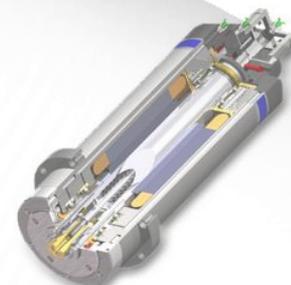


# 工具機主軸振動與檢測

黃興杰

2010.04.22



振動檢驗

頻譜量測

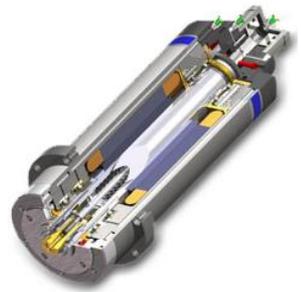
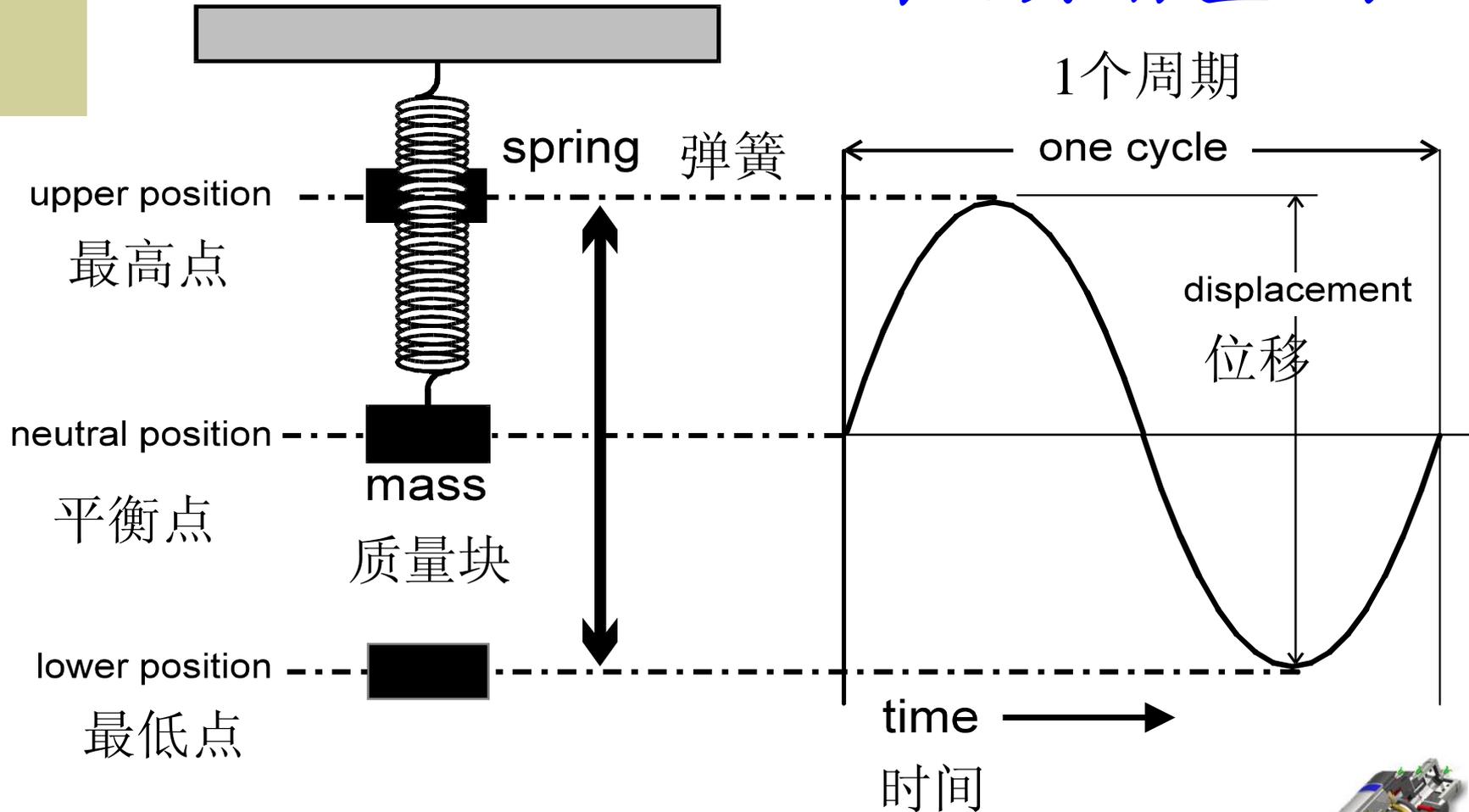


# 主軸振動檢驗

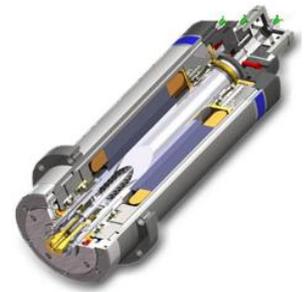
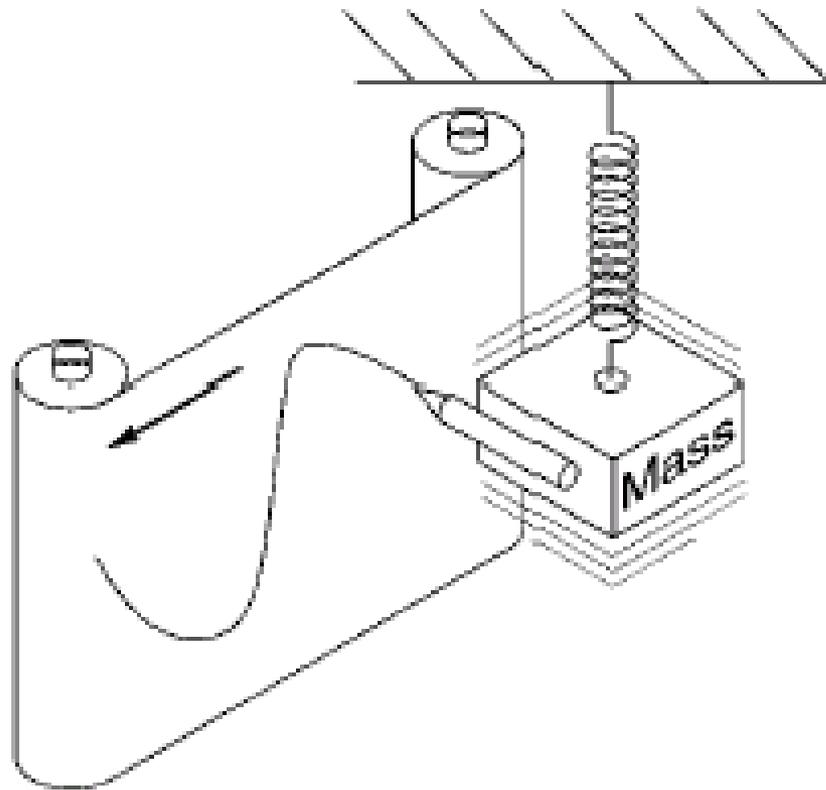
## 振動計



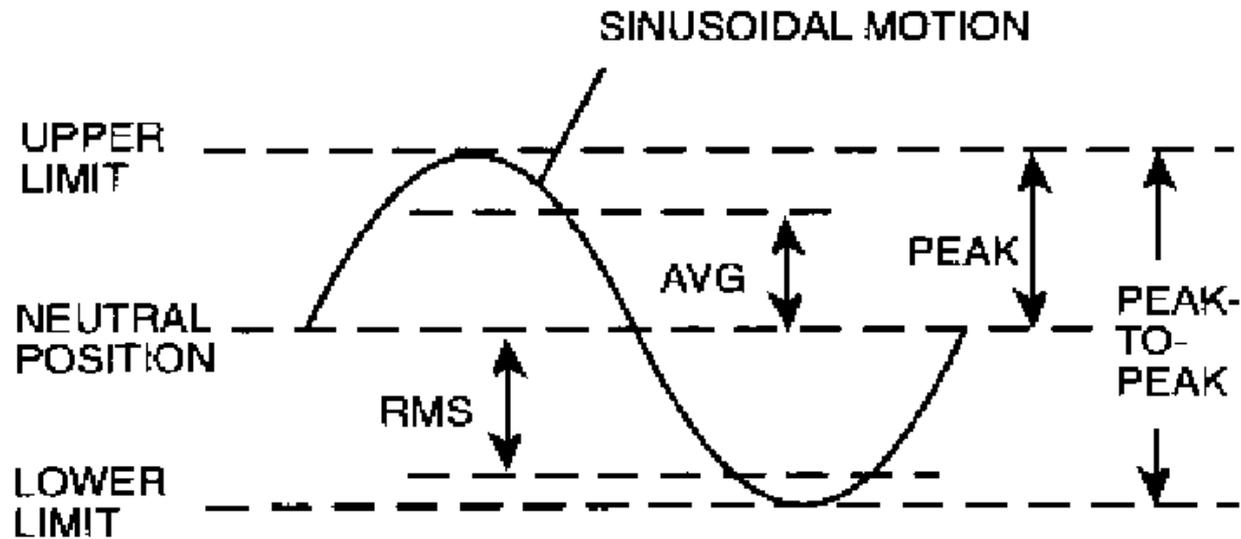
# 主軸頻譜量測



# 主軸振動檢驗



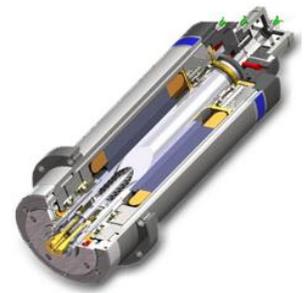
# 主軸振動檢驗



# 主軸振動檢驗

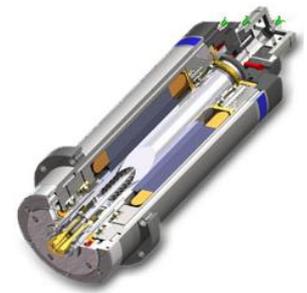
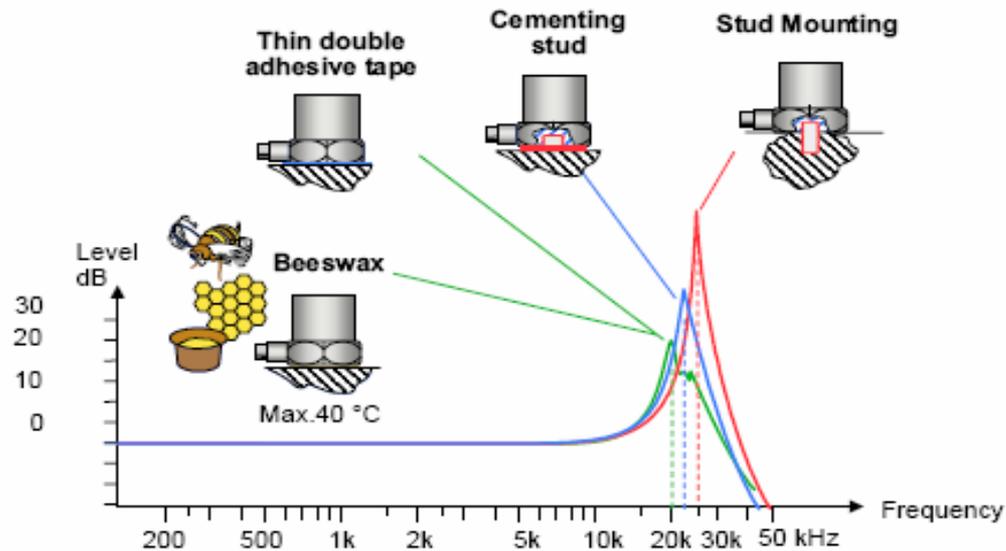
## 振動單位

加速度  $G_s$  (RMS)  
速度  $mm/s$  (0-P)  
位移  $\mu m$  (P-P)



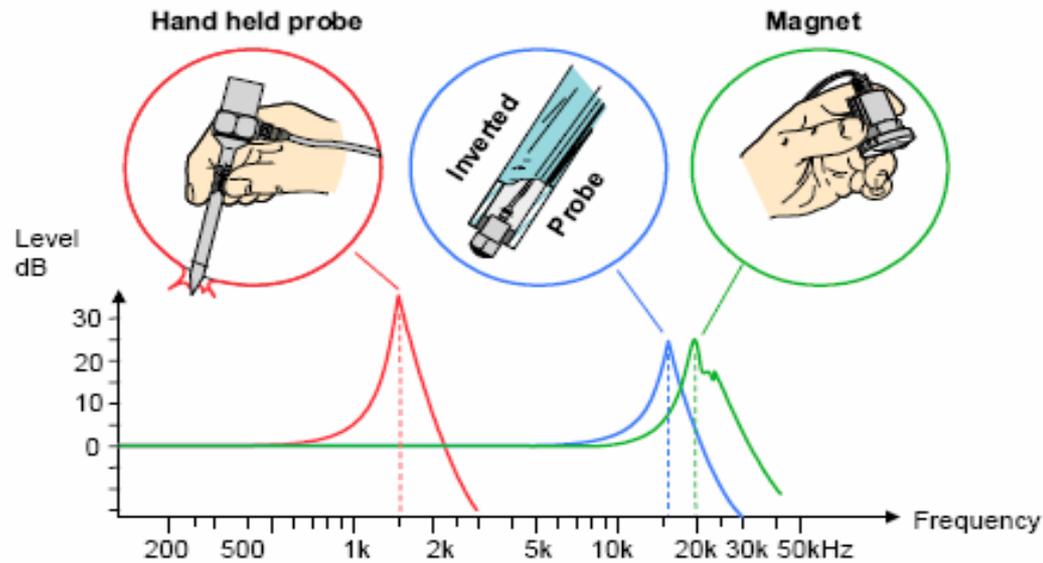
# 主軸振動檢驗

## Accelerometer Mounting — Fixed



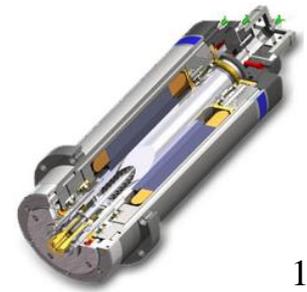
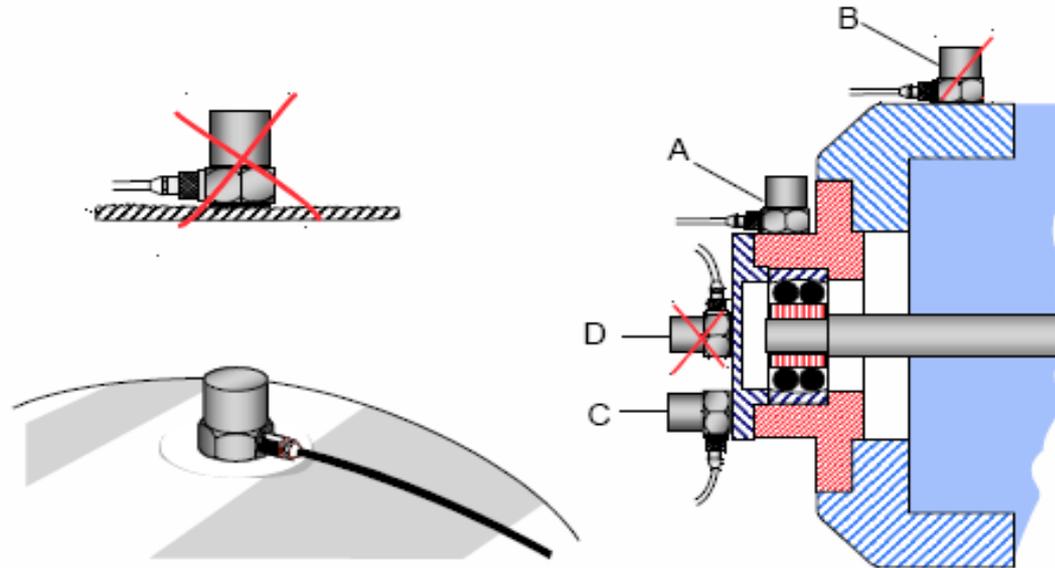
# 主軸振動檢驗

## Accelerometer Mounting — Handheld

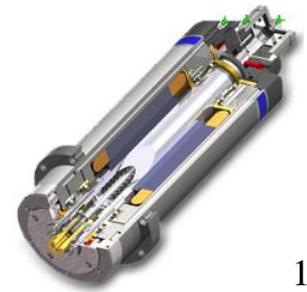
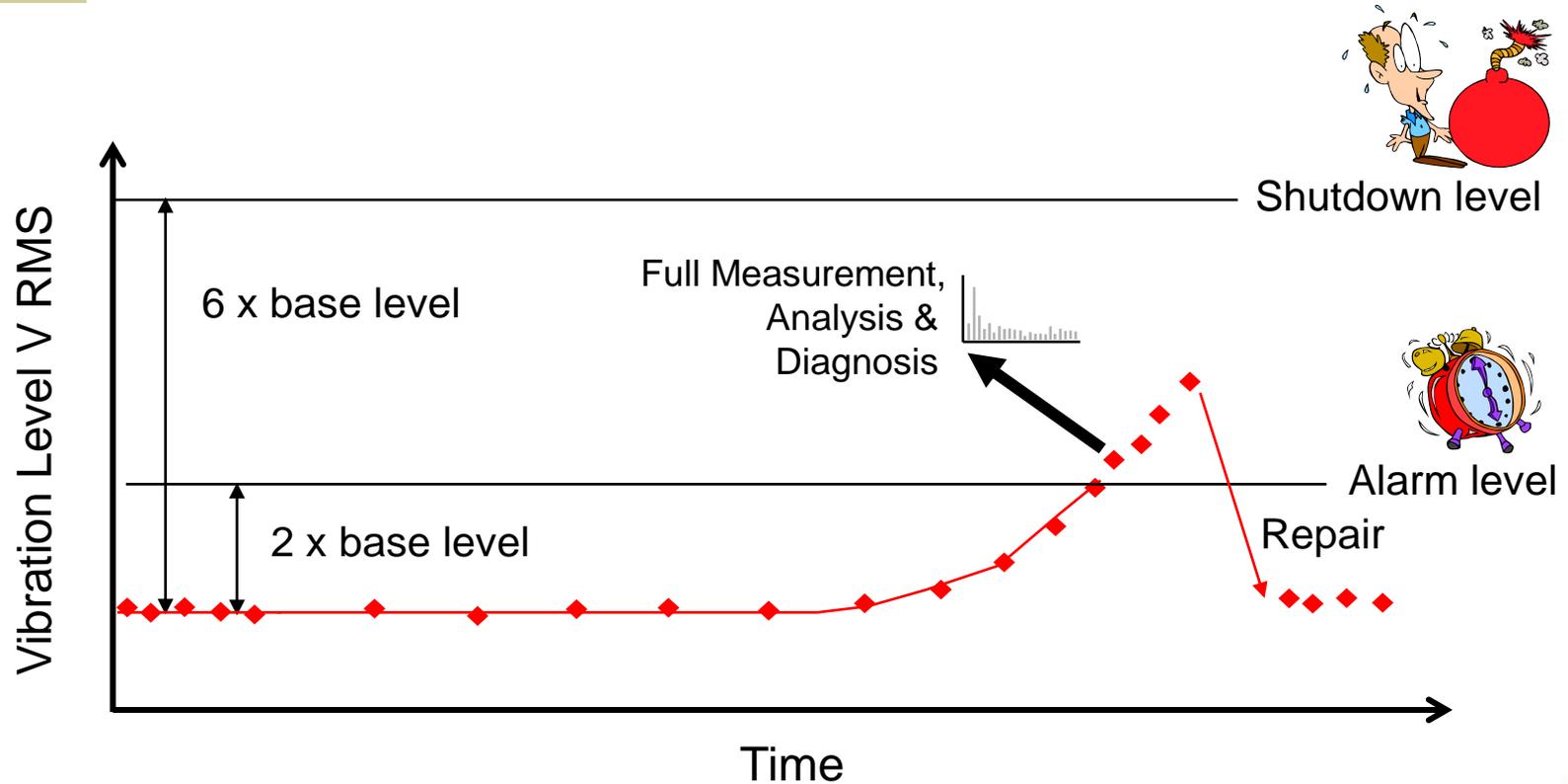


# 主軸振動檢驗

## Choosing a Mounting Position

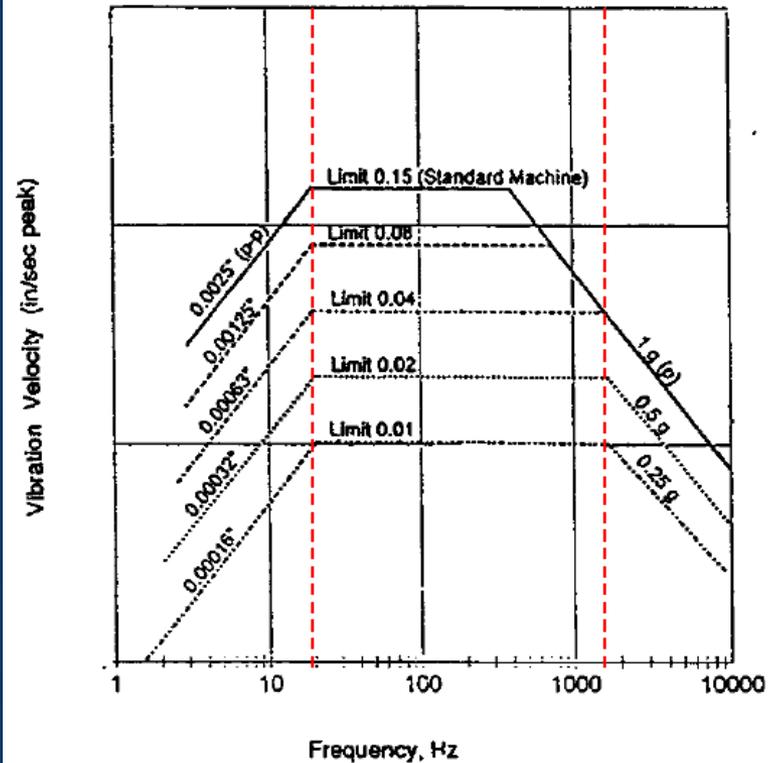


# 主軸振動檢驗

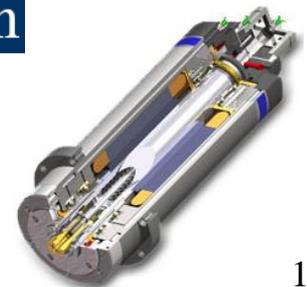


# Limits of Bearing Housing Vibration

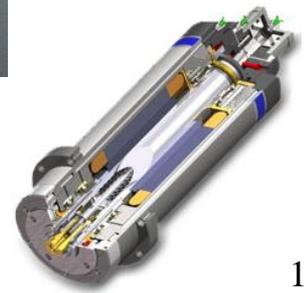
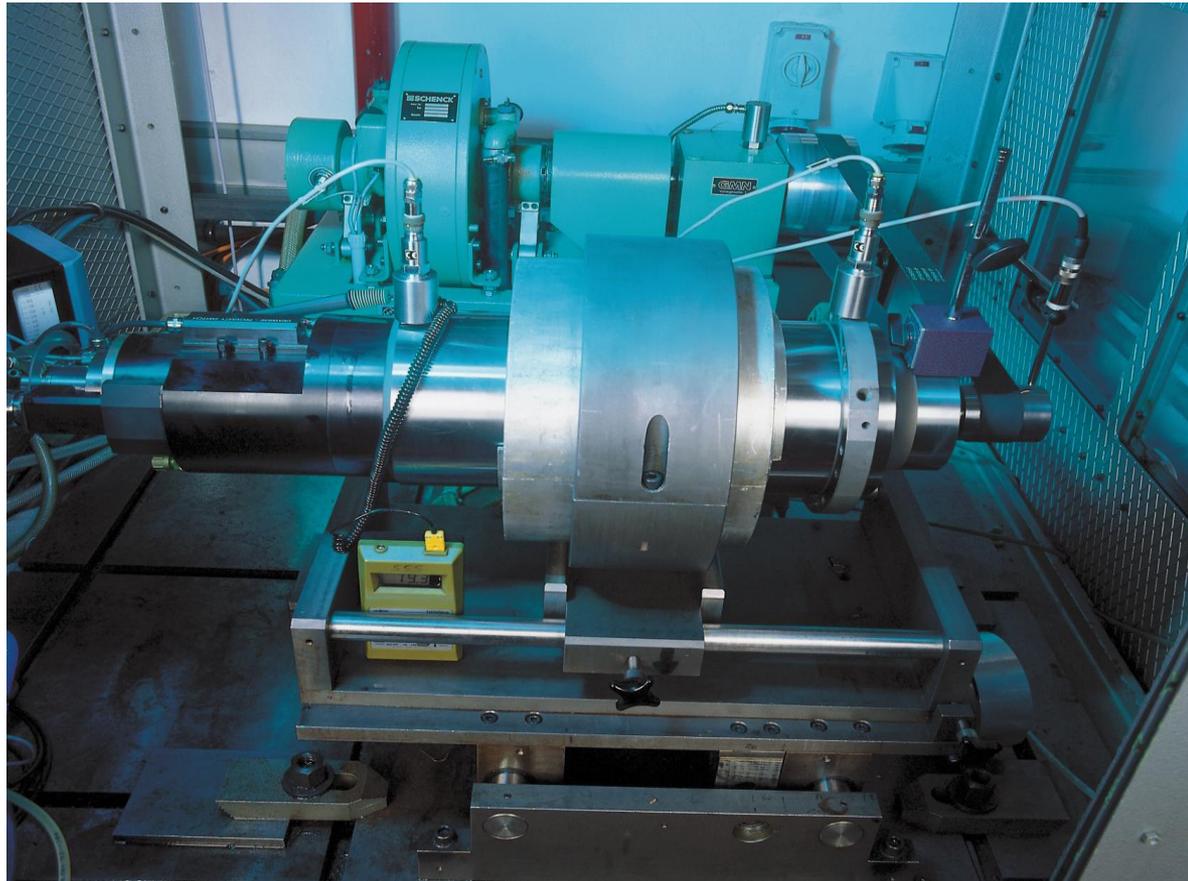
Vibration Limit (inch/sec)	Machine Type - General Examples
0.15	Standard industrial motors; motors for commercial or residential use
0.08	Machine tool motors; medium/large motors with special requirements
0.04	Grinding wheel motors; small motors with special requirements
0.02	Precision spindle and grinder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



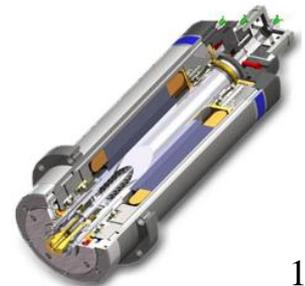
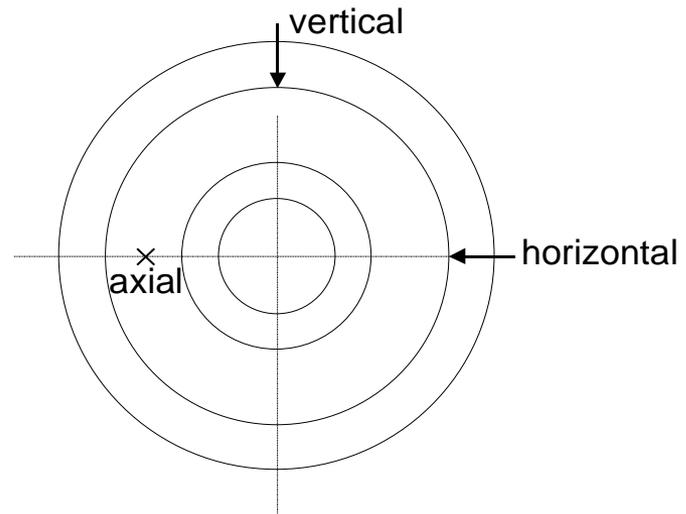
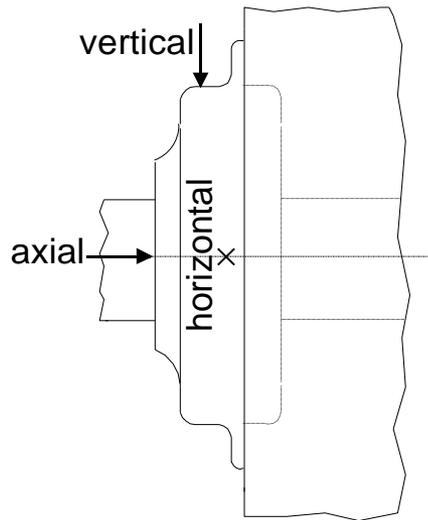
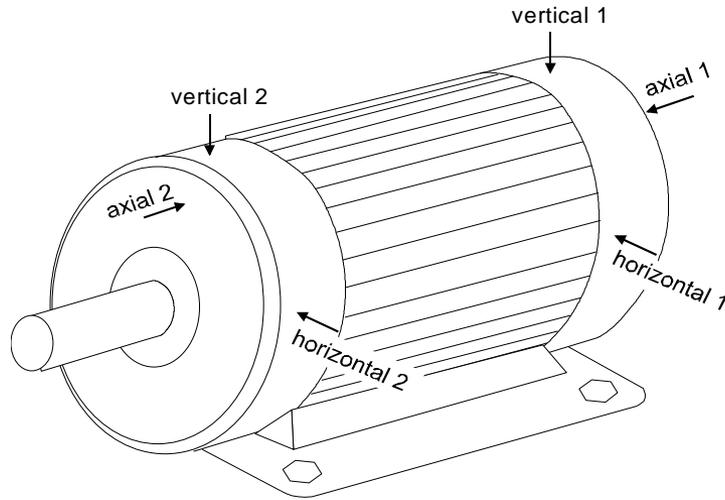
National Electrical Manufacturers Association



# 主軸振動檢驗



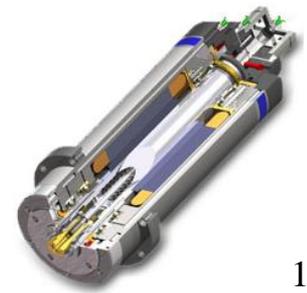
# 主軸振動檢驗



# 主軸振動檢驗

Machine Type	Power Rating or Shaft Height	Speed min <sup>-1</sup>	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



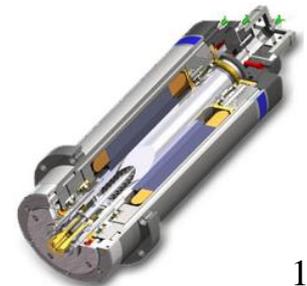
# 主軸振動檢驗

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			Good	
0.03	0.45				
0.04	0.71				
0.06	1.12				
0.10	1.80			Satisfactory	
0.16	2.80				
0.25	4.50				
0.39	7.10			Unsatisfactory	
0.62	11.20				
1.00	18.00				
1.56	28.00				
2.50	45.00				
3.95	71.00			Unacceptable	

Support classification according to ISO 2372

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

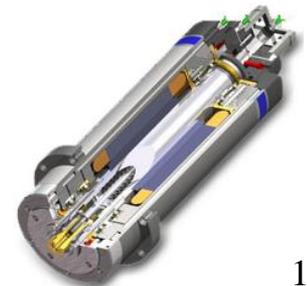
**Rigid Support:** The fundamental natural frequency of the machine/support system is higher than its main excitation frequency.



# 主軸振動檢驗

## 振動幅值的轉換表

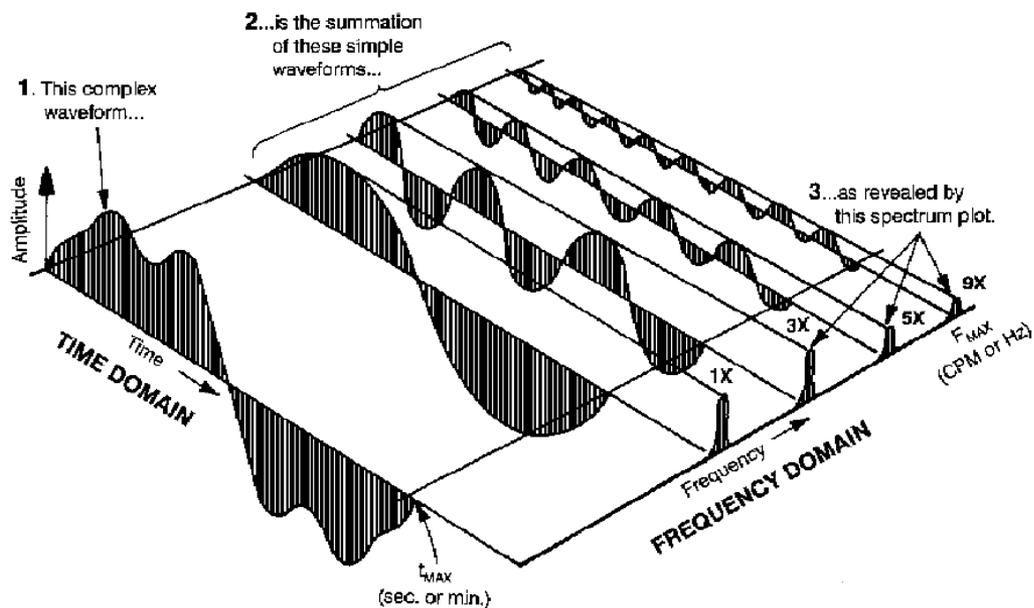
	MULTIPLY NUMBER OF	PEAK- TO- PEAK	PEAK	RMS	AVERAGE
TO OBTAIN	BY				
PEAK-TO-PEAK		1.000	2.000	2.828	3.142
PEAK		.500	1.000	1.414	1.571
RMS		.354	.707	1.000	1.5
AVERAGE		.318	.636	.900	1.000



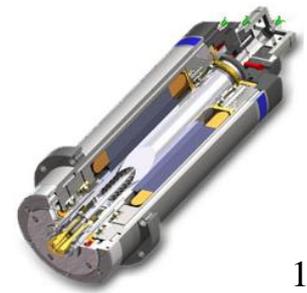
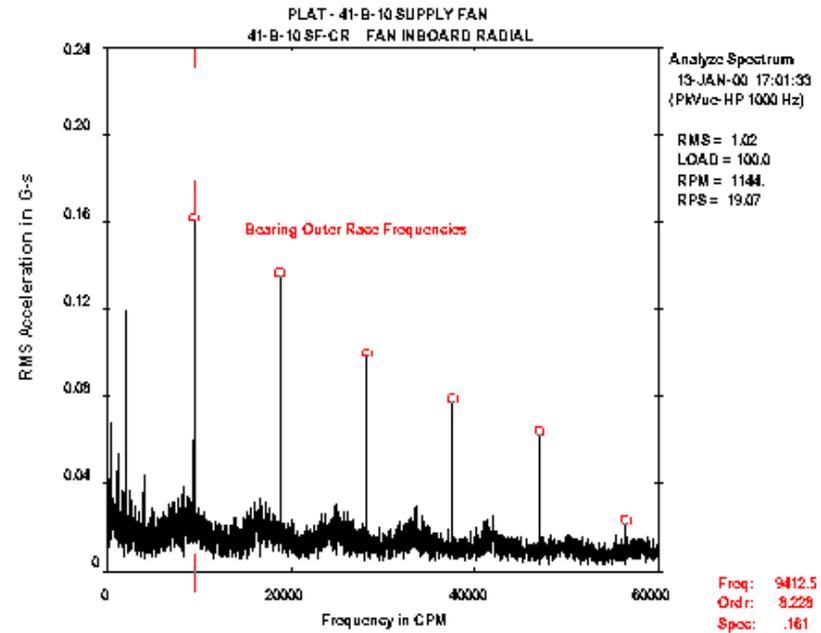
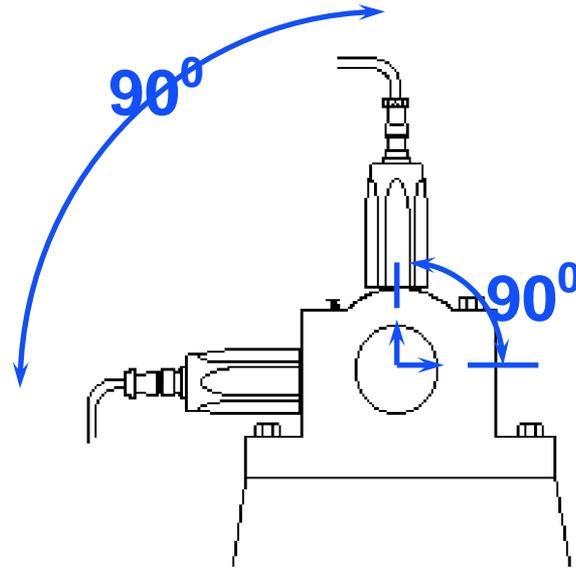
## 振動週期和頻率的轉換

頻率  $f(\text{Hz}) = \text{轉速 RPM (轉/每分鐘)} / 60$

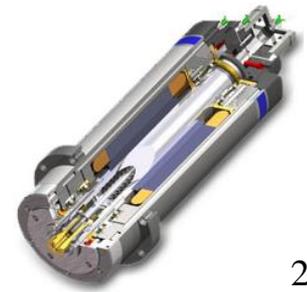
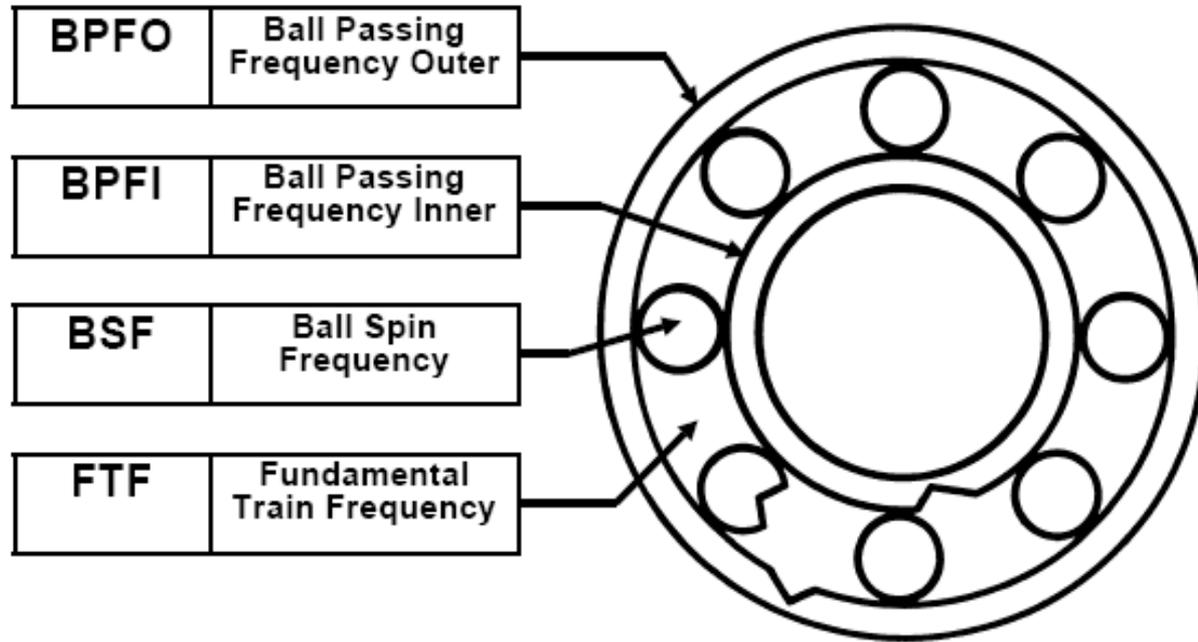
頻率  $f(\text{Hz}) = 1 / \text{週期 } T(\text{秒})$



# 主軸頻譜量測



# 主軸頻譜量測



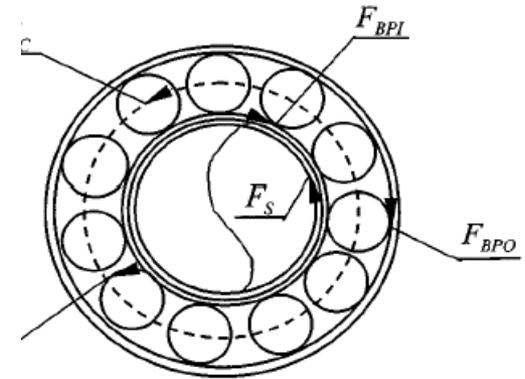
# 主軸頻譜量測

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

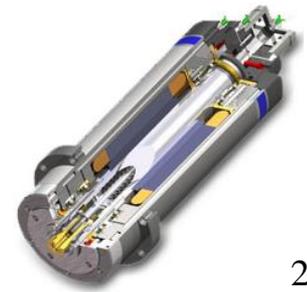
$$\text{BPFI} = \frac{N \times n}{2} \left( 1 + \frac{d}{D} \cos\beta \right)$$

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

$$\text{FTF} = \frac{N}{2} \left( 1 - \frac{d}{D} \cos\beta \right)$$

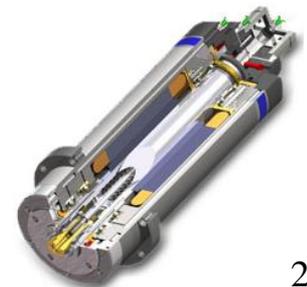
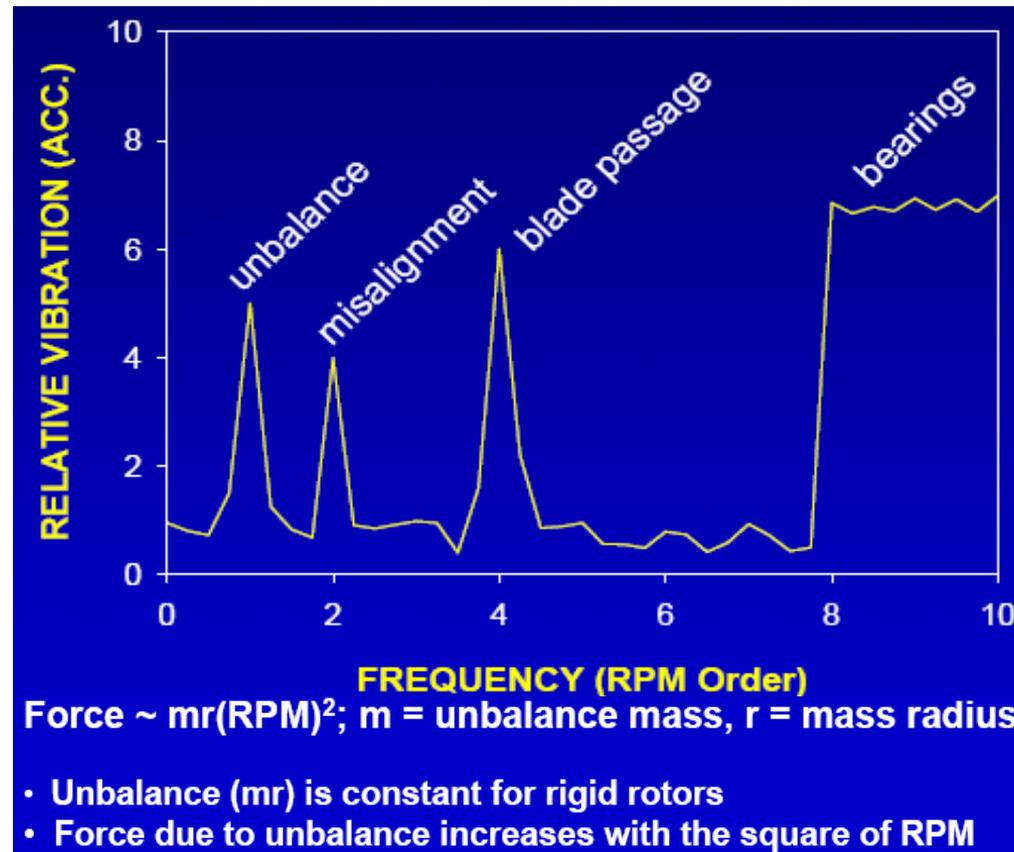


where  $N$  = Shaft Speed in Hz  
 $n$  = Number of Elements  
 $D$  = Pitch Diameter of Rolling Elements  
 $d$  = Rolling Element Diameter  
 $\beta$  = Contact Angle



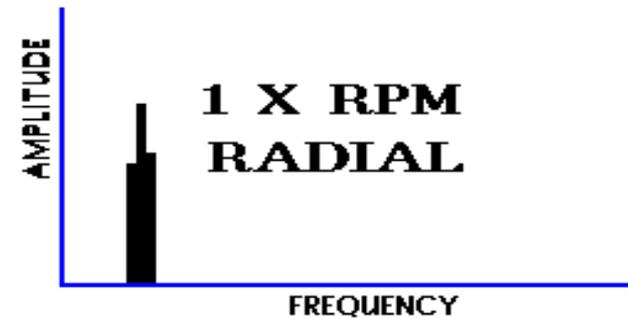
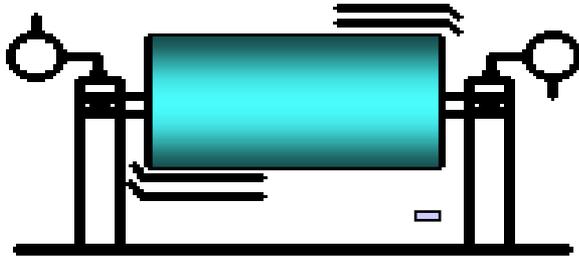
# 主軸頻譜量測

## Typical Machine Vibration Spectrum

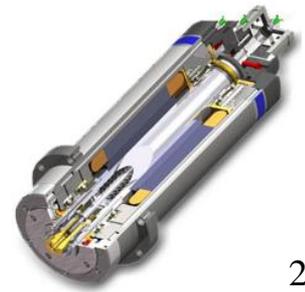


# 主軸頻譜量測

## UNBALANCE

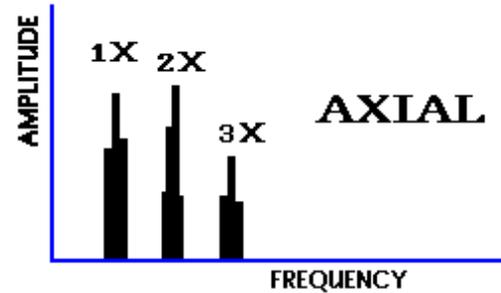
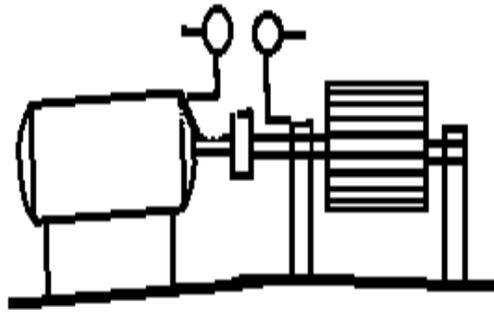


- ◆ 1X RPM always present and normally dominates
- ◆ Amplitude varies with square of increasing speed
- ◆ Can cause high axial as well as radial amplitudes

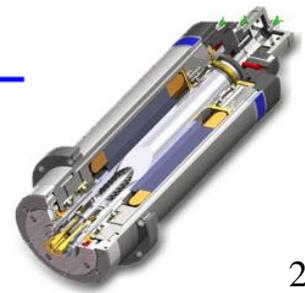
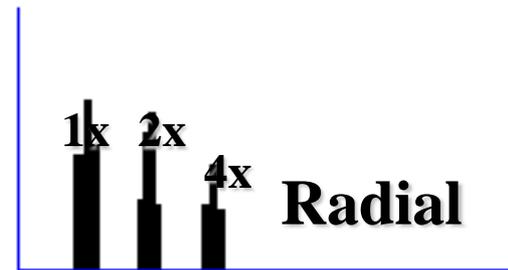
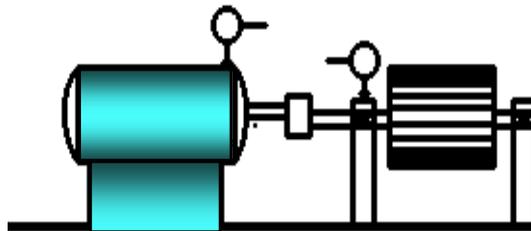


# 主軸頻譜量測

## ANGULAR MISALIGNMENT

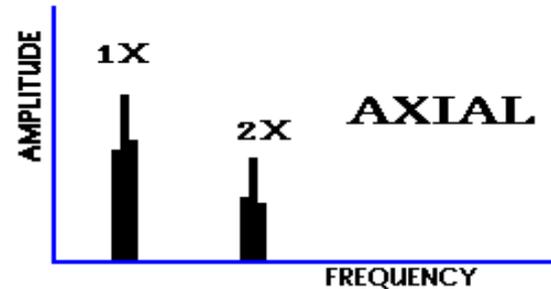
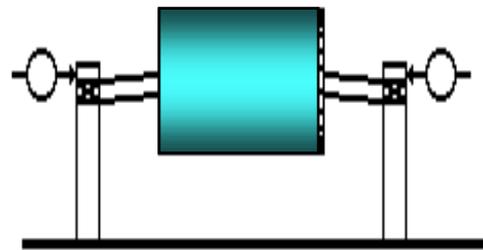


## PARALLEL MISALIGNMENT

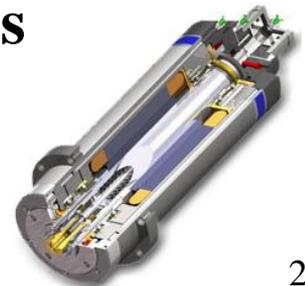


# 主軸頻譜量測

## BENT SHAFT

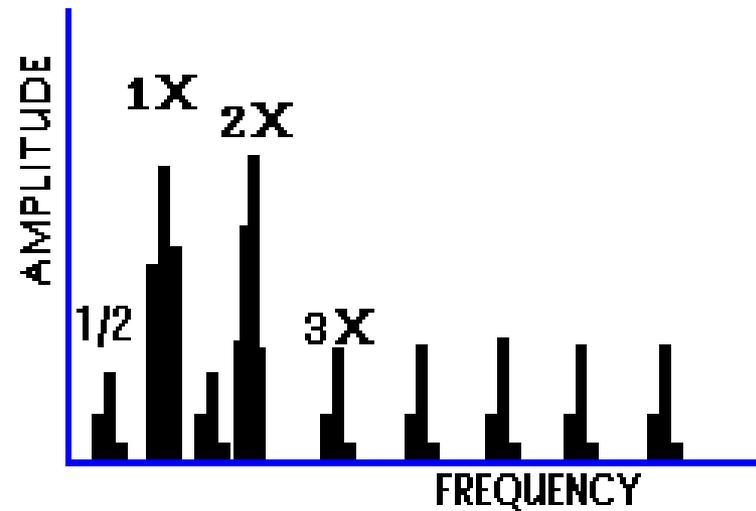
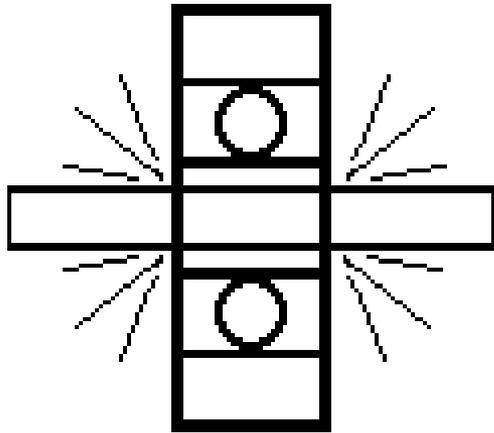


- ◆ Bent shaft problems cause high axial vibration
- ◆ 1X RPM dominant if bend is near shaft center
- ◆ 2X RPM dominant if bend is near shaft ends

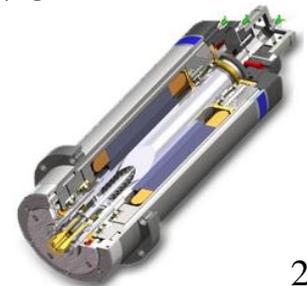


# 主軸頻譜量測

## MECHANICAL LOOSENESS (C)

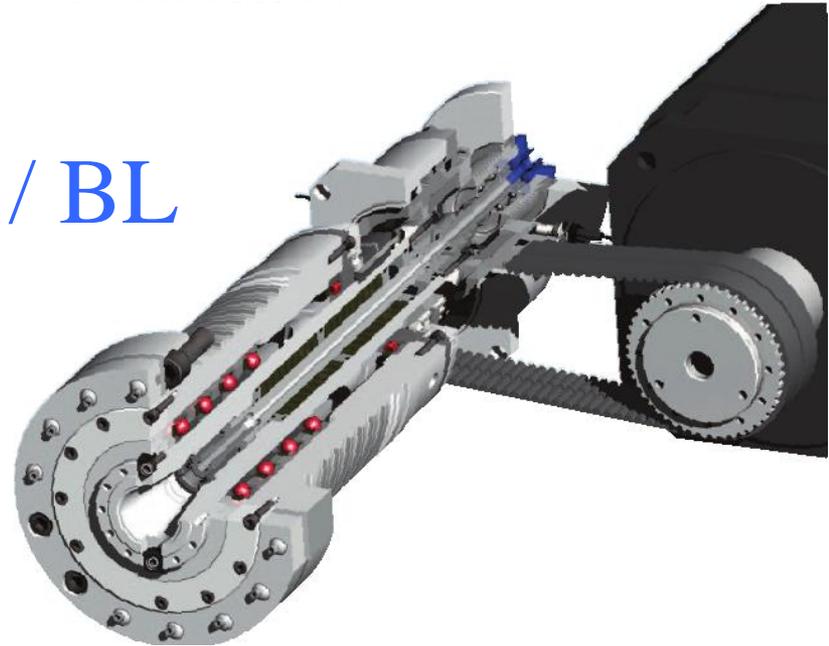


- ◆ Phase is often unstable
- ◆ Will have many harmonics
- ◆ Can be caused by a loose bearing liner, excessive bearing clearance or a loose impeller on a shaft



# 皮帶式主軸

$$BF = \pi * D * N / BL$$



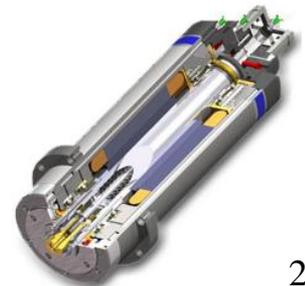
$\pi = 3.141596$

$D =$  Pitch Diameter of Sheave

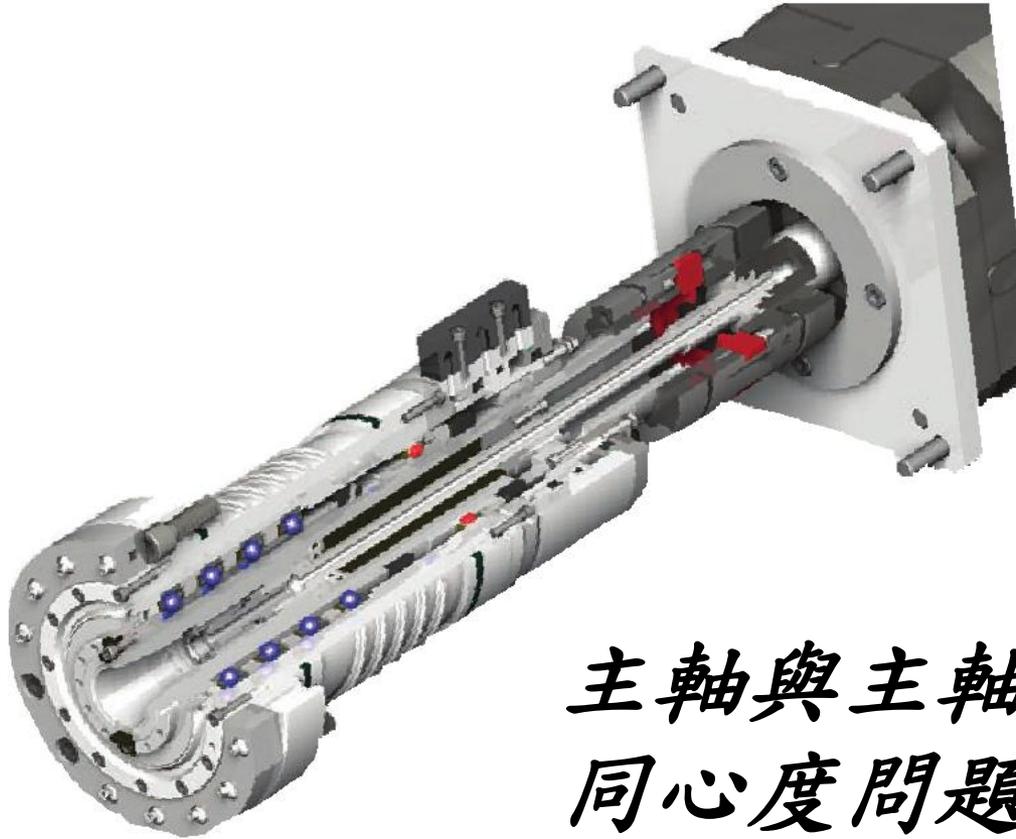
$N =$  Rotation Speed of Sheave

$BL =$  Belt Length

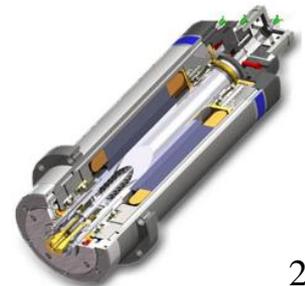
## 皮帶與組裝精度



# 直結式主軸



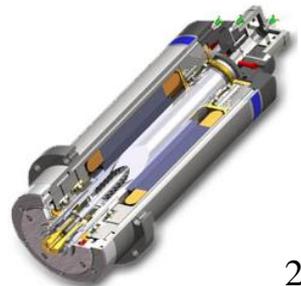
主軸與主軸馬達  
同心度問題：二倍頻



# 產生振動的原因

## Breakdown of all Vibration Problems

- 40% Unbalance
- 30% Misalignment
- 20% Resonance
- 10% Others



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# *Question & Discussion*



*See You Next Time*

Thank You

