

振動之量測介紹

徐森煌

必凱科技股份有限公司

課程大綱

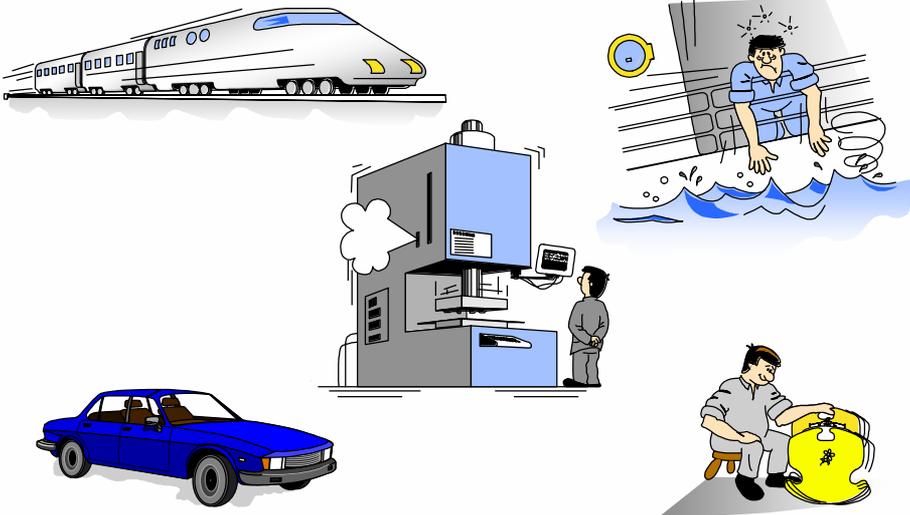
- 振動的定義
- 振動的參數
- 振動的原理
- 振動訊號型式
- 參數之關係
- 量測單位
- 訊號量測鏈
- 振動量測探頭
- 分析方法
- 顯示方式

振動之定義

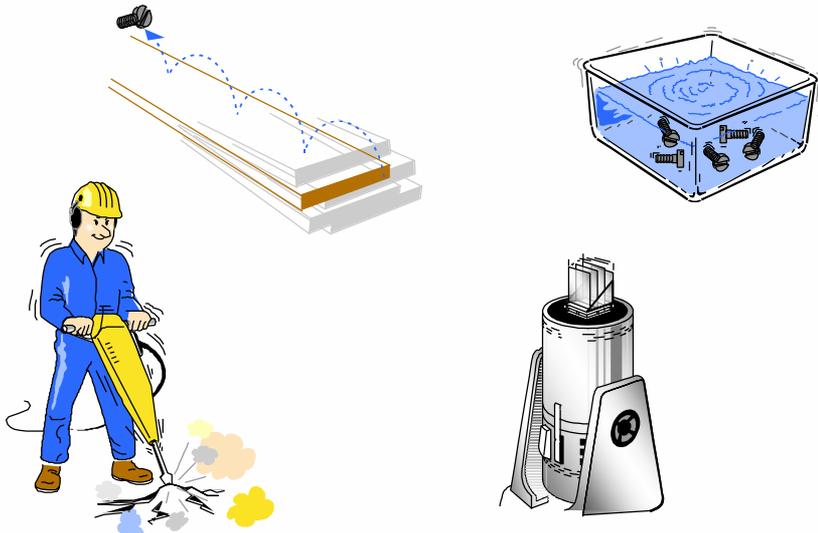
振動(Vibration)：一種機械系統的震盪(oscillation)行為。振動的大小是機械系統運動的一個參數(a parameter)。

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



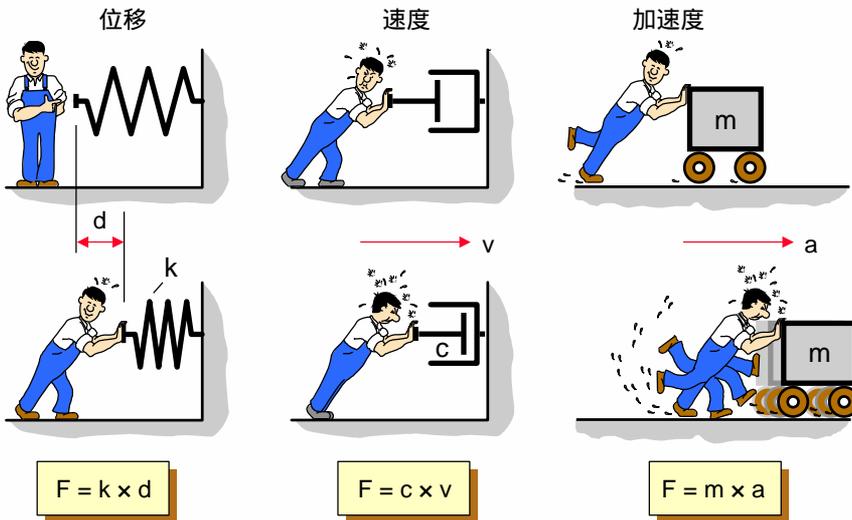
工業上的振動應用



BA 7674-12, 5

Brüel & Kjær 

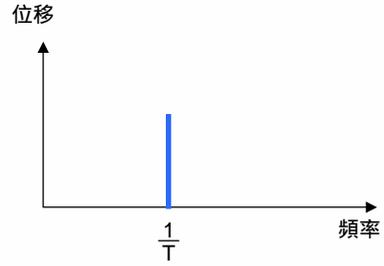
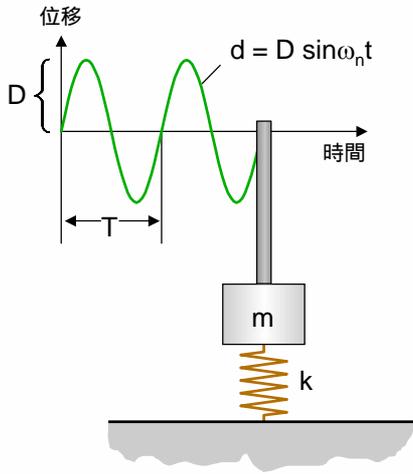
振動量測參數



BA 7674-12, 6

Brüel & Kjær 

簡單的振動系統

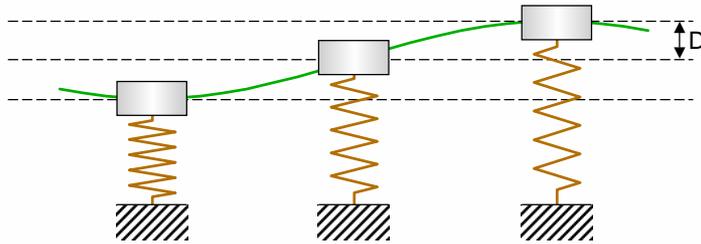


週期, T_n in [sec]

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)

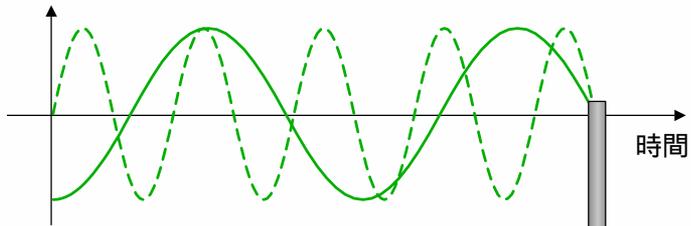
$$\Delta \text{動能} = - \Delta \text{位能}$$

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

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

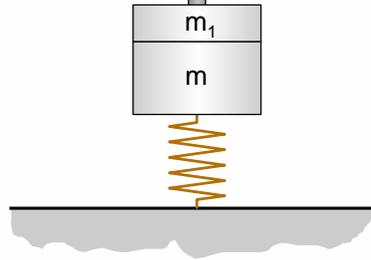
$$f_n = \frac{1}{2\pi} \sqrt{\frac{k}{m}}$$

質量與彈簧系統



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

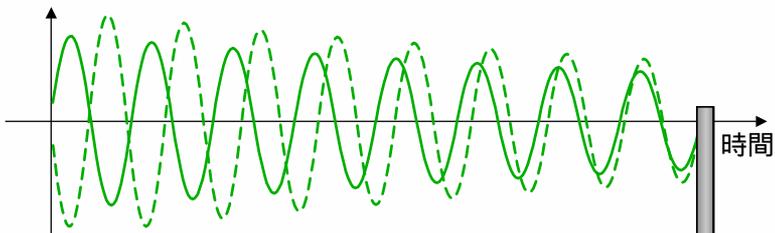
質量增加時
頻率降低



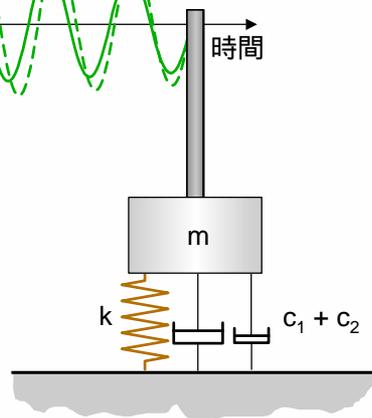
BA 7674-12, 9

Brüel & Kjær 

質量,彈簧與吸振器系統



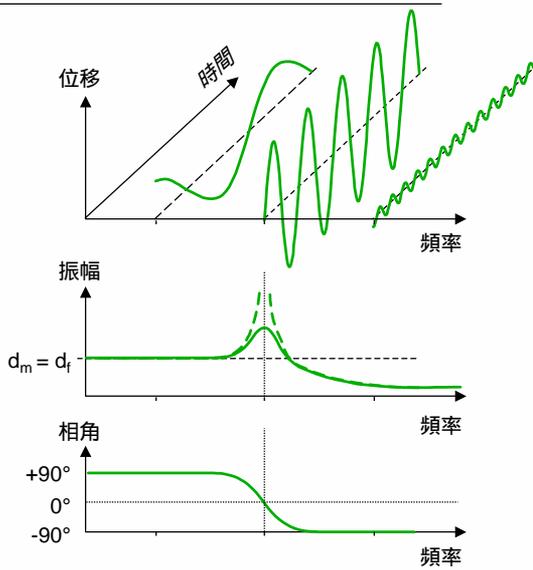
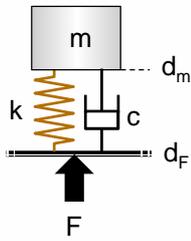
阻尼增加時
振幅減少



BA 7674-12, 10

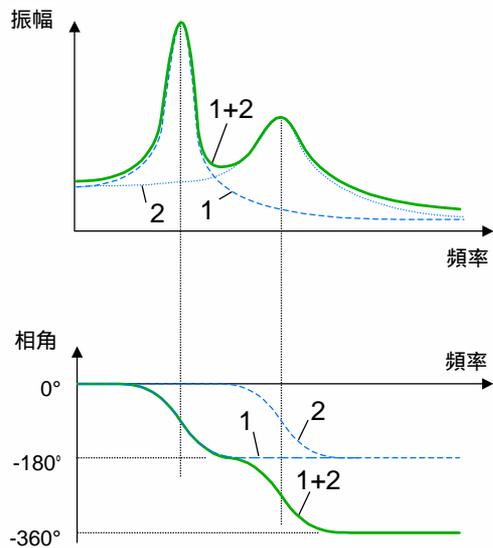
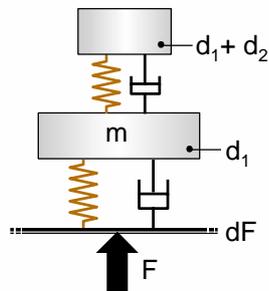
Brüel & Kjær 

強制振動



BA 7674-12, 11

複合的反應

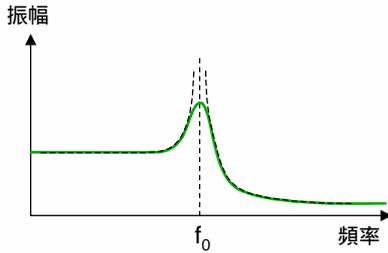
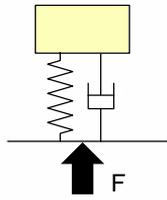


BA 7674-12, 12

反應的模式

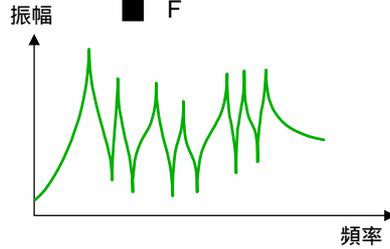
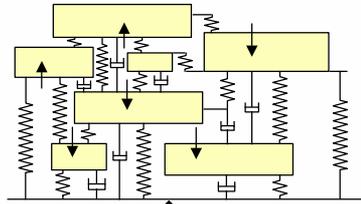
單一自由度之反應

SDOF

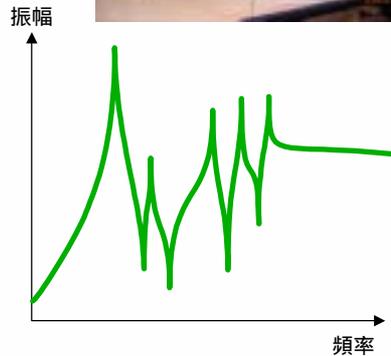
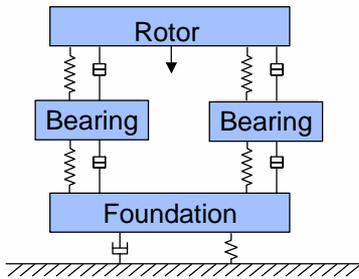
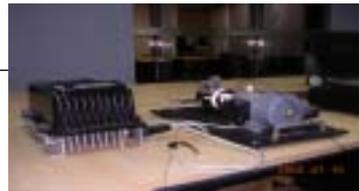


多自由度之反應

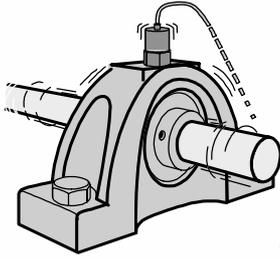
MDOF



“真實世界” 的反應



力量與振動



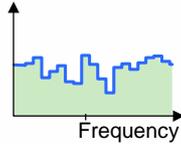
力量
輸入

+

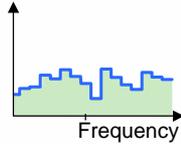
系統
響應
(Mobility)

=

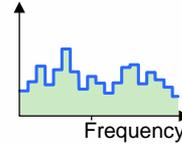
振動



+



=



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

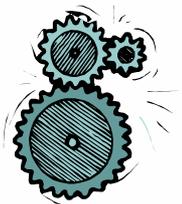
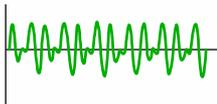
穩態訊號



非穩態訊號



穩定訊號



隨機訊號



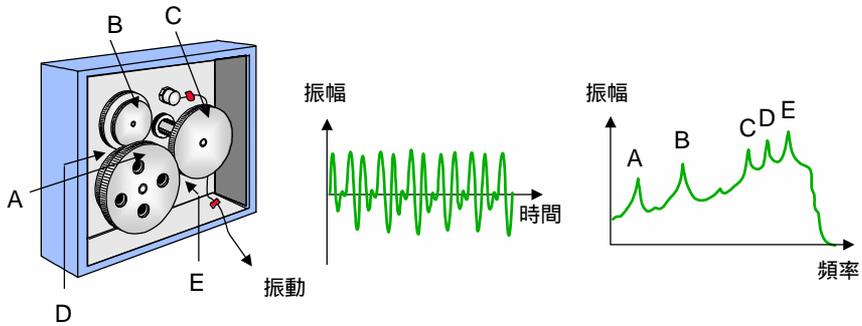
連續訊號



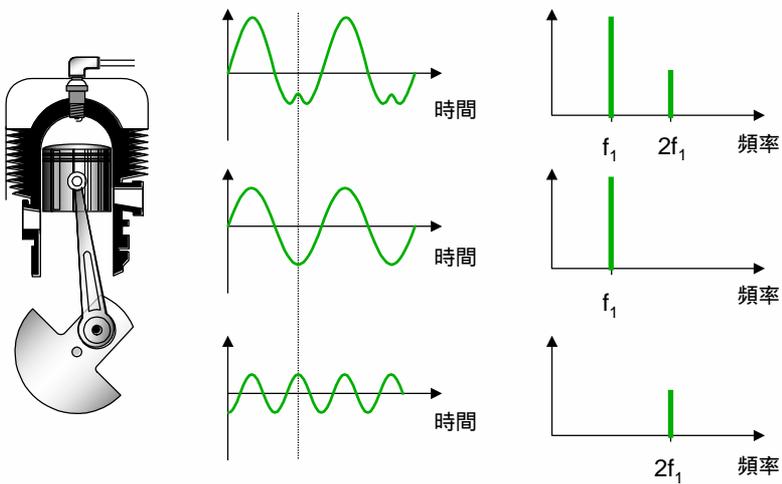
暫態訊號



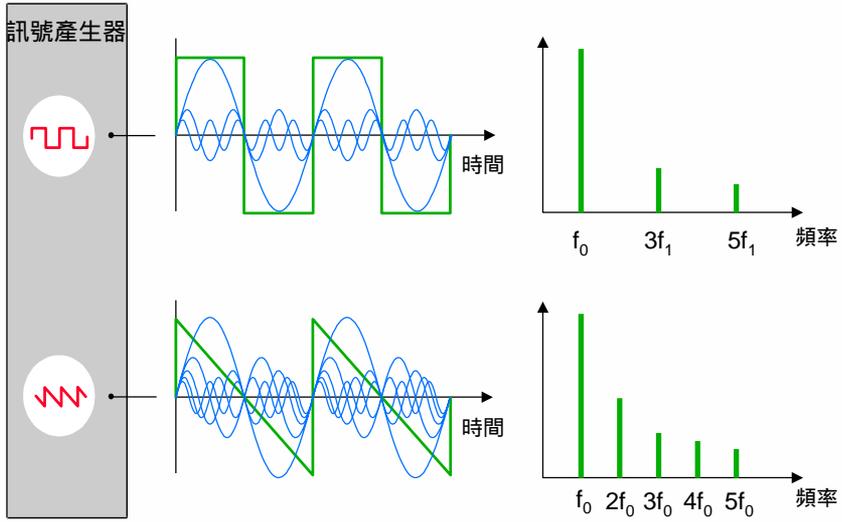
穩定的訊號



穩定訊號的組成



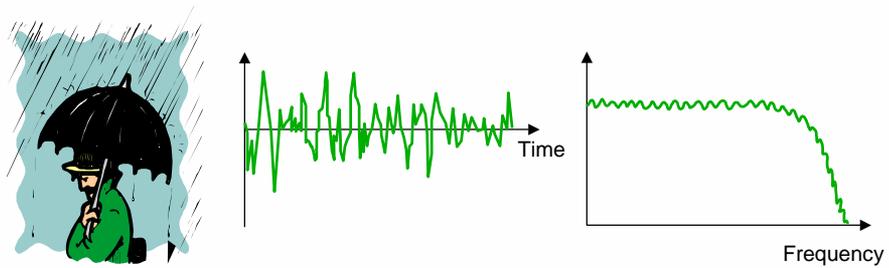
譜波之時頻關係



BA 7674-12, 21

Brüel & Kjær

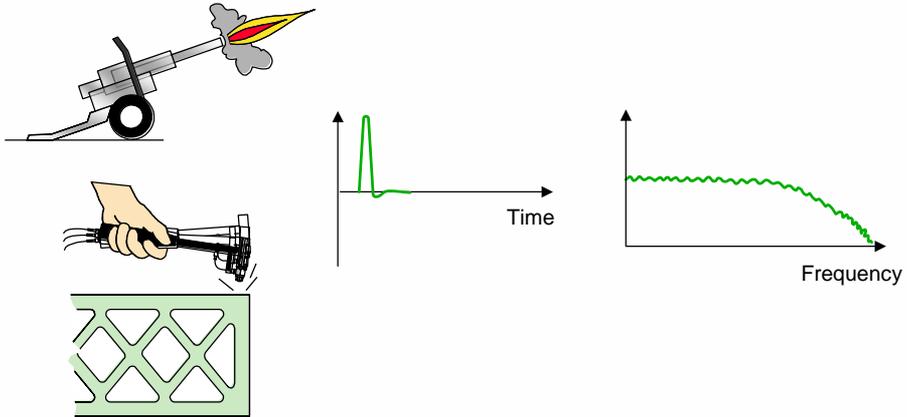
隨機訊號



BA 7674-12, 22

Brüel & Kjær

衝擊訊號



BA 7674-12_23

Brüel & Kjær 

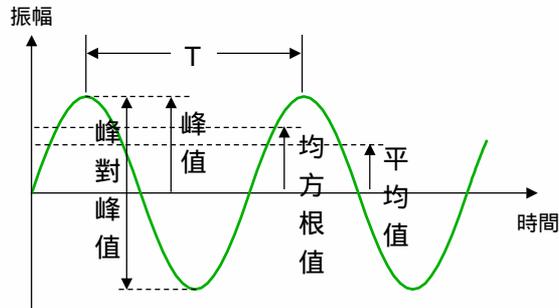
時域參數的選用

- 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)

BA 7674-12_24

Brüel & Kjær 

參數的意義

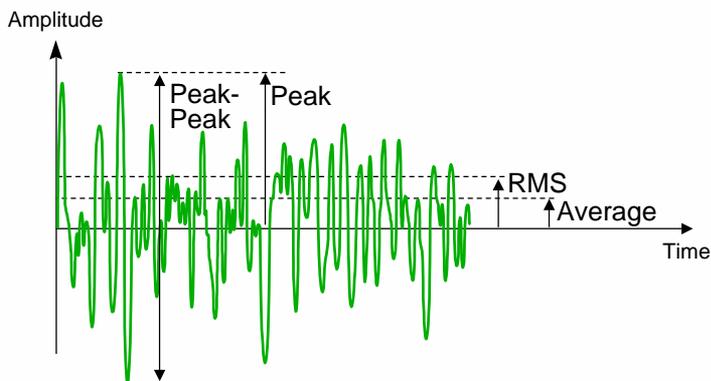


$$\text{均方根值} = \sqrt{\frac{1}{T} \int_0^T x^2(t) dt}$$

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

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

實際訊號之參數



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

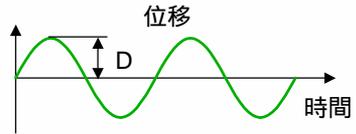
$$\text{平均值} = \frac{1}{T} \int_0^T |x(t)| dt$$

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

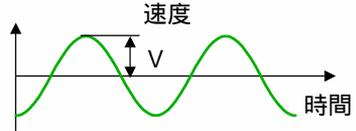
直線與震盪之移動



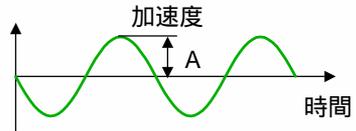
台北
35 公里



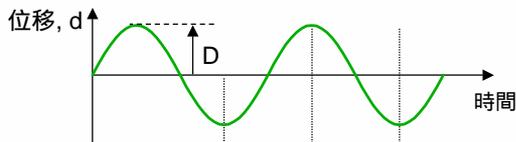
速限
60
公里/時



測試
0-60 公里/時
8.6秒

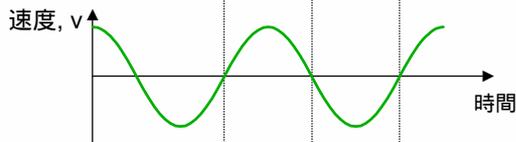


位移轉換至加速度之關係



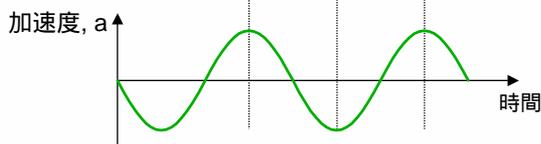
$$d = D \sin \omega t$$

$$d = D$$



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

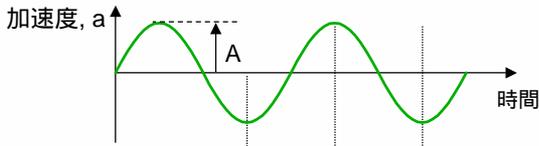
$$v = D\omega = D2\pi f$$



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

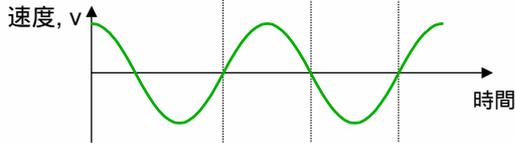
$$a = D\omega^2 = D4\pi^2 f^2$$

加速度轉換至位移之關係



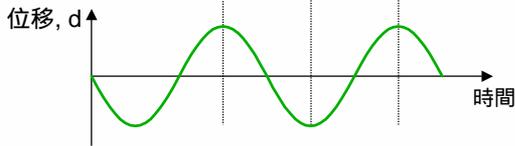
$$a = A \sin \omega t$$

$$a = A$$



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

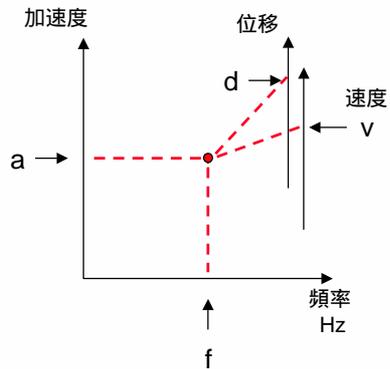
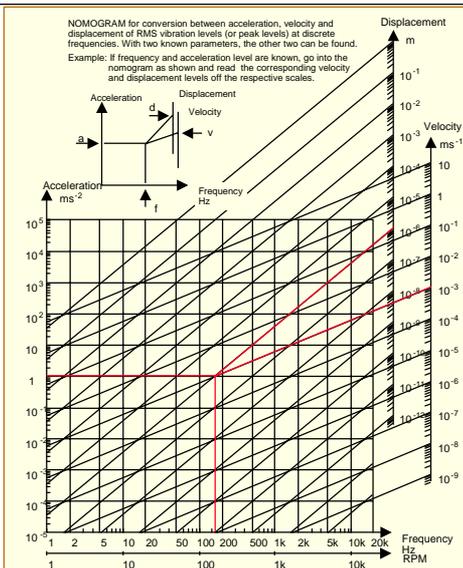
$$v = \frac{A}{\omega} = \frac{A}{2\pi f}$$



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

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

轉換關係表

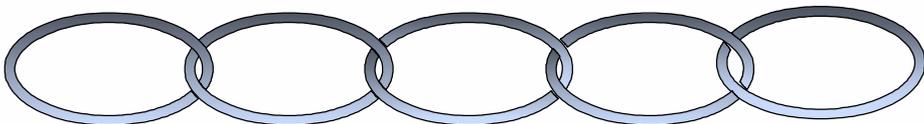
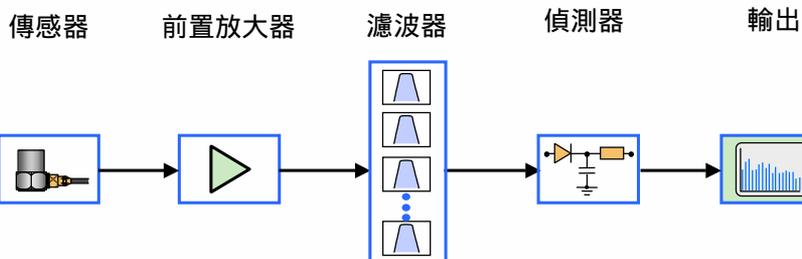


振動之單位

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

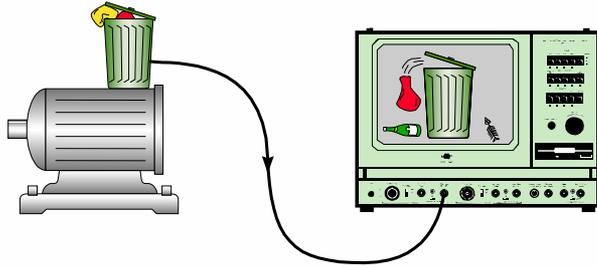
$$1g \equiv 9.80665 \text{ ms}^{-2}$$

訊號量測鏈



GIGO

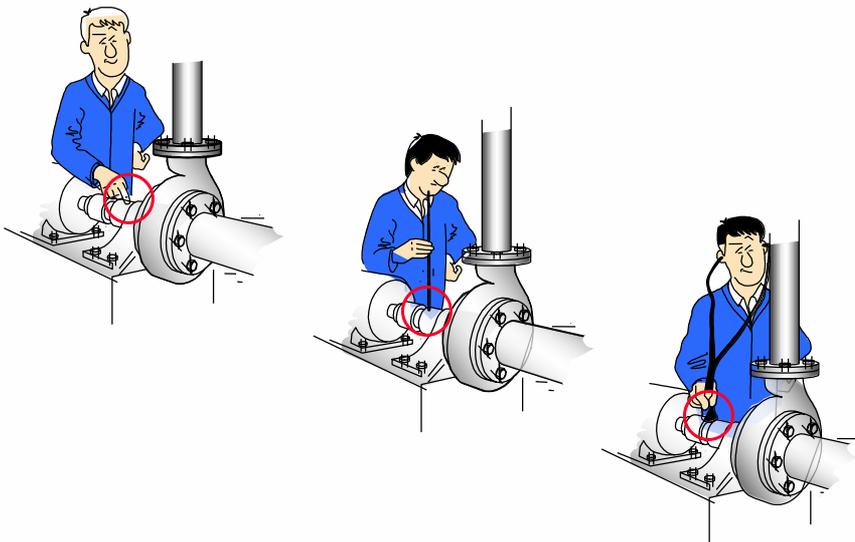
Garbage In = Garbage Out



BA 7674-12, 33 920046

Brüel & Kjær

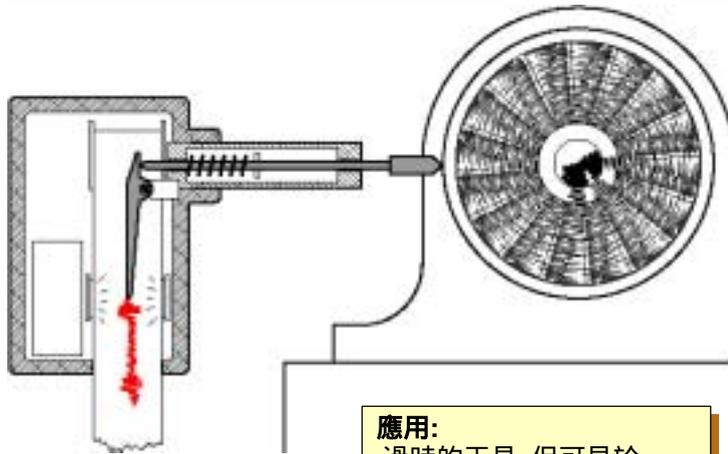
早期之振動量測



BA 7674-12, 34

Brüel & Kjær

機械槓桿

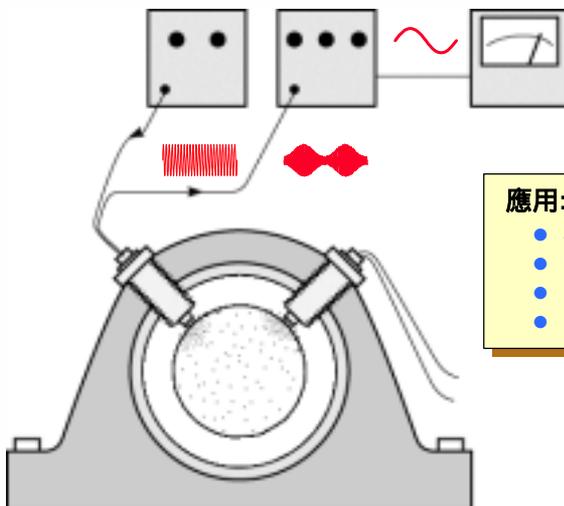


應用：
過時的工具，但可見於
一些水力電廠

BA 7674-12, 35

Brüel & Kjær

位移近接渦電流探頭

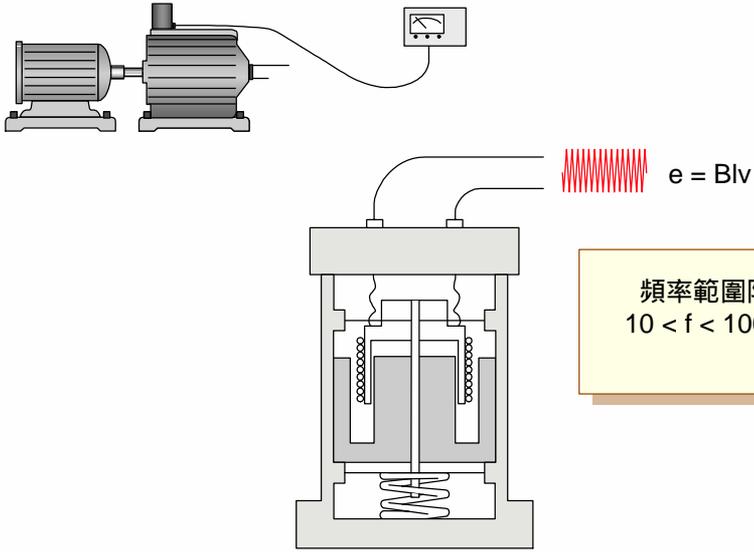


應用：
● 相對移動
● 軸偏心
● 油膜厚度
● 等等.

BA 7674-12, 36

Brüel & Kjær

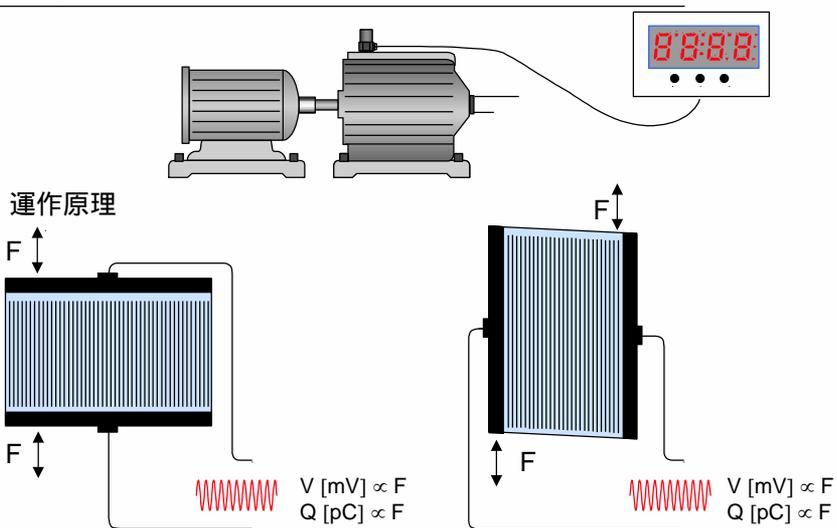
速度探頭



BA 7674-12, 3800289

Brüel & Kjær

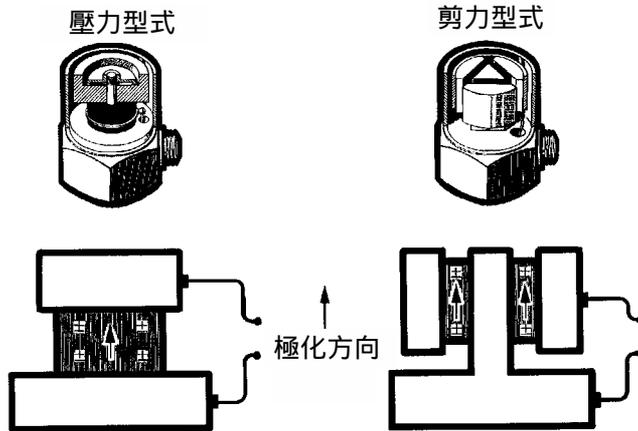
壓電加速規



BA 7674-12, 3800290/2

Brüel & Kjær

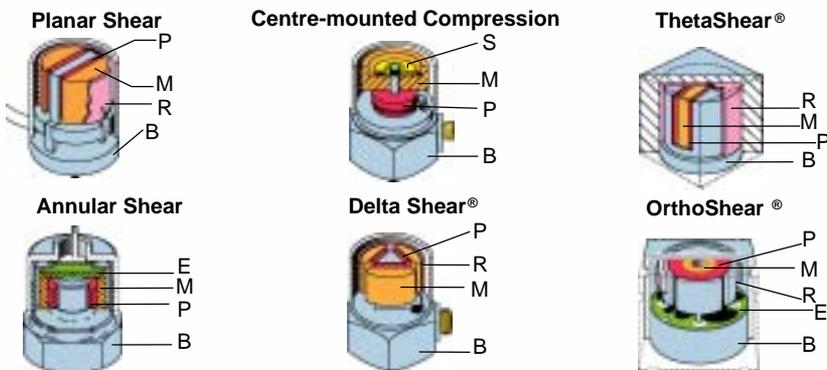
加速規之基本型式



BA 7674-12, 39

Brüel & Kjær

壓電加速規型式



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

BA 7674-12, 40 800284

Brüel & Kjær

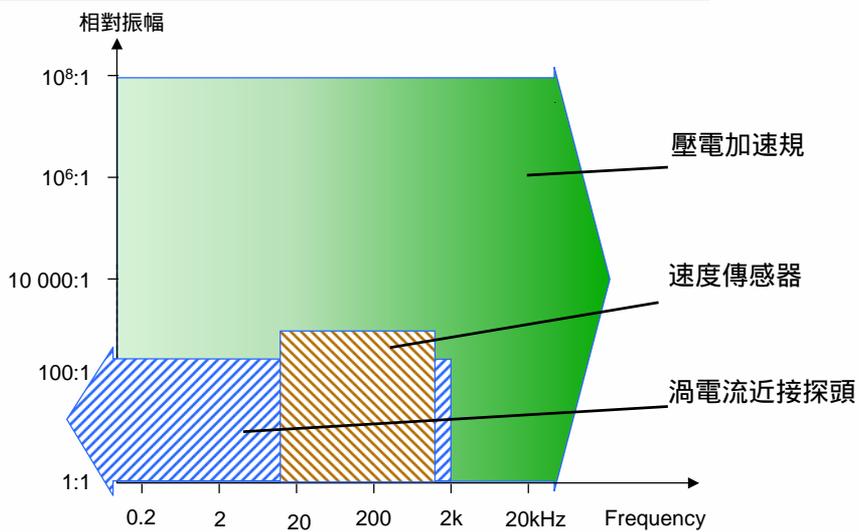
加速規之輸出訊號型式

- 電荷型
- 電壓型
- 電流型

BA 7674-12, 41

Brüel & Kjær 

各型振動探頭之量測範圍

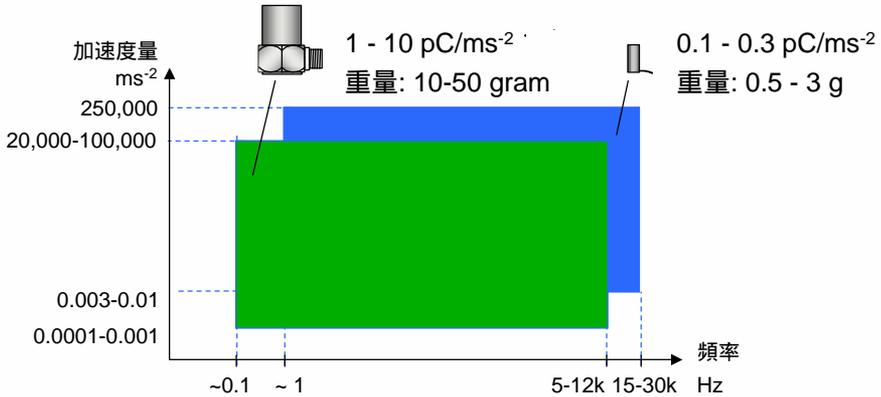


BA 7674-12, 42 930656

Brüel & Kjær 

加速規之選用

- 一般用途, 中等重量及感度
- 或
- 小、輕而高頻



BA 7674-12, 43 800299

Brüel & Kjær

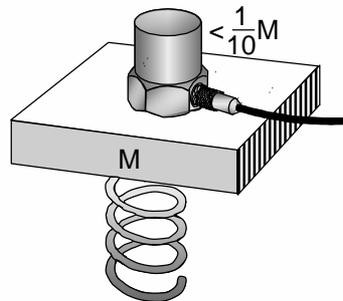
加速規之選用-質量效應

0,1 pC/ms^{-2}
0.65 g \Rightarrow $M > 7$ g

10 pC/ms^{-2}
54 g \Rightarrow $M > 600$ g

1000 pC/ms^{-2}
470 g \Rightarrow $M > 5$ kg

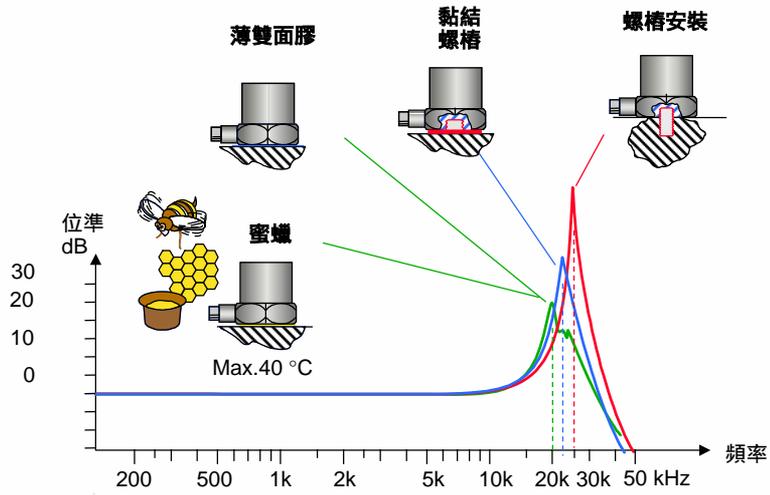
動態質量



BA 7674-12, 44 800304

Brüel & Kjær

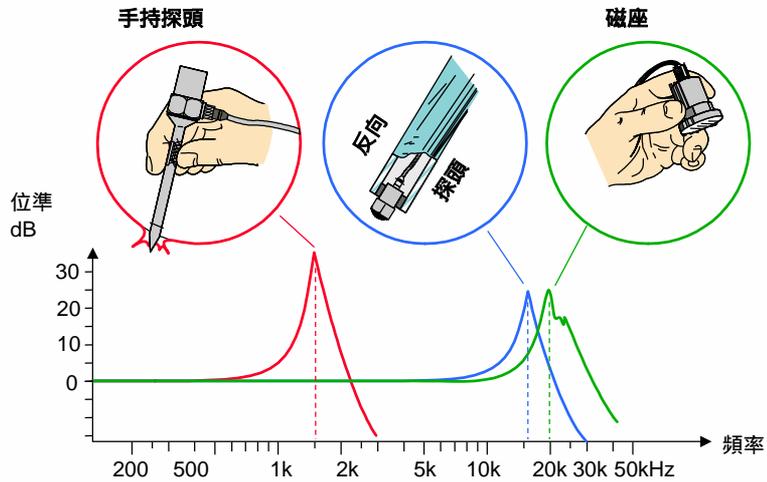
加速規之安裝(一)



BA 7674-12, 45 930616

Brüel & Kjær

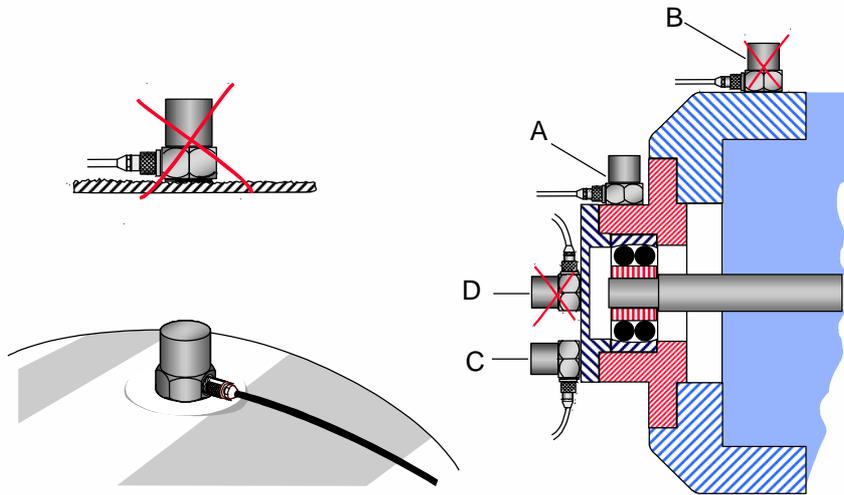
加速規之安裝(二)



BA 7674-12, 46 930617

Brüel & Kjær

位置之選擇



BA 7674-12, 47 800305

Brüel & Kjær 

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)

BA 7674-12, 48

Brüel & Kjær 

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