振動之量測介紹

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課程大綱

- 振動的定義
- 振動的參數
- 振動的原理
- 振動訊號型式
- 參數之關係
- 量測單位
- 訊號量測鏈
- 振動量測探頭
- 分析方法
- 顯示方式

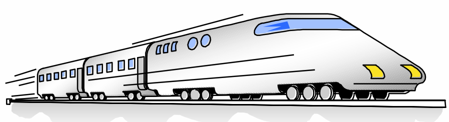
Brüel & Kjær

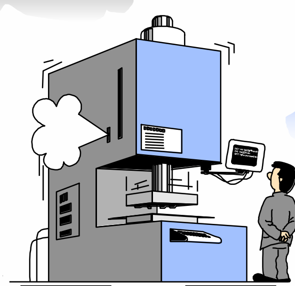
振動之定義

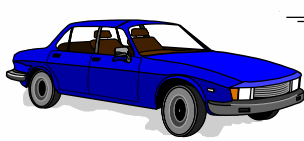
振動(Vibration) : 一種機械系統的震盪(oscillation)行為. 振動的大小是機械系統運動的一個參數(a parameter).

震盪(**Oscillation**) :隨著時間的過去,相對於參考位置,有著大小量的變化.

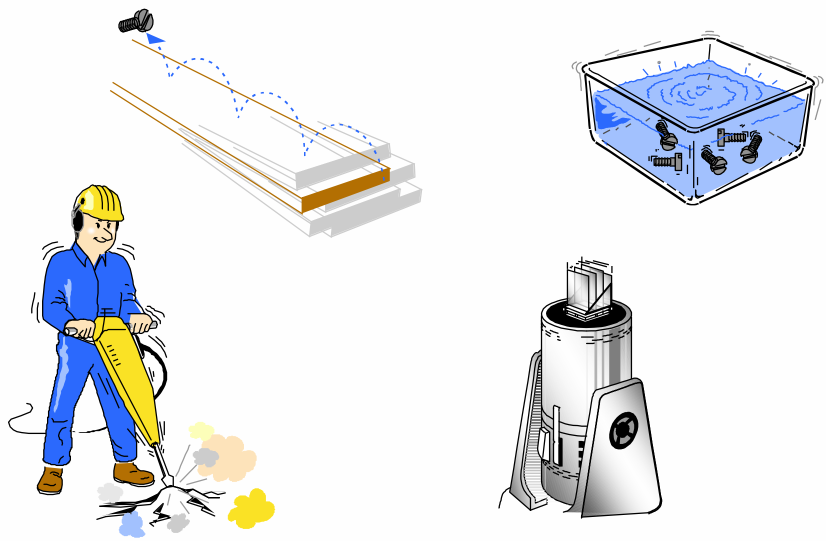
日常生活之振動



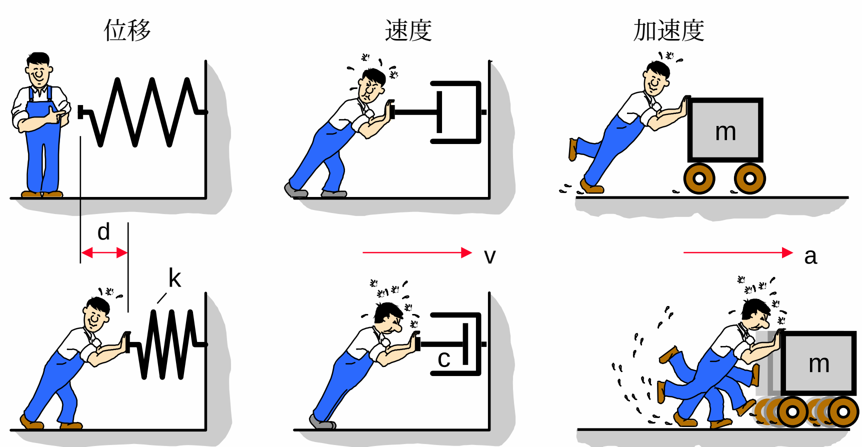




工業上的振動應用



振動量測參數

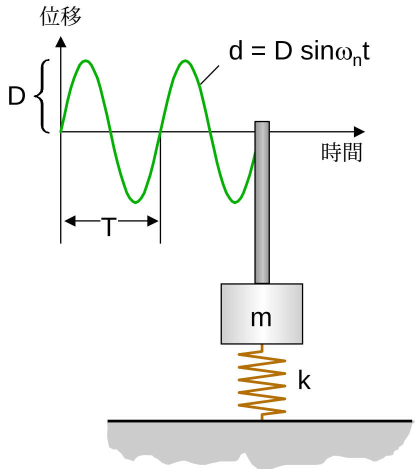


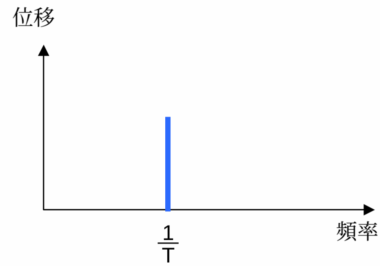
F = k × d

F = c × v

F = m × a

簡單的振動系統



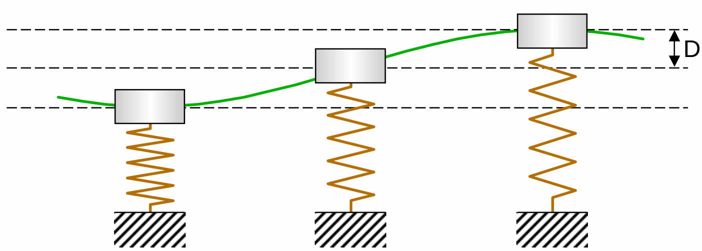


週期, T_n in [sec]

頻率, $f_n = \frac{1}{T_n}$ in [Hz = 1/sec]

$\omega_n = 2\pi f_n = \sqrt{\frac{k}{m}}$

自由振動



能量在動能及位能之間轉換
(assuming no damping)

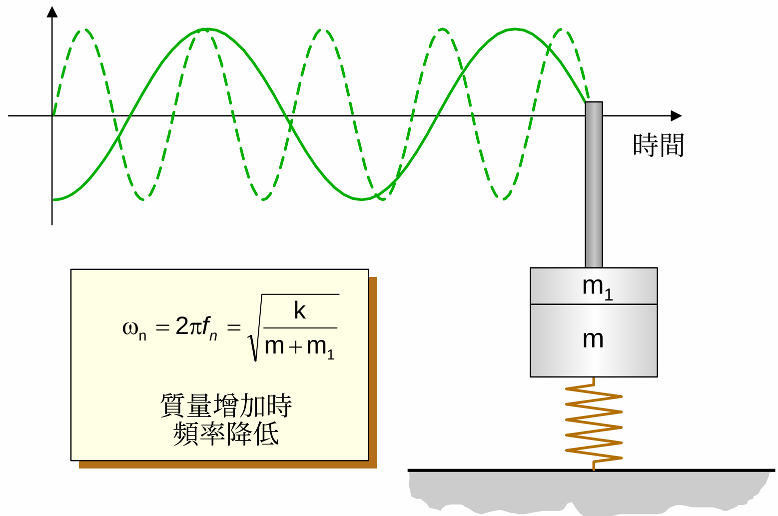
Δ 動能= - Δ 位能

$\frac{1}{2} m V^2 = \frac{1}{2} k D^2$, and $V = (2\pi f_n)D$

$\frac{1}{2} m (2\pi f_n)^2 D^2 = \frac{1}{2} k D^2$

$$f_n = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

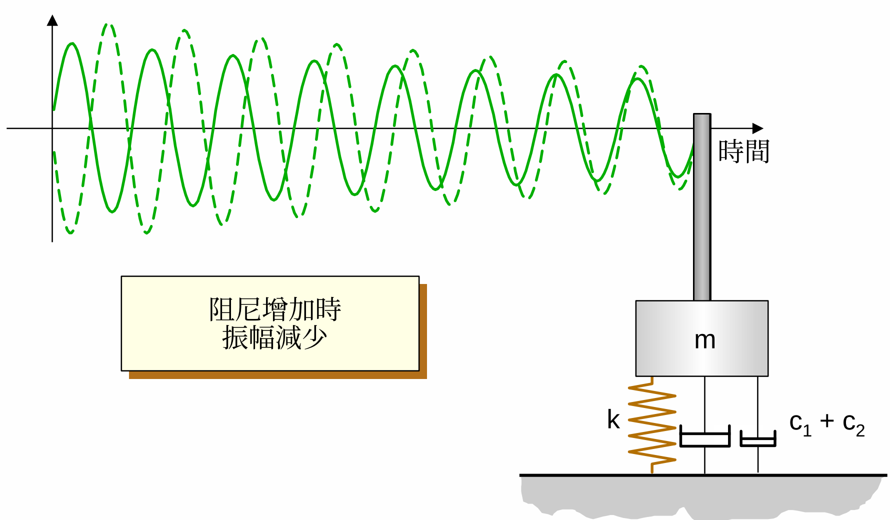
質量與彈簧系統



$$\omega_n = 2\pi f_n = \sqrt{\frac{k}{m + m_1}}$$

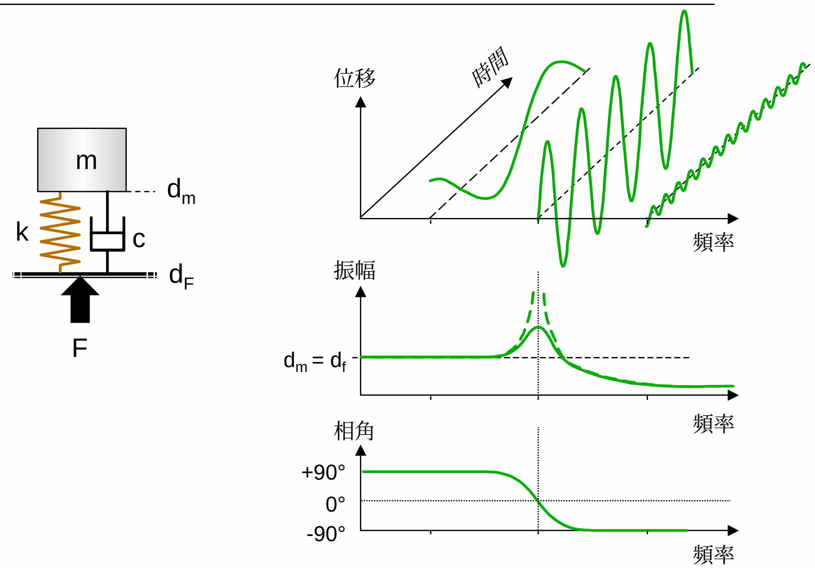
質量增加時
頻率降低

質量,彈簧與吸振器系統

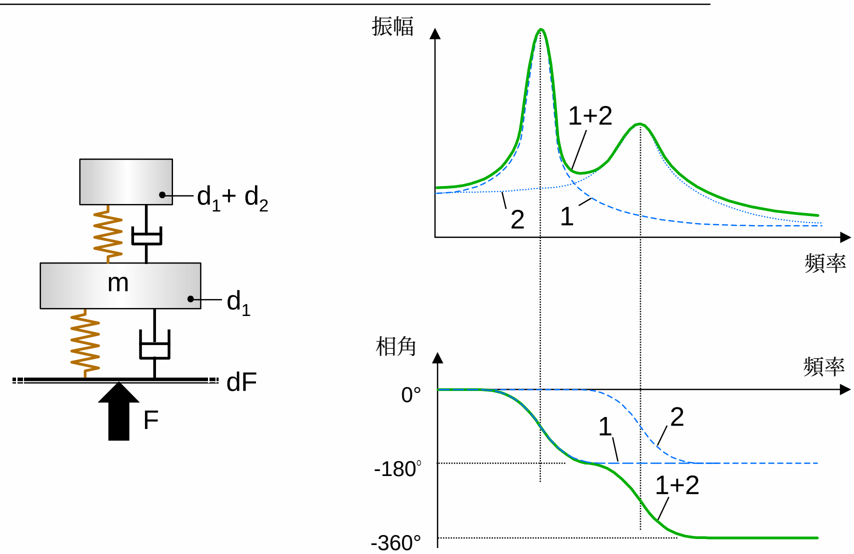


阻尼增加時
振幅減少

強制振動

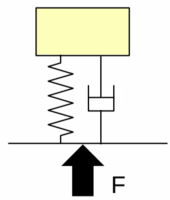

m
d_m
k
c
d_F
F
位移
時間
頻率
振幅
$d_m = d_f$
頻率
相角
+90°
0°
-90°
頻率

複合的反應

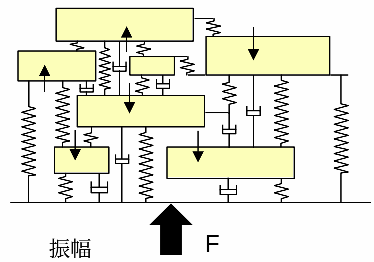

$d_1 + d_2$
m
d_1
dF
F
振幅
1+2
2
1
頻率
相角
頻率
0°
1
2
-180°
1+2
-360°

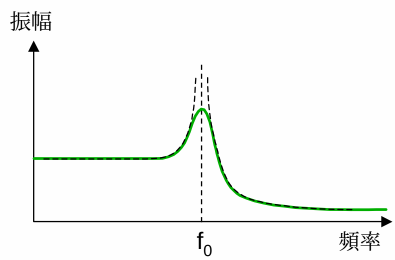
反應的模式

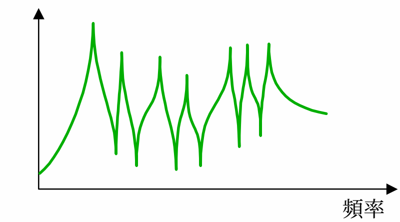
單一自由度之反應
SDOF



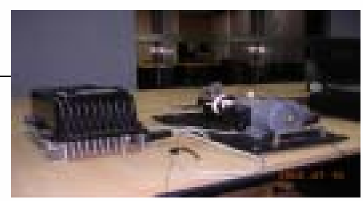
多自由度之反應
MDOF

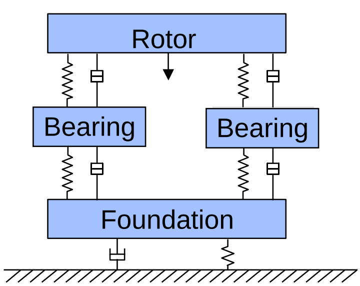


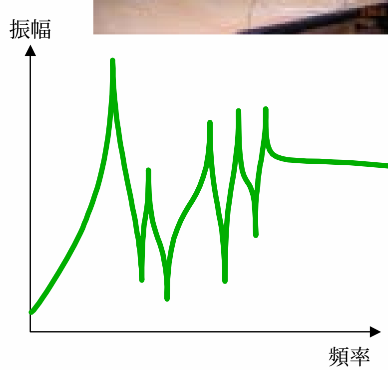




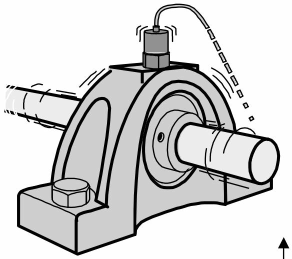
“真實世界” 的反應



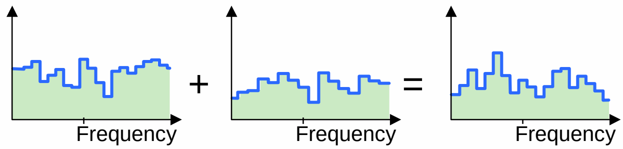




力量與振動



力量
輸入 + 系統
響應
(Mobility) = 振動



力量的產生

- 不平衡
- 衝擊
- 摩擦
- 聲音

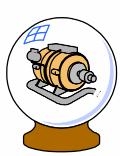
結構參數:

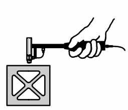
- 質量
- 剛性
- 阻尼

振動參數:

- 加速度
- 速度
- 位移

振動量測的目的





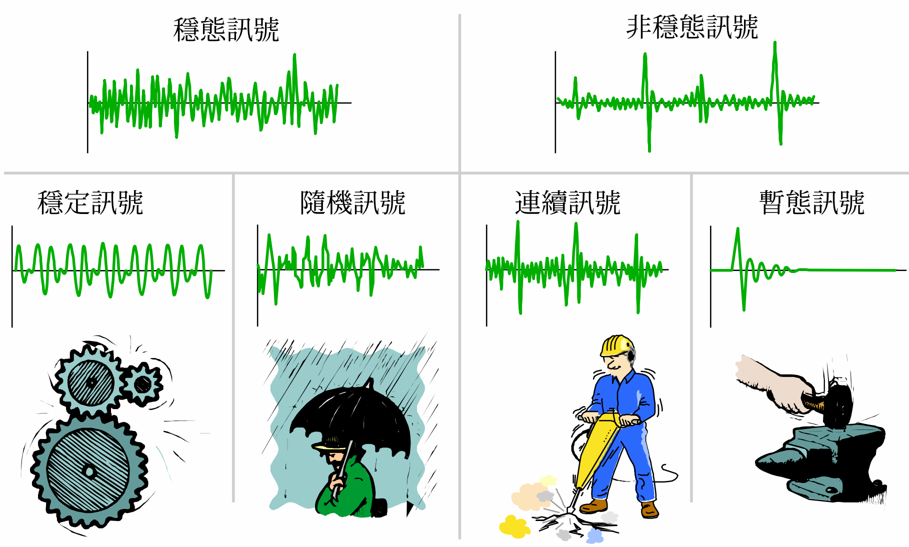
- 確認其大小及次數未超乎材料的極限 (例如 金屬疲勞常用的S-N Curve 或稱 Wöhler curves)
- 避免激發機器上的特定元件之自然頻率
- 能抑制或隔離振動源
- 進行機器之狀況監測
- 用於建構或確認結構之計算模型 (system analysis)

振動的量化

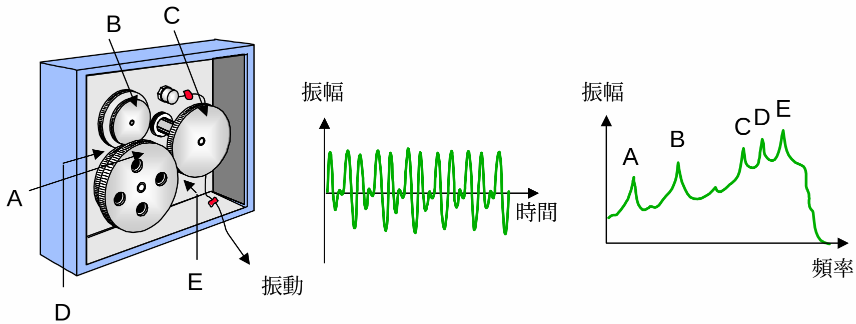
- 進行量測
- 分析量測資料(位準與頻率)

進行分析時, 我們需探討我們所面對的振動訊號型式
並需對各種訊號型式之單位選擇有所了解

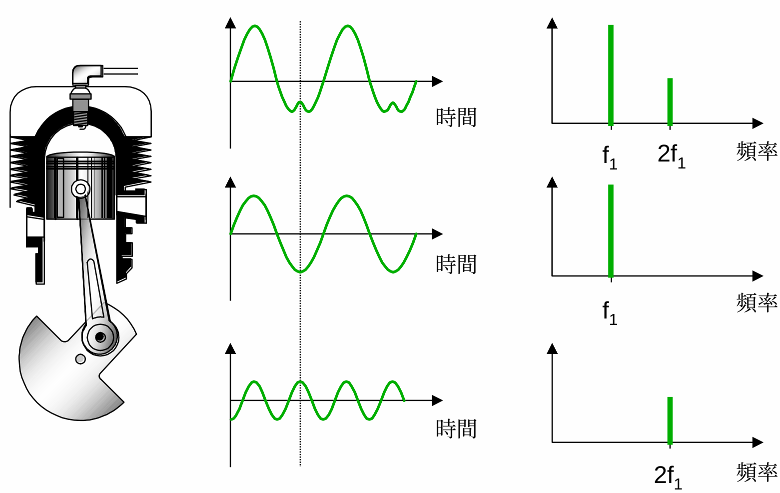
訊號型式



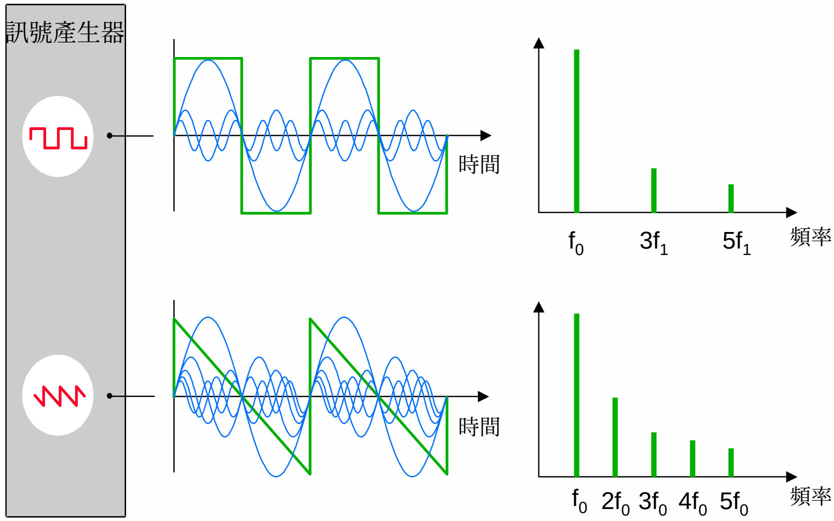
穩定的訊號



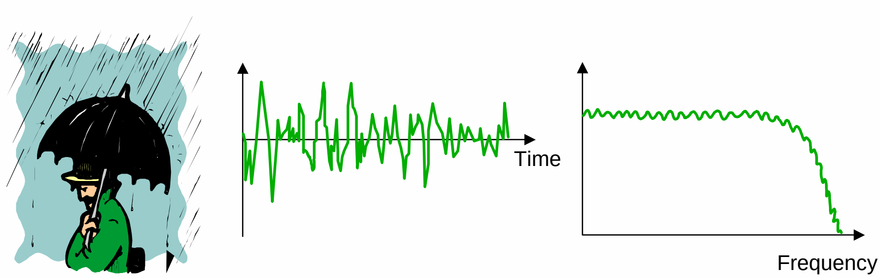
穩定訊號的組成



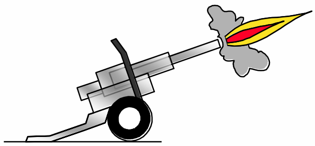
諧波之時頻關係

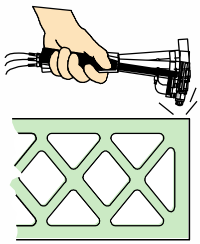


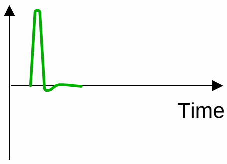
隨機訊號

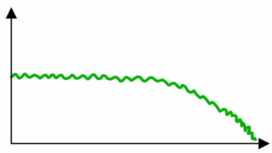


衝擊訊號





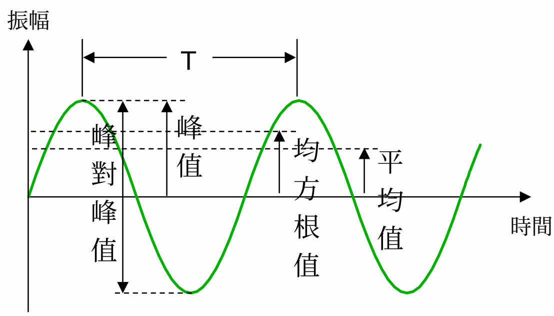




時域參數的選用

- 峰值(Peak)
- 峰對峰值(Peak-Peak)
- 平均值(Average)
- 均方根值(RMS)
- Crest Factor
- 持續時間(Duration)

參數的意義

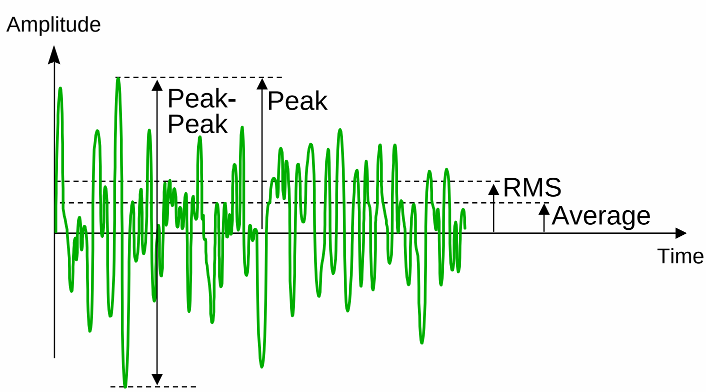


$$均方根值 = \sqrt{\frac{1}{T}\int_0^T x^2(t)dt}$$

$$平均值 = \frac{1}{T}\int_0^T |x(t)|dt$$

Crest Factor : $\frac{\text{Peak}}{\text{RMS}}$

實際訊號之參數

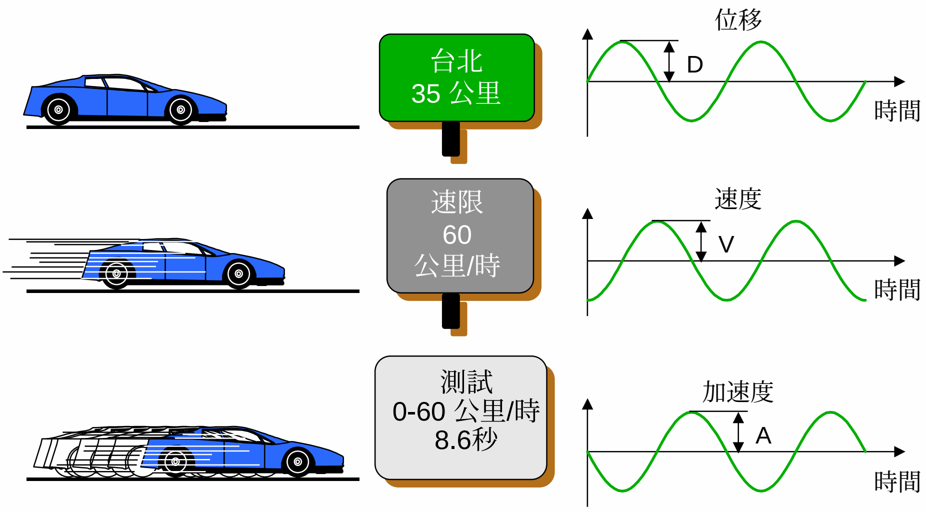


$$均方根值 = \sqrt{\frac{1}{T}\int_0^T x^2(t)dt}$$

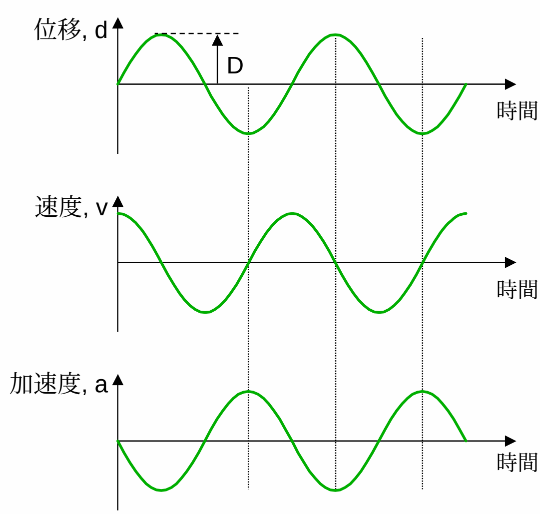
$$平均值 = \frac{1}{T}\int_0^T |x(t)|dt$$

Crest Factor : $\frac{\text{Peak}}{\text{RMS}}$

直線與震盪之移動



位移轉換至加速度之關係



$d = D \sin \omega t$

$d = D$

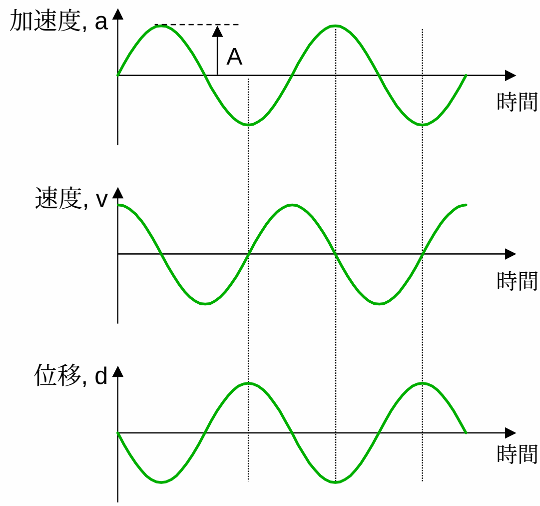
$v = \frac{dd}{dt} = D\omega \cos \omega t$

$v = D\omega = D2\pi f$

$v = \frac{d^2d}{dt^2} = D\omega^2 \sin \omega t$

$a = D\omega^2 = D4\pi^2 f^2$

加速度轉換至位移之關係



$a = A \sin \omega t$

$a = A$

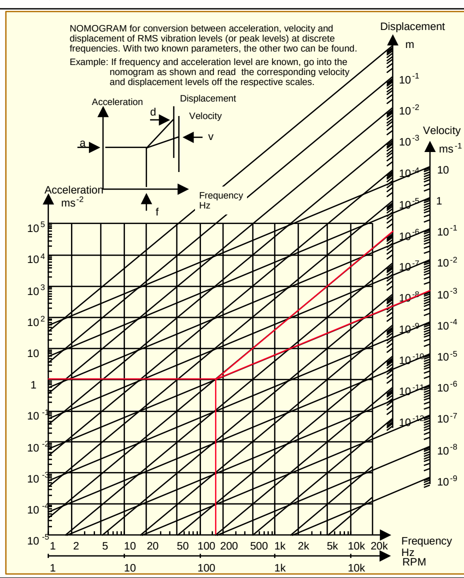
$v = \int a\,dt = -\frac{A}{\omega} \cos \omega t$

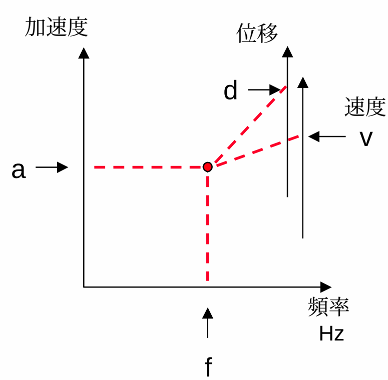
$v = \frac{A}{\omega} = \frac{A}{2\pi f}$

$d = \int\int a\,dt\,dt = -\frac{A}{\omega^2} \sin \omega t$

$d = \frac{A}{\omega^2} = \frac{A}{4\pi^2 f^2}$

轉換關係表



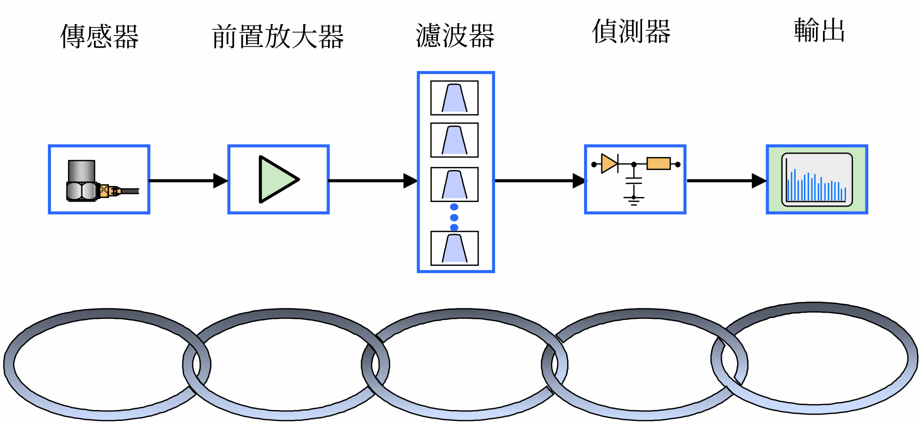


振動之單位

加速度 a	$1ms^{-2}$ (m/s^2)	= 0.102g = 39.4 in/s^2
速度 v	$1ms^{-1}$ (m/s)	= 3.6 km/h = 39.4 in/s
位移 d	1m	= 1000 mm = 39.4 in

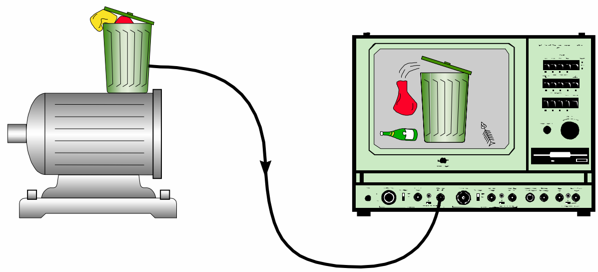
$1g \equiv 9.80665\ ms^{-2}$

訊號量測鏈

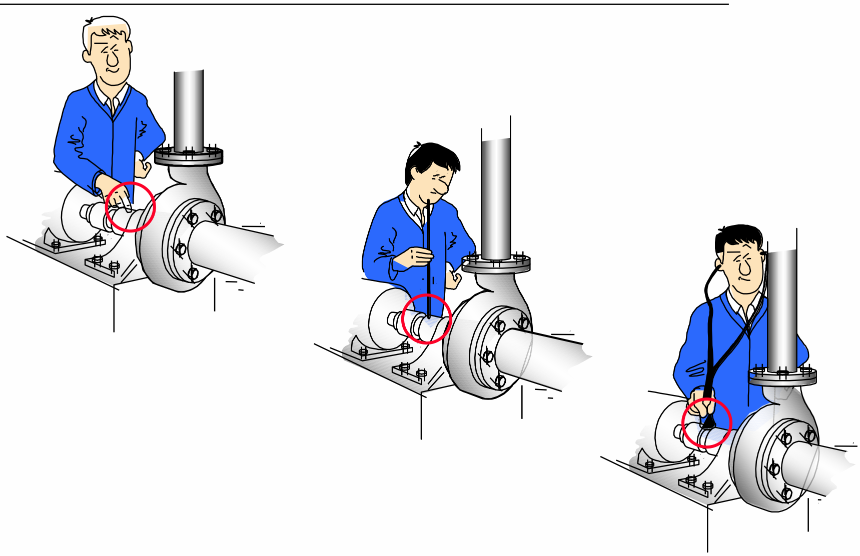


GIGO

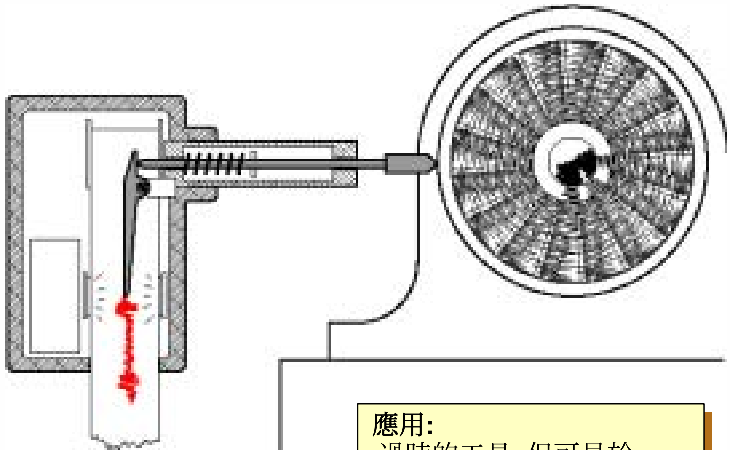
Garbage In = Garbage Out



早期之振動量測

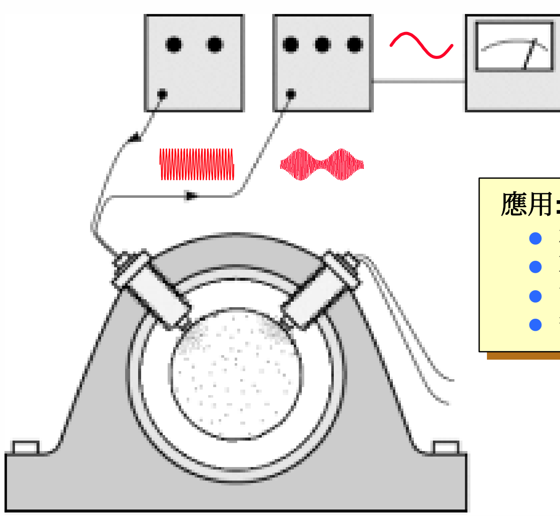


機械槓桿



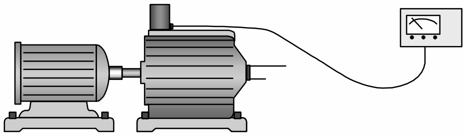
應用:
過時的工具, 但可見於
一些水力電廠

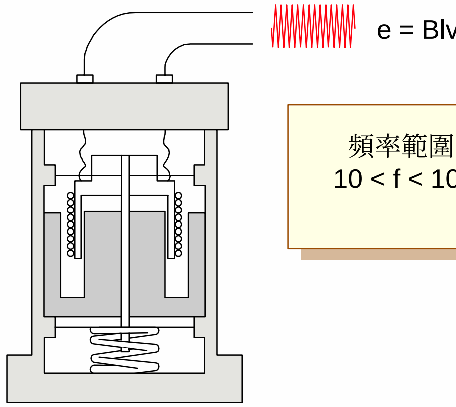
位移近接渦電流探頭



應用:
- 相對移動
- 軸偏心
- 油膜厚度
- 等等.

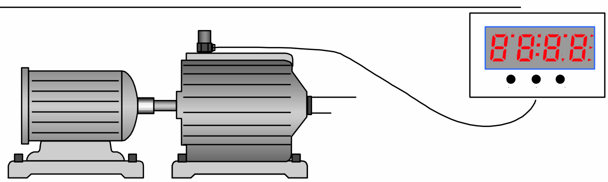
速度探頭



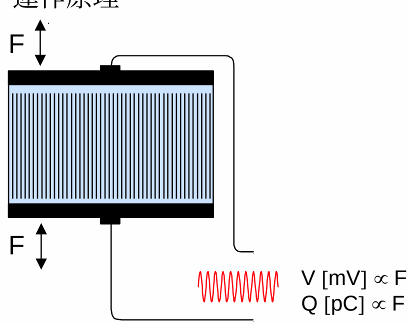


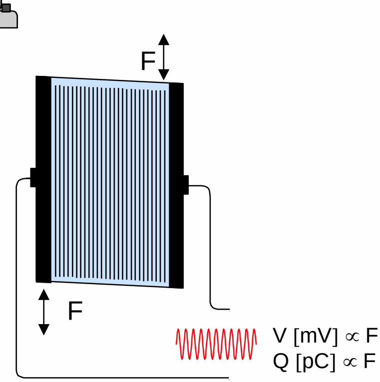
頻率範圍限制:
10 < f < 1000 Hz

壓電加速規

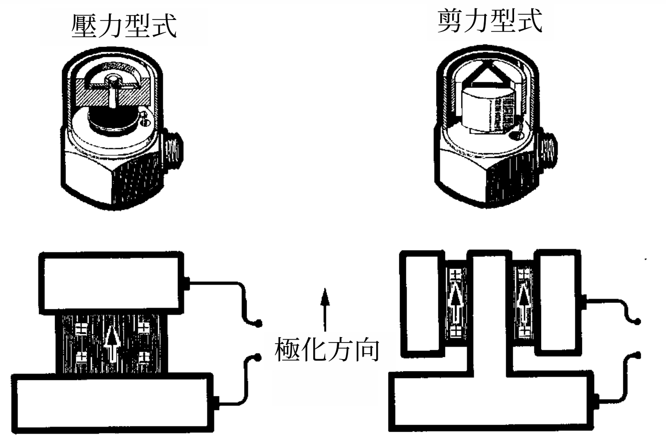


運作原理

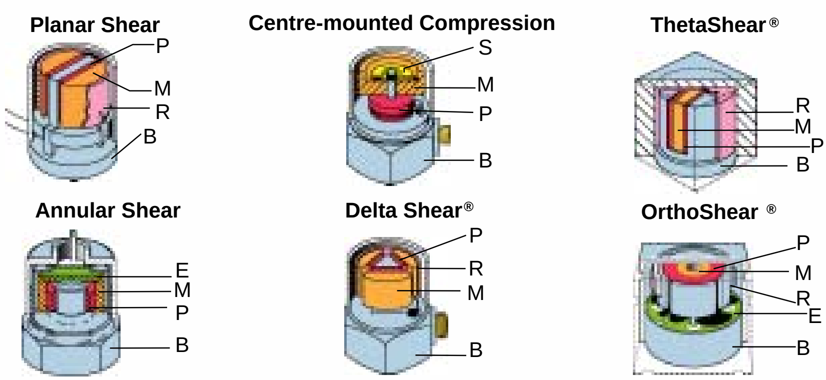




加速規之基本型式



壓電加速規型式

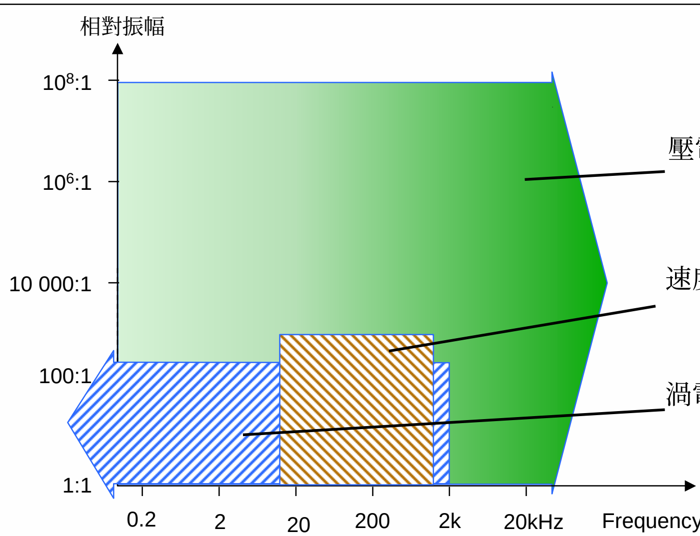


P: Piezoelectric Elements	E: Built-in Electronics	S: Spring
R: Clamping Ring	B: Base	M: Seismic Mass

加速規之輸出訊號型式

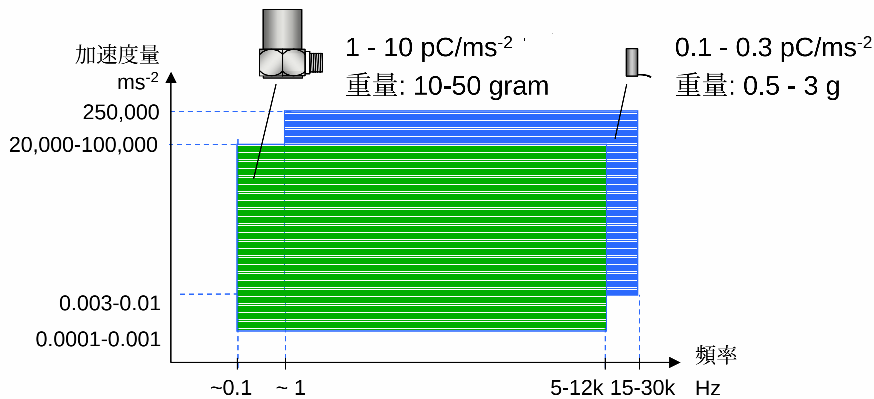
- 電荷型
- 電壓型
- 電流型

各型振動探頭之量測範圍

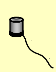


加速規之選用

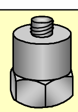
或
- 一般用途, 中等重量及感度
- 小、輕而高頻



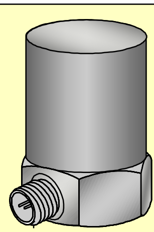
加速規之選用-質量效應



0,1 pC/ms^{-2}
0.65 g ⟹ M > 7 g

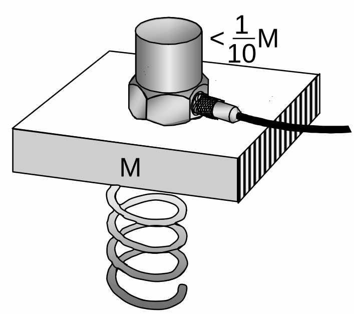


10 pC/ms^{-2}
54 g ⟹ M > 600 g

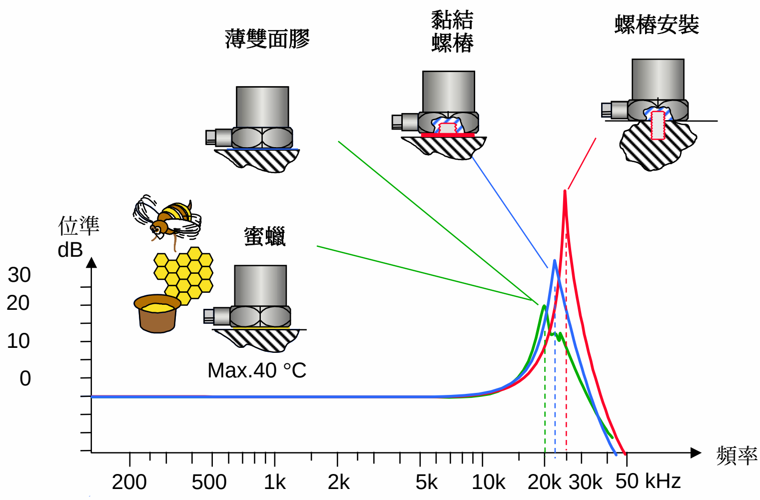


1000 pC/ms^{-2}
470 g ⟹ M > 5 kg

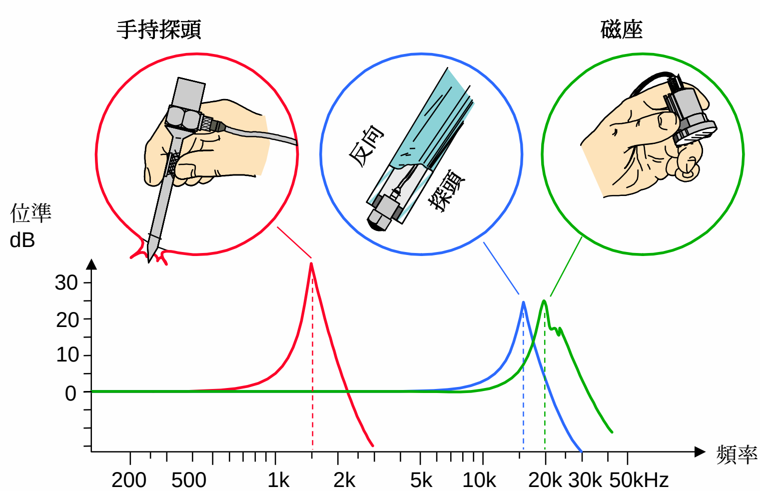
動態質量



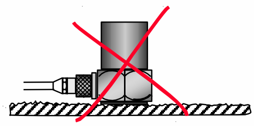
加速規之安裝(一)

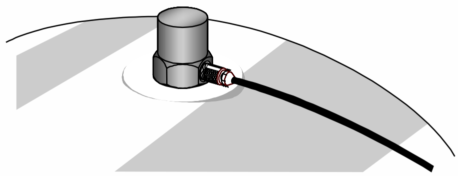


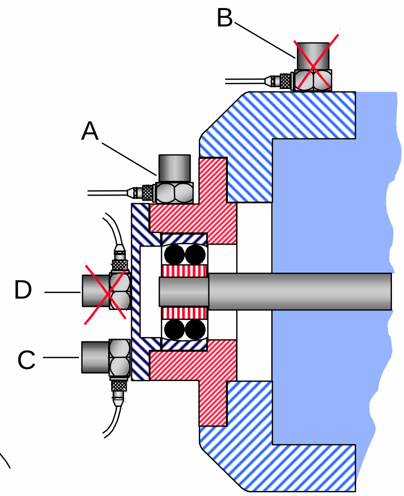
加速規之安裝(二)



位置之選擇







分析方法

- 總量分析(Overall Analysis)
- 頻率分析(Frequency Analysis)
  - FFT Analysis
  - 1/N Octave Analysis
- 階次分析(Order Analysis)

總量分析

- 峰值(Peak)
- 均方根值(RMS)
  - 線性平均
  - 指數平均

頻率分析

- 等頻寬(Constant Bandwidth)分析
- 等比頻寬(Constant Percentage Bandwidth)分析

階次分析

- 用於分析轉速相關倍數之振幅成分

顯示方式

- 振幅座標軸
  - 線性(Linear)
  - 對數(Logarithmic)
  - 分貝(deciBel,dB)
- 頻率座標軸
  - 線性(Linear)
  - 對數(Logarithmic)
  - CPB

結論

- 振動的定義
- 振動的參數
- 振動的原理
- 振動訊號型式
- 參數之關係
- 量測單位
- 訊號量測鏈
- 振動量測探頭
- 分析方法
- 顯示方式