Time Domain Sound Spectrum Measurements in Ducted Axial Fan under Stall Region

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ABSTRACT: *An axial fan is a one type of a compressor that increases the pressure of the air flowing during it. Axial fans draw its name from the truth that they bow air across their axis in a linear direction. The blades of these fans strength of air to move parallel to the streak about which the blades rotate. These types of fans find its applications in a large variety of mechanical and electrical gadgets. Sizes of these fans can choice from a small cooling fan for electronics to a giant fan used in wind tunnels. Presentation of axial fan is found to diminish significantly when insecurity is encountered during its operation. Performance of an axial fan is harshly impaired by many factors mostly related to system instabilities due to rotating stall and surge phenomenon experienced during its operation. The here work involves measuring the time domain sound signal in ducted axial fan under stall region at throttle positions 2 cm from the covering. Aim of the experiment is to measure the time domain sound signal in terms of decibel and understand the sound distinctiveness in ducted axial fan by using sound spectrum analyzer. Dissimilar types of time domain sound signals have been measured under stall region at throttle position 2 cm from the exterior for different rotor speed and different graphs are plotted for ducted axial fan.*

Keywords: *Microphone, BNC connector, Data Acquisition System, Spectrum Measurements, Throttle position, Rotor speed.*

I. INTRODUCTION

Axial flow fans, while incompetent of increasing high pressures, they are well appropriate for handling large volumes of air at moderately low pressures. In general, they are low in cost and have good efficiency, most have a large hug and can have blades of airfoil shape. The blades are typically not close together, they can be made in many forms, but the most efficient have airfoil sections. Angle modifies and twist is given to the blade at various positions outward from the hub to tip. Frequently inlet guide vanes are used to align and straight the air into the fan blades, which in turn impart energy to the incoming air. Axial flow fans show good efficiencies, and can operate at high static pressures if such operation is needed. The fan can be so planned that the horsepower is flat and non-overloading. The swirl imparted to the air by the fan blades can be eliminated by the guide vanes on the inlet side and, in some designs, on the outlet side as well.

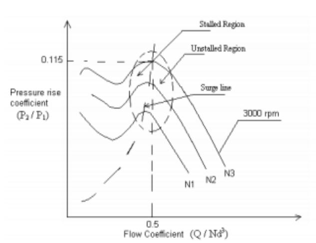

Fig 2. Graphical representation of Axial Fan performance curve

Mining fans and cooling tower fans usually employ axial blades and or needed to work under adverse ecological conditions. They have to operate in a narrow band of speed and throttle positions in order to give best presentation in terms of pressure rise high competence and also stable condition. Since the range in which the fan has to function under stable condition is very narrow, clear knowledge has to be obtained about the whole range of operating conditions if the fan has to be operated using active adaptive control devices. The performance of axial fan can be graphically represented above in figure 1.

II. CHARACTERISTICS OF AXIAL FANS

There are two common classifications of fans: the centrifugal or radial flow fan and the propeller or axial flow fan. In the broadest sagacity, what sets them not together is how the air passes during the impeller. The propeller or axial flow fan propels the air in an axial direction with a swirling peripheral motion created by the turning impeller blades. In a centrifugal fan the air enters the impeller axially and is accelerated by the blades and discharged radically.

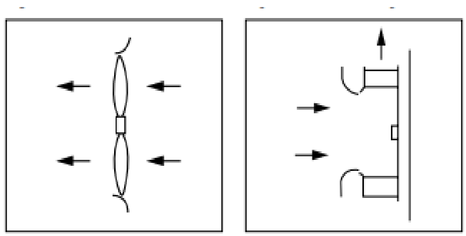

Figure 2. Axial Flow and Centrifugal Flow

The axial flow fan increases the air velocity through rotating or peripheral force which produces velocity pressure, kinetic energy, with a very small increase in static pressure, potential energy. The centrifugal fan induces airflow by the centrifugal force generated in a rotating column of air producing potential energy and also by the rotational velocity imparted to the air as it leaves the tip of the blades producing kinetic energy.

Axial Flow Fans: Axial flow fans come in lots of variations that all have one thing in common: they rotate about their axis and they move a column of air parallel to that axis. The axial fan is usually found in residential and profitable applications where emphasis is on moving large volumes of air against relatively low pressures as efficiently as possible. The axial fan is also ruling greater acceptance in industrial applications as alternative equipment to the more expensive centrifugal fans. While residential applications are concerned primarily with creature comfort, commercial and industrial requirements are extended to include aeration for process as well as worker comfort. There are many variations of axial flow fans, all of which have performance characteristics of the three basic types: propeller fans, tube axial fans and vane axial fans.

2.1Propeller Fans: Propeller fans can be placed in two categories:

- Air Circulator or Free Fans: A free fan is one that rotates in an ordinary unrestricted air space. Examples of free fans include ceiling fans, desk fans, pedestal fans, and wind fans. With the omission of the wind fans, most of these fans are more ornamental than functional. Low tech, low cost designs function to move and stir the air, but are not unavoidably the most efficient of designs.

- Orifice Panel or Orifice Ring Fans: These are the fans most associated with applications referred to as ventilating fans. There are many variations of these arrangements, some with long shaft extensions, direct connection to a motor, arranged with bearings and sheaves for belt drive and close coupled belted arrangements. These fans are designed to transfer air from one large space to another.

2.2 Tube axial Fans:

The tube axial fan is a propeller fan mounted in a cylindrical tube or duct and is often called a duct fan. Fans of this type employ a diversity of impeller designs comparable to those previously described under the business panel fan. The tube axial fan can activate in pressure ranges up to 4" water gauge mainly because its strong construction allows for higher speeds and horsepower. The presentation characteristics of the tube axial fan are very similar to those previously shown for the industrial panel fan. The performance curve is for a tube axial fan using the same impeller that was used in the industrial panel fan. Normally speaking, the tube axial fan will develop slightly better pressure characteristics than a similar well designed panel fan.

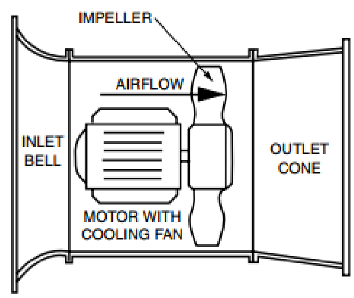

Fig 3. Direct Drive Tube axial Fan

Tube axial fans are planned for use in ducted applications. Much more adaptable than the panel fan by virtue of their construction, they are most malleable to ventilation of industrial processes. They can be built of materials which will stand up under light abrasion, temperatures up to 600°F, or air seriously infected with corrosive chemicals or explosive vapors. They can be mounted in parallel for higher airflows or they can be staged in series to increase their pressure capabilities. Also, as mentioned under the panel fans, using larger hub-to-tip ratio impellers increases the tube axial fan's capability to work beside pressure for a given speed or equally enables the fan to work against the same pressure at a lower speed.

2.3 Vane axial Fans: The vane axial fan is a deviation of the duct fan design which operates in the medium-to-high pressure ranges. Two to 10 inches water estimate is the predictable pressure range for a single stage fan. The presentation of the vane axial fan shows the pressure curve to rise steeply from free delivery to a maximum point and then dip stridently into stall. From the bottom of the stall range the pressure rises again to a higher pressure value at the point of no flow. The increased operating pressure characteristic of the vane axial fan is the shared result of impeller design and the guide vanes. The guide vanes are usually located at the discharge of the impeller. The function of the veins is to get better the energy of rotation and convert this into useful work. The efficiency of the veins axial fan rises to a maximum near the mid range peak pressure point. Its efficiency is higher than the efficiency of other types of axial fans, but the horsepower characteristic is not as flat as that of the business panel or tube axial fans. The power rises from free delivery to the mid-range peak pressure, dips similarly as does the static pressure curve, and then rises again toward the point of no flow.

In designing a system for the vane axial fan, it is required to be sure that the point of operation is to the right of the dip in the presentation curve, but not too far from the peak pressure point to take advantage of most efficiency. When operating vane axial fans in parallel, care should be taken to ensure that the flow is divided equally. Vane axial fans work well in series, either as two stages in a common housing or as two separate fans installed end to end. One valued feature of the vane axial fan is its facility to allow pitch changes for controlling air volumes, either through in-flight modifiable or physically adjustable versions. The changeable pitch versions are limited to clean air applications; however, fans with cast solid impellers can be designed to handle high temperatures and chemical impure air. Vane axial fans are not optional for applications containing abrasives, dust, stringy materials or overspray since buildup on the guide vanes will decrease fan performance.

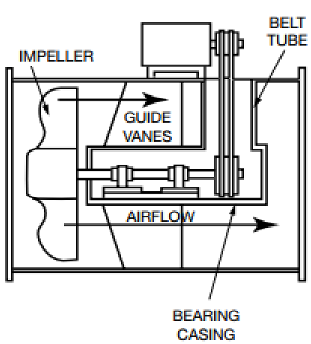

Fig 4.Belt Driven Vane axial Fan

III. TEST FACILITY AND INSTRUMENTATION

Experimental setup, fabricated to create stall conditions and to introduce unstill conditions in an industrial ducted axial fan is as shown in figure. The flow enters the test duct through a bell mouth entry of cubic profile. The bell mouth performs two functions: it provides a smooth undisturbed flow into the duct and also serves the purpose of metering the flow rate. The bell mouth is made of fiber reinforced polyester with a smooth internal finish. The motor is positioned inside a 381 mm diameter x 457 mm length of fan casing. The aspect (L/D) ratio of the casing is 1.2. The hub with blades, set at the required angle is mounted on the extended shaft of the electric motor. The fan hub is made of two identical halves. The surface of the hub is made spherical so that the blade root portion with the same contour could be seated perfectly on this, thus avoiding any gap between these two mating parts. An outlet duct identical in every way with that at inlet is used at the downstream of the fan. A flow throttle is placed at the exit, having sufficient movement to present an exit area greater than that of the duct.

Fig 5. Ducted Axial Fan Rig & Variable frequency Drive for speed control

3.1 Sound Measurement Analysis and Evaluation:

Sound requires a Source, a Medium for its transmission and a Receiver. The source is the axial fan wherein the trembling of air molecules takes place due to external energy source. The medium is the material which carries the sound energy from one molecule to another. The sound energy is transmitted through a medium back and forth in a way like to the vibration of the sound source. The fan which is transmitting the energy while transferring the rushed air creates compression of air. The slight increase in pressure is passed onto the molecules which are successively farther away from the sound source of an axial fan resulting in a slightly high pressure area moving away from the source. When the sound source completes its motion to the right it begins to move back to the left. This results in a decrease of force next to the object allowing the air molecules to spread apart, producing a rarefaction. This slight decrease in pressure is found in the air which is away from the fan signal sound source. Through the motion of the fan sound signal back and forth, it effectively ensures density followed by a rarefaction of air to form the sound wave. The receiver is the microphone which senses the signal. The sound pressure variation is periodic; one complete variation in sound pressure is referred to as a cycle. The time T for one complete cycle is called the period of sound pressure oscillation.

3.2 Basic Sound Spectrum Analyzer System:

Fundamental sound Spectrum analyzer schematic diagram consists of various components as shown in fig. Microphone acquires the sound pressure oscillation and converts them to an analog signal. BNC connector sends the signal to Data acquisition system. Data Acquisition system receive the signal from the BNC connector and sends to LABVIEW software. Once the amplitude of the signal has been measured, the computer system displays the measurement signal of spectrum through LABVIEW software.

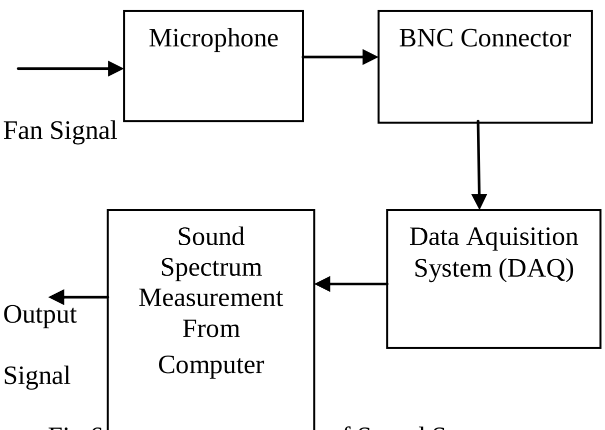

Fig 6. Schematic diagram of Sound Spectrum Measurement

3.3 Time Domain Sound Spectrum Measurements:
In an axial fan setup, eight number of axial fan blades are concerned in transferring the energy to the fluid. In one rotation of axial fan, the oscillation in pressure amplitude happens eight times. Every aerofoil blade transfers the energy to the fluid during an increase in the pressure levels in transmission medium of the fluid. Appropriate to change in static pressure of the fluid, the velocity of sound propagation will increase. It is also known that the static pressure is directly comparative to velocity of sound. In the stall region, flow division would also occur. When the flow separation starts in the aerofoil section of an axial fan, rotating stall occurs. Rotating stall is defined as the unstable flow around the annulus region of fan blade.

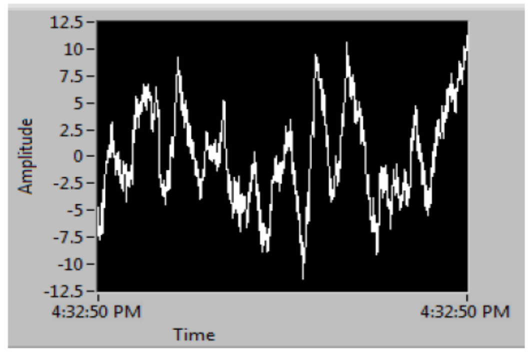

Fig 7.Rotor Speed 2400 Rpm

These rotating stall cells rotate at some exacting frequency and this situation would lead to pressure changes. Increase in the rotating stall frequency leads to making of more number of stall cell pockets important to stalling of the axial fan. The static pressure is found to decrease in the stall region whereas there would be an increase in the stagnation or total pressure of the system. Making of more number of stall cells leads to reversal of flow thus making a complete flow cycle in ducted axial fan. The rise in total pressure in the stall region leads to an increase in the velocity of sound.

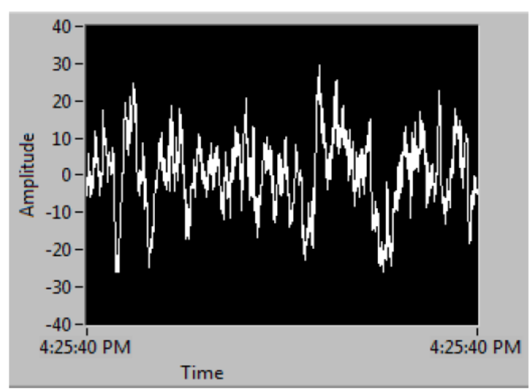

Fig 8.Rotor Speed 3600 Rpm

IV. CONCLUSION

In this paper, an effort has been made to determine the sound spectrum signal in time domain under stall region at throttle position of 2 cm with respect to rotor speeds in ducted axial fan by using spectrum analyzer. It is useful to scrutinize the characteristics of stall in ducted axial fan. Further, this work can be extensive by working on the mathematical model of sound spectrum study in ducted axial fan. The results so far discussed, point out that time domain sound spectrum measurements of ducted axial fan is very hopeful.

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