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Introduction to Vibration Analysis

By Salah Attia

www.mdisuatralia.com

Maintenance Strategies

Maintenance Strategies

Maintenance has evolved from run-to-breakdown methods, to time-based methods to modern predictive maintenance practices. This has resulted in less spares and manpower to maintain machines, and higher machine availability.

Reactive (Breakdown)

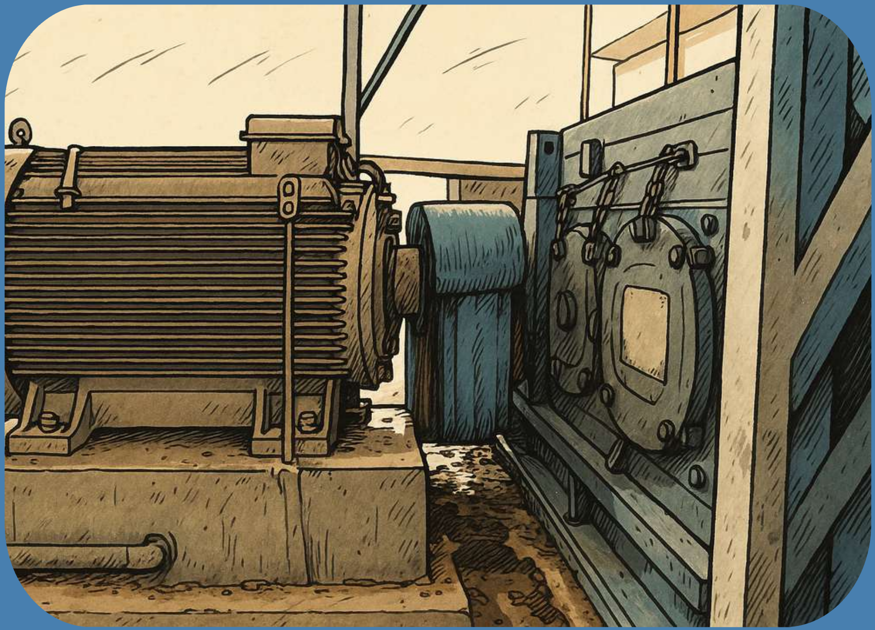
Preventative (Time based)

Predictive (Condition based)

Proactive (Addressing root causes)

Reactive Maintenance:

- Involves unplanned equipment failures that can occur at any time.
- Often leads to secondary damage, such as bearing failure, causing shaft or gear damage.
- Results in increased production downtime and maintenance costs.
- May pose risks to personnel safety and the environment.
- Suitable only for non-critical, small machines that are easy to replace and have readily available spare parts.
- Does not allow for the prediction or control of equipment reliability.

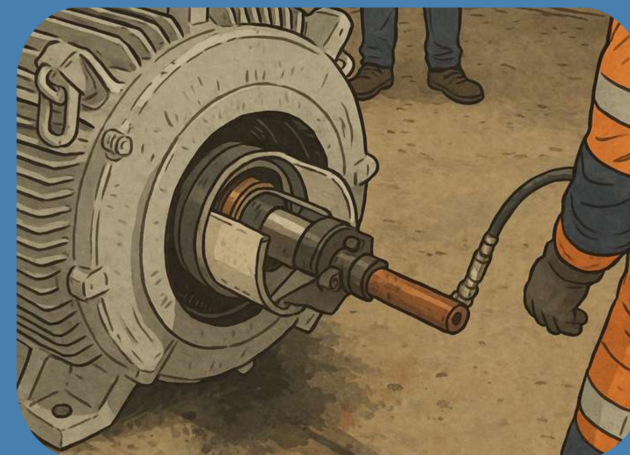


Predictive Maintenance

- A condition-based maintenance strategy that relies on real-time condition monitoring to assess equipment health.
- Prevents unnecessary maintenance activities by addressing issues only when indicators show potential failure.
- Enables continuous monitoring of machine condition to predict faults before they occur.
- Reduces manpower requirements, maintenance costs, and spare parts consumption.

Proactive Maintenance

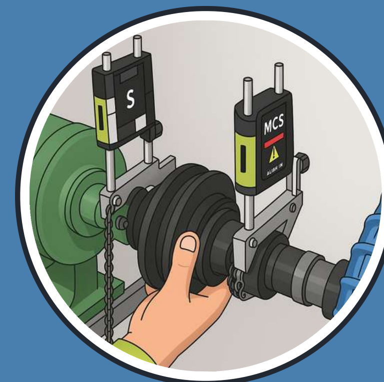
- Involves actions such as on-site and workshop balancing, precision alignment, and proper bearing installation.
- Includes advanced practices like equipment repairs, specialised investigations, and root cause elimination.
- Aims to extend asset lifespan and improve equipment reliability.
- Utilises methodologies such as Reliability-Centred Maintenance (RCM), Root Cause Analysis (RCA), Root Cause Failure Analysis (RCFA), and Failure Modes, Effects, and Criticality Analysis (FMECA).



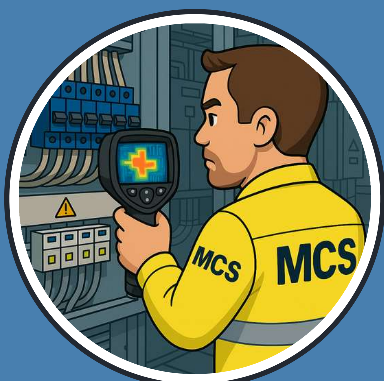
Condition Monitoring Techniques

Vibration Analysis

On-Site Balancing



Laser Alignment



Thermal Imaging

Oil Analysis

Ultrasound

Vibration Analysis

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Vibration Analysis

Why Do We Perform Vibration Analysis?

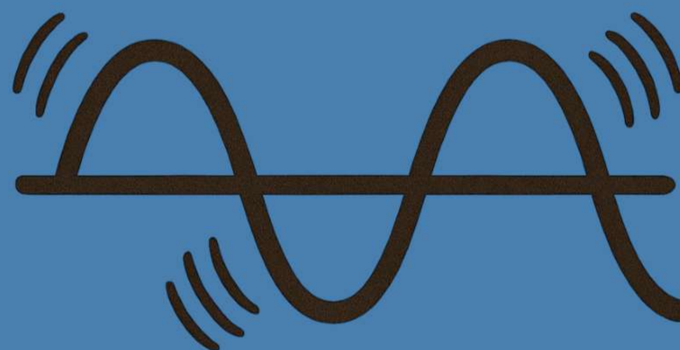
Vibration analysis allows us to assess all types of rotating equipment and identify the root cause of elevated vibration levels based on the fault type. This diagnostic test can be conducted while the machine is operating, meaning there is no need to shut it down or disassemble it to detect issues. The two main parameters in vibration analysis are:

Amplitude – Indicates the severity of the vibration.

Frequency – Helps identify the specific type of fault.

What affects Vibration Amplitude ?

- External and internal forces (Forcing frequency)
- RPM
- Stiffness
- Damping
- Mass inertia
- Proximity to natural frequency (Resonance)



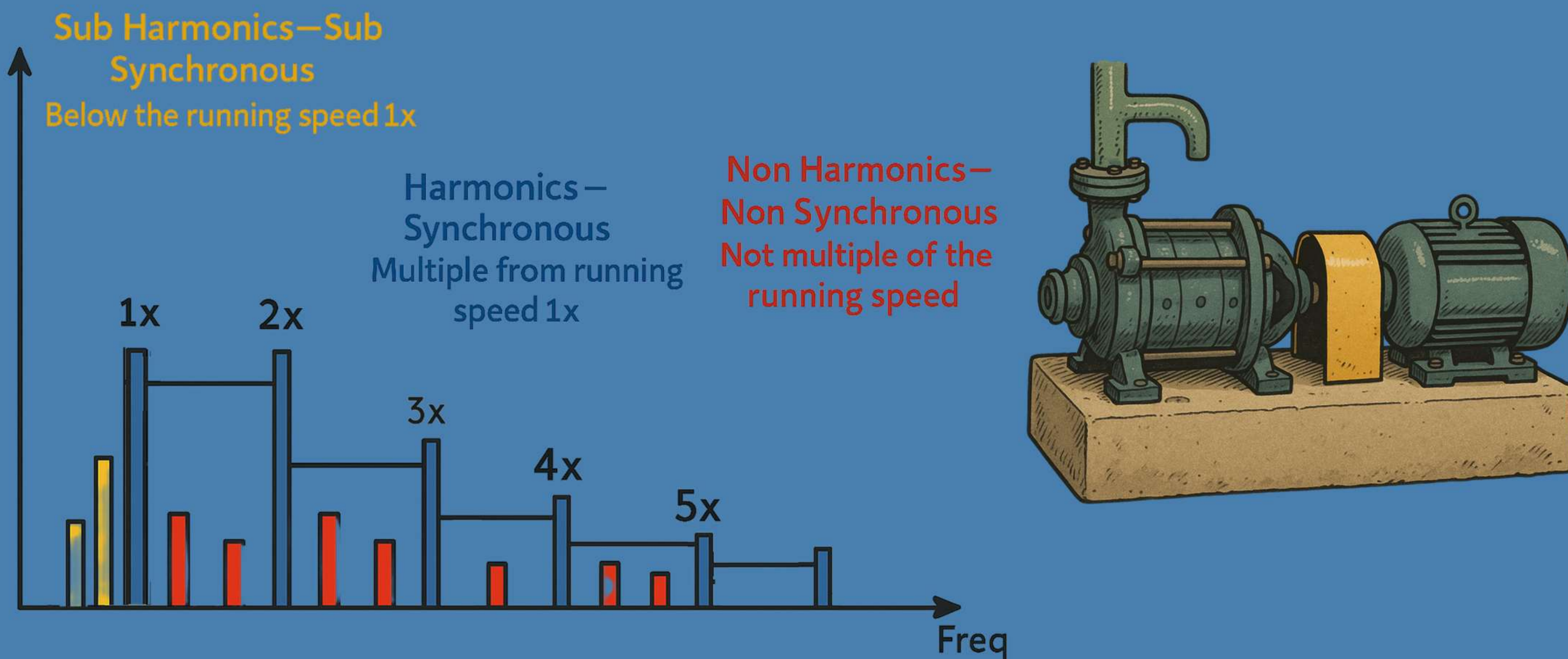
What affects Vibration Frequency ?

- Fault type, as every fault has its own pattern and shape which the vibration analyst should recognize.
- External and internal forces (Forcing frequency)

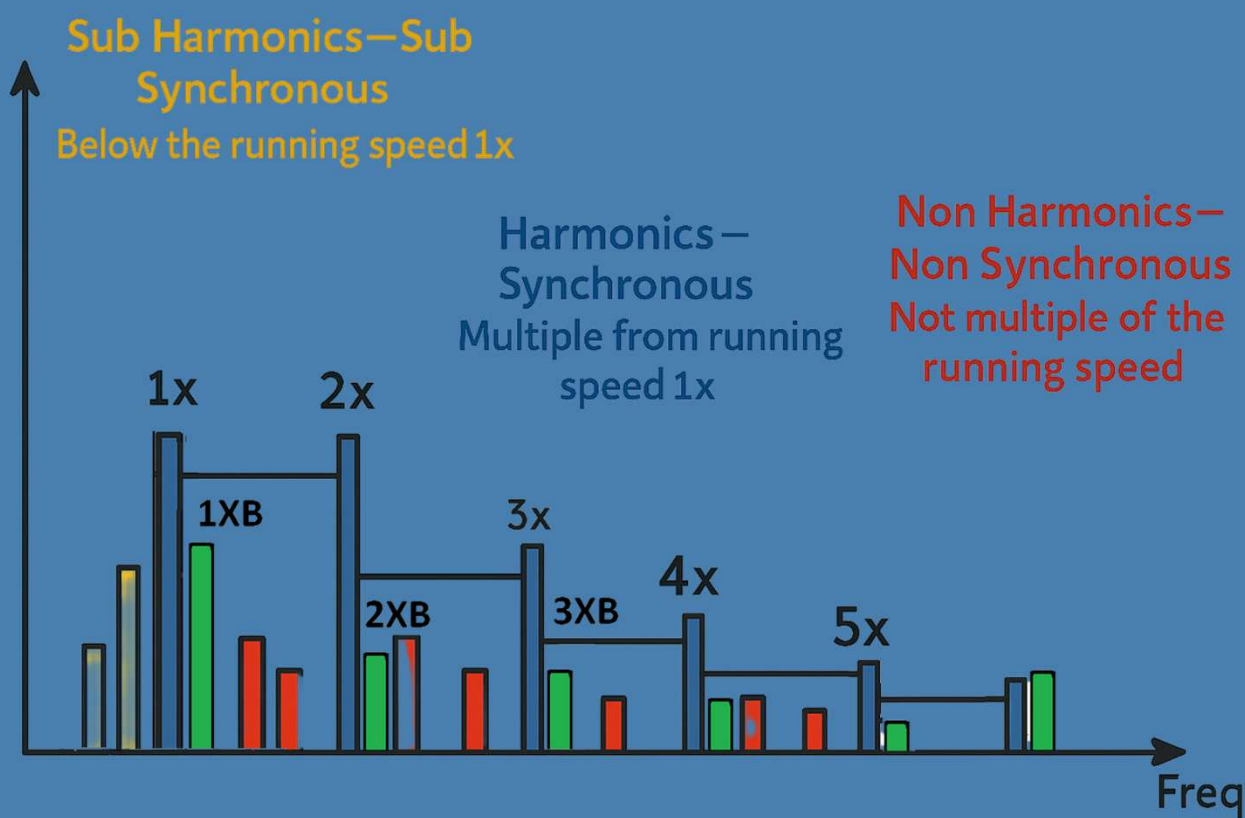
Vibration Overall Levels – Overview

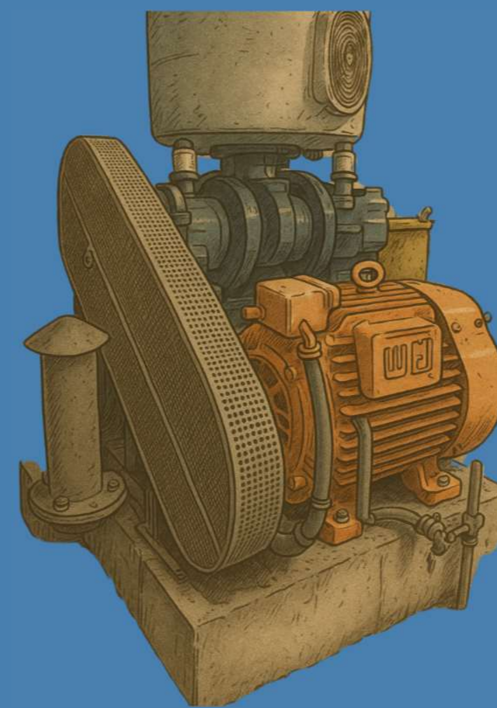
- Vibration meters are designed only for measuring overall levels. They are not suitable for in-depth machine diagnostics or bearing fault detection, unlike advanced data collectors.
- These meters have limited frequency ranges, typically up to 1000 Hz, meaning higher-frequency vibration components will not be detected.
- The ISO 10816 standard provides a guideline to assess machine condition based on overall vibration velocity levels.

Vibration Spectrum for One Speed Machine

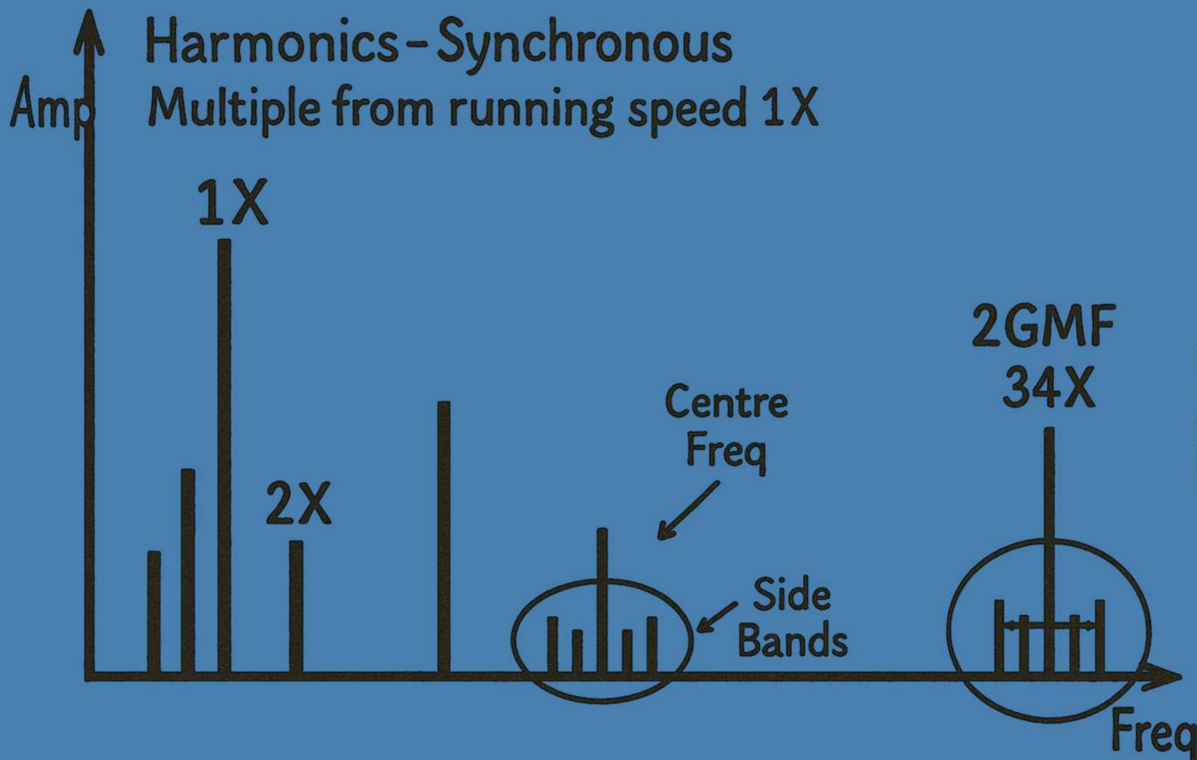


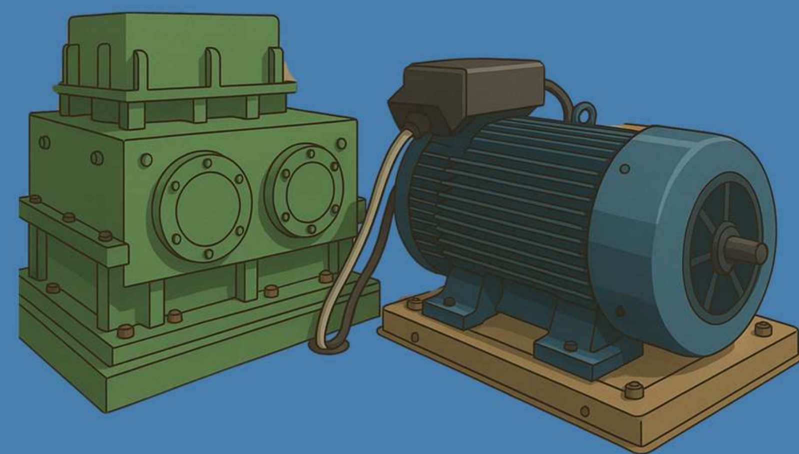
Vibration Spectrum for Multiple Speeds Machine



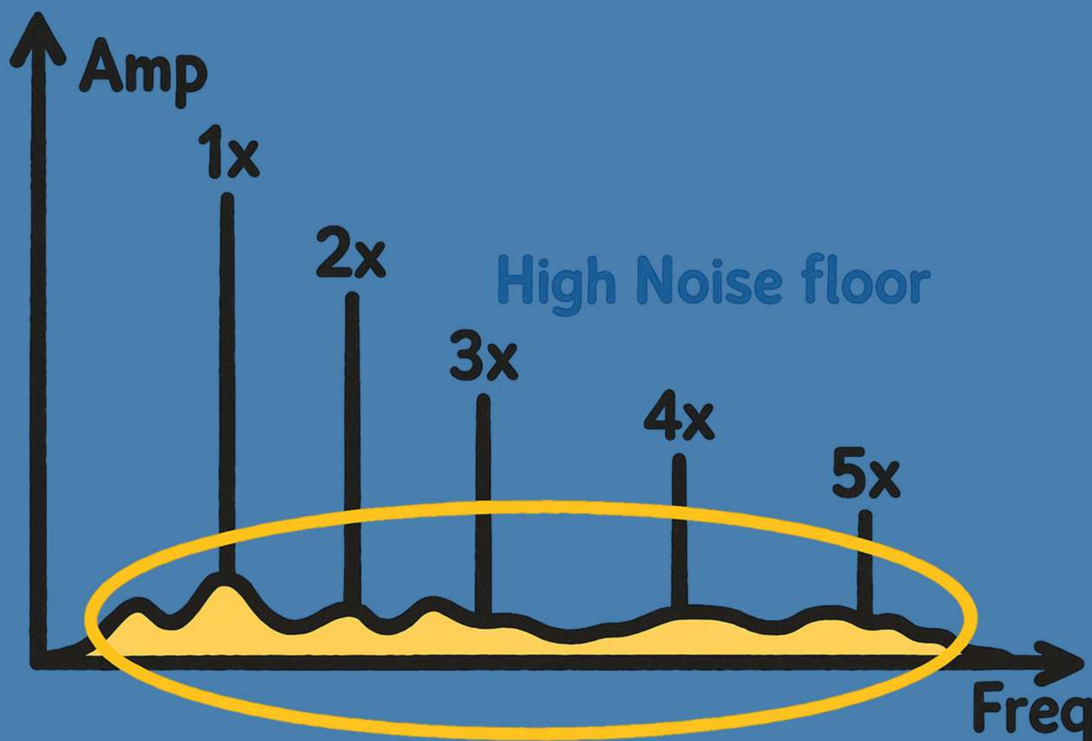


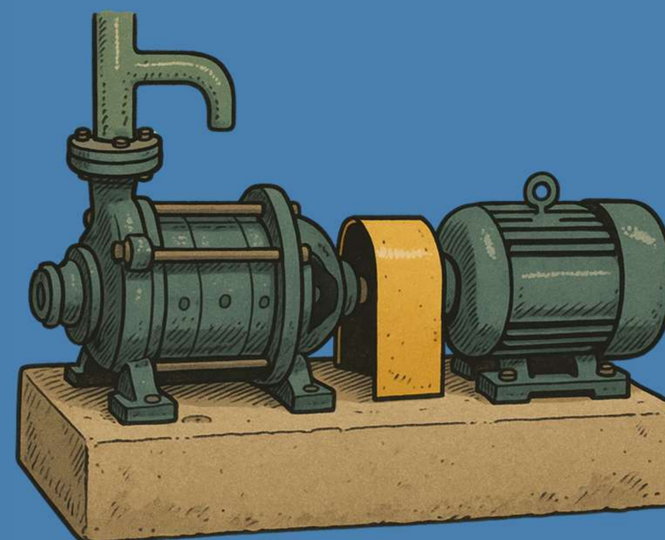
Vibration Spectrum - Side Bands



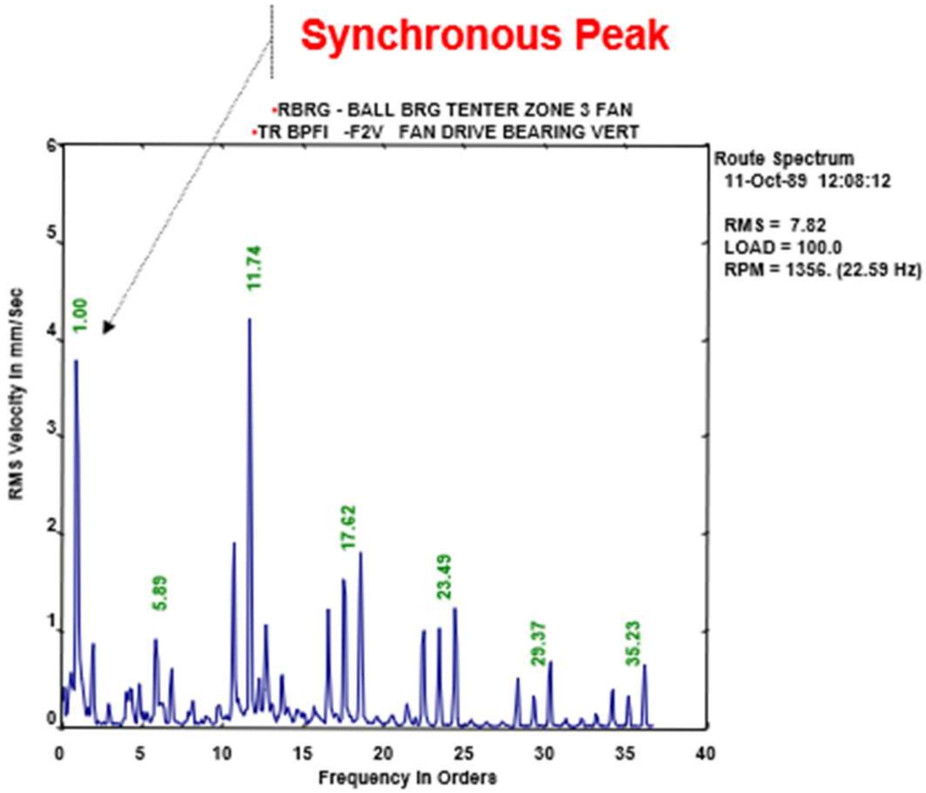


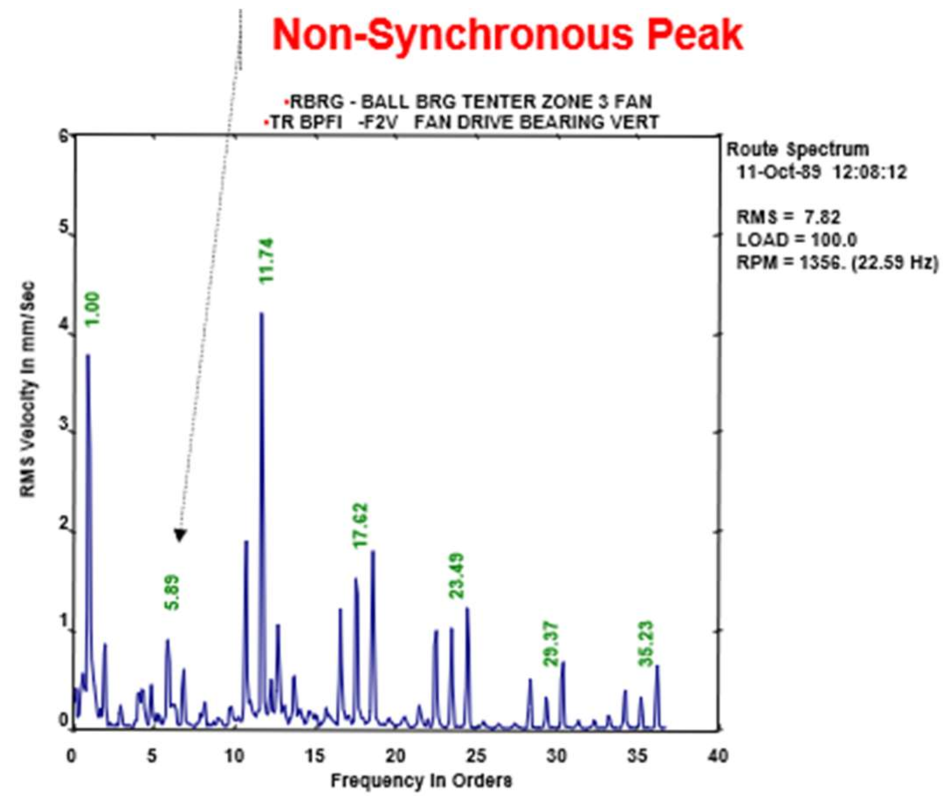
Vibration Spectrum - Noise Floor





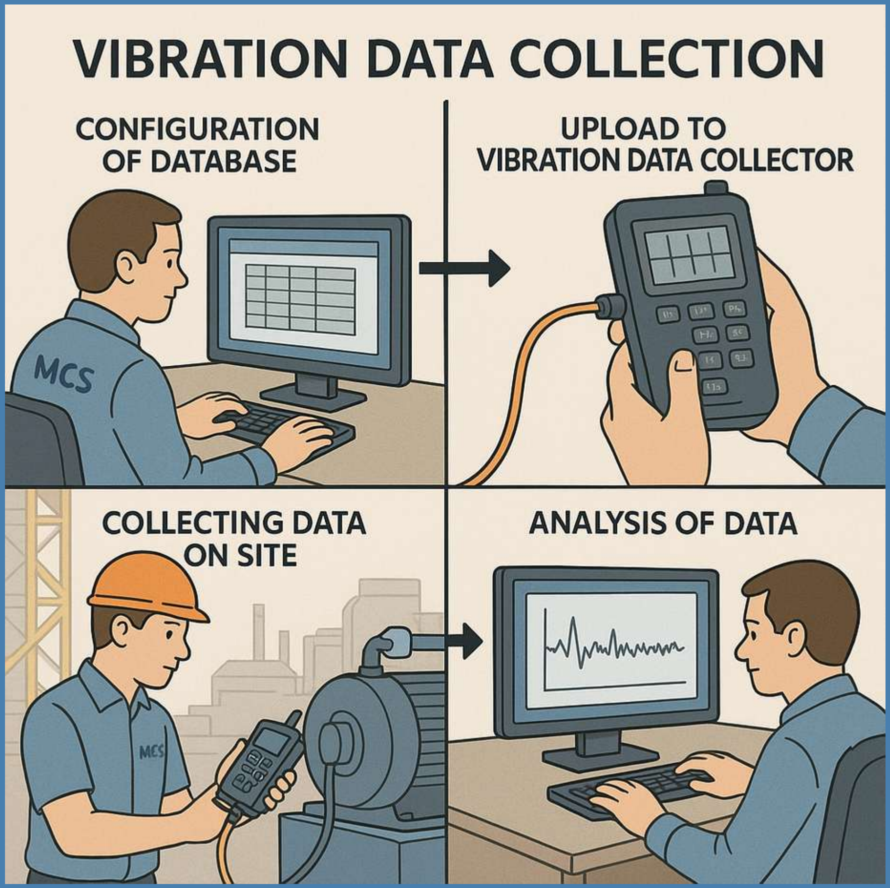
Vibration Spectrum





Vibration Measurement Sesnors & Data Collection

Vibration Data Collection and analysis Procsess



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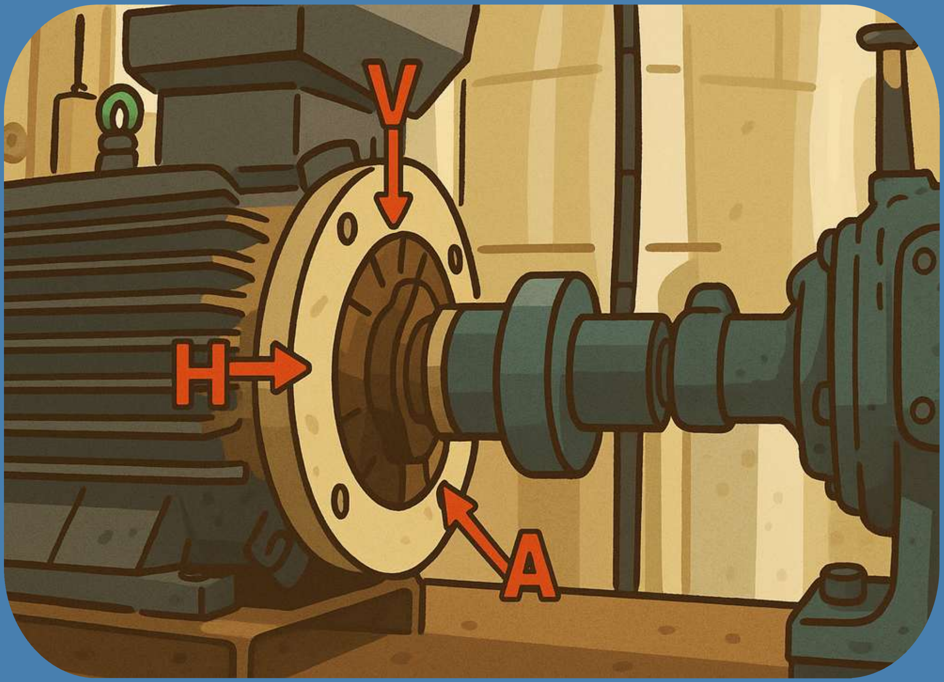
Measuremnt Directions H - V- A

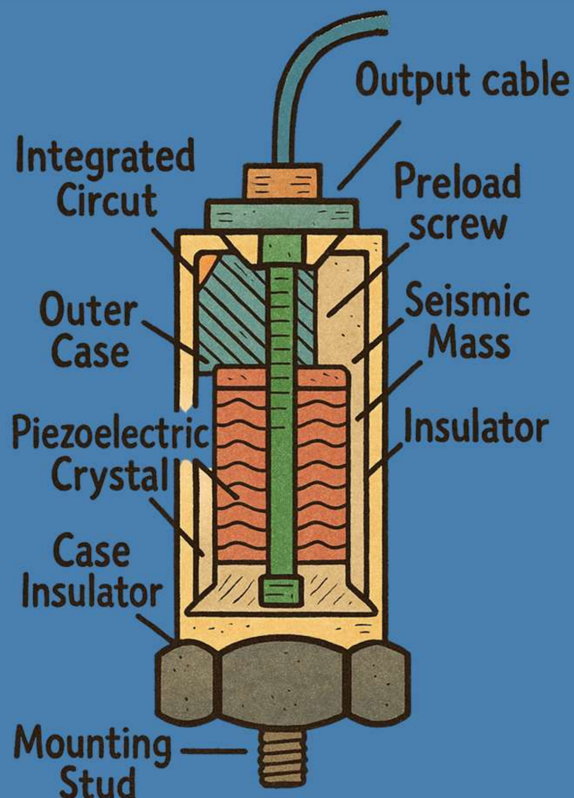
Why we Measuring vibration in the 3 directions ?

The main reason is that the stiffness is not the same in the 3 directions; that’s why the machine vibration response to the forced frequency will not be the same, which is a very important point in machine diagnostics



Vibration Measurement Sesnors & Data Collection

Accelerometers

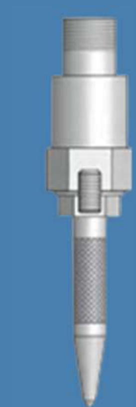


Accelerometer Mounting

Flat Magnet

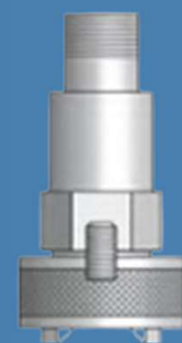
2k-5k HZ

Probe Tip



250-700 HZ

Curved Surface



2000 HZ

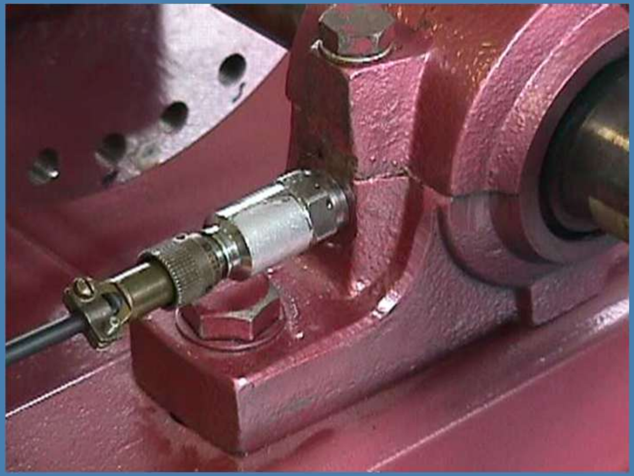
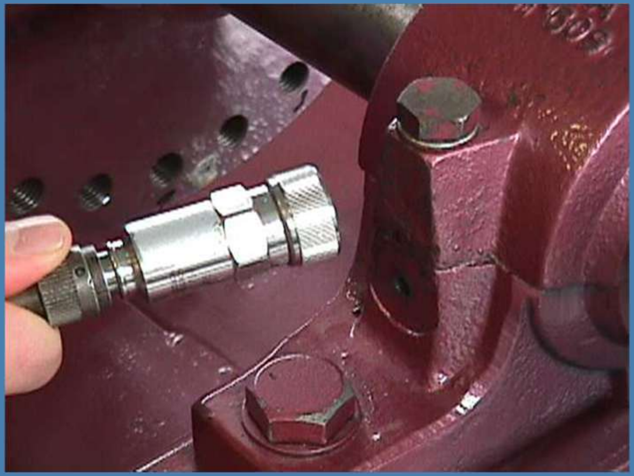
Direct Stud

15k-20k HZ

**Adhesiv
e**

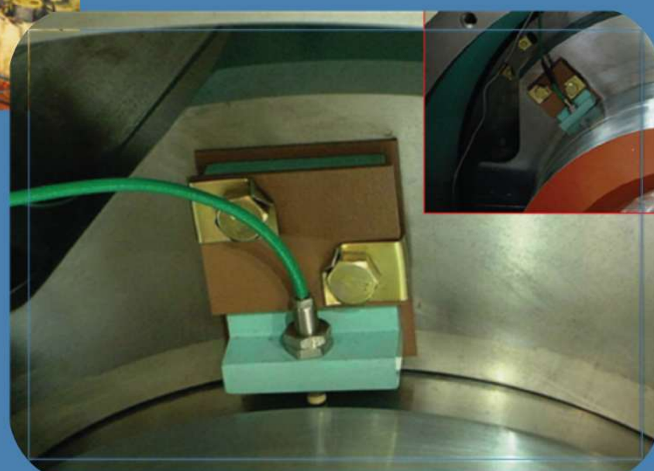
8k-16k HZ

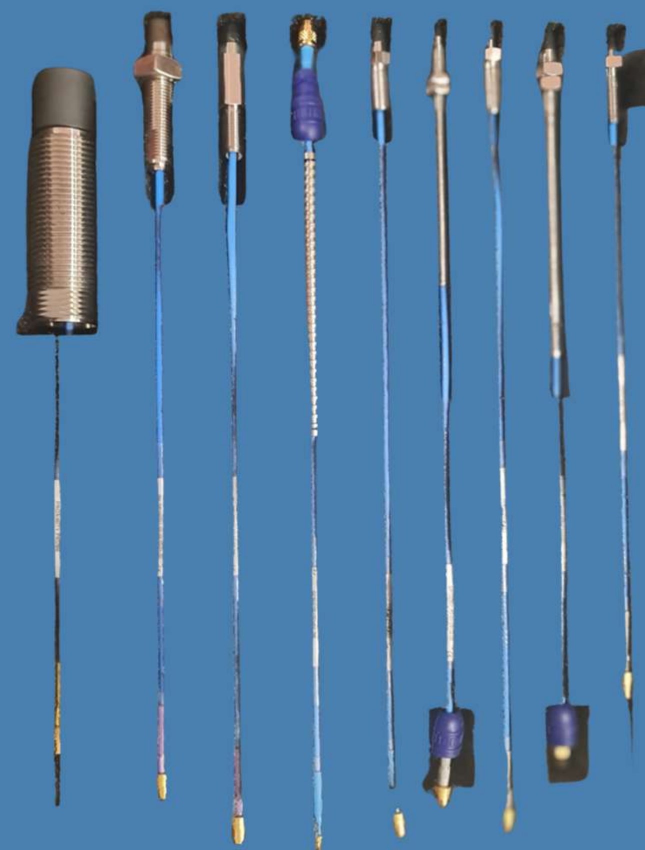
Accelerometer Mounting

Stud Mount	Magnet Mount	Handheld Mount
		

Vibration Measurement Sesnors & Data Collection

Displacment - Proximity Probes



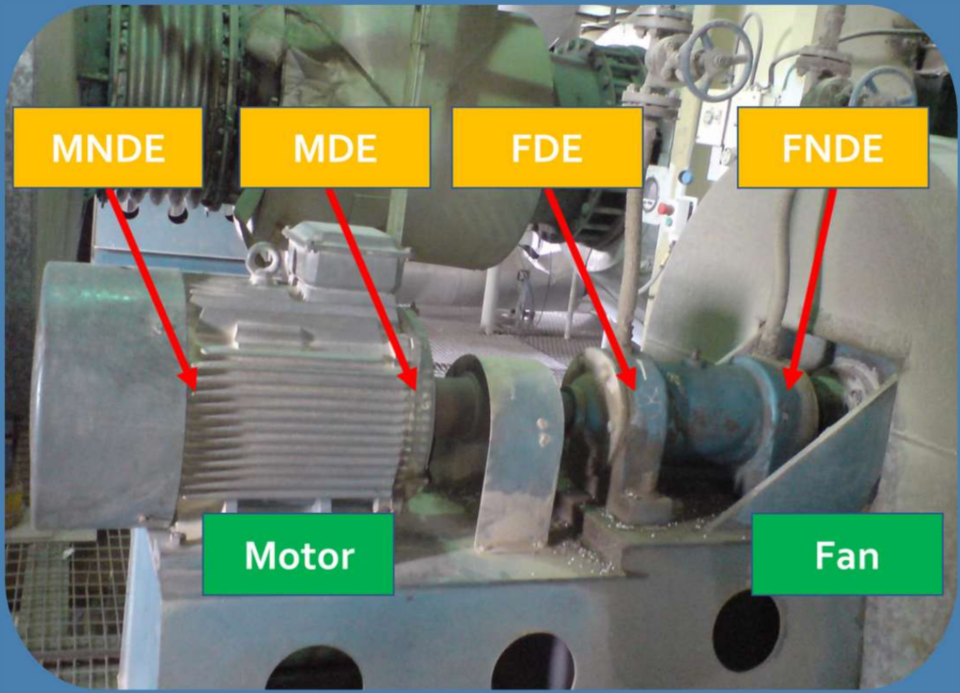


Vibration Measurement Sesnors & Data Collection

Measurement Point Naming

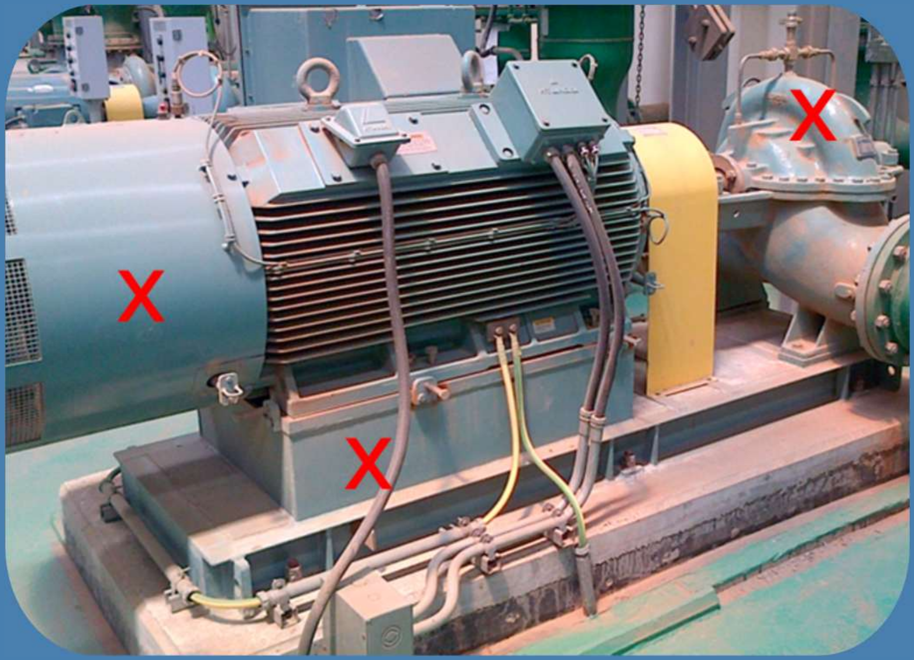
Naming the measurement points:

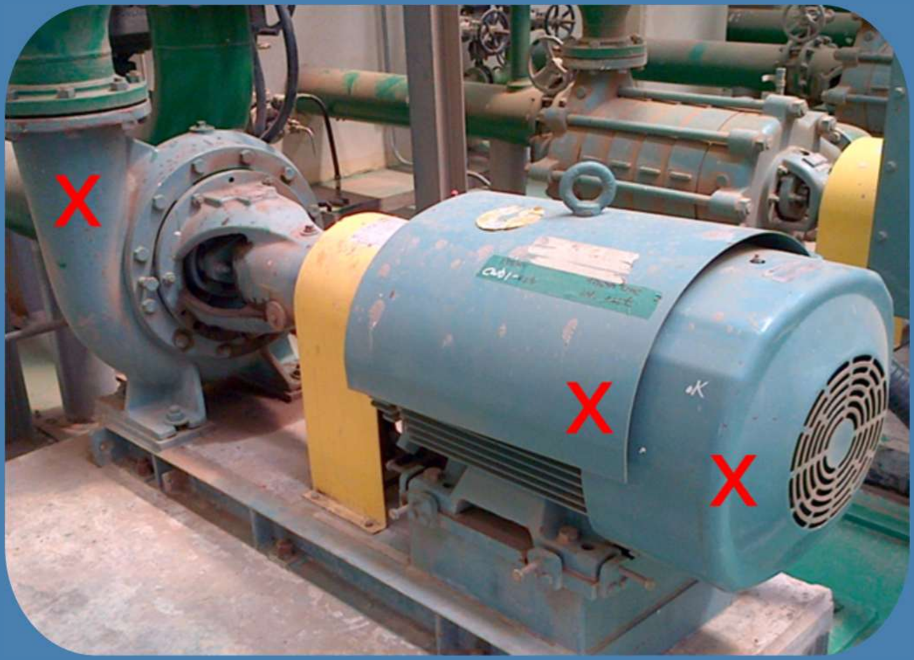
MNDE = Motor non drive end
MDE = Motor drive end
FDE = Fan drive end
FNDE = Fan non drive end



Vibration Measurement Sesnors & Data Collection

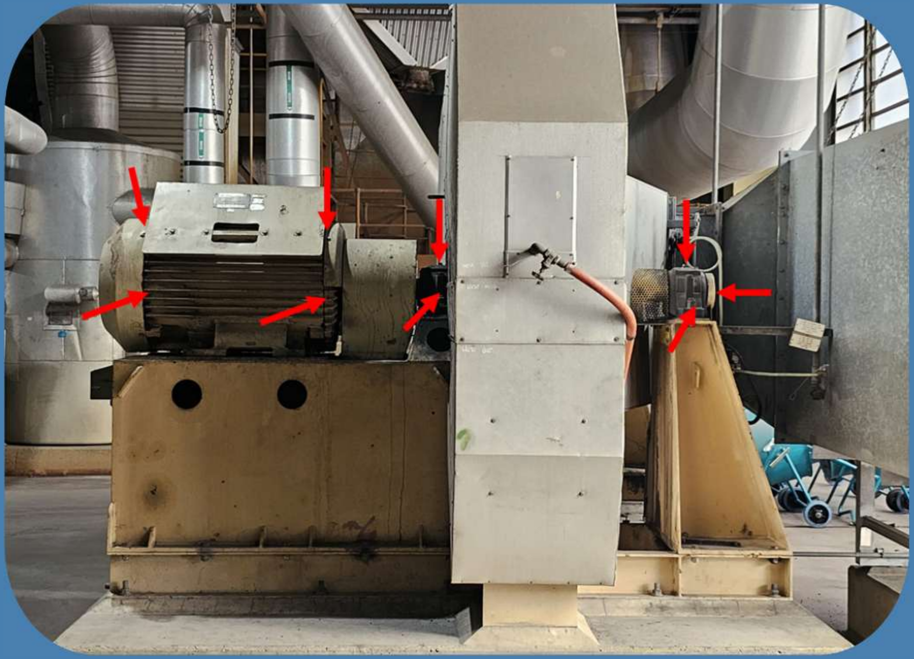
Wrong Measurement Location





Vibration Measurement Sesnors & Data Collection

Measurement Location



Fault Analysis

Unbalance - Fault Analysis

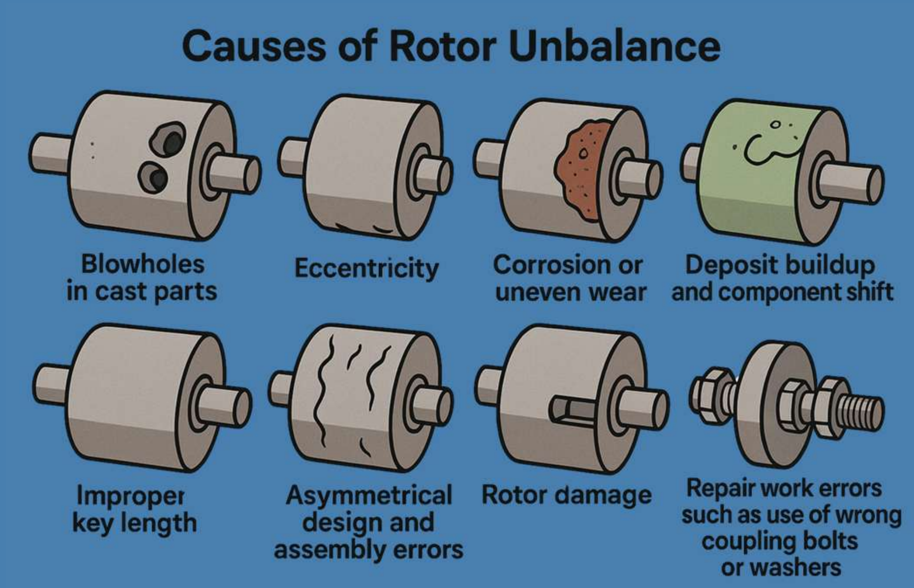
What is Unbalance?

Unbalance occurs when the centre of mass is not aligned with the centre of rotation. This creates a centrifugal force that acts on the rotor, leading to increased wear and vibration. This vibration typically appears at the running speed (1X) with no significant harmonics.
Rotor unbalance is one of the most common faults in rotating machinery and is usually easy to detect and correct.

Unbalance - Fault Analysis

Causes of Rotor Unbalance :

- Blowholes in cast parts
- Eccentricity
- Improper key length
- Stress relief distortion
- Thermal distortion
- Corrosion or uneven wear
- Deposit buildup and component shift
- Asymmetrical design and assembly errors
- Rotor damage
- Repair work errors, such as use of wrong coupling bolts or washers

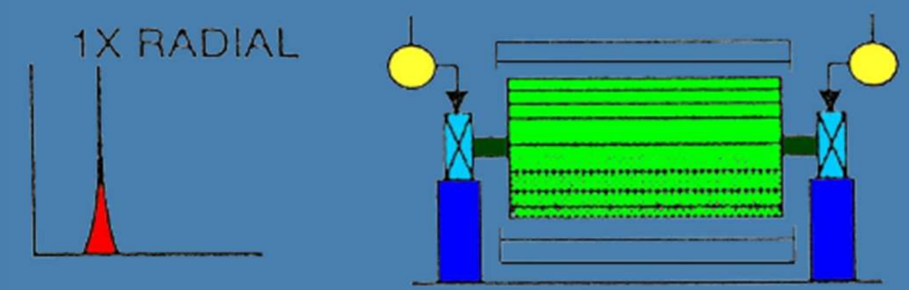


Unbalance - Fault Analysis

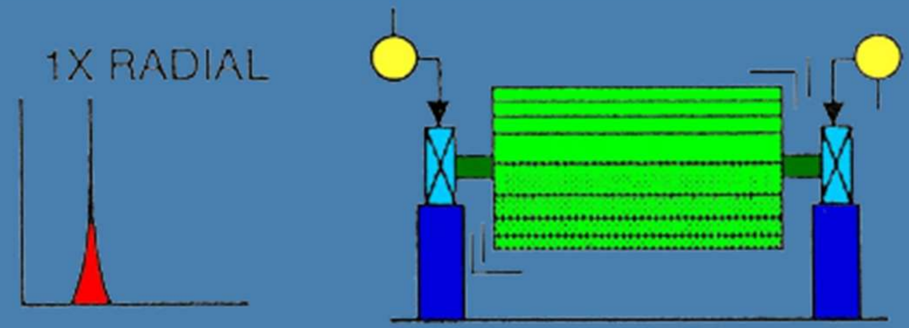
Unbalance

- For all types of unbalance, the spectrum will show a predominant 1X frequency of vibration. Vibration amplitude at the 1X frequency will vary proportional to the square of the rotational speed.
- Balance requires correction in one plane for static unbalance and two planes for couple unbalance.
- Vibration levels in the horizontal direction will be twice that of the vertical direction.

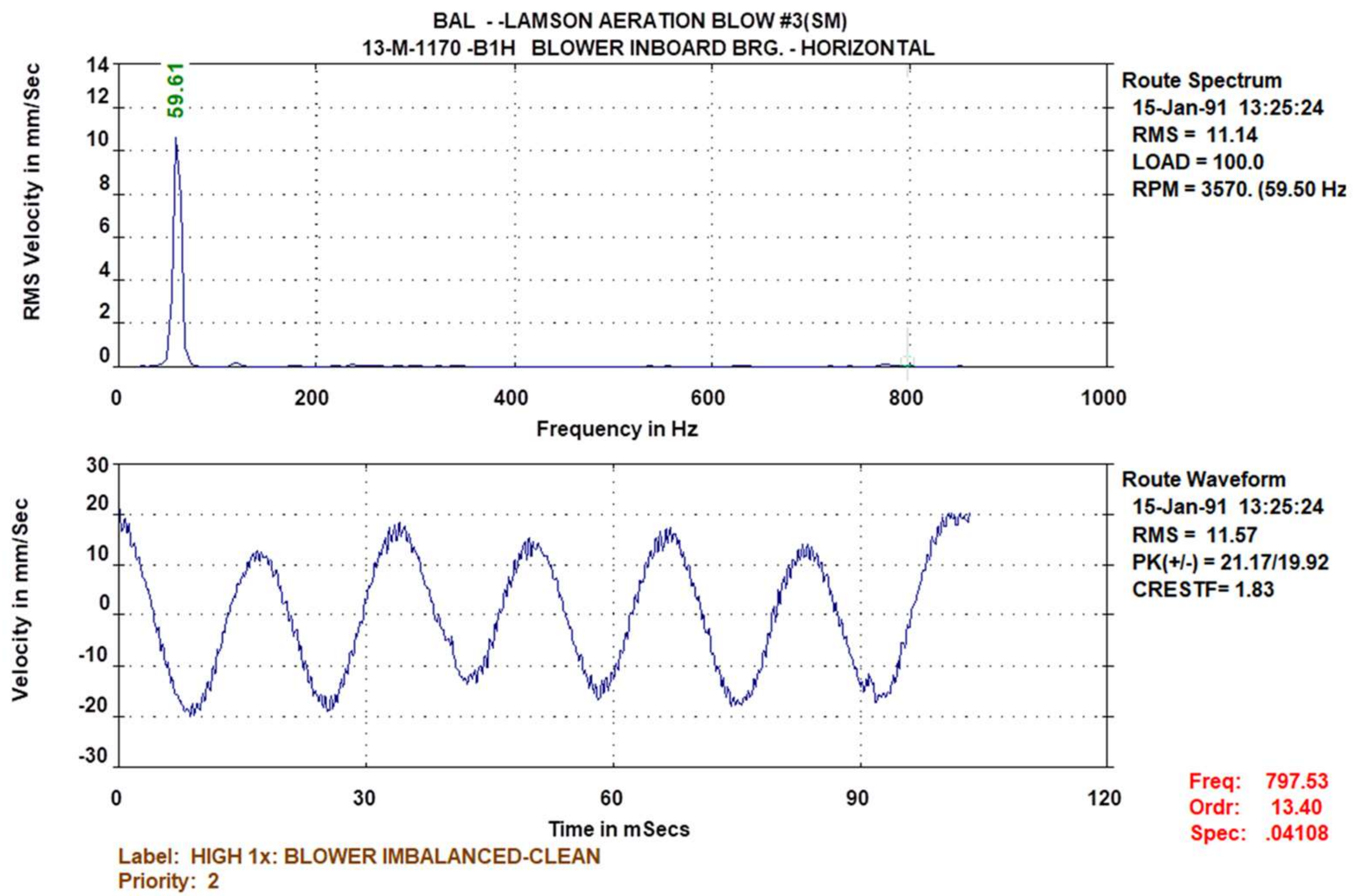
Static Unbalance



Couple Unbalance



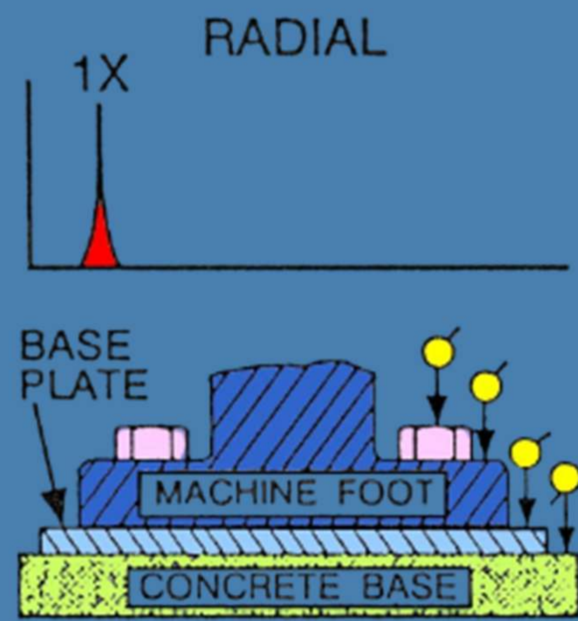
Unbalance - Fault Analysis



Structure Looseness - Fault Analysis

Structural looseness

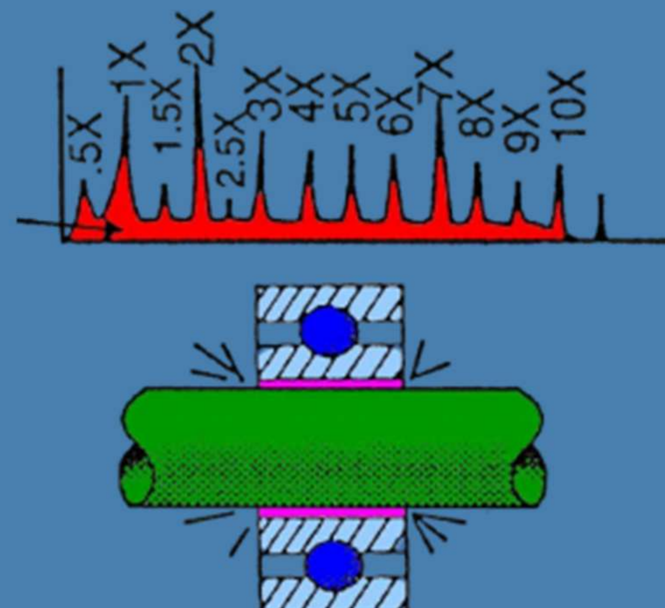
- Structural looseness will show in the vibration spectrum at the running speed component 1X with high amplitude in the horizontal direction compared to the vertical direction.
- Structural looseness caused by base or foundation flexibility or loose hold-down bolts, corrosion, or cracks on the foundation.
- Out of phase 180 degrees between the moving and the stationary part as a result of Structural looseness or cracks.



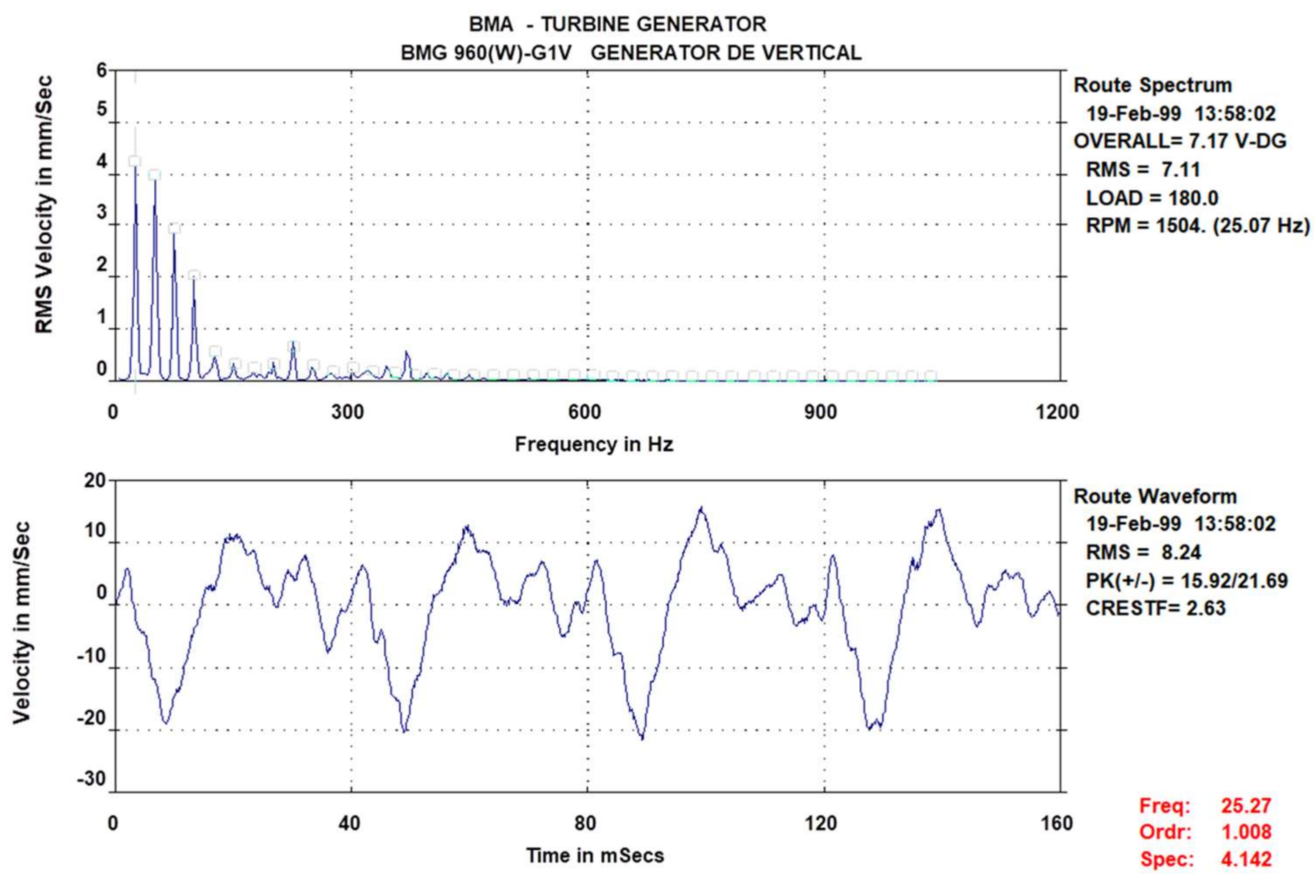
Structure Looseness - Fault Analysis

Rotating Looseness - Fault Analysis

- Looseness is caused by improper fit between parts, leading to multiple harmonics and a high noise floor in the vibration spectrum.
- It’s often due to loose bearings, excessive clearances, or rotating components shifting on shafts
- The phase is often unstable
- Will have many harmonics
- Can be caused by a loose bearing liner, excessive bearing clearance or a loose impeller on a shaft



Rotating Looseness - Fault Analysis



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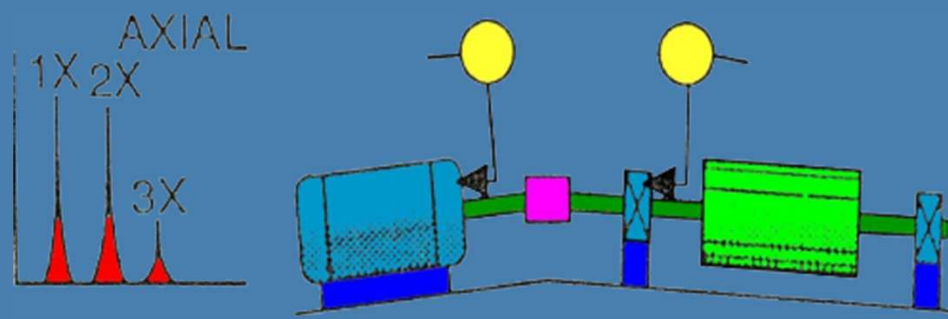
Misalignment - Fault Analysis

Misalignment

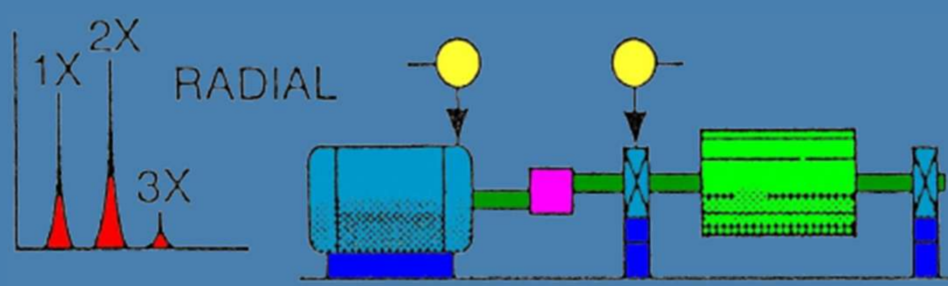
Misalignment will generally result in elevated vibration amplitude due to load transfer from one bearing to an adjacent bearing. The increase will show up as higher amplitude at 1X and 2X in spectrum plots, with 2X amplitude reaching or exceeding 1X amplitude as the severity of the misalignment increases.

The misalignment may be coupling, or internal misalignment caused by improper bearing elevations.

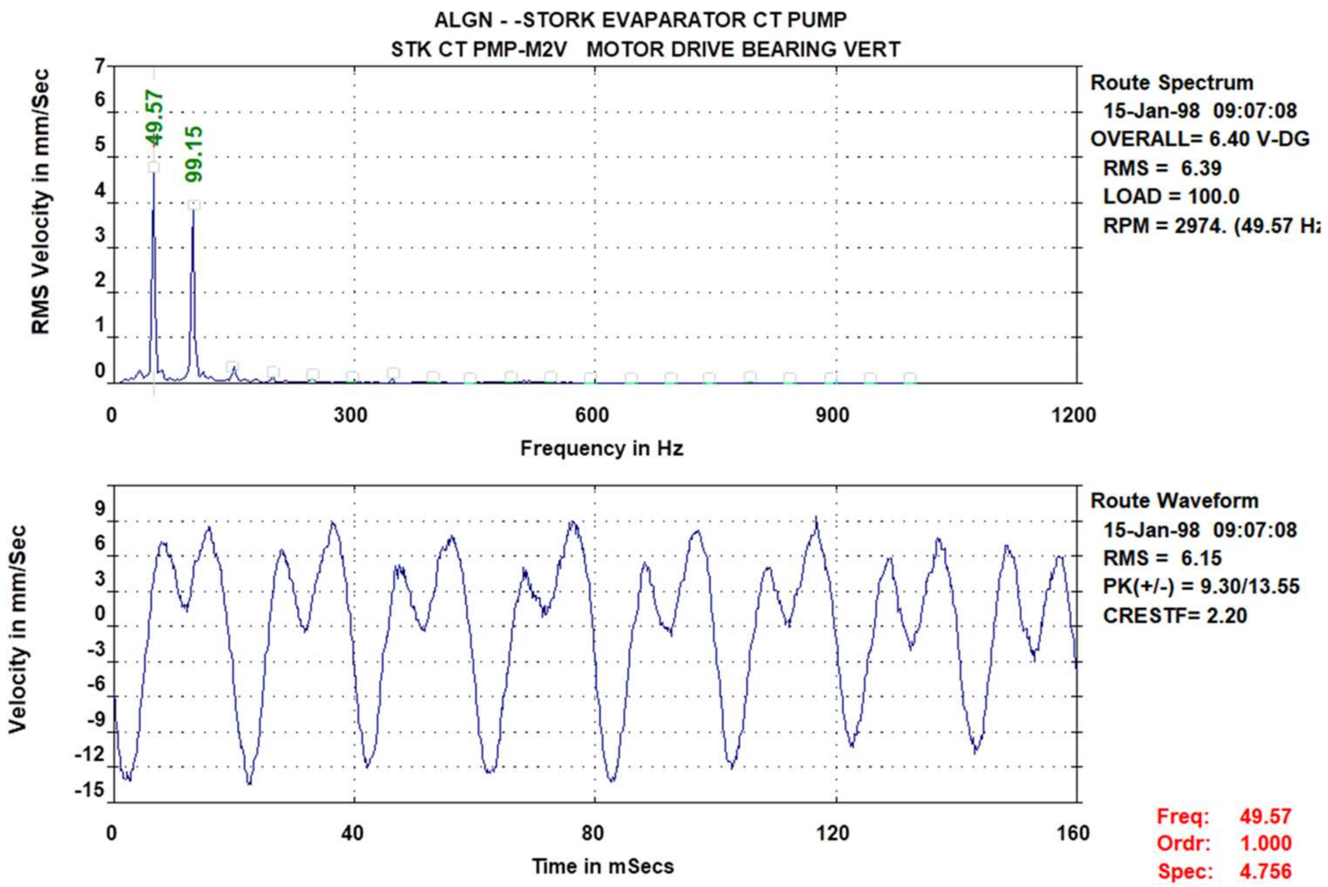
Angular



Offset



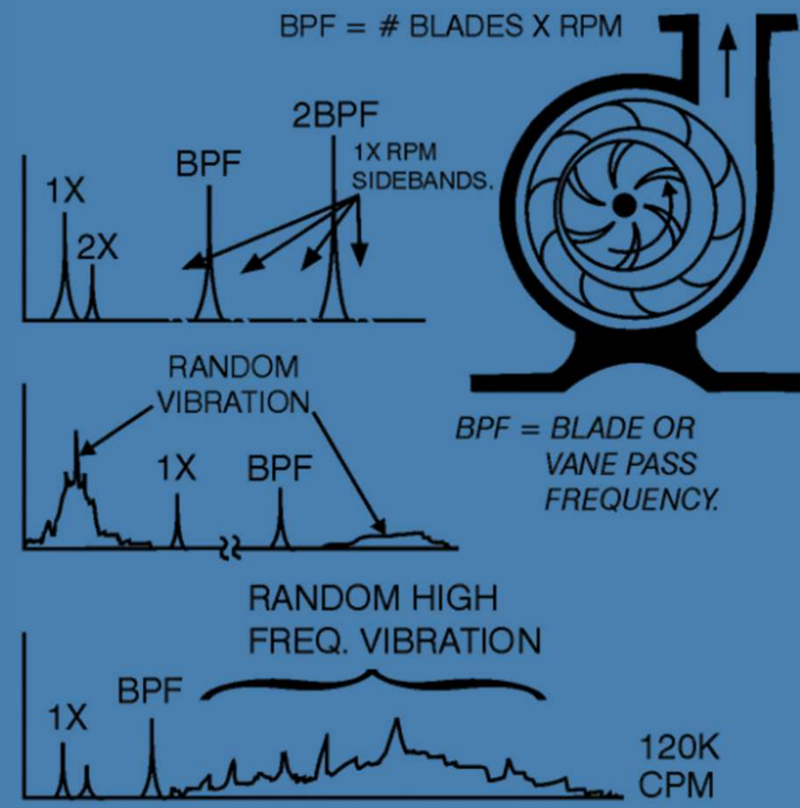
Misalignment - Fault Analysis



Pump, Compressor, and Fans - Fault Analysis

Flow Problems Summary

- **Blade Pass Frequency (BPF):** Normal in pumps/fans, but high BPF may indicate wear, misalignment, or flow obstructions.
- **Flow Turbulence:** Caused by pressure/velocity changes. Leads to random low-frequency or broadband vibration.
- **Cavitation:** Caused by low suction pressure. Produces high-frequency vibration and can damage impellers.



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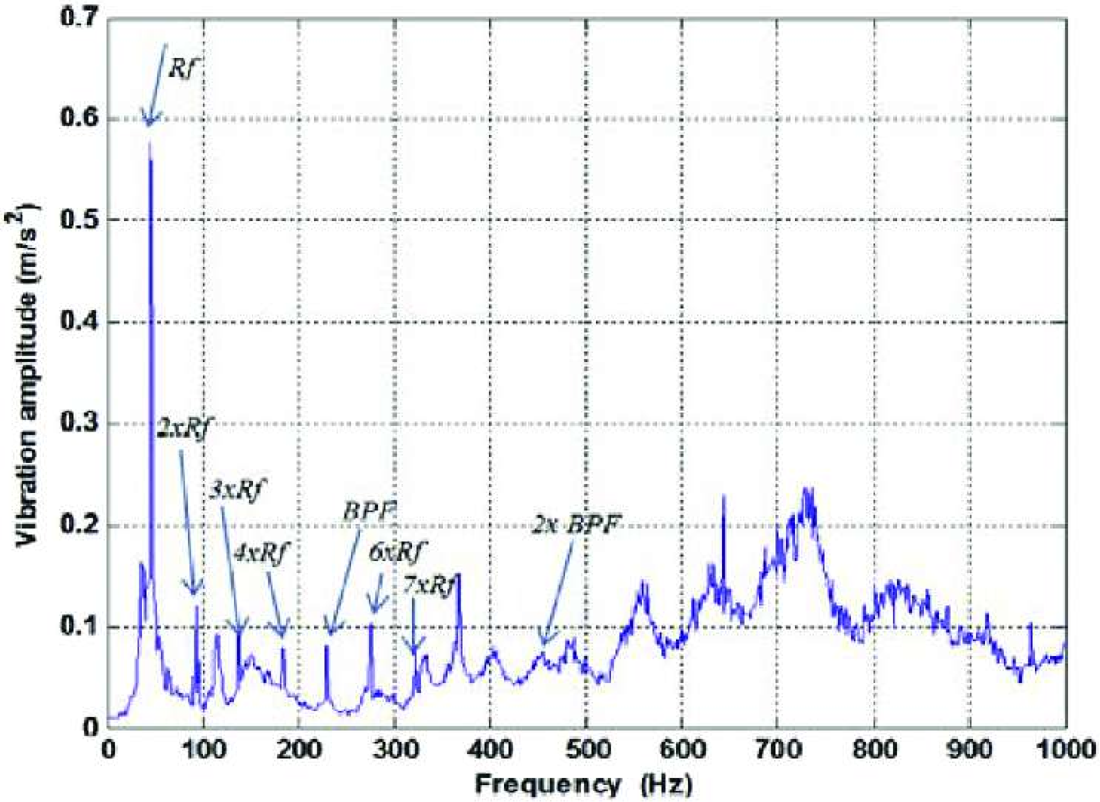
Pump, Compressor, and Fans - Fault Analysis

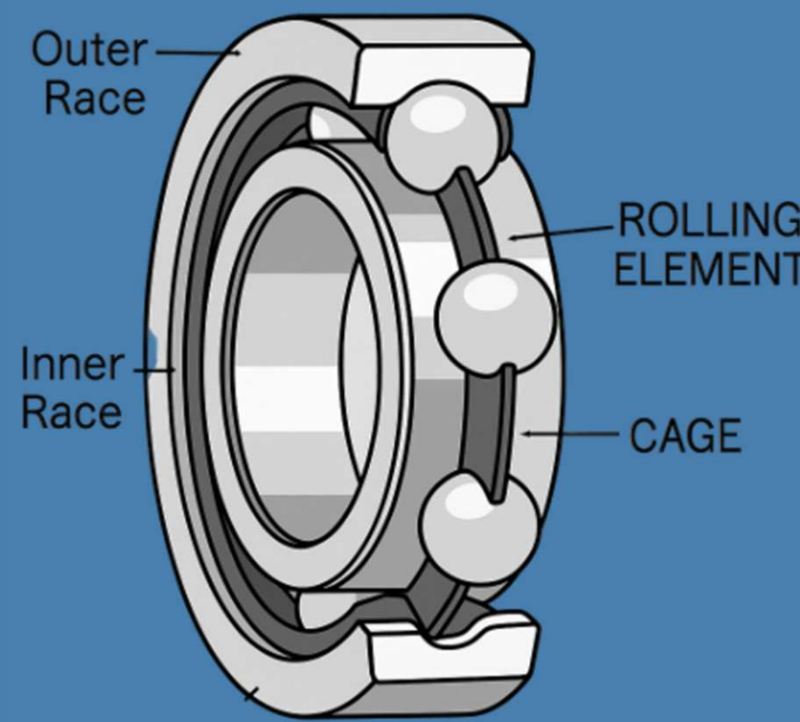
Cavitation



Bearings - Fault Analysis

Vibration analysis for bearings is a technique used to detect early signs of wear and failure in rotating machinery. It monitors vibration signals to identify bearing-specific fault frequencies related to the inner race, outer race, rolling elements, and cage.

By analyzing time waveforms, spectra, and high-frequency envelope data, it can detect defects such as spalling, cracking, or lubrication issues. The method helps track defect progression through various stages.



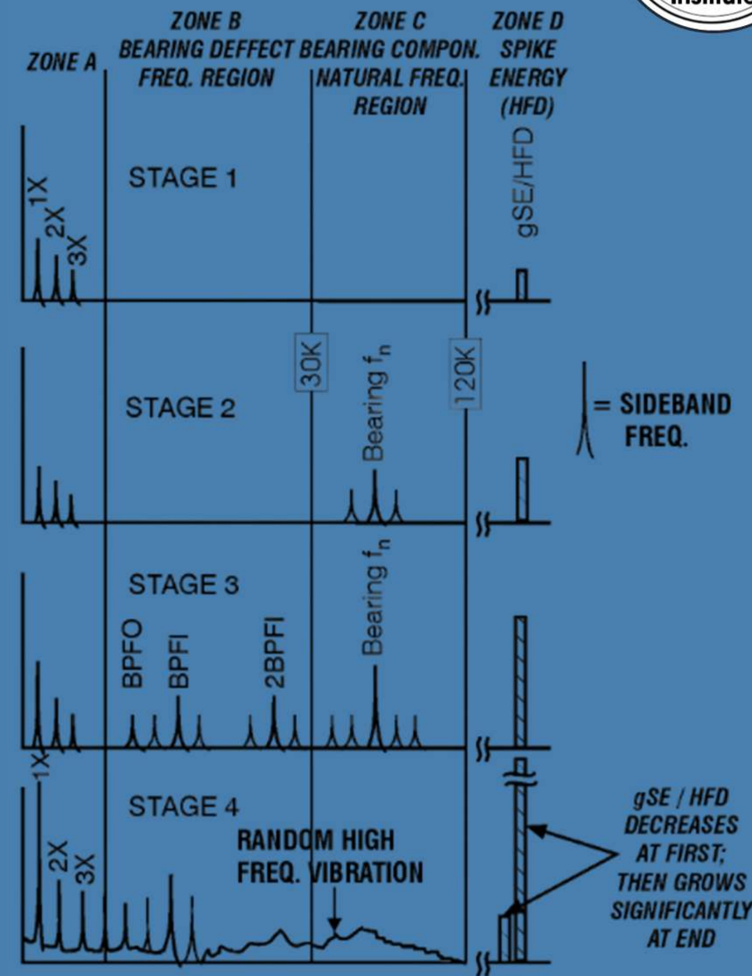
Bearings - Fault Analysis

Stage 1: Early fault signs appear in ultrasonic range (250k–350k Hz) as minor spike energy (~0.25 gSE).

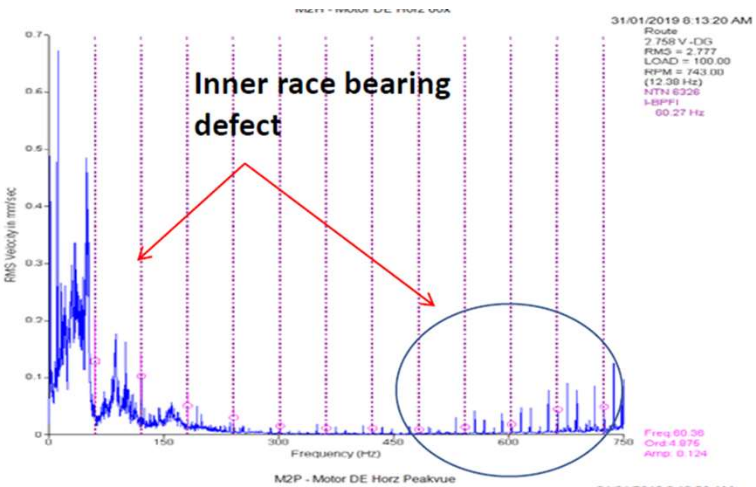
Stage 2: Bearing natural frequencies start to "ring" (30k–120k CPM); sidebands and spike energy increase.

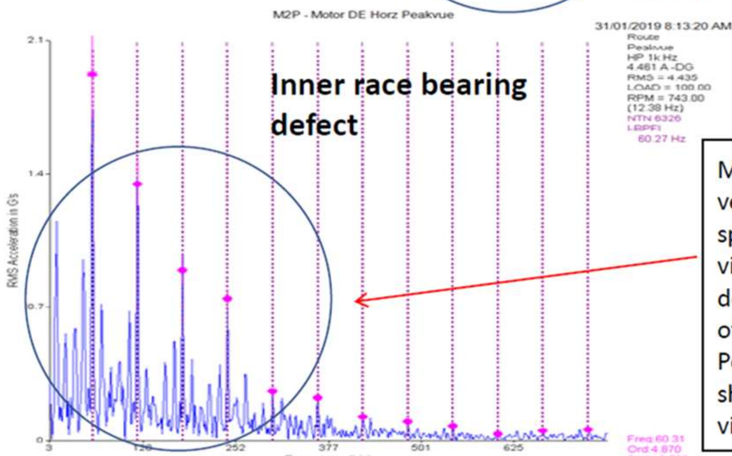
Stage 3: Defect frequencies and harmonics develop with clear sidebands; wear is often visible.

Stage 4: Advanced damage leads to high 1X RPM vibration, broad harmonics, and strong random noise.

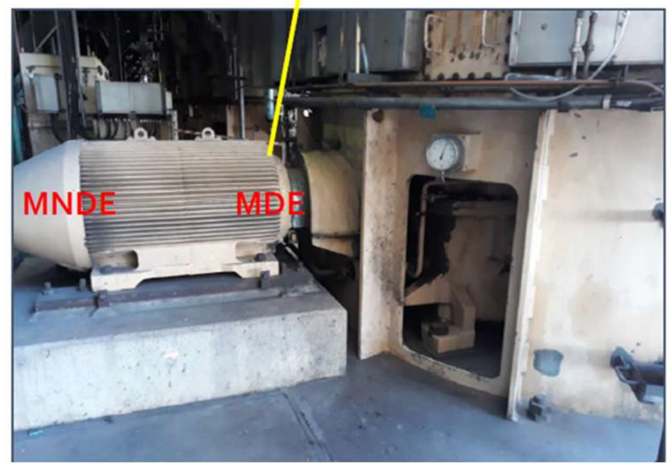


Bearings - Fault Analysis





Motor drive end bearing velocity and the Peakvue spectrum showed elevated vibration at the inner race defect frequency indicative of bearing fault, the Peakvue vibration trend showed increase on vibration levels up to 2.1 g's



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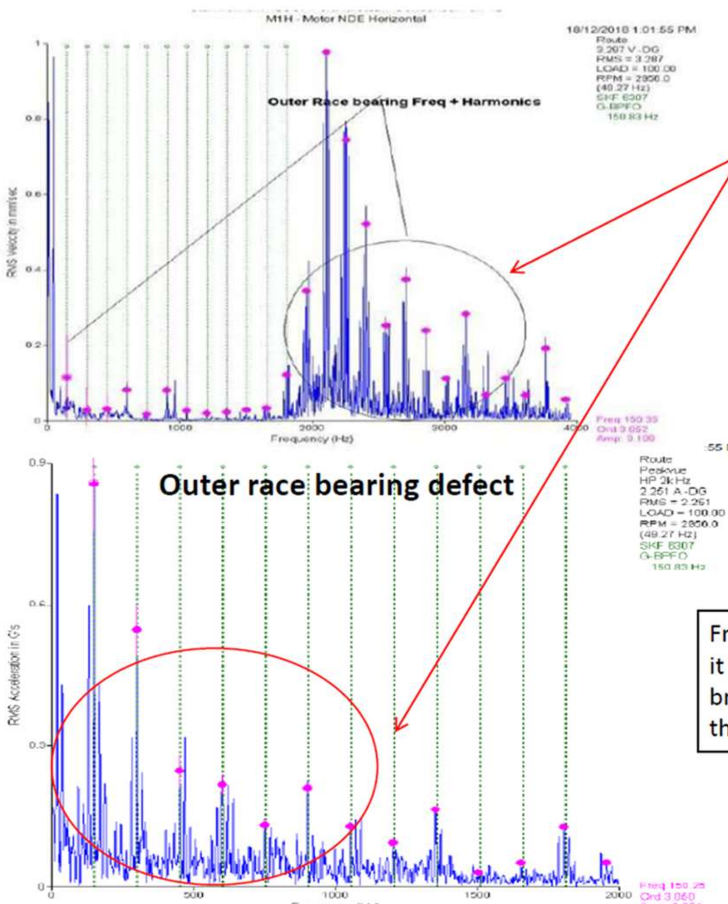
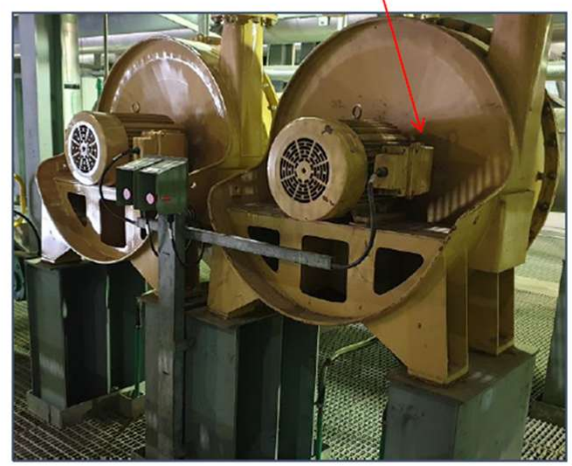
Bearings - Fault Analysis



Both Motor drive end bearing velocity and the Peakvue spectrum showed elevated vibration at the outer race defect frequency indicative of bearing fault.

From bearing inspection it was found that false brinelling is root cause of the failure



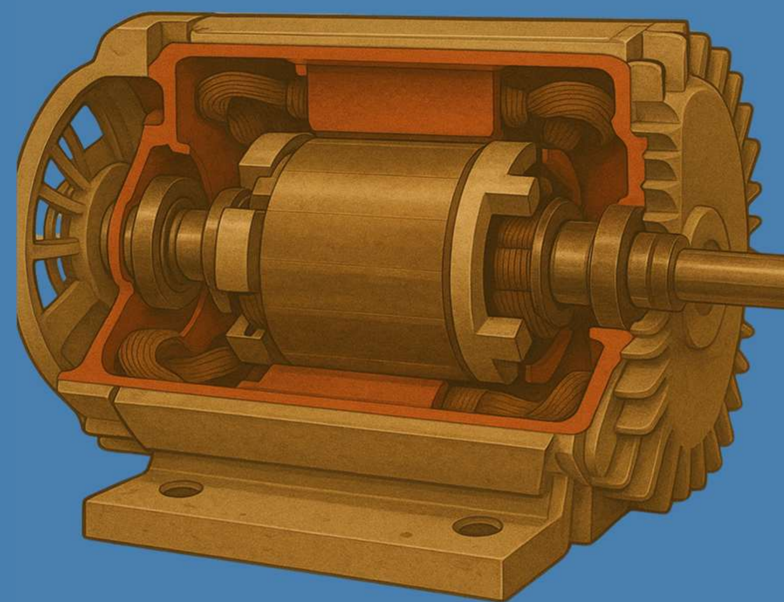
Electrical Motors- Fault Analysis

Vibration analysis helps detect mechanical and electrical faults in electric motors without stopping operation.

It identifies issues like stator short, eccentricity, soft foot and rotor bar problems

Analysing spectrum and time waveform data reveals fault signatures and severity.

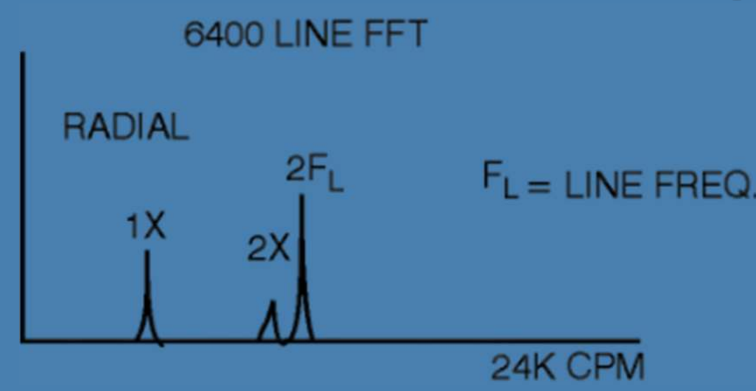
Regular monitoring extends motor life and prevents unexpected failures.



Electrical Motors- Fault Analysis

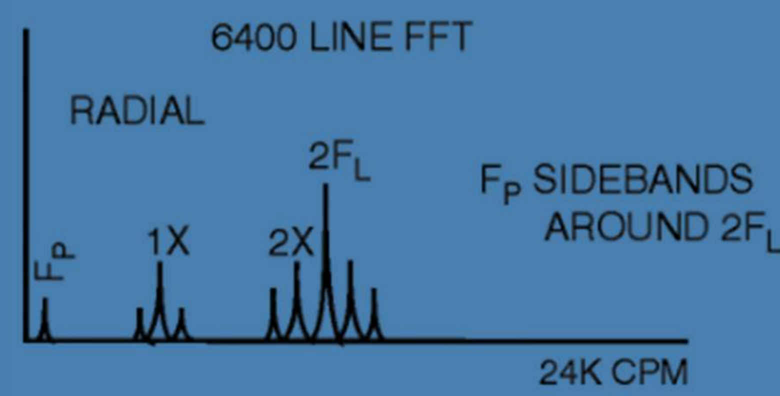
Stator Eccentricty:

- Stator issues cause high vibration at 2X line frequency due to uneven air gaps and directional forces.
- Problems like soft foot, loose iron, and shorted laminations can distort the stator and worsen over time

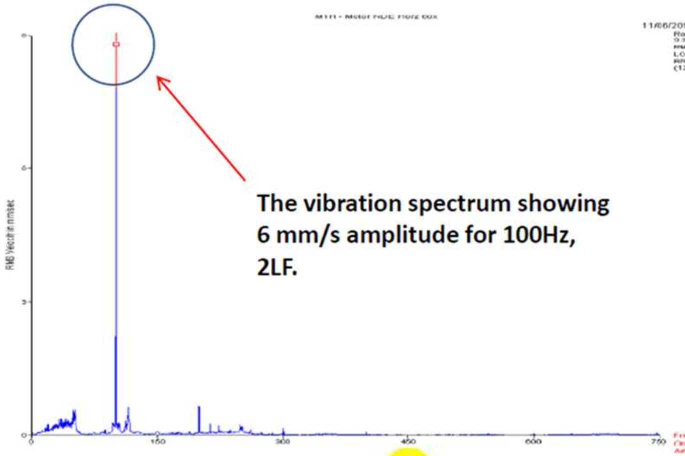


Rotor Eccentricity:

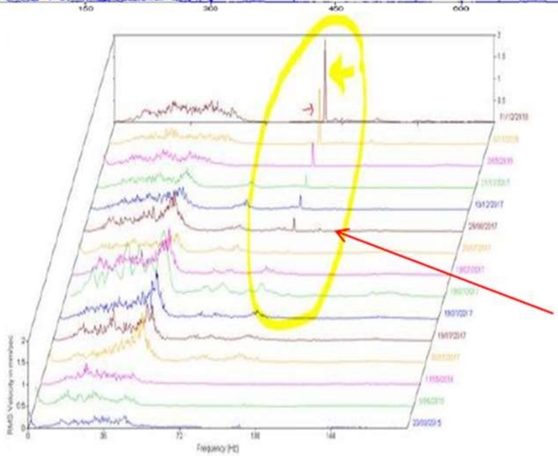
- Eccentric rotors cause a rotating variable air gap, leading to pulsating vibration near 2× line frequency and running speed.
- Twice Line Frequcney with Side bands at PPF (Pole passing frequcney)



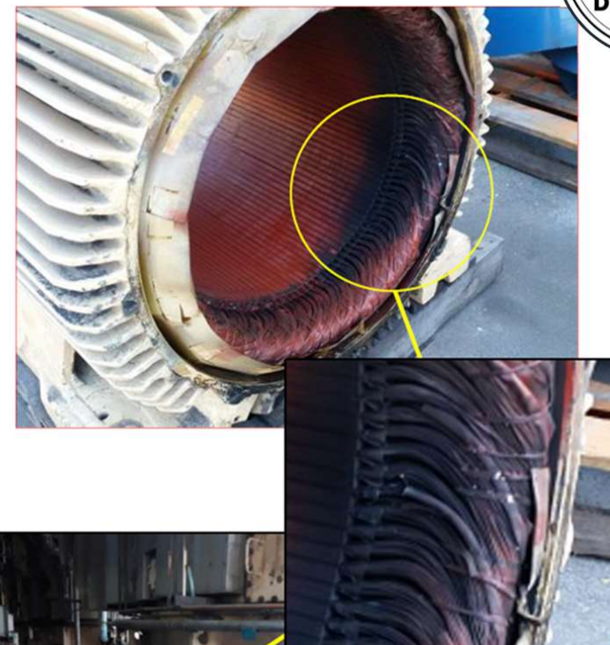
Electrical Motors- Fault Analysis

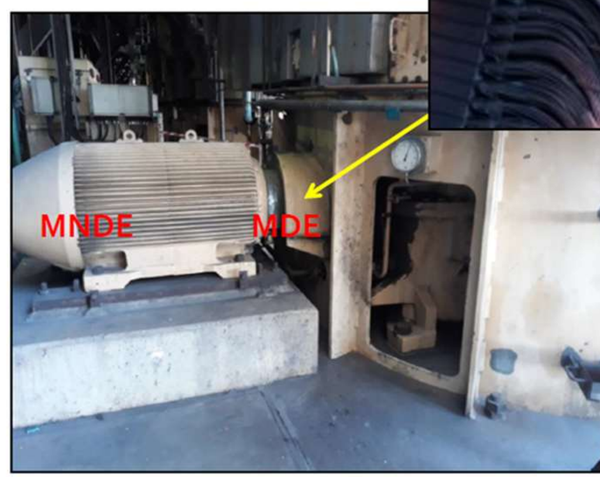


Condition considered marginal and immediate inspection advisedWork order raised to check the motor for electrical problem and check Motor for soft foot and correct if required also re-check coupling alignment and soft foot correction Check incomer connections are secure. Check phase balance/voltages within 5% differential.



During the last 6 month that motor showed elevated vibration at 100Hz on Motor (2LF), with highest amplitudes in Horiz plane.
Possible causes include rotor eccentricity, stator eccentricity.





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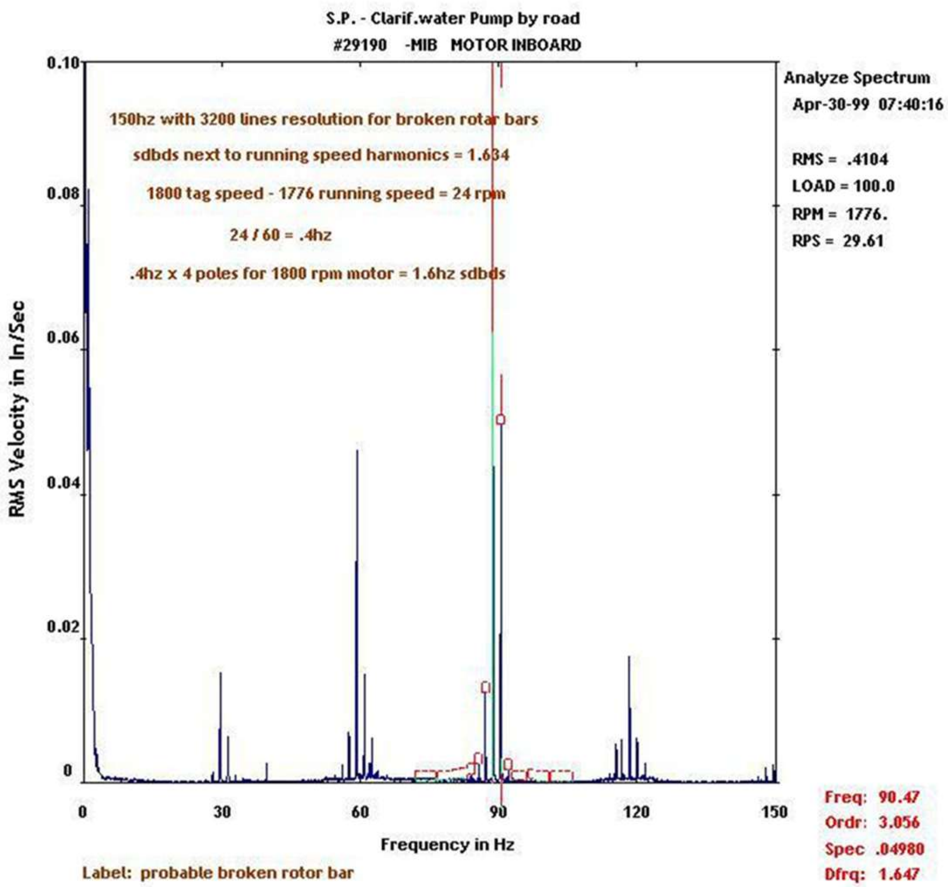
Electrical Motors- Fault Analysis



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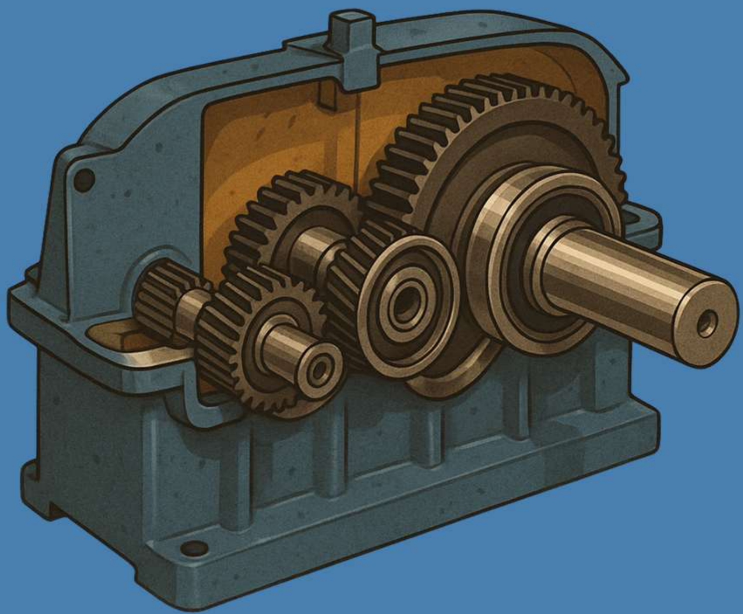
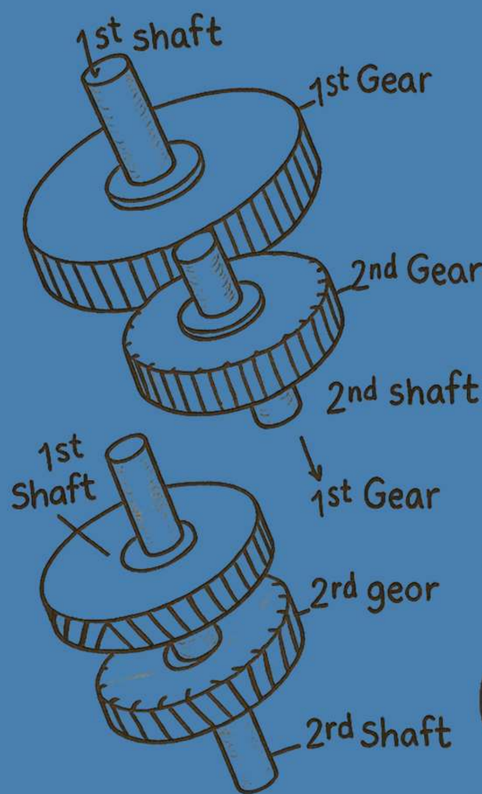
Gearbox- Fault Analysis

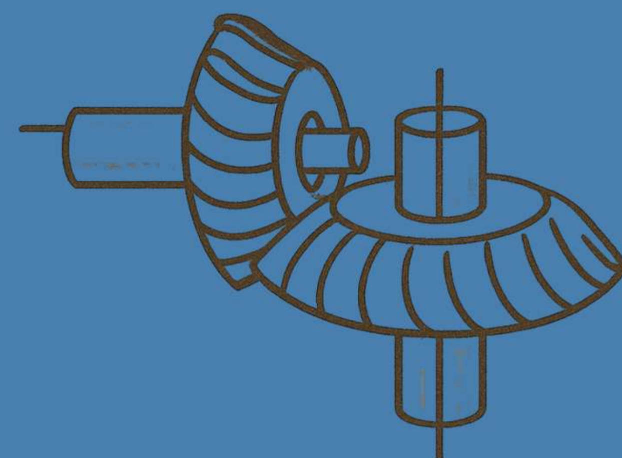
All gear sets create a frequency component referred to as gear mesh. The fundamental gearmesh frequency is equal to the number of gear teeth times the running speed of the shaft.

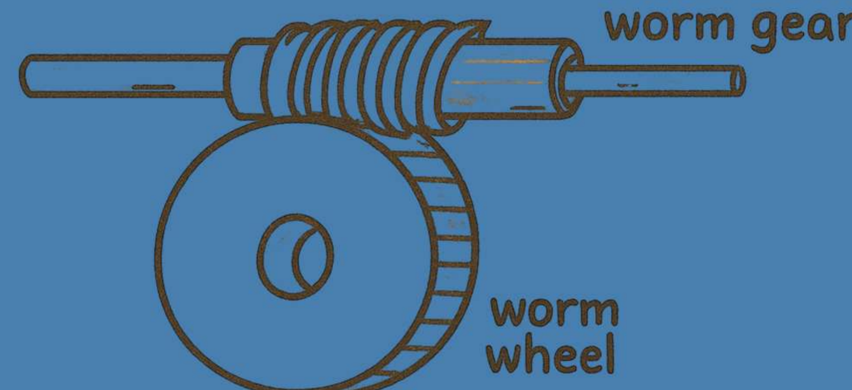
In addition, all gear sets create a series of sidebands or modulations that are visible on both sides of the primary gear-mesh frequency.



Gearbox- Fault Analysis



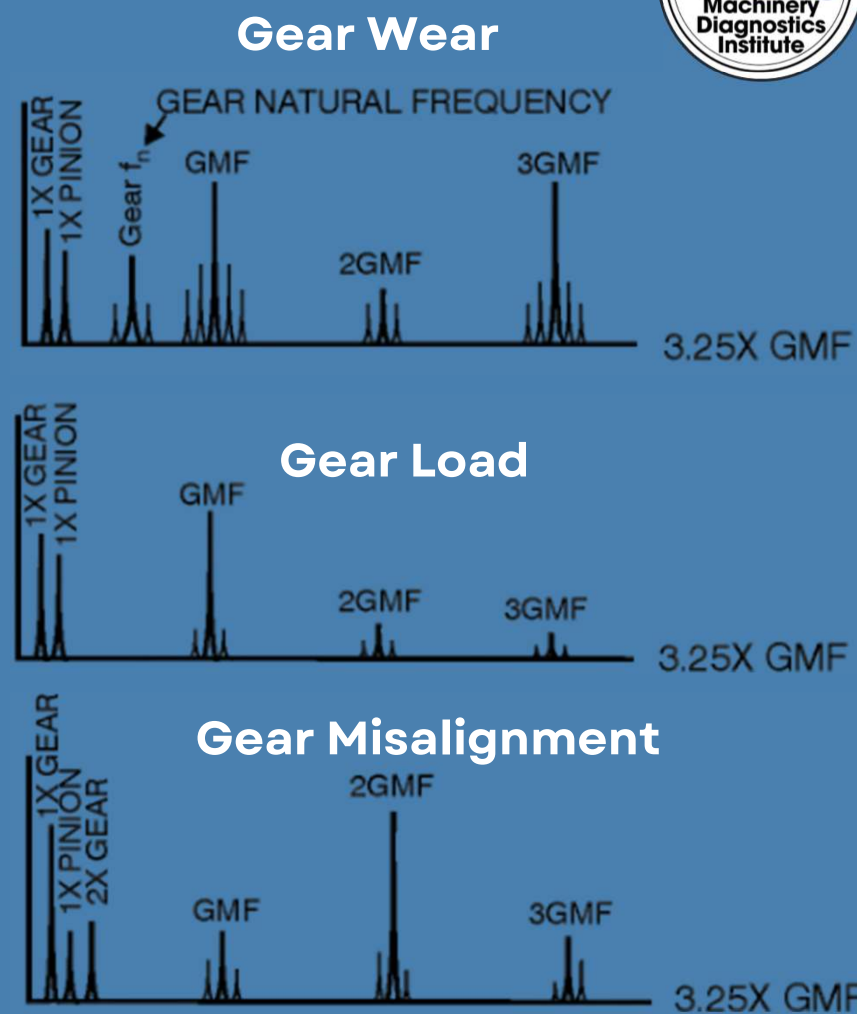




Gearbox- Fault Analysis

Gearbox Faults:

- Gear mesh frequency is the number of gear teeth multiplied by the shaft's running speed.
- All gear sets produce symmetrical sidebands around the gear mesh frequency.
- These sidebands are spaced by 1X input shaft speed and occur in equal pairs above and below the GMF.
- A cracked or broken tooth will generate high-amplitude impacts in the TWF - Time Waveform.



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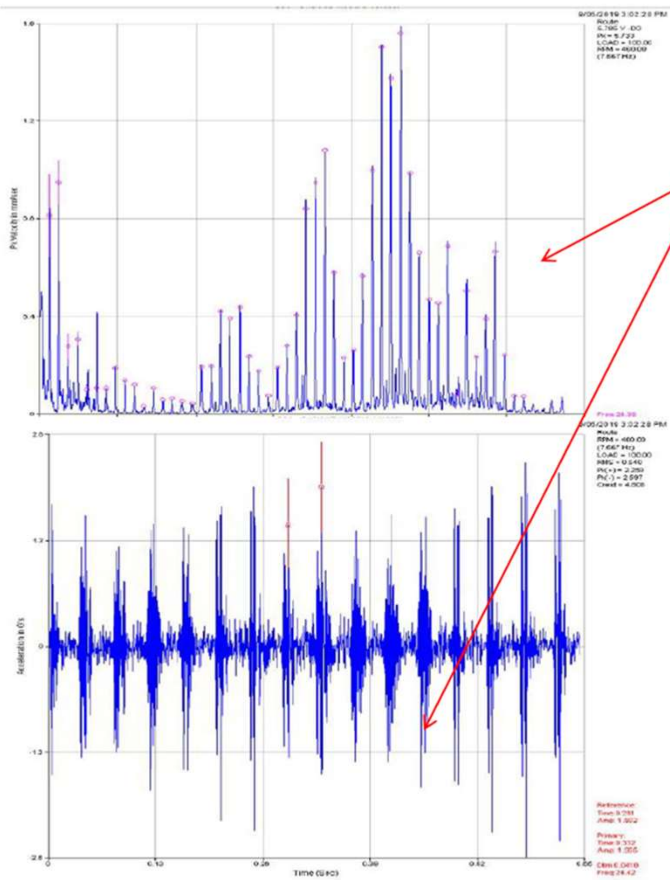
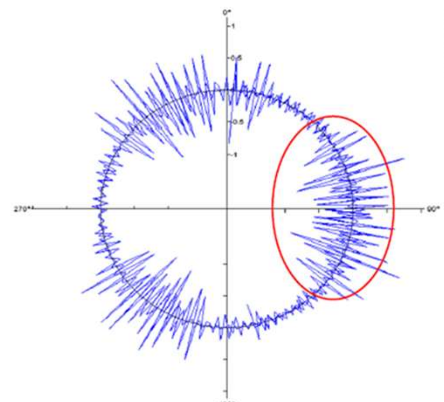
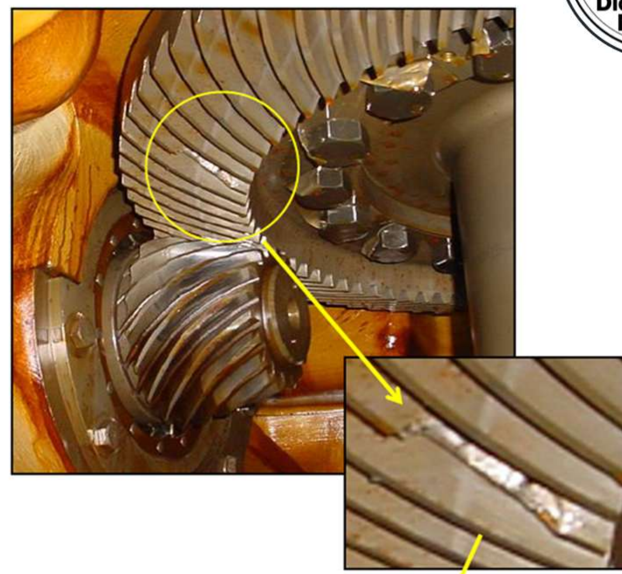
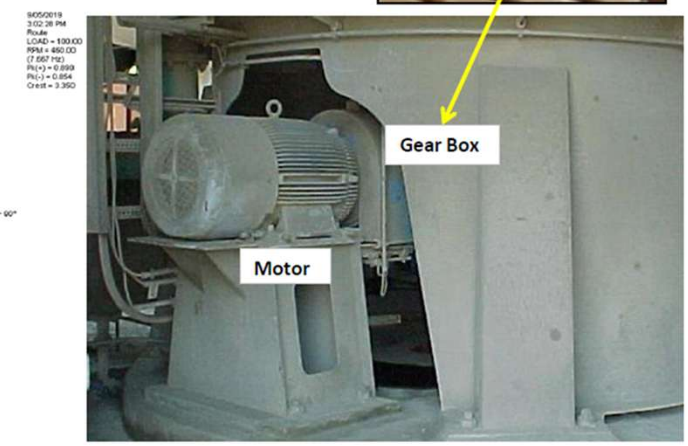
Gearbox- Fault Analysis



Gear box bearing spectrum showing elevated vibration at the running speed with harmonics in addition to high amplitude impacting vibration at the time wave form at the running speed indicative of cracked or broken gear teeth







Severity and ISO Standards

VIBRATION SEVERITY PER ISO 10816

Vibration Velocity Vrms in/s	Vibration Velocity Vrms mm/s	Class I small machines	Class II medium machines	Class III large rigid foundation	Class IV large soft foundation
0.01	0.28	good	good	good	good
0.02	0.45	good	good	good	good
0.03	0.71	good	good	good	good
0.04	1.12	satisfactory	good	good	good
0.07	1.80	satisfactory	satisfactory	good	good
0.11	2.80	unsatisfactory	satisfactory	satisfactory	good
0.18	4.50	unsatisfactory	unsatisfactory	satisfactory	satisfactory
0.28	7.10	unacceptable	unsatisfactory	unsatisfactory	satisfactory
0.44	11.2	unacceptable	unacceptable	unsatisfactory	unsatisfactory
0.70	18.0	unacceptable	unacceptable	unacceptable	unsatisfactory
0.71	28.0	unacceptable	unacceptable	unacceptable	unacceptable
1.10	45.0	unacceptable	unacceptable	unacceptable	unacceptable

Thank You