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DESIGN OF AXIAL FAN USING COMPUTATIONAL FLUID DYNAMICS

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ABSTRACT:- The purpose of this work is to study the influence of heat discharge rate and effect of flow characteristics when modification made on operating speed, blade thickness, diameter of hub, vane angles, shape of blades. This work is done on axial flow fan used in automobiles. For this we use ANSYS software for modeling of axial fan and by using computational fluid dynamics, we compare the results obtained by this analysis with the existing.

Keywords: Axial flow fan, ANSYS, CFD analysis

INTRODUCTION

The axial fan is a device which is used to create flow within a fluid typically a gas i.e. air. The fan consists of a rotating arrangement of vanes or blades which act on the fluid. The rotating assembly of blades and hub is known as an impeller, a rotor, or a runner. Usually, it is contained within some form of housing or case. This may direct the airflow or increase safety by preventing objects from contacting the fan blades. Most fans are powered by electric motor but other sources of power can be used, including hydraulic motor and internal combustion engine.

There are three types of fans namely- axial, centrifugal (also called radial) and cross flow (also called tangential). Axial-flow fans have blades that force air to move parallel to the shaft about which the blades rotate. Axial fans blow air along the axis of the fan, linearly, hence their name. Standard axial flow fans have diameters from 300–400 mm or 1800 to 2000 mm and work under pressures up to 800 Pa.

Examples of axial fans are table fans, ceiling fans.

Fig. 1. axial fan

Types of blades- Followings are the types of blades-

1. Airfoil profile- This series of axial fan can be used in almost any air moving application such as cooling tower, engine cooling.
2. Broad paddle profile- This series of axial fan is designed for coil applicationwith low speed motor and moderate power consumptions.
3. Increasing arc profile- It is a suitable solution in applications that demand high performance in challenging inlet conditions.
4. Pressure Max profile - Multi-Wing's new Pressure MAX axial fan series is designed for radiator /engine cooling applications that require high pressure in a narrow cooling envelope. Tier 4 emissions standards and the Stage III B Standards for off highway engines, which call for stringent reductions in particulate matter and nitrogen oxide levels.
5. Sickle profile- Multi-Wing's sickle axial fan series is the answer for generating pressure with low noise axial fans. The sickle blade's swept design and thin trailing edge reduce pure tones in the sound spectrum and decrease vortex shedding to generate low wake turbulence

for a quieter axial fan. The sickle profile's large chord length and overall surface area also combine to generate greater pressure at slower speeds.

6. True reversible profile- Multi-Wing's innovative true reversible axial fan series is designed for applications that require high efficiency in a reversible configuration.

Fan Materials- Each application calls for different combinations of materials to suit different working conditions, speeds and temperatures. Multi-Wing fan blades are available in 6 different materials as listed below. PPG, PAG, PAGI, PAGAS, PAGST and AL. Multi-Wing hub parts are as standard manufactured in a pressure die cast silumin alloy (Al Si12 Cu). Certain hub parts are also available in glass reinforced polypropylene (PPG) to make up complete non-corrosive fan solutions.

PROBLEM STATEMENT

Causes of unstable flow – Stalling and surging effects the fan performance, blades, as well as output and are thus undesirable. They occur because of the improper design, fan physical properties and are generally accompanied by noise generation.

Stalling effect/Stall- The cause for this is the separation of the flow from the blade surfaces. This effect can be explained by the flow over an air foil. When the angle of incidence increases (during the low velocity flow) at the entrance of the air foil, flow pattern changes and separation occurs. This is the first stage of stalling and through this separation point the flow separates leading to the formation of vortices, back flow in the separated region. For further the explanation of stall, rotating stall refer to compressor surge. The stall zone for the single axial fan and axial fans operated in parallel are shown in the figure 2.

Surging effect/Surge - Surging should not be confused with stalling. Stalling occurs only if there is insufficient air entering into the fan blades causing separation of flow on the blade surface. Surging or the Unstable flow causing complete breakdown in fans is mainly contributed by the three factors

- System surge
- Fan surge
- Paralleling

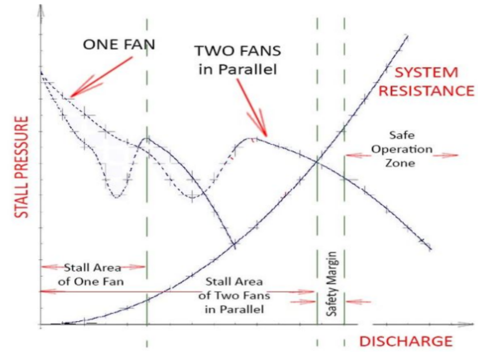

Fig. 2. The stall zone for the single axial fan and axial fans operated in parallel are shown in the figure

System surge - This situation occurs when the system resistance curve and static pressure curve of the fan intersect have similar slope or parallel to each other. Rather than intersecting at a definite point the curves intersect over certain region reporting system surge. These characteristics are not observed in axial fans.

Fan surge - This unstable operation results from the development of pressure gradients in the opposite direction of the flow. Maximum pressure is observed at the discharge of the impeller blade and minimum pressure on the side opposite to the discharge side. When the impeller blades are not rotating these adverse pressure gradients pump the flow in the direction opposite to the direction of the fan. The result is the oscillation of the fan blades creating vibrations and hence noise.

Paralleling - This effect is seen only in case of multiple fans. The air flow capacities of the fans are compared and connected in same outlet or same inlet conditions. This causes noise, specifically referred to as Beating in case of fans in parallel. To avoid beating use is made of differing inlet conditions, differences in rotational speeds of the fans, etc.

METHODOLOGY

The heat required to be discharged from an engine is significantly influenced by the axial fan. The blades used for the fan guides the air to flow over the engine which takes heat from the engine. The water circulates from the engine becomes cool from the air. So an attempt is made to modify the blade parameters like- operating speed, no. of ribs, diameter, axial dimensions, hub to tip ratio, no. of blades, attack angle, depth at the radial edge and blade thickness. The methodology include designing of blades dimensions using ANSYS software with some modifications and analysis of its performance is done by using CFD analysis software. CFD is the acronym that refers that “Computational Fluid Dynamics”. CFD uses numerical methods to solve the fundamental nonlinear differential equations that describe fluid flow (the Navier-Stokes and allied equations) for predefined geometries and boundary conditions. The result is a wealth of predictions for flow velocity, temperature, density, and chemical concentrations for any region where flow occurs. A key advantage of CFD is that it is a very compelling, non-intrusive, virtual modeling technique with powerful visualization capabilities, and engineers can evaluate the performance of a wide range of HVAC/IAQ (Heating, Ventilation, Air Conditioning)system configurations on the computer without the time, expense, and disruption required to make actual changes onsite.

CFD has seen dramatic growth over the last several decades. This technology has widely been applied to various engineering applications such as automobile and aircraft design, weather science, civil engineering, and oceanography. Today, the HVAC/IAQ industry is one of the fields that has initiated utilizing CFD techniques widely and rigorously in its design.

The many reasons CFD is being widely used today are as follows:

- CFD predicts performance before modifying or installing systems:
  - Without modifying and/or installing actual systems or a prototype, CFD can predict which design changes are most crucial to enhance performance.

- CFD provides exact and detailed information about HVAC design parameters:
  - The advances in HVAC/IAQ technology require broader and more detailed information about the flow within an occupied zone, and CFD meets this goal better than any other method, (i.e., theoretical or experimental methods).

Dependent & Independent Variables

One can carry out the initial analysis using Diameter of hub, number of blades, Speed are independent variables while annulus area and the velocity pressure so that total pressure can be known for each choice of D. Flow characteristics like-kinematic, thermodynamics and miscellaneous properties are dependent variables.

Performance characteristics- The relationship between the pressure variation and the volume flow rate are important characteristics of fans. The typical characteristics of axial fans can be studied from the performance curves. The performance curve for the axial fan is shown in the figure. (The vertical line joining the maximum efficiency point is drawn which meets the Pressure curve at point "S") The following can be inferred from the curve -

1. As the flow rate increases from zero the efficiency increases to a particular point reaches maximum value and then decreases.
2. The power output of the fans increases with almost constant positive slope.
3. The pressure fluctuations are observed at low discharges and at flow rates (as indicated by the point "S") the pressure deceases.
4. The pressure variations to the left of the point "S" causes for unsteady flow which are due to the two effects of Stalling and surging.

Analysis of Previous Work

WORK	Operating speed	No. of ribs	No.of ribs	Result	
Optimization of sirocco fan blade to reduce Noise of air purifier using a metamodel and evolutionary algorithm	810 rpm	5EA	51 EA	Compared to the initial model, the fan blade operating noise decreased by 4.5 dB(A) in the main range.	
Prediction and measurement of axial flow fan aerodynamic and aero acoustic performance in a split-type air-conditioner outdoor unit	3-FORWARD SWEPT BLADE				
	DIAMETER (MM)	AXIAL DIMENSIONS (MM)	HUB TO TIP RATIO (MM)	**Result**	
	401	119	0.26	Both modified fan geometries are effective to reduce the noise but the flanging outer-edge blade is more effective.	
PIV measurement and numerical simulation of fan-driven flow in a constant volume combustion vessel	NO. OF BLADES	ATTACK ANGLE	DIAMETER (MM)	DEPTH AT THE RADIAL EDGE (MM)	BLADE THICKNESS (MM)
	8	30°	25.4	6.35	0.89
Proposed dimensions(Approx.) Operating speed 800 rpm	8	29.5	26	6.30	0.82

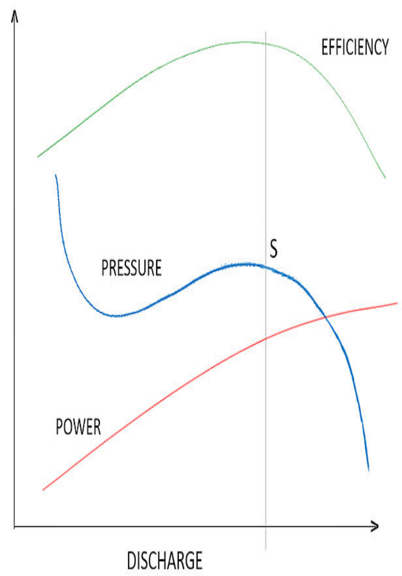

Fig. 3. This Figure shows the Performance Curve for Axial Flow Fan.

CONCLUSION

The study is done on following papers, Optimization of sirocco fan blade to reduce Noise of air purifier using a meta model and evolutionary algorithm, Prediction and measurement of axial flow fan aerodynamic and aero acoustic performance in a split-type air-conditioner outdoor unit , PIV measurement and numerical simulation of fan-driven flow in a constant volume combustion vessel . The results of these papers are framed in the table. In this study, the design parameters based on the different works are taken and modifications are made to improve the flow characteristics of an axial fan are going to be improved and the performance of flow of air over the blades are compared with the exisisting design by CFD.

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