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FAULT DIAGNOSIS OF MULTIFAULT IN ROTOR BEARING SYSTEM

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Abstract:
Rotating machinery combined fault diagnosis is a difficult process, primarily because of the complexity of the vibration signals and the interface of several multiple components.The study of multi-fault (two and more combinations) using different techniques by a few researchers. The vibration parameter provides sufficient information about location and severity, as well as the earliest failures. In this study vibration analysis is used to diagnose multiple faults, including unbalance, misalignment, and bent shafts.Phase and amplitude are typically used to determine the fault type.The result shows spectrum and phase detects unbalance, misalignment and bent shaft fault accurately.
Keywords: Faults diagnosis; Vibration analysis; Phase analysis; Multifault

1. Introduction

In the field of rotor dynamics and fault identification, the multi-fault rotor system is a current topic. The rotor system, which forms the foundation of rotating machinery, is widely utilized in various of mechanical devices. To confirm the current condition of the machines and to diagnose any faults before they cause catastrophic failure, early fault detection is crucial. The second most frequent problem in rotating machinery is misalignment between the driven and driver machine shafts. [1, 2]. Unbalance and misalignment faults are found using a model-based technique that is based on residual generation. Model based technique is used to detect fault condition and location of fault [3]. Unbalance andmisalignment faults of rotor using equations of motion; investigation of the dynamic response of a flexible rotor subjected to imbalance and misalignment is made possible by the resolution of the equation of motion by the spectral approach. [4]. The effects of unbalance and clearance on the bearings of an overhung rotor is identified. Finite Element method is used to discretize the system and Assumed Modes is used to reduce the system. They analysed Fast Fourier Transform (FFT) of time signal and that high unbalance of an overhung rotor with clearance cause the appearance of many harmonics in the frequency spectrum [5].Through simulation and experiment, the effect of the residual shaft bow on the rotor vibration is examined.They recognized the dynamics model of a warped rotor and simulated the effect of residual shaft bow on rotor vibration in different cases. They found that the residual shaft bow can have a significant impact on the rotor vibration even when the eccentricity and damping ratio are relatively low. [6]. Bow shaft displays the frequency of the 1x rpm vibration [7].They created the motion equations for the rotor transverse crack and bow. They analysed steady state and transient response analysis of the rotor. When the bow is present, the FFT spectrum shows increased 1x rpm vibration frequency [8].Unbalance is one of the most common fault in rotating machinery and it is reported by many researchers [9,10]. Model-based approach for the online detection of two rotor cracks. He found that FFT spectrum shows 2X and 3X harmonic components [11]. They reported that when machines operate below the first critical speed, angular misalignment fault shows an axial phase difference across the connection of roughly 180° [12].To identify an unbalance problem in a rotor system, two alternative techniques are used: equivalent load minimization and vibration minimization method. Using the this techniques, an unbalance fault is found by detecting transverse vibrations only once[13].They presented a detailed finite element and dynamic simulation model of a vibration test rig [14].To diagnosis of multi fault of rotor bearing system, dynamic model of the combined fault is used to explore the phenomena of multi-fault in the rotor-bearing system[15]. They found vibration response of unbalanced multirotor system. Analyze the vibration response of the rolling element bearings in the rotating system under various weights and running speed conditions, experimental tests are carried out on a dynamic rotor test device [16]. They presented orbit analysis for imbalance fault diagnosis of rotating machinery [17]. They used operational deflection shape for detecting unbalance and misalignment in rotaor bearing system[18,19]. Fault diagnosis of electrical rotating machines used FFT.

Mostly single fault in roatating machines are identified by several reseachers, but in actual practice multi-fault (two and more combinations) are developed in the machines. Unbalance, misalignment and bent shaft are most common faults in machines. In this paper, multifault such as unbalance, misalignment and bent shaft are developed in rotor bearing system. FFT spectrum and phase analysis of unbalance, misalignment and bent shaft are obtained.

2. Experimental Set-up

The tests were conducted on the test rig as shown in Fig. 1. The test-rig consists of a shaft 25 mm diameter and 700 mm length which is supported on two double row deep groove ball bearings (SKF1205). At the midpoint of the bearings, a single 130 mm-diameter, 18 mm-thick rotor disc is mounted. Eight evenly distributed 12 mm diameter holes with a 45 mm radius are present on the rotor disc, which can be used to produce an unbalance by adding weight.A 1 HP DC motor drives the rotor, and a DC controller regulates its speed. The rigid flange coupling is used to connect the rotor shaft (driven shaft) and motor shaft (driving shaft). The parallel misalignment of 0.2 mm in vertical direction was created in coupling by placing shims below DE and NDE bearings housing.After measuring 98.2 m of bend, the shaft is bent at the centre by a bending machine.The rotor operating speed was kept at 1000 rev/min.

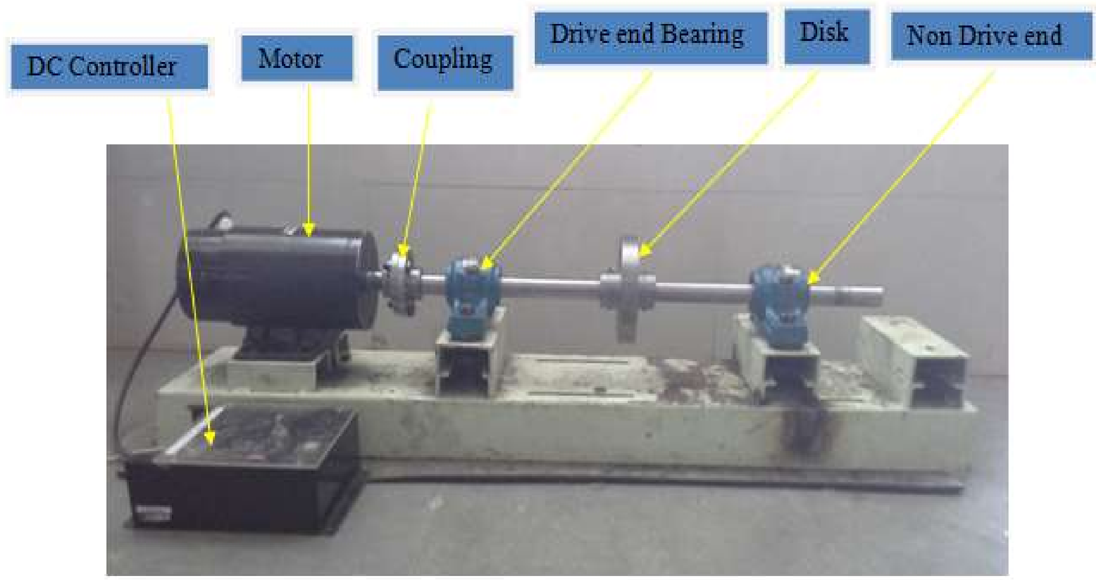

Fig.1: Actual photograph of Rotor Test Rig

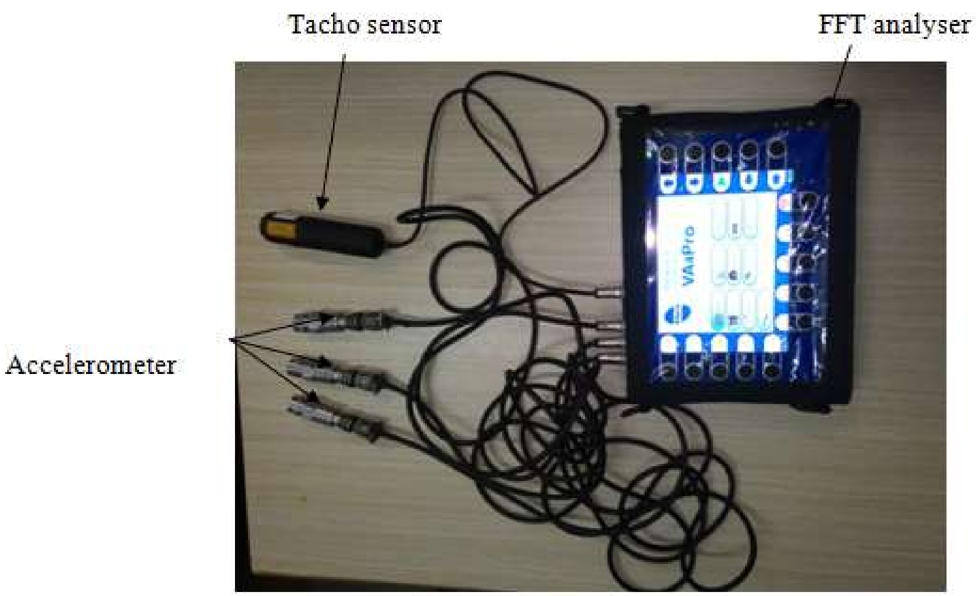

Fig. 2: Photograph of FFT analyzer

Four channel FFT analyzer (Make: Adash; Model: VA4Pro) is used to measure and analysis vibration (Fig. 2). The vibration signals in the Horizontal (H), Vertical (V), and Axial (A) direction at a bearing-housing are collected using three piezoelectric accelerometers (Make: CTC; Model: AC102-1A), sensitivity = 100 mV/g.Velocity is the most common parameter for vibration analysis. For time waveform analysis, it is advised to employ 1600 lines (4096 samples) when the machine rotates between 600 and 3000 rpm in order to obtain adequate precision. Set the maximum frequency (F-max) for general rotating machinery at 20-40 times the rotational frequency. The details of data acquisition parameters are given in Table 1. Maximum five peaks (1X and harmonics) in descending orders are reported in all FFT spectra which are discussed in subsequent sections.

Table 1: Data acquisition parameters

Sampling Frequency	4096 Hz
No. of Samples	4096
Window	Hanning
No. of lines	1600
Frequency range	10 Hz -1600 Hz
Time	1 second

3. Result and Discussion

Vibration response of unbalance, misalignment and shaft bent is carried out. Table 2 shows the overall velocity-rms amplitude of the multi-fault in the V, H, and A axes. It is clear from Table 2 that the velocity-rms values of amplitude in axial direction at DE and NDE bearing are greater than the acceptable limit (1.8 mm/s) as per ISO 2372. At the drive-end bearing (DE), unbalance, misalignment, and bent shaft FFT spectra are obtained in the vertical (Fig. 3), horizontal (Fig. 4), and axial (Fig. 5) directions. Also, the vertical (Fig. 6), horizontal (Fig. 7) and axial (Fig. 8) FFT spectra of multiple faults at non-drive-end (NDE) bearing are obtained. Fig. 3 and 4 shows 1X and 2X frequency peak are strong in vertical and horizontal direction. The 1X peak is strong in vertical and horizontal direction indicates possibility of unbalance fault and 2X peak in vertical and horizontal direction shows chances of parallel misalignment. Fig. 5 shows 1X and 2X peak is high in axial direction and 1X is greater than 2X indicates possibility of shaft bent at center and angular misalignment. Fig. 6 and 7 shows 1X and 2X frequency peak are strong in vertical and horizontal direction. The 1X peak is strong in vertical and horizontal direction indicates possibility of unbalance fault and 2X peak in vertical and horizontal direction shows chances of parallel misalignment. Fig. 8 shows 1X and 2X peak is high in axial direction and 1X is greater than 2X indicates possibility of shaft bent at center and angular misalignment. Table 3 shows phase values for MDE, DE, and NDE bearings in the axial, horizontal, and vertical direction. Phase analysis is used to confirm shaft bend and angular misalignment.

Table 2: overall velocity-rms amplitude in V, H, and A direction at DE bearing

Speed (rev/min)	**Velocity-rms Amplitude (mm/s)**			
	Bearing End	**Direction**		
		Vertical (V)	**Horizontal (H)**	**Axial (A)**
1000 (17 Hz)	Drive end (DE)	**6.17**	**6.19**	**9.18**
	Non drive end (NDE)	**5.25**	**6.29**	**9.77**

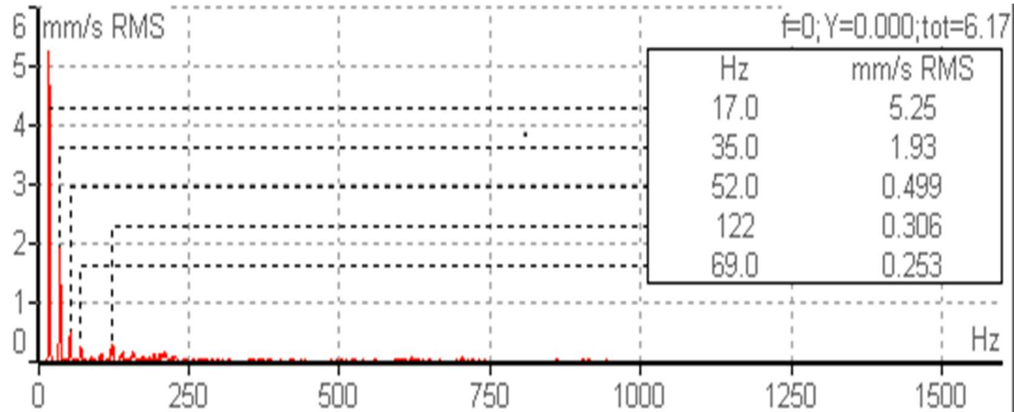

Fig. 3: FFT spectrum of Unbalance, Misalignment and shaft bent at drive-end in vertical direction(DE-V)

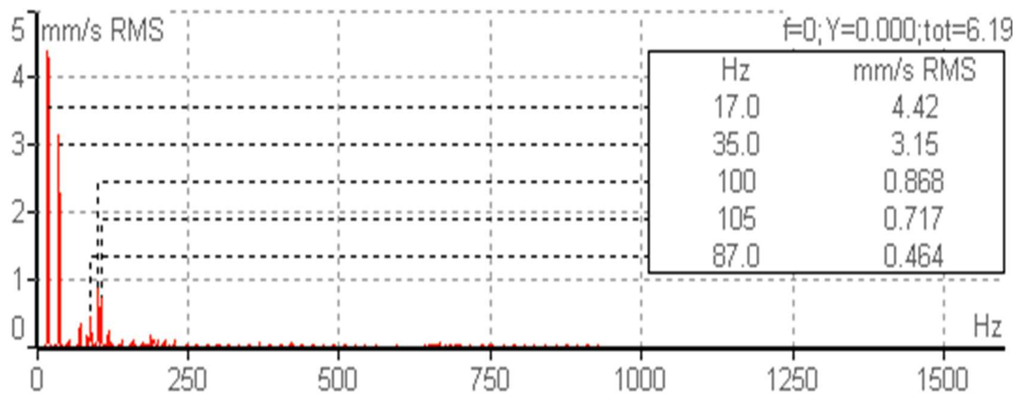

Fig. 4: FFT spectrum of Unbalance, Misalignment and shaft bent at drive-end in horizontal direction (DE-H)

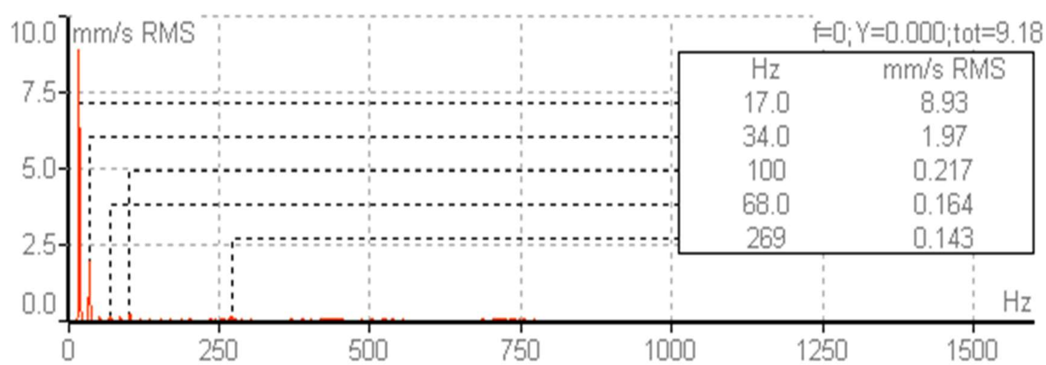

Fig. 5: FFT spectrum of Unbalance, Misalignment and shaft bent at drive-end in axial direction (DE-A)

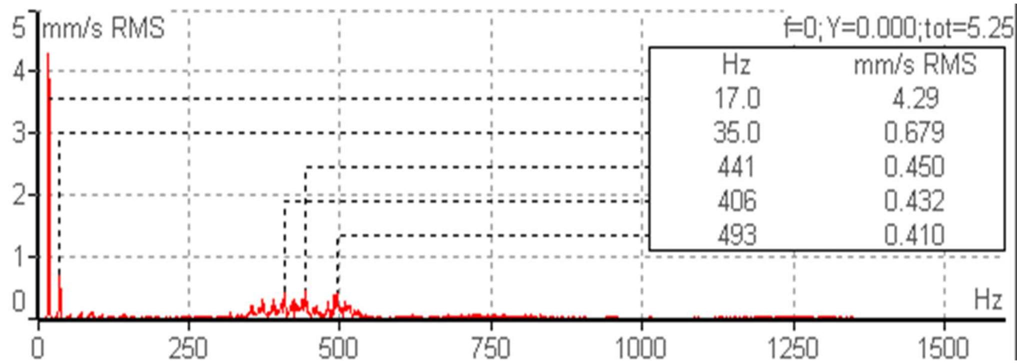

Fig. 6: FFT spectrum of Unbalance, Misalignment and shaft bent at non drive-end in vertical direction(NDE-V)

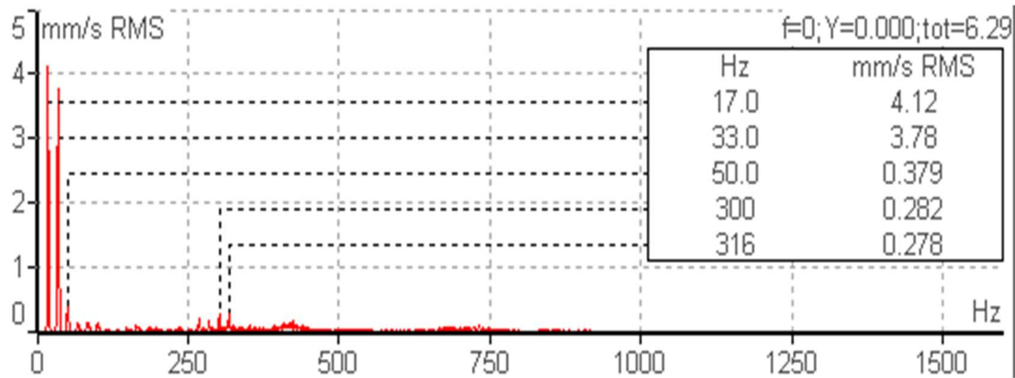

Fig. 7: FFT spectrum of Unbalance, Misalignment and shaft bent at non drive-end in horizontal direction (NDE-H)

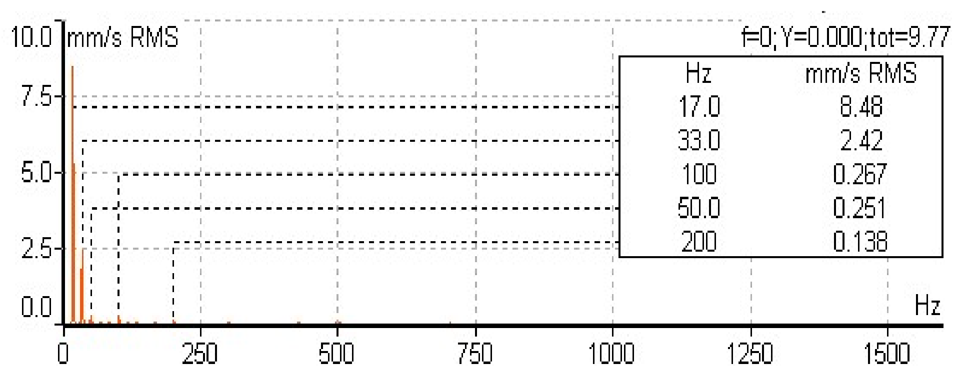

Fig. 8: FFT of Unbalance, Misalignment and shaft bent at non drive-end in axial direction (NDE-A)

Axial phase differenceat MDE and DE across coupling is 162°, vertical phase difference between MDE and DE across coupling is 173.6°, i.e., 90° ± 30°. Phase difference results confirm that the misalinment is present. The axial phase difference at DE bearing and NDE bearing is obtained as 179.4 º, i.e., 180 ± 30°. This result shows that the shaft is bent at the center. The phase difference, calculated between DE-V and DE-H, is 114°, between NDE-V and NDE-H is 99.1°, i.e., 90° ± 30°. This result indicates that the unbalance fault is present.

Table 5: Phase values at MDE, DE bearing, and NDE bearing in the axial, horizontal, and vertical directions

<table>
<tr><th>Direction</th><th>MDE bearing</th><th>DE bearing</th><th>NDE bearing</th><th>Axial phase difference at MDE and DE across coupling</th><th>Vertical phase difference at MDE and DE across coupling</th><th>Axial phase difference at DE and NDE</th><th>Phase difference between V and H at DE bearing</th><th>Phase difference between V and H at NDE bearing</th></tr>
<tr><td>V</td><td>6.7 º</td><td>166.9 º</td><td>-147.7 º</td><td rowspan="3">162 º</td><td rowspan="3">173.6 º</td><td rowspan="3">179.4º</td><td rowspan="3">114 º</td><td rowspan="3">99.1 º</td></tr>
<tr><td>H</td><td>28.3 º</td><td>52.9 º</td><td>-48.6 º</td></tr>
<tr><td>A</td><td>-31.2 º</td><td>130.8º</td><td>-49.8 º</td></tr>
</table>

Axial phase differenceat MDE and DE across coupling is 162°, vertical phase difference between MDE and DE across coupling is 173.6°, i.e., 90° ± 30°. Phase difference results confirm that the misalinment is present. The axial phase difference at DE bearing and NDE bearing is obtained as 179.4 º, i.e., 180 ± 30°. This result shows that the shaft is bent at the center. The phase difference, calculated between DE-V and DE-H, is 114°, between NDE-V and NDE-H is 99.1°, i.e., 90° ± 30°. This result indicates that the unbalance fault is present.

4. Conclusion

With the appropriate implementation of vibration diagnosis techniques, fault diagnosis of multi fault in rotating machines is obtained.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 spectrum. Fault type and location are usually identified from phase and amplitude. Spectrum and phase analysis to overcome the promising faults to the industry.

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