this experiment was to notice whether splitter blades make a considerable difference in the performance of the fan or not. The splitter blades are widely used in axial compressors and play an active role in the improvement of the overall performance of compressors. They concluded that the performance of the fan with splitter blades is better than that of the prototype fan.
2. M.G.Beiler and T.H.Carolus wrote a research paper about computation and measurement of the flow in axial flow fans with skewed blades. In this experiment a numerical analysis of the flow in axial flow fans with skewed blades has been conducted to study the three-dimensional flow phenomena pertaining to this type of blade shape. The results were analyzed, leading to a design method for fans with swept blades. Forward swept fans designed accordingly exhibited good aerodynamic performance.
3. MahajanVandana N., Shekhawat Sanjay P. conducted the analysis of blades of axial flow fan using the software Ansys. CFD (Computational Fluid Dynamics) based investigation has been reported in order to study the effect of change in speed of fan on velocity, pressure,

and mass flow rate of axial flow fan. In order to predict the mass flow output, velocity and pressure on stator and rotor section this is good option.

4. Renjing Cao measured and predicted the aerodynamic stability of an axial-flow ventilation fan near the stall condition. The attempt is made to look at the unsteady flow pressure on the blade tip in order to quantify the inception of instability of an axial-flow ventilation fan. That resulted as the stall margin for the axial-flow ventilation fan were numerically predicted and compared with experimental results.
5. S. Jain, and Y. Deshpande did the CFD modeling of a radiator axial Fan for air flow distribution because the axial fans are widely used in the engine cooling application in the radiator. This presents a computational fluid dynamics (CFD) model of air flow distribution from a radiator axial flow fan used in an acid pump truck. Typically this model shows the approximated path of the air flow. A CFD simulation can be very useful for predicting and understanding the flow distribution from a radiator fan.
6. John F. Foss, Scott C. Morris, Douglas R. Neal conducted experiments and wrote a research paper about axial fan research for automotive and building ventilation applications. Axial fans are utilized in a wide range of applications. Two of these: under hood cooling fans and building ventilation fans. These two have been considered in this communication. The aerodynamic shroud has been shown to enhance the performance of both styles of fans.
7. Stefano Bianchi, Alessandro Corsini, Anthony G. Sheard researched about one of the critical problems of occurrence of loss of energy in fans i.e. stall. They wrote a research paper in which critical reviews of stall control techniques in industrial fans were included. The basic objective was to understand the key physical phenomena that occur with stall inception that is critical to alleviate stall by design or through active or passive control methods. The methods and prospects for early stall detection to complement control systems with a warning capability.
8. Thomas Carolus, Marc Schneider conducted review of noise prediction methods for axial flow fans. In this experimental research, some methods to predict aerodynamic noise produced by rotating blades in low Mach number, low to medium speed axial flow fans with an emphasis on broad band noise. To the knowledge of the authors none of the more advanced noise prediction methods are used routinely in fan design.
9. Ali Aktürk, CengizCamci experimentally tried to control the axial flow fan tip leakage flow using tip platform extensions. The present experimental study uses a stereoscopic particle image velocimeter to quantify the three dimensional mean flow observed near the blade tip, just downstream of a ducted fan unit. It is also observed that a proper tip leakage mitigation scheme significantly reduces the tangential velocity component near the tip of the axial fan blade.
10. Manikandapirapu P.K., Srinivasa G.R., Sudhakar K.G. Madhu D. did the modeling and simulation of ducted axial fan for one dimensional flow. The prime objective of the research was to develop the analogy for modeling and simulation of ducted Axial Fan by using the one dimensional flow equation of axial turbo machines. The analogies for modeling and simulation has been investigated for optimize the parameter of pressure rise in ducted axial flow fan.
11. Manikandapirapu P.K., Srinivasa G.R., Sudhakar K.G., Madhu D. did the aerodynamic instability studies in axial fan. This experiment was about an analysis of stall and surge

suppressive studies in axial fan. Main objective of this experiment is to suppress rotating stall and surge, to extend the stable operating range of the axial fan system by using active feedback control methods. Active control and monitoring system to be extending the stable operating range through suitable instrumentation and compare with mathematical modeling results.

12. Carl Howard determined the experimental results of synchro phasing two axial fans in a duct, an experimental investigation of this method. The experiment involved synchro phasing two axial fans in a duct to reduce the radiated blade passage tonal noise. The sound pressure level at the blade passage frequency can be reduced by 10dB at the error microphone and in the free field by adjusting the relative angle between the two fans.

DESIGN METHODOLOGY

From these work only requires changing the blade angle of a fan which might be used for general purposes. The advantage of analyzing the performance of a commercially used fan is that we can compare the experimental readings to the standard readings. This way we can compare better than to develop a new designed model and then compare it. The design data or the specifications of the fan and motor are given below.

Fan diameter = 30 cm

Material = Cast Iron

Mass flow rate (m) = **ρAV**

Where, ρ = Density of air which is approximately 1.1 to 1.2 kg/m^3

A= Area of the fan = $Лr^2$

V = Velocity of air

N = 1400 rpm

Standard Temperature and Pressure Conditions.

The performance characteristics of an axial flow fan at a certain rotational speed are obtained by measurement of total pressure rise across the fan at various flow rates. The efficiency of the fan system shall be calculated at each operating point and this is made possible by dividing the fluid power to the motor input power. The flow rate is obtained by traversing the Pitot tube at predetermined locations on measurement plane. The dynamic pressure values at discrete points on measurement plane are recorded and flow rate is calculated by performing a calculation procedure as follows:

Where

h= Dynamic pressure at a certain point

$$V_m = \sqrt{\frac{2gh}{\rho}}$$

V_m= Average velocity on 'm' plane

ρ = Air density on 'm' plane

EXPERIMENTAL PROCEDURE

First of all the casing of about 3 feet is manufactured by means of rolling process of sheet metal. The bought fan will be assembled with the motor and then the fan and motor assembly will be fitted in the manufactured casing. The readings of different characteristics of the fan shall be taken first in the default and unchanged position. Then the fan will be unmounted from casing. The fan will be then be machined for creating grooves at the bottom of each blade on the fan hub. The machined fan will be mounted again and thus we will be able to move the blade in different positions. The readings of the characteristics of the fan shall be taken at different blade positions.

For obtaining the pressure reading a pitot tube will be attached to the assembly and at the end of which there will be a U-Tube manometer which will measure the stagnation pressure and by using calculative methods the velocity will be obtained. The rpm of the fan will be measured with the help of a non-contact type digital tachometer and the change of angle will be measured by a set square. We can also obtain the wind flow velocity with the help of anemometer. After obtaining the results in the normal blade conditions and the modified angle condition, we can determine the relative changes in pressure, power and efficiency with respect to rpm of the fan and thus we can do the analysis of the mechanical and aerodynamic characteristics of the axial flow fan.

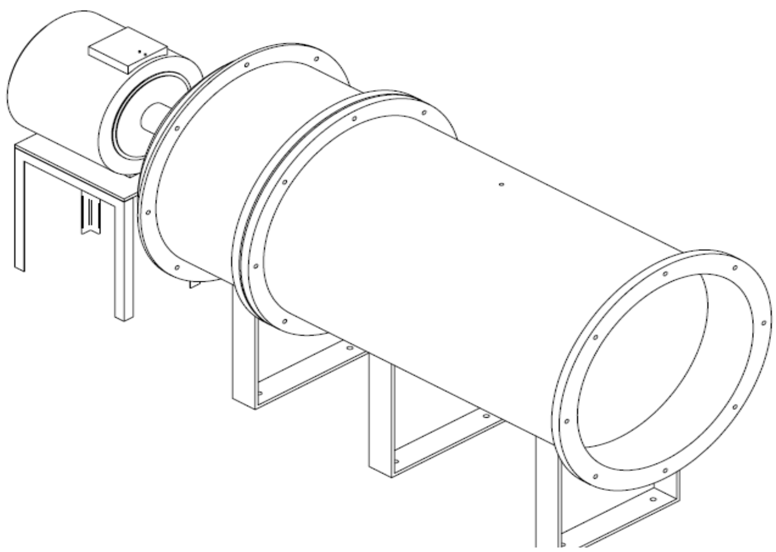

Figure 1 Experimental Setup

RESULTS AND DISCUSSION

Table 1 Relation between blade angles and average velocity

Blade Angle (Degree)	Velocity of Flow at Different Locations (m/s)			Average Velocity (m/s)
	Left	Centre	Right	
5^0	0.7	0.3	0.7	0.5666
10^0	0.9	1.0	1.3	1.0666
15^0	3.2	2.8	3.2	1.5333
20^0	4.0	4.3	4.8	4.3666

Table 2 Relationship between velocity and discharge

Average Velocity (m/s)	Area of Fan (m^2)	Discharge (m^3/s)
0.5666	0.07065	0.04003
1.0666	0.07065	0.05355
1.5333	0.07065	0.10832
4.3666	0.07065	0.30850

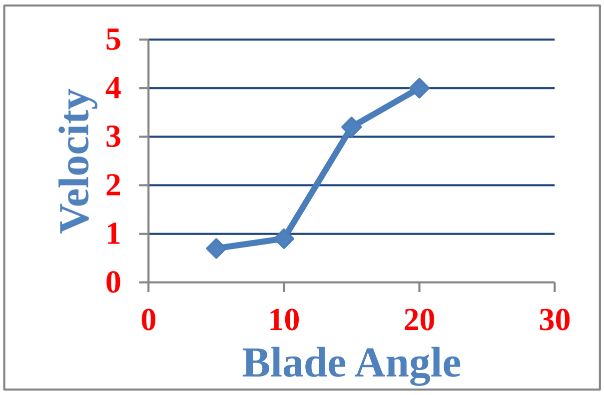

Figure 2. Velocity at left side Vs. Blade angle

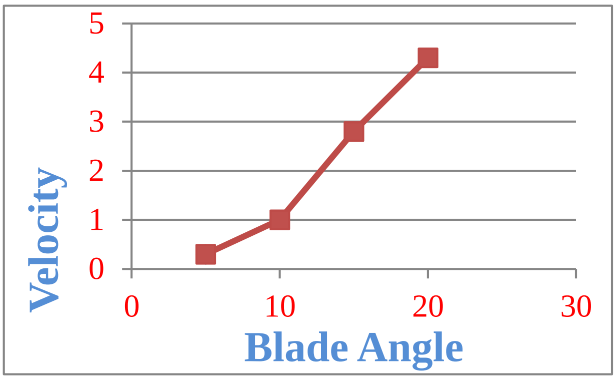

Figure 3.Velocity at centre side Vs. Blade angle

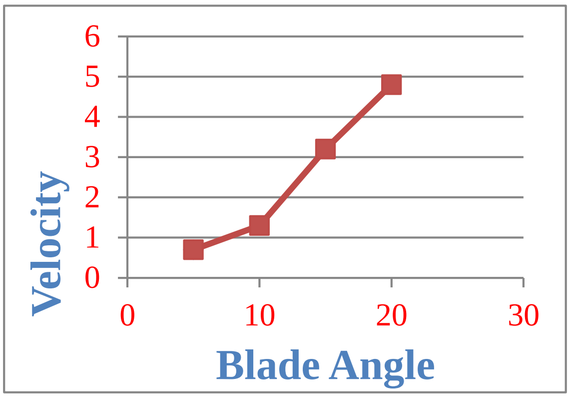

Figure 4. Velocity at right side Vs. Blade angle

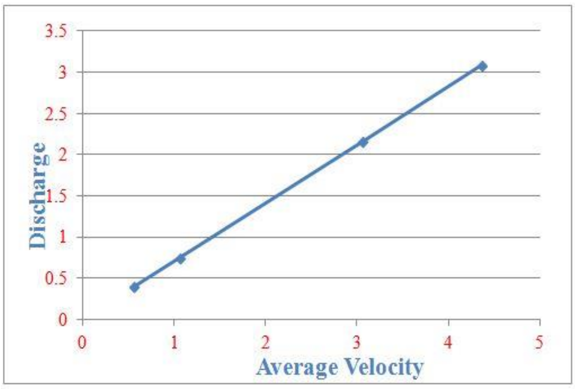

Figure 5. Discharge vs. Average Velocity

CONCLUSION

The major conclusions which we have drawn from the present experiment are as follows.

1. The angle of blade having greater influence on flow velocity.
2. As the blade angle increase in forward direction with respect to plane of rotation, the velocity will increase.
3. In the present experimental setup, because fan capacity is low to measure flow velocity, anemometer is the better option than manometer.
4. So, finally the main conclusion of this experimental work is in design of any axial flow fan, position of blade plays an important role in development of commercially accepted fans.

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