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FAULT DIAGNOSIS OF FORCED DRAFT FAN BY ORDER ANALYSIS

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Abstract

Faults like unbalance, mechanical looseness, misalignment, bearing fault and bent shaft etc. causes vibration in rotating machinery. Detection of these faults in machines is required to avoid serious and significant economic losses. In this paper, mainly concentrated on the implementation of vibration based maintenance on forced draft fan in sugar factory. Order analysis technique is used for fault diagnosis of forced draft fan. In order analysis technique, both amplitude and phase are obtained. The results show that the faults in the forced draft fan, such as unbalance, looseness and bent shaft are effectively identified. It can detect faults effectively and precisely before the failure occurs.

Keywords: Faults diagnosis, FFT, Forced draft fan, Order analysis

1. INTRODUCTION

Forced draft (FD) fan is critical machine in power plants and sugar factory. FD Fan is mounted near the base of the boiler and to increase the efficiency of the boiler. In many industries, FD fan stoppage would lead to a complete closure of the plant. Therefore, precise diagnosis of FD fan faults becomes crucial in these cases. Vibration in FD fan due to unbalance, bearing fault, misalignment, looseness and bent shaft etc. These faults become very severe and result in unexpected shut down. Thus, vibration based condition monitoring is used for diagnosis of multi-fault in rotating machineries. Vibration analysis is important techniques for fault diagnosis in rotating machinery. It is the easiest way to continue machines healthy condtion and proficient in the long run and increase the overall efficiency of the plant. It reduces the down time period and overall operating cost. The early detection and diagnosis of various types of faults has become critical in the modern engineering systems for the help of condition monitoring. If these faults are not detected at the early stage, they may lead to failure of machines [1]. The faults in fan effect the safety of a thermal power plant and the reliability and economy of the system. The vibration signal is extracted and fan faults are categorized using a set of features [2]. The fast Fourier transform or discrete is used for extracted useful features from the vibration signal [3]. Jalan and Mohanty [4] used model based technique for identification of misalignment and unbalance faults. It is based on residual generation technique. This technique is used to detect fault condition and location are successfully. You et al.[5] used vibration and acoustic analysis technique for cooling fan fault diagnosis. Neupane and Seok [6] discussed the bearing fault and machinery faults diagnosis using deep learning algorithm. Panda et al.[7] applied vibration analysis technique is for fault diagnosis of induced draft fan of thermal power plant. The vibration level and spectrum are analysed to diagnose the defect in it. Kumar et al. [9] used a vibration analysis technique for diagnosis of excessive vibration of boiler feed pump. They have measured vibration parameter such as displacement, velocity and acceleration. The spectrum analysis is used to detect the causes of vibrations in boiler feed pump. Dhamande et al.[10] presented condition monitoring of induced draught (ID) fan using vibration analysis. The vibration parameters are analysed to identify the health condition of fans. They found that vibration measurement is an efficient technique for condition monitoring. Li et al.[11] used vibration analysis technique to detect imbalance problem in blower and dynamic balance test is performed. The vibration amplitude is reduced after balancing. Zhang [12] proposed dynamic neural network to detect early fault in power plant fans. They reported that the dynamic neural network model has high prediction accuracy on normal operations and produces large prediction errors when a failure occurs. Prasad et al. [13] proposed vibration analysis technique for the induced draft (ID) fan beaing failure diagnosis. Fault diagnosis using velocity measurement and trend monitoring method. The result revealed that high vibration severity is due to incorrect bearing clearances.

Most of researchers, FFT spectrum is used for fault diagnosis. FFT spectrum shows multifault as per the frequency component peaks, but some faults have same frequency components. So the present work presents the order analysis technique for fault diagnosis of forced draft fans which helps to confirm the fults in fan.

2. METHOD

2.1 Order Analysis: In order analysis both amplitude and phase are obtained. Evaluation of amplitude and phase is done by order analysis at a machine speed frequency (rotation). Order analysis is based on synchronized sampling of time signal with the machine speed. Order analysis requires an external trigger, which matches both the zero time sample in the time domain buffer and the sample clock such that the 1x frequency component is always the first order. Firmware corrections of the analyser are canceled out the tracking filter phase errors. First order (1x frequency) shows phase value. Hence, It should be highlighted that phase analysis is the relative movement of different parts of the machine at a given frequency, and is not restricted to a specific frequency. Order analysis is to hold the display to the machine rotating speed under test. This ensures that even if the machine operating speed (frequency) changes, the order components will still be shown on the display. Thus, when the speed changes 1x frequency component is not shift. A phase verses orders display provides phase relationships with respect to the trigger.

3. SPECIFICATION AND FEATURES OF FORCED DRAFT FAN

This work is mainly focused on implementation of vibration based condition monitoring on forced draft fan in sugar factory which is one of the boilers auxiliary. Fault diagnosis of forced draft fan using order analysis. Specification of induced draft fan is shown in Table 1. Photograph of forced draft fan as shown in Fig.2. Fig. 3 shows horizontal, vertical and axial measurement on DE bearing and NDE bearing of forced draft fan. Vertical measurement on DE and NDE bearing pedestal of forced draft fan is shown in Fig. 3. Standard vibration levels for class III machines (As per ISO 10816 -3) are mentioned in Table 2.

Table 1 Specification of forced draft fan

Speed	1480 rev/min
No. of blades	12
Driven	Induction Motor
Power	55 Hp

The three piezoelectric accelerometers are used to collect the vibration signals in vertical (V), horizontal (H) and axial (A) direction at bearing. Vibration data is collected and analysis using four channel vibration analyser. Vibtation is measurd in terms of velocity.

Fig. 1. Forced draft fan

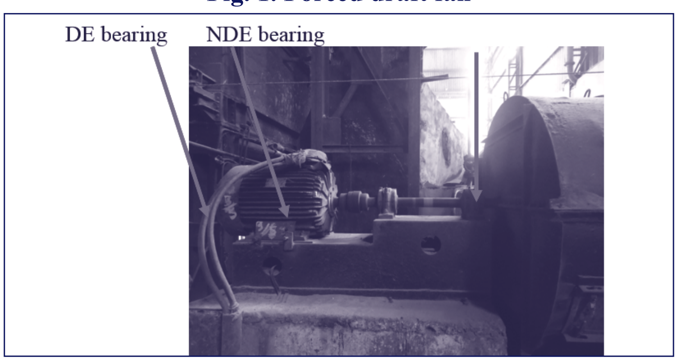


Fig. 2. Vertical, horizontal and axial measurements on DE bearing and NDE bearing of Forced draft fan

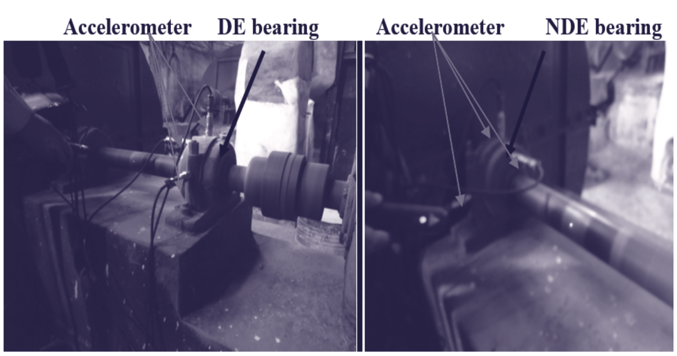


Fig. 3. Vertical measurement on DE and NDE bearing pedestal of Forced draft fan

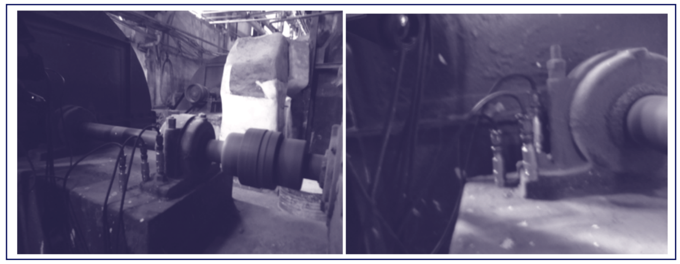


Fig. 4 Photograph of vibration analyser

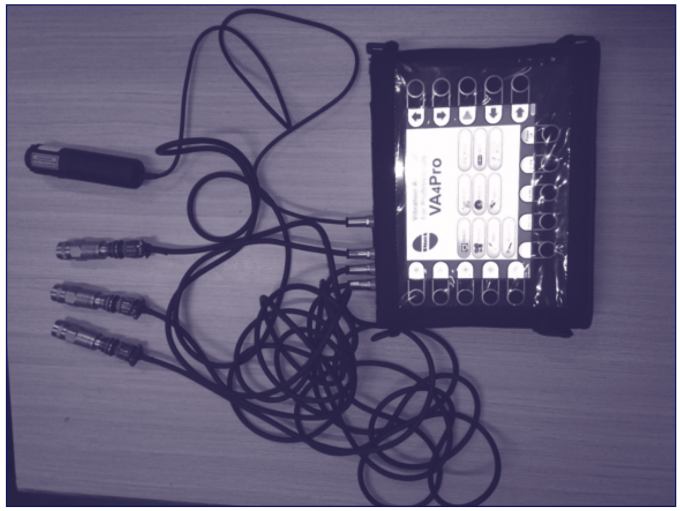


Table 2 Standard vibration level for class III machines. (As per ISO 10816 -3)

Standard Vibration Level (RMS) mm/s	Machine condition
0 -2.3	Good (A)
1.8- 4.5	Normal (B)
4.5-7.1	Restricted (C)
Above 7.1	Critical (D)

4. RESULTS AND DISCUSSIONS

The vibrations are measured in three directions vertical, horizontal and axial directions at drive end (DE) bearing and non-drive end (NDE) bearing of forced fan.

4.1. Vibration response of DE and Non NDE bearing

Table 3 shows the overall rms amplitude in V, H and A directions at DE and NDE bearing. It is clear from it that, overall rms amplitude are greater than the acceptable limit as per ISO 10816-3. Overall RMS value of amplitude of DE bearing in V, H and A direction is in restricted zone (alarm) and axial direction is in critical zone as per ISO 10816-3 (Table 2). Overall rms value of amplitude of NDE bearing in V, H and A direction is in critical zone as per ISO 10816-3 (Table 2). Therefore, the FFT spectrum is obtained. Fig. 5 shows FFT spectrum at DE bearing in vertical direction, DE-V. Spectrum in horizontal direction, DE-H as shown in Fig.6. Spectrum in axial direction, DE-A as shown in Fig.7. The FFT spectrum in vertical direction at NDE bearing, NDE-V as shown in Fig. 8. The spectrum in horizontal direction, NDE-H as shown in Fig. 9 and axial direction, NDE-A as shown in Fig. 10. Figs. 8 to 10 show maximum five peaks. FFT spectrum shows harmonics and sub harmonics of multifault, but these are not suffient information to confirm the faults.

Table 3 Overall RMS values of amplitude in V, H and A directions at DE and NDE bearing of the rotor

Speed (rev/min)	RMS Amplitude (mm/s)			
	Bearing end	Direction		
		Vertical	Horizontal	Axial
1480	DE	**4.93**	**6.25**	**13.0**
	NDE	**8.21**	**7.79**	**13.3**

Fig. 5. FFT spectrum in the vertical direction at the DE bearing

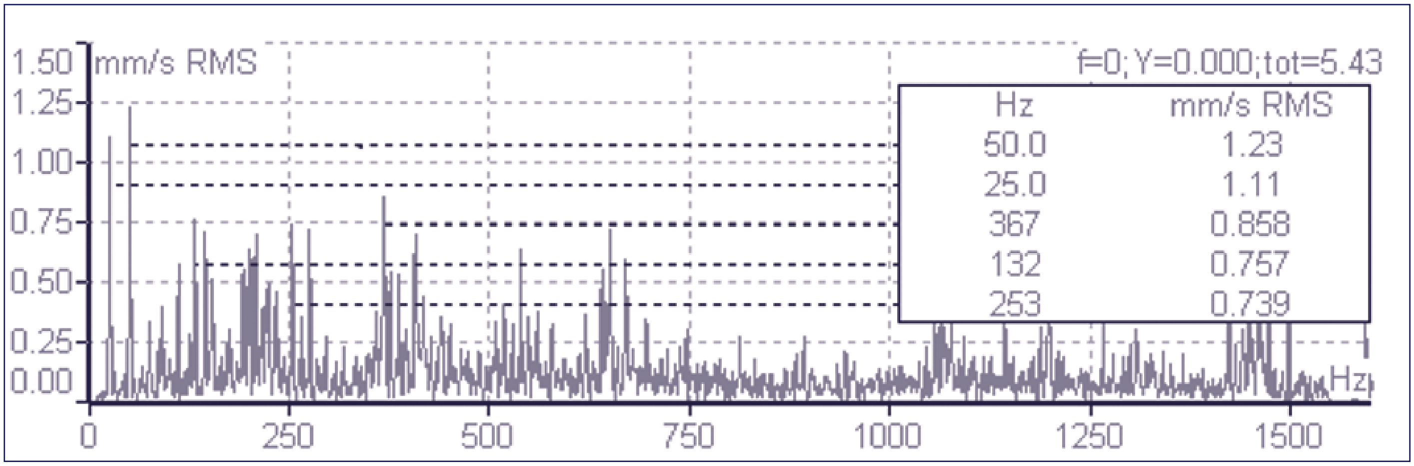


Fig. 6. FFT spectrum in the horizontal direction at the DE bearing

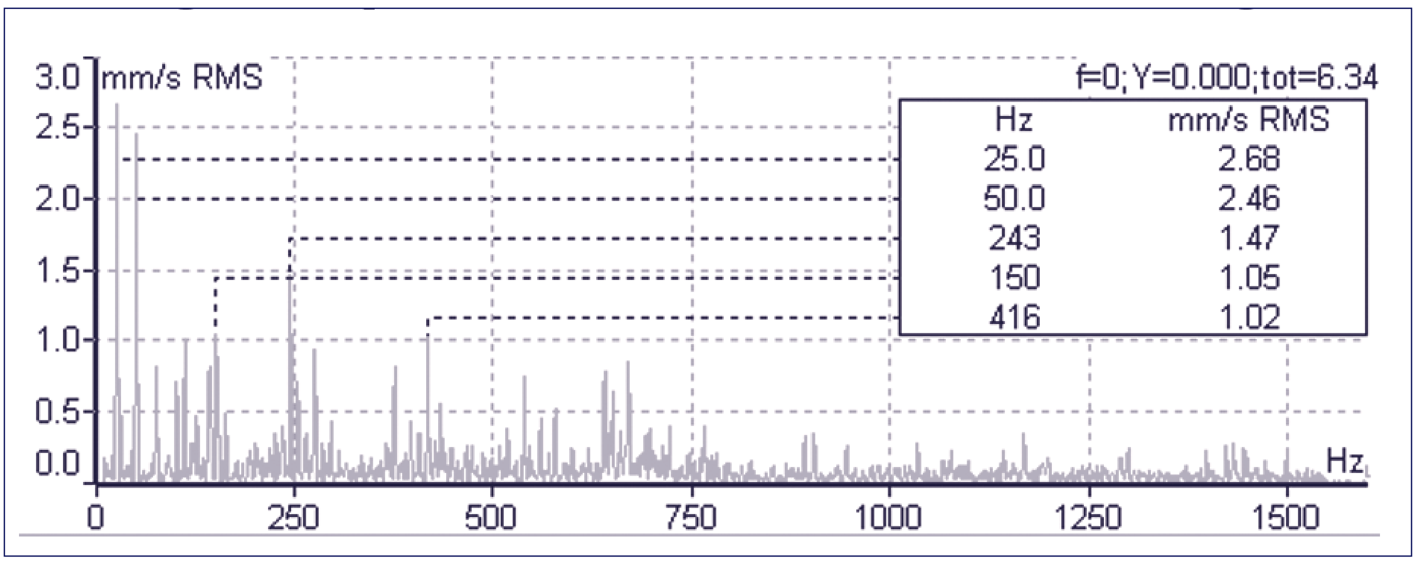


Fig. 7. FFT spectrum in the axial direction at the DE bearing

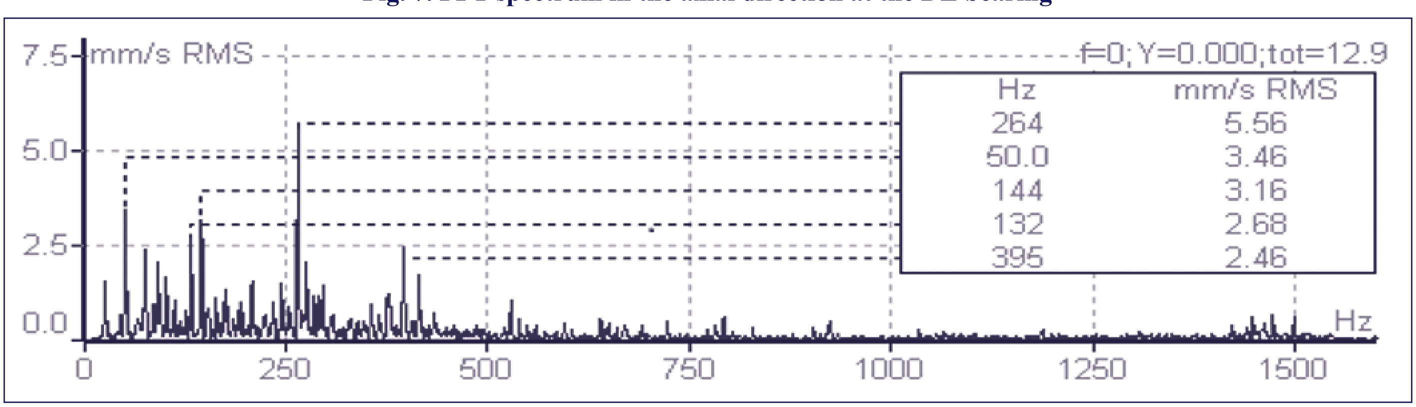


Fig. 8. FFT spectrum in the vertical direction at the NDE bearing

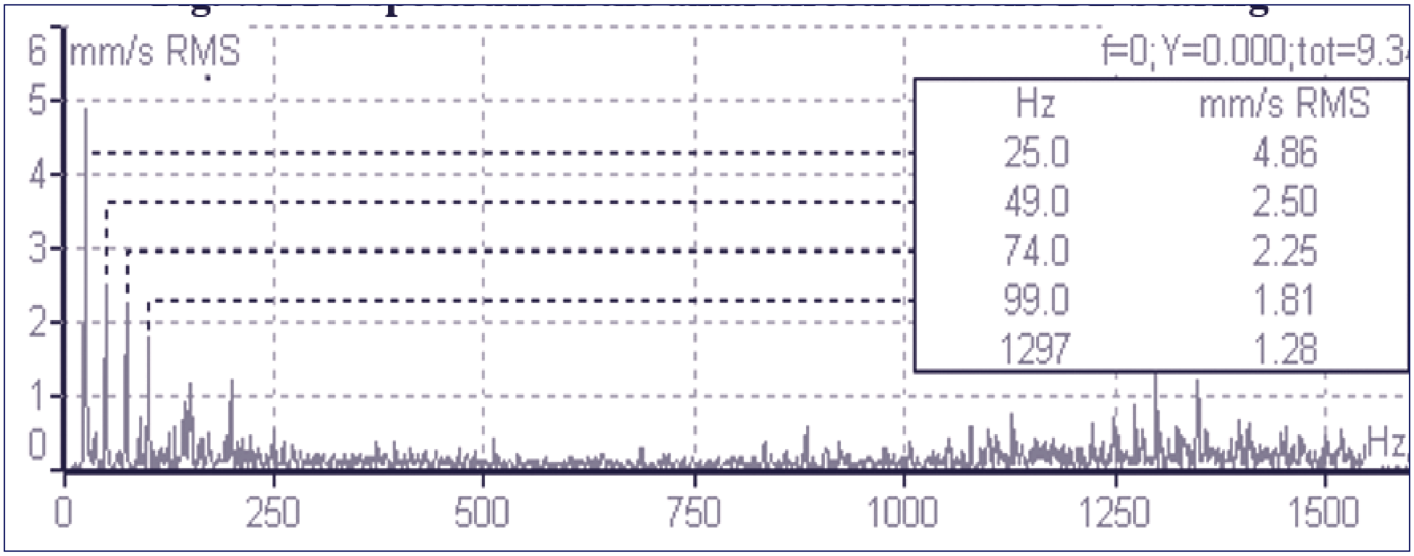


Fig. 9. FFT spectrum in the Horizontal direction at the NDE bearing

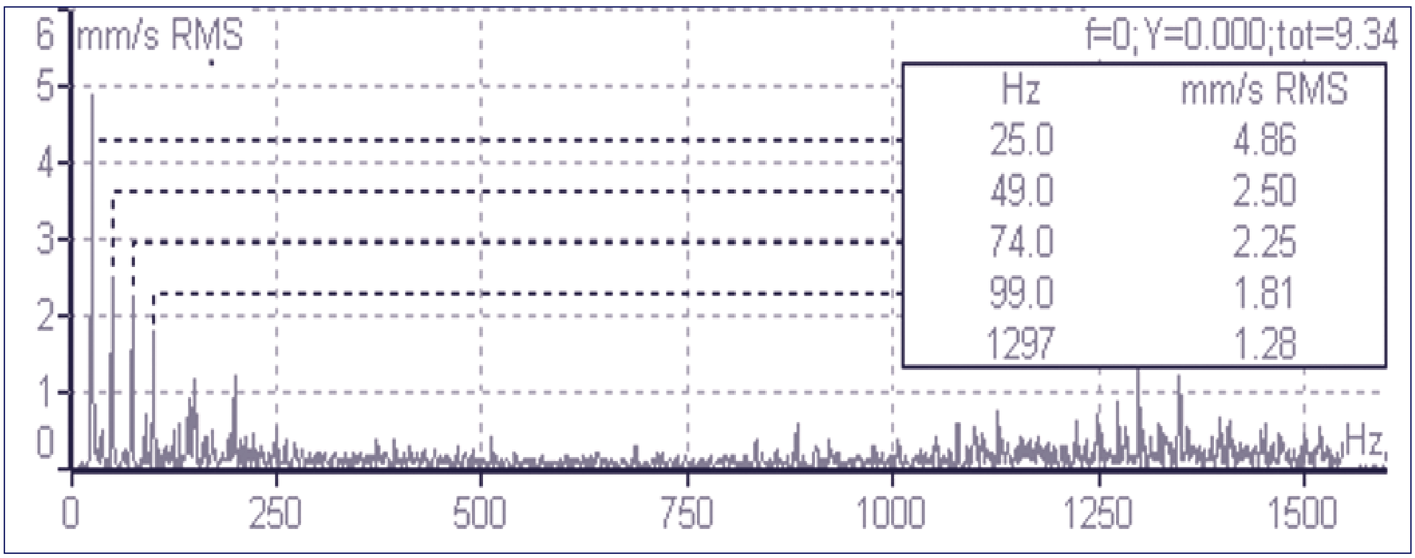
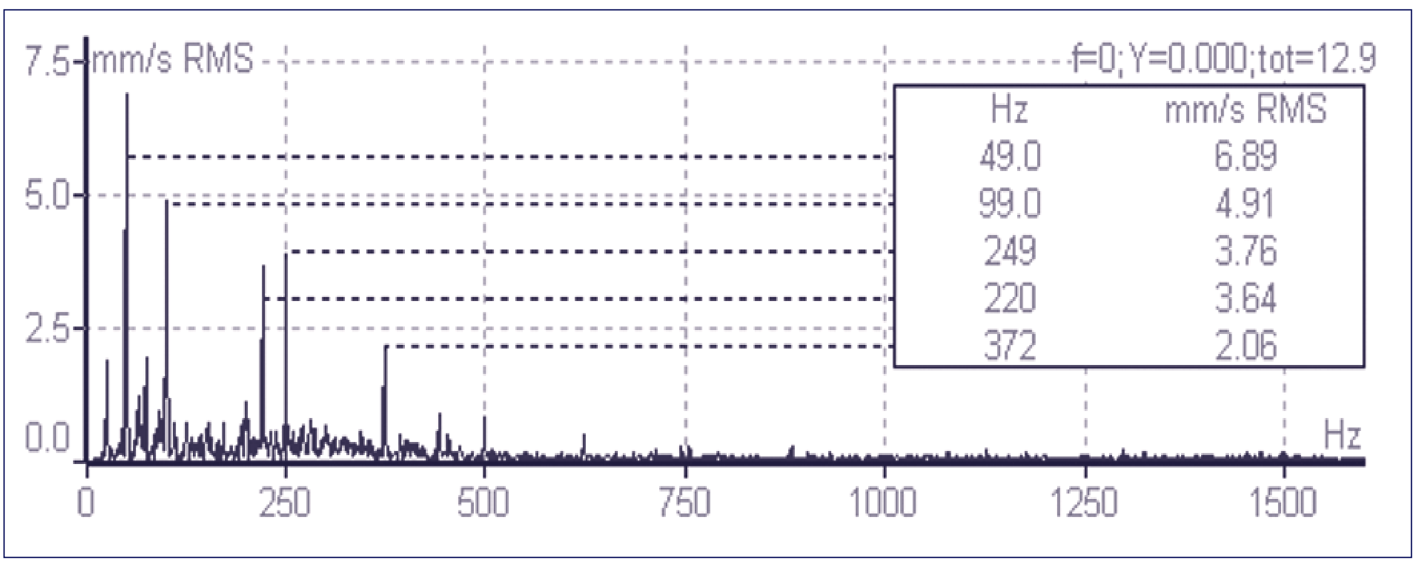


Fig. 10. FFT spectrum in the axial direction at the NDE bearing



FFT spectrum shows 1x component and 2x componet is high, so unbalance and shaft bent fault is observed. FFT spectrum shows multifault as per the frequency component peaks but not confirm the fault. Thus confirm the fault phase analysis is required.Order analysis shows both spectrum and phase.

4.2. Order analysis of Drive end (DE) and Non-Drive end (NDE) bearing

Accelerometer is mounted on DE end and NDE bearing in vertical, horizontal and axial direction. Fig. 11 shows order spectrum of DE bearing in vertical direction, DE-V. Order spectrum in horizontal direction, DE-H as shown in Fig.12 and in axial direction, DE-A as shown in Fig. 13.

Fig. 11. Order spectrum and phase in the vertical direction at the drive-end (DE-V)

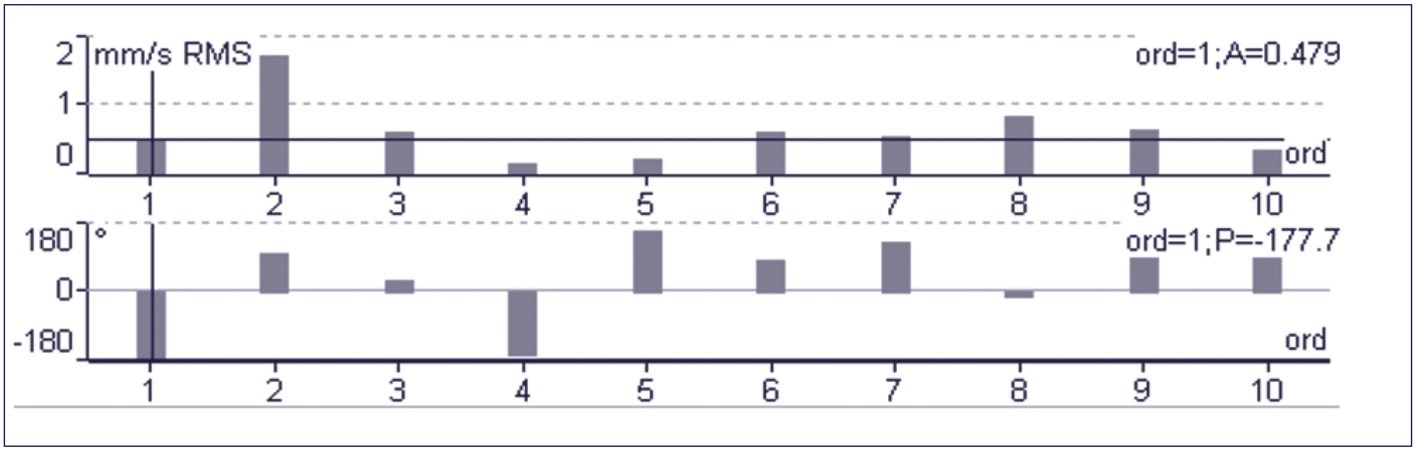


Fig. 12. Order spectrum and phase in the horizontal direction at the drive-end (DE-H)

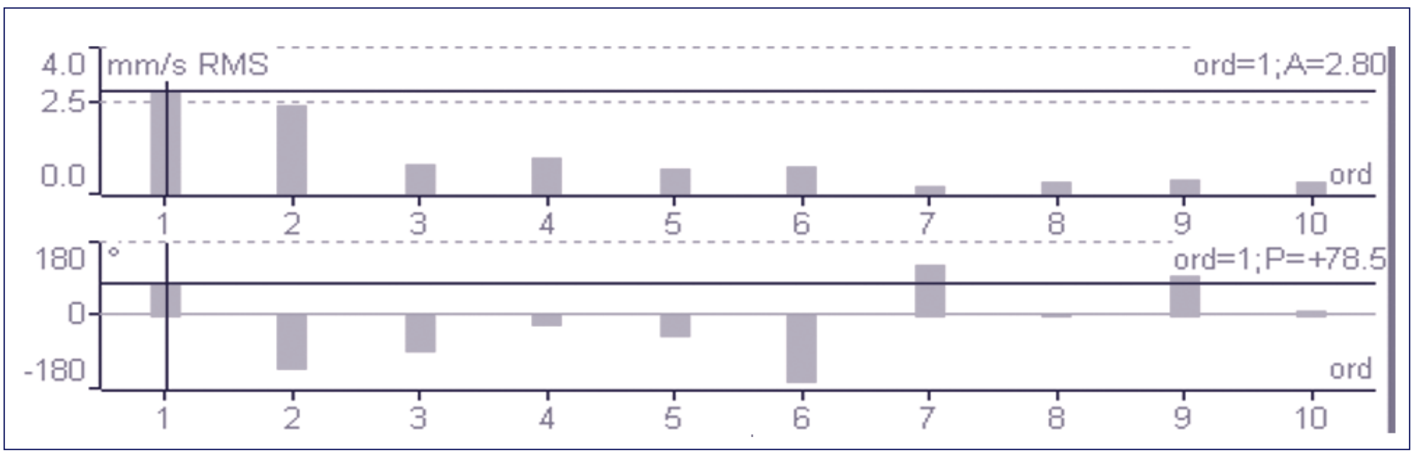
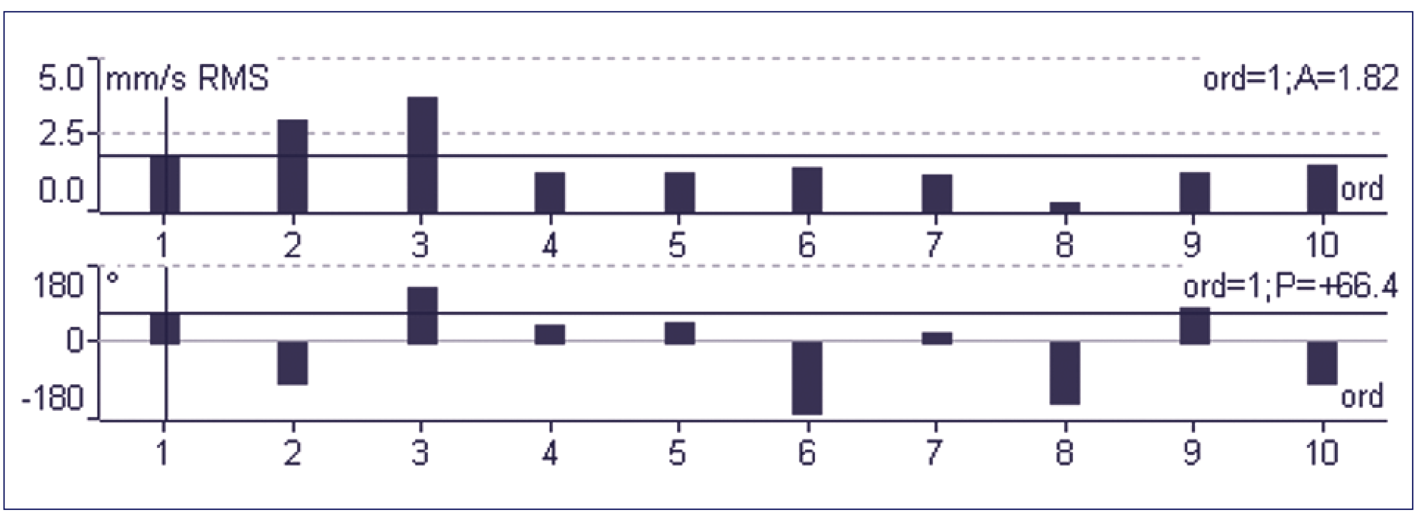


Fig. 13. Order spectrum and phase in the axial direction at the drive-end (DE-A)



The high amplitude peak at second order is seen to be high in vertical direction, first order at horizontal direction and third order in axial direction. From spectrum, harmonics and subharmonics are observed, so looseness between machine to the base plate (crack in structure or bearing pedestal, loose bearing housing bolts) fault is detected. The order spectrum in vertical direction at NDE bearing, NDE-V as shown in Fig.14, The order spectrum in horizontal direction, NDE-H as shown in Fig. 15 and in axial direction, NDE-A as shown in Fig. 16.

Fig. 14. Order spectrum and phase in the vertical direction at the non-drive-end (NDE-V)

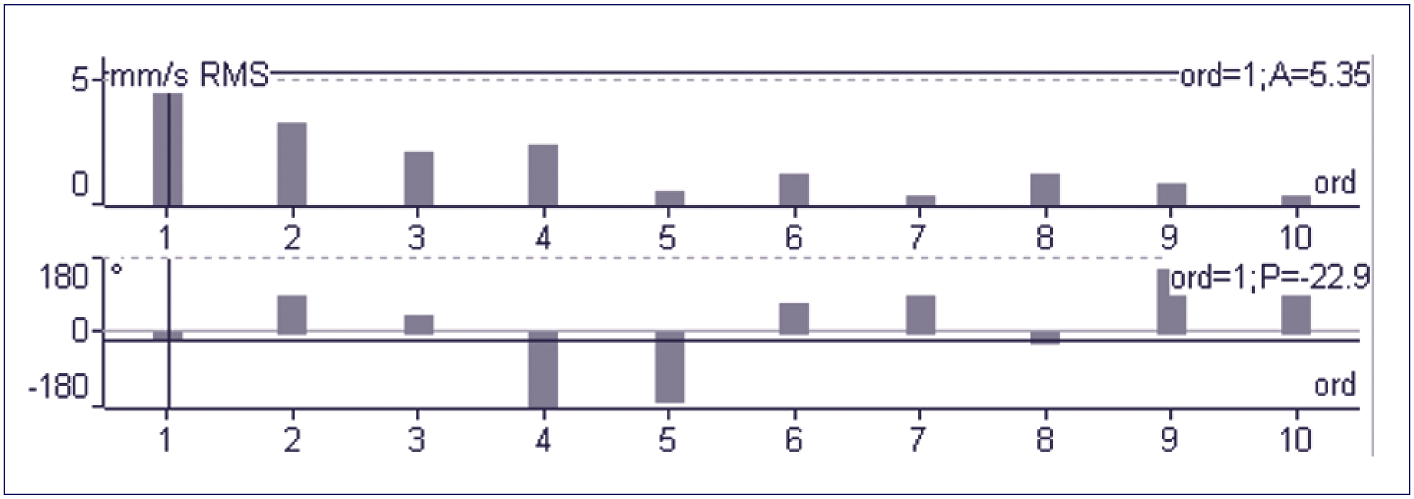


Fig. 15. Order spectrum and phase in the horizontal direction at the non-drive-end (NDE-H)

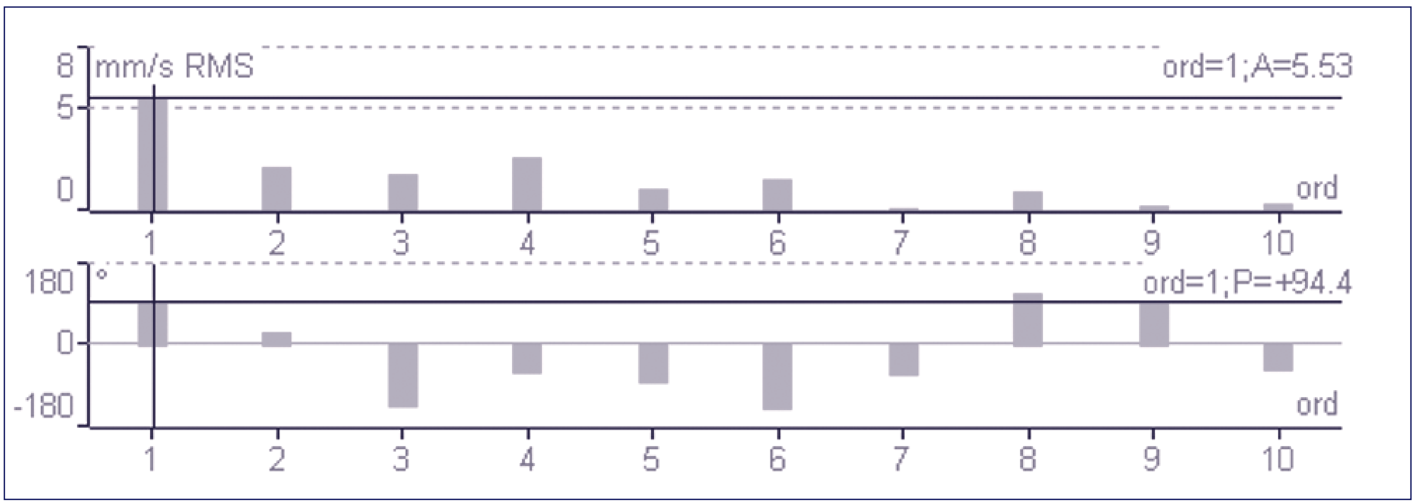
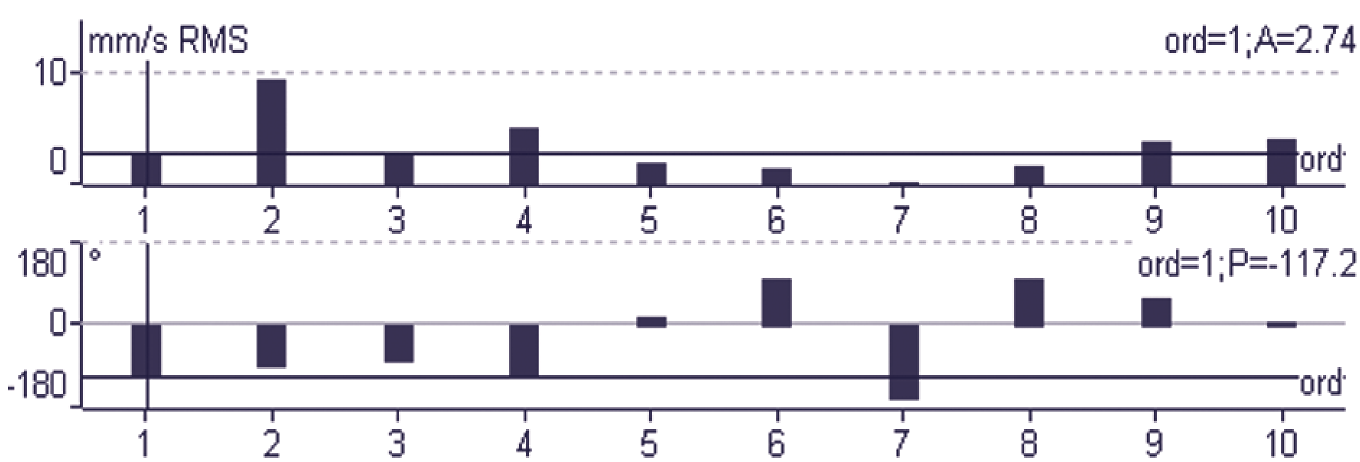


Fig. 16. Order spectrum and phase in the axial direction at the non-drive-end (NDE-A)



Order spectral analysis reveals a high amplitude peak at first order, i.e. 1480 rev/min. From spectrum, looseness between machine to the base plate (crack in structure or bearing pedestal, loose bearing housing bolts) fault is detected. The high amplitude peak at second order is seen to be high in the axial direction.

From order spectrum, phase analysis is carried out for confirm fault. Table 5 shows phase values in V, H and A directions at DE and NDE bearing.

Table 4 Phase values at DE and NDE bearing in the V, H, and A directions

Direction	DE	NDE
V	-177.7^0	-22.9^0
H	78.5^0	94.4^0
A	66.4^0	-117.2^0

Table 5 Phase values in vertical direction at DE and NDE bearings

Direction	Location	DE bearing	NDE bearing	Vertical phase difference at DE bearing	Vertical phase difference at NDE bearing
V	Bearing pedestal	176.9 º	-1.9 º	35 º (bearing pedestal and base plate)	0.5 º (bearing pedestal and base plate)
V	Base plate	-148.1 º	-2.4 º	40.8 º (base plate and base	5.8 º (base plate and base)
V	Base	-107.3 º	-8.2 º		

The axial phase difference between DE bearing and NDE bearing is obtained as 183.6^0, i.e., 180 ± 30° .The results of the phase analysis show that the shaft is bent at the center. The phase difference calculated between DE-H and NDE-H is 15.9°, i.e., 0° ± 30° [13]. Phase difference results confirm that the unbalance is present in the fan.

Table 6 shows phase values in vertical direction at DE and NDE bearings on the machine foot, baseplate and base for structural looseness fault. Phase analysis shows phase difference is 35^0 and 40.8^0 at DE bearing and 0.5^0 and 5.8^0 at NDE bearing. It is clear that looseness fault is not present in pump. Phase and amplitude accurately identify FD fan faults. Order analysis displays both phase and amplitude in addition to the FFT spectrum, which only shows the amplitude.

5. CONCLUSION

With the appropriate implementation of vibration diagnosis techniques, FD fan can operate with higher reliability and effectiveness. Order analysis is the most effective for fault diagnosis of FD fan. FFT spectrum shows multifault as per the frequency component peaks but not confirm the fault. Phase analysis allows to differentiate which of the several possible machine problems dominates. Phase analysis provides deep information related to machine diagnostics in combination with the information primarily provided by the order spectrum. Fault type and location are usually identified from phase and amplitude. Order analysis is helpful for early fault detection accurately so that corrective action taken to avoid failure of fan.

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