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Research Paper

SOUND SPECTRUM MEASUREMENTS IN DUCTED AXIAL FAN UNDER STALL CONDITIONS AT FREQUENCY RANGE FROM 9000 HZ TO 9600 HZ

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Performance of axial fan is found to reduce drastically when instability is encountered during its operation. Performance of an axial fan is severely impaired by many factors mostly related to system instabilities due to rotating stall and surge phenomenon experienced during its operation. The present work involves measuring the sound spectrum measurements in ducted axial fan under stall conditions at frequency range from 9000 Hz to 9600 Hz. Objective of the experiment is to measure the frequency domain signal and study the sound Characteristics in ducted axial fan by using spectrum analyser. Different types of FFT signals have been measured under stall conditions for the frequency range of 9000 Hz to 9600 Hz with respect to rotor speed and different graphs are plotted for ducted axial fan.

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

INTRODUCTION

Mining fans and cooling tower fans normally employ axial blades and or required to work under adverse environmental conditions. They have to operate in a narrow band of speed and throttle positions in order to give best performance in terms of pressure rise, high efficiency and also stable condition. Since the range in which the fan has to operate 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 as shown in Figure 1.

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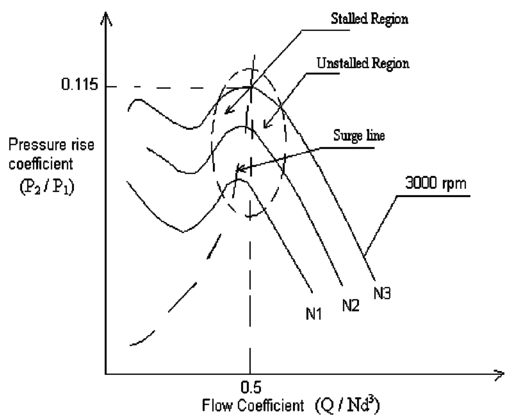
Figure 1: Graphical Representation of Axial Fan Performance Curve



TEST FACILITY AND INSTRUMENTATION

Experimental setup, fabricated to create stall conditions and to introduce unstall conditions in an industrial ducted axial fan is shown in Figures 2 to 5.

A 2 HP Variable frequency 3-phase induction electrical drive is coupled to the electrical motor to derive variable speed ranges. Schematic representation of ducted fan setup is shown in Figure 6.

Figure 2: Ducted Axial Fan Rig

Figure 3: Side View of Ducted Axial Fan Rig

Figure 4: Variable Frequency Drive for Speed Control

Figure 5: Automatic Throttle Controller

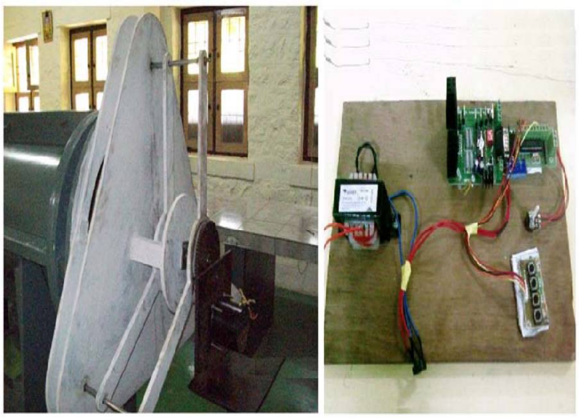
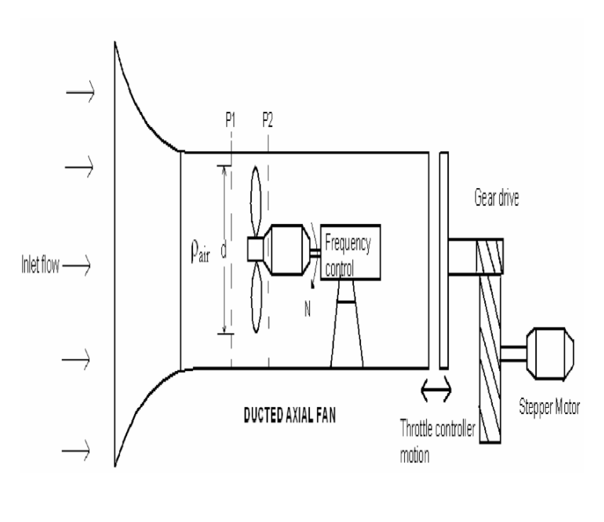


Figure 6: Ducted Axial Fan - Schematic



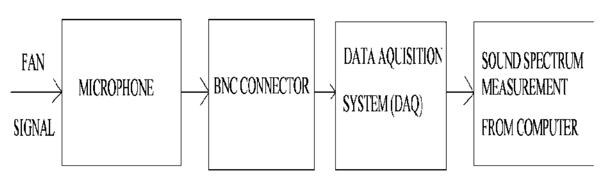
The flow enters the test duct through a bell mouth entry of cubic profile. The bell mouth performs two functions: it provides a smooth undisturbed flow into the duct and also serves the purpose of metering the flow rate.

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 down stream of the fan. A flow throttle is placed at the exit, having sufficient movement to present an exit area greater then that of the duct.

BASIC SOUND SPECTRUM ANALYSER SYSTEM

Basic sound Spectrum analyzer schematic diagram consists of various components as shown in Figure 7. Microphone acquires the sound pressure fluctuation 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.

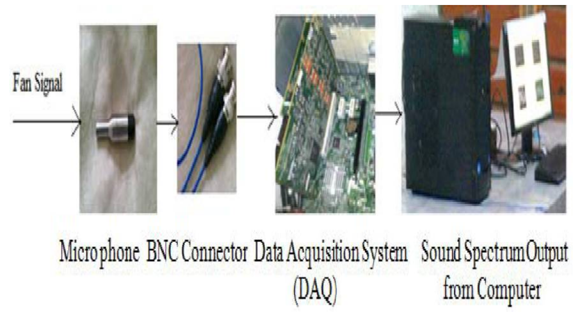
Figure 7: Schematic Diagram of Sound Spectrum Measurement



SOUND SPECTRUM ANALYSER

Experimental setup of Spectrum analyser consists of various components is shown in Figure 8. Microphone acquires the sound signals, frequency range from 0 Hertz to 10000 Hz and measure the decibel range from 0 to 130 decibel. Microphone sensitivity is the ratio of its electrical output to the sound pressure at the diaphragm of the microphone. Since a microphone output is usually measured in mill volts (mv) and sound pressure is measured in Pascals. The unit of sensitivity of microphone is mv/Pa. microphone connects to BNC connector. BNC connector transmits the signal to DAQ system. DAQ card consists 2 channel input port to acquire the signal and send the signal to system achieve through LABVIEW software inbuilt with National Instruments noise and vibration acquisition system and 2 channel output port to receive the signal from the system and to make a active feedback control system in ducted axial fan.

Figure 8: Experimental Rig for Sound Spectrum Analyser



SOUND SPECTRUM MEASUREMENTS

Experiments were carried out to examine the nature of sound pressure variations in a ducted axial fan under stall condition for the frequency range from 9600 Hz to 9600 Hz at throttle position of 3 cm and rotor speed varying from 2400 rpm to 3600 rpm by using spectrum analyser. The variation in sound pressure amplitude level as a function of rotor speed at throttle position 3 cm from the casing is shown in Figure 9. In an axial fan setup, eight number of axial fan blades have been transferred the energy to the fluid. In one rotation of axial fan rotor, aerofoil cross section of axial fan blades transfers the energy to the fluid achieving through by lift force. Lift force of Newton across the fan blade area develop the pressure rise to the fluid as per the operating condition and design condition of axial fan. In a single rotation of blade of ducted axial fan, eight times sound pressure amplitude value will raise and down periodically. For a same rotation, increase the sound pressure amplitude through energy transfer of blade to fluid. Two blades between the gap fluids enter freely, for that no energy transfer between fluids to blade. So, decrease the sound pressure amplitude in between the gap of blades. Every rotation, rotor speed varies from 2400 to 3600 rpm and throttle position of 3 cm from the casing, with respect to blade passing frequency sound pressure amplitude will rise suddenly up and abruptly falls down in ducted axial fan periodically. A variation in sound pressure amplitude of air at throttling positions of 3 cm when the rotor rotates at 2400 rpm is shown in fig.9. Maximum sound pressure amplitude is found to be 60 decibels at stall condition and the Minimum sound pressure amplitude is found to be 43 decibels at stall conditions which is attributable to combinatorial effects of blockage in mass flow, rotating stall, periodic vibration due to air flow and excitation of fan blade.

A variation in sound pressure amplitude of air at throttling positions of 3 cm when the rotor rotates at 2700 rpm is shown in Figure 10. Maximum sound pressure amplitude is found to be 62 decibels at stall condition and the Minimum sound pressure amplitude is found to be 52 decibels at stall conditions.

A variation in sound pressure amplitude of air at throttling positions of 3 cm when the rotor rotates at 3000 rpm is shown in Figure 11. Maximum sound pressure amplitude is found to be 64 decibels at stall condition and the Minimum sound pressure amplitude is found to be 36 decibels at stall conditions.

Figure 9: Rotor Speed 2400 Rpm, Throttle Position 3 cm

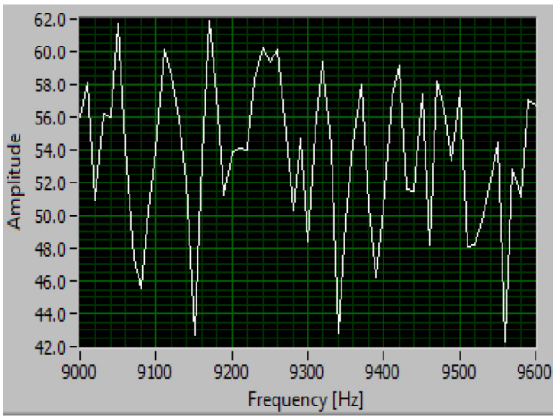


Figure 10: Rotor Speed 2700 Rpm, Throttle Position 3 cm

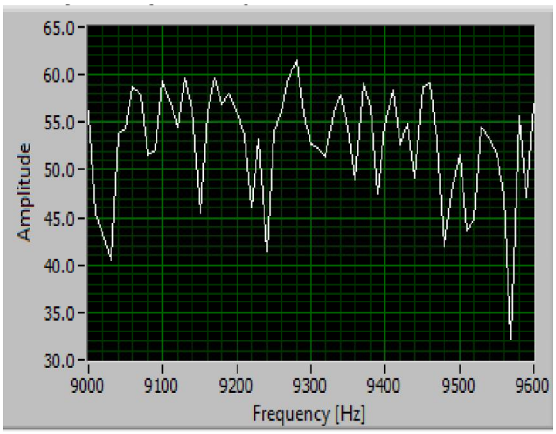
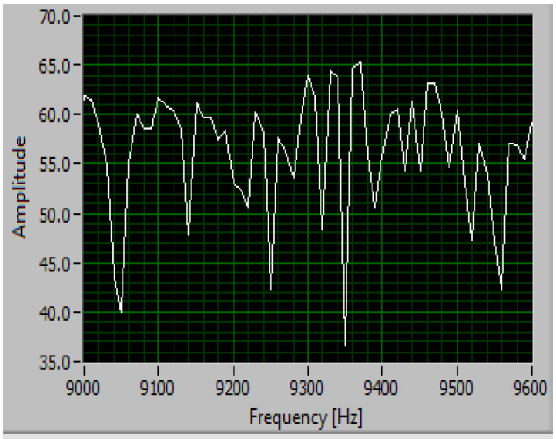


Figure 11: Rotor Speed 3000 Rpm, Throttle Position 3 cm



A variation in sound pressure amplitude of air at throttling positions of 3 cm when the rotor rotates at 3300 rpm is shown in Figure 12. Maximum sound pressure amplitude is found to be 72 decibels at stall conditions and the Minimum sound pressure amplitude is found to be 44 decibels at stalled conditions. A variation in sound pressure amplitude of air at throttling positions of 3 cm when the rotor rotates at 3600 rpm is shown in Figure 13. Maximum sound pressure amplitude is found to be 70 decibels at stall condition and the

Figure 12: Rotor Speed 3300 Rpm, Throttle Position 3 cm

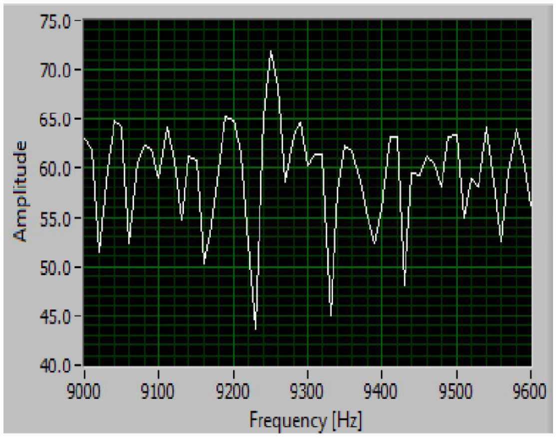
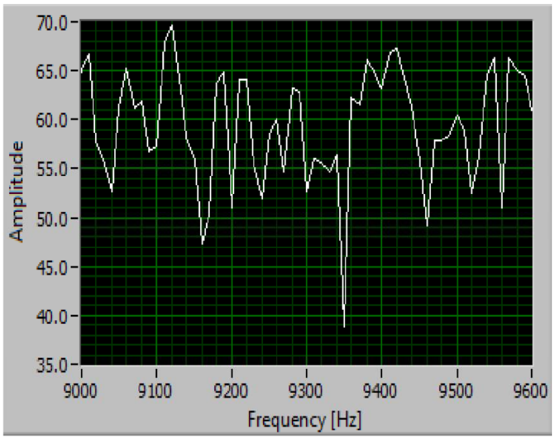


Figure 13: Rotor Speed 3600 Rpm, Throttle Position 3 cm



Minimum sound pressure amplitude is found to be 48 decibels at stall conditions.

CONCLUSION

In this paper, an attempt has been made to measure the sound spectrum in frequency domain for the frequency range from 9000 Hz to 9600 Hz under stall condition with respect to rotor speeds in ducted axial fan by using spectrum analyzer. It is useful to examine the characteristics of stall in ducted axial fan. Further, this work can be extended by working on the mathematical model of sound spectrum study in ducted axial fan. The results so far discussed, indicate that sound spectrum measurements of ducted axial fan is very promising.

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NOMENCLATURE

ν_w = Whirl velocity in m/s

ψ = Pressure ratio

N = Tip speed of the blades in rpm

Δp = Pressure rise across the fan in N/m^2

d = Diameter of the blade in m

ρ_{air} = Density of air in kg/m^3

Lp = Sound Pressure Level in db

BPF = Blade passing frequency in Hz

L_N = Normalized Sound Level in db

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