STLE HOUSTON SECTION

PUFFER SWEIVEN

STLE Houston Chapter Lunch Seminar

Equipment Condition Monitoring Using Vibration Analysis

January 12, 2018

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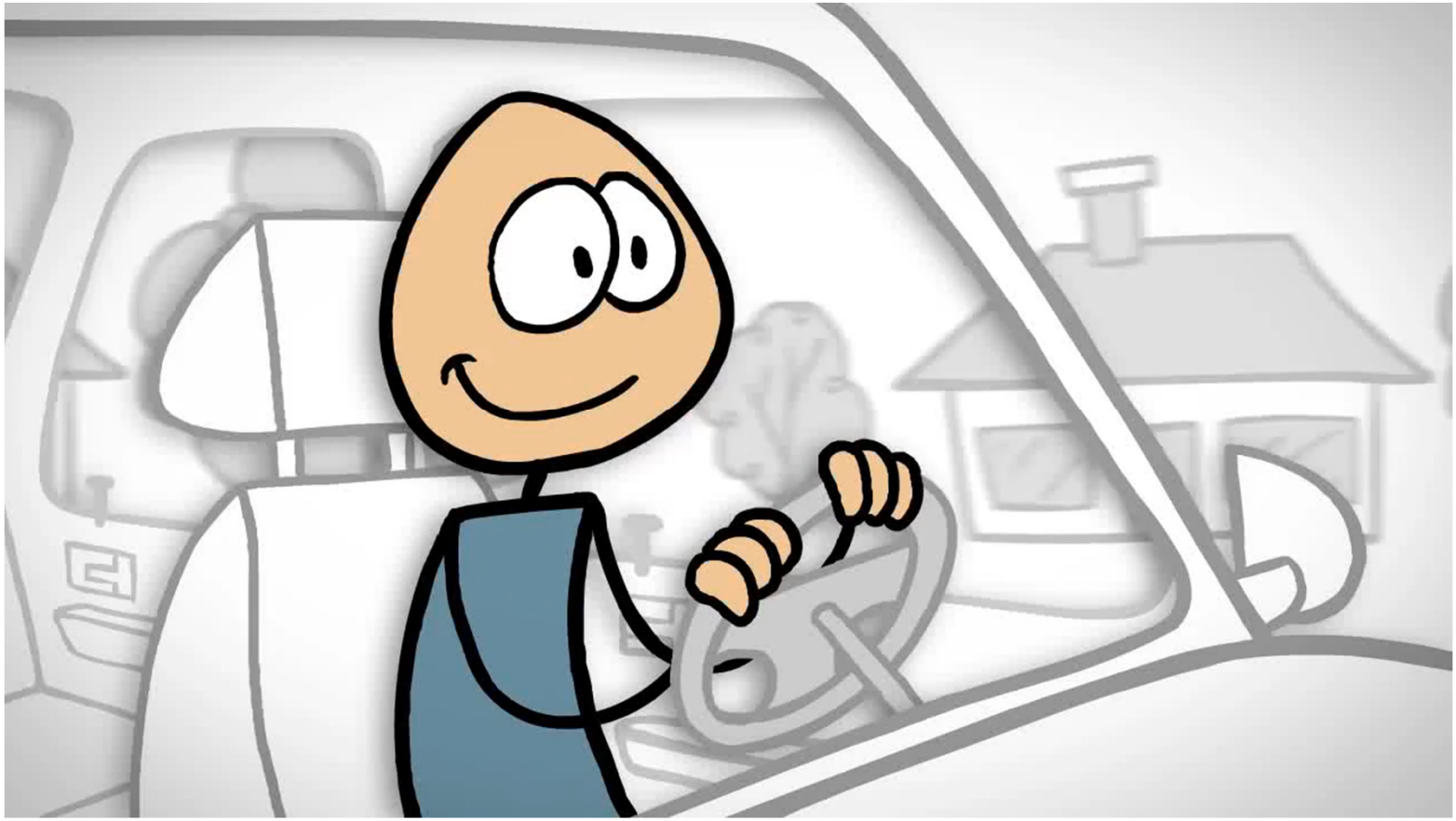
Puffer-Sweiven

Safety Moment



Who is Puffer-Sweiven Reliability Solutions?

- Reliability Consulting
  - Reliability Program Gap Assessment
  - CMMS/EAM Master Data Development-Data Integrity & Criticality Ranking
  - Reliability Focused CMMS/EAM Implementation Support & Accelerators
  - RCM/FMEA Based Reliability Strategy Development
  - Materials Master & BOM Development, Spares Stocking Strategy
  - The Reliability Game® Workshop
  - Customized Reliability Business Case Development
- Machinery Health PdM
  - Vibration Data Collection, Analysis, Reporting Services
  - Technology Mentoring and Equipment Training
  - AMS Machinery Manager Vibration Database Optimization
  - Infrared Thermography & Ultrasound Inspections
  - Lube Oil Handling, Dispensing, Sampling and Analysis

Who is Puffer-Sweiven Reliability Solutions?

- Online Vibration Monitoring Systems
  - Turnaround Support — System and Sensor Field Validation and Documentation, Sensor Additions with Design Drawings, System Additions, and Configuration Improvements
  - Project Management & Support — System Design, Staging, Configuration, Field Installation, Upgrades, Repairs
  - On-Demand Support — Scheduled Upgrades or Emergency Troubleshooting and Repair
- AMS Device Manager (DM) Optimization and HART Loop Commissioning
  - Develop Loop Commissioning Procedures Leveraging AMS DM QuickCheck™ SNAP-ON™ Application
  - Reduce Loop Commissioning Time and Headcount
  - Automate Interlock Validation to Save Days on Start-ups
  - Improve Commissioning Documentation With Audit Trail
  - Optimize Alert Monitor to Elevate Actionable Device Diagnostics

Agenda

- What is Vibration?
- How do we measure it?
- What are we looking at?
- What does it all mean?
- How do Vibration and Lubricant Analysis work together?
- Questions / Open Discussion

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What is Vibration?

- A textbook definition
  - Vibration is the motion of a body about a reference position caused by a force

What is Vibration Analysis?

- Before we actually get into the “what”, let’s talk about the “why”

The why of Vibration Analysis…

"Of all the parameters
that can be measured
non-intrusively
in industry today,
the one containing
the most information
on machinery health
is the vibration signature."

Art Crawford
Acknowledged expert in the field of vibration analysis

The why of Vibration Analysis…

- Track progressing stages of **Bearing Failure**
- Identify/correct **Imbalance** and **Misalignment**
- Identify/correct **Resonance**
- Identify **Mechanical Wear** in couplings, bearings, support structures, etc.
- Detect other defects such as:
  - ***Lube failure*** / soft foot / broken rotor bars
  - Pump cavitation, and many more…

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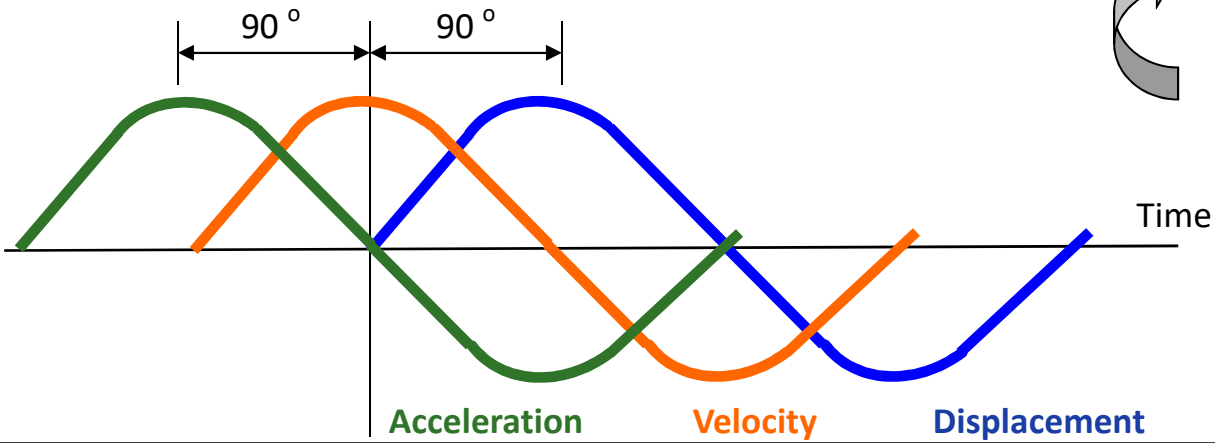
How do we measure it?

- A pre-requisite
  - Vibration “Fundamentals”
- Definitions
  - Frequency units
    - Hz
    - CPM (RPM)
    - Multiples of an arbitrary frequency
      - Harmonics
    - Multiples of the operating frequency
      - Orders

Vibration Fundamentals

Vibration Measuring Units

Acceleration	a
Velocity	a / 2 π f
Displacement	a / 4 π^2 f^2

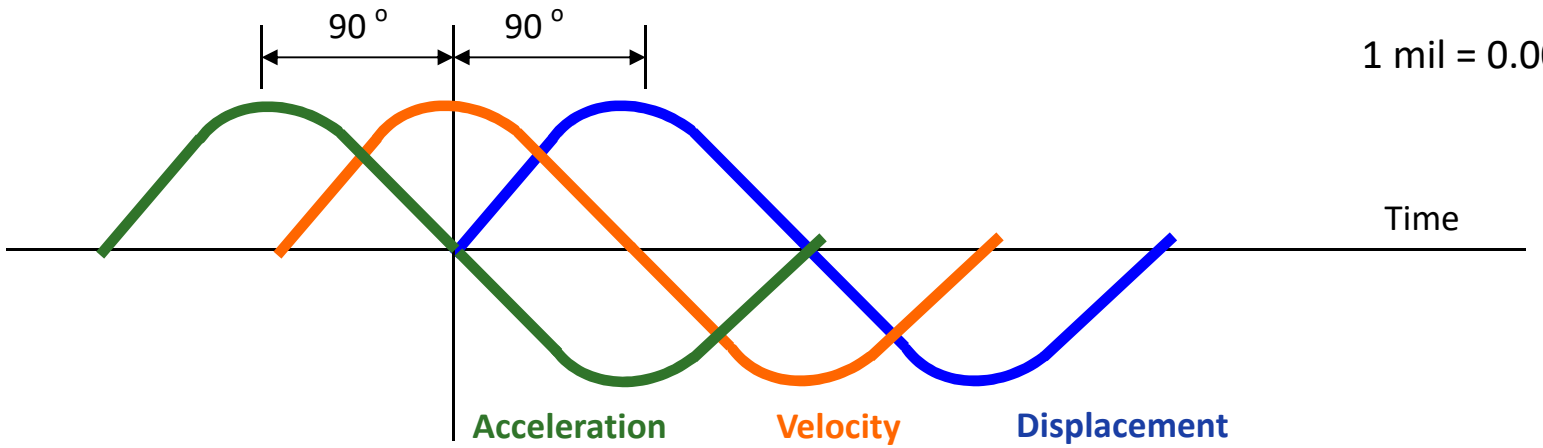


Acceleration
G's or in/s^2
(180 deg phase lead)

Velocity
inches/sec
(90 deg phase lead)

Displacement
.000" or Mils

Vibration Fundamentals



1 mil = 0.001” =25.4 um

Displacement	Mils (um)	Peak-to-Peak / Peak
Velocity	In/Sec (mm/s)	Peak / RMS
Acceleration	G’s (mm/s^2)	RMS

Measuring Vibration

- Transducers, Sensors, Probes…oh my…
- Translation of mechanical vibration (movement) into a representative electrical signal
- Three units of measurement, three types of measurement devices

Measuring Vibration

- Accelerometers
  - Measure acceleration…
  - Piezoelectric device
  - ICP most common

Measuring Vibration

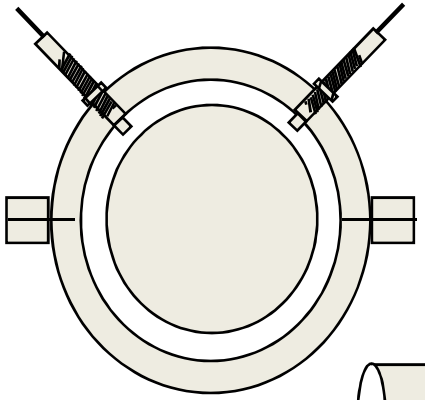
- Velocity Probes (Velometers)
  - Measure velocity…
  - Mostly piezoelectric
  - ICP
  - Have a built-in integrator
  - Mechanical in the past

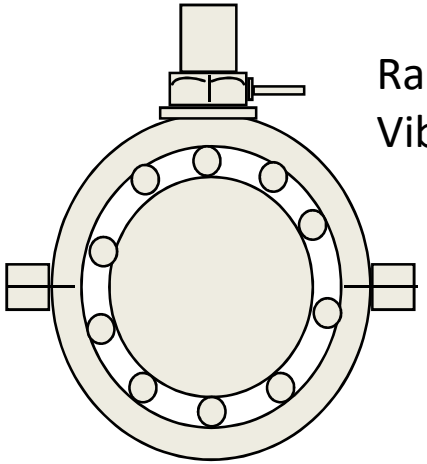
Measuring Vibration

- Displacement Probes (Eddy Current Probes)
  - Measure displacement…
  - Non-contact
  - Induces eddy current

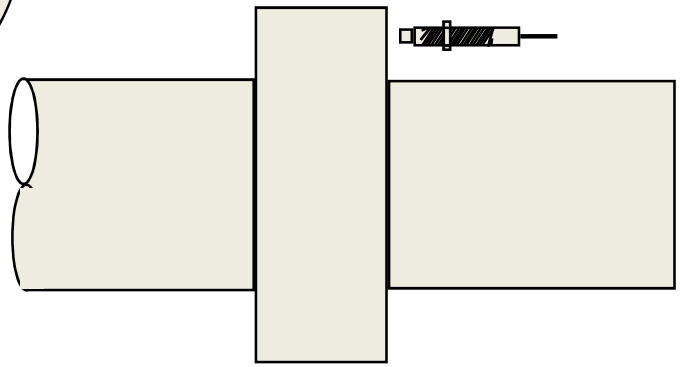
Measuring Vibration – Typical Applications

Radial Shaft
Vibration & Position



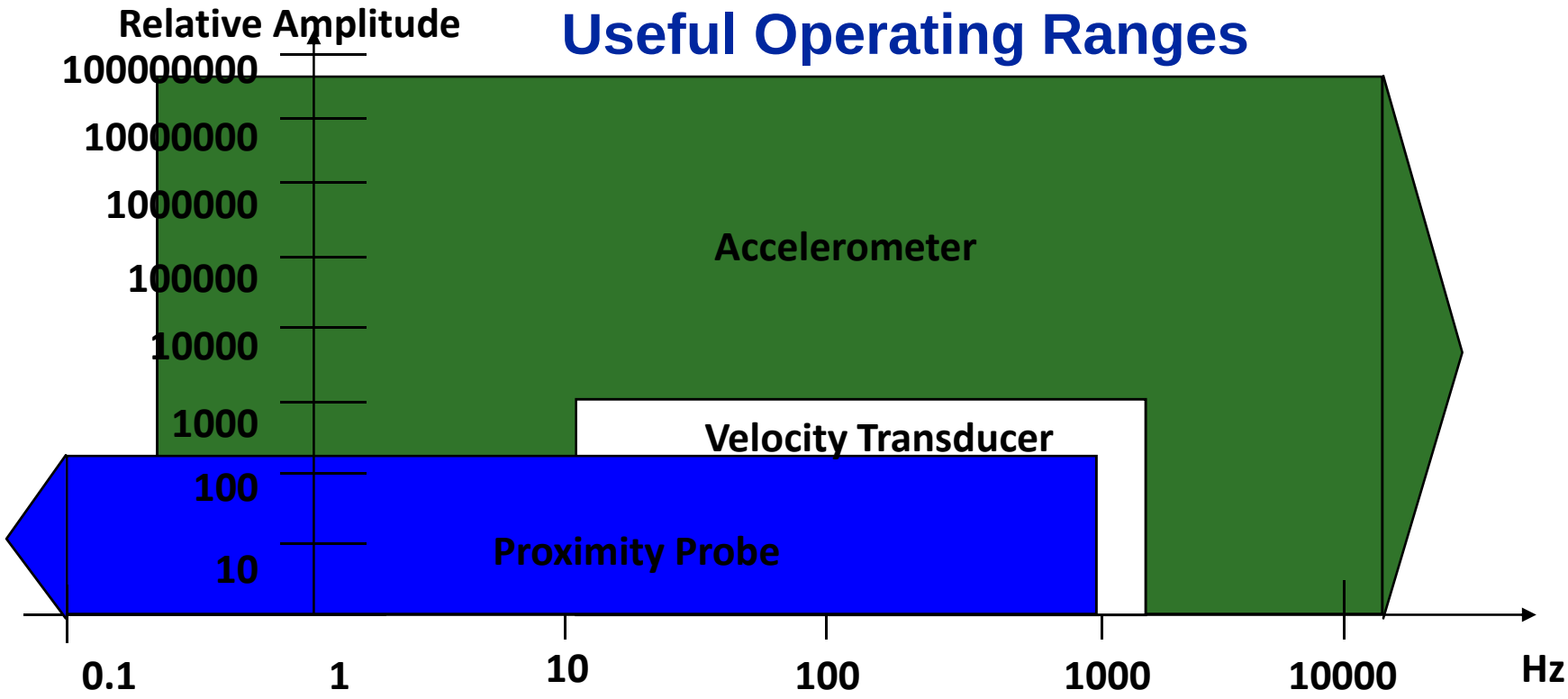


Radial Casing
Vibration

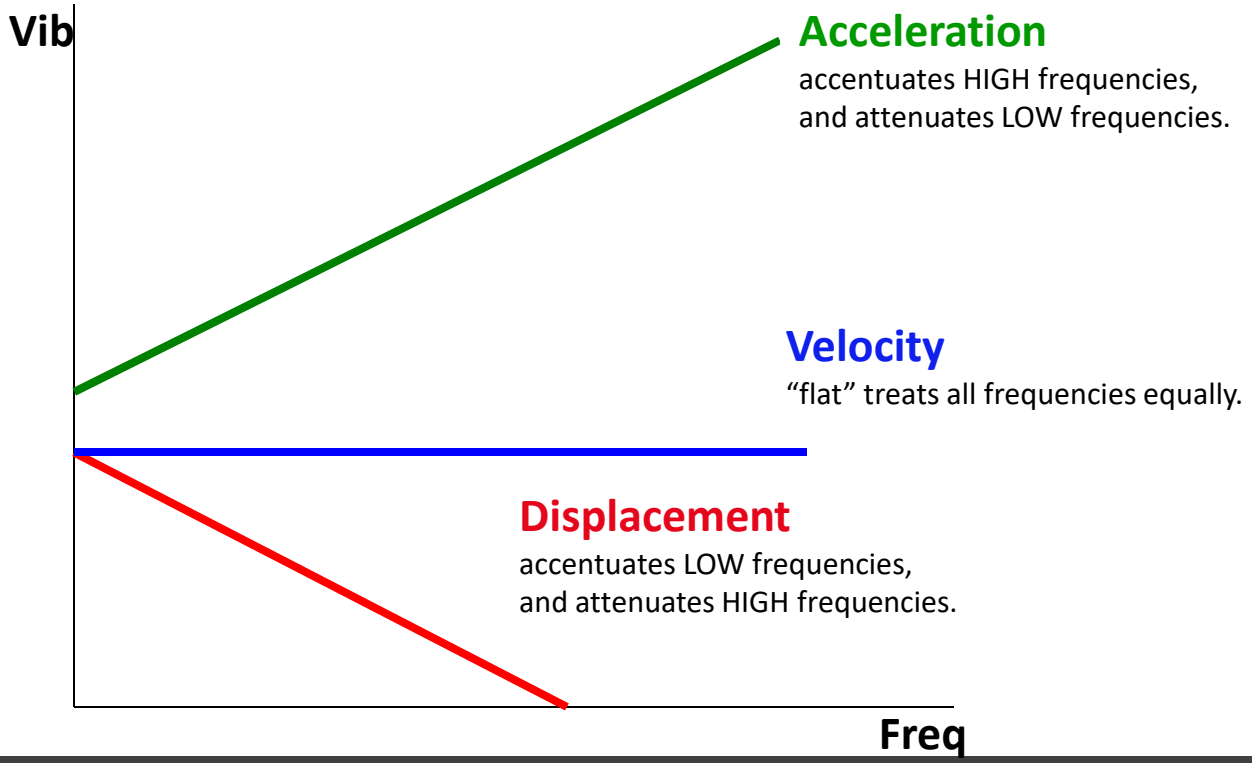


Axial Shaft
Vibration & Position

How do the probes perform over a range?



What units should we use?



Acceleration
accentuates HIGH frequencies,
and attenuates LOW frequencies.

Velocity
"flat" treats all frequencies equally.

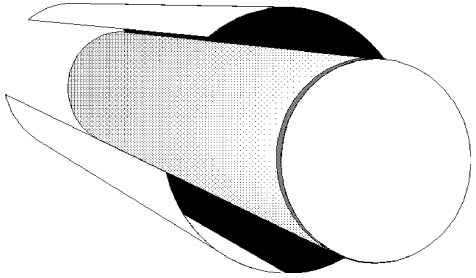
Displacement
accentuates LOW frequencies,
and attenuates HIGH frequencies.

How do I pick a probe?

Types of Bearings

Journal Bearings

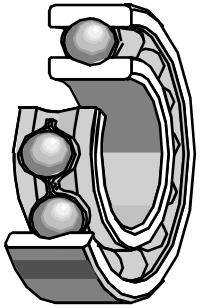
- **Stationary Signals**
- **Relative Low Frequency**



Use Proximity probes

Rolling Element Bearings

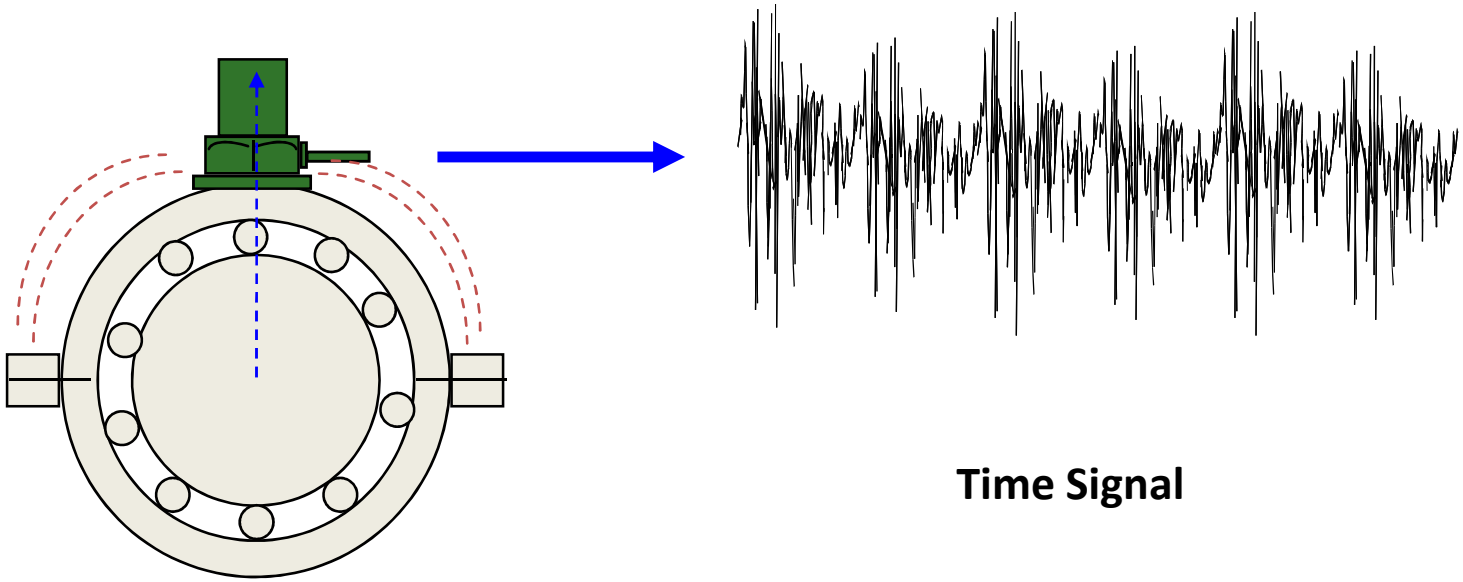
- **Modulated Random Noise**
- **Pulsating signals**
- **High Frequency**



Use Accelerometers

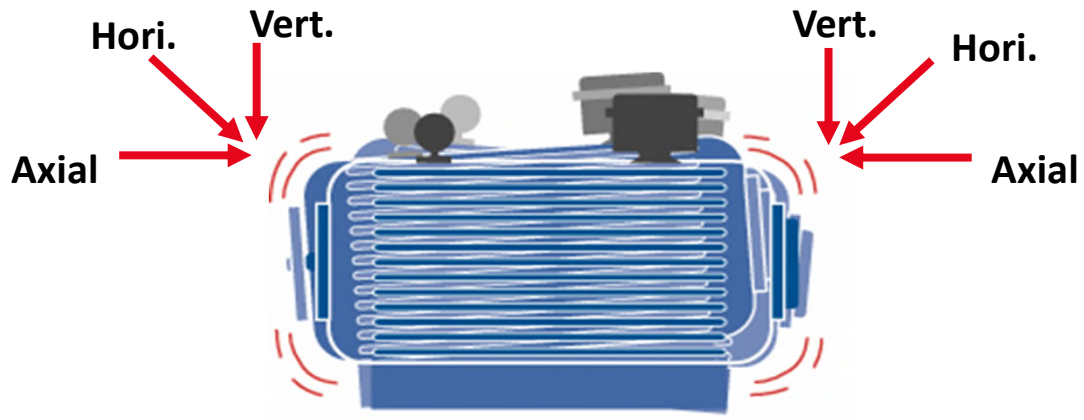
What is the output of a probe?

Machine Vibration Signal



Time Signal

Where do we put the probes?



For detail study of vibration dynamics of machine
– vertical, horizontal and axial at each bearing location

For monitoring – one point per bearing and add axial when
There is a thrust bearing or axial potential faults eg. misalignment

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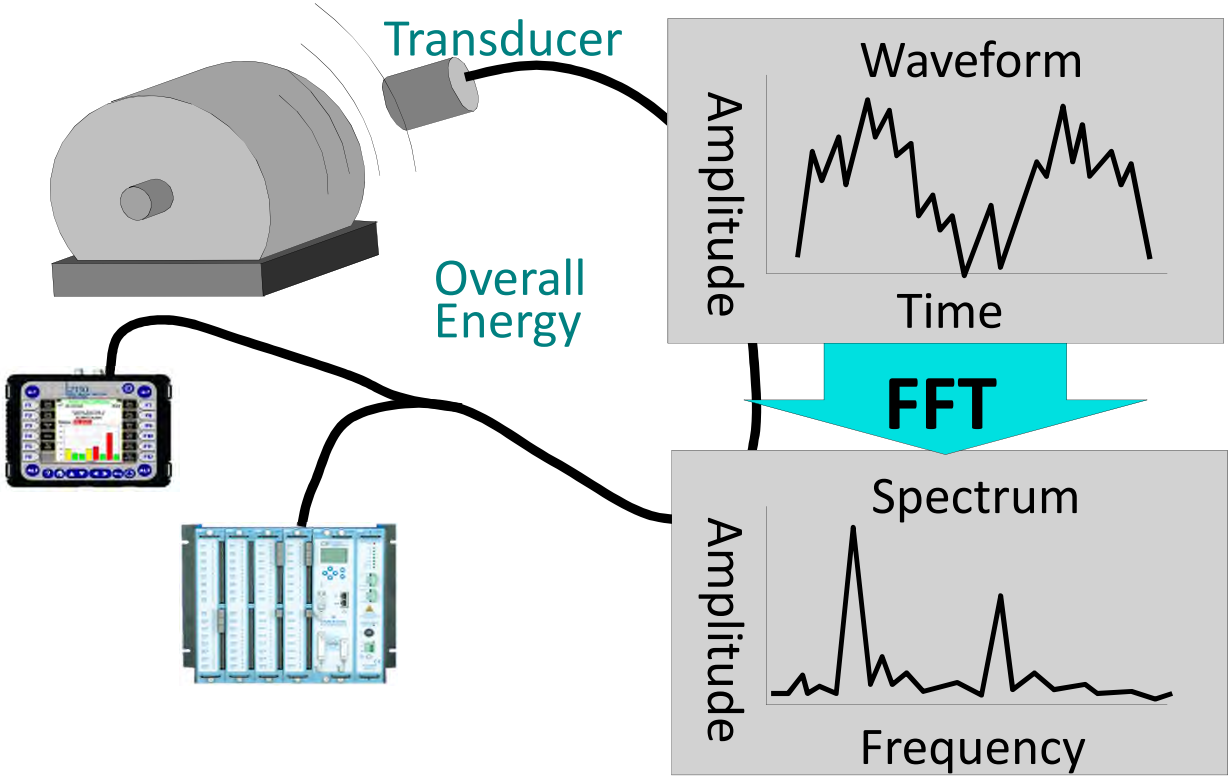
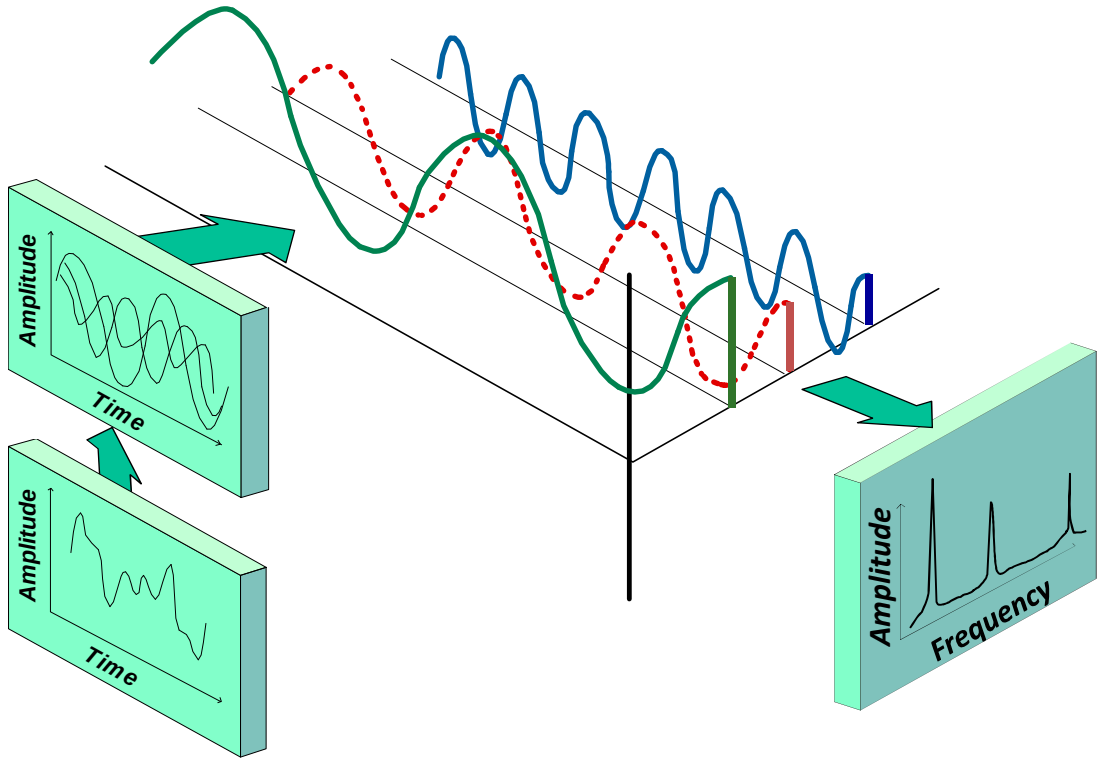
What are we looking at?

- How do we make sense out of a raw-data waveform?
- What is a spectrum?
- How is a spectrum calculated?
- What can we do with a spectrum?

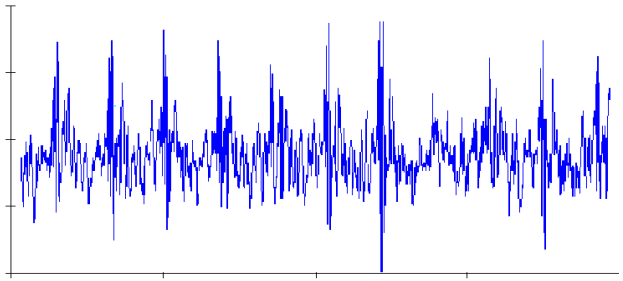
Going from Time to Frequency



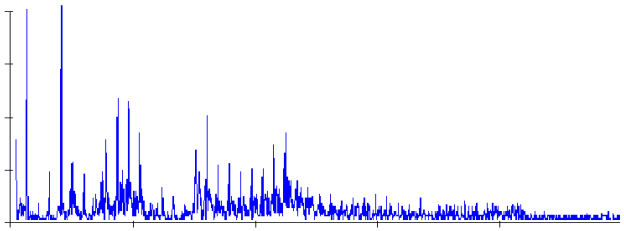
Going from Time to Frequency



Pros and Cons of Time and Frequency



FFT
Fast Fourier
Transformation



Time Signal:
transient signals, repeat frequencies, beats and sine waveform good visible
→ but:
Individual Frequencies of the Vibration Spectrum almost not visible

Amplitude Spectrum:
good visibility of the dominant frequencies of the vibration signal
→ but:
transient Signals, shocks with repeat frequency and beat signals almost not visible

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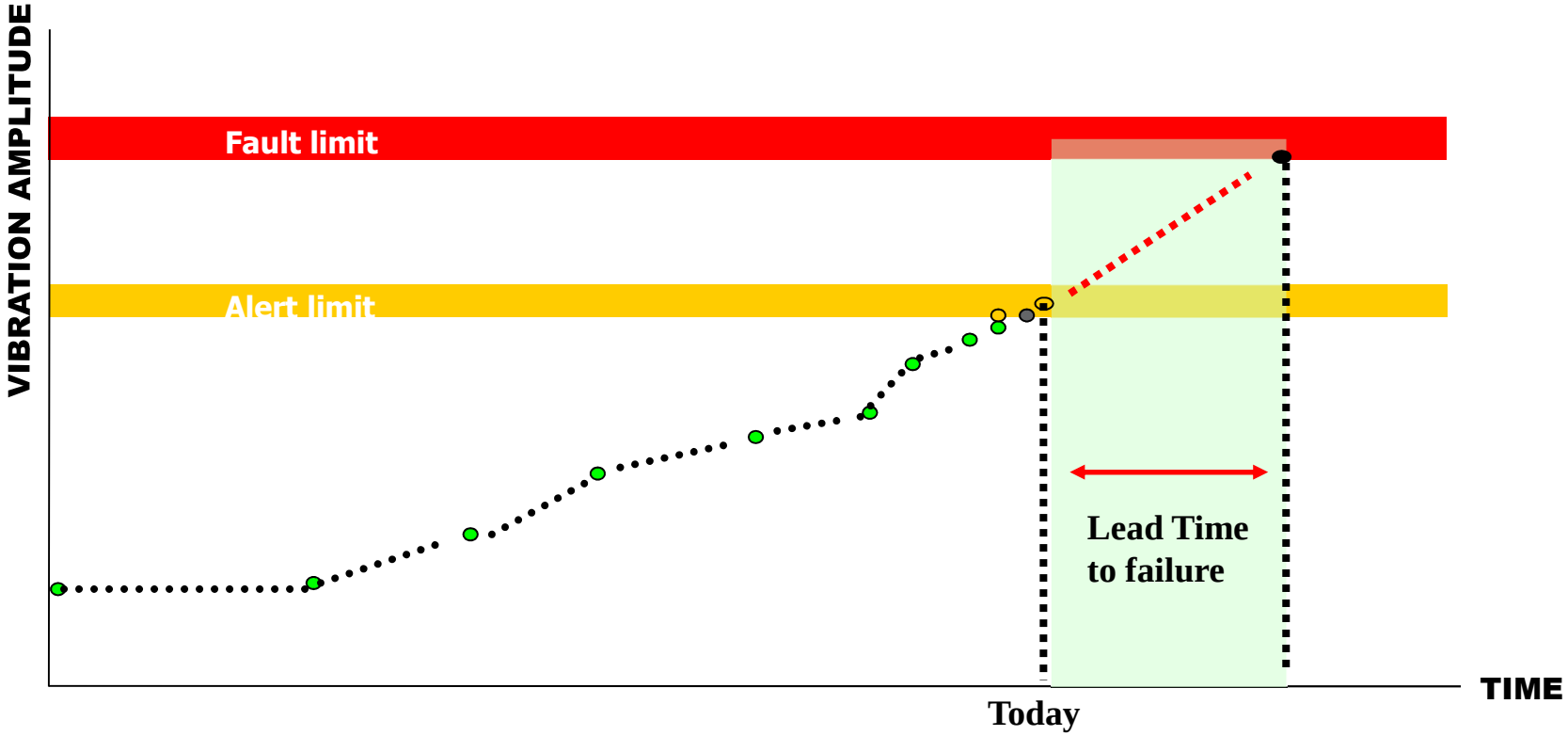
“Rubber, meet Road”

- Monitoring
- Diagnostics

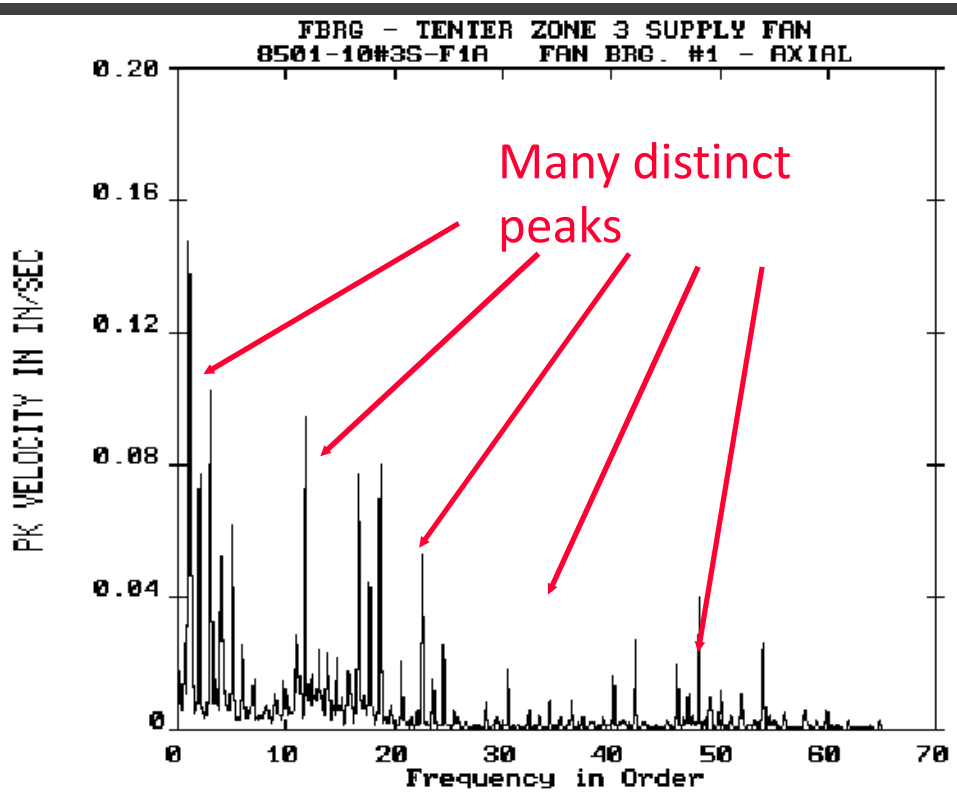
Not an atypical monitoring idea



Diagnostic Tips

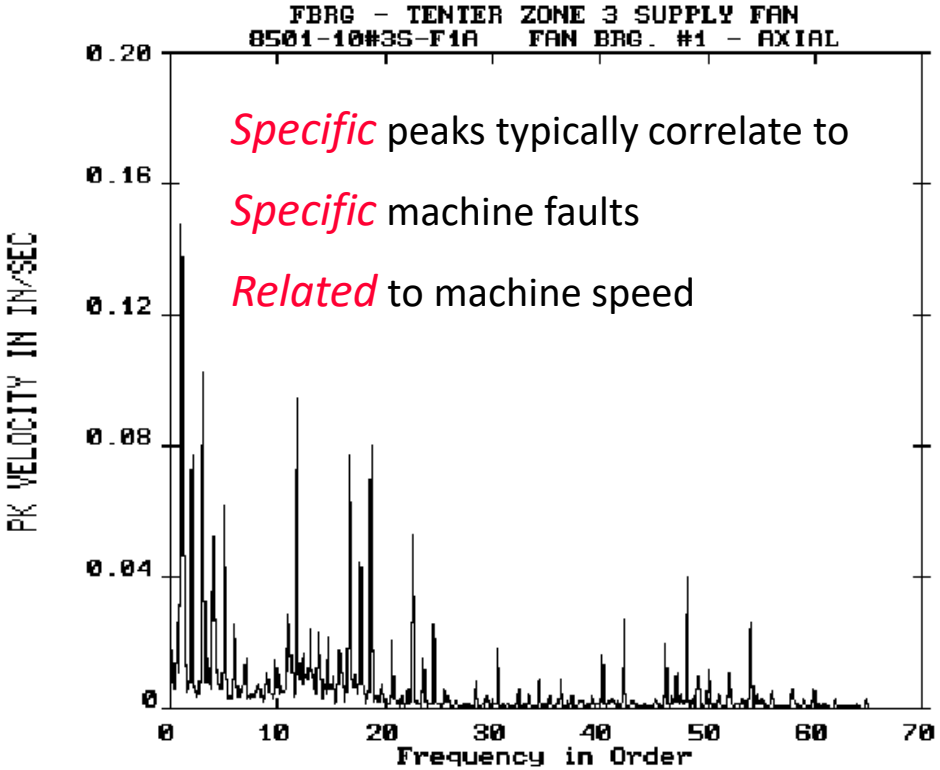
- Each machine fault generates a specific vibration pattern
- The frequency of the vibration is determined by the machine geometry and operating speed
- A single vibration measurement provides information about multiple components

Not an atypical spectrum

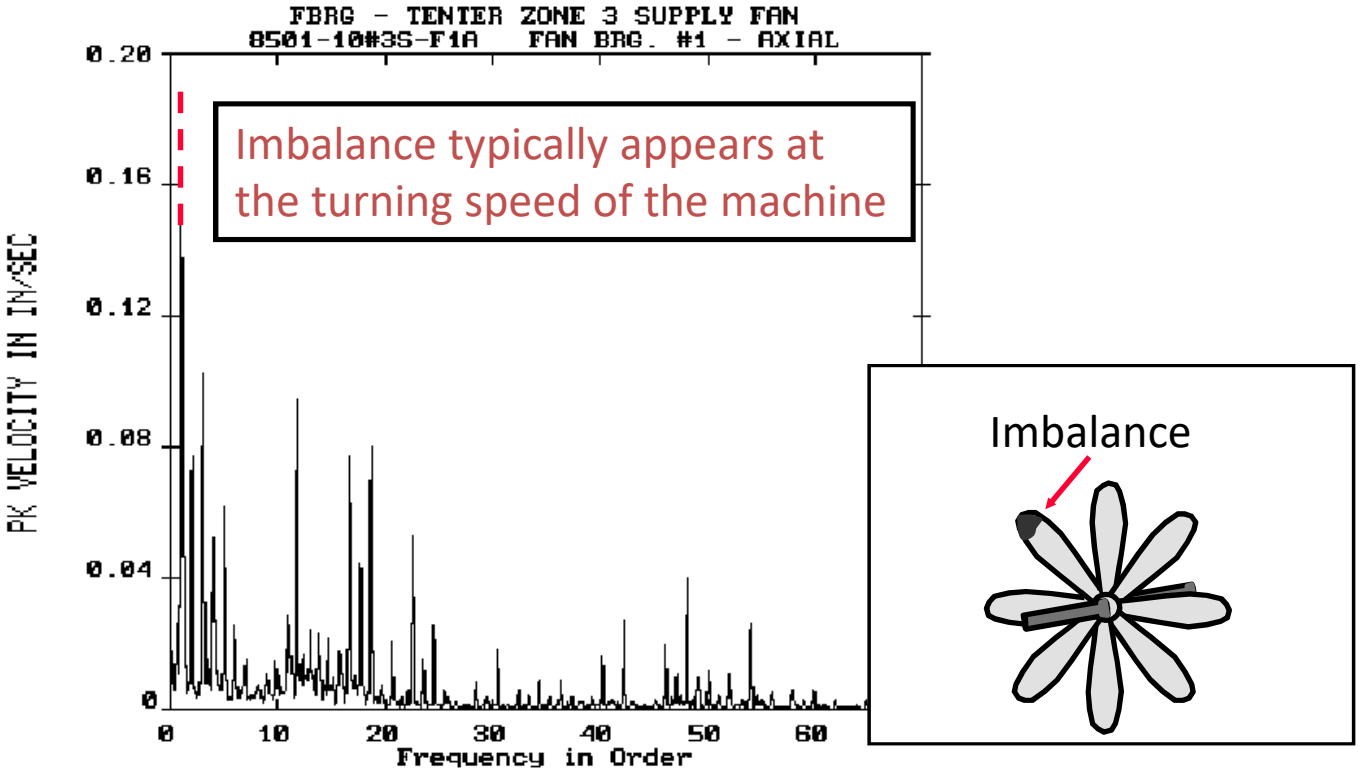


What does this mess mean?

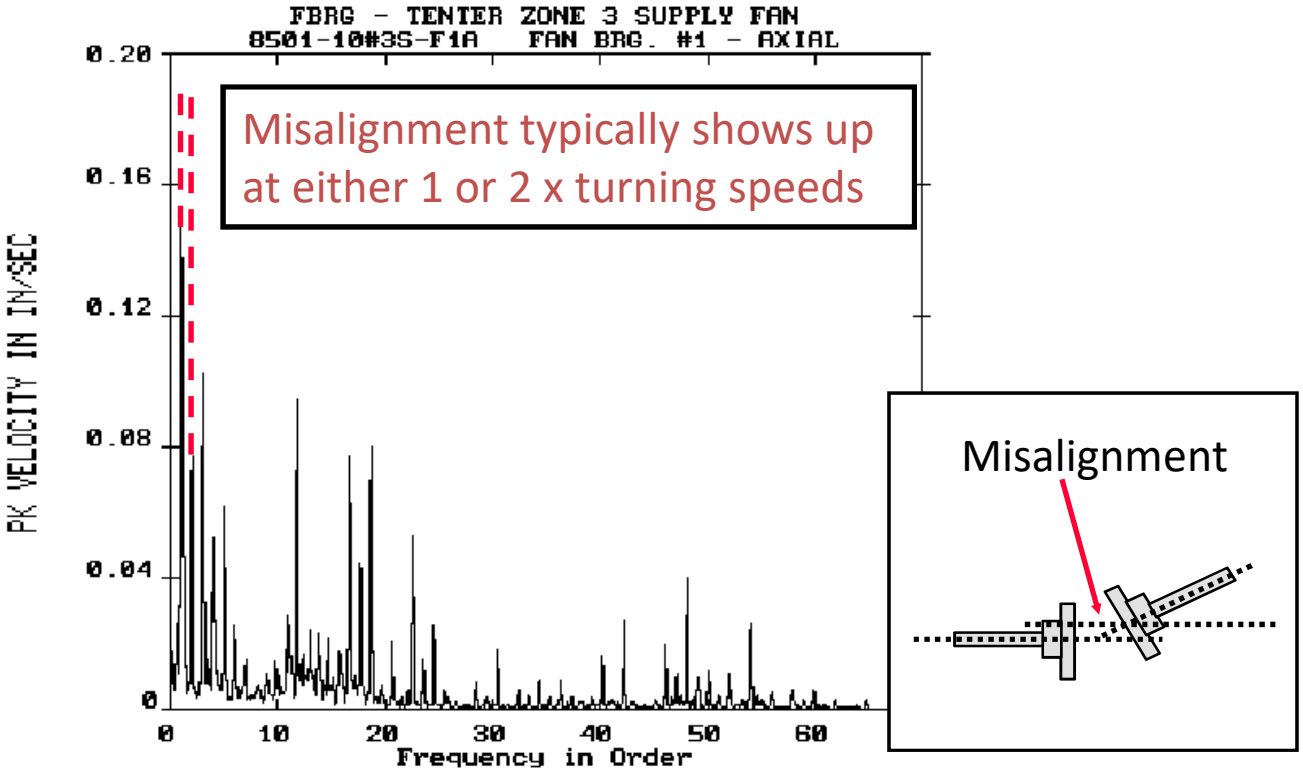
So what does this mean?



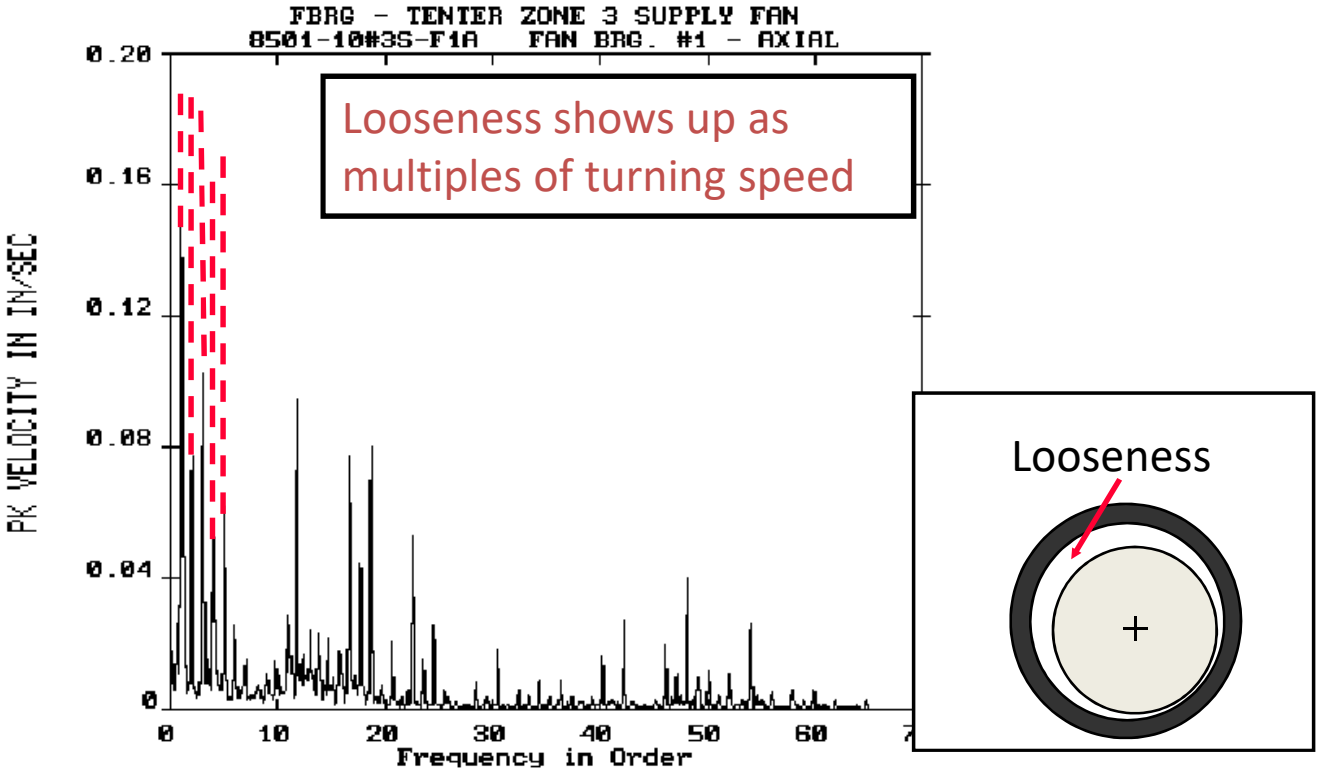
Is it a balance problem?



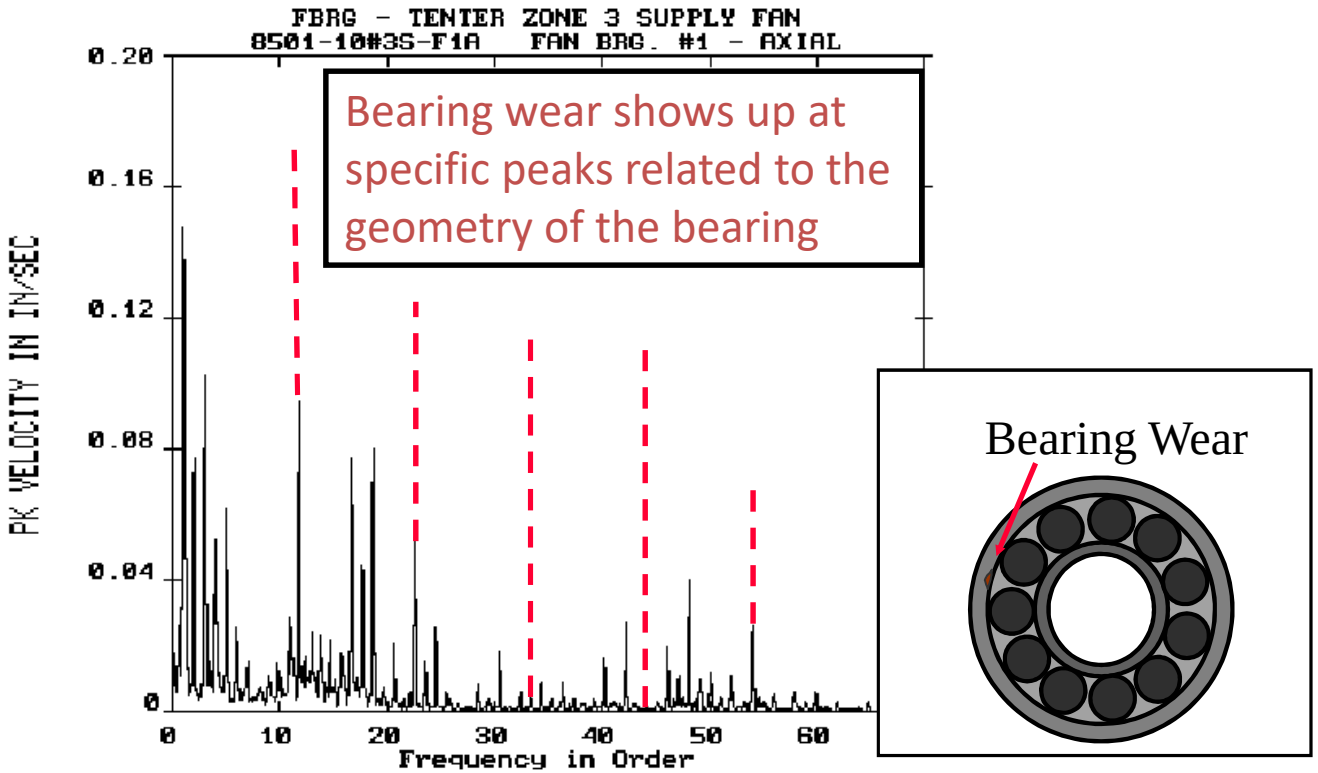
An alignment problem?



A looseness problem?



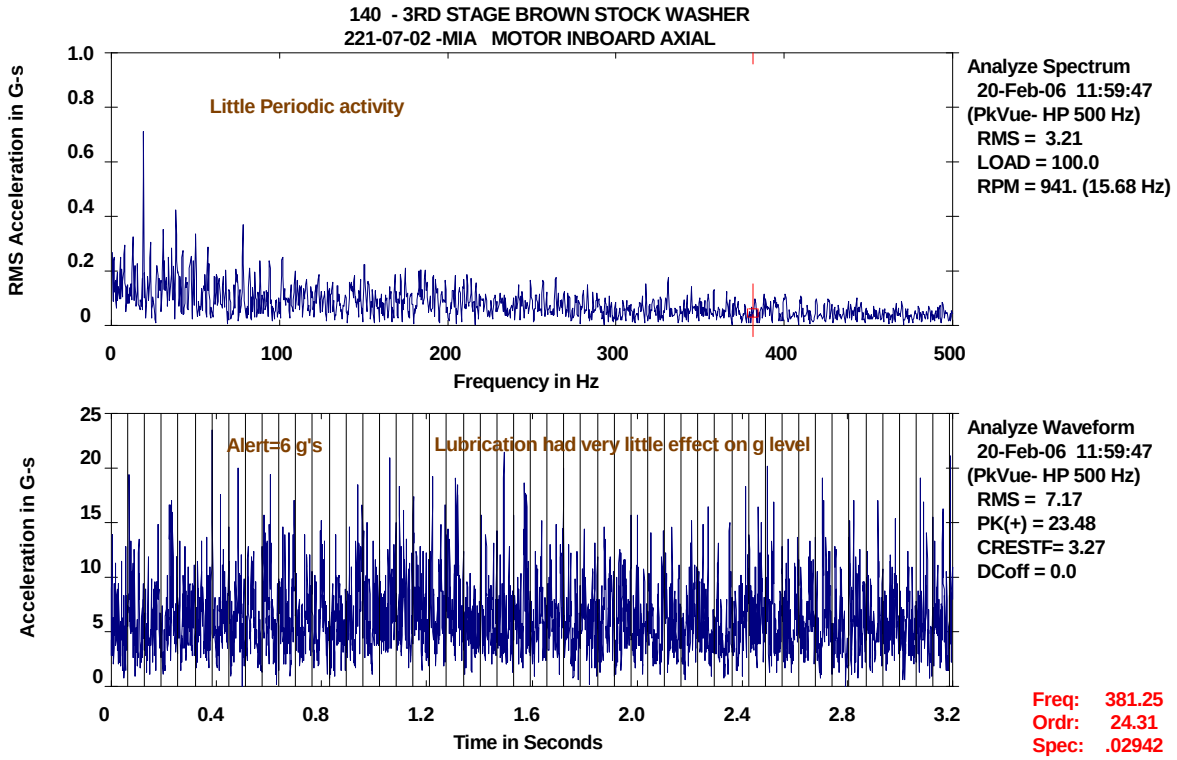
A bearing problem?



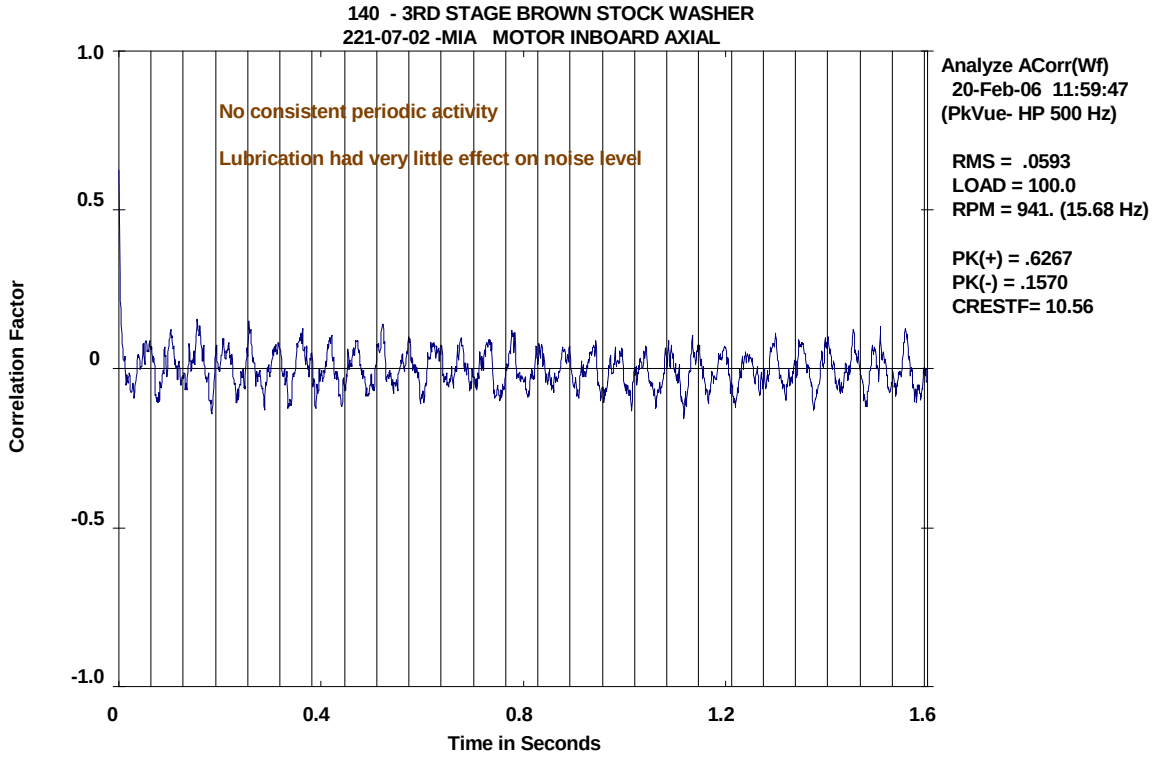
Lubrication faults…

- You can find “Lack of Lubrication” fairly effectively
  - Noisy waveform
  - No real harmonically related spectral data
  - Autocorrelated waveform shows little or no correlation

Missing Cage / Lubrication Issue



Autocorrelated Waveform



This is what caused the signature

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Vibration and Lubrication Analysis Together

- Complementary
- Lubrication will typically lead vibration
- Generally, Lubrication Analysis will indicate very incipient problems that can then be monitored with Vibration
- Vibration Analysis will confirm the fault
- Should we really let it get this far?

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THANK YOU!