主軸振動與頻譜分析

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主軸振動檢驗　　　內 容
主軸頻譜量測

Rotating Machinery
(Pump,Motor,Turbine Generator, Compressor, etc.)

**Vibration Analysis**　　　**Monitoring & Diagnostics**

主軸振動檢驗

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主軸振動檢驗

振動計

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主軸振動檢驗

SINUSOIDAL MOTION

UPPER LIMIT
NEUTRAL POSITION
LOWER LIMIT
AVG
PEAK
PEAK-TO-PEAK
RMS
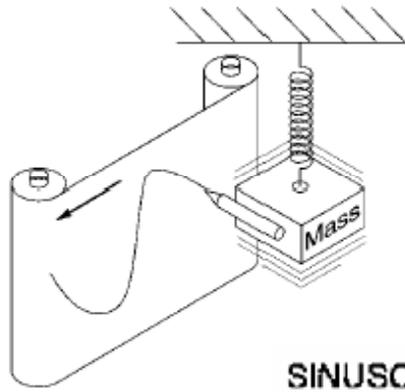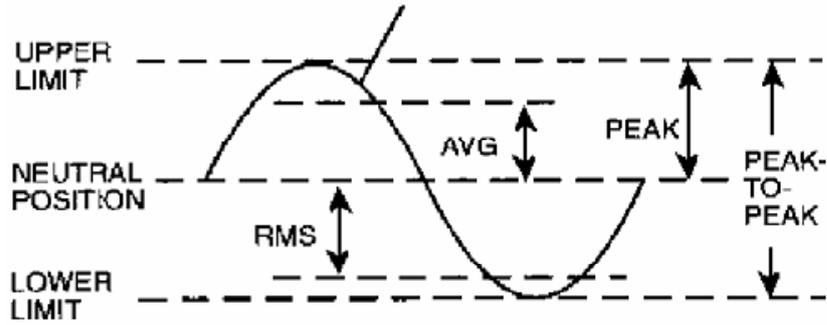
主軸振動檢驗

振動單位

加速度　　*Gs　(RMS)*

速度　　　*mm/s (0-P)*

位移　　　*μm (P-P)*

Accelerometer Mounting — Fixed
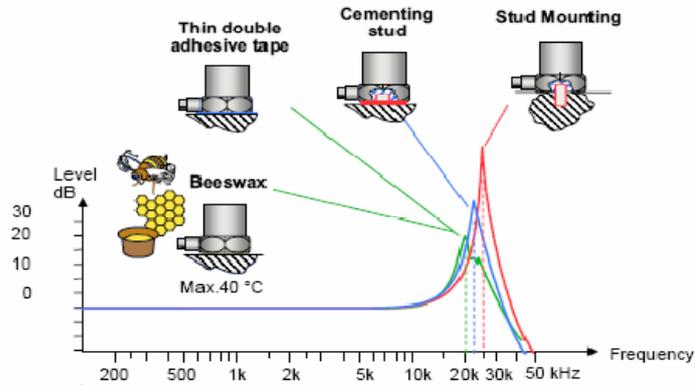
Accelerometer Mounting — Handheld
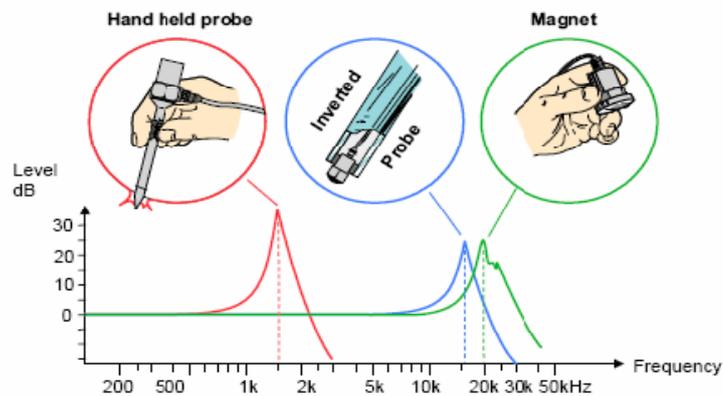
Choosing a Mounting Position

Shutdown level

6 x base level

Full Measurement, Analysis & Diagnosis

Alarm level

Repair

Vibration Level V RMS

2 x base level

Time
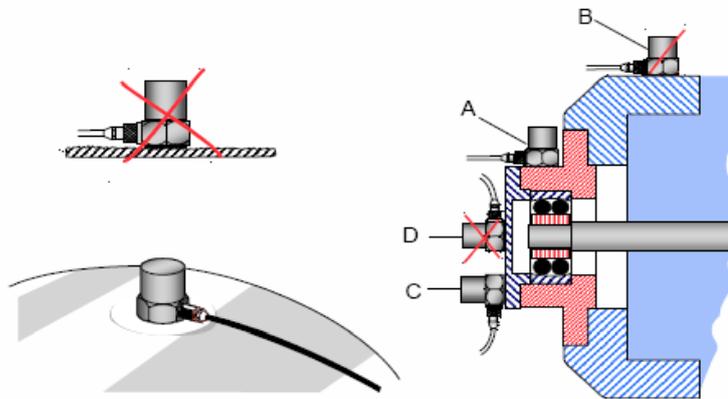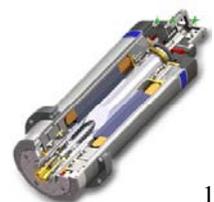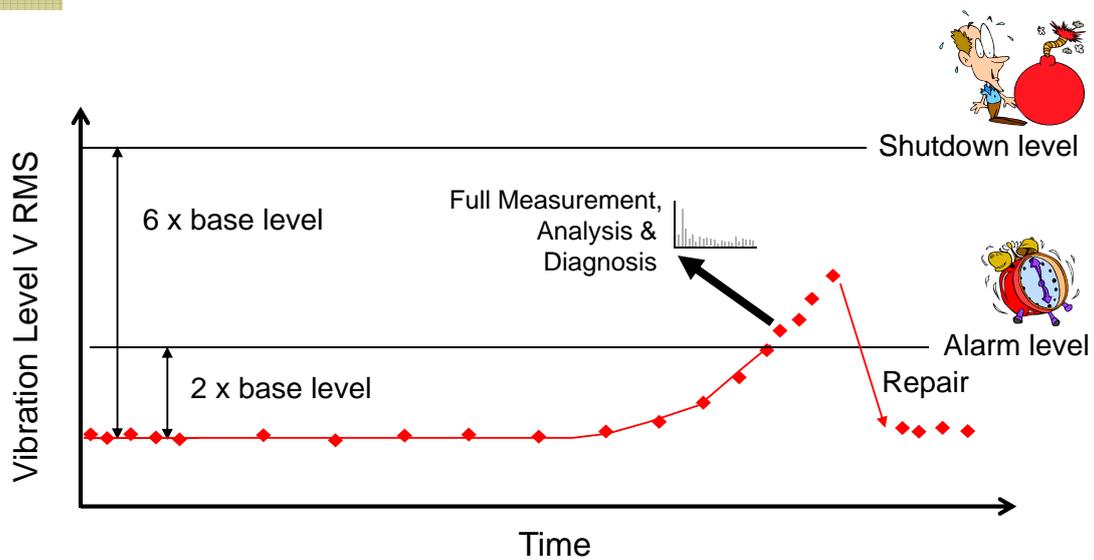
Limits of Bearing Housing Vibration

| Vibration Limit (inch/sec)	Machine Type - General Examples
0.15	Standard industrial motors; motors for commercial or residential use
0.08	Machine tool motors; medium/large motors with special requirements
0.04	Grinding wheel motors; small motors with special requirements
0.02	Precision spindle and grinder motors
0.01	Precision motors with special requirements
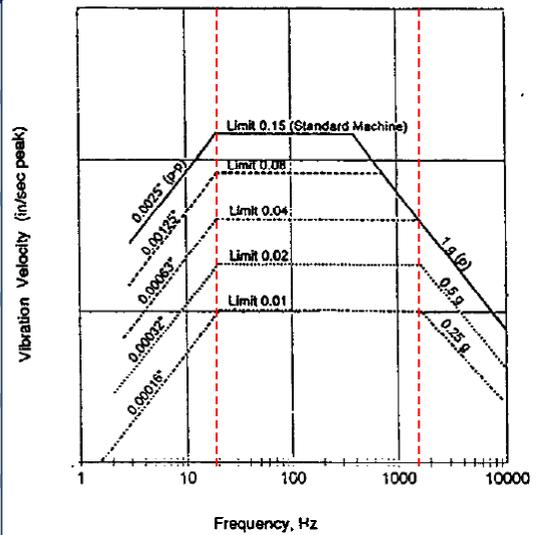
**National Elcctrical Manufacturcs Association**

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主軸振動檢驗

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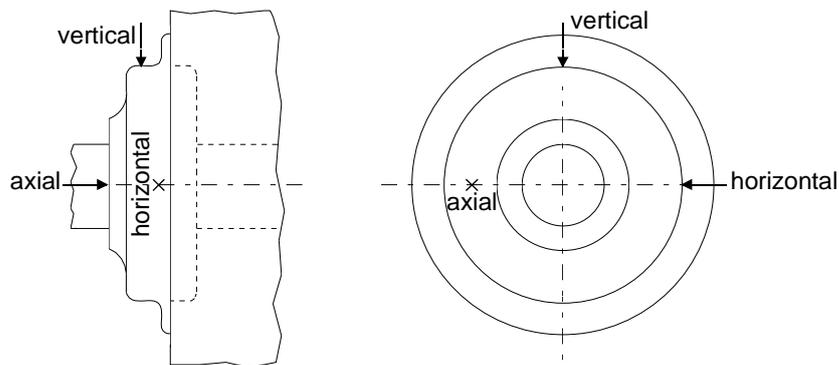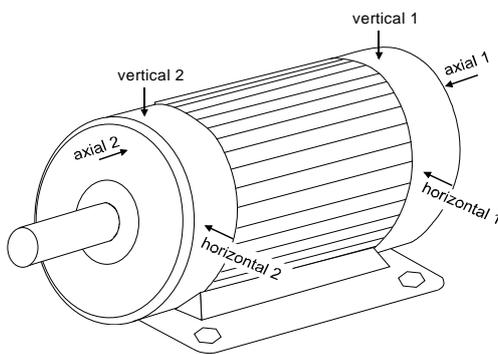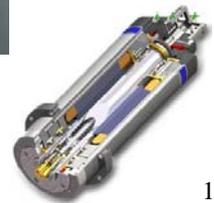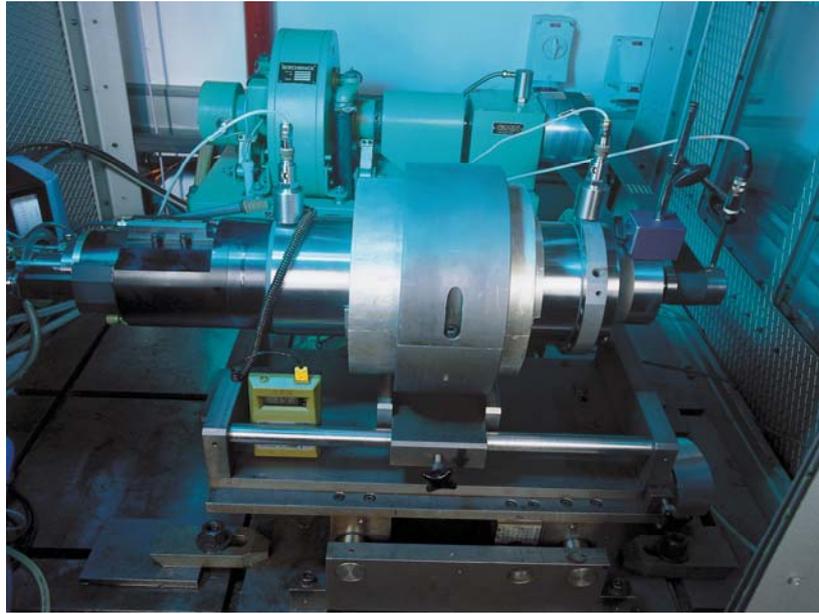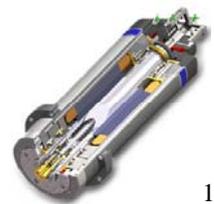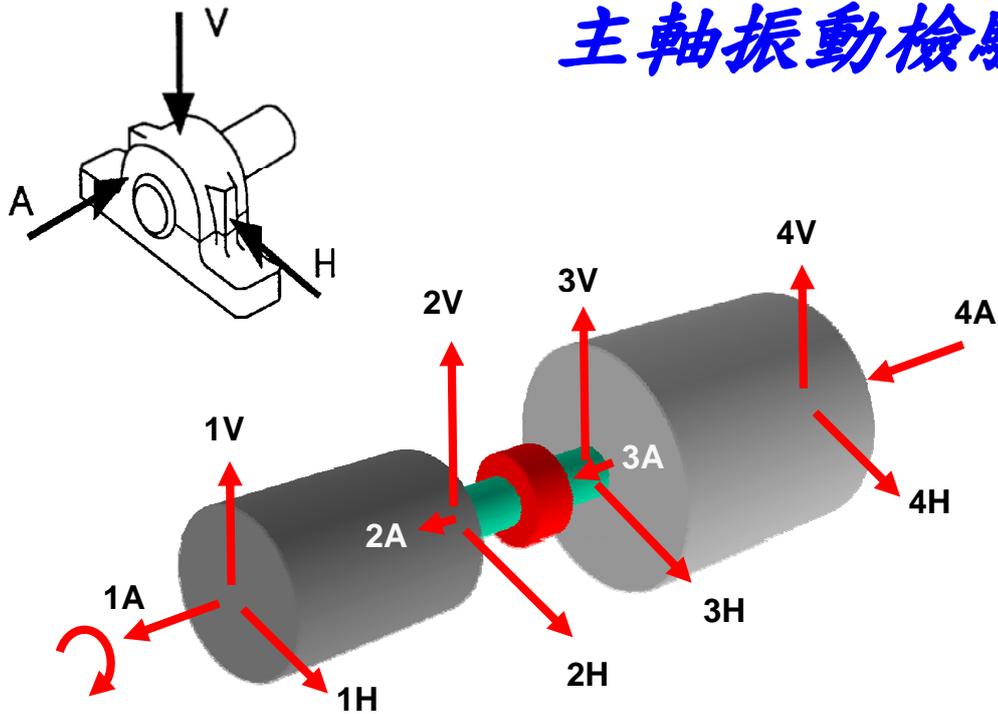
Machine Type	Power Rating or Shaft Height	Speed min⁻¹	Foundation	Max. Continuous value mm/s
Steam Turbines	300 kW – 50 MW		rigid	7.1
	300 kW – 50 MW		flexible	11
	> 50 MW	< 1500	rigid	7.1
	> 50 MW	< 1500	flexible	11
	> 50 MW	1500 – 1800		8.5
	> 50 MW	3000 – 3600		11.8
	> 50 MW	> 3600	rigid	7.1
	> 50 MW	>3600	flexible	11
Electrical Engines	< 160 mm		rigid	2.8
	< 160 mm		flexible	4.5
	160 – 315 mm		rigid	4.5
	160 – 315 mm		flexible	7.1
	> 315 mm	120 – 15000	rigid	7.1
	> 315 mm	120 – 15000	flexible	11
Gas Turbines	< 3 MW		rigid	7.1
	< 3 MW		flexible	11
	> 3 MW	3000 – 20000		14.7
Generators	> 50 MW	1500 – 1800		8.5
	> 50 MW	3000 – 3600		11.8
Blowers, Compressors	< 15 kW		rigid	2.8
	< 15 kW		flexible	4.5
	15 – 300 kW		rigid	4.5
	15 – 300 kW		flexible	7.1
	> 300 kW		rigid	7.1
	> 300 kW		flexible	11
Pumps with separate drive	< 15 kW		rigid	4.5
	< 15 kW		flexible	7.1
	> 15 kW		rigid	7.1
	> 15 kW		flexible	11
Pumps with integrated drive	< 15 kW		rigid	2.8
	< 15 kW		flexible	4.5
	> 15 kW		rigid	4.5
	> 15 kW		flexible	7.1

Vibration Severity Limits
ISO 10816-1

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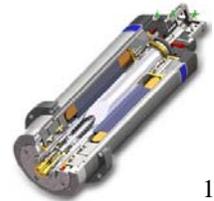
主軸振動檢驗

Vibration Severity		Velocity Range Limits and Machinery Classes ISO Standard 2372			
CMVP40 in/s eq. Peak	CMVP50 mm/s RMS	Small Machines	Medium Machines	Large Machines	
		Class I	Class II	Rigid Supports Class III	Flexible Supports Class IV
0.02	0.28				
0.03	0.45				
0.04	0.71		Good		
0.06	1.12				
0.10	1.80		Satisfactory		
0.16	2.80				
0.25	4.50		Unsatisfactory		
0.39	7.10				
0.62	11.20				
1.00	18.00		Unacceptable		
1.56	28.00				
2.50	45.00				
3.95	71.00				

Support classification according to ISO 2372

Flexible Support: The fundamental natural frequency of the machine/support system is lower than its main excitation frequency.

Rigid Support: The fundamental natural frequency of the machine/support system is higher than its main excitation frequency.

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主軸振動檢驗

振動幅值的轉換表

MULTIPLY NUMBER OF → BY TO OBTAIN ↓	PEAK-TO-PEAK	PEAK	RMS	AVERAGE
PEAK-TO-PEAK	1.000	2.000	2.828	3.142
PEAK	.500	1.000	1.414	1.571
RMS	.354	.707	1.000	1.5
AVERAGE	.318	.636	.900	1.000

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主軸頻譜量測

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Transducer

Waveform
Amplitude
Time

FFT

Spectrum
Amplitude
Frequency

Data Collector/Analyzer
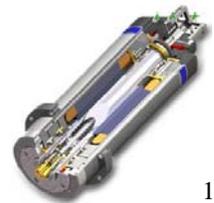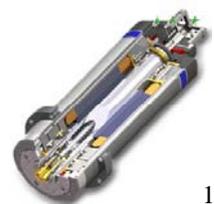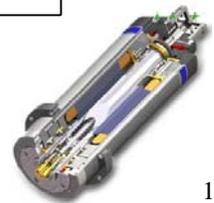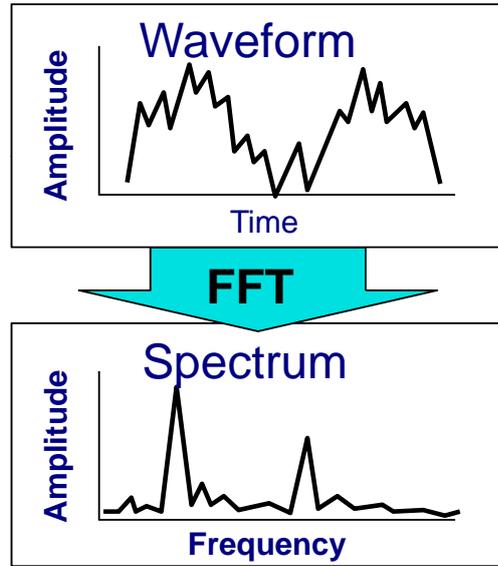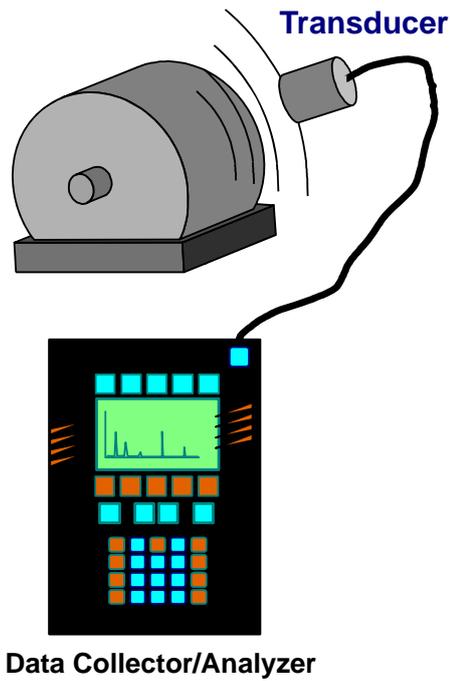
振動週期和頻率的轉換

頻率f(Hz)=轉速RPM(轉/每分鐘)/60

頻率f(Hz)=1/ 週期T(秒)

1. This complex waveform...

2...is the summation of these simple waveforms...

3...as revealed by this spectrum plot.

Amplitude

TIME DOMAIN

Time

(sec. or min.)

Frequency

FREQUENCY DOMAIN

1X

3X

5X

9X

Fmax (CPM or Hz)

BPFO	Ball Passing Frequency Outer
BPFI	Ball Passing Frequency Inner
BSF	Ball Spin Frequency
FTF	Fundamental Train Frequency

Pitch Diameter

Ball Diameter

Number of Balls
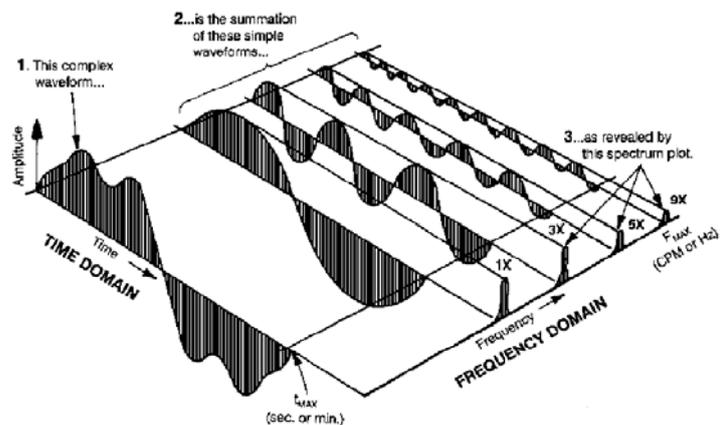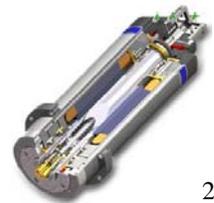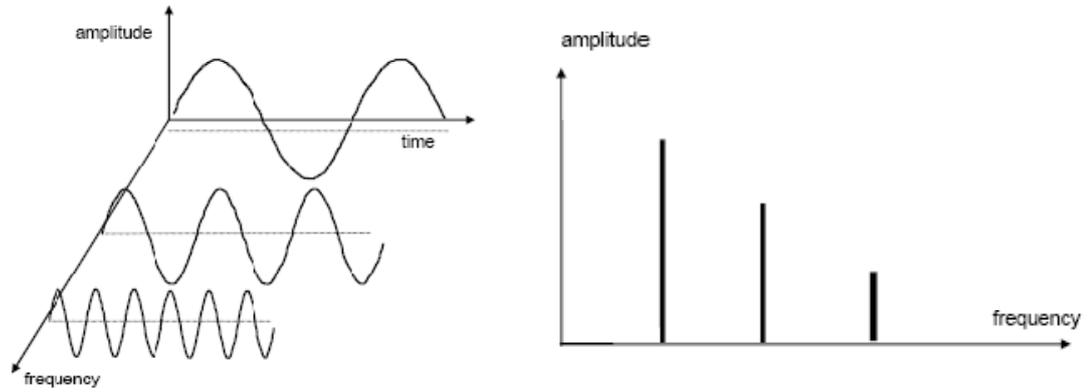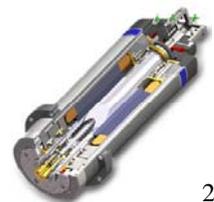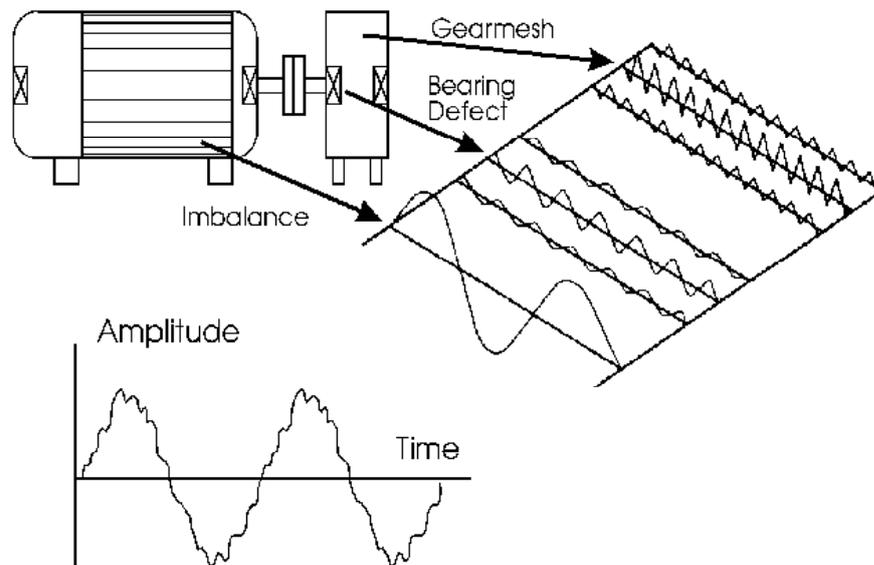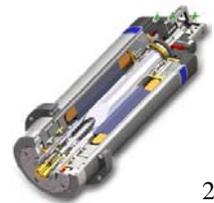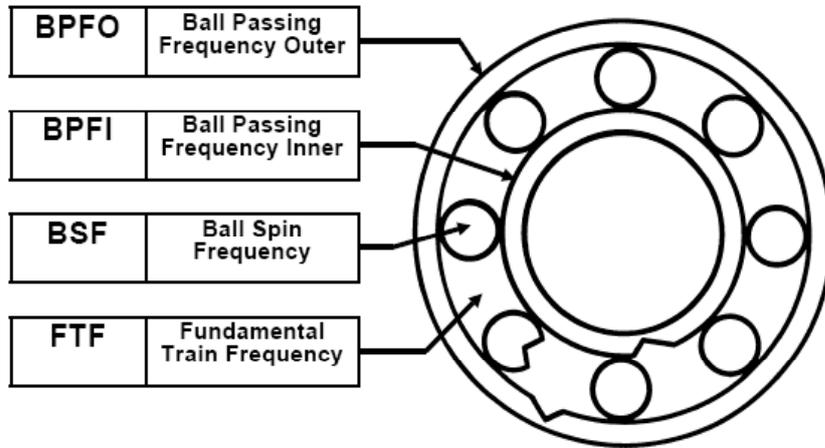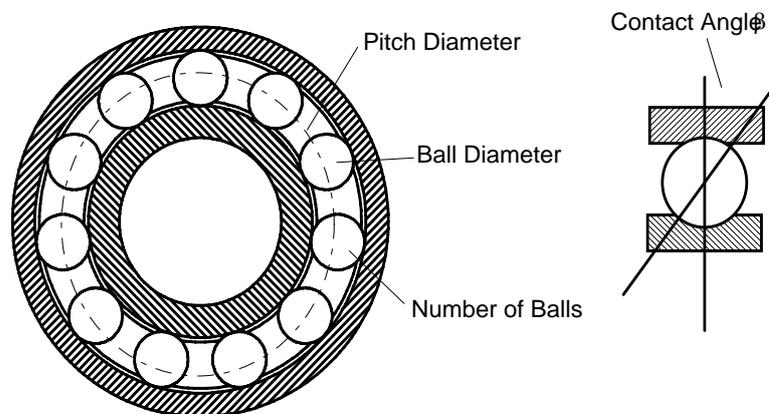
Contact Angle β

$$BPFO = \frac{N \times n}{2}\left(1 - \frac{d}{D}\cos\beta\right)$$

$$BPFI = \frac{N \times n}{2}\left(1 + \frac{d}{D}\cos\beta\right)$$

$$BSF = \frac{N}{2} \times \frac{D}{d}\left(1 - \left(\frac{d}{D}\cos\beta\right)^2\right)$$

$$FTF = \frac{N}{2}\left(1 - \frac{d}{D}\cos\beta\right)$$
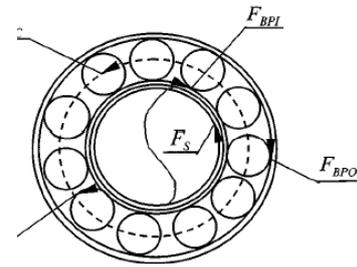
where N = Shaft Speed in Hz
n = Number of Elements
D = Pitch Diameter of Rolling Elements
d = Rolling Element Diameter
β = Contact Angle

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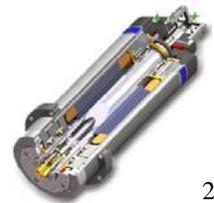
Typical Machine Vibration Spectrum

Force ~ mr(RPM)²; m = unbalance mass, r = mass radius

- Unbalance (mr) is constant for rigid rotors
- Force due to unbalance increases with the square of RPM

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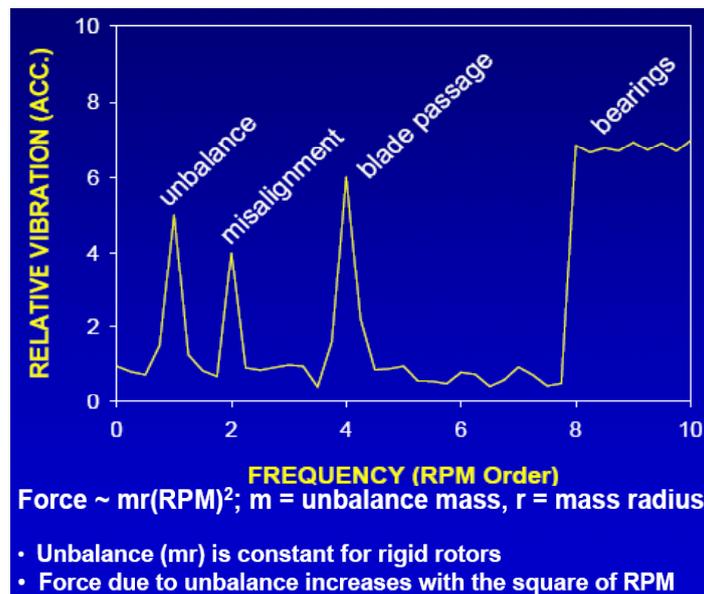
UNBALANCE
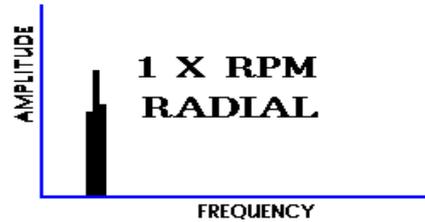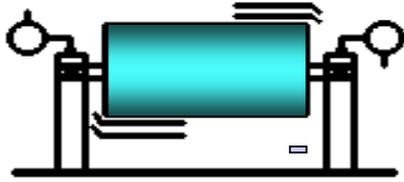
1 X RPM
RADIAL

◆ **1X RPM always present and normally dominates**

◆ **Amplitude varies with square of increasing speed**

◆ **Can cause high axial as well as radial amplitudes**

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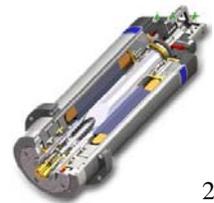
ANGULAR MISALIGNMENT


1X 2X 3X AXIAL
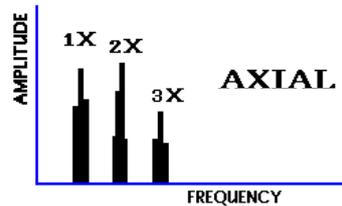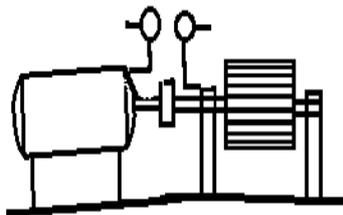
# PARALLEL MISALIGNMENT

1x 2x 4x Radial

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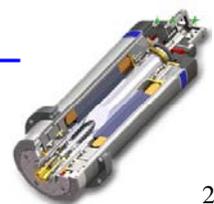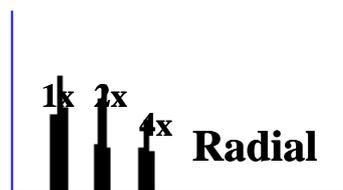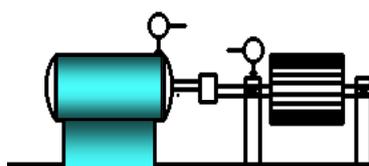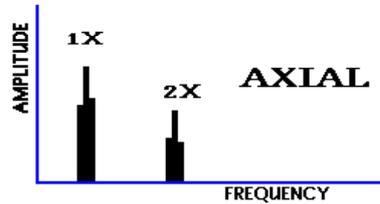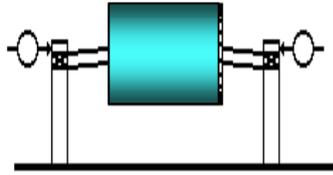
BENT SHAFT

◆Bent shaft problems cause high axial vibration

◆1X RPM dominant if bend is near shaft center

◆2X RPM dominant if bend is near shaft ends

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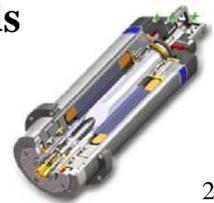

MECHANICAL LOOSENESS (C)
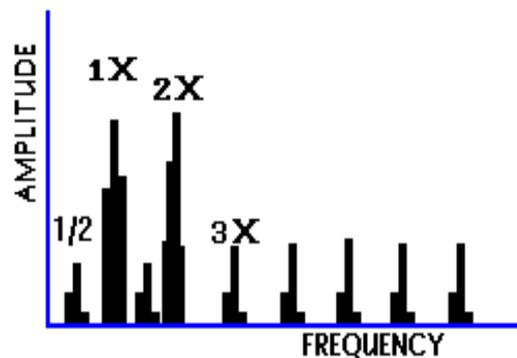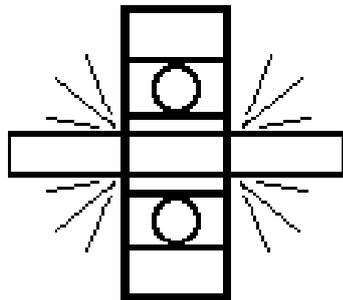
◆Phase is often unstable

◆Will have many harmonics

◆Can be caused by a loose bearing liner, excessive bearing clearance or a loose impeller on a shaft

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PLAT - 41-B-10 SUPPLY FAN
41-B-10-SF-CR   FAN INBOARD RADIAL
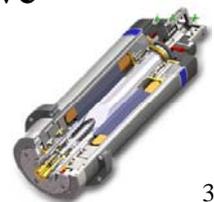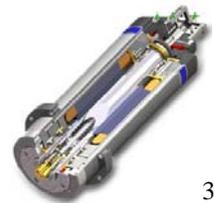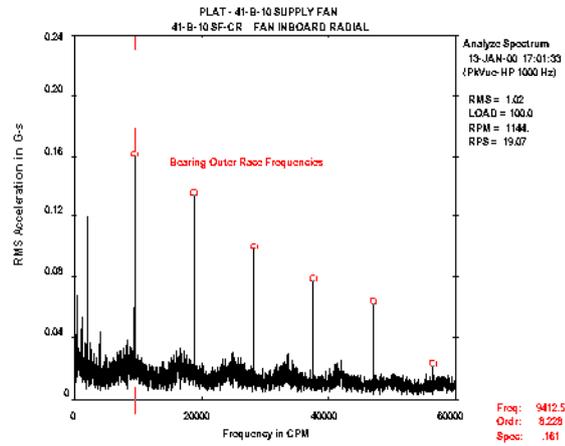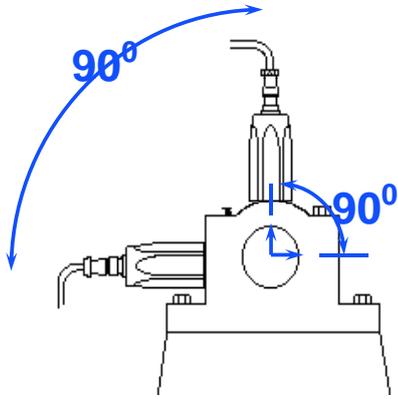
皮帶式主軸
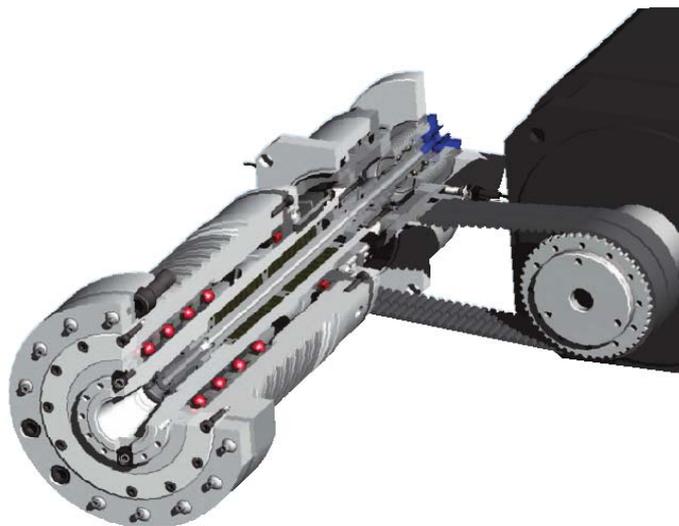
皮帶與組裝精度
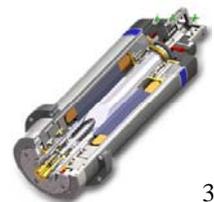
直結式主軸

主軸馬達組裝精度
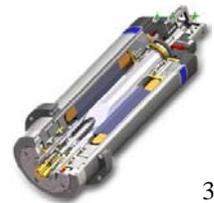
Question & Discussion

See You Next Time