BETM 3583

Vibration Analysis and Monitoring

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2. Experimental modal analysis

Learning Outcome

1. Understand the procedure of vibration measurement
2. Understand the procedure for modal analysis experiment

Vibration testing / measurement

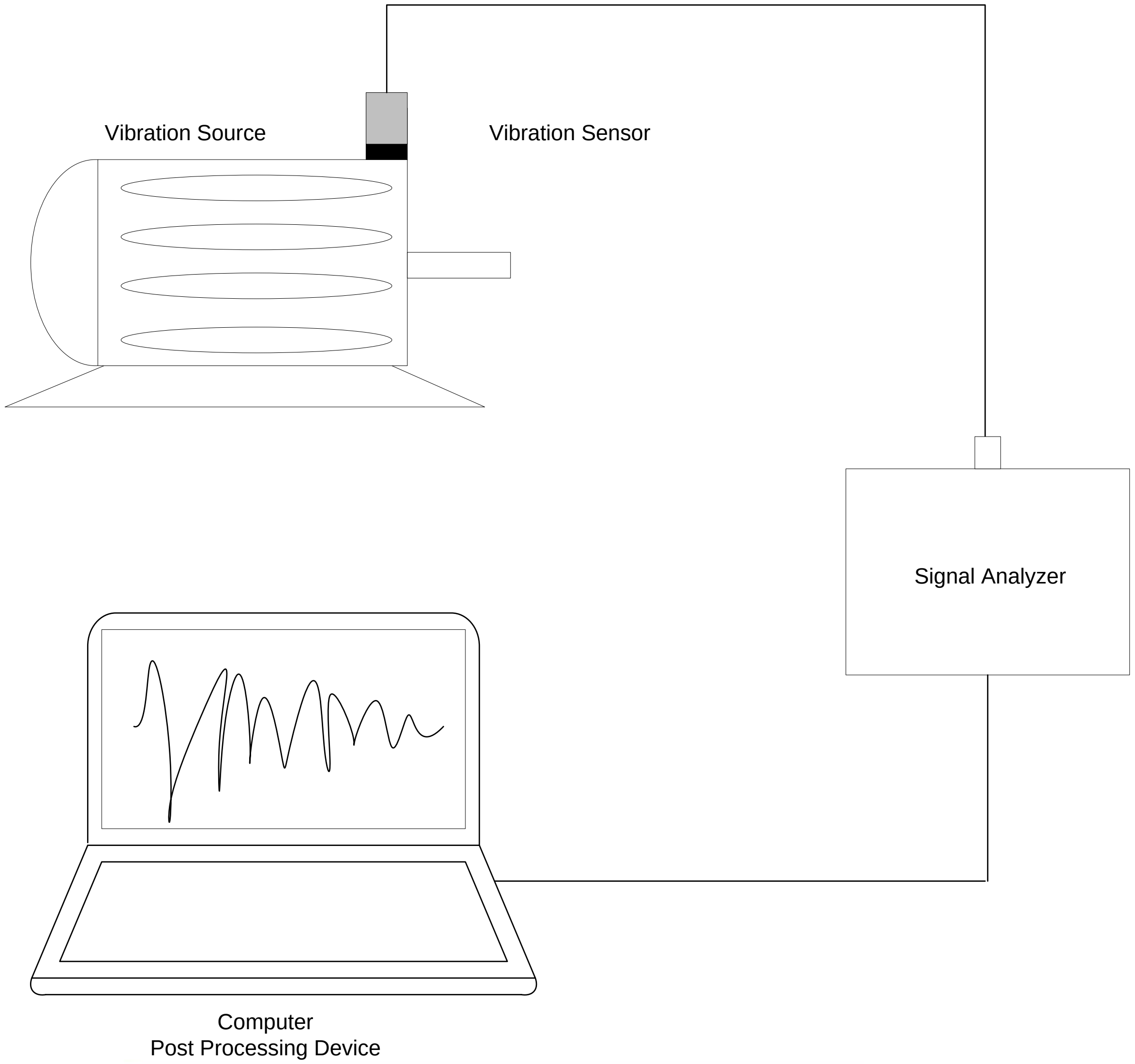
Measuring vibration is the most important aspect in the vibration analysis.

Without good data, good result can not be otained.

Good data comes from good measurement.

How to conduct a good measurement?

Vibration testing / measurement



Vibration testing / measurement

Making a good measurement involves :

- Selecting the correct transducer

  (Accelerometer/Velocity Trans./Displacement Probe)

- Selecting the model that suits the environment

  (Low / high temp?, Low/High speed?)

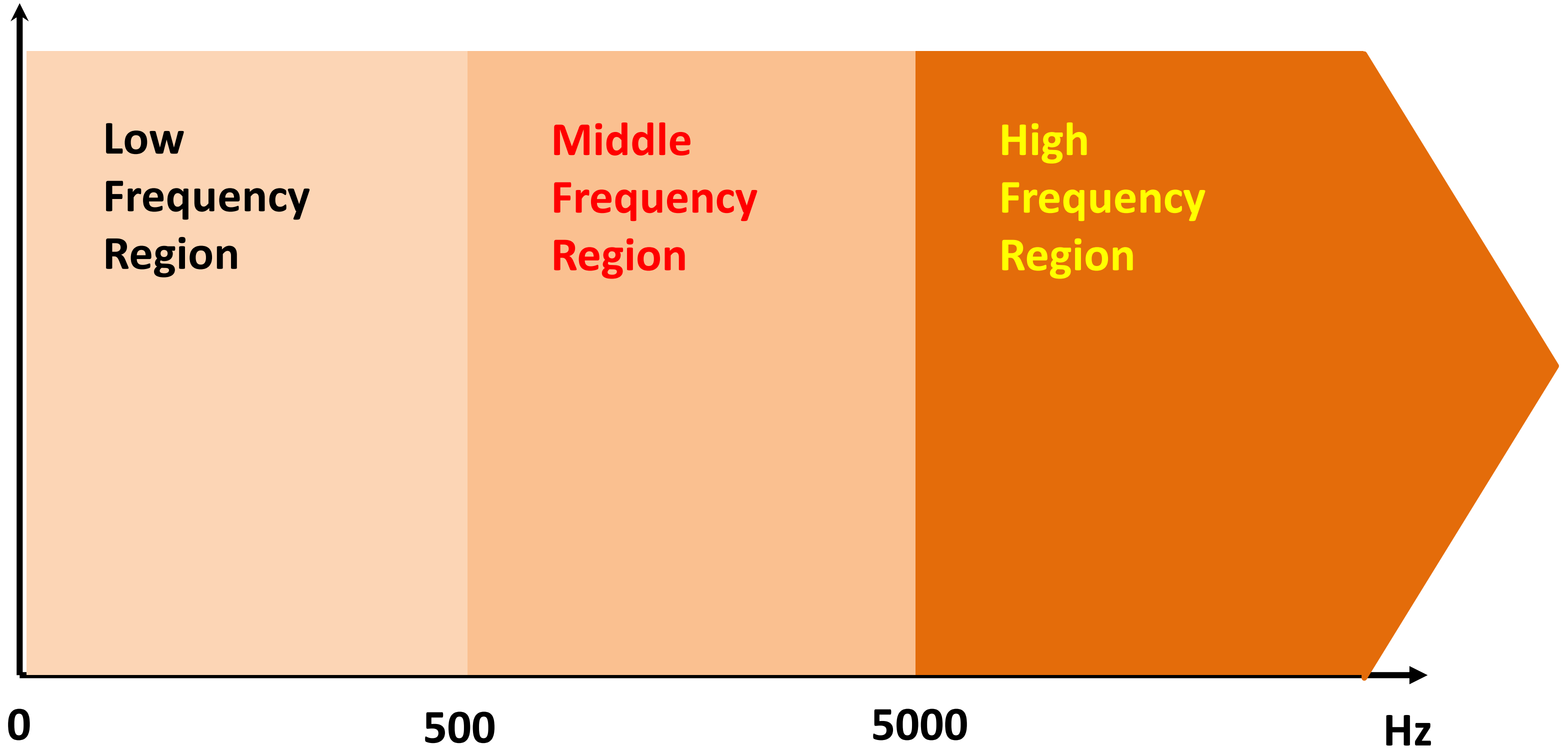
- Mounting the sensor correctly

  (Location? Position?)

Vibration testing / measurement

- Selecting the correct Transducer

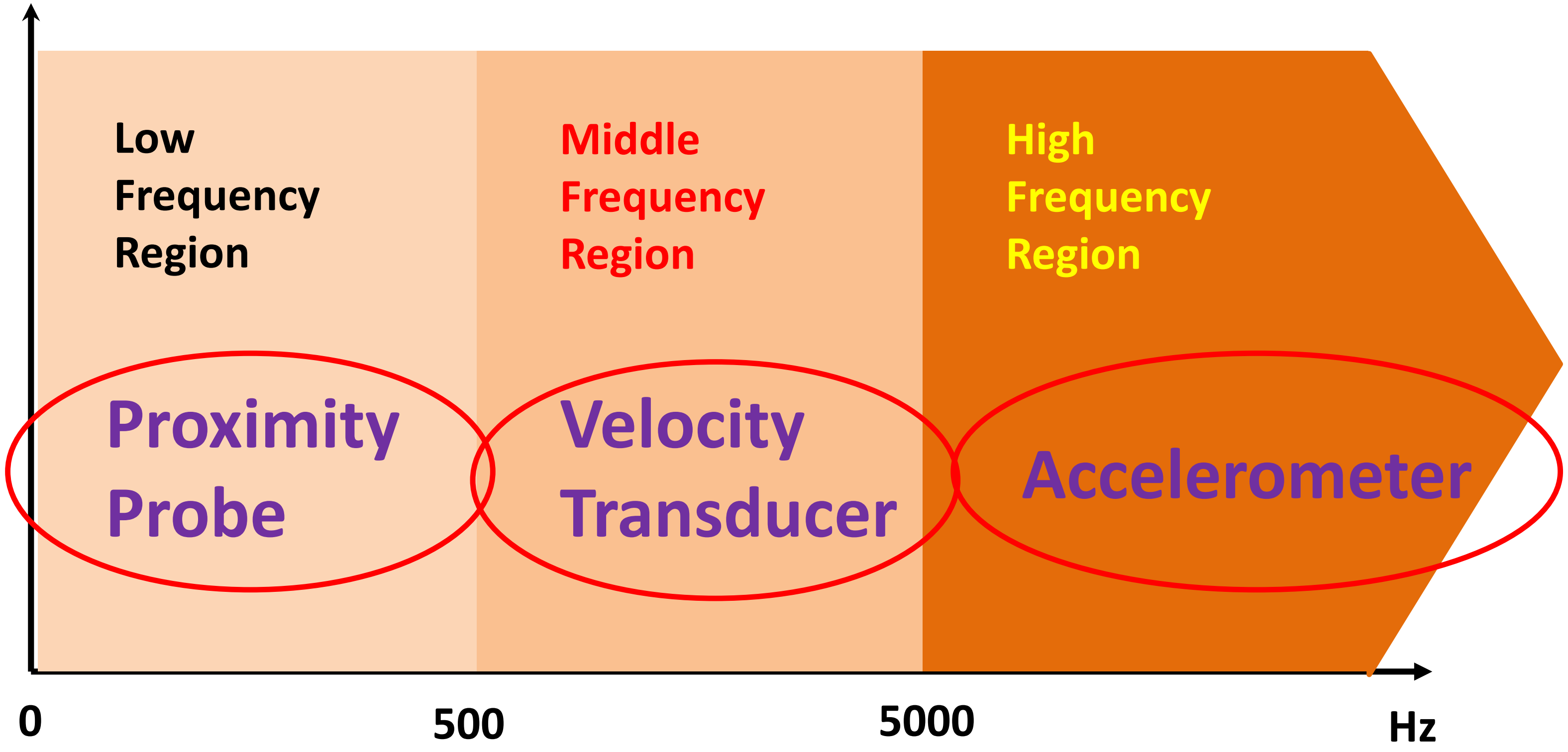
Based on the experts experience :



Vibration testing / measurement

- Selecting the correct Transducer

It is recommended by the experts :



Vibration testing / measurement

- Selecting the correct Transducer

However, using only Accelerometer will also capable to give all frequency range data, since :

$$\text{Acceleration} = \frac{d}{dt}\ (\text{Velocity}) = \frac{d^2}{dt^2}\ (\text{Displacement})$$

Vibration testing / measurement

- Selecting the correct Transducer

Commercial Accelerometer

(Bruel & Kjaer, *Accelerometers & Conditioning,* Product Catalogue, Bruel & Kjaer, 2009)

Vibration testing / measurement

- Selecting the model that suits the environment

Necessary :

1. Survey the machine :
   1. Speed and Load
   2. Bearing type
   3. Number or rotor bar / blade / impeller
   4. Sheave sizes
   5. Number of teeth of gear / sprockets

Vibration testing / measurement

- Selecting the model that suits the environment

Necessary :

2. Survey the Environment :
    1. Temperature
    2. Maximum acceleration level
    3. Moisture
    4. Noise level
    5. Space between machines
    6. Magnetic fields

Vibration testing / measurement

- Selecting the model that suits the environment

Technology	Temperature range
Piezoelectric – general	-55 ^{0}C to 260 ^{0}C
Piezoelectric – high temperature	-55 ^{0}C to 650 ^{0}C
Cryogenic piezoelectric	-184 ^{0}C to 177 ^{0}C
IEPE general type	-55 ^{0}C to 125 ^{0}C
IEPE high temperature	-55 ^{0}C to 175 ^{0}C
Piezoresistive	-55 ^{0}C to 66 ^{0}C

Vibration testing / measurement

- Mounting the sensor correctly

"Correct installation of the sensor is paramount to achieve good results"

Safe Access ! → no risk entangled, burned leaning over moving or rotating parts

Good mechanical transmission path between the source and sensor

Vibration testing / measurement

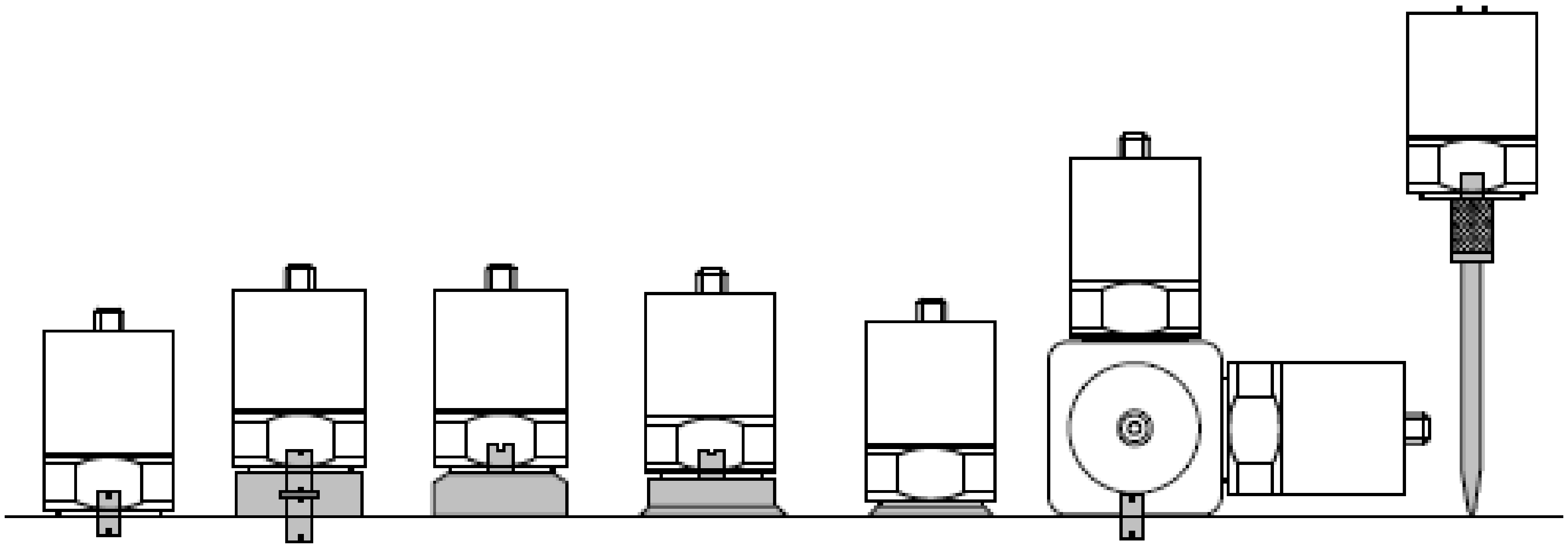
- Mounting the sensor correctly

Mounting type :

1. **Stud / Flange Type**
2. **Magnetic Type**
3. **Adhesive**
4. **Probe**

Vibration testing / measurement

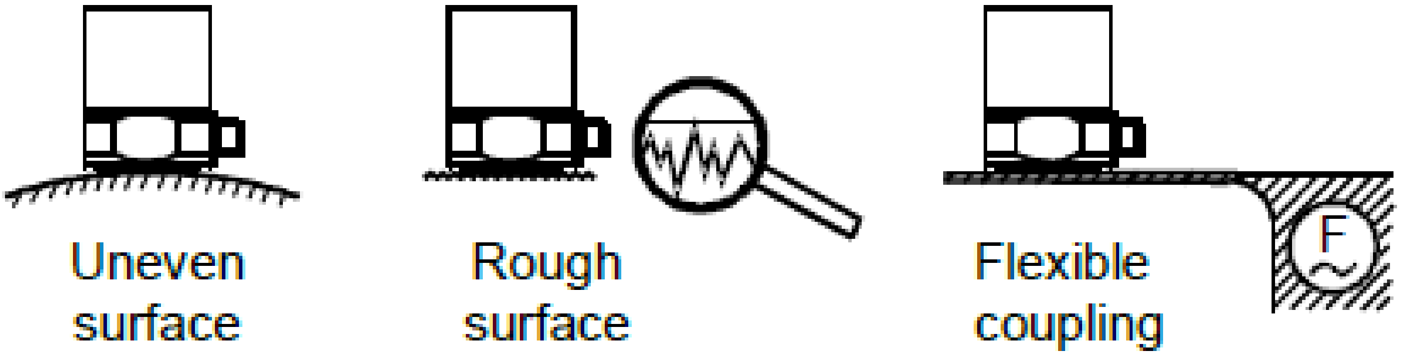
- Mounting the sensor correctly



(Weber, M. *Piezoelectric Accelerometers, Theory and Application*, Metra Mess und Frequenztechnik in Radebeul e.K., 2012)

Vibration testing / measurement

- Typical mounting errors



(Weber, M. *Piezoelectric Accelerometers, Theory and Application*, Metra Mess und Frequenztechnik in Radebeul e.K., 2012)

Experimental Modal Analysis

Experimental Modal Analysis

Experimental Modal Analysis

- Modal analysis means a study of the dynamic character of a system which is determined independently from the loads applied and the response of the system
- Modes (also known as resonances are inherent properties of a structure.
- Modes or resonances are determined by the properties of the material (i.e. mass, stiffness, and damping properties), and also boundary conditions of the system.

Experimental Modal Analysis

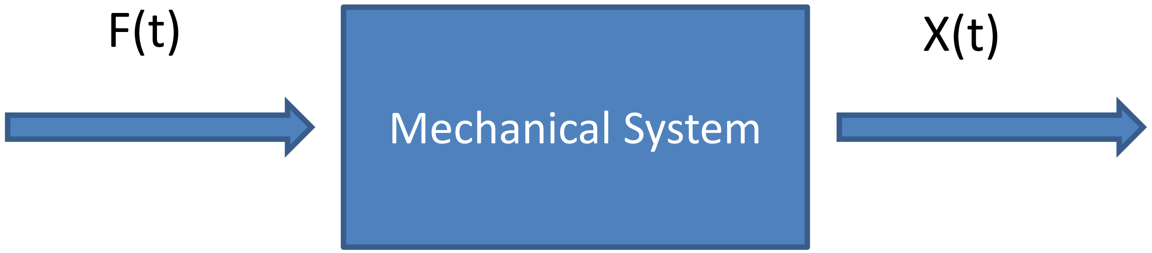
- Recently, impact testing (also known as bump testing) has been widely spread and become a fast and economical ways to find the modes of vibration of a machine.

- Impact testing involves :
  - Making FRF Measurement
  - Modal Ecitation Techniques
  - Modal Parameter Estimation

Experimental Modal Analysis

FRF Measurement

The FRF describes the input-output relation on a mechanical system (between two points) as a function of frequency, as shown as



$$F(\omega) \times H(\omega) = X(\omega)$$

Experimental Modal Analysis

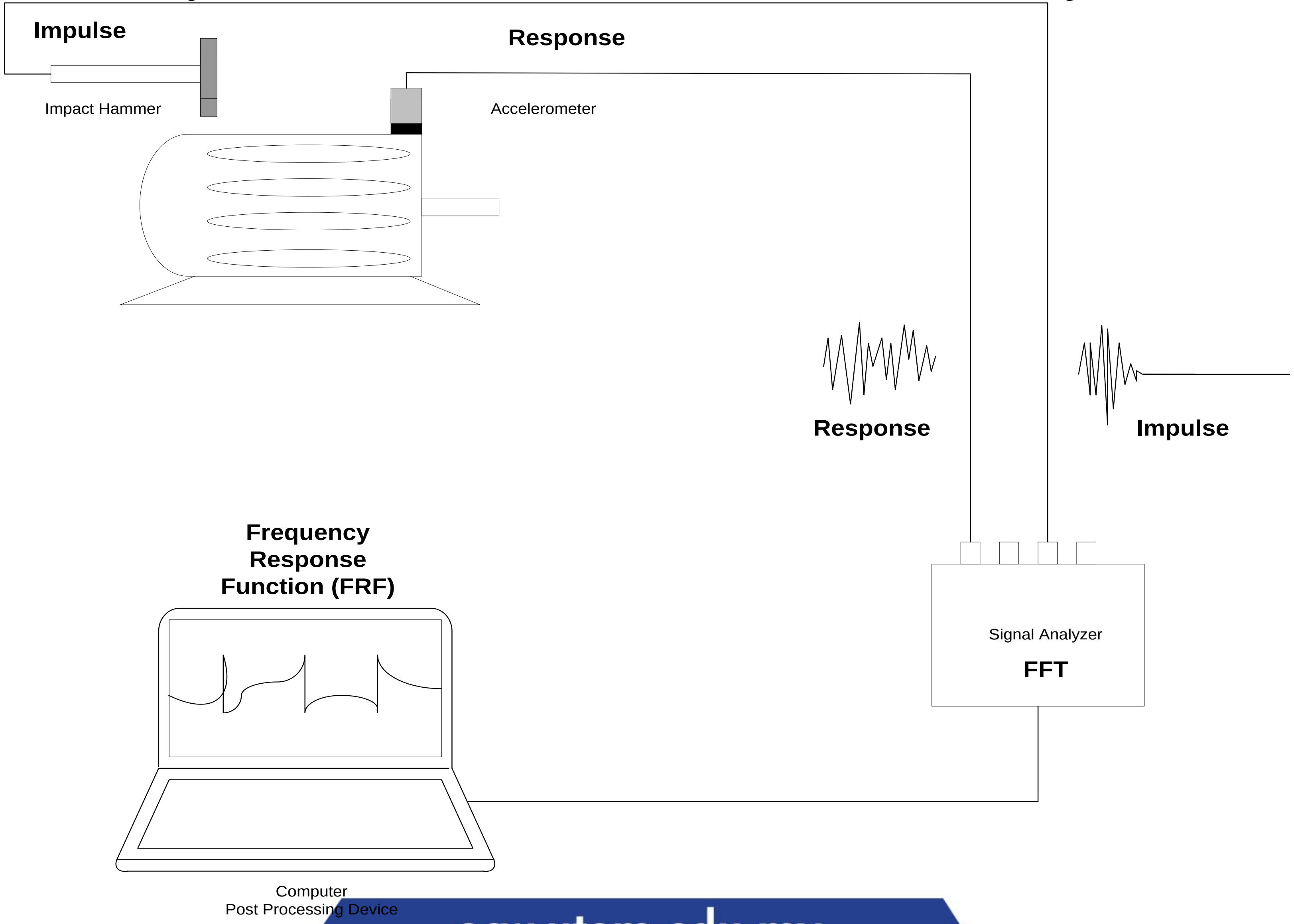
- FRF is defined as the ratio between an output response X(ω) to the input force F(ω)
- Other names of FRF :
  - Compliance = (displacement / force)
  - Mobility = (velocity / force)
  - Inertance / receptance = (acceleration / force)
  - Dynamic stiffness = (1/compliance)
  - Impedance = (1/mobility)
  - Dynamic mass = (1/inertance)

Experimental Modal Analysis

EXCITING MODE WITH IMPACT TESTING

1. Impact Hammer
   to measure the input force using a load cell on its head.
2. Accelerometer
   to measure the responce acceleration at fixed point & direction
3. FFT Analyzer
   to compute FRFs
4. Post processing modal software
   for identifying modal parameters and displaying the mode shape in animation.

Experimental Modal Analysis



References

- Bruel & Kjaer, *Accelerometers & Conditioning,* Product Catalogue, Bruel & Kjaer, 2009
- Weber, M. *Piezoelectric Accelerometers, Theory and Application*, Metra Mess und Frequenztechnik in Radebeul e.K., 2012

Thank you

Q n A