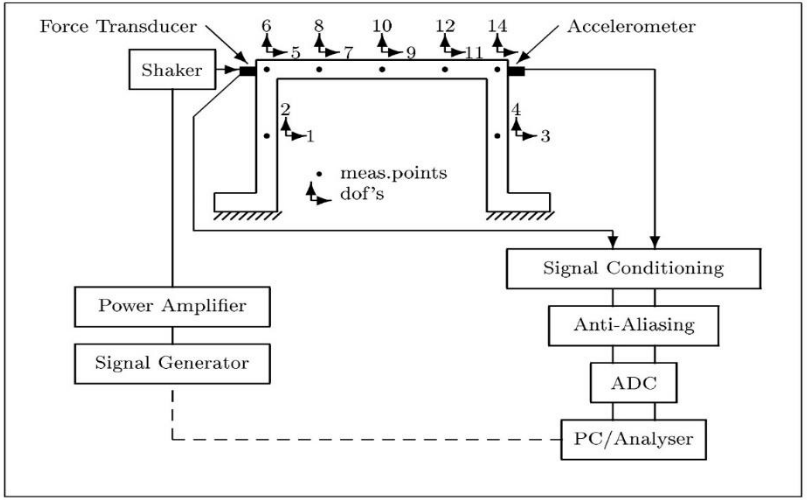

6. EMA basic approach

Structural Dynamics part of 4DM00

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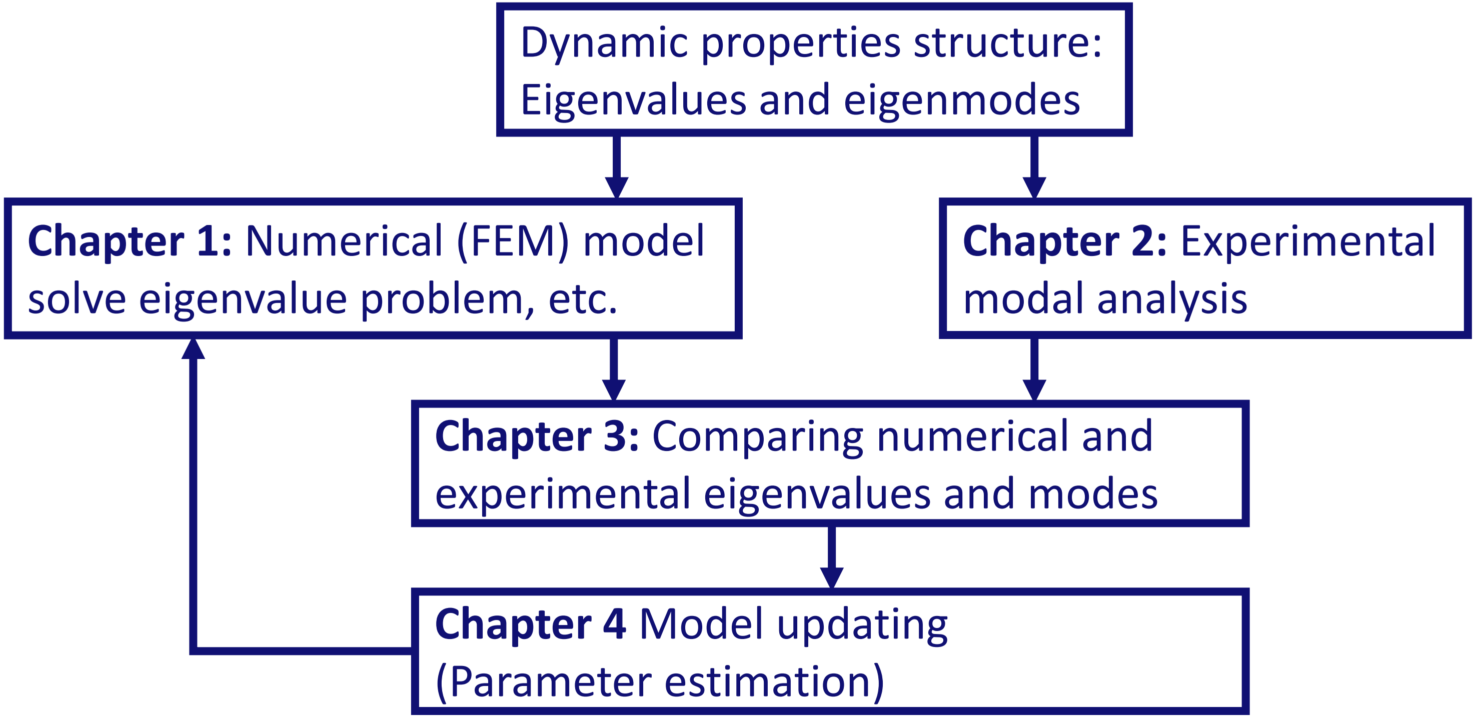
Structure of course (SD part)



Experimental Modal Analysis (EMA)

More or less standard analysis tool for:

- experimental identification of the dynamic behaviour of complex mechanical structures
- experimental derivation of eigenvalues and eigenmodes

Is applied on large scale in practice

Basic assumption: dynamic system is linear

Important to understand the possible error sources in the experimental data

Experimental Modal Analysis in 5 steps

1 Experimental data

Measure time signals

Excitation: $x(t_k)$
Response: $y(t_k)$

2 Fourier Transformation

$X(f_n), Y(f_n)$ (DFT/FFT)

Signal leakage, Aliasing

3 Random Processes

$$S_{xx} = \frac{1}{NT} \sum_{k=1}^{N} \bar{X}_k X_k$$

$$S_{xy} = \frac{1}{NT} \sum_{k=1}^{N} \bar{X}_k Y_k$$

4 System Identification

$$Y = HX$$
$$H_1 = S_{xy}/S_{xx}$$
$$H_2 = S_{yy}/S_{yx}$$

5 Modal Parameter Fit

$H's \rightarrow \lambda's, u's$

$\lambda's$: eigenvalues
$u's$: eigenmodes

Optimal sensor locations?

Basic approach

How to collect suitable experimental data?

Items to discuss:

- Boundary of the system/structure
- Excitation of the structure at 1 or more points and directions
- Measuring the response of the structure,
  in general in a (large) number of measurement points
- Data acquisition (conditioning and digitizing of signals)

Boundary of the structure

2 main situations:

1. Structure is part of larger system or connected to fixed world
   e.g.: oil exploration platform in North Sea
   Environment (water, bottom of the sea) influences the dynamic behaviour

2. Structure is isolated from its environment (ideal lab situation)
   e.g.: car frame which hangs on soft springs
   Environment hardly influences the dynamic behaviour

Sometimes also in the lab it is necessary to apply certain boundary conditions. Delicate task!

- clamping is never infinitely stiff: flexibility is introduced
- additional stresses may be introduced, which influence dynamic behaviour!
  example: clamping of a thin flat square plate on 4 sides

Excitation

Two main principles:

1. Shaker connected to structure via force transducer
2. Modal hammer excitation with force transducer heads made of different materials

Other special methods (heavy structures):

- Introduce a step load by cutting the cable between:
  - an off-shore structure and a pulling tug-boat
  - a bridge and a hanging large weight
- Use multiple shaker excitation to introduce sufficient vibrational energy in an airplane

Shaker excitation

Types of shakers

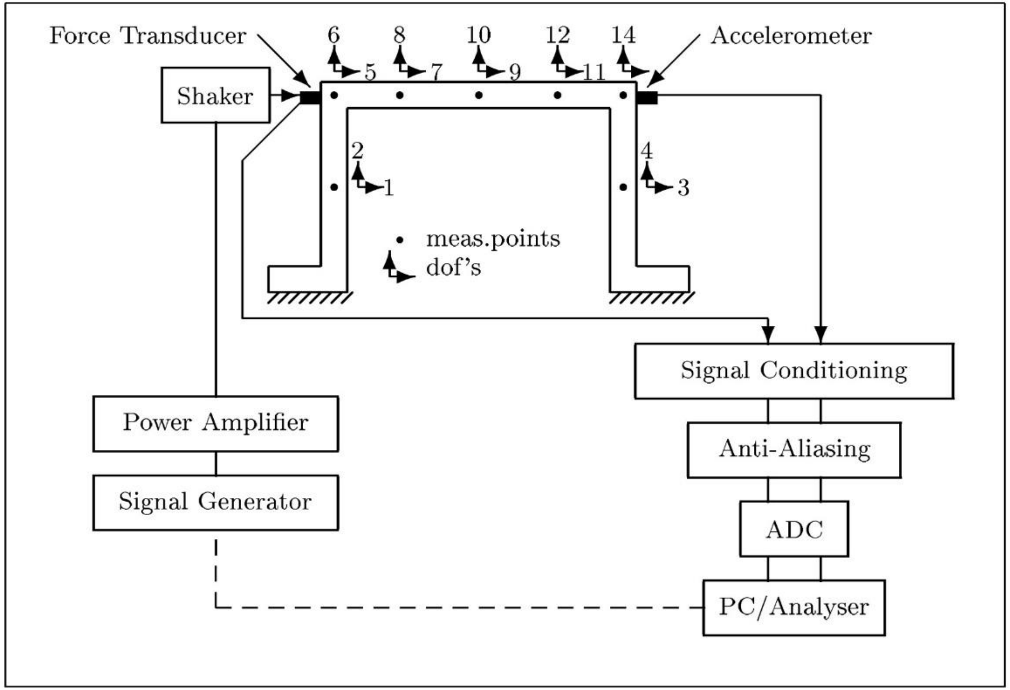
- electro-magnetical shakers
- hydraulical shakers (high force level, frequency content limited)

Signals sent to the shaker:

- (white) noise
- frequency sine sweep

In general: frequency content of these signals not equal to frequency content of excitation force because of shaker dynamics
Solution: controller, adjusts shaker input to realise desired output (normally not necessary)
Usually sufficient: global spectrum + accurate force measurement

Example: EMA using shaker excitation



Shaker excitation

Pay careful attention to the connection of shaker to the structure

Connection (called stinger) should be:

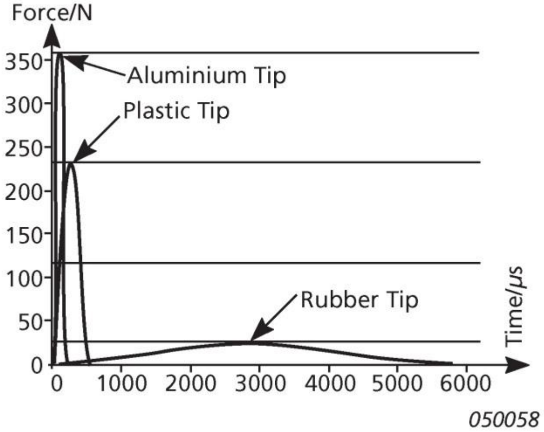
1. stiff in excitation direction
2. soft in other directions

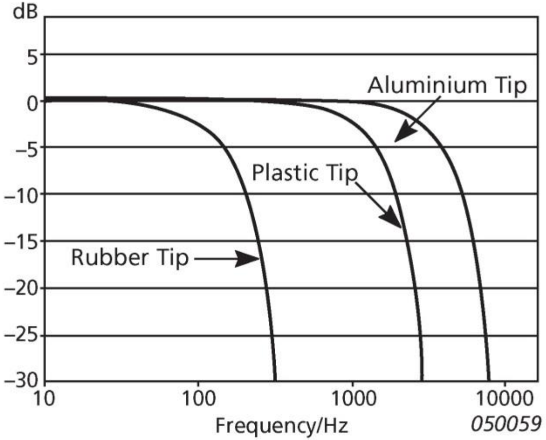
Avoid misalignment

Modal hammer (impact) excitation

In principle: signal is Dirac function (all freq. with uniform amplitude)

In practice: bandwidth will be limited
influenced by material of hammer head (rubber, plastic, aluminium etc) and mass of hammer





Modal hammer (impact) excitation

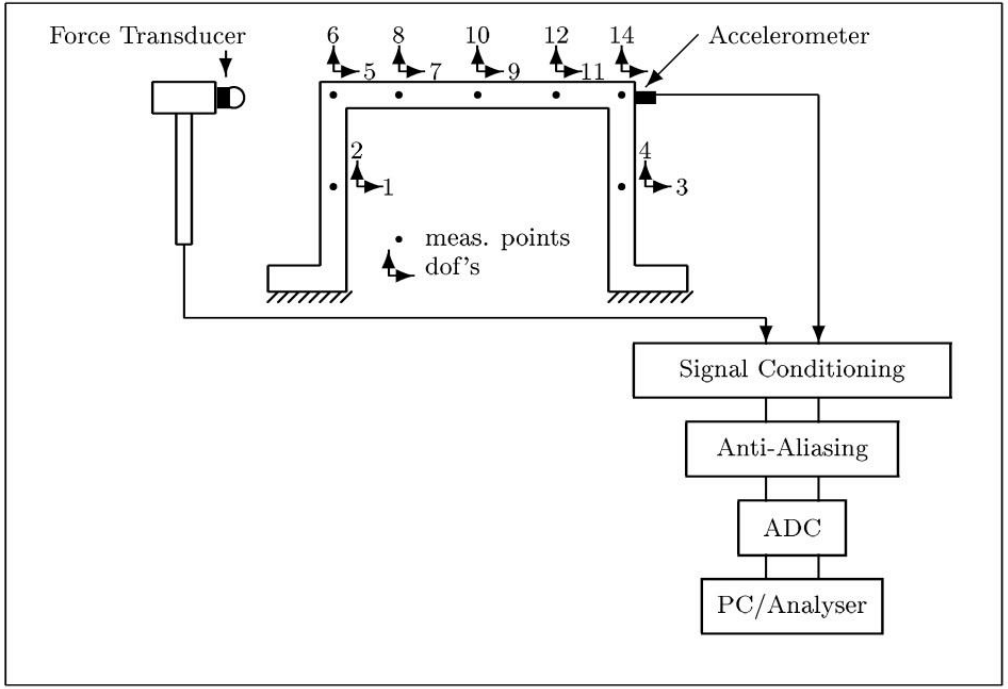
Advantages:

- practical simplicity
- doing a large amount of measurements in a short time

Disadvantages:

- may be difficult to get enough energy in structure.
  can lead to damage or introduction of non-linear effects
- Repeating the experiment may be difficult.
  hitting at the same place in the same direction (averaging)

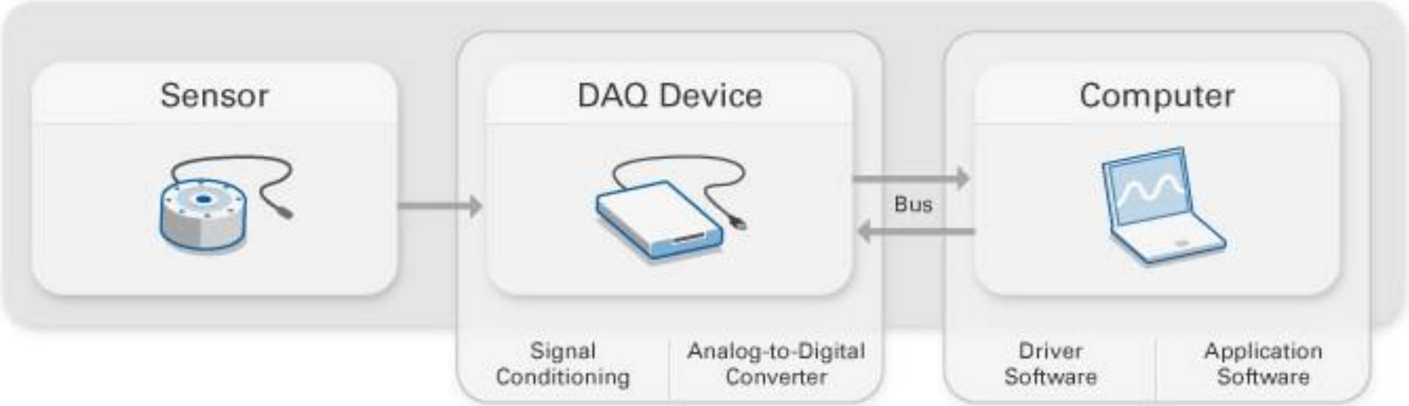
Example: EMA using Hammer excitation



Response measurement

1. Accelerometers:
   Advantages: simple, cheap, simultaneous measurements (saves time)
   Disadvantage:accelerometer mass causes a frequency shift in light structures
2. Laser-Doppler vibrometers (velocity sensors):
   Advantage: non-contact measurement, no extra mass, measurement of low frequencies
   Disadvantage:rather expensive, measurement location changes
3. LVDT (Linear Variable Differential Transformer):
   (Relative) displacement measurement
4. Strain-gauges

Data Acquisition (DAQ)



Analogue signals from sensors are fed in multi-channel DAQ interface.

In the DAQ, analogue signals are:

- conditioned (filtered to avoid aliasing, amplified/attenuated, etc)
- and subsequently digitized (ADC: Analogue Digital Converter)

The digital signals can then be further processed in a computer.