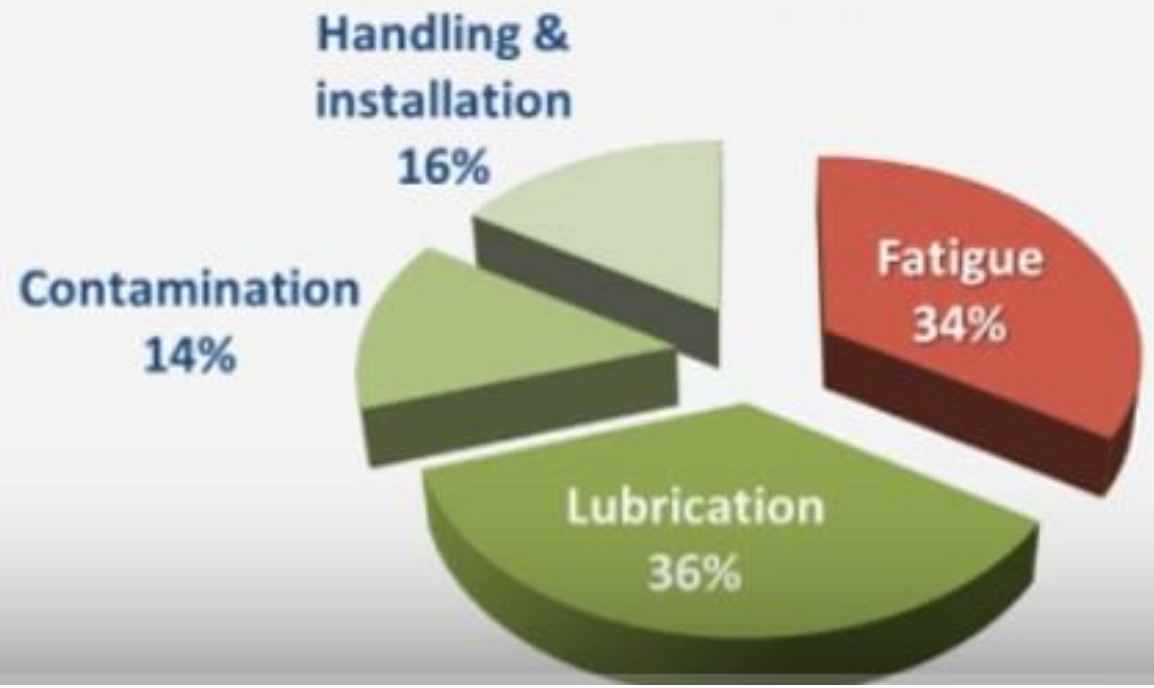
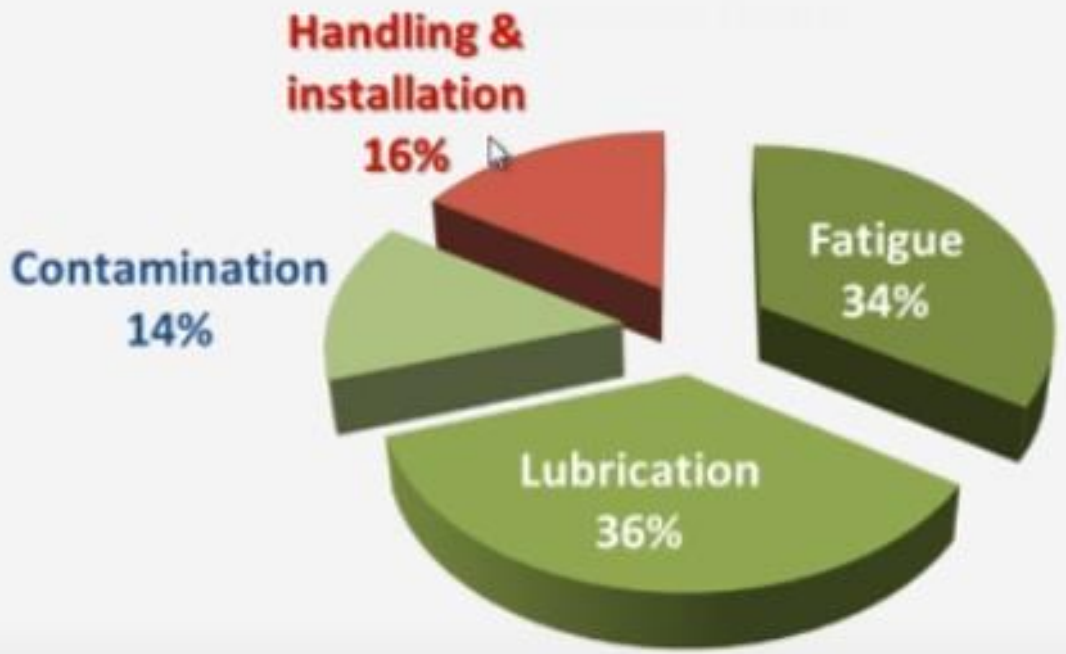
Fatigue causes 34% of bearing failures

- "Parasitic" loads reduce life: $L_{10} \approx \frac{1}{\Delta RPM} x \frac{1}{[\Delta LOAD]^3}$



Poor Handling & Installation: 16%

- Fits and tolerances are critical.
- Proper tools and skills are essential.
- Transportation and storage.



Condition monitoring

- **Replace lubricant based on condition:**
  - Contaminated
  - Chemistry unacceptable
- **Replace bearing based on condition:**
  - Wear particles detected
  - Vibration indicates defect
  - Listen with ultrasound
  - Watch for late stage wear with thermography
- **Avoid catastrophic failure**

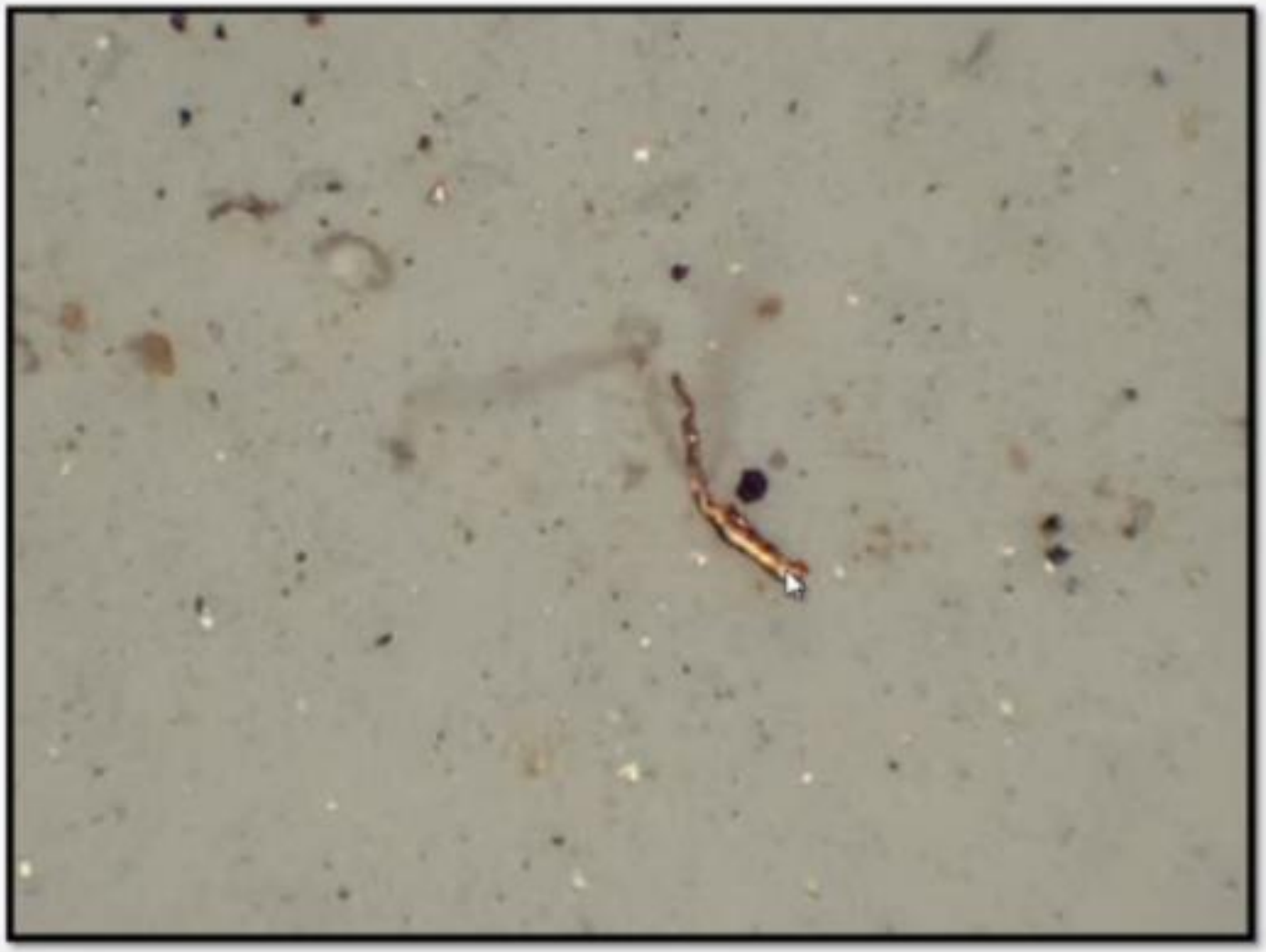
Vibration analysis applications

- We can detect issues related to bearings that will ***cause*** failure:
  - Poor lubrication
  - Fluting or EDM
  - Cocked bearing (installation)
  - Skidding and sliding
- We can detect other faults that will ***result*** in bearing damage:
  - Unbalance
  - Misalignment
  - Looseness
  - Resonance

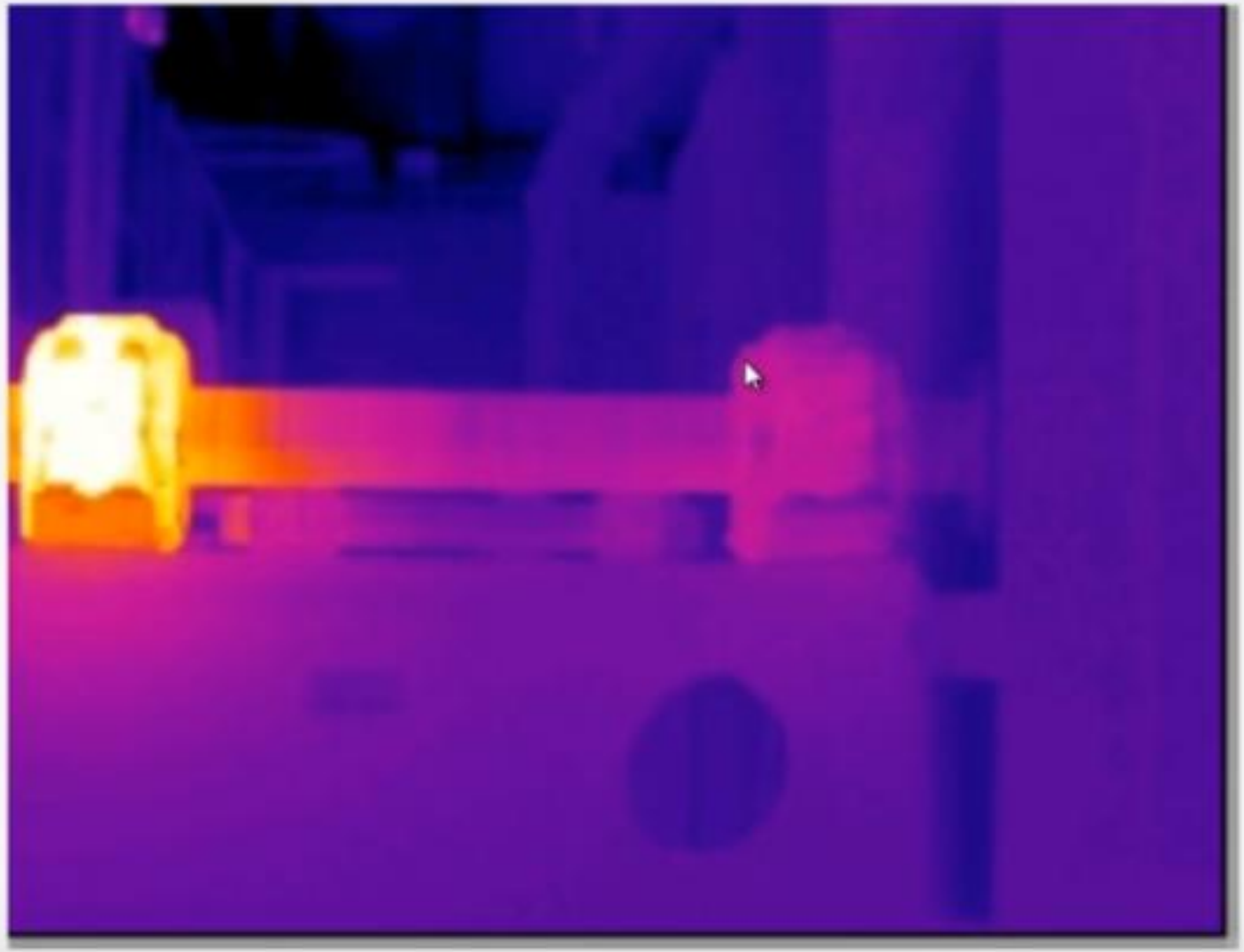
Oil analysis

- Determine the condition of the lubricant
  - Viscosity, acidity, alkalinity, additives
- Detect contamination
  - Water, particles (dirt, etc.), chemicals
- Detect particles
  - Particle counting, elemental analysis
  - Most techniques ***cannot*** detect particles >10 micron

Wear particle analysis



Thermography



Precision maintenance (focus on bearings)

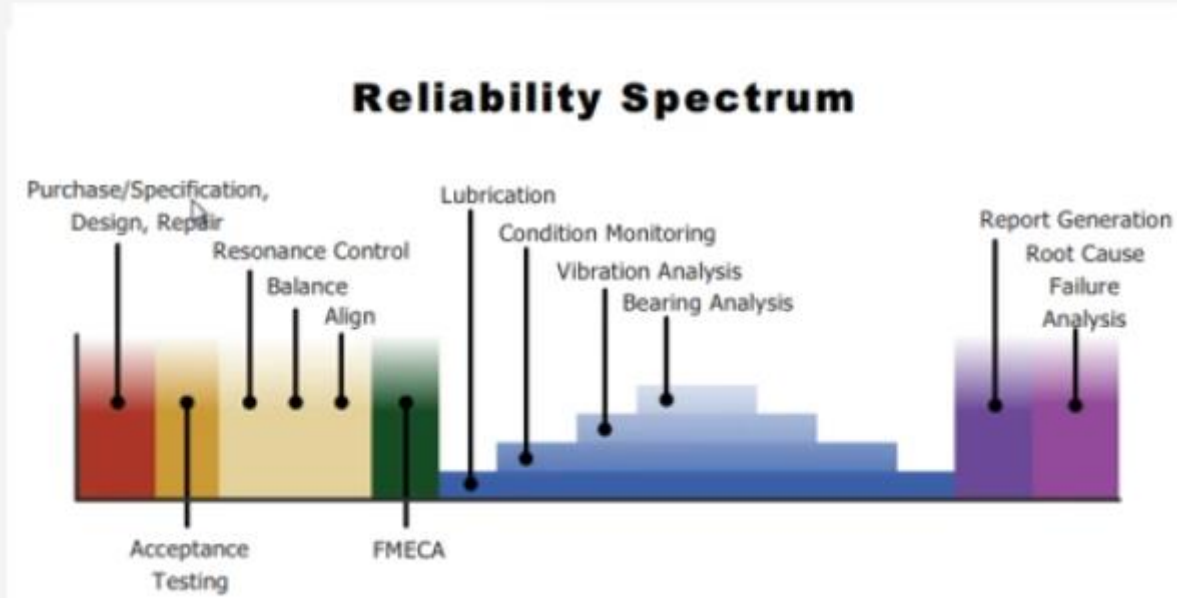
- Poor design, purchase, transport, storage, installation, lubrication, operation and poor maintenance leads to reduced bearing life.
- **What are you going to do about it?**

The Proactive Approach: Lubrication + contamination

- Bearings should be correctly lubricated with clean oil or grease.

Precision maintenance: Reliability spectrum

- You need a *complete* approach.



“Advanced” vibration analysis techniques

Using vibration analyzers with spectrum analysis, time waveform analysis and “high frequency techniques”.

Vibration analysis methods

Very high frequency

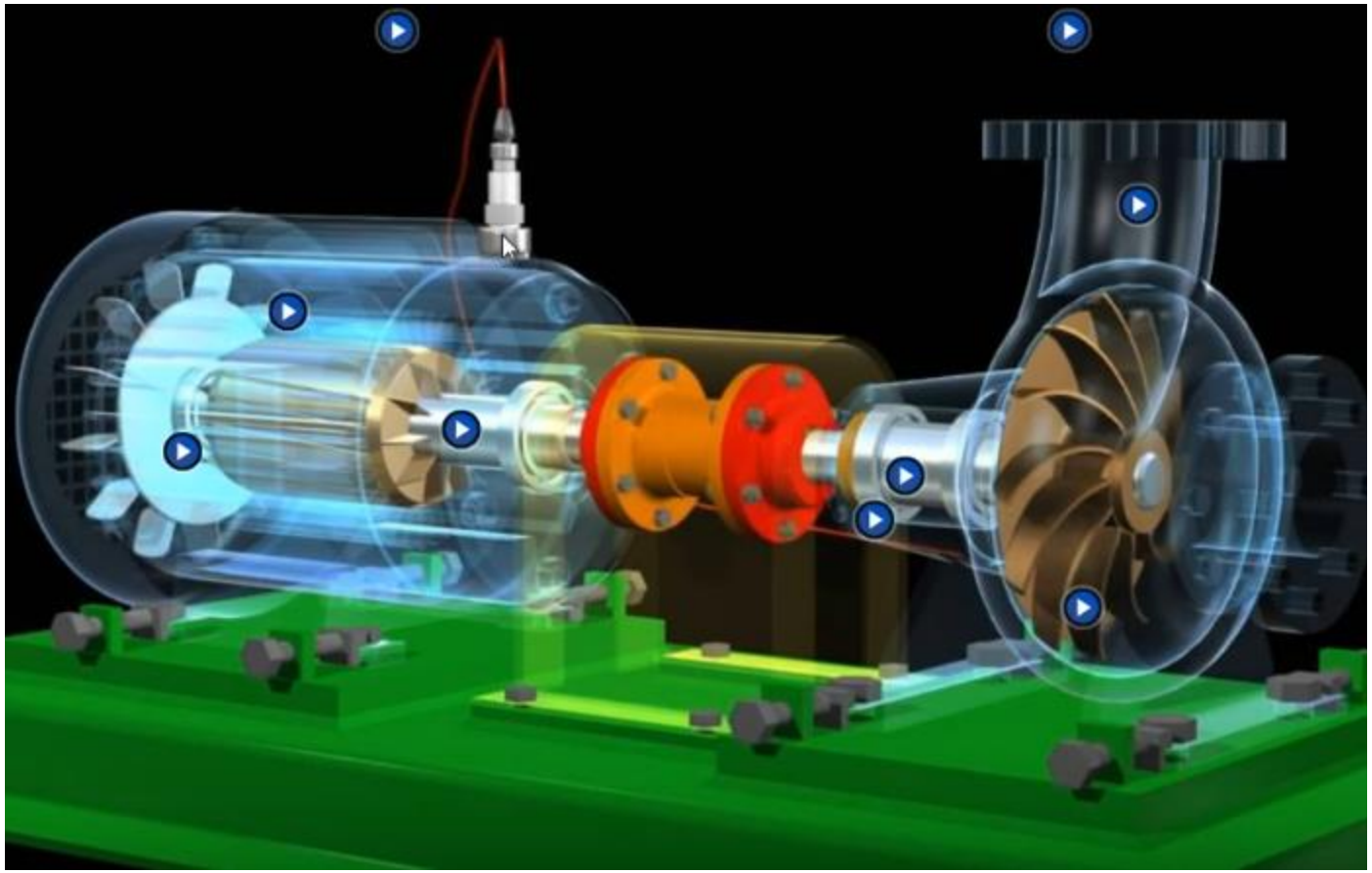
- Ultrasound and stress testing
- Shock Pulse®, Spike Energy®, SEE®, PeakVue®

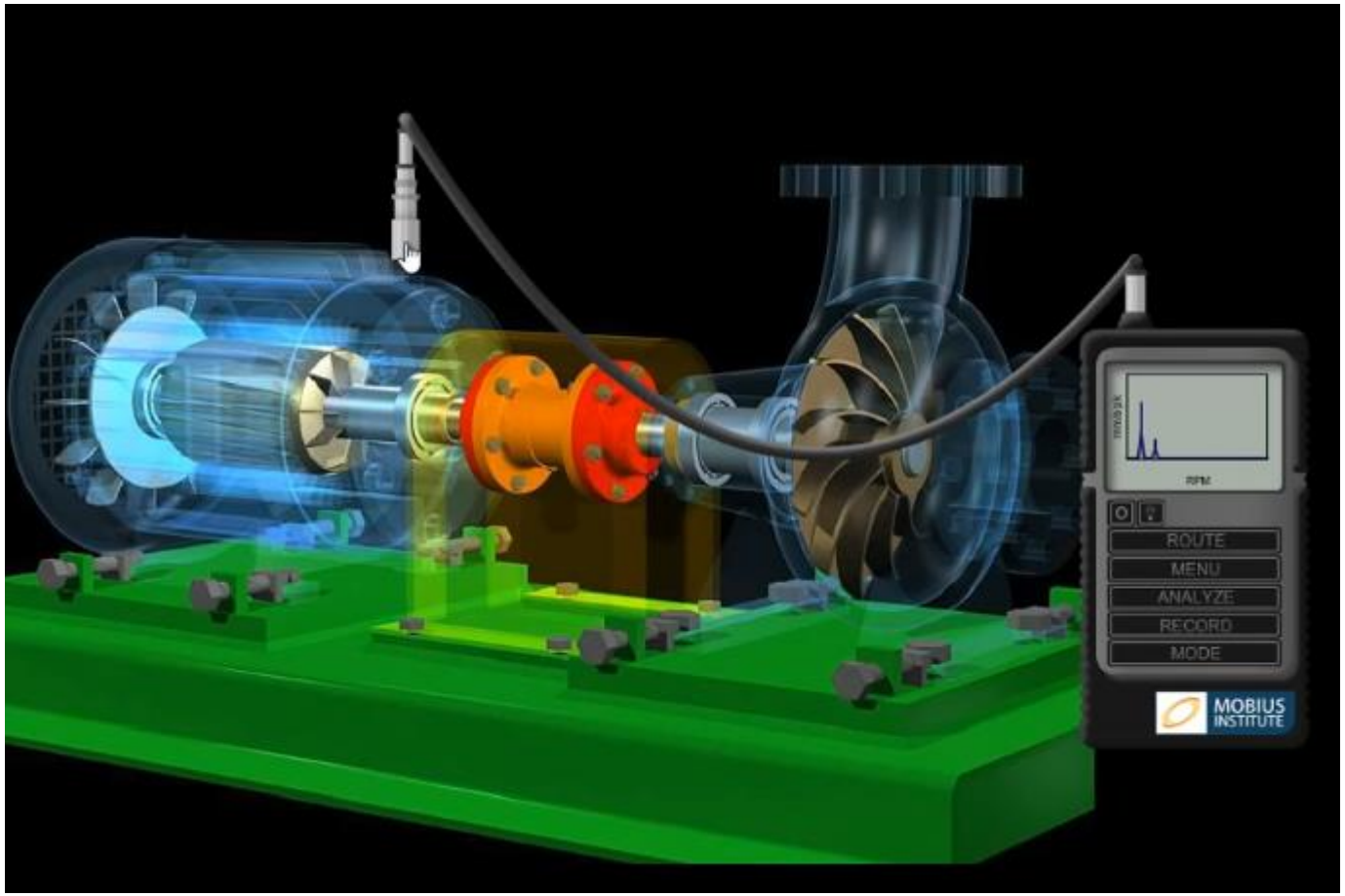
High frequency

- Enveloping and Amplitude demodulation
- Acceleration spectrum

Mid-low frequency

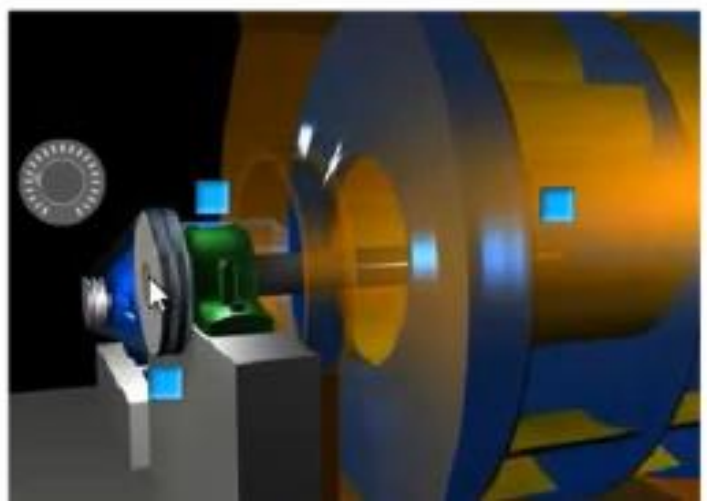
- Velocity spectrum
- Time waveform analysis
- Overall level vibration

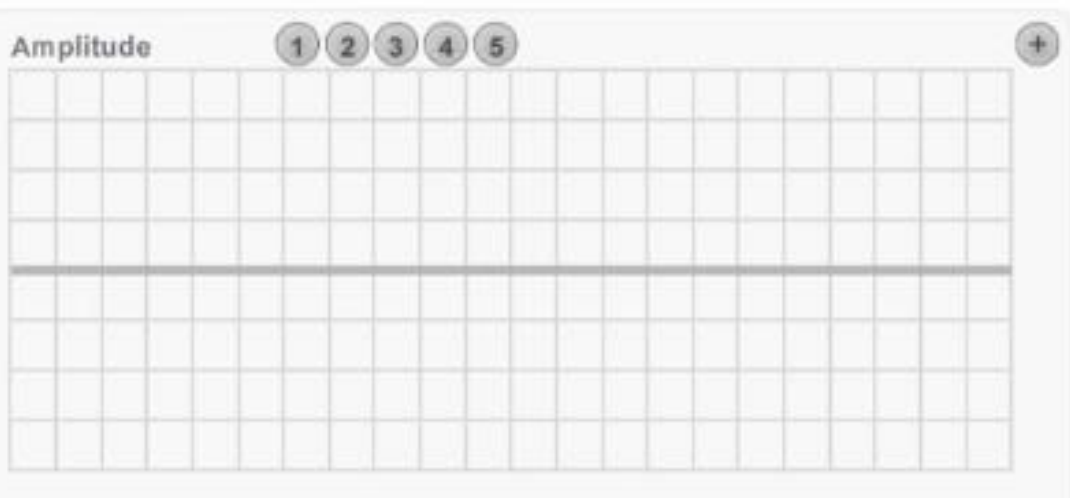



ROUTE
MENU
ANALYZE
RECORD
MODE
MOBIUS
INSTITUTE

Spectrum analysis

- The spectrum is generated from the waveform
- *In basic terms*, each component generates a single frequency
- The spectrum makes each source of vibration easier to see
- [Harmonics and sidebands tell us that the motion is more complex.]





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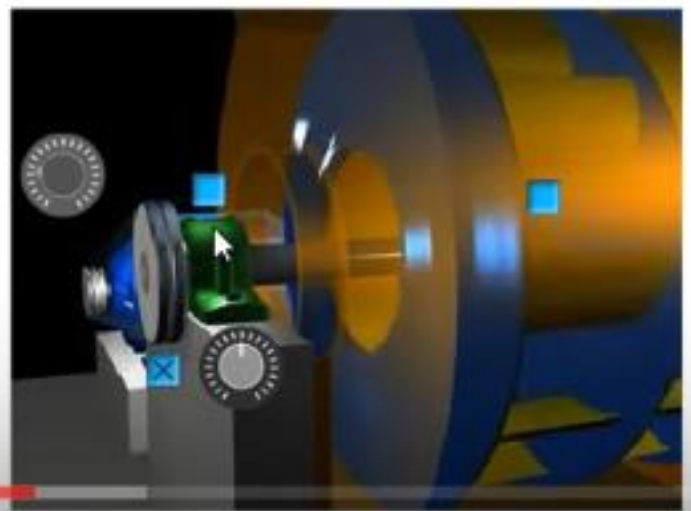

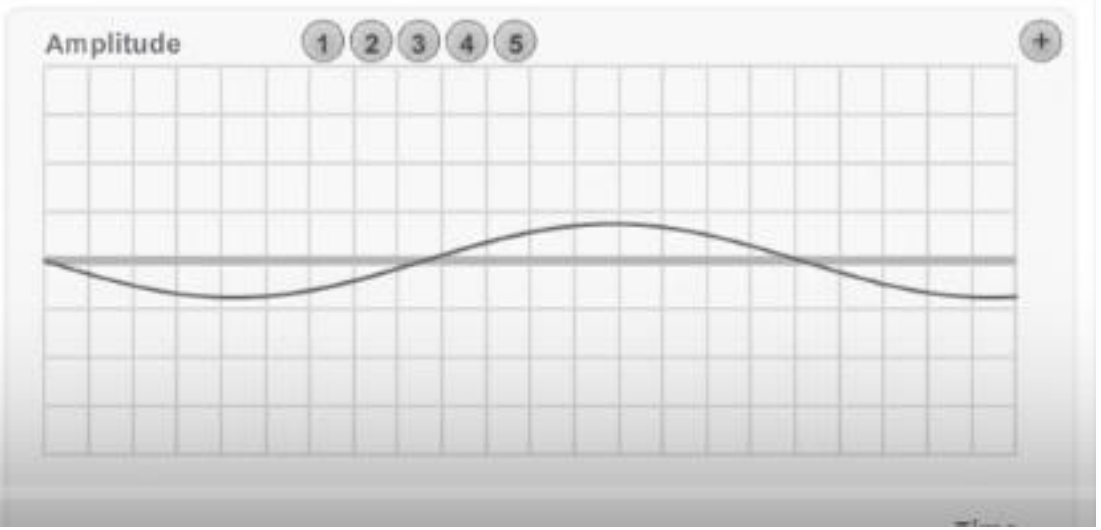

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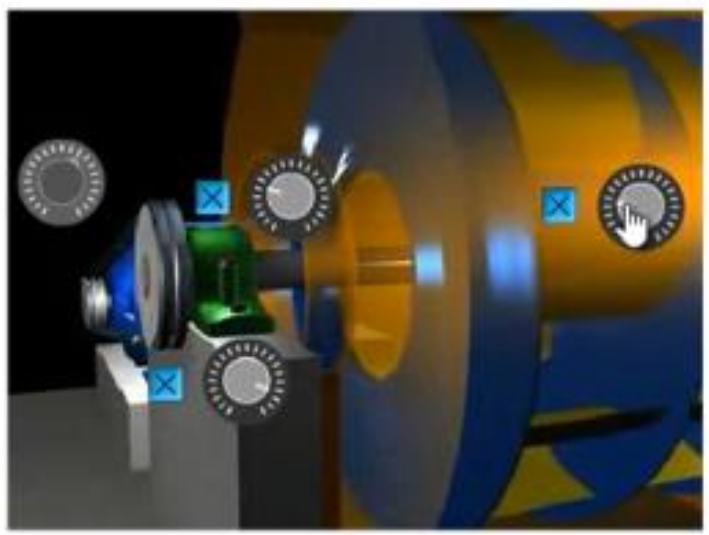

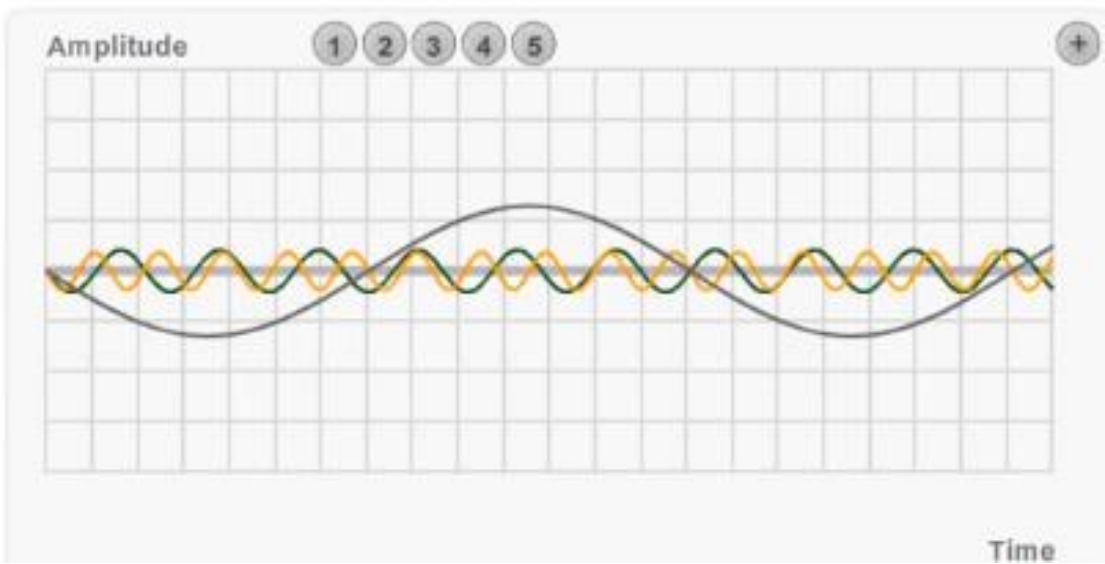

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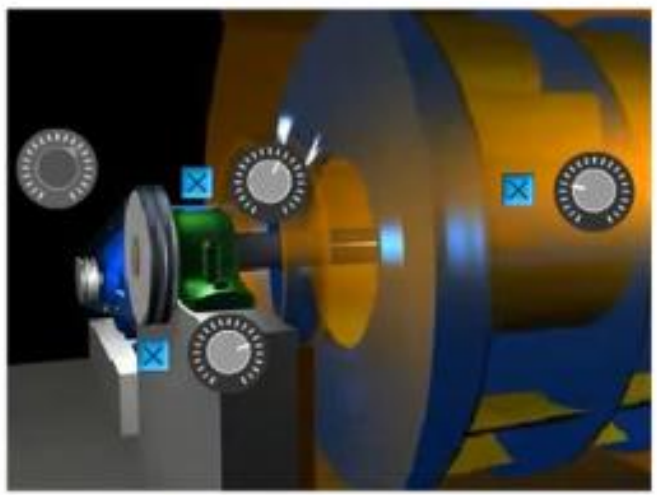
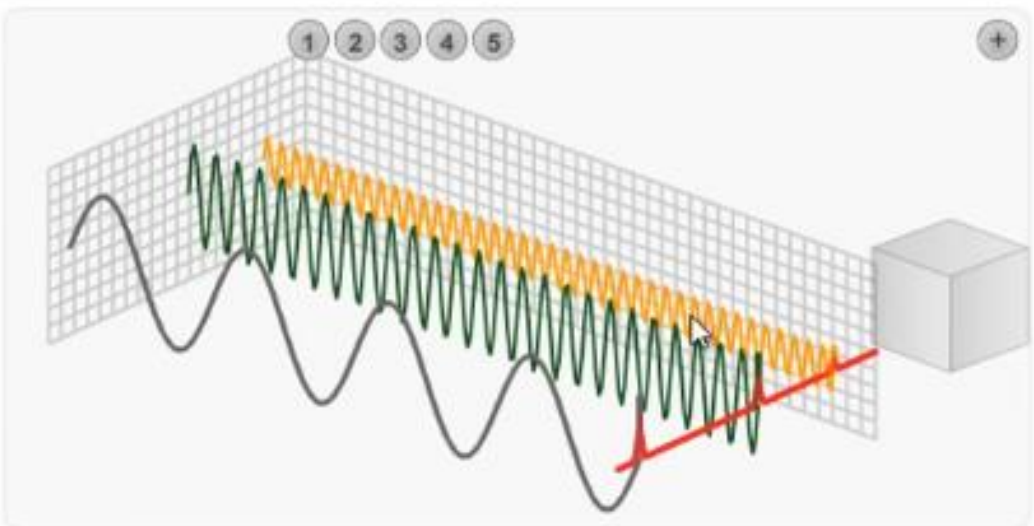
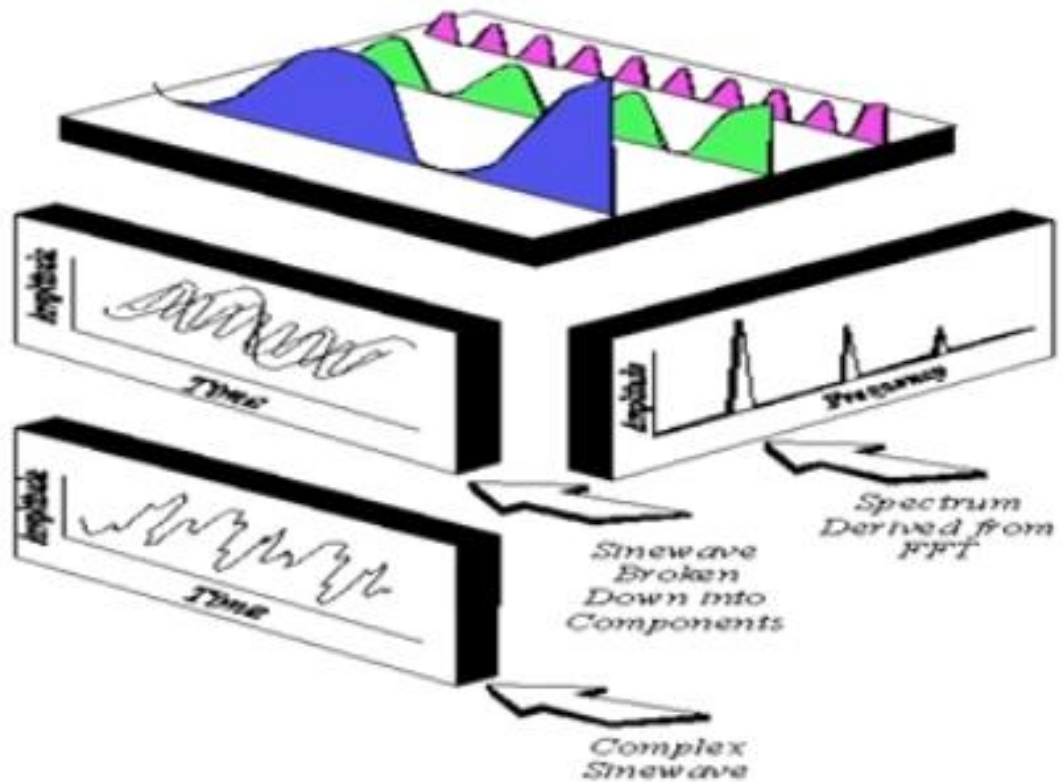




Fast Fourier transform FFT



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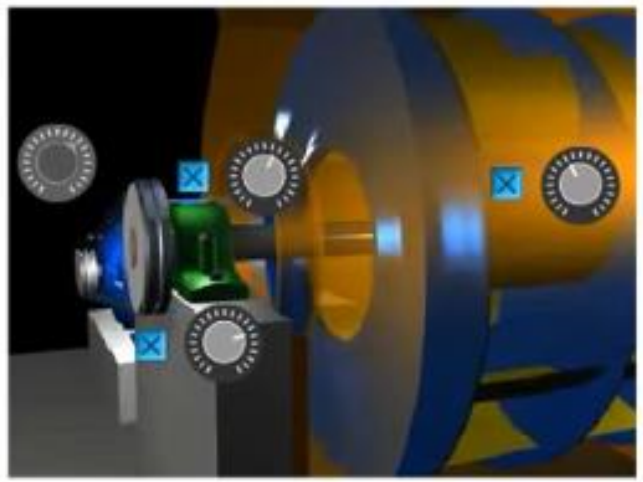
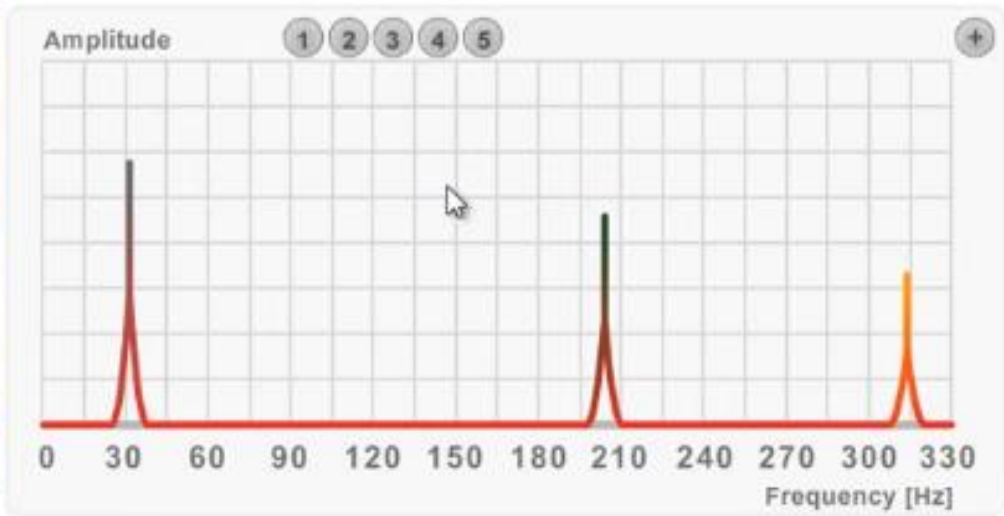
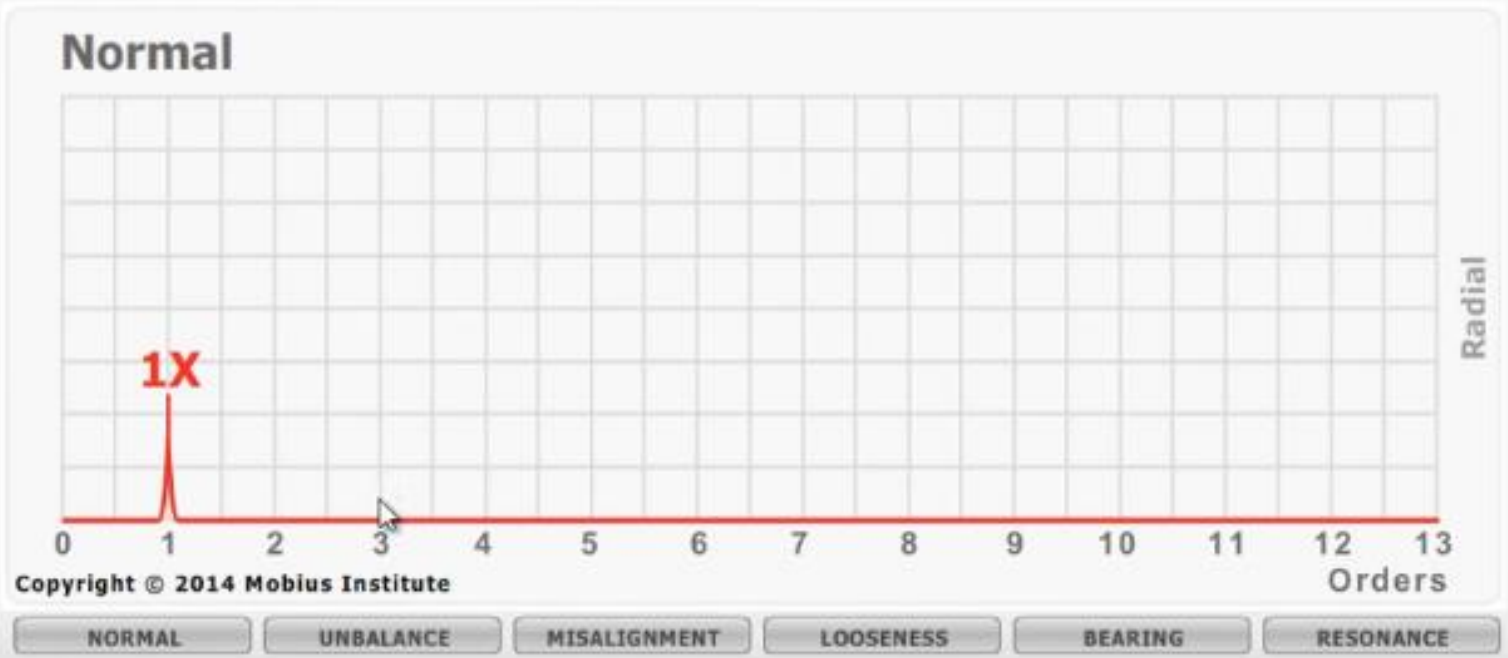




Spectrum analysis

- Different fault conditions generate different patterns.
- We are often interested in 1X, 2X, and 3X, and in harmonics and sidebands.
- Real spectra are far more complicated than the idealized patterns shown here.



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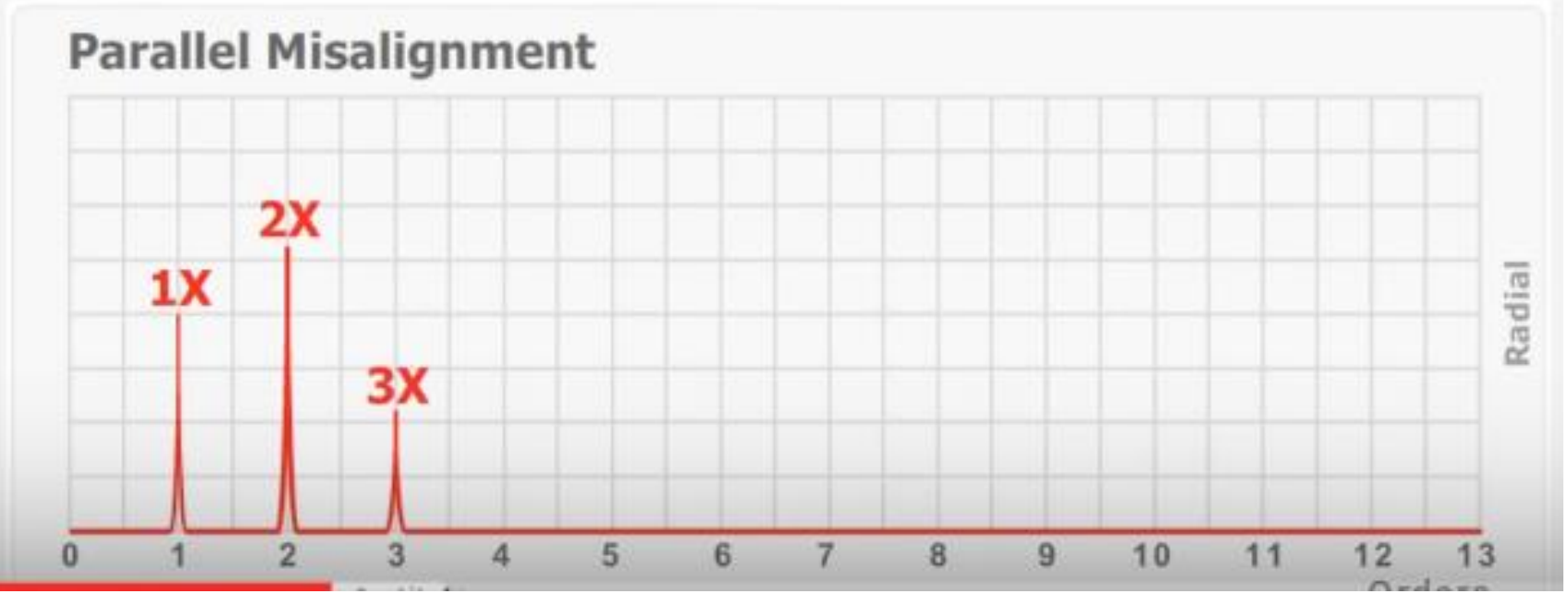
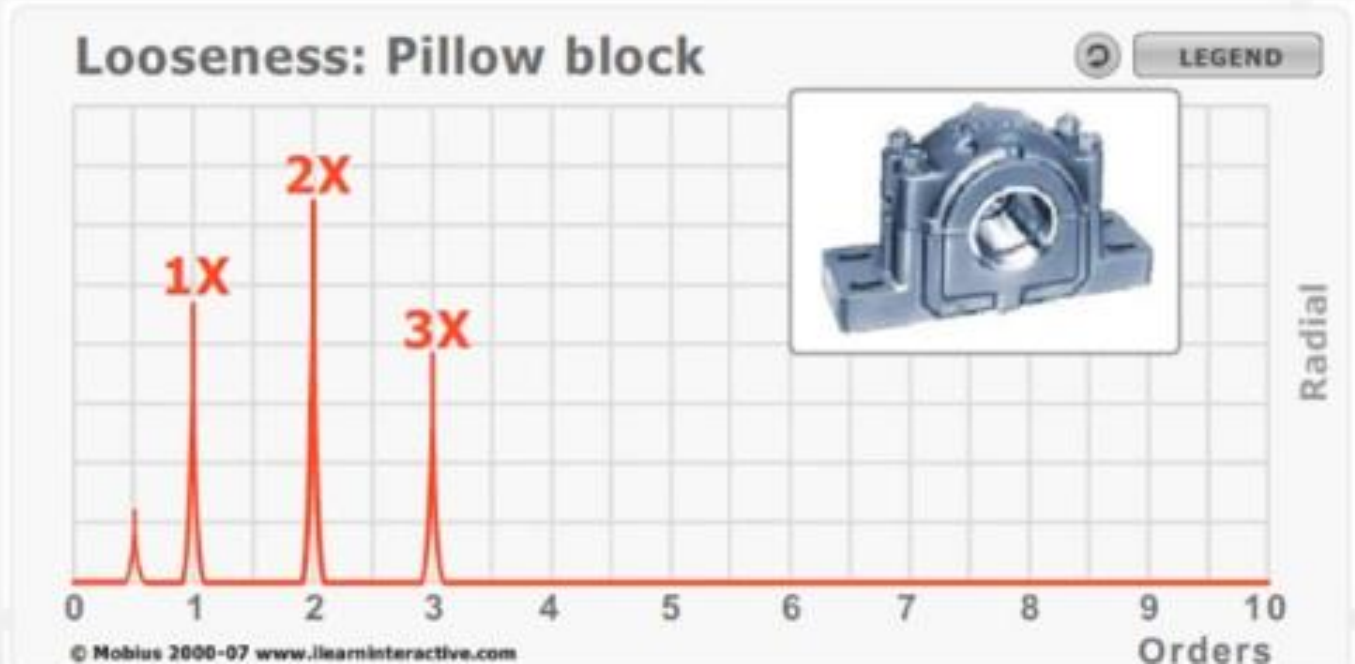


High frequency techniques

- Certain faults generate low amplitude, high frequency vibration.
- Techniques such as demodulation, enveloping, Shock Pulse, PeakVue, Spike Energy, HFD, SEE and others work on this principle.

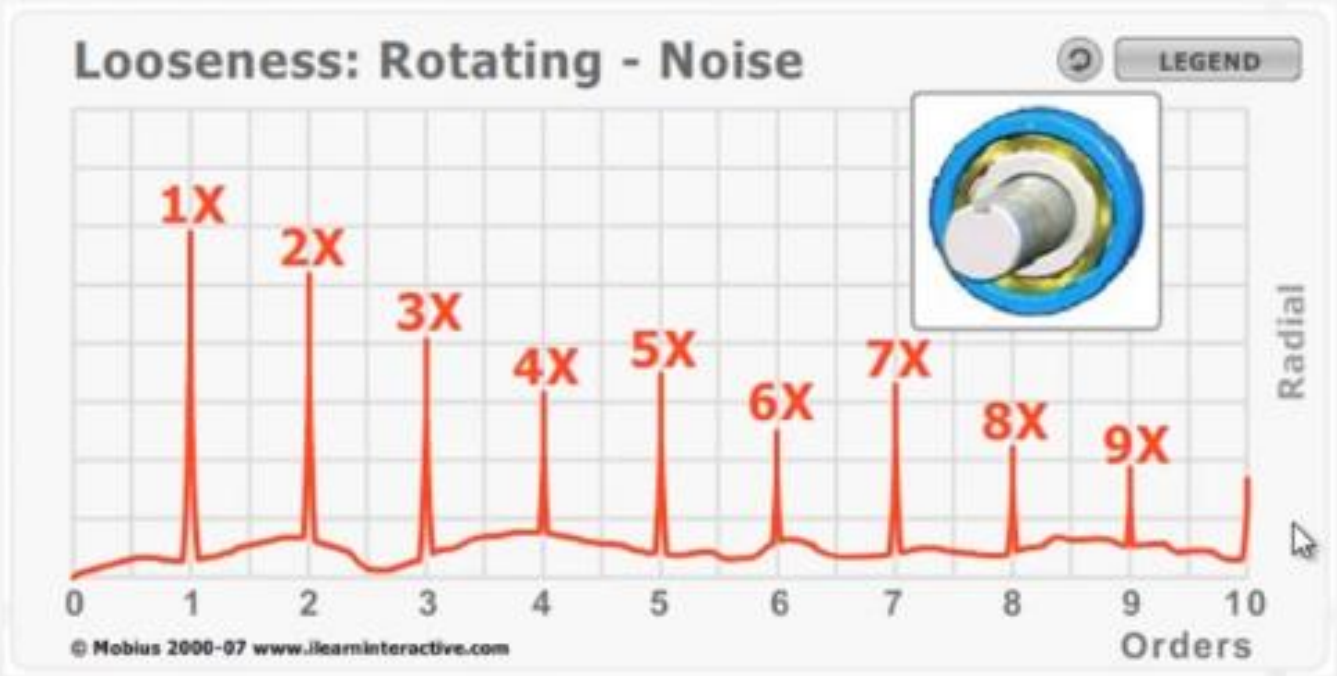
Pedestal looseness

- **Type B:** Cracked structure or pedestal bearing looseness
  - High 1X and 2X vibration
  - Phase erratic



Rotating looseness

- **Type C:** Rotating looseness
  - High 1X and harmonics
  - Phase erratic



Low Vibration

- Displacement - Stress
  - Measured in Mil’s
    - Use when vibration is slow, under 10 Hz or 600CPM

Mid range

- Velocity - Fatigue
  - Measured in IPS (inches per second)
  - or IPP (inches Pseudo peak)

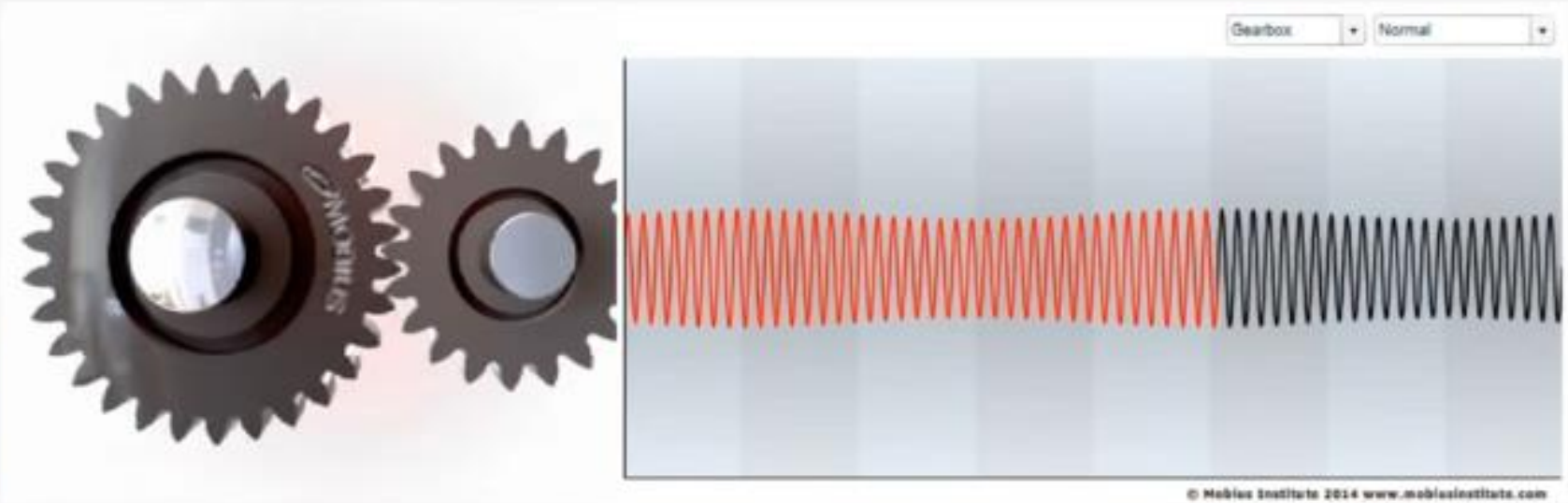
    - Use when vibration is between 10 Hz and 1000Hz
      - 600 cpm and 60,000 cpm

High Vibration

- Acceleration - Force
  - Measured in G’s 386.4 inches per second or 1 G

Time waveform analysis

- The time waveform is used to generate the spectrum – *you don't have to collect extra data*.
- The waveform shows you what happened from one moment to the next – the spectrum summarizes everything that happened whilst the data was recorded.



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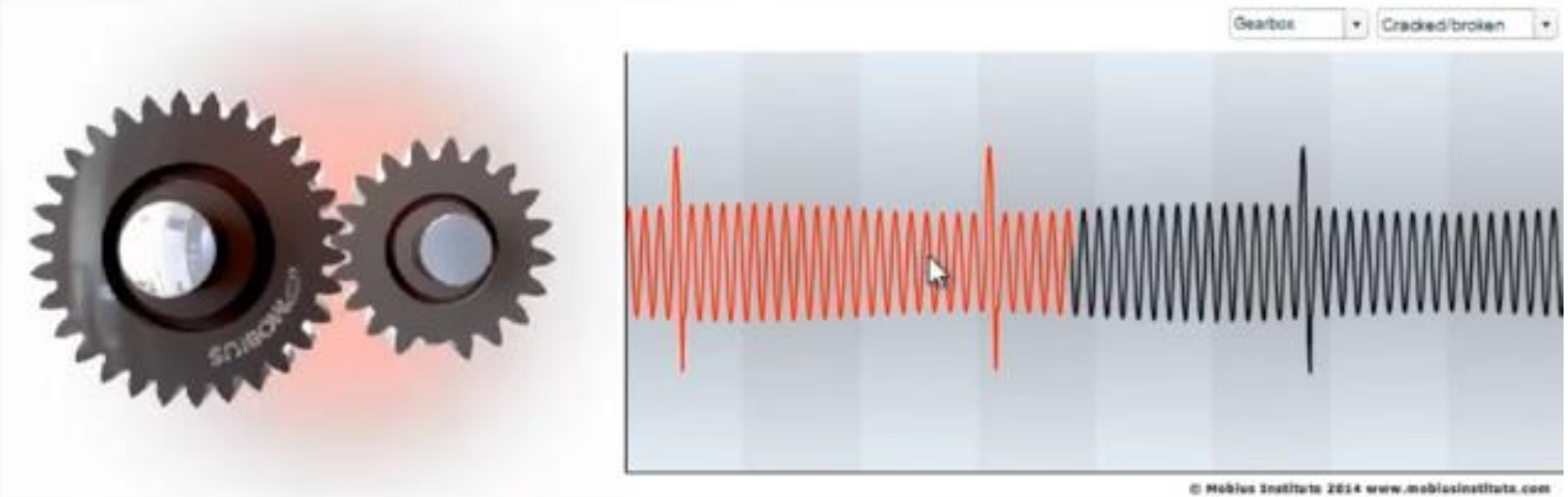
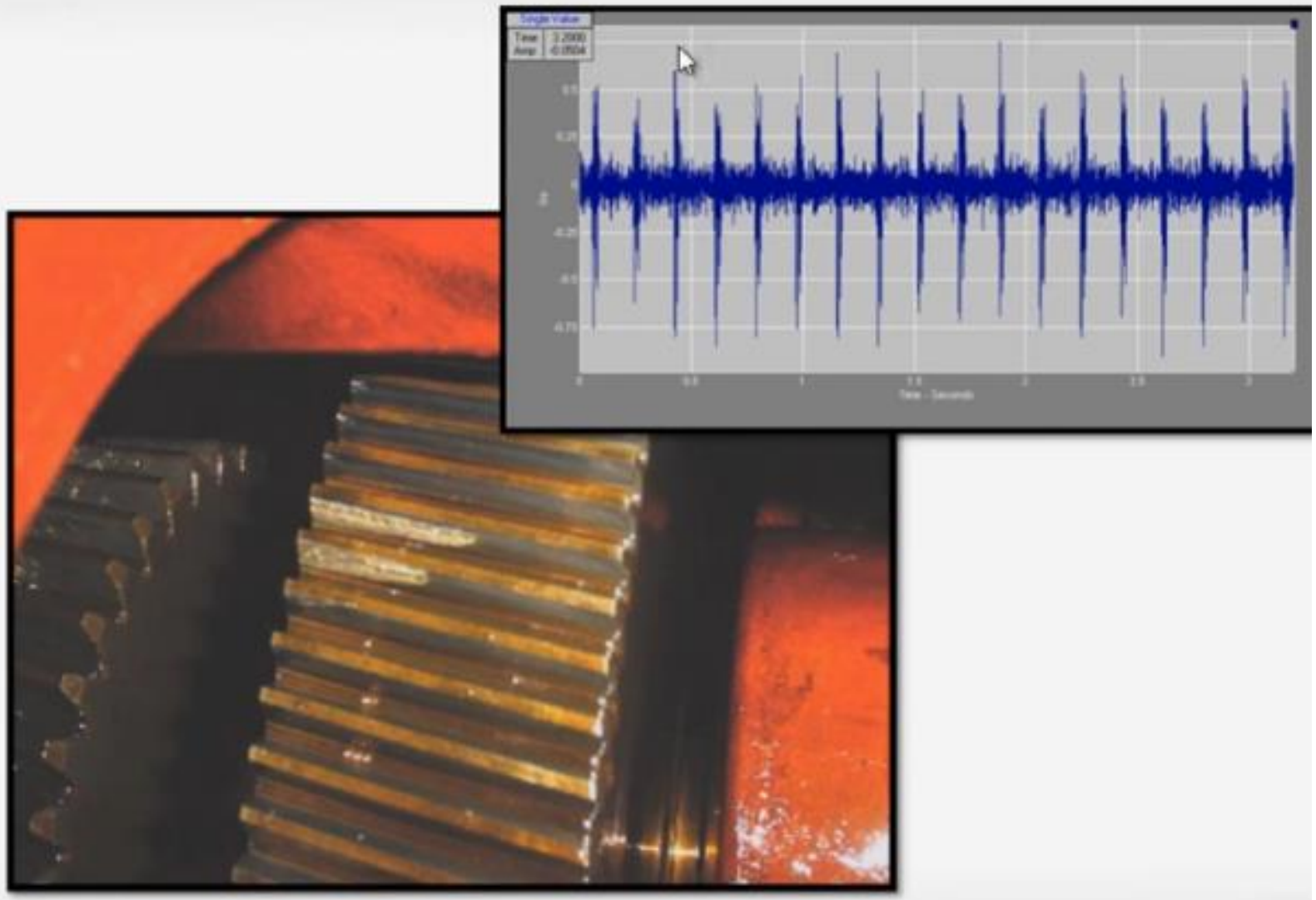
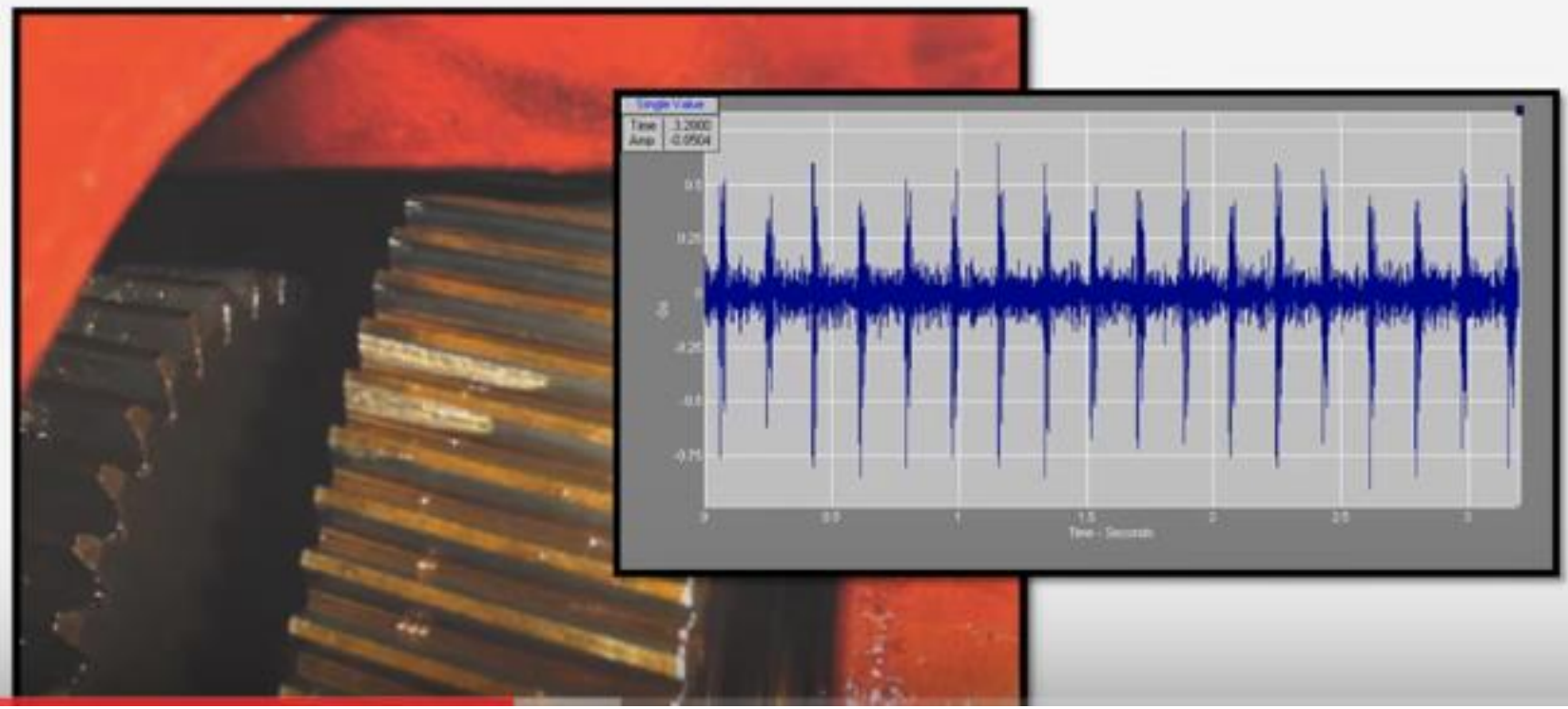


Time waveform analysis: Tooth damage



Time waveform analysis

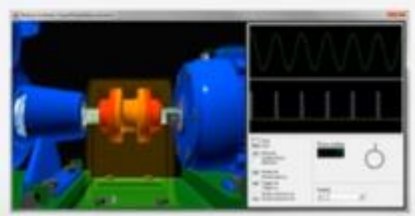
- Time waveform analysis provides detail not found in the spectrum.
- You see what happened from moment to moment.

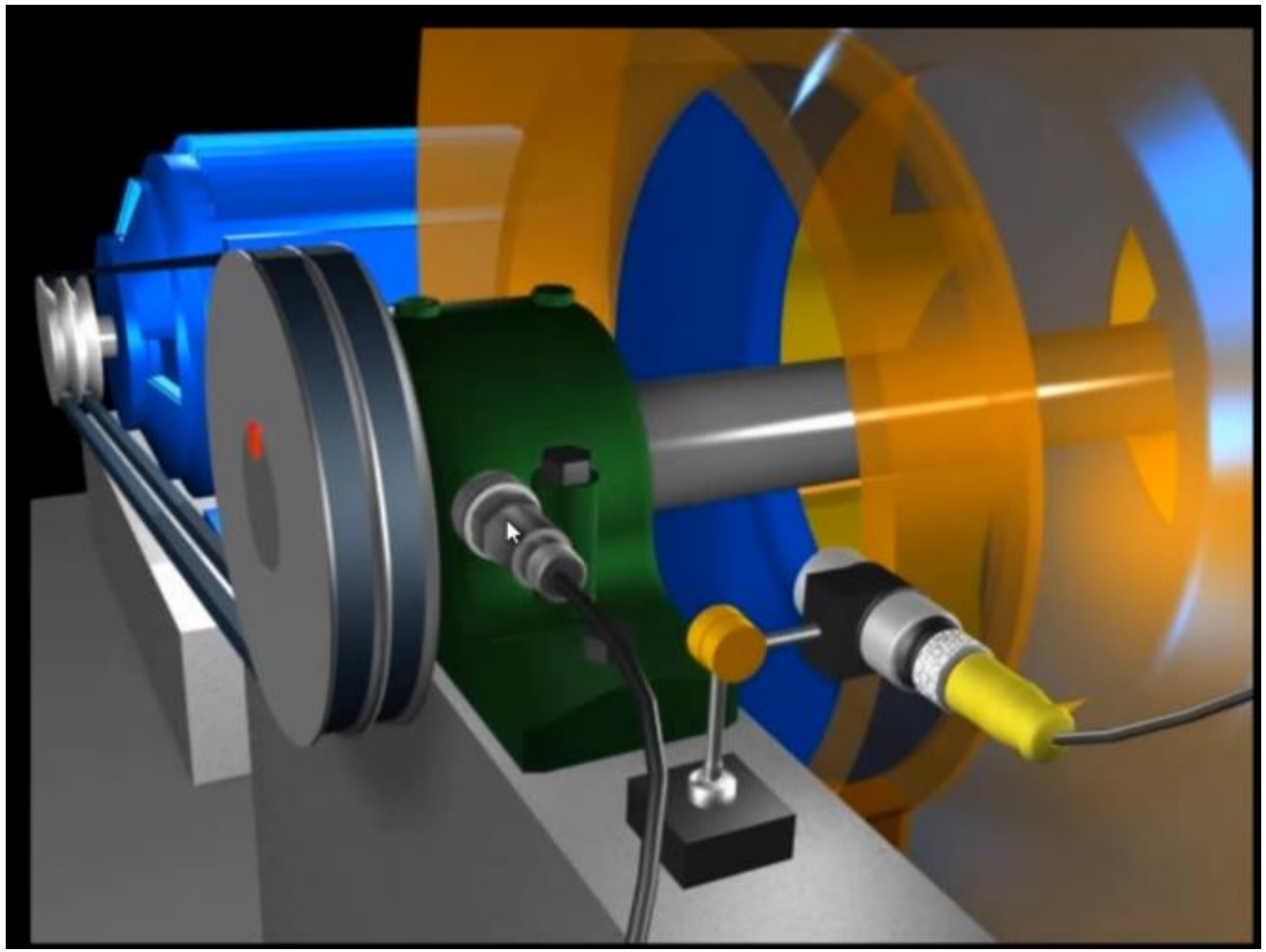


Phase: Visualizing vibration

- With many fault conditions, the spectral symptoms are similar; when you see 1X, 2X and 3X peaks, what are you going to do?

- Phase can help you distinguish between:
  - Unbalance (static, couple, dynamic, and overhung)
  - Misalignment (belt and shaft)
  - Eccentricity
  - Bent shaft
  - Cocked bearing
  - Foundation flexibility
  - Looseness
  - Resonance



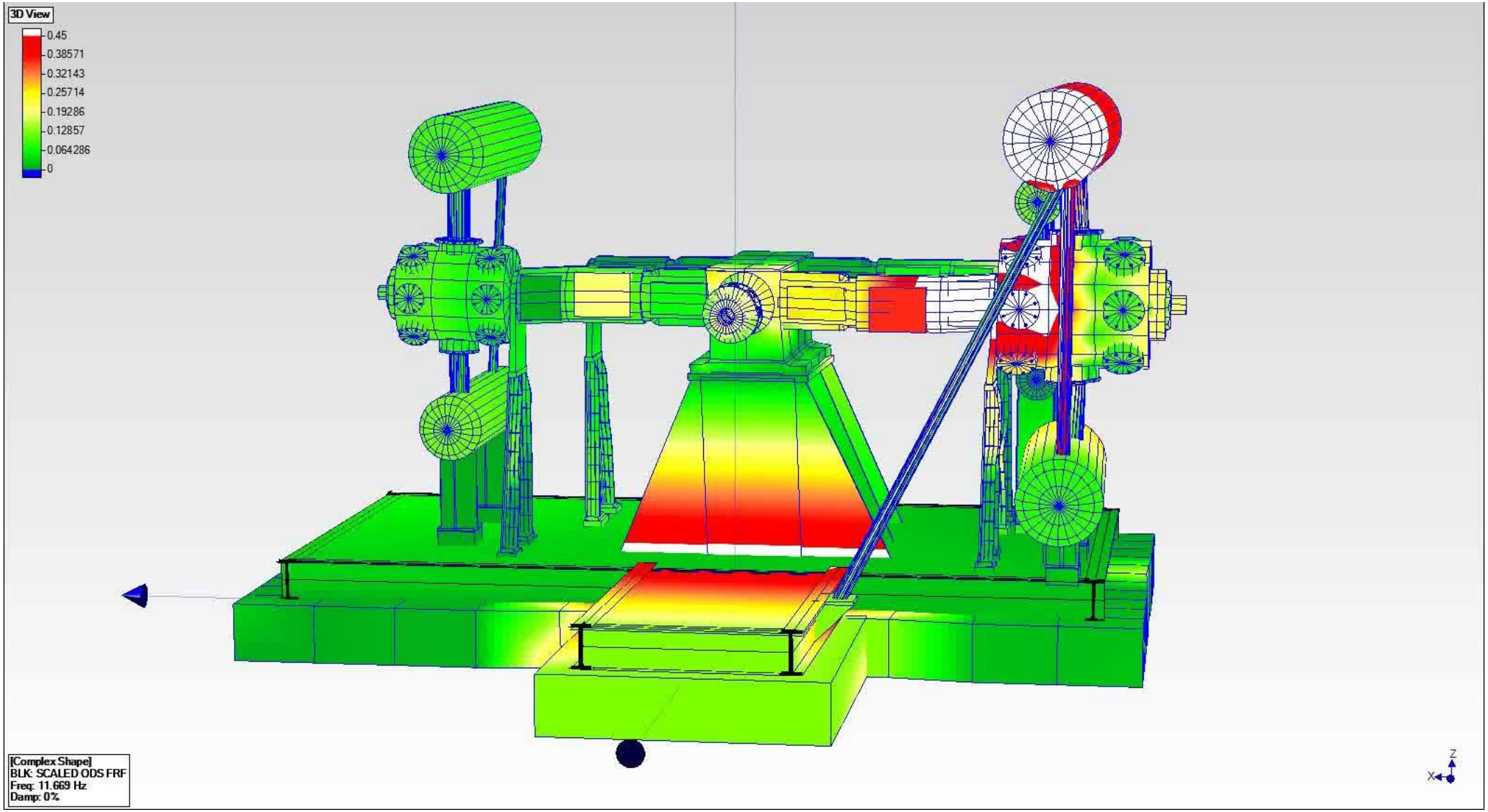


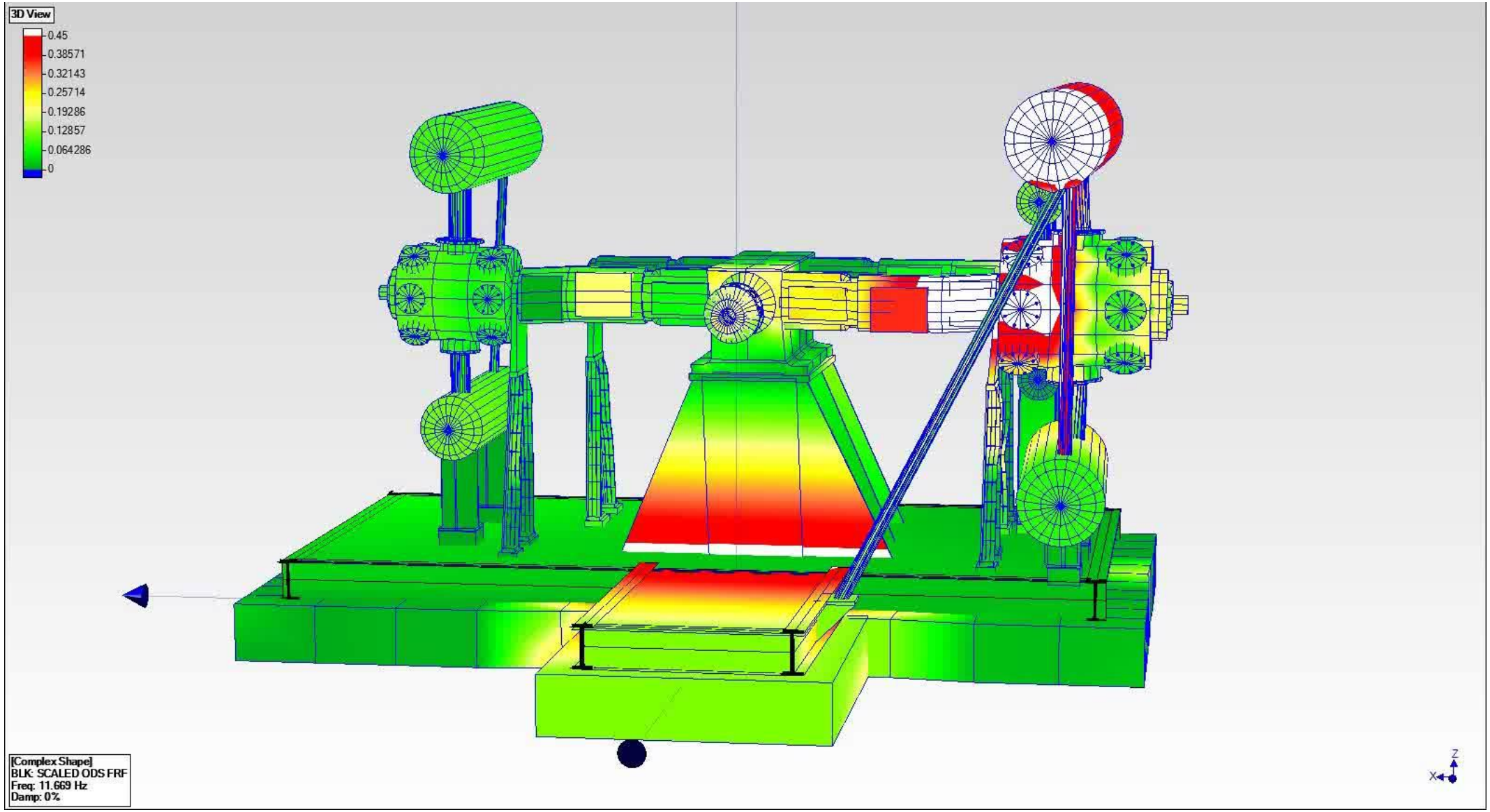
- Spectrum analysis is the most commonly used vibration analysis tool – the peaks usually relate to the components within the machine.

- Time waveform analysis is a very important tool – especially for gearboxes and bearing faults.

- Phase helps you understand the motion of the machine. It enables you to distinguish between different types of common fault conditions.

- It is important to understand the machine, the fault conditions, and the measurement setup (signal processing).


3D View
0.45
0.38571
0.32143
0.25714
0.19286
0.12857
0.064286
0
[Complex Shape]
BLK: SCALED ODS FRF
Freq: 11.669 Hz
Damp: 0%
Z
X


3D View
0.45
0.38571
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0
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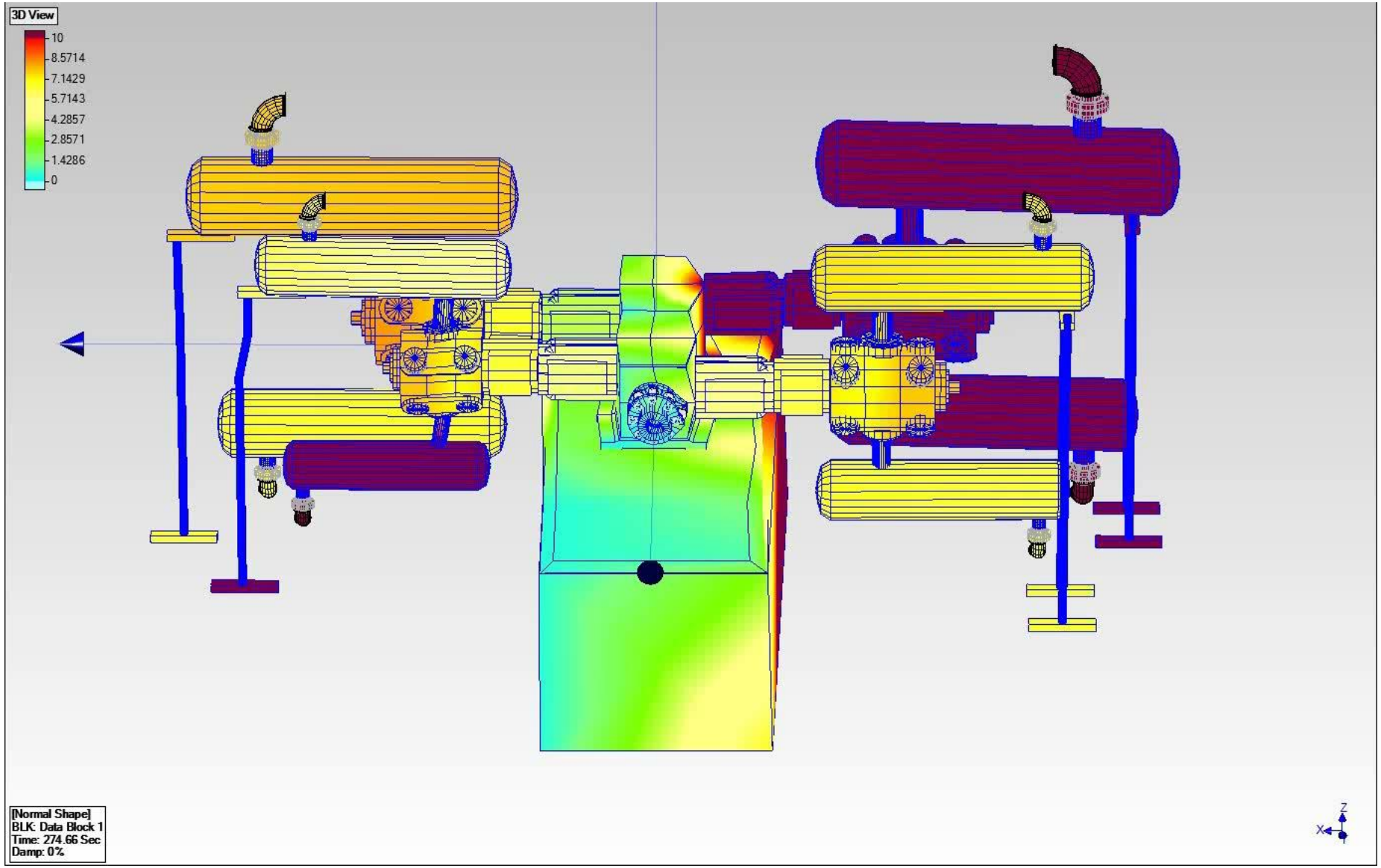
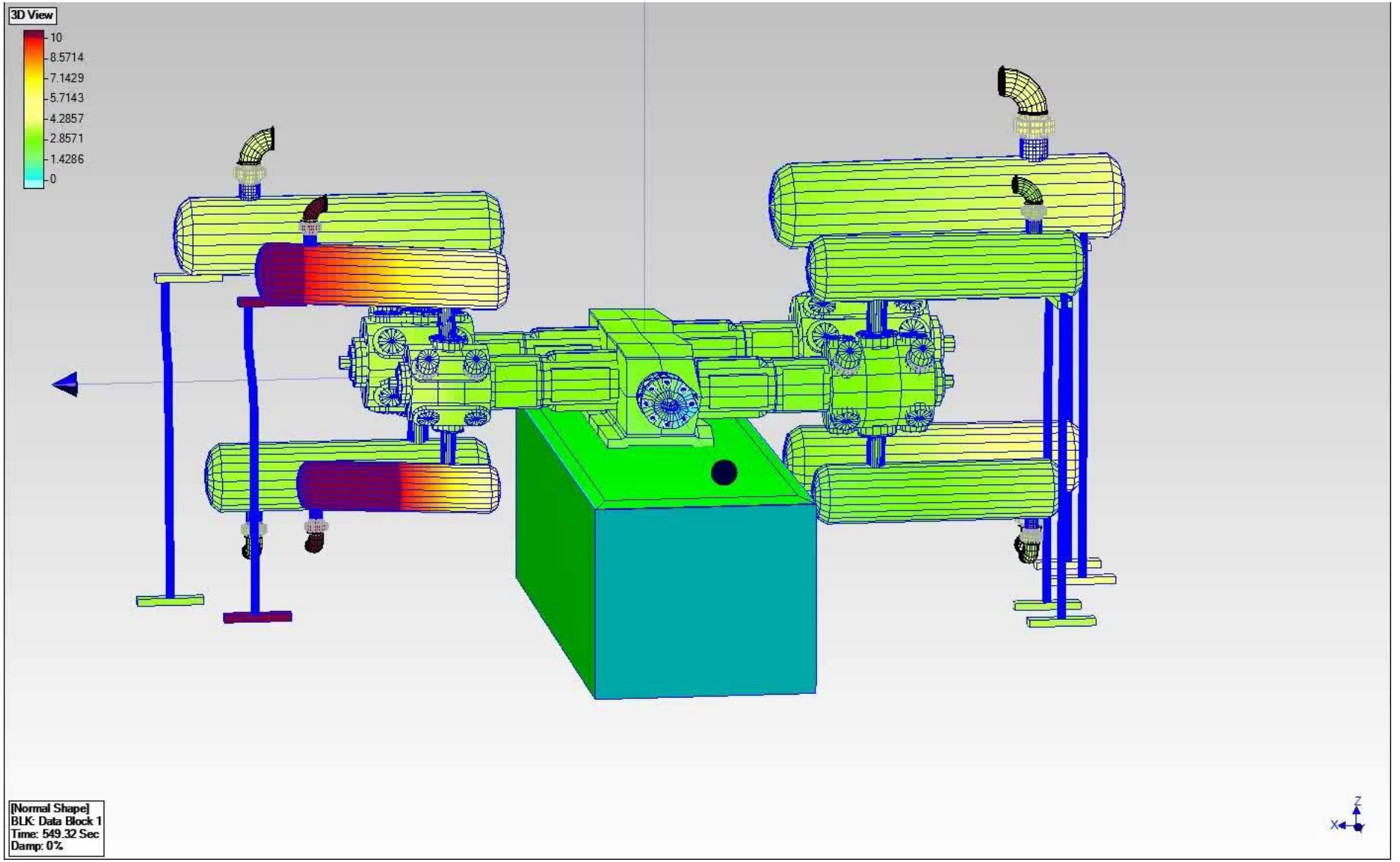
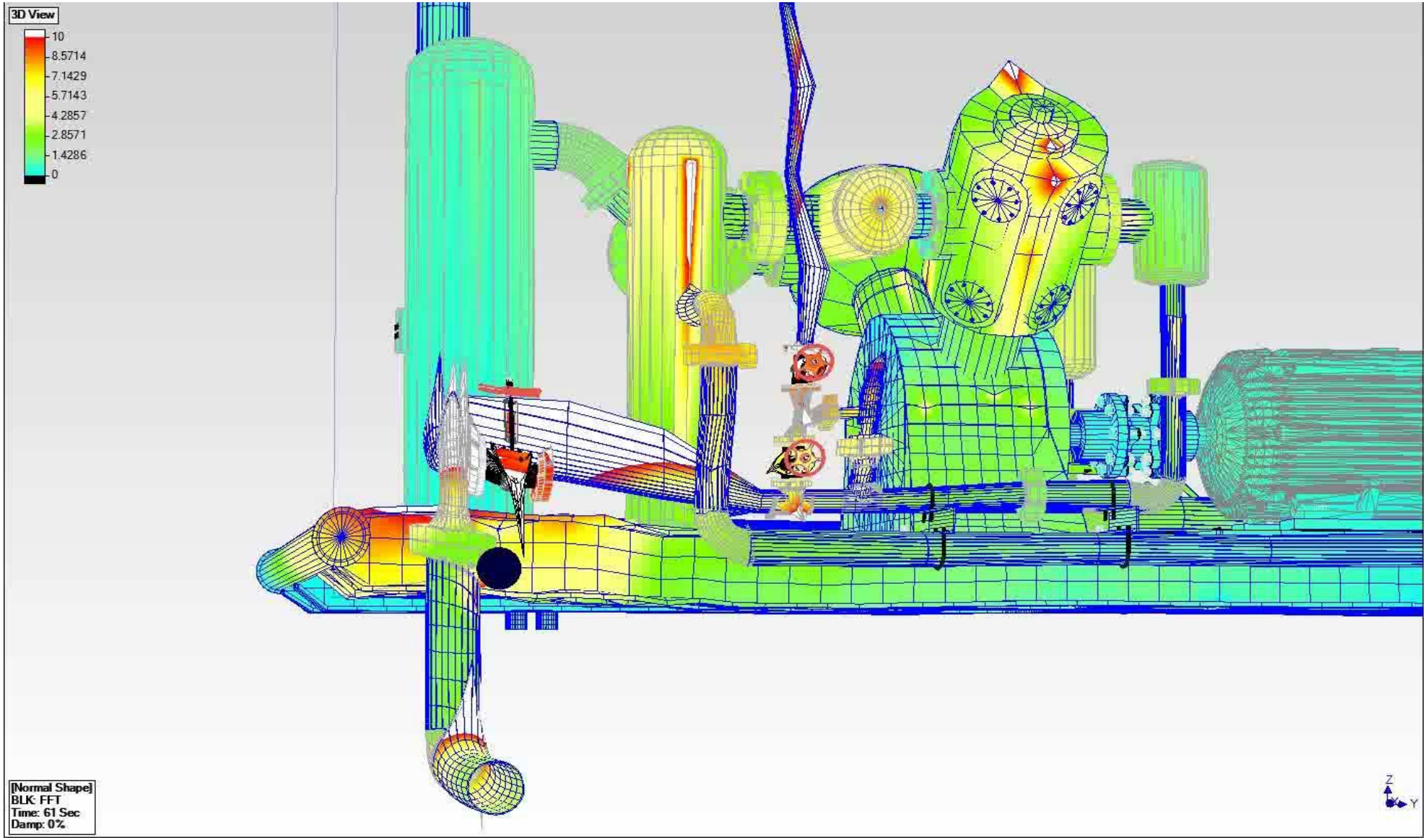
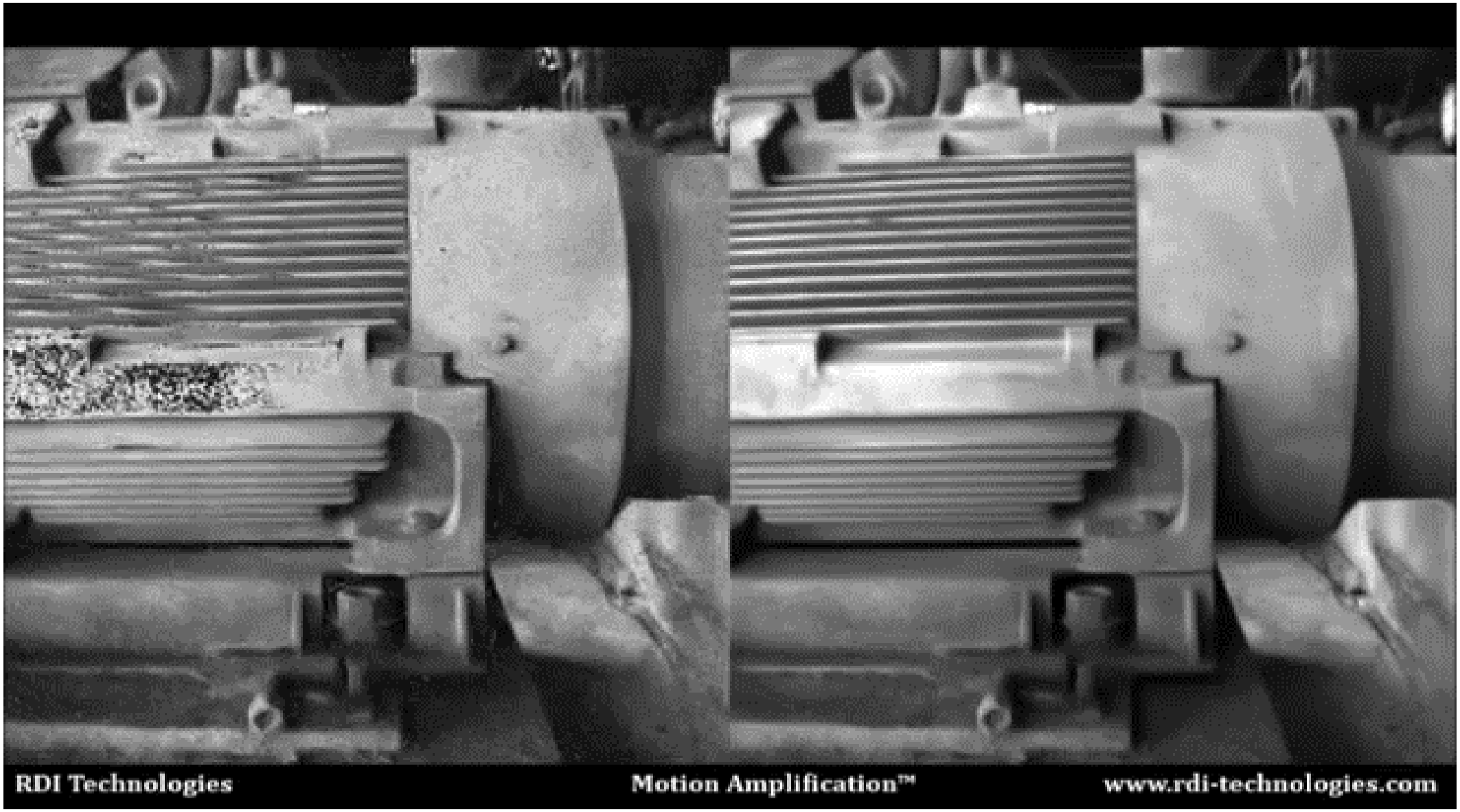
Z
X


3D View
10
8.5714
7.1429
5.7143
4.2857
2.8571
1.4286
0
[Normal Shape]
BLK: Data Block 1
Time: 274.66 Sec
Damp: 0%
Z
X


3D View
10
8.5714
7.1429
5.7143
4.2857
2.8571
1.4286
0
[Normal Shape]
BLK: Data Block 1
Time: 549.32 Sec
Damp: 0%
Z
X


3D View
10
8.5714
7.1429
5.7143
4.2857
2.8571
1.4286
0
[Normal Shape]
BLK: FFT
Time: 61 Sec
Damp: 0%
Z
Y


RDI Technologies Motion Amplification™
www.rdi-technologies.com


RDI Technologies
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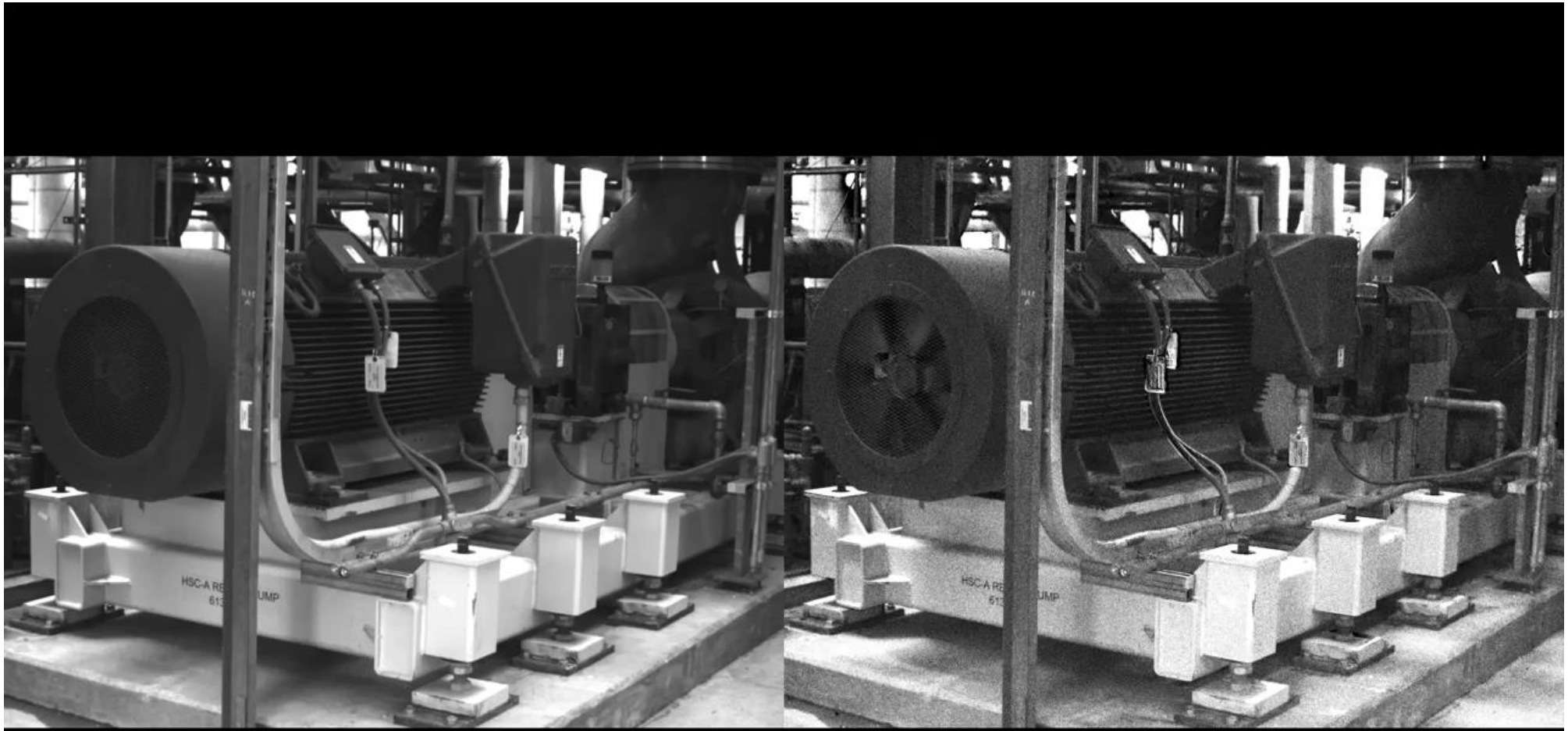

Circulation pump set (a)

Visual Reliability