

Rotating Machinery WebEx

Appetizer to

Rotating Machinery Diagnostics

29 November 2006 – 3 days

Hands-on

Brüel & Kjær Headquarter Denmark

1 Rotating Machinery Appetizer

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Rotating Machinery WebEx

Transducers

Measurement Chain

FFT Analysis

Signal / System Analysis

Order Analysis

Sources of Vibration, Characteristics

Cepstrum Analysis

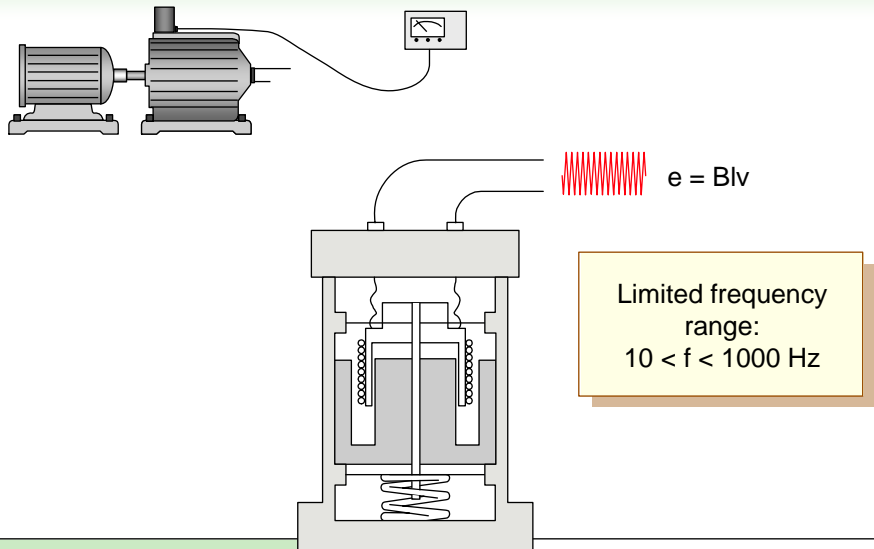
Envelope Analysis

ODS, Operating Deflection Shape

2 Rotating Machinery Appetizer

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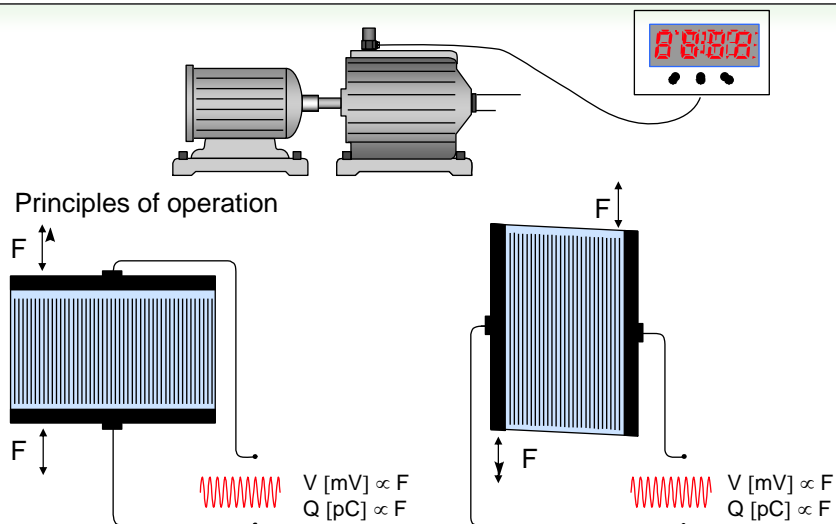
Velocity Pickup



3 Rotating Machinery Appetizer
800289

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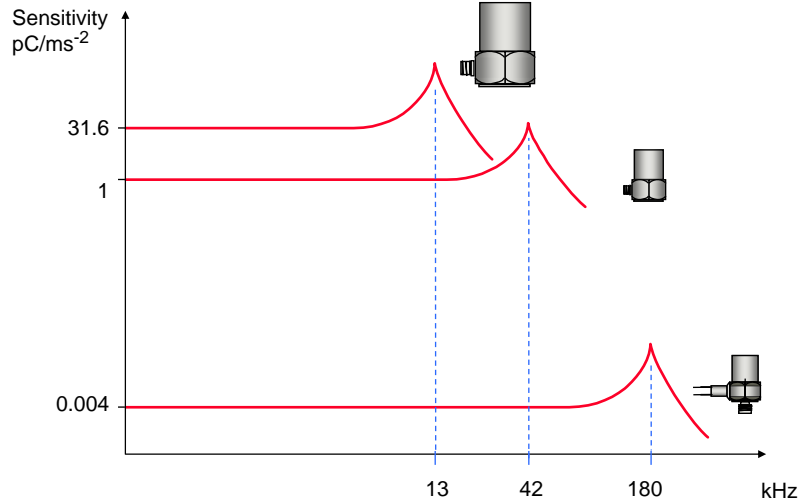
Piezoelectric Accelerometer



4 Rotating Machinery Appetizer
800290/2

Brüel & Kjær  over 100 years

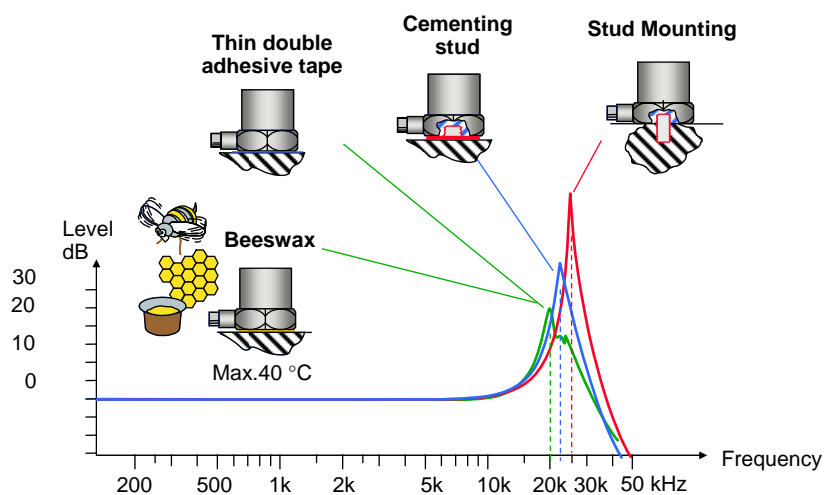
Sensitivity and Frequency Range



5 Rotating Machinery Appetizer
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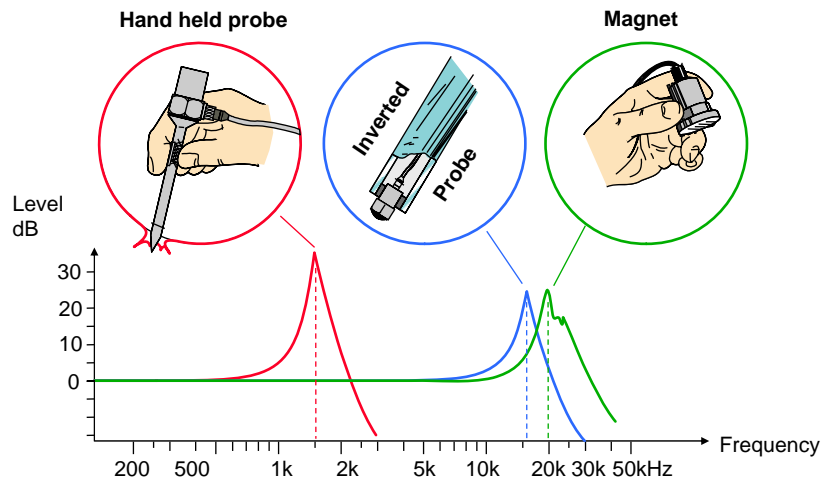
Accelerometer Mounting — Fixed



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930616

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Accelerometer Mounting — Handheld

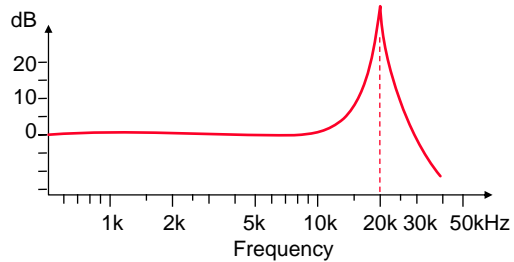
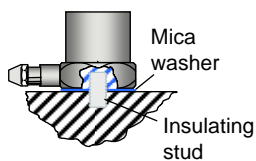


7 Rotating Machinery Appetizer
930617

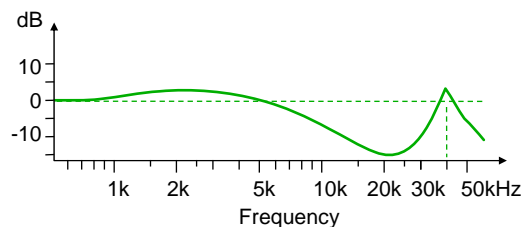
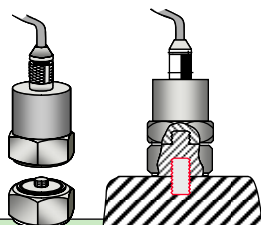
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Isolating the Accelerometer

Electrical
(Prevention of ground loops)



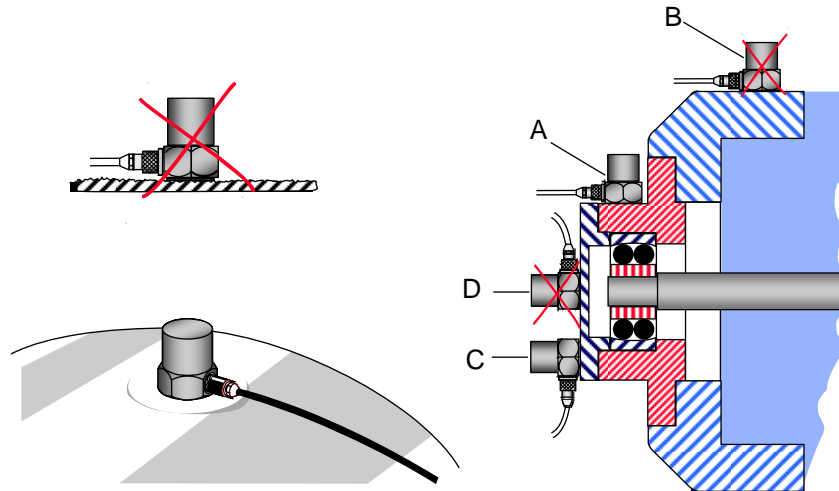
Mechanical Filter
(Protection against high shocks)



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Choosing a Mounting Position



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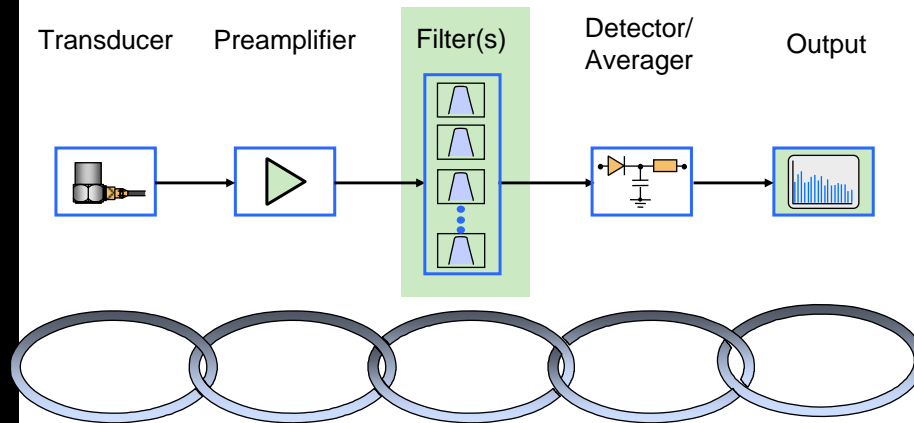
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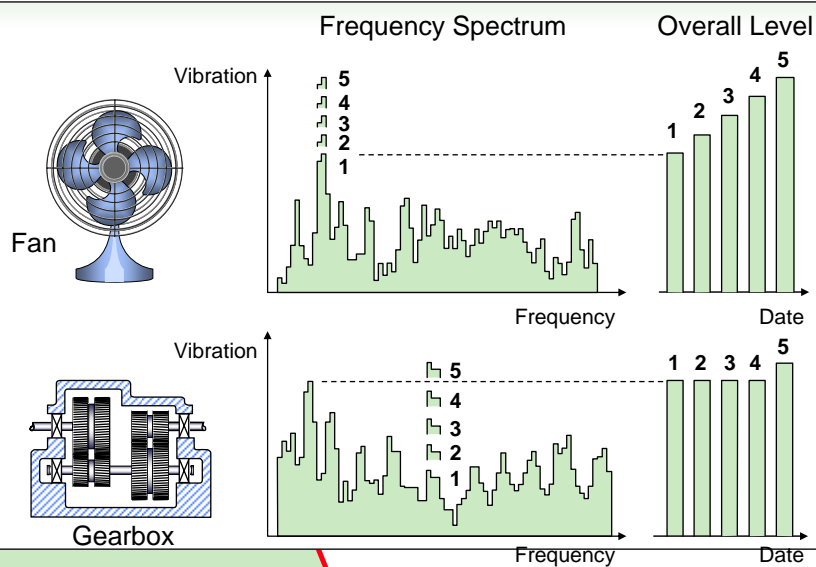
The Measurement Chain



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Frequency Spectrum or Overall Level



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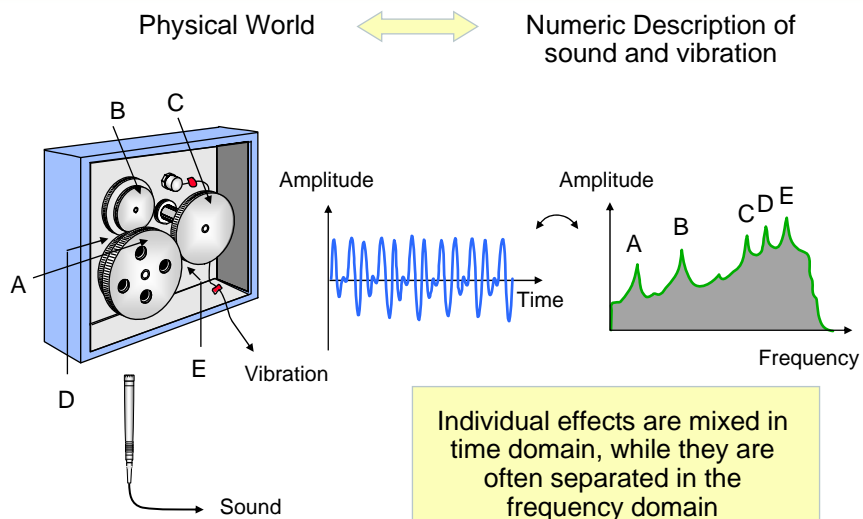
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Why Make a Frequency Analysis



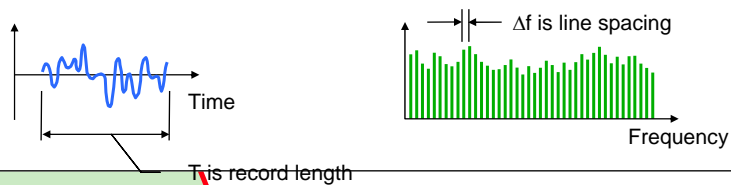
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Uncertainty Principle

$$\Delta t \cdot \Delta f \geq 1$$

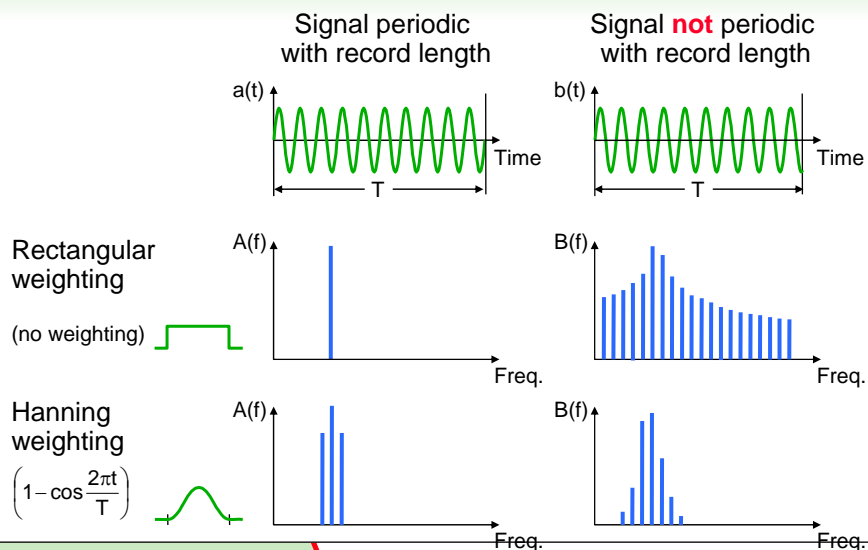
For FFT analysis $T \cdot \Delta f = 1$



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Leakage

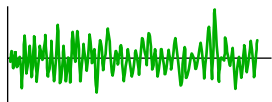


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Types of Signals

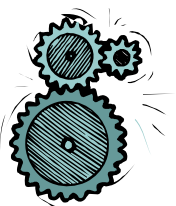
Stationary signals



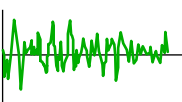
Non-stationary signals



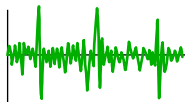
Deterministic



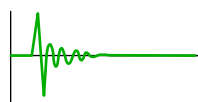
Random



Continuous



Transient



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Use of Weighting Functions in *Signal* Analysis

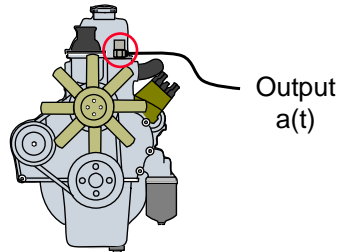
	Weighting					
	Rect-angular	Hanning	Transient	Expo-nential	Kaiser-Bessel	Flat Top
Transients:						
• General purpose	✓					
• Short transient			✓			
• Long decaying transients				✓		
• Very long transients		✓ + overlap				
Continuous signals:						
• General purpose		✓				
• Two-tone separation					✓	
• Calibration						✓
• (Pseudo random)	✓					

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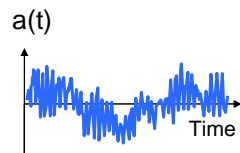
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Signal Analysis

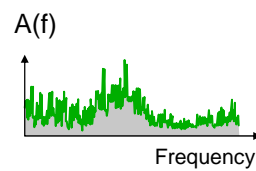
Definition



Time signal

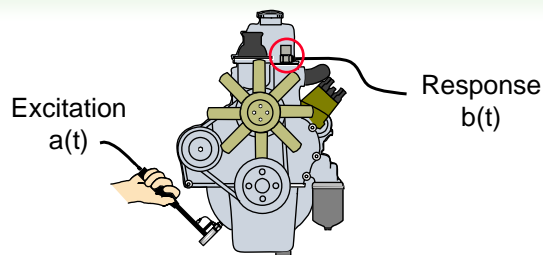


Frequency spectrum

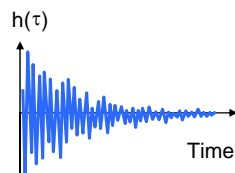


System Analysis

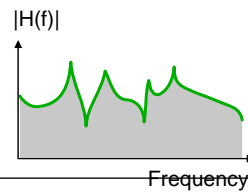
Definition



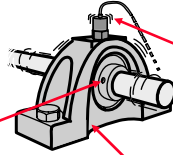
Impulse Response Function



Frequency Response Function



Forces and Vibration



Forces caused by

- Imbalance
- Misalignment
- Gear mesh
- Shock

Structural

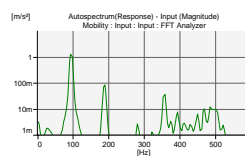
Characteristics:

- Mass
- Stiffness
- Damping

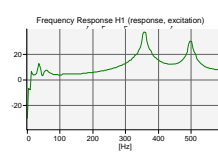
Vibration

Response:

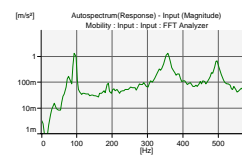
- Acceleration
- Velocity
- Displacement



x



=



Force Excitation

x

System Properties

= Vibration Response

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Transducers

Measurement Chain

FFT Analysis

Signal / System Analysis

Order Analysis

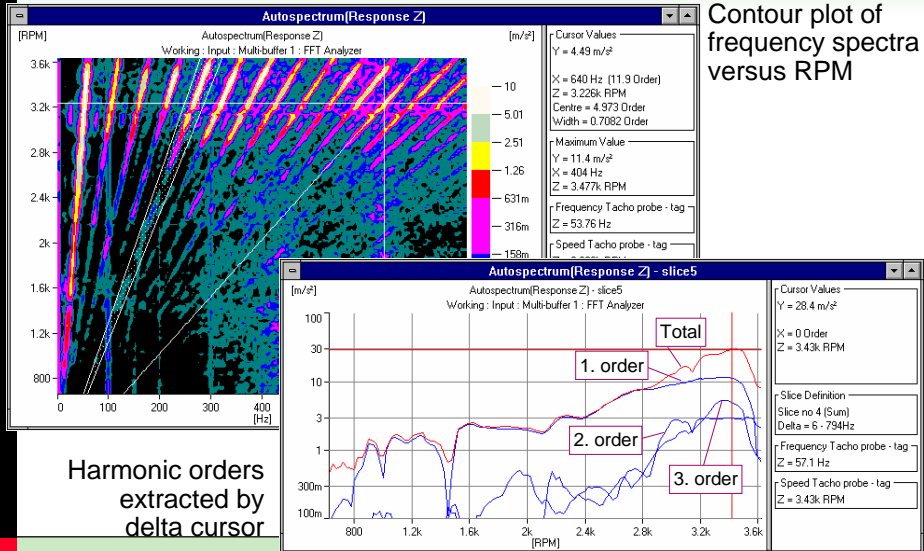
Sources of Vibration, Characteristics

Cepstrum Analysis

Envelope Analysis

ODS, Operating Deflection Shape

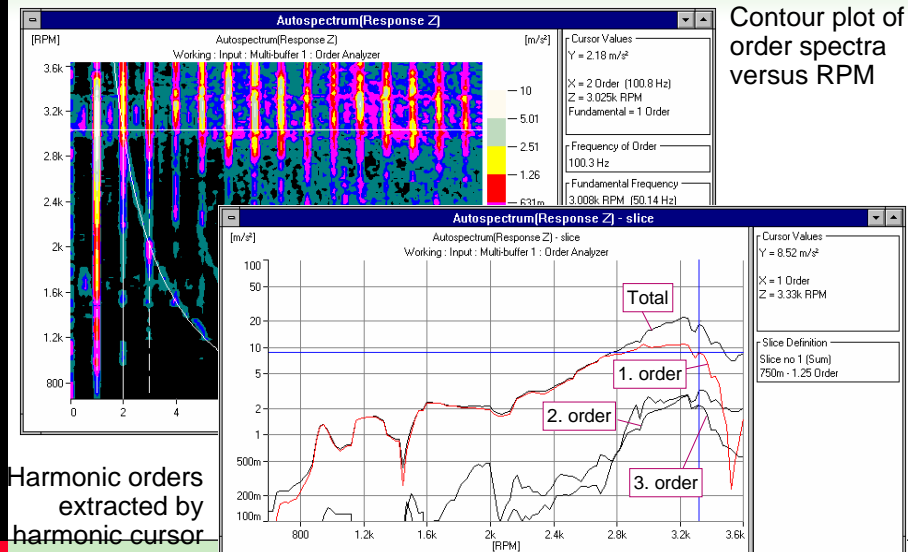
Run-up/down Tests without Tracking



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Run-up/down Tests with Tracking

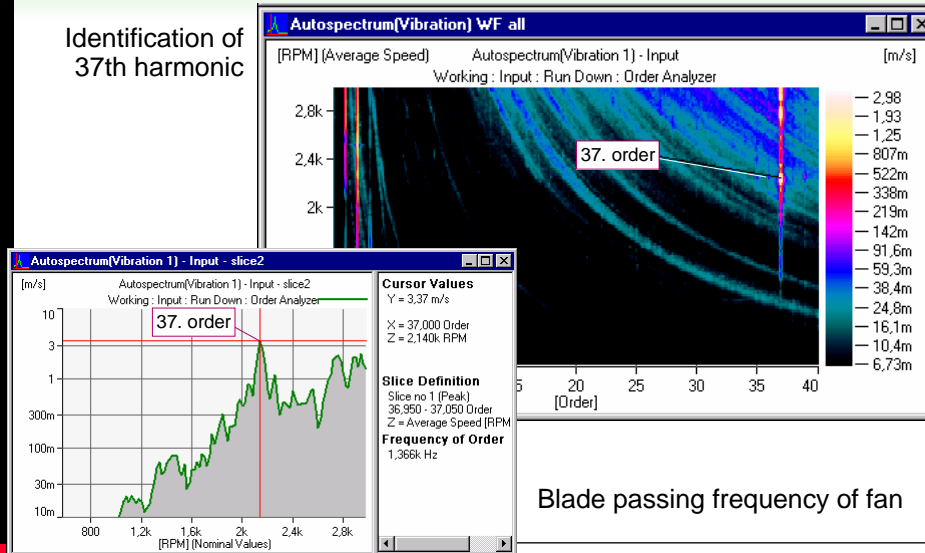


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Order Tracking - diagnostics on higher harmonics

Identification of
37th harmonic



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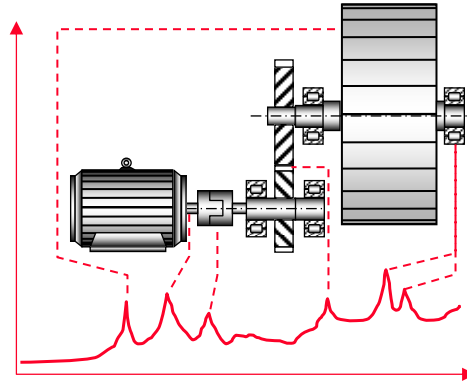
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Fault Diagnosis

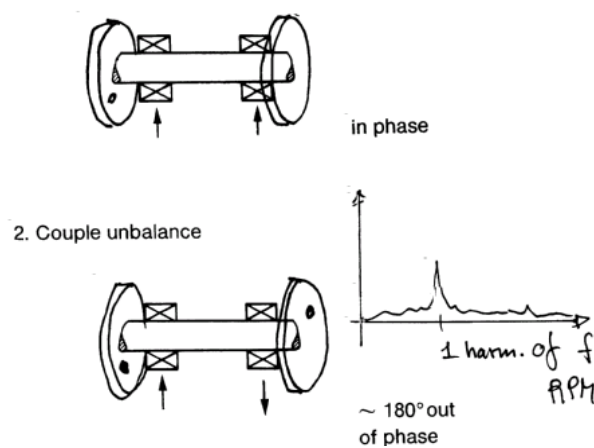
Frequency analysis: The tool for diagnosis of faults



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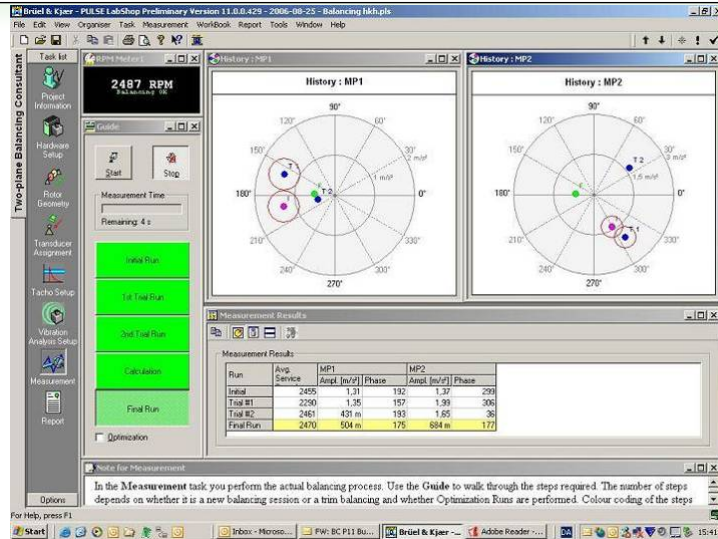
Unbalance



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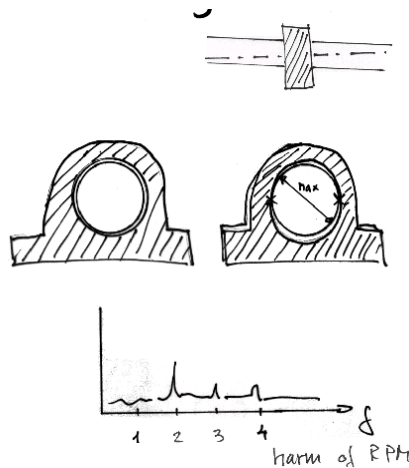
Balancing Consultant



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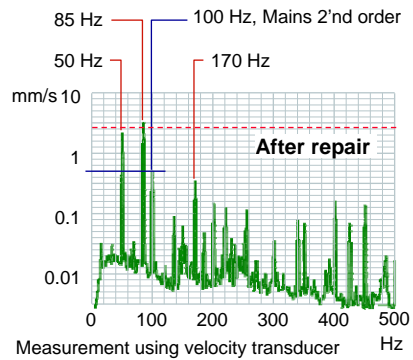
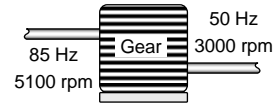
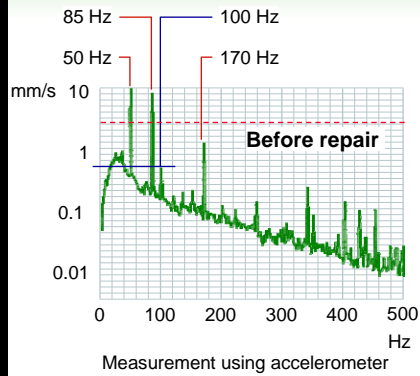
Misalignment



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Misalignment in Gearbox

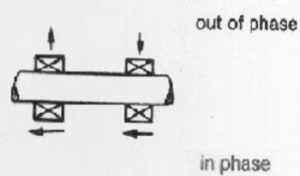


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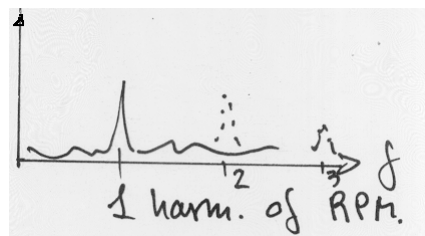
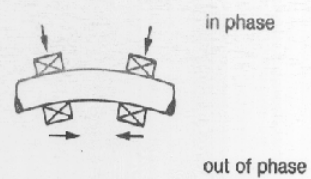
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Rotating Shaft

1. Rocking Motion



2. Bent shaft



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Fault in Bearings

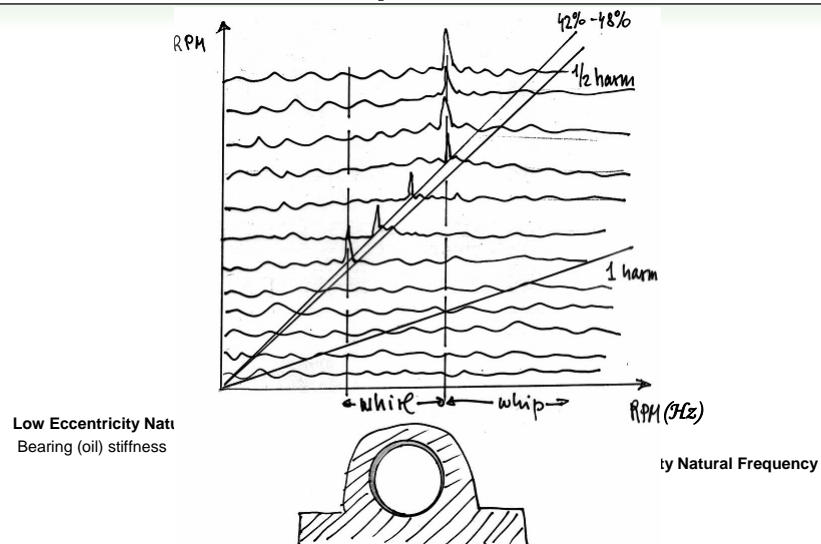
OIL WHIRL (in journal bearings)

- Self excited vibration typically arises in lightly loaded high speed machine
- Mainly radial vibration
- 42 to 48% of the rotation speed

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Oil Whirl and Oil Whip



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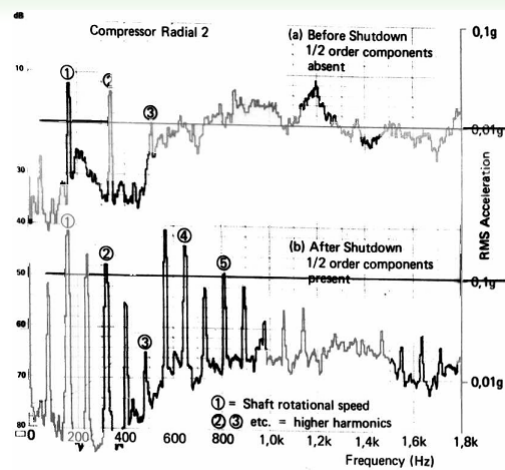
Loose Journal Bearing

LOOSE BEARING COMPONENTS

Vibration: mainly radial

Frequencies: increase in low harmonics plus
sub-harmonics and interharmonics

Journal Bearing Looseness (after repair)



1/2 and 1/3 interharmonics.

Vibration from Gears

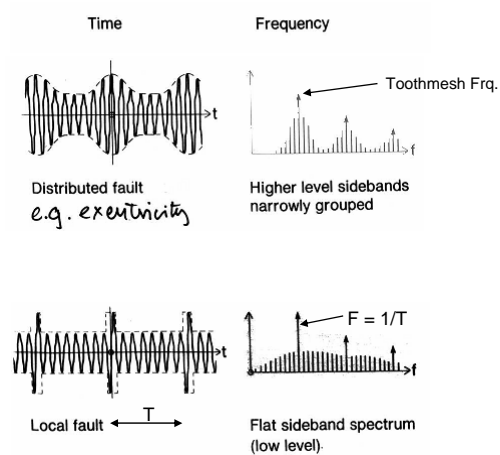
Vibration from gears comes from several sources, including:

- Tooth deflection under load
- Uniform wear around the gear
- Local effects such as cracked teeth

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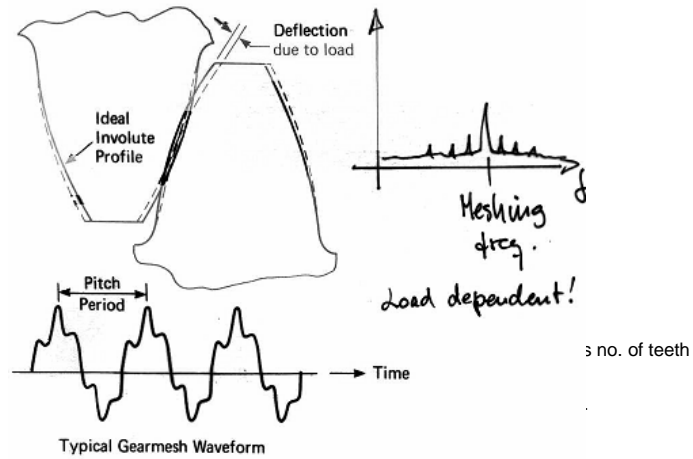
Faults in the Vibration Spectrum



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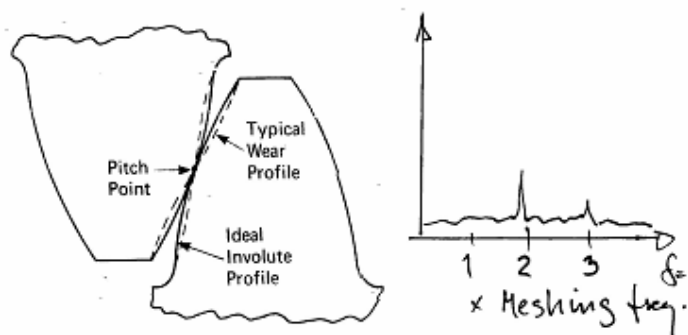
Tooth Deflection



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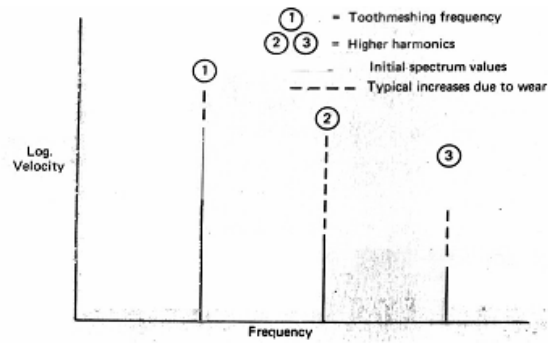
Tooth Wear



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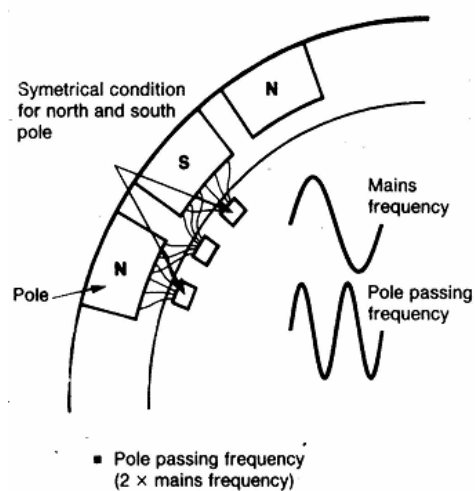
Tooth Meshing Frequency and Harmonics



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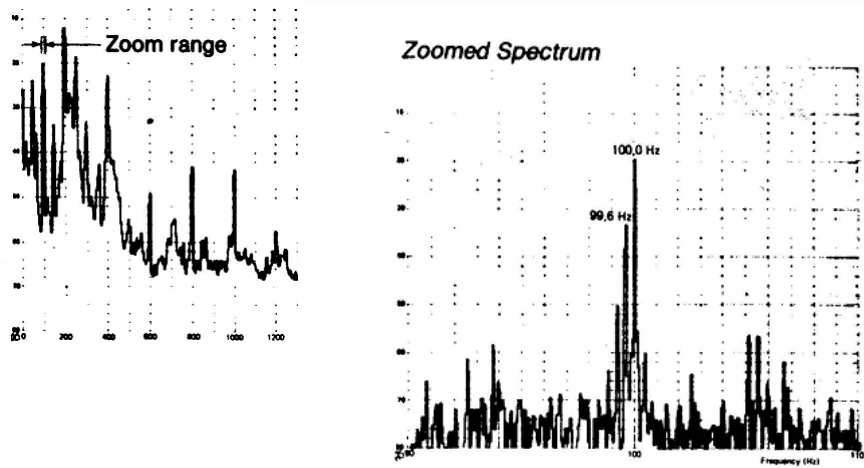
Electrical Machines



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Electric Motor Vibrations



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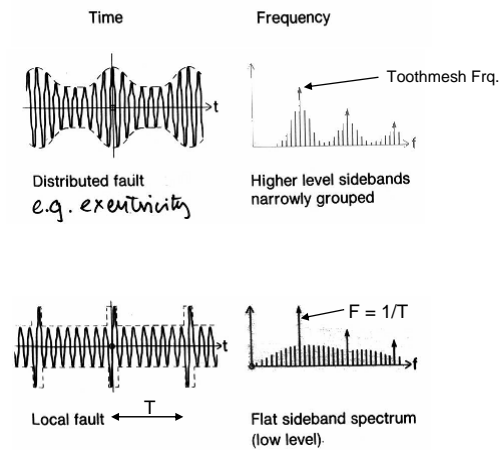
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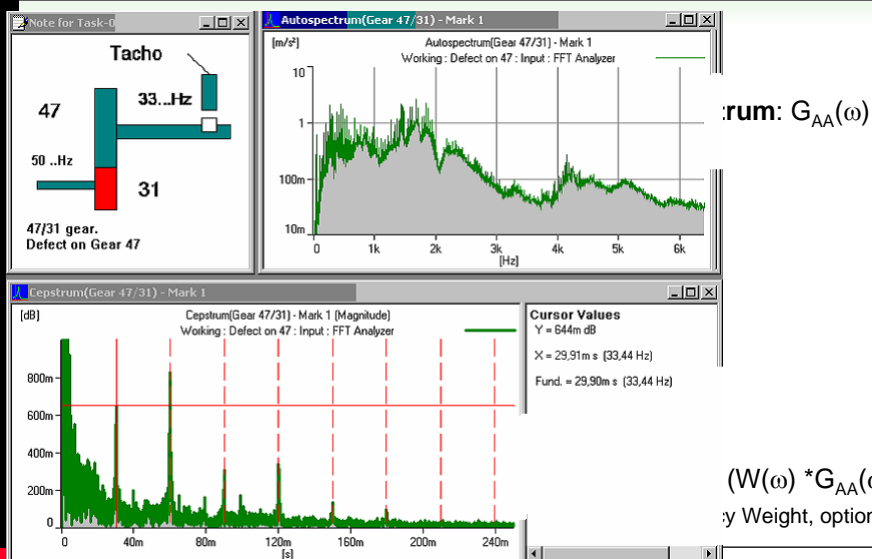
Faults in the Vibration Spectrum



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Autospectrum and Cepstrum



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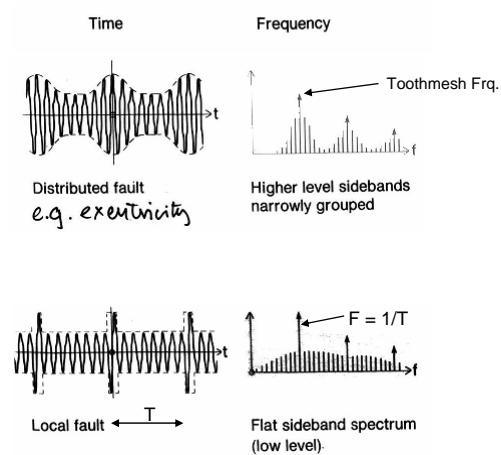
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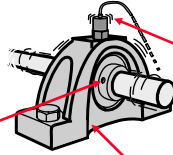
Faults in the Vibration Spectrum



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Forces and Vibration



Forces caused by

- Imbalance
- Misalignment
- Gear mesh
- Shock

Structural

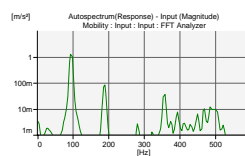
Characteristics:

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- Damping

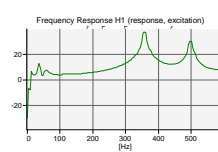
Vibration

Response:

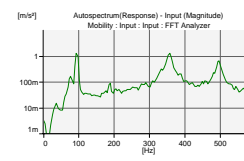
- Acceleration
- Velocity
- Displacement



x



=



Force Excitation

x

System Properties

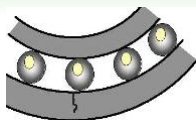
=

Vibration Response

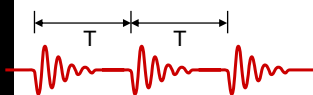
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Envelope Detection step by step.

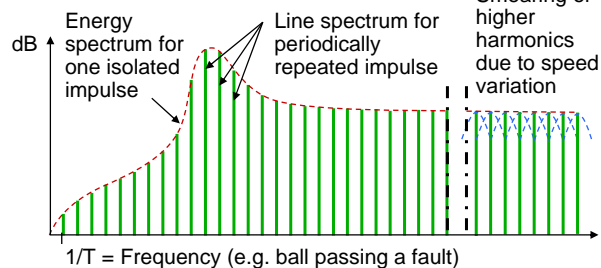


Impact fault:
Repeated impulse



A structural resonance amplifies the higher harmonics. This may be interpreted as 'amplitude modulation of the resonance by a $1/T$ Hz signal'.

Spectrum of repeated impulse



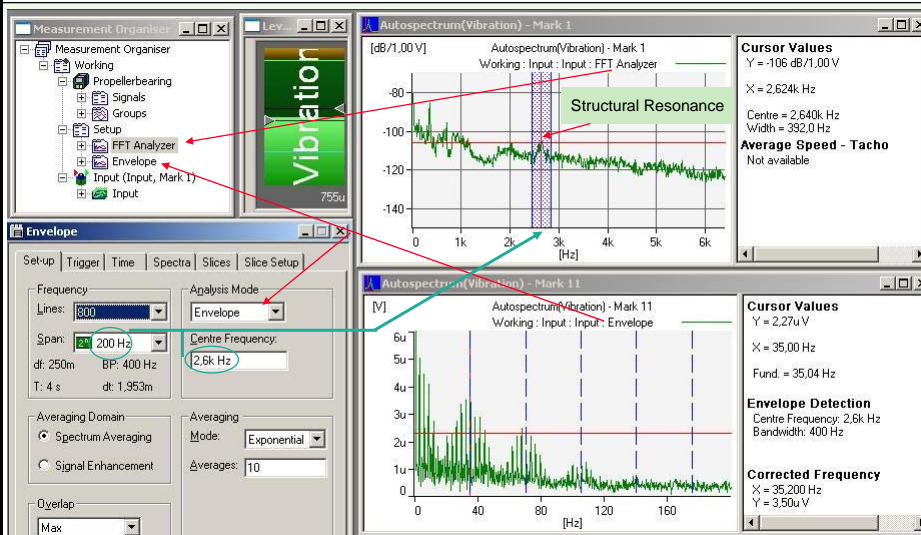
Smearing of higher harmonics due to speed variation

The ' $1/T$ Hz signal' is revealed by amplitude demodulation = envelope detection around the resonance

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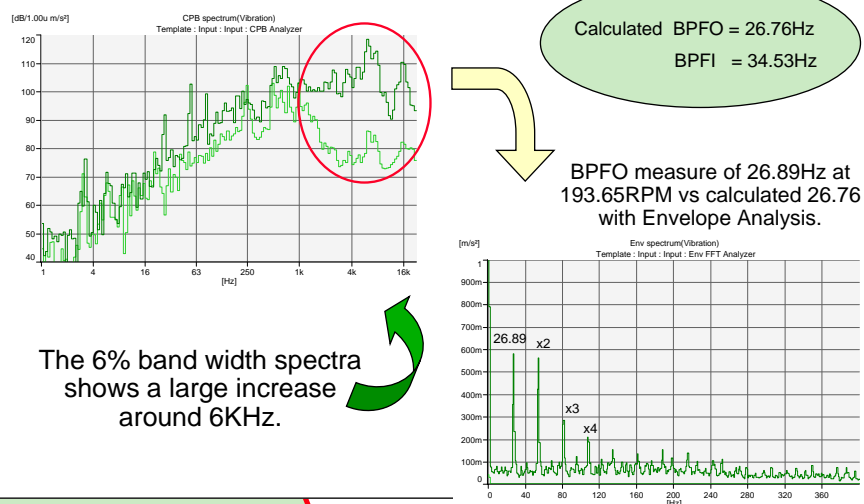
Envelope Analysis / Detection



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BPFO Fault example



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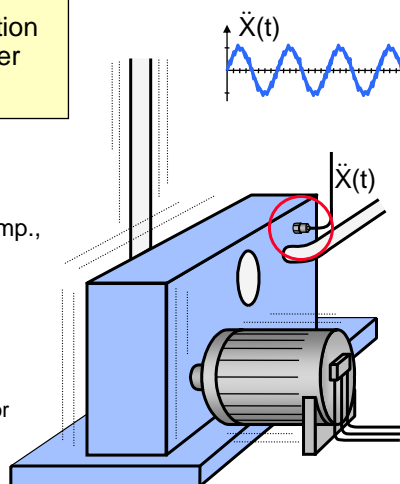
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Operating Deflection Shapes

Determination of the vibration pattern of structures under operating conditions

- Operating conditions:
 - RPM, Load, Pressure, Temp., Flow, ...
- Vibration signals:
 - Stationary
 - Quasi-stationary
 - » slightly varying speed or excitation level
 - » run-up/down
 - Transient



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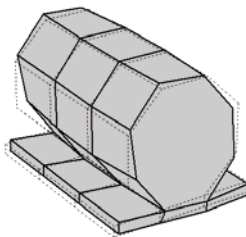
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Operating Deflection Shapes

- Operating Deflection Shapes documented in terms of
 - Animated geometry
 - Tables of Acceleration, Velocity, Displacement

Measurements at different points and directions (Degrees-of-freedom, **DOFs**)

Ex.: ODS of a frequency (order) component (i.e. sinusoid)



DOFs	Shape 1 Accel. (m/s ²)	Shape 1 Vel. (m/s)	Shape 1 Disp. (m)
+1Y-1Y	1,2596	368,53E-6	107,83E-9
+2Y-1Y	19,427E-3	5,6837E-6	1,6629E-9
+3Y-1Y	0,42542	124,46E-6	36,413E-9
+4Y-1Y	6,0324E-3	1,7649E-6	516,34E-12
+5Y-1Y	0,74126	235,87E-6	63,447E-9
+6Y-1Y	34,663E-3	10,143E-6	2,9669E-9
+7Y-1Y	0,49648	145,25E-6	42,495E-9
+8Y-1Y	0,18894	55,247E-6	16,163E-9
+26Y-1Y	0,47658	139,43E-6	40,793E-9
+27Y-1Y	8,9399E-3	2,6125E-6	765,3E-12
+28Y-1Y	0,47475	138,98E-6	40,636E-9
+29Y-1Y	1,9376E-3	566,99E-6	165,85E-12
+30Y-1Y	0,6873	201,08E-6	58,829E-9
+31Y-1Y	8,1696E-3	2,3901E-6	699,26E-12
+32Y-1Y	0,50661	146,28E-6	43,38E-9
+33Y-1Y	2,4844E-3	726,86E-6	232,65E-12

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