

INVESTIGATION OF FAN FAULT PROBLEMS USING VIBRATION AND NOISE ANALYSIS

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Abstract - Cooling fans are used to solve the thermal problems of most critical electronic parts in systems. Therefore, it is very important to monitor the fans condition periodically dealing with the detection, location and analysis of the possible faults. The fault diagnosis of rotating systems is increasingly paying attention. The main purpose of this study is to investigate the possible faults in a rotating system using vibration and noise measurements. A simple cooling fan is used for implementing the experimental measurement. Some artificial faults are performed for measuring the system responses. The empirical results show that Acoustic Emission (AE) technique is very useful to detect the faults at the system.

1. INTRODUCTION

In the today's industry and industrial facility management [1], meeting the consumer needs, continuity of production and safety of the processes have a great importance. Continuous Fault Condition Monitoring (FCM) can avoid downtime and also reduce the total cost of products. In spite of their initial capital investment cost, monitoring the health of these structures has a great importance and FCM needs in the industry is increasing day by day. Providing an early detection of structural, mechanical or electrical problems allow operators to see where faults occurred and suggest when the system will break down approximately. Any abnormalities or faults in the machinery or equipment must be detected and analyzed at the early stage to avoid major problems. Therefore, FCM of rotating machinery has a crucial role in industry as it keeps the system at healthy condition for maximum productivity, while detecting and diagnosing the faults at early stage. As a result, it is possible to prevent the serious problems, damage and more cost.

Tian et al. [2] introduced an approximate theory to describe fan conditions. For the case of different working conditions, vibration signals of the fan were analyzed by utilizing the approximate theory. The obtained results showed that the approximate theory was able to identify the conditions of the fan with faults compared with the normal condition. Miao et al. [3] proposed a vibration based fan bearing fault detection through the wavelet transform and the Hilbert transform in computer cooling fan systems.

An experiment study was implemented to identify the different bearing faults. Elmaleeh et al. [4] applied several condition monitoring techniques to improve the plant reliability and reduce the downtime. Effectiveness of AE technique was investigated for incipient detection of faults at rotating machineries. The exact faults in the machine were tried to identify using time and frequency analysis of the signals. Velarde-Suarez et al. [5] employed an experimental study about the aerodynamic tonal noise sources in a centrifugal fan with backward-curved blades.

Acoustic and pressure fluctuation measurements were implemented for different flow rates. For explaining the some features of the aerodynamic tonal noise generation, both pressure and vibration signals were

analyzed and correlation analysis between methods was discussed. Another study of the same research group [6] investigated the influence of some geometric features of the aeroacoustic behavior of a squirrel-cage fan, used in automotive air conditioning units. They focused on the effect of both shape and the position of the volute tongue on the noise generated by the fan. Acoustic behavior of the fan was characterized by acoustic pressure measurements near the fan inlet.

Frequency analysis results were used to describe the characteristics of the fan. Wu et al. [7] presented a formula for predicting the noise spectra of axial flow fans. Acoustic pressure and line spectrum were obtained by taking a Fourier series expansion and also, a normal distribution like shape function was designed which divided the frequency into consecutive bands at BPF and its harmonics. Lin et al. [8] performed an experimental study for monitoring the possible faults using AE technique based on Hilbert-Huang transform. Time-frequency analysis was used for extracting the features of the wind turbine bearings. AE in the wind turbine bearing was described in terms of features such as frequency and energy. Tian [9] employed a study based on the major failure mechanisms and failure modes of cooling fan system. An accelerated life testing methodology was presented. Reliability analysis and failure criteria of components were analyzed and life testing was accelerated by using high temperature testing, condition monitoring, noise control, failure mode analysis and Weibull distribution. Yin et al. [10] proposed a fan system condition monitoring based on virtual prototyping technology. Three dimensional model of the fan system was built and imported to the ADAMS to simulate the system under different working conditions.

Measured and virtual signal data were obtained and compared to identify the real fan condition. Three accelerometers were used to obtain real vibration signal data. For pattern recognition, cross correlation function was selected to find the most similar simulation condition. Tandon ve Choudhury [11] tried to describe the source of vibration and noise generation on bearings. Using the signal processing techniques in time and frequency domain, the high frequency resonance technique was applied. On the other hand, sound pressure, sound density and sound radiation techniques were used for acoustic measurements. Waveform transforming and automatic data processing techniques were used to detect bearings faults. Loutas et al. [12] implemented some practices using acoustic emission techniques for detecting faults on rotary machine elements such as gearboxes. AE signals of the healthy gearbox were identified and related data were obtained by creating artificial failures. Toutountzakis et al. [13] applied AE techniques to detect the possible faults at rotating machinery elements such as gearboxes and practiced to determine fault characteristics of seeded gearboxes. As a result, it was observed that AE technique had some application difficulties in which some seeded artificial fault locations.

Cooling fans are one of the most critical parts in computer system and in most of electronic products. Since a fan assembly includes both electronic and mechanical parts, it can fail electronically, mechanically, or both. The electronic parts include control circuitry, motor and its mechanical and electronic components [14]. The mechanical parts of a fan consist of bearing, lubricant, shaft, fan blades or propeller and fan housing. A fan can have either “hard failures” in which the fan is non-functional or “soft failures” (parametric failures) such as slower RPM, increased input current, or higher noise level [9]. To have a good experience of fan reliability, all possible failure mechanisms and failure modes of the components should be considered. Cooling fans have a great importance in many electronic systems.

Researches performed up to now, have been usually focused on these techniques such as classical vibration monitoring technique, thermal analysis, corrosion and performance analysis technique, analyzing oil particle properties. In addition to that, in recent years, AE technique has become the focus of attention by the

researchers. AE is defined as the elastic waves which results of rapid release of the energy in many localized sources of materials under stressed conditions.

At the researches, they pointed to many advantages of AE technique such as, earlier fault detection, detecting micro cracks and wear. This technique is based on monitoring the systems at their working conditions for detecting the possible faults in mechanical systems before them break down and providing maintenance against these faults.

Main goal of this research is to show the effectiveness of AE technique compared to vibration signal analysis and especially is to show that how AE fault characteristics of different fan faults, such as broken fan blades, deformed blade shape, bearing faults, cracked part at the root of the fan blades. It is aimed to determine the possible faults that may occur in the system by the acoustic properties obtained from the system. Furthermore, acoustic and vibration characteristics are analyzed together and these characteristics, which are obtained from the system simultaneously, are compared to each other. For this purpose, this paper is organized as follows; Section 2 describes the experimental analysis. Results and conclusion are given in sections 3 and 4, respectively.

2. EXPERIMENTAL TEST RIG

In this study, a simple cooling fan in a computer power supply is used for implementing the experimental measurement. The used fan has got seven blades. Artificial fan faults such as broken fan blades, deformed blade shape, bearing faults, lubrication problems, cracked part at the root of the fan blades are considered as outlined in Fig. 1. Both vibration and acoustic measurements are performed to evaluate the system responses.

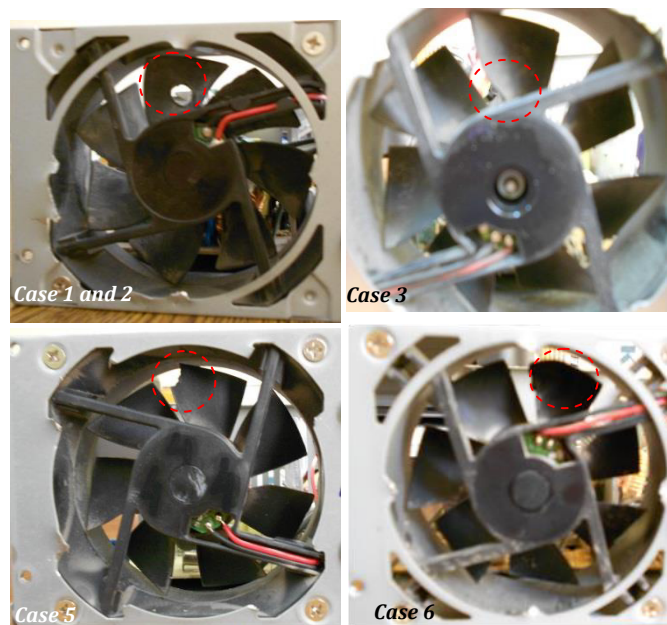


Fig. 1: Artificial fan faults

Classification of the artificial faults is outlined in Table 1.

Table 1. Artificial fault classifications

Case identification	Fault Description
Case 1	Hole with 4 mm
Case 2	Hole with 7 mm
Case 3	Blade fault (near the bearing)
Case 4	Bearing fault (Lubrication problem)
Case 5	Blade fault
Case 6	Blade shape deformation

In the measuring stage, a tool for measuring the vibration and acoustic signals, “Bruel-Kjaer (B&K) portable and multi-channel pulse 3560-B-X05” was used to obtain and analyze results. Vibration and acoustic signals were measured simultaneously. Available analysis program is able to measure the time and frequency domain analysis of the obtained signals from the computer cooling fan.

In order to measure the acoustic signals, it was used an acoustic sensor with a preamplifier (4189-A-021 - ½inch free-field microphone with Type 2671 preamplifier) and used an accelerometer (B&K 4514B) for measuring vibration data. Properties of used sensors are outlined in Table 2.

Table 2. Specifications of vibration and acoustic sensors [15]

Properties of acoustic sensor		Properties of vibration sensor	
Diameter	1/2 inch	Frequency	1 -12000 Hz
Dyn. Range	16.5 - 134 dB	Sensitivity	10 mV/g
Freq. Range	20 - 20000 Hz	Temperature	-51 - 121 °C
Inherent Noise	16.5 dB A	Residual Noise Level in Spec Freq Range (rms)	± 0.8 mg
Lower Limiting Frequency	20 Hz	Maximum Operational Level (peak)	500 g
Pressure Coefficient	-0.01 dB/kPa	Maximum Shock Level (± peak)	3000 g
Sensitivity	50 mV/Pa	Weight	8.7 gram
Standards	IEC 61094-4 WS2F	Electrical Connector	10-32 UNF
Temperature Coefficient	-0.006 dB/°C	Mounting	Magnet
Temperature Range	-30 - 100 °C	Clip/Stud/Screw included	10-32 Stud
Input Type	CCLD IEPE	Resonance Frequency	32 kHz

Block diagram for vibration and acoustic measurements are outlined in Fig. 2.

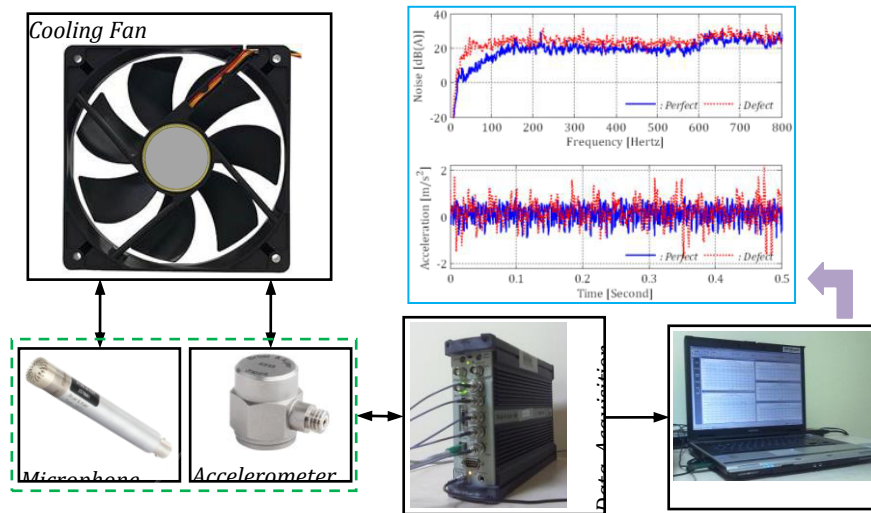


Fig.2: Block diagram of experimental measurement

3. RESULTS

The effects of vibration and acoustic measurement on the fault diagnoses are considered together. A simple cooling fan in a power supply is considered for experimental investigations. Different types of faults are implemented artificially. Acoustic and vibration measurements are performed simultaneously. Other noise sources arising from environment, notebook fans etc. are isolated from the experimental system. Same measurement conditions were adjusted for healthy and defective fans.

The results of noise and vibration measurements for Case 1 are outlined in Fig. 3.

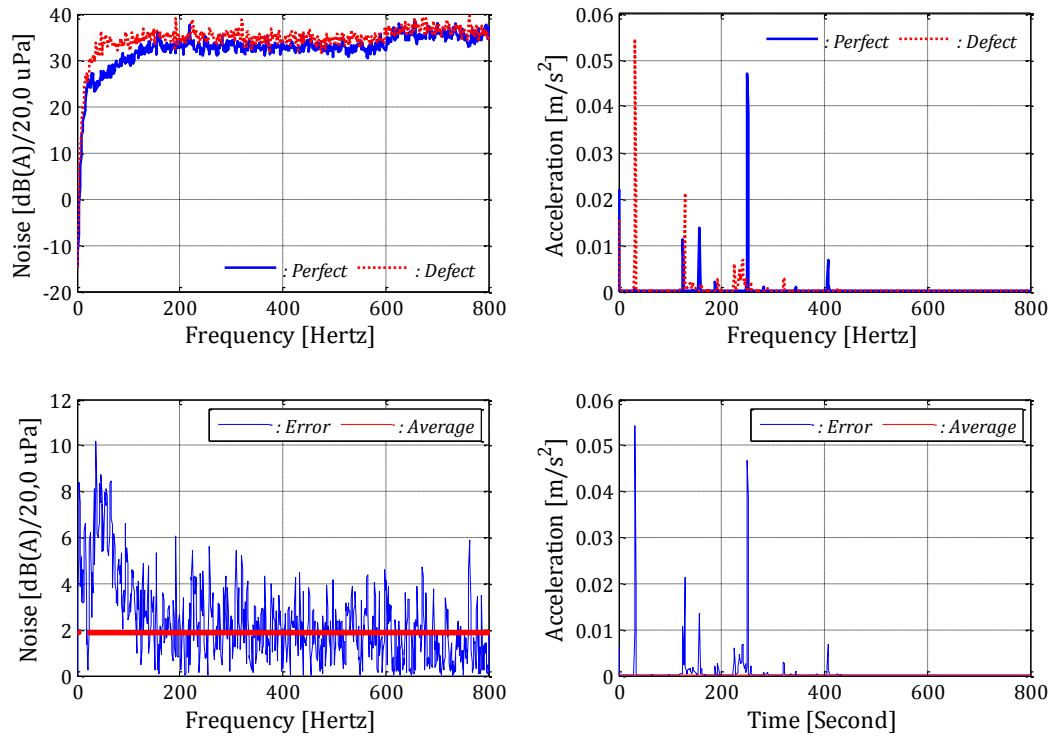


Fig. 3: Noise and vibration measurements for Case 1

In Case 1, an artificial hole with 4 mm diameter was implemented. Naturally, this fault affects the balancing of the fan. Acoustic and vibration measurements give the differences between healthy and defective fans. When the hole diameter is increased from 4 mm to 7 mm, the obtained result are outlined in Fig. 4,

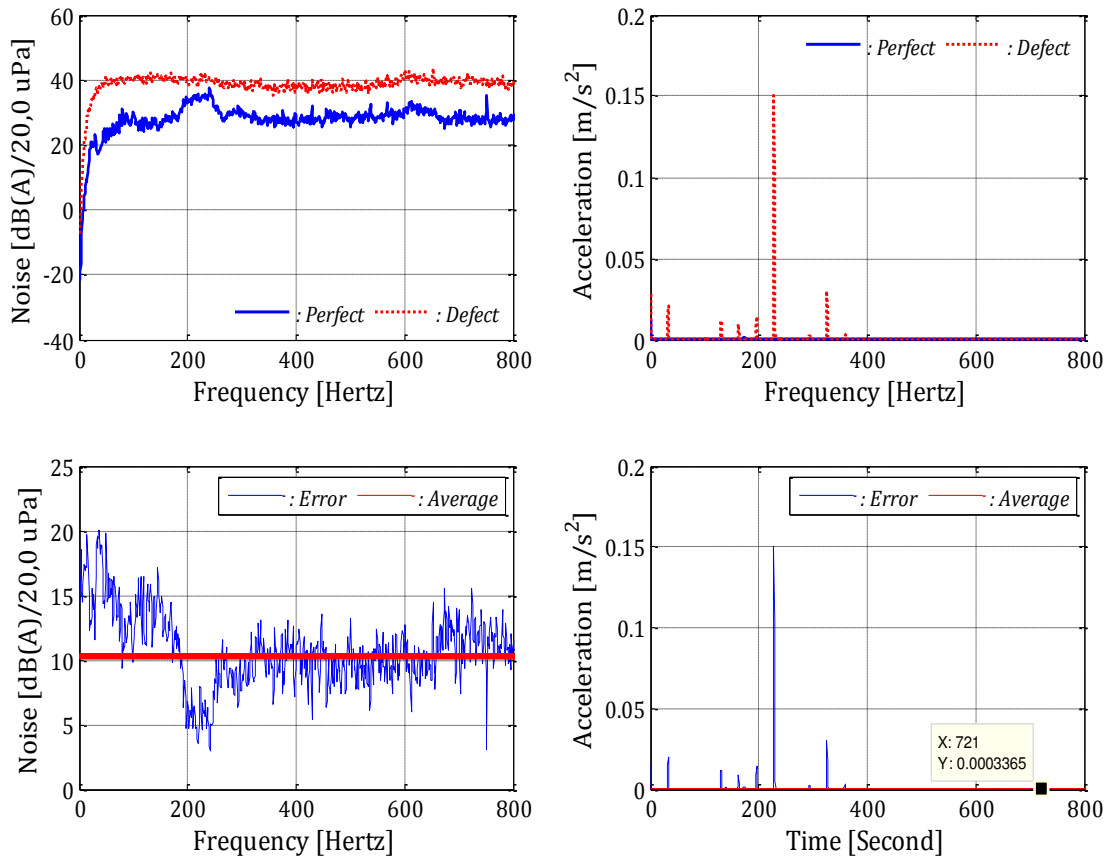


Fig. 4: Noise and vibration measurements for Case 2

It is clear from Fig. 4 that the increasing of hole diameter makes the vibration and noise characteristics worse. Both vibration amplitude and noise level increase. The results of noise and vibration measurements for Case 3 are outlined in Fig. 5,

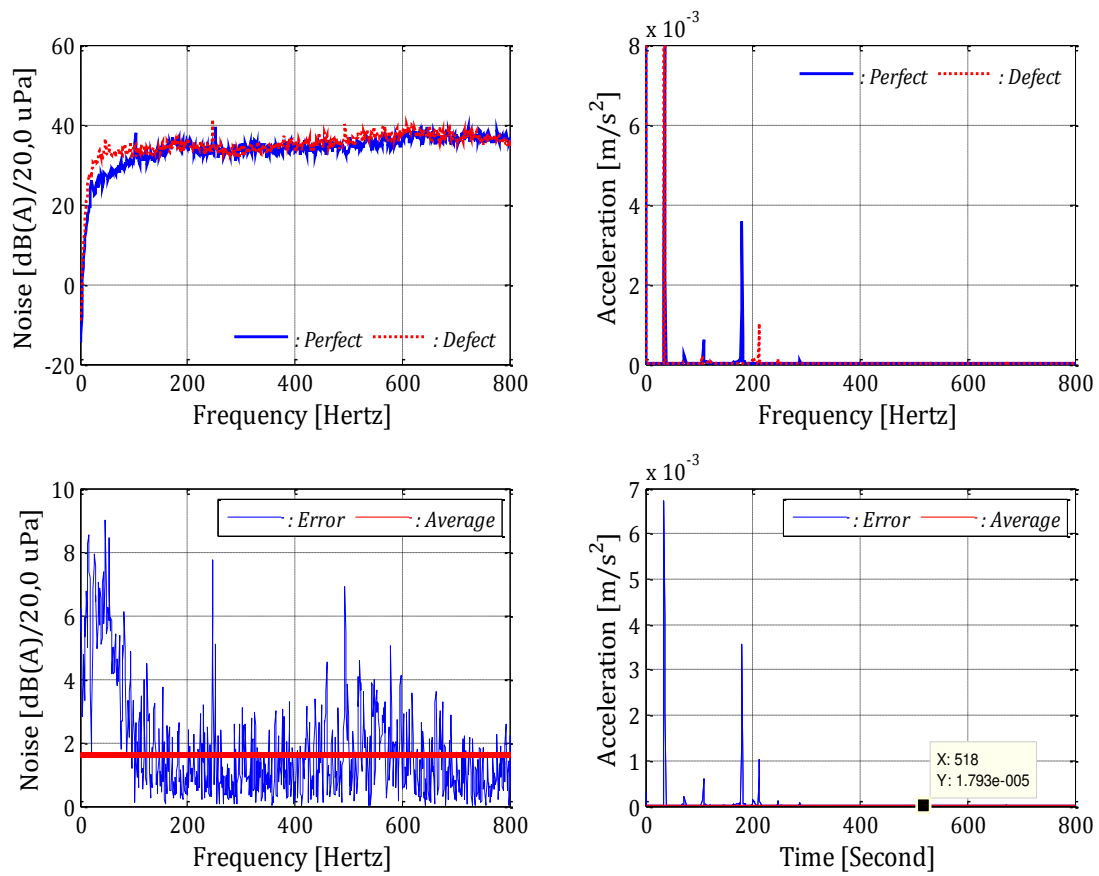


Fig. 5: Noise and vibration measurements for Case 3

As seen from Fig. 5, it is clear that, there is a certain difference between perfect and defect fans. Particularly, noise characteristic has a clear difference. So, it is said that noise measurement can be used effectively to detect this fault type in mechanical systems. For the Case 4, the results of noise and vibration measurements are given in Fig. 6.

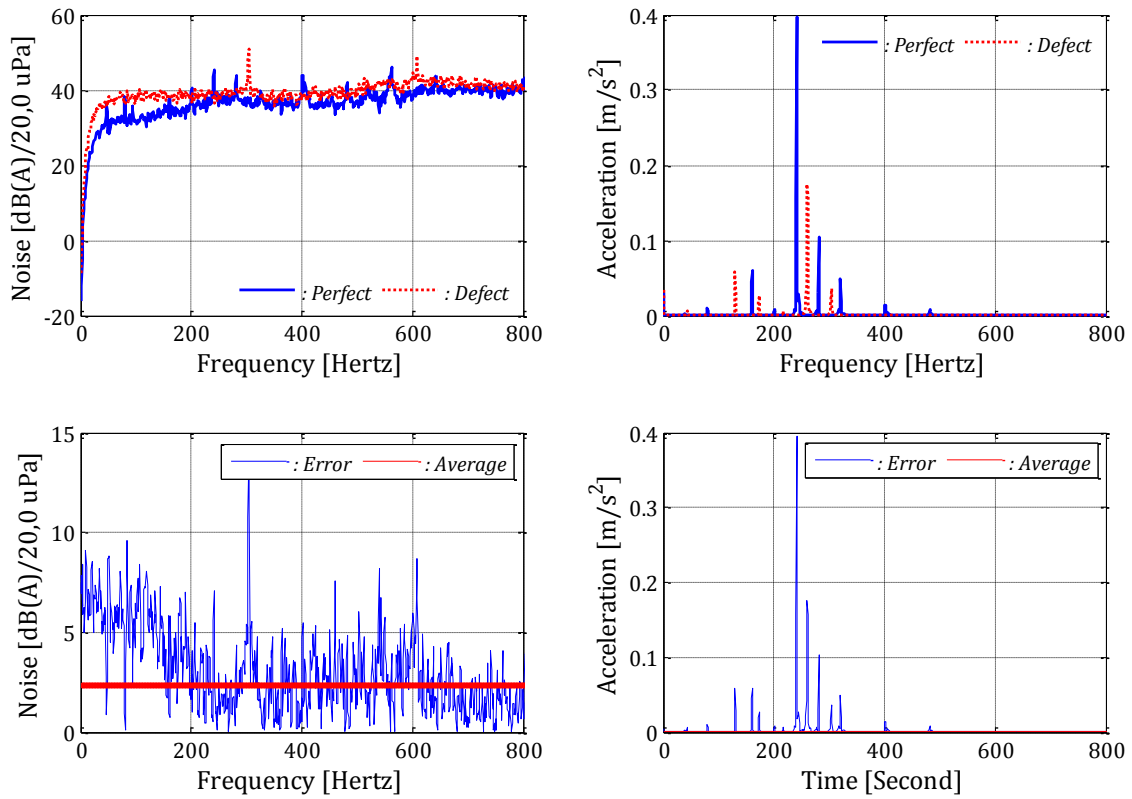
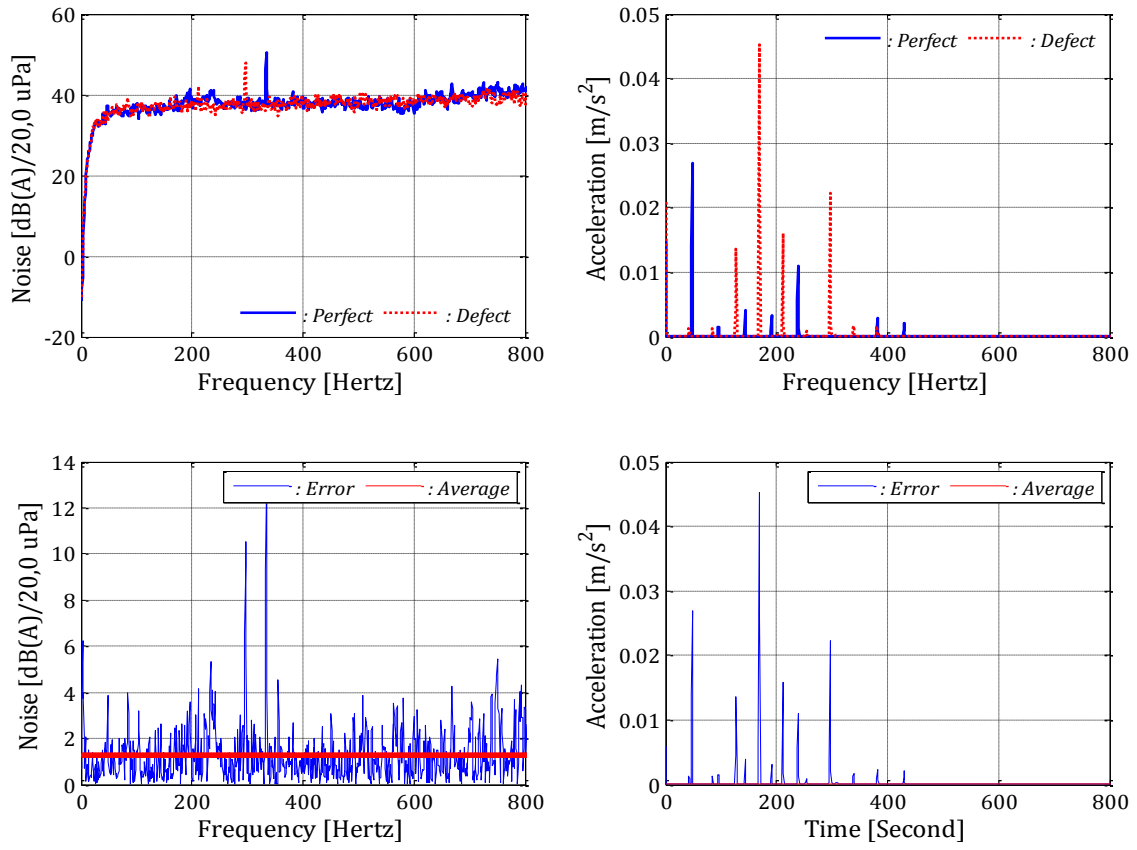


Fig. 6: Noise and vibration measurements for Case 4

In this Case, bearing has a lubrication problem. By evaluating the vibration measurement in Fig. 6, the acceleration values are nearly same for perfect and defect fans. On the contrary, there is a certain difference for noises of perfect and defect fans. So, it is very effective to use the noise measurement to detect this fault type in mechanical systems.

The results of noise and vibration measurements for Case 5 and Case 6 are outlined in Figs. 7 and 8, respectively.



1. Fig. 7: Noise and vibration measurements for Case 5

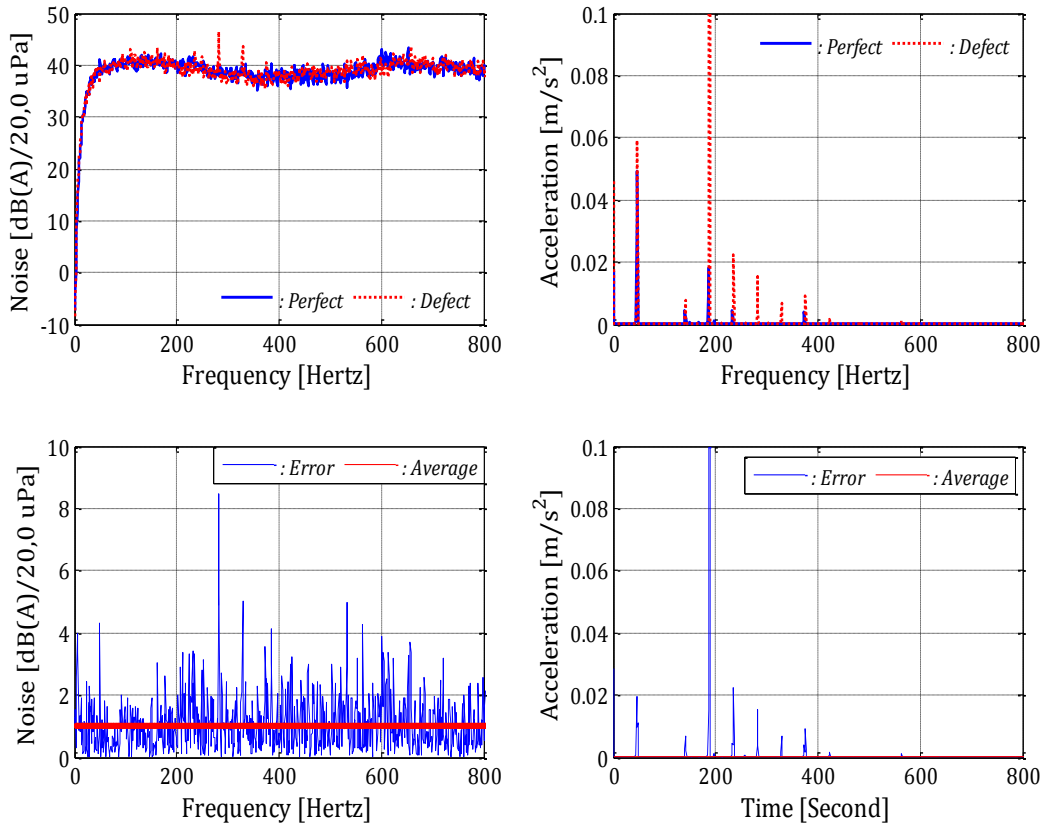


Fig. 8: Noise and vibration measurements for Case 6

As seen from Figs. 7 and 8, there is a clear difference for vibration results of perfect and defect fans. On the contrary, for each case, the noise results are nearly same. So, vibration measurement is very effective to detect these faults types. Numerical values for different cases are outlined in Table 3.

Table 3. Numerical evaluations for different case studies

	Crest Factor		Kurtosis		Average error		Max. error		Max. error freq.	
	Noise	Vibr.	Noise	Vibr.	Noise	Vibr.	Noise	Vibr.	Noise	Vibr.
Case 1	16,95	21,72	10,01	312,42	1,92	0,00026	10,02	0,0542	37	32
Case 2	14,08	21,87	10,07	357,69	10,4	0,00034	20,1	0,1505	37	228
Case 3	17,20	11,38	13,78	274,52	1,64	0,000018	8,98	0,0067	47	35
Case 4	27,17	42,73	396,0	266,0	2,43	0,00133	14,34	0,3963	304	241
Case 5	38,09	18,55	437,7	188,7	1,34	0,00018	13,52	0,0453	334	169
Case 6	23,38	25,55	117,08	548,9	1,05	0,00042	8,473	0,30	282	187

According to the Kurtosis formulation, if the Kurtosis value is bigger than 3, there is a fault in the system. In this study, each case has an artificial fault. As outlined in Table 3, all Kurtosis values for noise are bigger than 3. On the contrary, these values for vibration are not fully bigger than 3. So, noise measurement is more sensitive for detecting the faults than vibration in such mechanical systems.

4. CONCLUSION

In this study, noise and vibration measurement are implemented to investigate the fan fault problems. As outlined in different case studies, noise measurement in addition to vibration can be used for detecting the faults in system. Particularly, noise measurement is very effective to detect the possible faults in blade problem (near the bearing) and lubrication problem. Another advantage of noise measurement is a contactless measurement. Acoustic sensor can be located everywhere on the system. But, there are some constraints for vibration sensor. It has to be usually located on bearing.

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