On the Design of a Dedicated Sample for Interlaboratory Comparison of Frequency Response Analysis

PLOT showcase 20/11/2013

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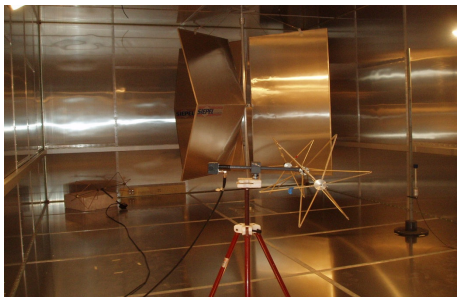
www.labodenayer.be

- ISO17025 accredited for
  - EMC (civil, Mil,…)
  - Electrical Safety (LVD)
  - Mechanical
  - Climatic
  - Antenna Calibration
- Notified Body EMC
- Notified Body LVD



Overview

- ISO17025 requirement
- Sample description
- Fixture analysis
- Sample analysis and uncertainty budget
- Test lab comparison
- Conclusions and future work

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

Sample description

Sample choice:

Requirements:

1) Representative

2) Stable over (test)time

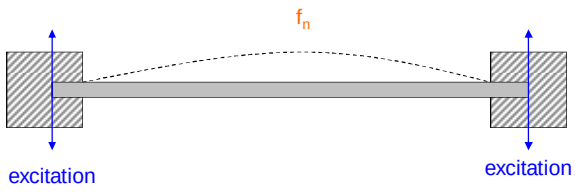
3) Homogeneous (-> identical sample for each lab)

4) (not too) elementary

Sample description

Design concept:

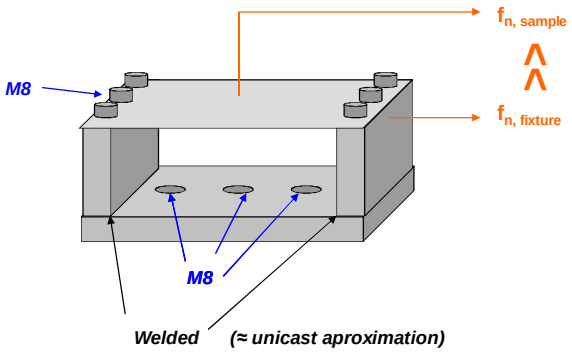
Fixed-fixed beam structure with uniform mass distribution
determine f_n by application of uniaxial forced vibration

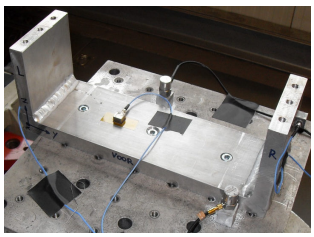


Sample description

Sample design:

Need for rigid reference structure near fixed ends

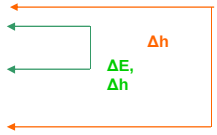


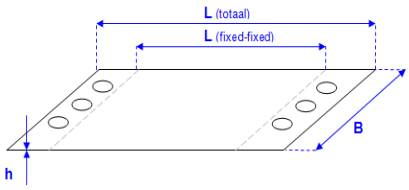


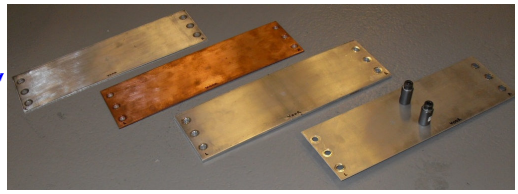
Sample description

Different materials and dimensions ($L_{(fixed-fixed)}$: 300mm; B: 100mm)

- Thin Al plate (h: 1,5mm)
- Thick Cu plate (h: 3mm)
- Thick Al plate (h: 5mm)

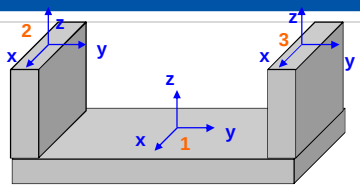


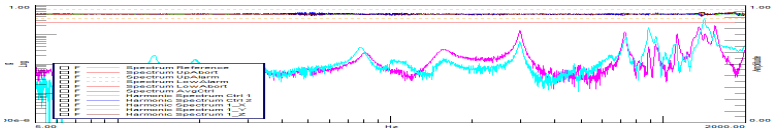




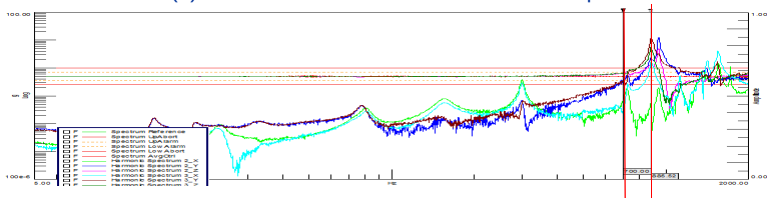
Fixture analysis

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





- First recorded resonance (Z) for acc2 and acc3 at 860Hz. Fixture ok up to **700Hz**

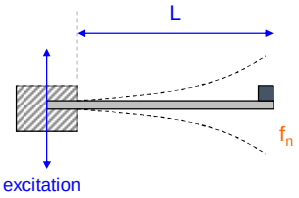


HUF = 700Hz | **F_{n1} = 860Hz**

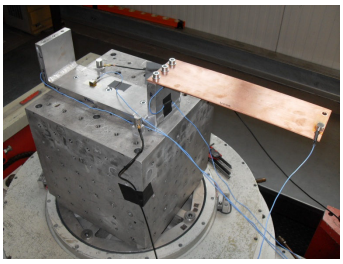
Sample Analysis - calculation

- ***Step 1***: Young's modulus by resonance measurement of cantilever
  - Cantilever setup for each plate type
  - Measurement of f_n
  - $$E = [2\pi f_n]^2 \cdot L^3 \cdot \left[\frac{0.2235.(m_{sample}) + m_{accelerometer}}{3I}\right]$$

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

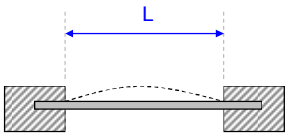


Sample	f_n *(Hz)*	E *(kN/mm²)*
Thin Al	11,44	**59,8**
Cu	18,91	**124,9**
Thick Al	40,89	**56,4**



Sample Analysis - 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**

Sample Analysis - FEM

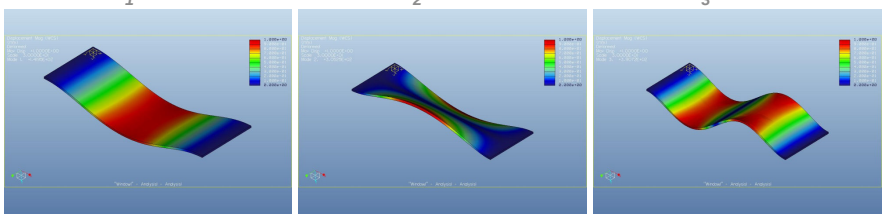
FEM of first bending modes

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

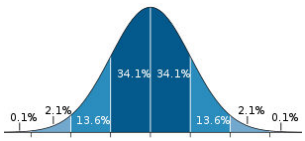


Uncertainty budget

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

Results: e.g. 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%

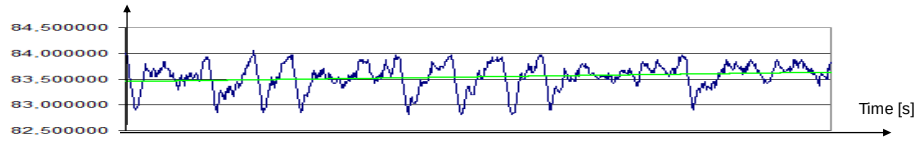
k = 2,3 (n = 9) (Gaussian distribution)

U = (2,3 . RSD) within 95% interval

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: e.g. thin Al plate



σ_2 = 0,2578

(RSD = 0,31%)

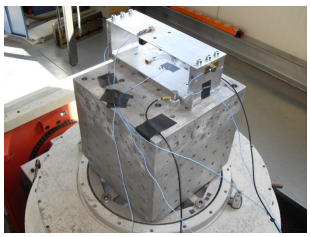
BUT: no specific trend (——— = linear trend analysis)

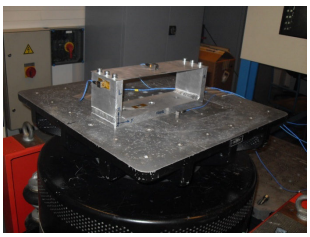
data spreading assumed to be due to dwell algorythm

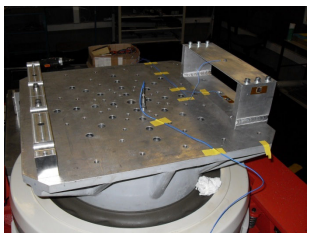
=> contribution 2 will not be taken into account

Test lab comparison

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





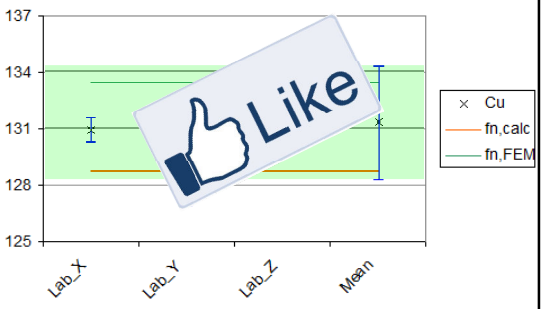


Lab1	Lab2	Lab3
LDS V964LS	RMS SW6507	LDS V850

Test lab comparison

- Sample 2: Cu

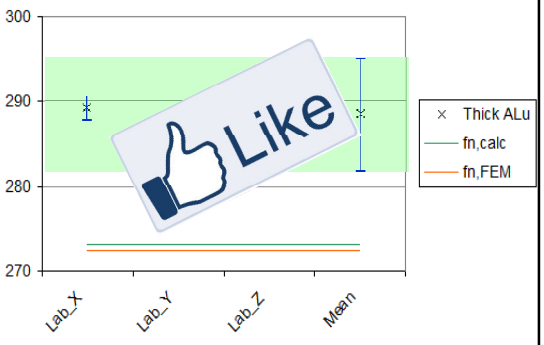
Test lab	$f_{n,1}$ *(Hz (±Hz))*
Lab_x	**130,86** (± 0.65)
Lab_y	**129,5** (± 2,59)
Lab_z	**133,52** (± 0,45)
Mean (with test sample uncertainty)	**131,29** (± 2,99)



Test lab comparison

- Sample 3: Thick Al

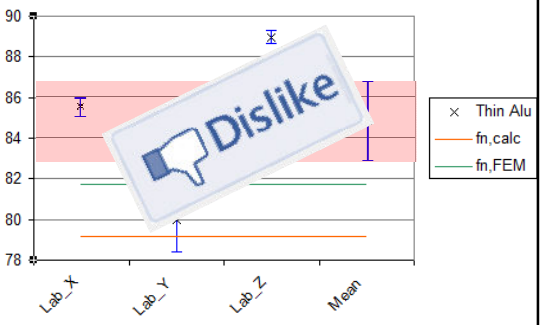
Test lab	$f_{n,1}$ *(Hz (±Hz))*
Lab_x	**289,2** (± 1,45)
Lab_y	**282,7** (± 5,65)
Lab_z	**293,43** (± 1,00)
Mean (with test sample uncertainty)	**288,44** (± 6,58)



Test lab comparison

- Sample 1: Thin Al

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

- Correlated results during comparative study for all but one sample
- Interlaboratory errors are systematic
- Thin Al plate needs further investigation due to systematic differences in measurement results
  - Plate thickness has been evaluated for uniformity
  - Differences in mass of accelerometers between laboratories?
  - Exact location of accelerometers?
  - Type of adhesive (bee wax, glue)?
- Repeated intermediary precision on thin Al plate:
  - 30 intra-laboratory test runs performed
  - Relative standard deviation: 0,81%, with k≈2: U = 1,62%

    → deviations are due to interlaboratory differences

Further on…

- Larger population:

  Additional participants for comparison study

  interested parties in Netherlands:
  - Thales
  - NLR
  - Sebert