Research Paper Engineering

Experimental Determination of Noise Level Characteristics and Noise Reduction for Industrial Fan Using CFD Software

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ABSTRACT

IndustrialFans are one of the main noise sources in industries. Tonal noise produced at a multiple of the rotational frequency of the fan, so-called Blade Passing Frequency (BPF) and its higher harmonics generally dominate fan noise. Noise reduction is perhaps one of the most important parameter in industries. Every noise reduction process starts with identification of noise sources and ranking of sound sources from the machinery. After the initial identification of typical noise sources, the noise levels are to be eliminated or reduced either by modifying noise producing equipment or redesigning. In the present work, industrial fan (Almonds E 300S) fan model is used. PRO – E software is used to model the fan system and Computational Fluid Dynamic (CFD) technique are implemented for the analysis. The numerical results obtained through CFD are corroborated with experimental results and they are found to be in good agreement. The fan is optimised by changing the geometrical parameter to reduce the noise levels. The noise levels are computed and compare with the experimental fan model results. The optimising fan results indicate that the noise level reduce up to 5-10%.

KEYWORDS Industrial fan, Free field condition, CFD.

1. Introduction

In modern world, the environment has been suffering from problems of noise. Noise is significant part of pollution problem in industries of textile, paper making, sugar, wine manufacturing which is pollutes working environment of companies. There is danger of permanent hearing loss when a person is exposed to noise above threshold level. Most industries are motivated to address the problem effectively. The noise treatment and its control must not interface in the operation of the appliances or machines.

Fan is a device that creates a pressure difference by exchanging momentum from the blades to the surrounding gaseous fluid.Fan noise consists of tonal noise, broadBand aerodynamic noise, mechanical noise and motor noise. The fan noise has been focused for inlet turbulence and flow distortions in the observed sound pressure level. The measured level of blade passing frequency determines the overall fan noise level. This level can vary by several decibels depending on the parameter in the operation.

Thispaper work involves the characteristics of noise level in industrial fan and to study the key parameter which enhances the vibration. The parameter is fixed and to be optimised to have minimum vibration and sound pressure level. The simulation method is used and validated with experimental results. The results are tabulated and presented in graphical form for parametric aspects of industrial fan.

2. Problem Approach

Modeling of Industrial Flow Fan was done in PTC Creo v2.0(-figure 1).The .stp file for whole assembly is created and then the meshing is carried into ANSYS software. (Figure2).The mesh is exported to the fluent solver and the problem is defined by choosing the appropriate flow model and prescribing the boundary conditions. Fluent uses a control volume based technique to convert the governing equations.In acoustic Fluid Structural Interaction (FSI) problems, the structural dynamics equation must be considered along with the Navier-Stokes equations of fluid momentum and the flow continuity equation.A complete Computational Fluid Dynamic (CFD) analysis has been made and the details of the parameters used for analysis are provided .The noise level from the fan at different receiver locations is found out and are plotted. The model used for noise level due to the flow of air Ffowcs- Williams&-Hawkings and it considers the mean velocities obtained from the CFD analysis to predict the high noise level from the fan. In this analysis the intention is to see the flow of the fluid and the noise radiated from the fan itself.A commercial CFD software, Fluent, is used to develop the CFD model. Three- dimensional flow simulations are performed at single fan speeds for a specific fan model. The noise levels are calculated and compared with experimental measurements and fan law predictions to validate the CFD model.

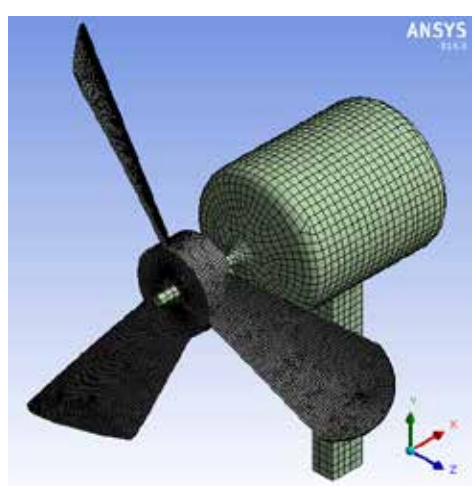


Fig 1.0 Meshed Fan Model.

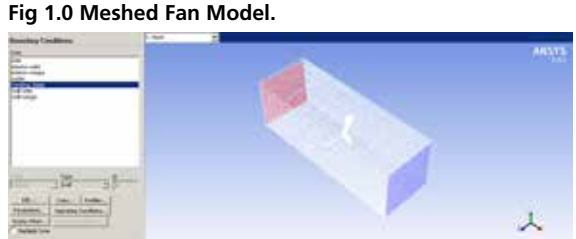


Fig 2Boundary Condition applied to Fan geometry fixed

Structural loads and boundary conditions can be applied as usual using standards objects. The fixed support set all degrees of freedom to zero (fixed support) as applied on nodes connected to acoustic elements and pressure degree of freedom will also be set to zero.

3. Experimental Setup

The experimental works were carried out to find frequency spectrum characteristics of fan system and analyser the effect of each component were found. Free field techniques are required for estimating the sound power of any system producing sounds which contain prominent discrete frequency components or narrow band spectra. Normally a large anechoic chamber would be used to measure noise characteristics. But it is tedious to have such a system and hence the experiment is carried out in a free –field condition.

Fig. 3.0 shows experimental set-up for baseline fan to measure noise in free field condition. The walls, and ceiling and the working space in the centre of the room is6x6x4 mThe result so obtained from numerical analysis is compared with the experimental results obtained by conducting experiment in free field condition. It is found that there is good agreement between numerical and experimental results which are presented in later sections. It is observed the variation between numerical analysis results and experimental results is 5 to7dB. The error between numerical and experimental observed may be due to interference between the vibrations due to unbalanced rotating masses etc. FollowingTable shows the comparison of the measured and CFD overall SPL values for baseline fan.

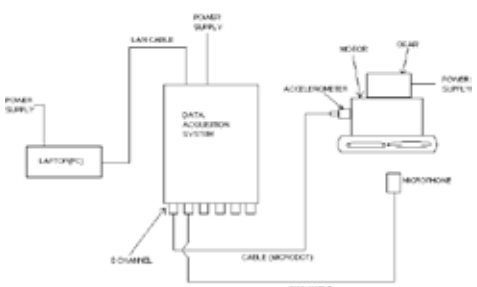


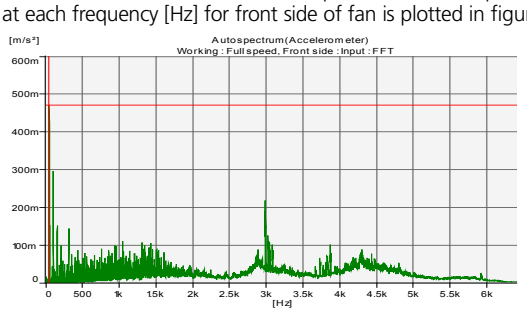
Figure 3 Experimental set up

4. Results and Discussion

In order to validate the procedure developed is implemented to estimate the noise generated by the fan due to fluid flow along the blade passages. The first step is to analyse the fluid flow through the fan. A number of test cases have been run in fluent a commercially available CFD code for the fluid dynamics.Pressure and velocity change are studied to indicate the maximum noise level area. SPL value at each frequency from five sides is found and given in tabular format.

Experimental results are presented for the measurement point located at 1 m of the fan inlet, with the microphone aligned to the impeller shaft for baseline fan.The Constant Percentage Bandwidth (CPB) is used for sound pressure level (SPL) measurement and the latter is plotted with frequency.

The Accelerometer [m/s^2] and microphone [dB (A)/20 µPa] value at each frequency [Hz] for front side of fan is plotted in figure 4.



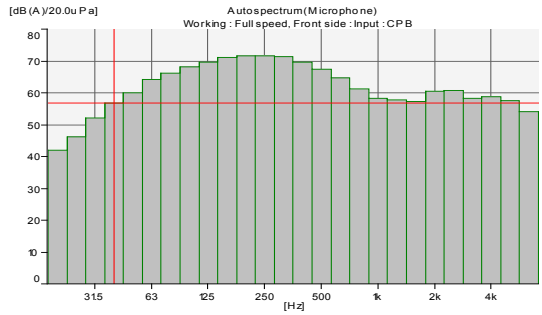


Figure 4 Front side of Industrial fan

As shown in figure 4, the frequency of blade is 123 Hz and hence harmonic frequency is 246 Hz. The sound pressure level is maximum for both blade frequency and harmonic frequency having magnitude of 70 dB.

For the front side, direct flow and air flow noise indicate that the air strikes directly to blade. The SPL value is combination of structural and air born noise. It does not give exact SPL value for the specific component.The flow noise is a contributor to energy frequency band.

For other side, structural vibration yielded noise with pattern of 1/3 band. The blade noise is emitted at 125 Hz & 246 Hz.

The noise due to blade thicknessis generated by volume displacement of fluid. As the motor rotates, the volume of each blade displaces fluid and consequently fluctuation in pressure and there by noise is generated. This noise is tonal at the running frequency and generally weak for fans due to their low speed. Therefore, thickness of fan blades little effect on fan noise.

The overall Sound Pressure Level (SPL) for existing fan is 69.51 dB. This value is higher because of straight blade design which produces more turbulence.

Pressure and velocity change are studied and plotted to study the maximum noise level area. SPL value at each frequency from five sides is found and given in table 1.

From experimental results in table 2 it is observed that the effect of motor on total SPL is not significant and the dominant noise source is motor-fan which is dipolar noise source which is generated due to aerodynamic pressure fluctuation.

These results indicate that the blade of fan is the main contributor to the acoustic characteristics of the flow field.

Table 1Computational results of fan

Receiver position	Frequency (Hz)	Overall SPL (dB)
Front	125	66.02
Back	125	26.28

Table 2 Experimental result for fan

Receiver position	Frequency (Hz)	Overall SPL (dB)
Front	125	69.51
Back	125	39.41

Parametric studies are carried out to find the optimum rake angle for the noise level of fan in the range of 25^0-45^{0}with constant air flow rate. After optimizing the rake angle up to 33.6^o, the noise level is reduce by 15 dB.The result is given in following

Table 3 Computational results of optimized fan

Receiver position	Frequency (Hz)	Overall SPL (dB)
Front	125	64.82
Back	125	25.12

The comparison of experimental and simulation results are shown in table 4

Table 4 comparison of experimental and simulation results

Frequency (Hz)	Experimental value of SPL(dB)	Simulation value of SPL(dB)
20	41.77	55.0093
40	56.62	60.4294
60	64.05	63.00
80	66.09	64.2581
100	68.06	64.7643
120	69.51	62.4267
140	70.23	64.6193
160	71.02	64.2686
180	71.32	63.8401
200	71.52	63.3757
220	71.63	62.8999
240	71.39	62.4267

From the table 4 it is observed that experimental and CFD values are in closer approximation at frequency 120 Hz.

5. Conclusions

The noise level characteristics of fan and effects of each component on functionality are obtained by experimental methods. CFD analysis is performed to find out the maximum noise level and the key parameters. The optimization is done with blade rake angle as key parameter to reduce the noise level and then emphasised.

Optimization of fan is made by varying the rake angle from 25^0 to $45^0$by keeping the air flow rate constant. Initially rake angle was 27.8 ° having noise level 69.51 dB and later on it is optimized to 33.6 ° with the noise level reduction to 54.23 dB.

Similar values are obtained for frequency and sound level for simulated and experimental results.

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