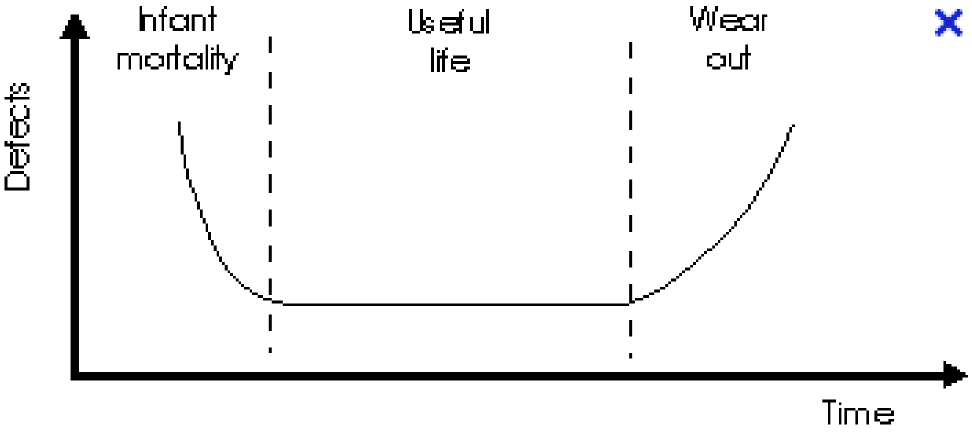
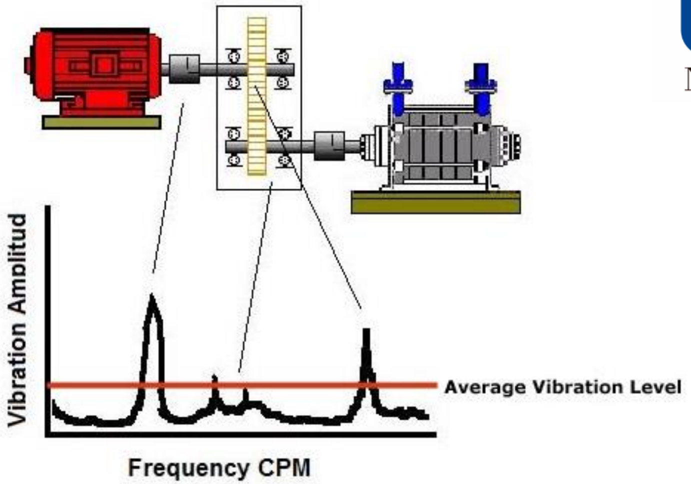
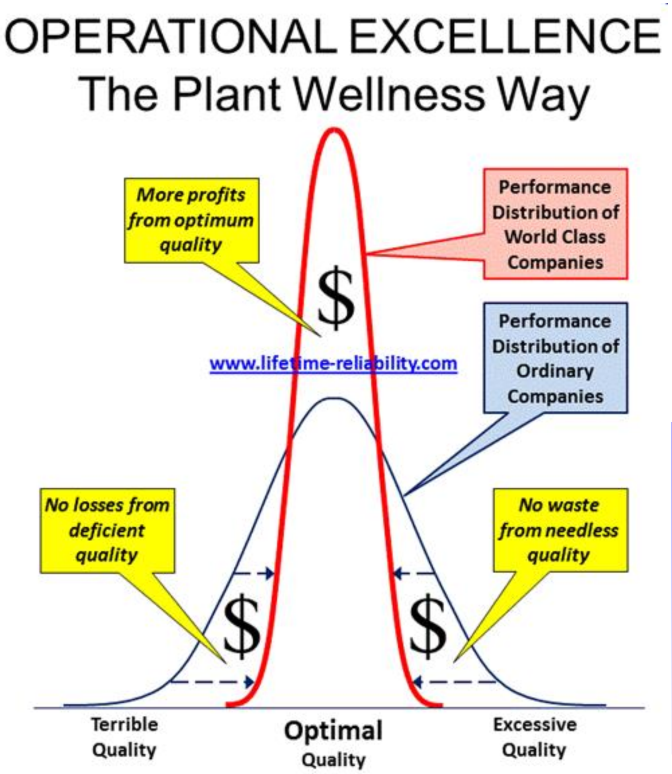
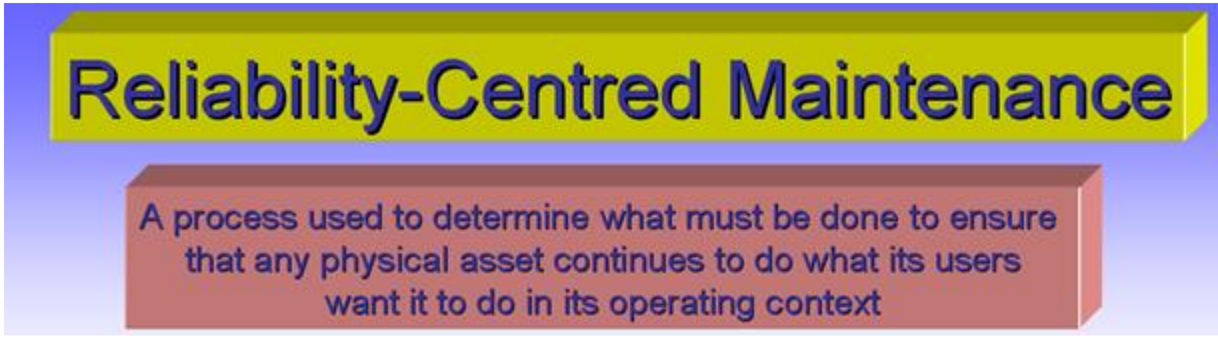






RAMS seminar

Vibration by
Viggo Pedersen



Vibration and Machine Learning

Features

Label

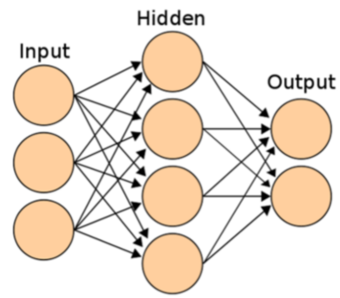
Vibration measurement

Vibration data

Neural network

Prediction

x,y,z
x,y,z
x,y,z
x,y,z
x,y,z
x,y,z
x,y,z



Car ok

Failure imminent

Machine learning – schematic model

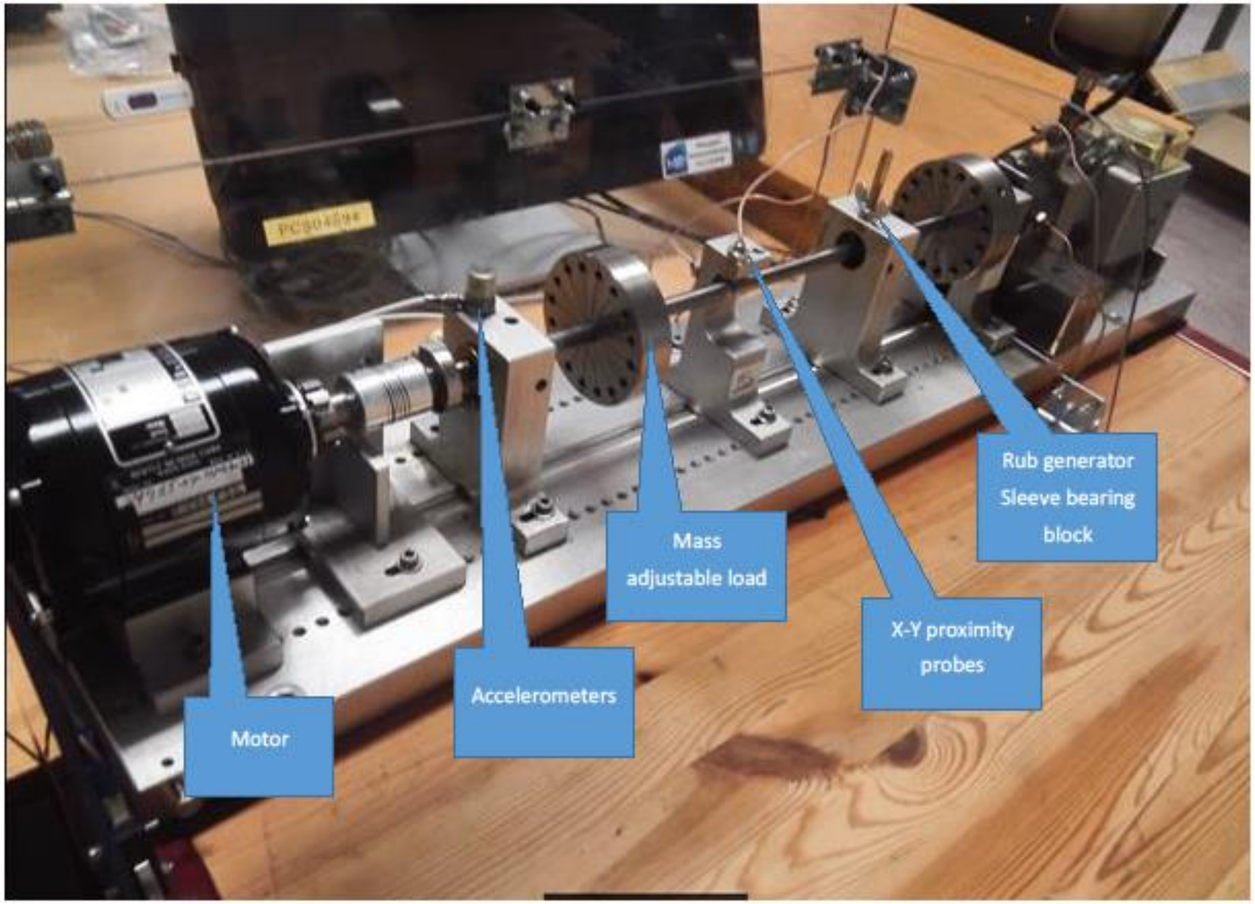
Predictive maintenance

- Probability of failure
- Remaining useful life

Machine learning when:

- Complex process
- Large amounts of data
- High cost equipment
- Failure impact high (costs, life, etc.)

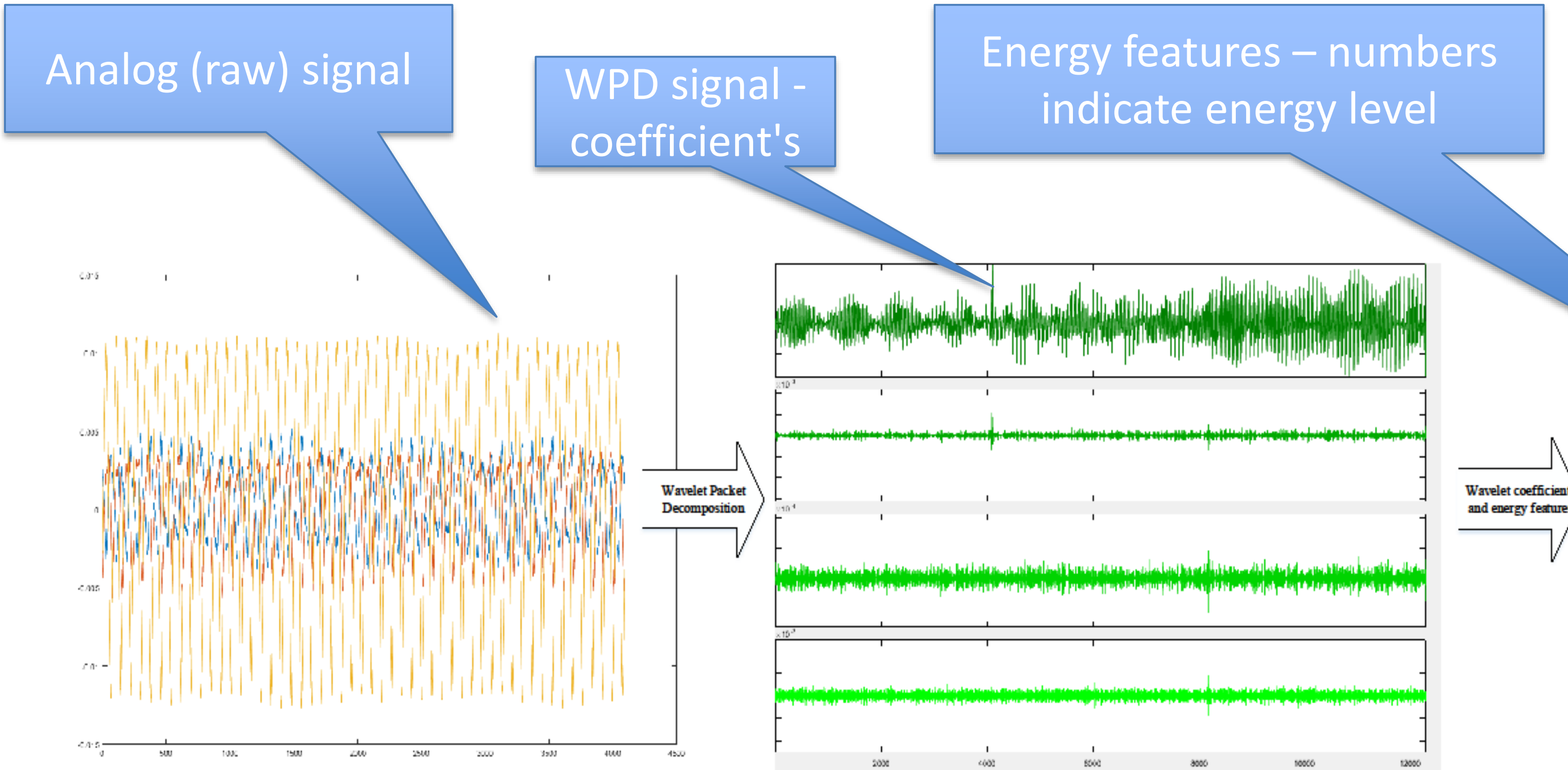
Vibration and Machine Learning



Analog signal (charge) emitted from Kistler piezo electric accelerometers mounted on the rotor kit is proportional to the vibration level. A discrete-time signal sampled over a period of time is representing the vibration level of rotating machinery in the time domain. Sample frequency is 5000 points in one second. One sample a second.

A Bently Nevada Rotor Kit is used for the experiments. Max rotor speed 10 000 rpm, can be adjusted in infinite steps.

Feature Extraction



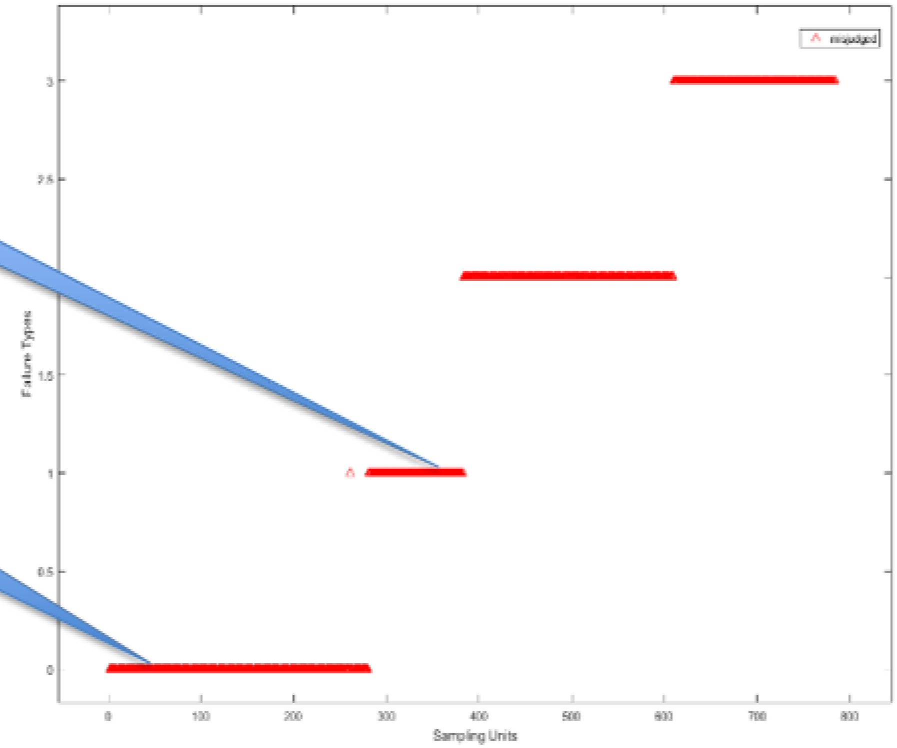
0.0002	0.0857
0.0014	0.1067
0.9729	0.2774
0.3392	0.0002
0.1265	0.0002
0.1185	0.0003
0.2117	0.0026
0.0003	0.9922
0.0020	0.0143
0.9680	0.0276
0.2255	0.6992

Three types of failures are introduced: bearing looseness, axel friction, and unbalance. For each type of failure, the vibration signals and rotating speed was measured by means of accelerometers (x,y,z) and proximity probe.

Classification of measurements

Fault type 1

No fault



Classification result from the back-propagation neural network. 10169 samples were extracted. 6033 samples used to train the BPNN and trained BPNN using remaining 784 samples (randomly)

Supervised learning

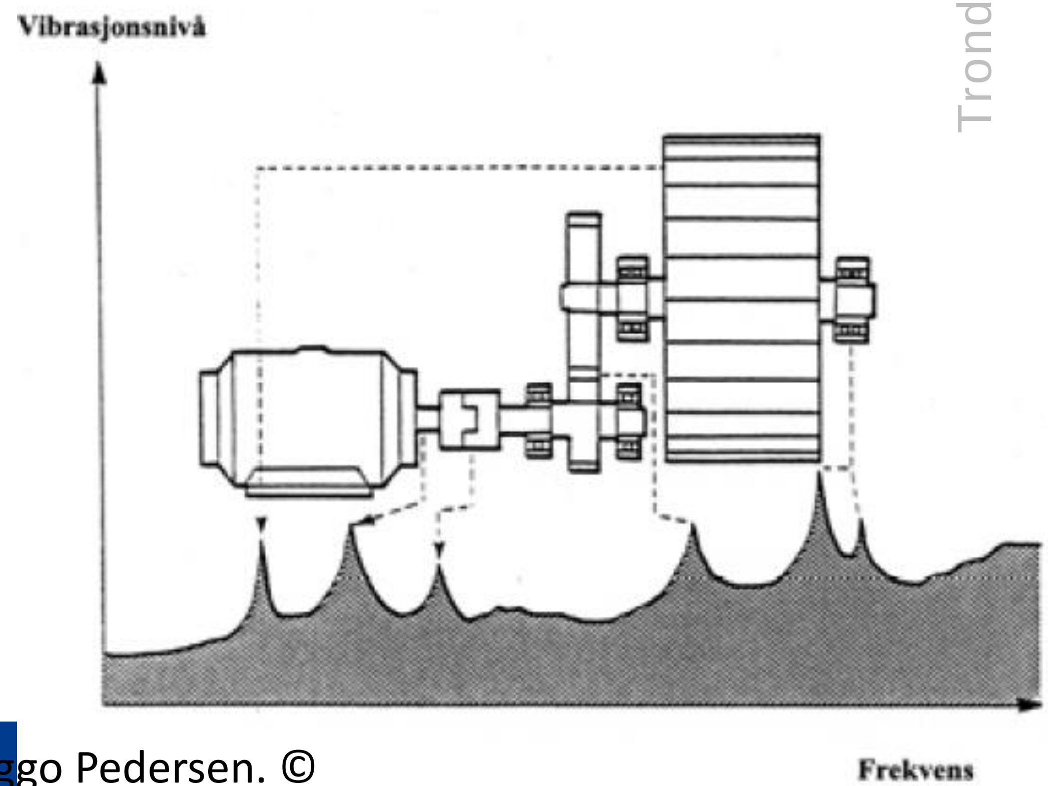
Conclusions

- The new method introduced in this paper is able to detect the failures introduced on the rotor kit with high accuracy (ISO 5725-1). Only one sample of 784 randomly selected samples is misjudged.

https://link.springer.com/chapter/10.1007/978-981-10-5768-7_54

Vibration analysis

- A machinery set up consists of several components
- Each component will have a vibration footprint at a certain frequency (using FFT to transform analog signal in time domain to frequency domain)
- A change in frequency «amplitude» indicates something is wrong – and the root component of the wrong



WHAT IS VIBRATION ?

- Simply put:
  - The motion of a machine or its part back and forth from its position of rest
- The displacement X of a spring mass system with respect to time can be expressed:
  - X=$X_0 sin\omega t$
    - X_0= max displacement
    - ω =2 * π * f, f=frequency [Hz]
    - t= time [seconds]
- Velocity = $\frac{dX}{dt}$
- Acceleration = $\frac{d(velocity)}{dt}$

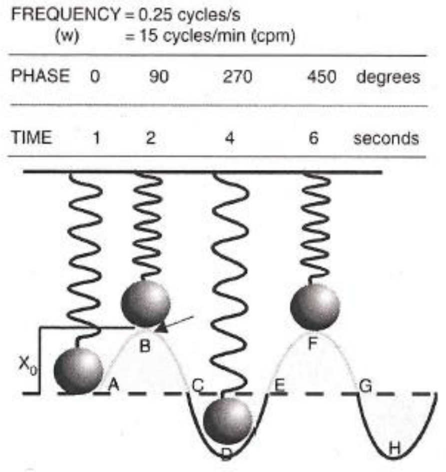


Figure 2.4
Simple harmonic wave – locus of spring-mass motion with respect to time

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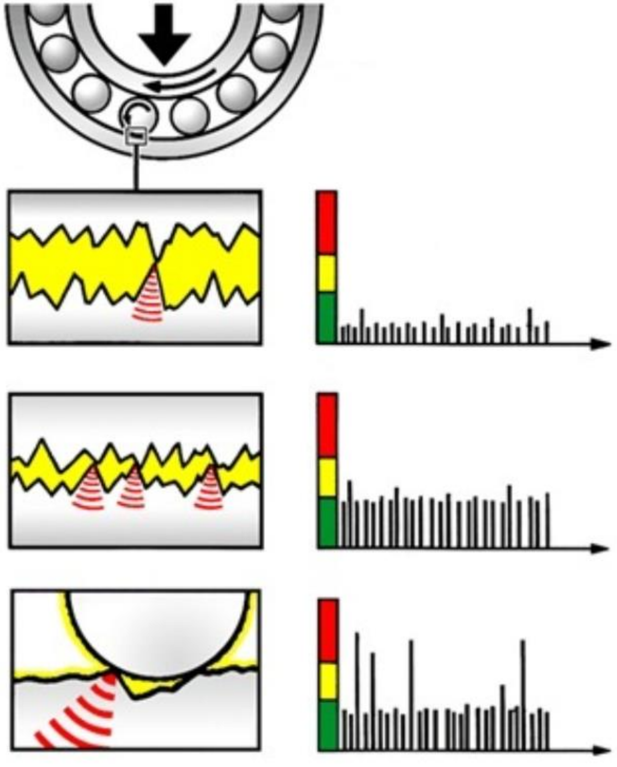
Shock Pulse Method

- The SPM method is used to monitoring   roller and ball bearings.
- Two metal surfaces in contact with each other while in motion will generate a shock wave on impact – this wave travels through metal in the ultrasonic range and is around 36 kHz.

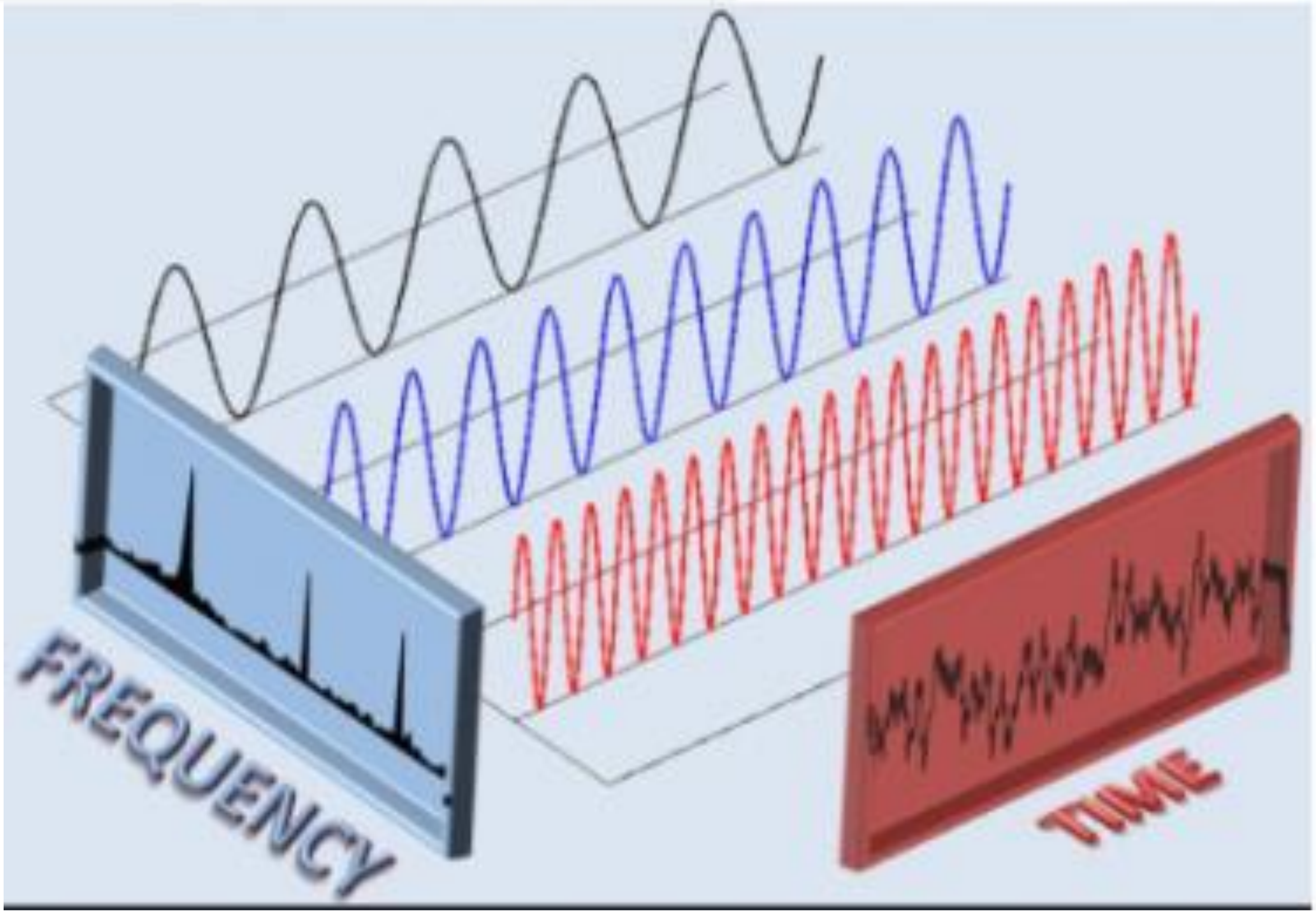


- Reference : SPM

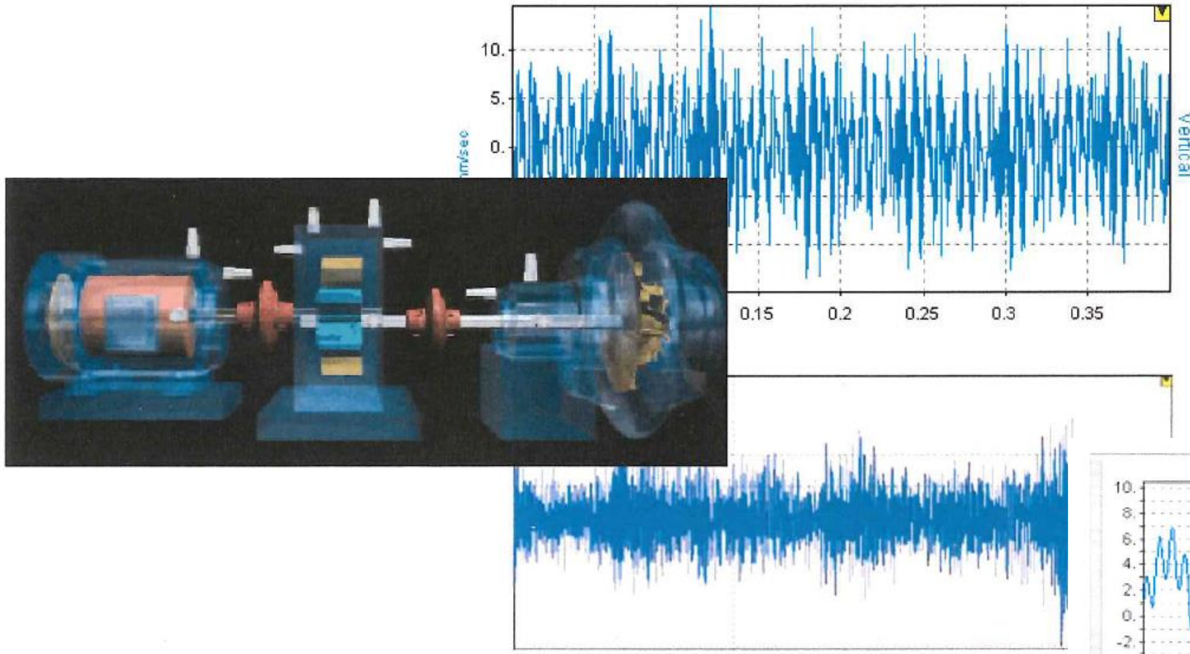
Vibration signals

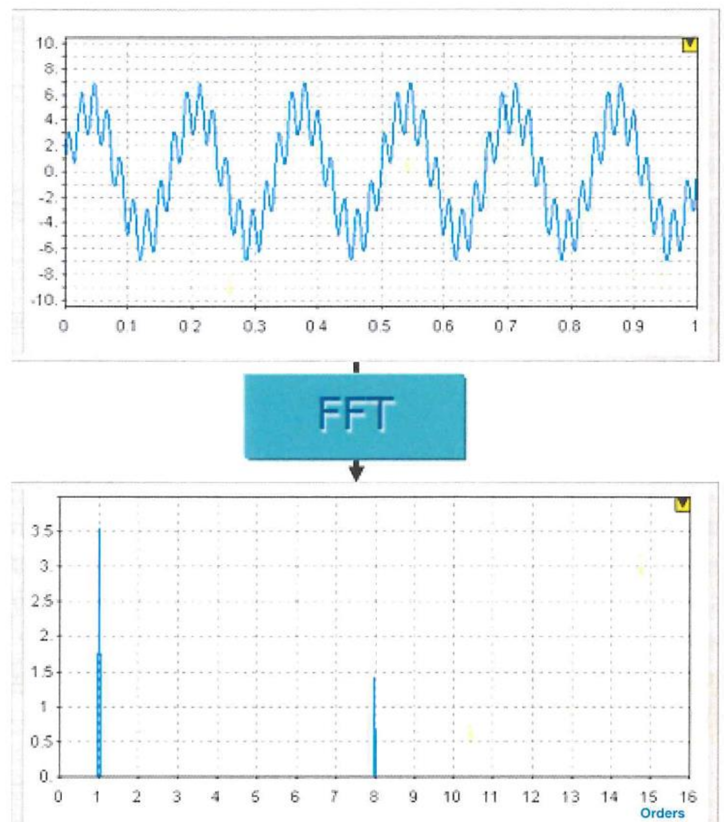
FFT is most frequently used in vibration analysis signal transformation

$$X(k) = \sum_{n=0}^{N-1} x(k)\cos\frac{2\pi kn}{N} - j\sum_{n=0}^{N-1} x(k)\sin\frac{2\pi kn}{N}$$



Vibration signals





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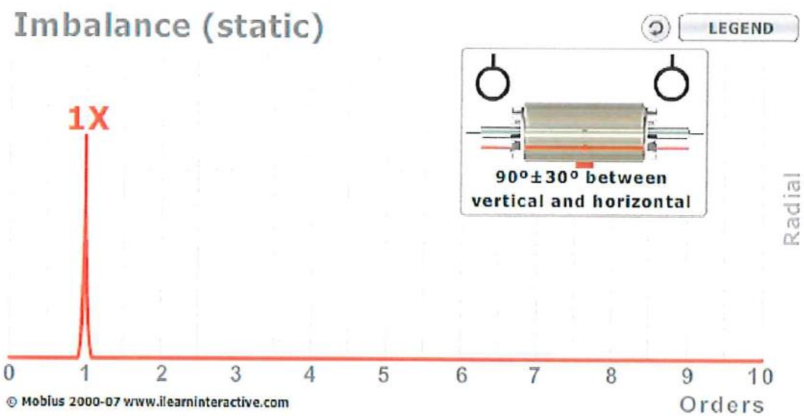
Vibration patterns -unbalance

There is almost always some residual unbalance, so there is almost always a 1x peak.

If the spectrum is dominated by 1x and the amplitude is high, suspect mass unbalance.



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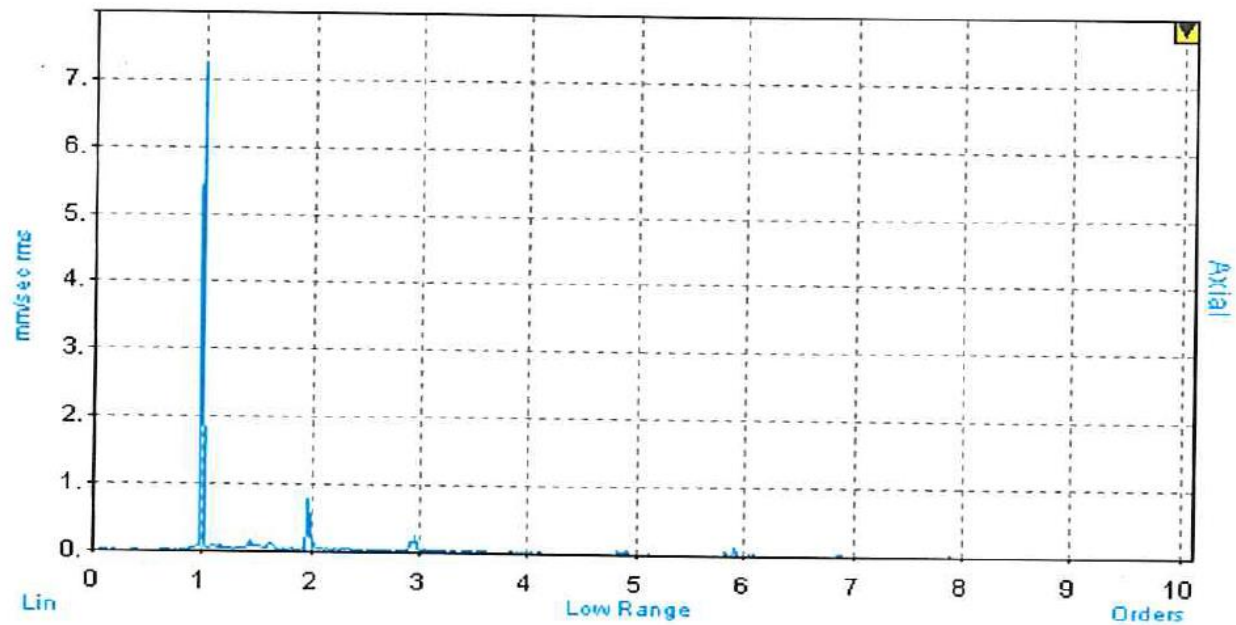

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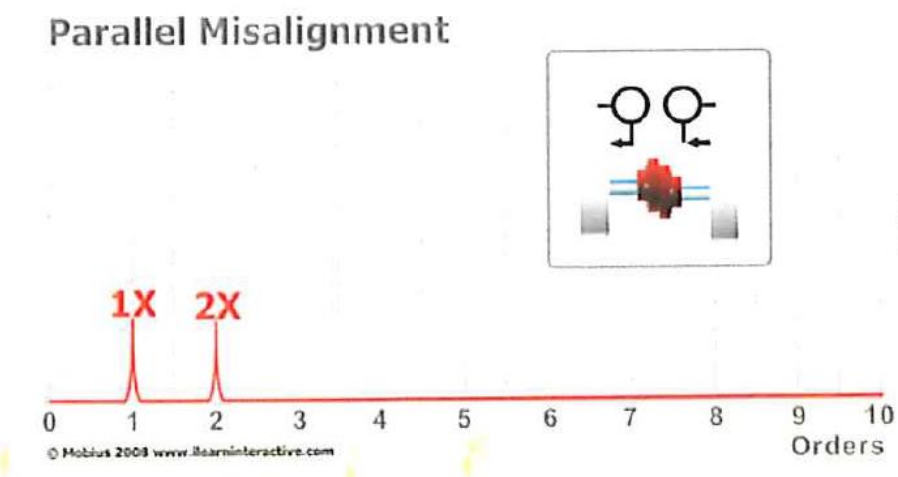
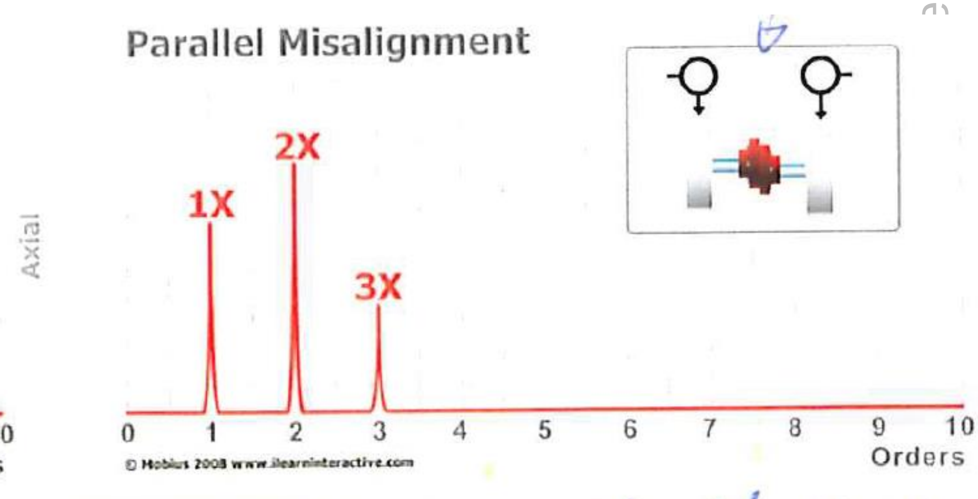
Vibration patterns - misalignment





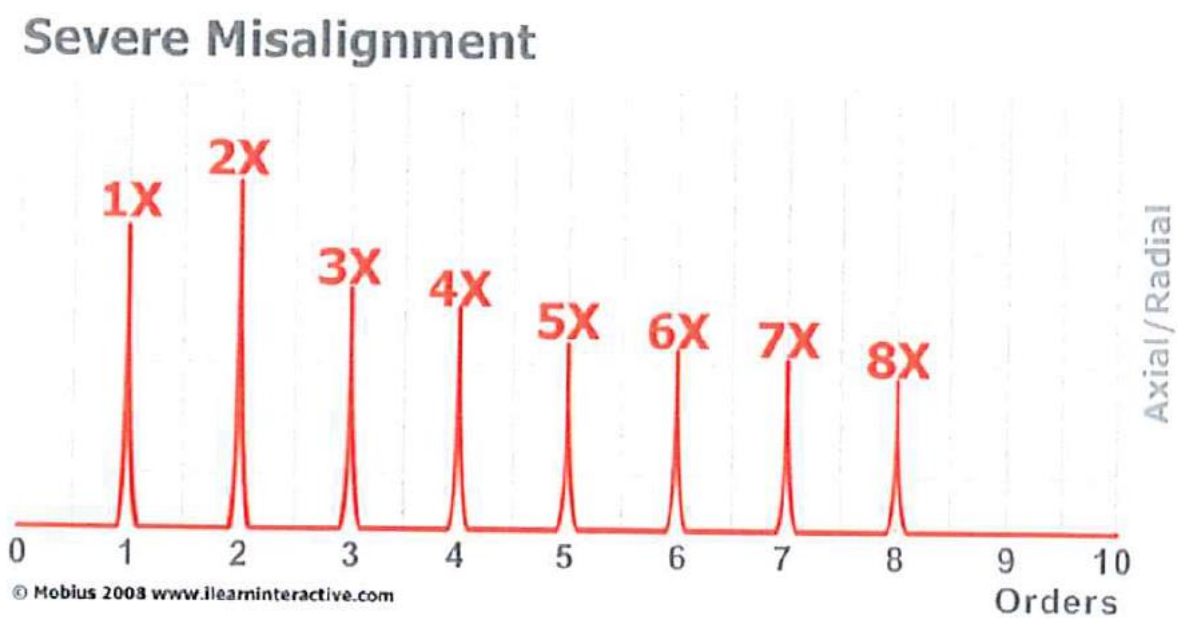


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Figure 9-11 - Severe misalignment produces 1x harmonics

Vibration patterns – Resonance

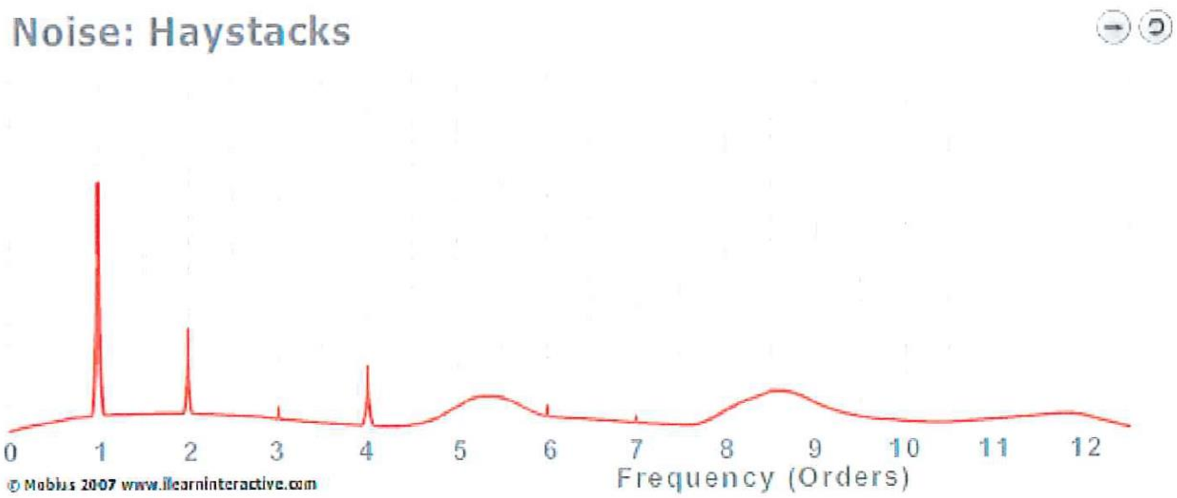
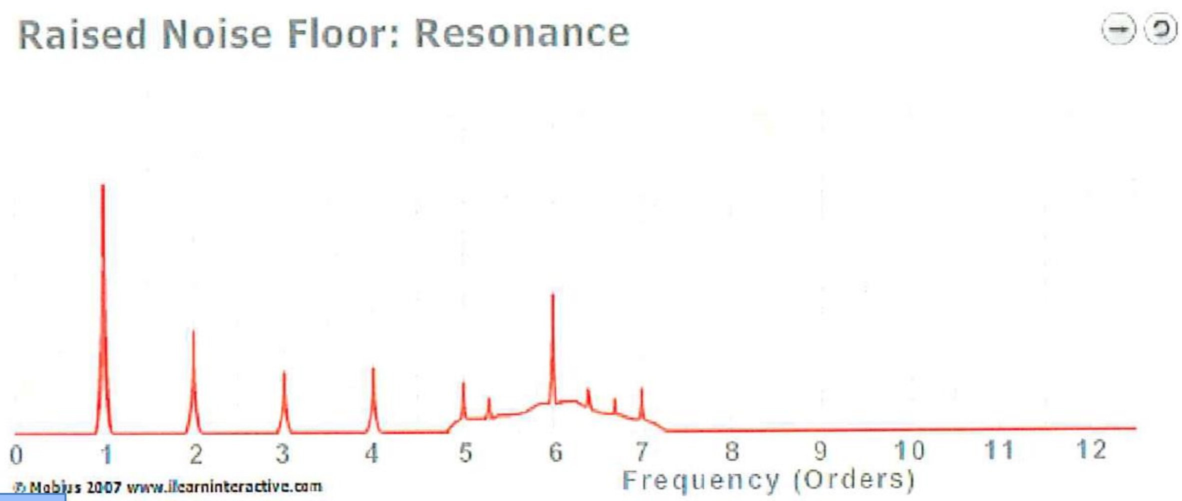


Figure 2-39



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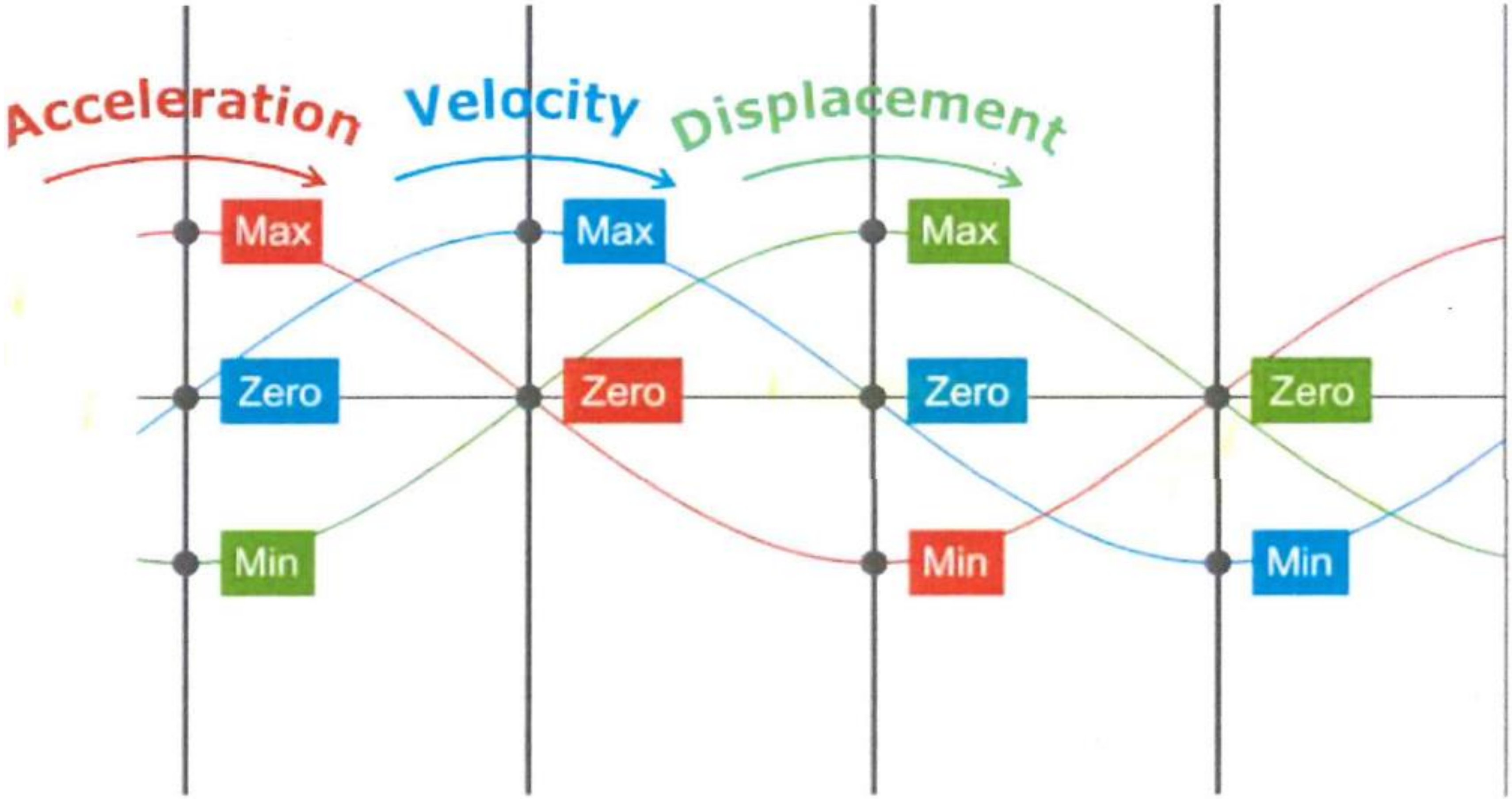
Vibration – amplitude can be measured 3 ways



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The 3 amplitudes

- Displacement – the distance a mass moves
- Velocity – how fast the mass is moving at any given point
- Acceleration – the rate of change of velocity

- 90 deg. apart

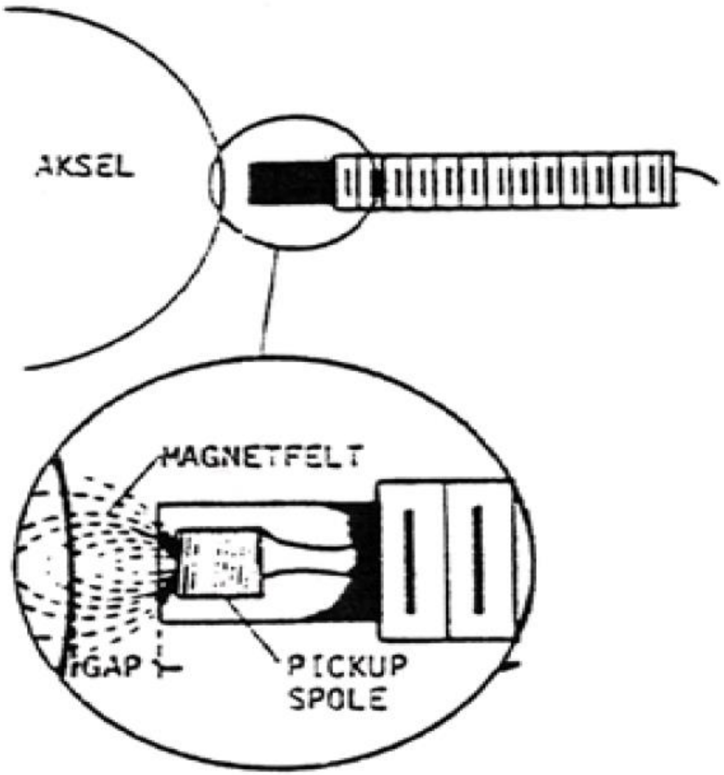
- Displacement measured in micron (µm)– proportional to stress $[\frac{N}{mm^2}]$
  - Lower speed machines (below 600 rpm)
  - Proximity sensors

- Velocity measured in $[\frac{mm}{sek}]$ – proportional to fatigue [strain cycles]
  - Accelerometers (beware measurement range)

- Acceleration measured in $[\frac{m}{s^2}]$ – proportional to forces within a machine[N]
  - High speed machines (10 000 rpm and above)
  - Accelerometers

Proximity sensor

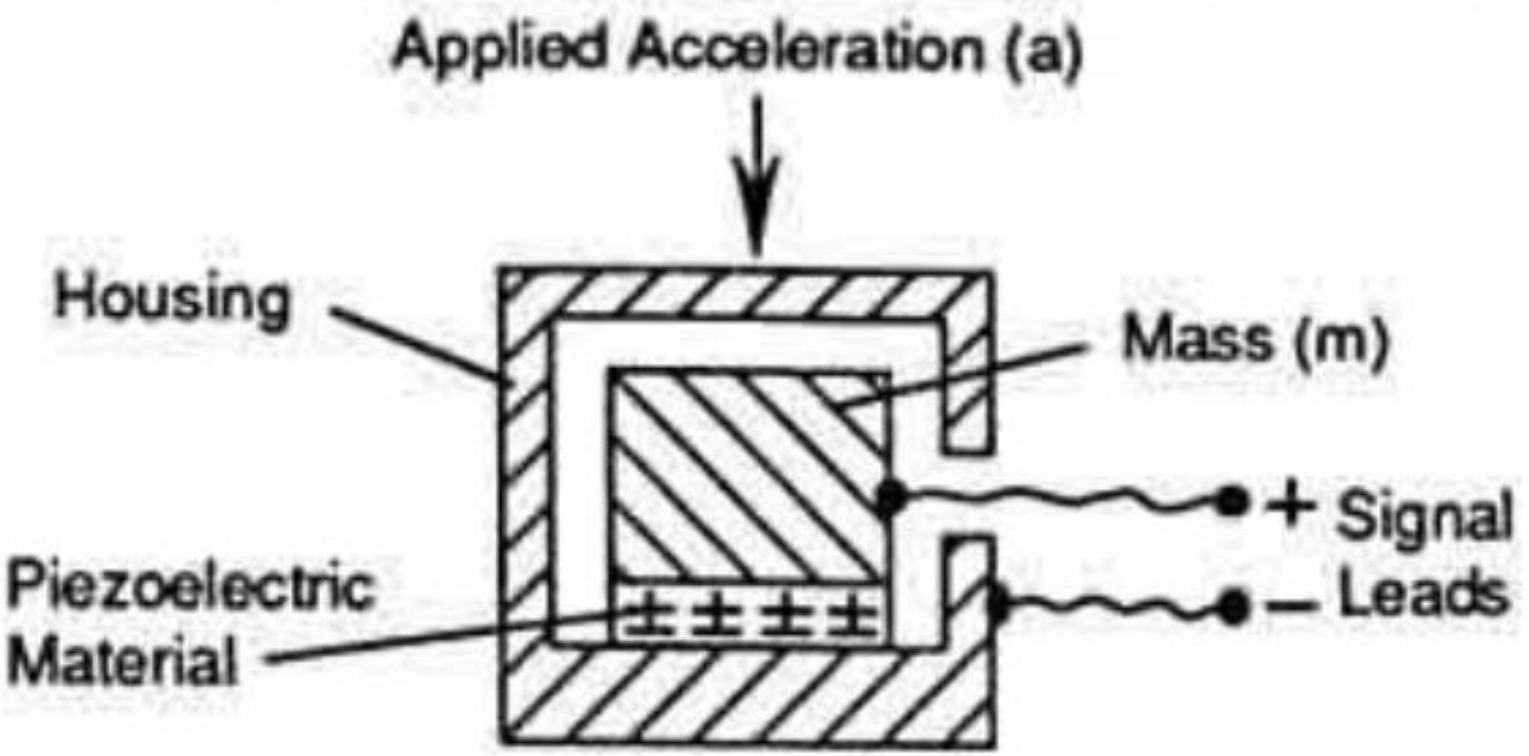
- Magnetic field is set up by the electrically powered sensor.
- The magnetic field changes as the axel comes nearer to the probe.



PIB

Accelerometer

- Piezoelectric element
- Pressure added to element – changing electric charge



PC control

Sensor Mounting

Evaluation of machine condition

- Determining harmful vibration level is often based on
  - ISO 2372 or 10816
  - Vendor recommendations
  - Owner experience
  - Consultants advice

Evaluation of machine condition

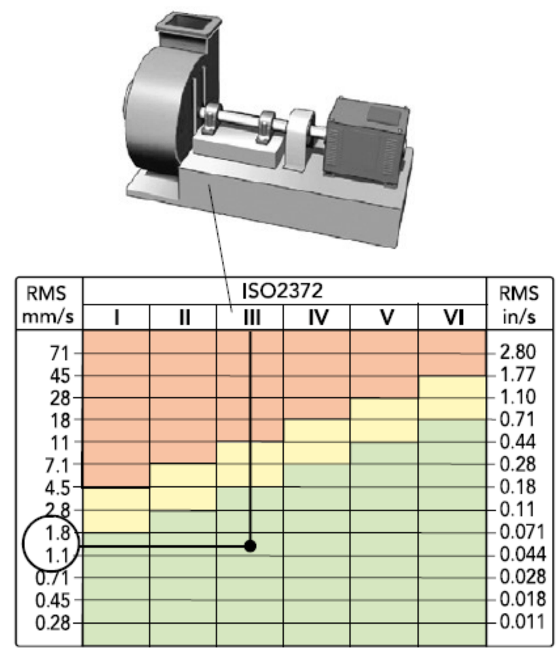
The evaluation consists of a comparison of the measured value with the ISO limit values recommended for 6 different classes (see definition on the next page).

The majority of industrial machinery belongs to the vibration classes 2, 3, and 4:

Class 2: Medium size machines without special foundations

Class 3: Large machines on rigid foundations

Class 4: Large machines on soft foundations.



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Thanks for listening

Referanser: Bye, Per I. (2009). Vedlikehold og driftssikkerhet. Trondheim