Interlaboratory comparison
for mechanical vibration testing

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FHI PLATFORM OMGEVINGSTECHNOLOGIE

Overview

- ISO17025 requirement
- First round
- Second round
- Test sample analysis and uncertainty budget
- Test lab comparison
- Conclusions and To Do

ISO17025 Requirement

§5.9: Assuring the quality of test and calibration results

- Use of quality control procedures for monitoring the validity of test/ calibrations
- Monitoring may include, but not limited to
  - a) Use of certified materials
  - b) Participation in inter-laboratory comparisons/ proficiency testing
  - c) Replicate testing
  - d) Re-testing / re-calibration of retained items
  - e) Correlation of results for different characteristics

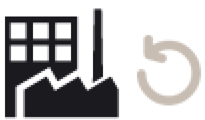
Third line control

ISO17025 Requirement

Proficiency testing: comparative testing in order to assure quality of test results by application of test methods

Intra-laboratory comparison: 1st and 2nd line control

Repeatability



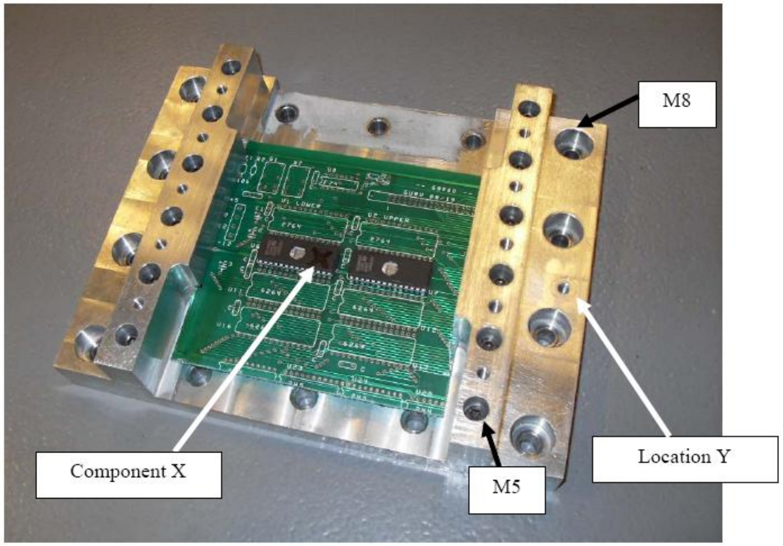
Interlaboratory comparison: 3rd line control

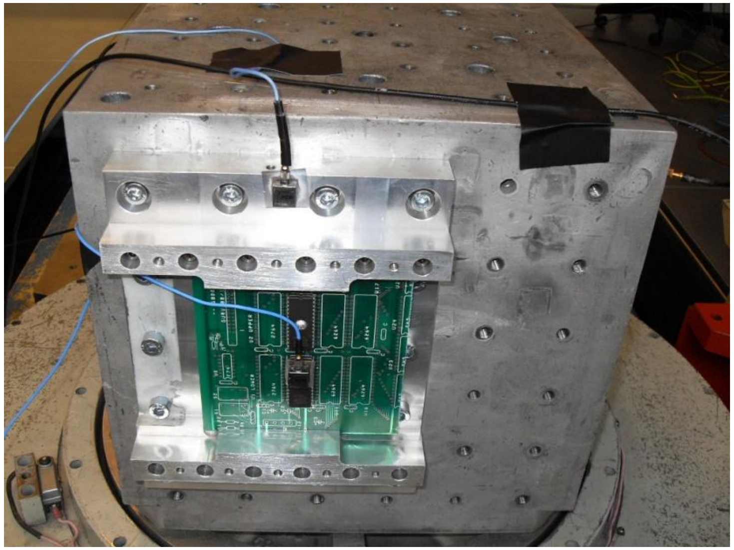
Reproducibility

➡ No substitute for calibration !

First round

- Sample:





Sample showed to be too unstable and not homogeneous

Second round

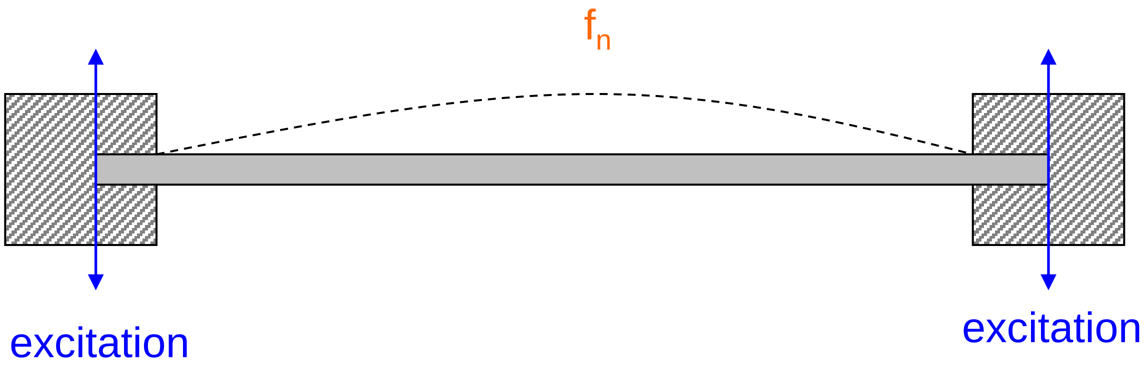
- Sample choice:

    Needs to be:
    1) Representative
    2) Stable over (test)time
    3) Homogeneous (-> identical sample for each lab)
    4) (not too) elementary

Second round

- Sample description and measurement criteria:

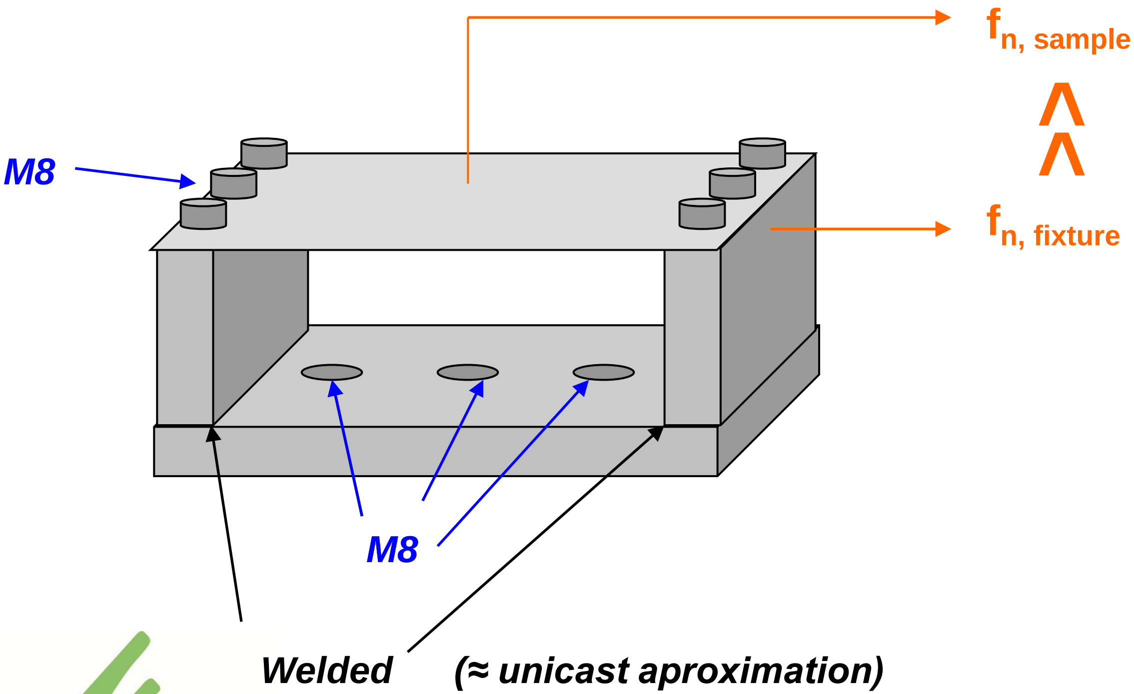
Considering a fixed-fixed beam structure with uniform mass distribution as SDoF system, determine f_n by application of uniaxial forced vibration

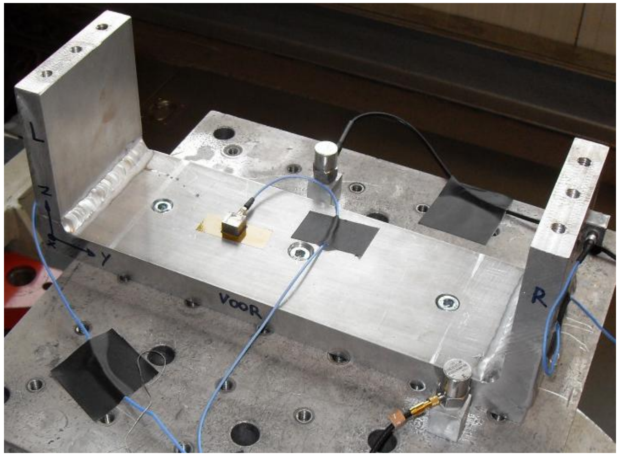


Second round

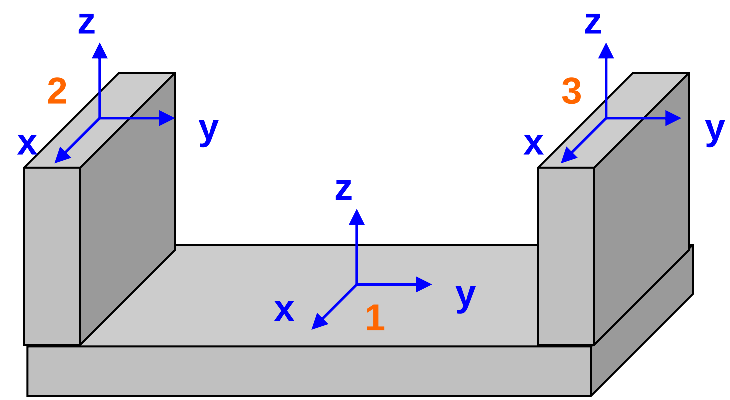
- Sample design:

  Need for rigid reference structure near fixed ends (SDoF !)

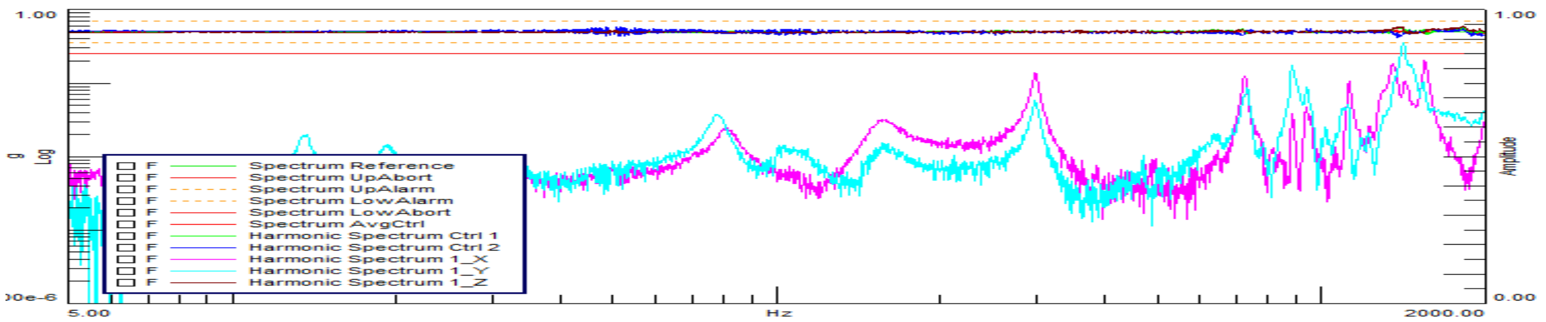




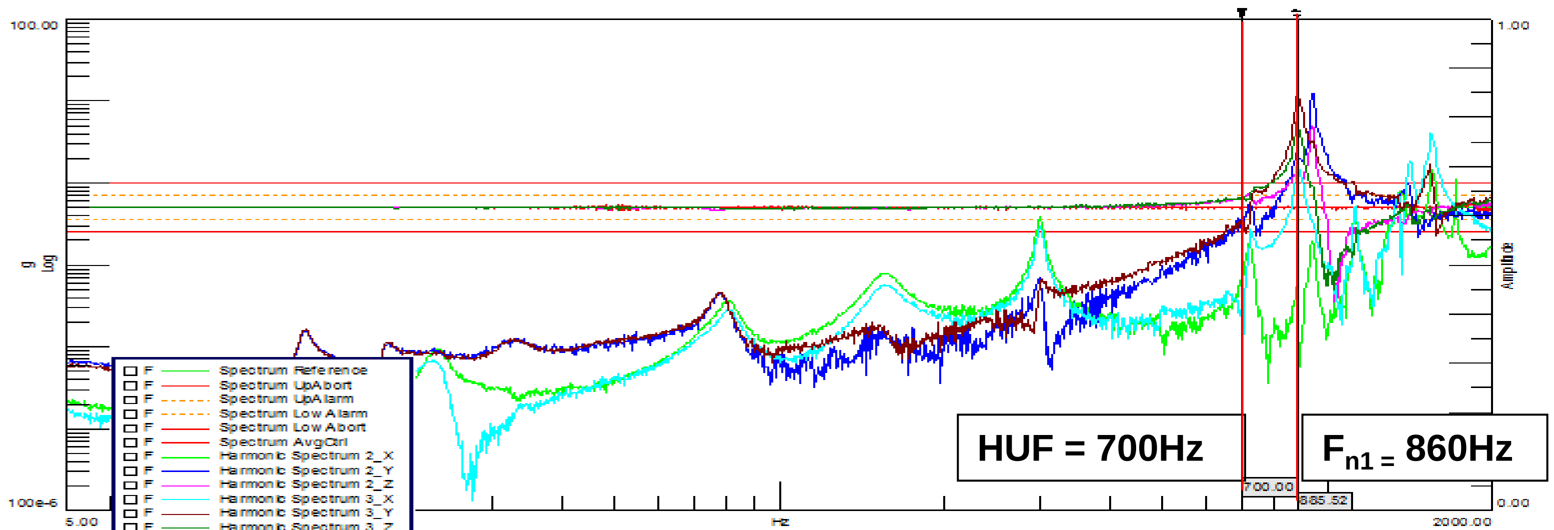
Fixture analysis



- Triax 1,2,3 with forced excitation in Z-direction
- No resonance for acc1



- First recorded resonance (Z) for acc1 and acc2 at 860Hz. Fixture ok up to **700Hz**

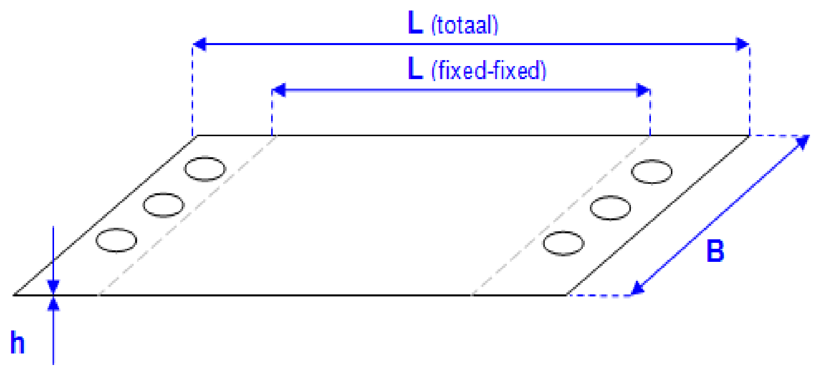


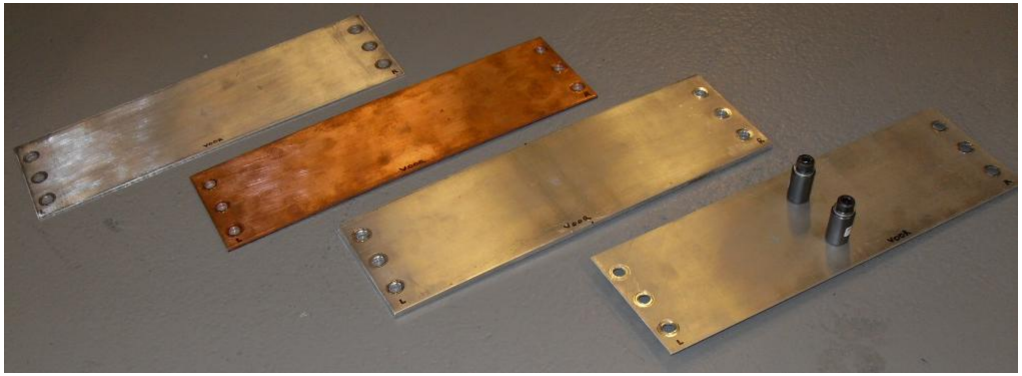
Test samples

- Different materials and dimensions ($L_{(fixed\text{-}fixed)}$: 300mm; B: 100mm)
  - Thin Al plate (h: 1,5mm)
  - Thick Cu plate (h: 3mm)
  - Thick Al plate (h: 5mm)
  - Thin Al with central mass (h: 1,5mm)

ΔE, Δh (Thin Al plate vs. Thick Cu plate)

Δh (Thin Al plate vs. Thick Al plate)

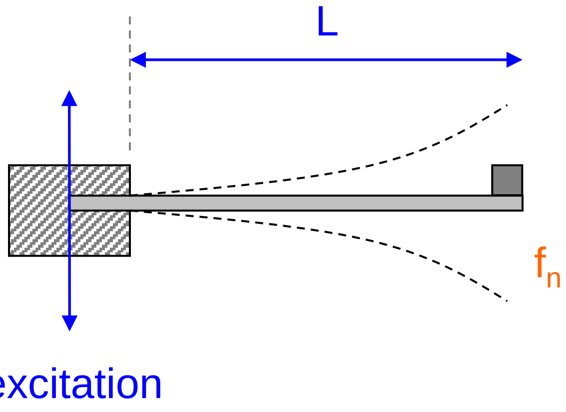




Test sample analysis - by calculation

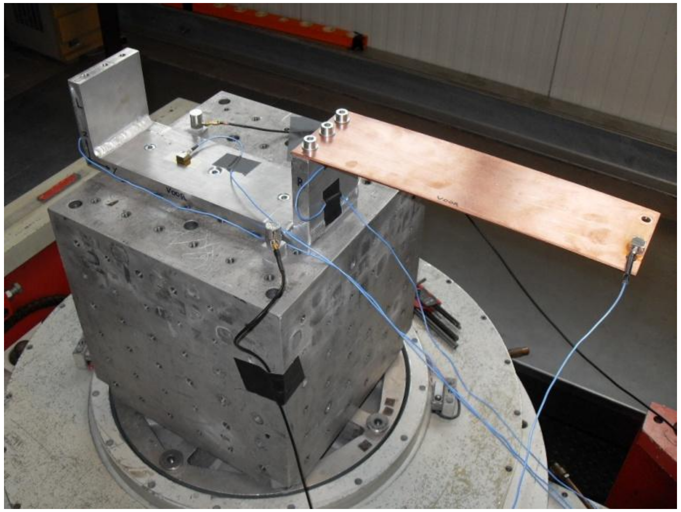
- *Step 1*: Young's modulus by resonance measurement of cantilever
  - Cantilever setup for each plate type
  - Measurement of f_n
  - $$E = \left[2\pi f_n . \frac{L^2}{3.5156}\right]^2 . \left[\frac{0{,}2235.(m_{sample}/L) + m_{accel}}{I}\right]$$

    with: $I = \frac{1}{12} B h^3$



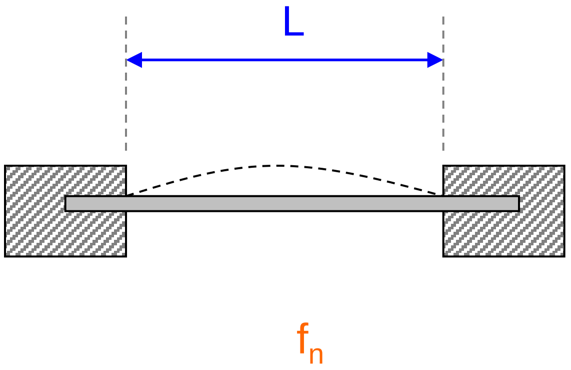
  - Results:

Sample	f_n *(Hz)*	E *(kN/mm²)*
Thin Al	11,44	**59,8**
Cu	18,91	**124,9**
Thick Al	40,89	**56,4**



Test sample analysis - by calculation

- *Step 2*: calculation of first f_n for fixed-fixed setup
  - $$f_n = \frac{1}{2\pi}\left[\frac{22.373}{L^2}\right]\sqrt{\frac{EI}{m_{sample}/L}}$$



Calculation results:

Sample	$f_{n,\ calc}$ *(Hz)*
Thin Al	**79,17**
Cu	**128,72**
Thick Al	**273,14**

Test sample analysis - by FEM

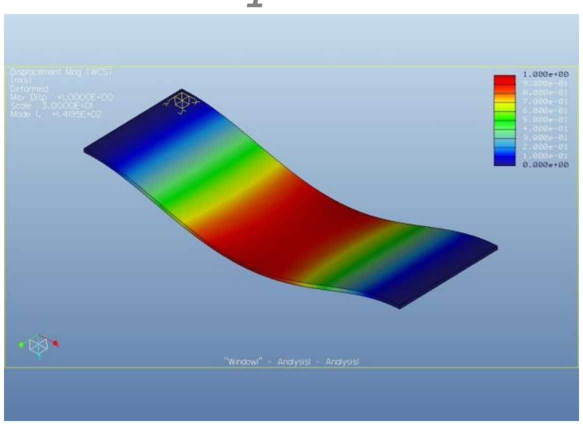
- FEM of first bending modes

Sample	$f_{n,1,\ calc}$ *(Hz)*	$f_{n,1,\ FEM}$ *(Hz)*
Thin Al	**79,17**	**81,7**
Cu	**128,72**	**133,4**
Thick Al	**273,14**	**272,4**

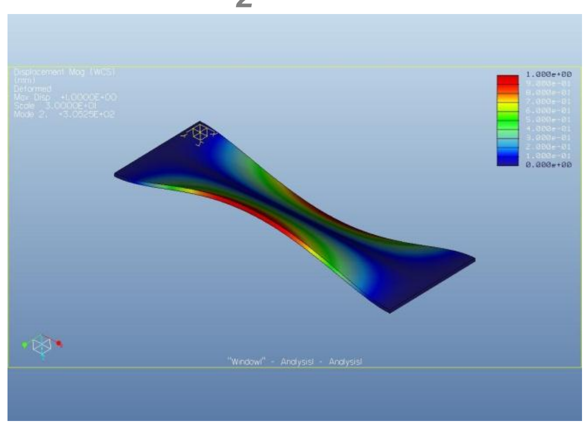
- Are NOT "holy" values, But are used for verification

-Remark: (max) 3,5% deviation between $f_{n,calc}$ and $f_{n,FEM}$

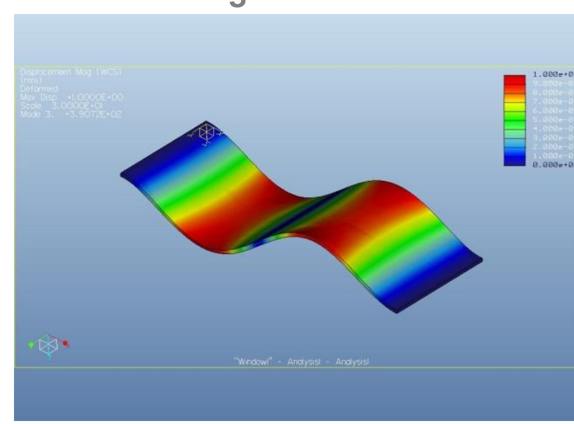
f_1



f_2



f_3



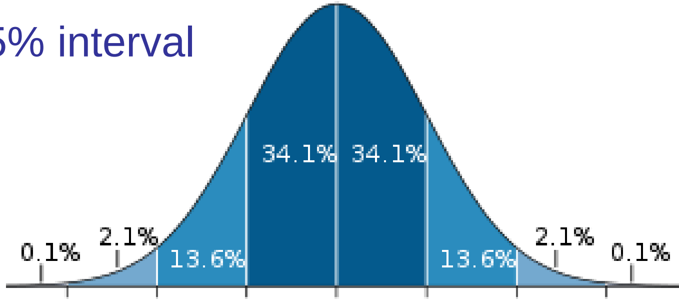
Test sample uncertainty budget

- **Contribution 1:** Intermediairy precision:
  - Examination of effect due to random events in same lab
  - Possible variables: setup, engineer, accelerometers (positions), torque [20-25Nm]

<u>Results:</u> worst case = thin Al plate

n	freq (Hz)
1	86,94
2	85,04
3	84,8
4	84,57
5	86,07
6	85,51
7	86,7
8	85,04
9	84,1

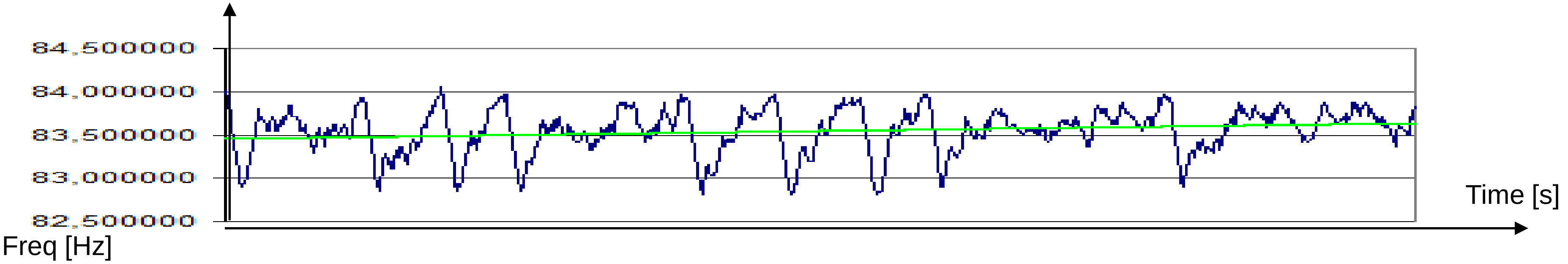
σ_1 = 0,9694
RSD = 1,14%
k = 2,3 (n = 9) (Gaussian distribution)
U = 2,3 . RSD
= $\pm$2,28% within 95% interval



Test sample uncertainty budget

- **Contribution 2:** Stability over time:
  - Examination of effect due to frequency shift over time
  - Recorded with tracked sine dwell @f_n with time recording over 10' (3x)

Results: worst case = thin Al plate



σ_2 = 0,2578

(RSD = 0,31%)

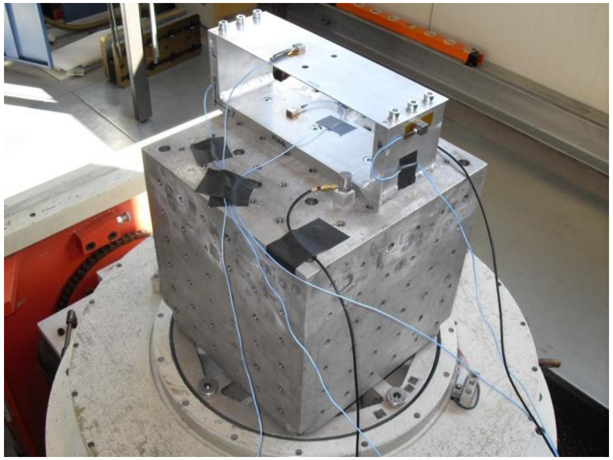
BUT: no specific trend (= linear trend analysis)

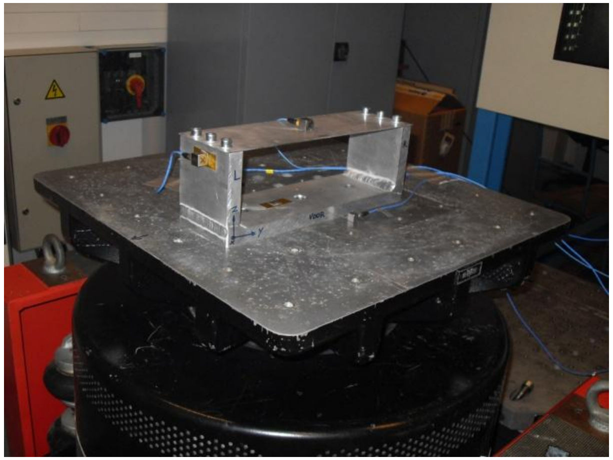
data spreading assumed to be due to dwell algorythm

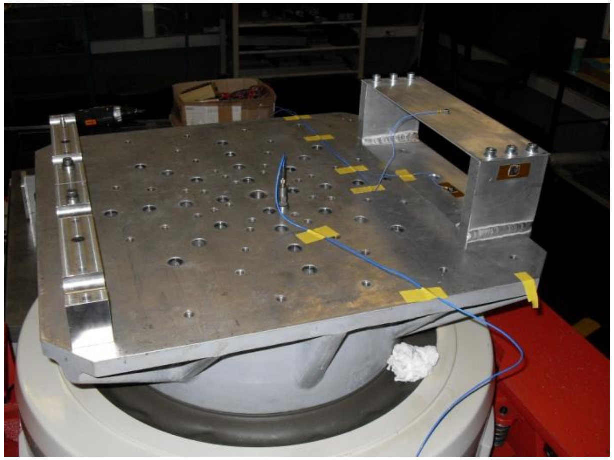
=> contribution 2 will not be taken into account

Test lab comparison

- Measurement results comparison for 3 laboratories (# participants limited)
- Sine sweep 0,5g (sweep up), 5Hz – 700Hz, 1 Oct/min







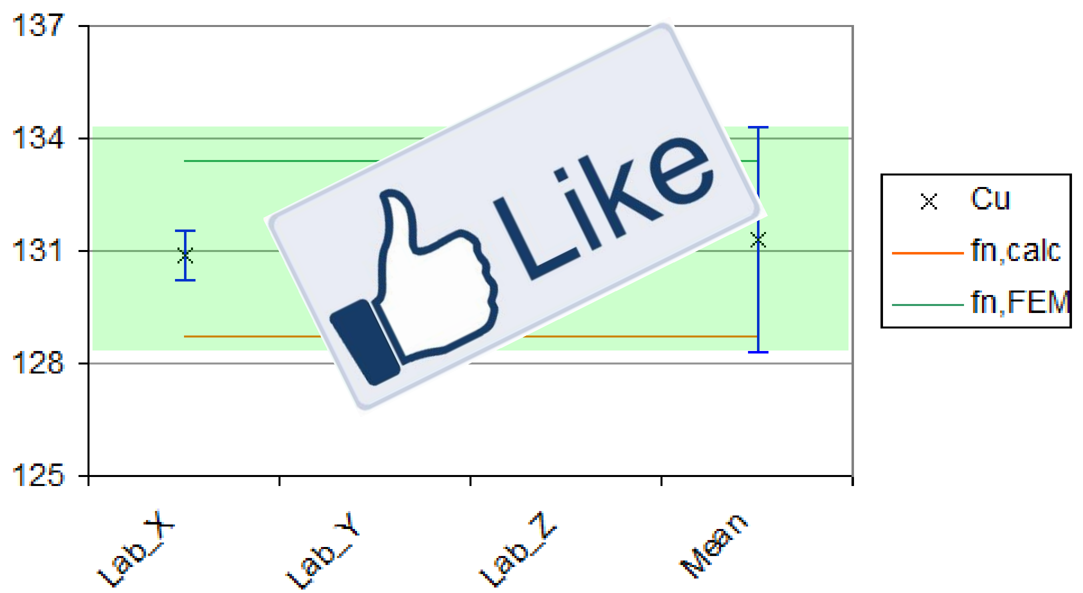
Lab1	Lab2	Lab3
LDS V964LS	RMS SW6507	LDS V850

Test lab comparison - results

- Sample 2: Cu

  **: x,y,z not related to pictures on previous slide*

Test lab*	$f_{n,1}$ ***(Hz (±Hz))***
Lab_x	**130,86** (± 0.65)
Lab_y	**129,5** (± 2,59)
Lab_z	**133,52** (± 0,45)
Mean (with test sample uncertainty)	**131,29** (± 2,99)

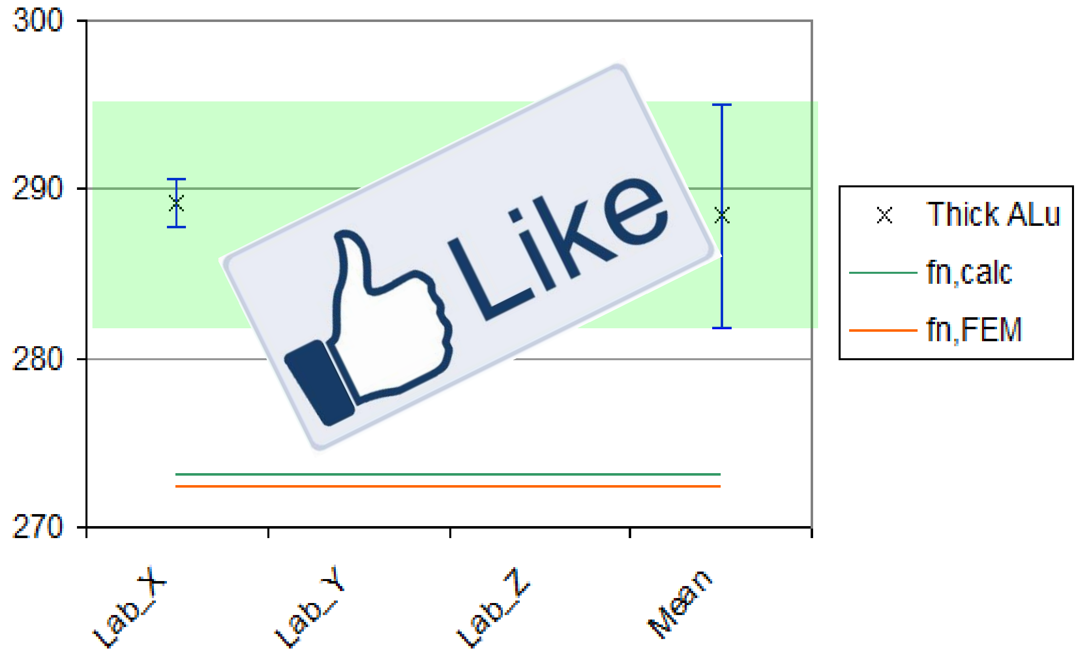


Test lab comparison - results

- Sample 3: Thick Al

  **: x,y,z not related to pictures on previous slide*

Test lab*	$f_{n,1}$ *(Hz (±Hz))*
Lab_x	**289,2** (± 1,45)
Lab_y	**282,7** (± 5,65)
Lab_z	**293,43** (± 1,00)
Mean (with test sample uncertainty)	**288,44** (± 6,58)

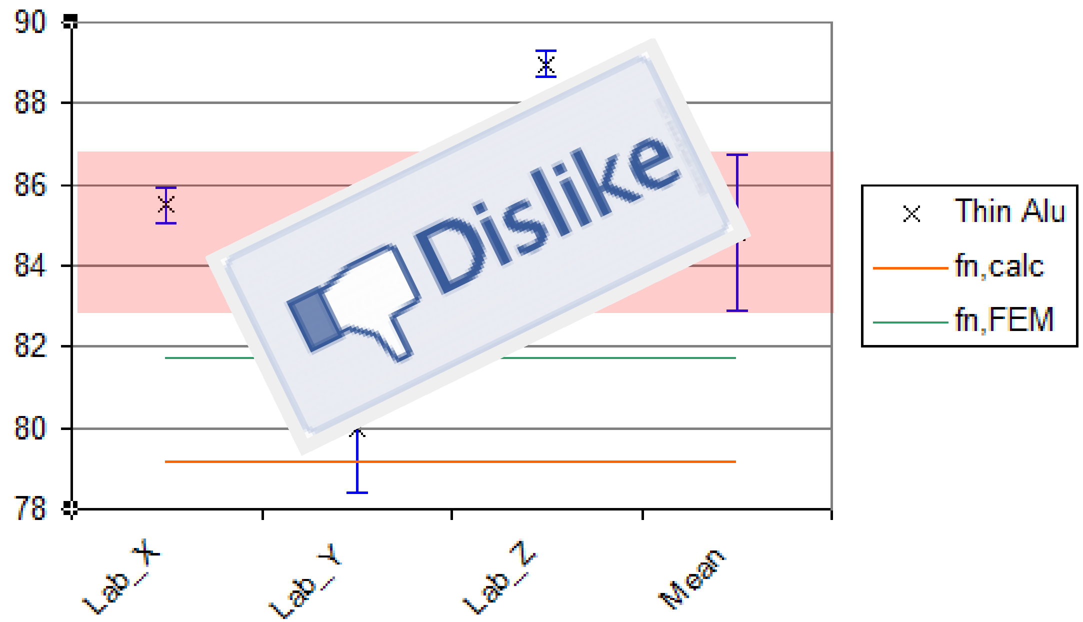


Test lab comparison - results

- Sample 1: Thin Al

  **: x,y,z not related to pictures on previous slide*

Test lab*	$f_{n,1}$ *(Hz (±Hz))*
Lab_x	**85,5** (± 0.43)
Lab_y	**80** (± 1,60)
Lab_z	**88,98** (± 0,30)
Mean (with test sample uncertainty)	**84,83** (± 1,93)



Conclusions

- Comparative results are correlating for 2 out of 3 samples
  - => Sample 1 needs further evaluation
- Differences are systematic , not random

To Do

- Further analysis of sample 1
- Theoretical analysis of sample 4
- …

Questions..?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