MISALIGNMENT FAULT DIAGNOSIS IN ROTATING MACHINERY THROUGH THE SIGNAL PROCESSING TECHNIQUE – SIGNATURE ANALYSIS

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ABSTRACT
Fault detection of mechanical equipment based on vibration analysis consists in determine the relation between measured signal and fault model signals. Fault model signals are generated by simulation based on a prior knowledge about the mechanical behavior of the process. The signature analysis is considered the most popular fault detection method now a day because it can easily detect the common mechanical faults such as unbalance, misalignment, crack, bearing deterioration, looseness etc. Unbalance and misalignment are the common faults in the mechanical system which create the another fault in the system. The present paper discusses the fundamentals of Signature analysis and signal processing for identifying the spectrums for the misalignment fault.

KEY WORDS: Signature analysis, misalignment, Signal processing, fault diagnosis, vibration analysis.

1. INTRODUCTION
The word signature has been coined to designate signal patterns which characterize the state or condition of a system from which they are acquired. Signatures are extensively used as a diagnostic tool for mechanical system. In many cases, some kind of signal processing is undertaken on those signals in order to enhance or extract specific features of such vibration signatures. It is very important to consider the type and range of transducers used as pickup for capturing vibration signal. Signature-based diagnostic makes extensive use of signal processing techniques involving one or more methods to deal with the problem of improvement in the signal to noise ratio. These methods have traditionally been applied, separately in time and frequency domains. A time-domain analysis focuses principally on statistical characteristics of vibration signal such as peak level, standard deviation, skewness, kurtosis, and crest factor. A frequency domain approach uses Fourier methods to transform the time-domain signal to the frequency domain, where further analysis is carried out, and conventionally using vibration amplitude and power spectra [1]. Vibration analysis has provided quick and reliable information on the condition of the bearings. Integration of this condition monitoring technique with another condition technique resulted in a comprehensive diagnosis of the machinery condition [2]. In general, the vibration will exist in the radial direction, axial direction, or both. The radial direction is usually broken up into the vertical and horizontal planes to better describe the characteristics of the vibration. The understanding of this allows the determination of ideal sensor positions likely to record a maximum of information in the best Conditions [3]. The characteristics of a machine vibration can be used to identify specific problems. There are numerous causes of vibration in machines, but about 90% of all problems are due to unbalance or misalignment. Some of the other Sources of vibration are mechanical looseness, bad drive belts or chains, bad bearings (antifriction type), hydraulic forces, bent shafts, electromagnetic forces, aerodynamic forces, resonance, worn, damaged or eccentric gears and rubbing [4]. Misalignment is common cause of machinery malfunction. A poorly aligned machine can cost a factory 20% to 30%. In machine down time, replacement parts, inventory, and energy consumption. A large payback is often seen by regularly aligning machinery. Operating life is extended and process conditions are optimized [5]. Shaft misalignment occurs when the centerlines of rotation of two or more machinery shafts are not in line with each other. There are two types of misalignments: parallel misalignment occurs when the shaft centerlines of the two machines are parallel, but offset to each other, and angular misalignment occurs when the shaft centerlines are not parallel, but inclined to each other. Misalignment in shafts produces high radial loads in one or more bearings [6]. In the present work, it is intended to apply fault to a mechanical system to identifying the spectrum of misalignment defect. For this purpose record the Fast Fourier Transform (FFT). The FFT spectrum will, hence, be analyzed and compare them with the normal operating conditions.

2. VIBRATION ANALYSIS FOR ROTATING MACHINERY
Tests have been carried out on a reactor system which runs on the induction motor. The reactor is the equipment which is used in chemical industries to mix or separate the different chemical from each other. Detail of motor which is used in reactor given in table 1.

<table>
<thead>
<tr>
<th>Table 1. Detail of induction motor.</th>
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<tbody>
<tr>
<td>Induction motor Description</td>
</tr>
<tr>
<td>Input power</td>
</tr>
<tr>
<td>Motor speed</td>
</tr>
<tr>
<td>Rotor of Motor speed</td>
</tr>
<tr>
<td>Phase</td>
</tr>
</tbody>
</table>

The speed of the motor is 960 RPM therefore the velocity in rms should be measured. The vibration readings are taken at the point A and Point B. Point A is the Non Drive End (NDE) and point B is the Drive End (DE) of the motor. The rotor of the motor is balanced so no need to take the data of rotor side. The block diagram is given in Fig. 1. The SKF FFT analyzer is used to measure the velocity in rms with the help of piezoelectric accelerometer. The speed of motor is medium so maximum frequency range is 1000 HZ with the 800 spectrum lines. The sensor is
mounted at the point A and B in radial as well as axial direction to identify the fault in the system.

![Diagram of reactor](image)

**Fig. 1 Block diagram of reactor.**

### 3. RESULTS AND DISCUSSIONS

The FFT spectrums have been recorded for the NDE and DE in radial and axial direction. Standard ISO 10816 – 1 has been used for testing the vibration amplitudes. The results showed that the overall vibration values of axial directions are higher at NDE and DE. The warning overall vibration recommend value in ISO 10816 – 1 for this motor is 7.1 mm/sec but overall vibration values and mean of them are higher than standard value. It showed that more vibration values indicated problem in the system. The peak occurs at the lower range of the frequency. Table 2 represents the overall vibration values at the NDE and DE side of the motor.

According to the Fig. 2 and Fig. 3 the values at the NDE in radial direction are under the permissible limit of ISO 10816 – 1. The value at the axial direction in Fig. 4 is beyond the permissible limit.

<table>
<thead>
<tr>
<th>Measurements</th>
<th>RMS value (Velocity)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Position</strong></td>
<td><strong>A</strong></td>
</tr>
<tr>
<td>Vertical</td>
<td>5.92</td>
</tr>
<tr>
<td>Horizontal</td>
<td>4.918</td>
</tr>
<tr>
<td>Axial</td>
<td>44.7</td>
</tr>
</tbody>
</table>

Table 2. Overall vibration values.

Similarly Fig. 5 and Fig. 6 show the vibration values at the DE side of the motor which are under the permissible limit but the value of amplitude in axial direction of DE side Fig. 7 is more than the permissible limit. The values are higher in the axial direction at the NDE and DE side. RMS of vibration velocity in the axial direction are higher than the standard value and points are critical.

![FFT spectrum NDE side vertical](image)

**Fig. 2** NDE side vertical.

![FFT spectrum NDE side horizontal](image)

**Fig. 3** NDE side horizontal.
Fig. 4 NDE side axial.

Fig. 5 DE side vertical.

Fig. 6 DE side horizontal.
The velocity frequency spectrums of the NDE and DE side of the motor show a dominant frequency corresponding to the rotor speed (16.25 Hz). The harmonics of this frequency are also giving the higher values. It indicates that there is problem of angular misalignment. So there is misalignment between the motor and coupling. It is noticed that vibrations are higher at the lower speed, when motor is stopped. This is clear indication of fact that system is operating above its natural frequency. There is no harm in running such system at its normal RPM. But several start up and stoppage may create high vibrations to adjoining areas. So after correcting the misalignment in coupling and motor the vibration level will be controlled.

4. CONCLUSION
Vibration analysis has provided quick and reliable information on the condition of the mechanical system. Trend of overall frequencies and vibration spectrum provide useful information to analyze defects in the mechanical system. The following points may be drawn from the results and discussions:
1. The misalignment fault occurs at the running frequency and their harmonics of the system.
2. The maximum peak occurs at the 1x frequency of the system.
3. Analysis of vertical and axial direction is important for the angular misalignment.

5 FUTURE WORK
It is required to analyze the different faults in the mechanical system by using the Signature analysis. The modeling is also possible to identify the fault without any expert.

REFERENCES