HIGH-FREQUENCY TESTING FOR FATIGUE BEHAVIOUR AND XCTE SPIN-OFF

D-STANDART Final Dissemination Event

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SPIN-OFF: XCTE

Journey & Next Steps

WHAT WE DO

Accelerated, vibration-based performance testing for composites, tracking dynamic properties in real time to reveal degradation and fatigue behaviour orders faster than classic campaigns.

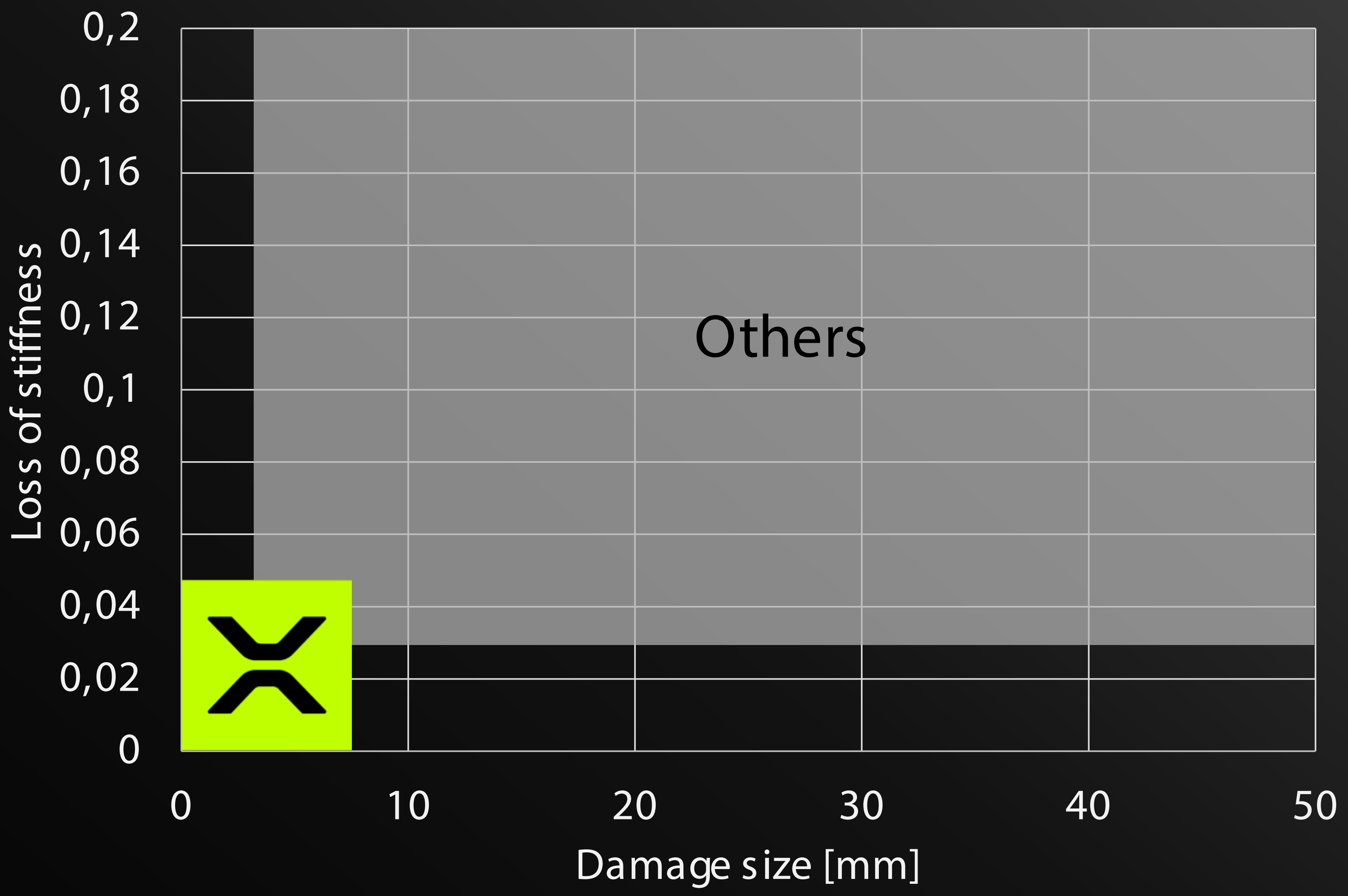
WHAT WE DO

- Front-end layer to test workflows:
  - Screen, rank and characterise early
  - Run standard tests more efficient
- Data driven design choices

THE XCTE APPROACH

- High frequency excitation of specimens
- Continuous tracking of dynamic properties
- Software analytics detect onset and progression of degradation
- Output: Relative performance ranking

THE XCTE APPROACH



TIMELINE

Past

- Method Developed
- Lab Validation
- Technology Recognised

Now

- Shaping Business Model
- IP Strategy
- Pilot Talks

Next

- Company Launch
- Starting Pilot Projects
- Customer Expansion

Future Vision

- Simulation Integration
- Industry Adoption
- Global Customer Base

FUTURE VISION

- Correlation & Validation: Mapping to standard fatigue outcomes
- Create Business Model: Testing-as-a-service + later product
- Commercialisation: Hardware + control + analytics
- Data & Models: Growing a materials-behaviour dataset
- Standards alignment: Pre-standardisation work; documented protocols

HIGH-FREQUENCY TESTING FOR FATIGUE BEHAVIOUR

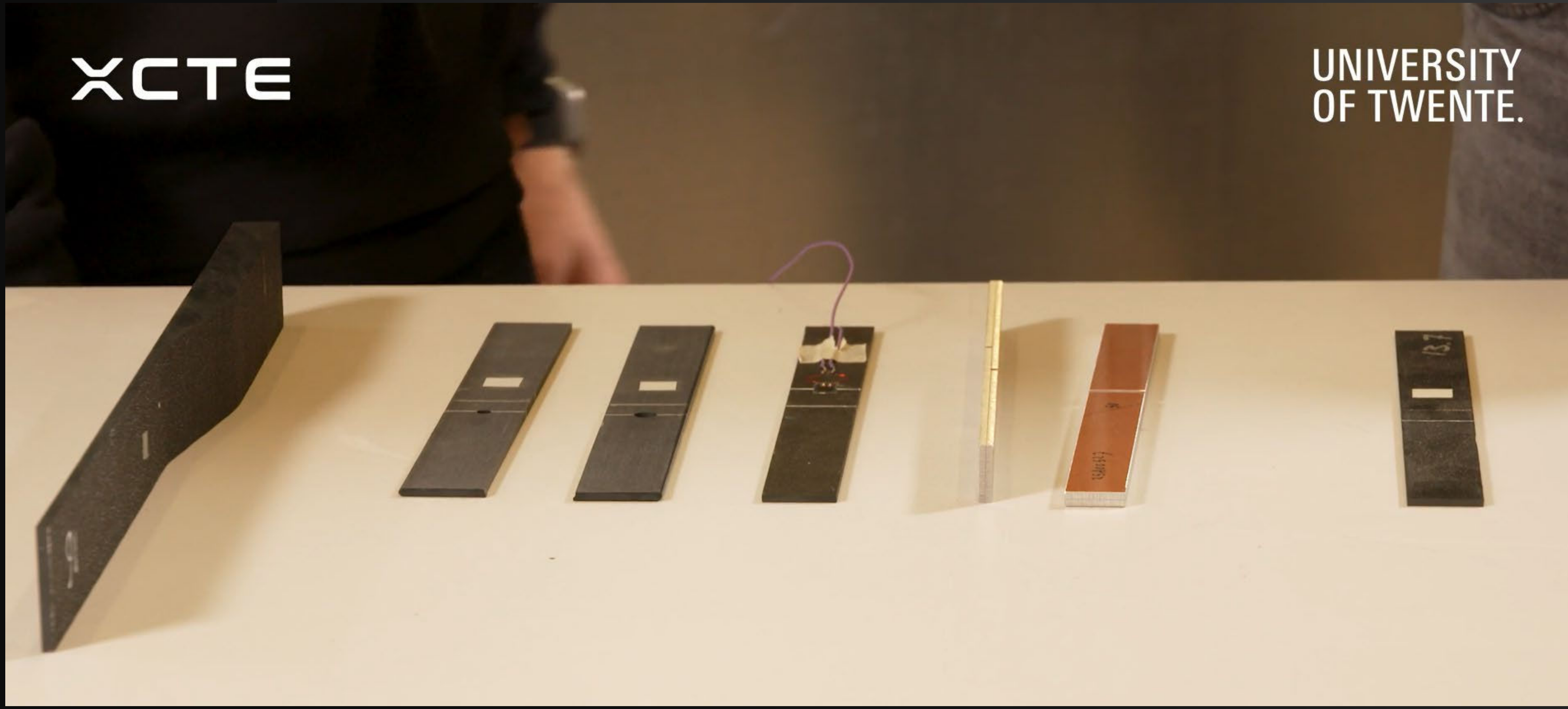
The testing method explained

SAMPLE SELECTION

- Cut ply
- Milled coupon
- Drilled hole

SAMPLE SELECTION

- Cut ply:
  - Laminate properties
  - Feature properties
- Milled coupon:
  - Adhesives testing
- Drilled hole:
  - Test existing materials



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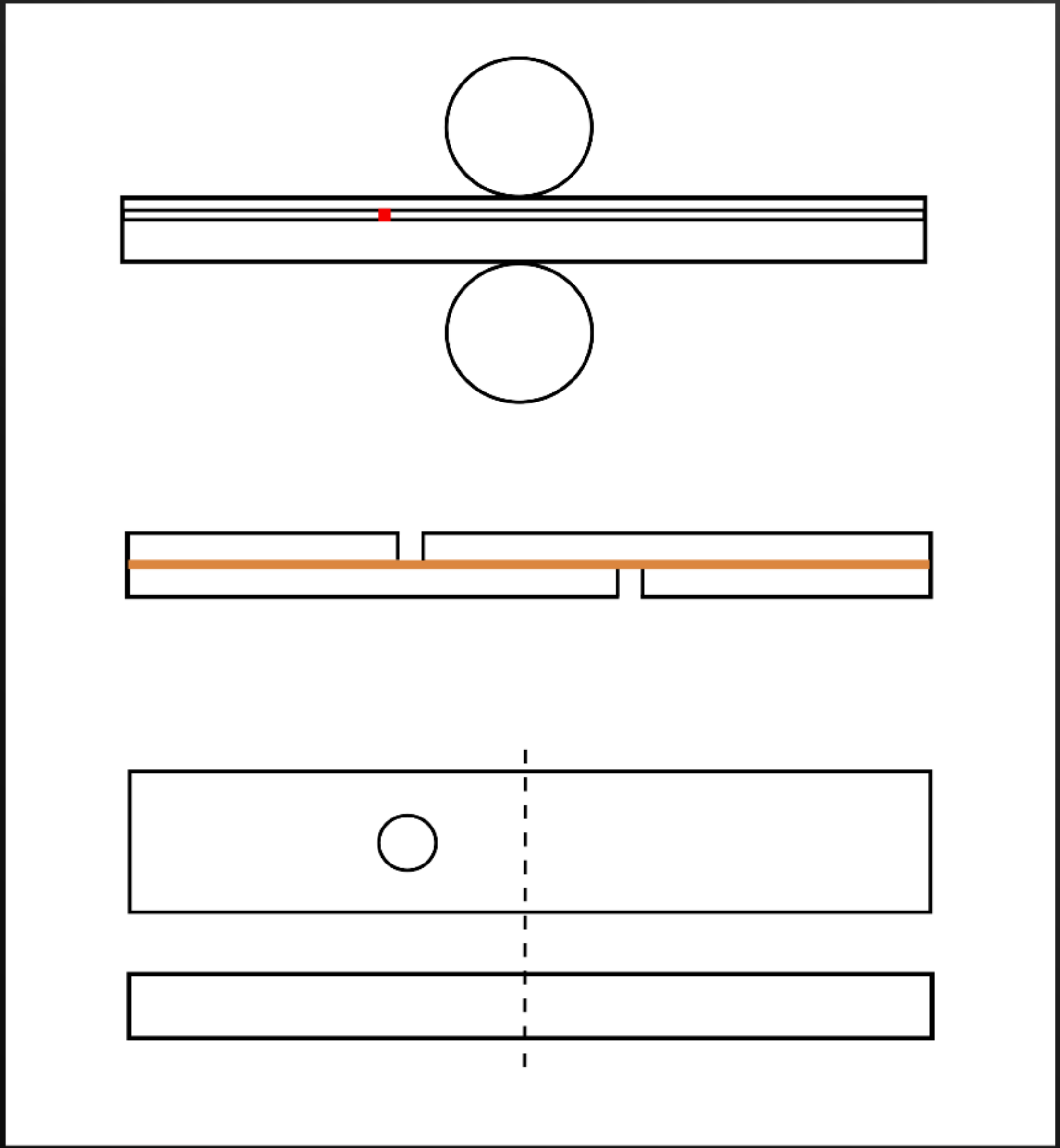
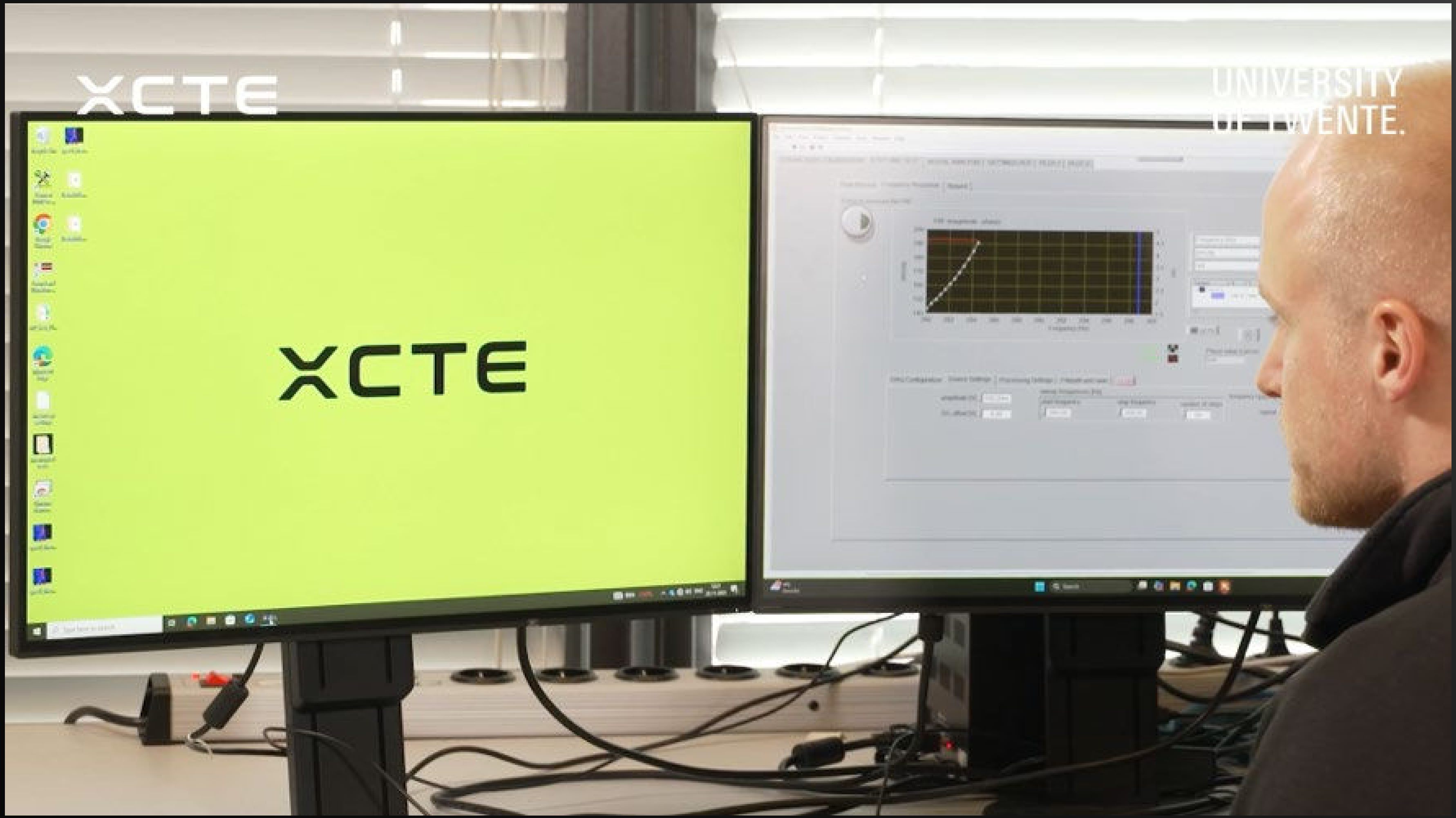


SETTING UP

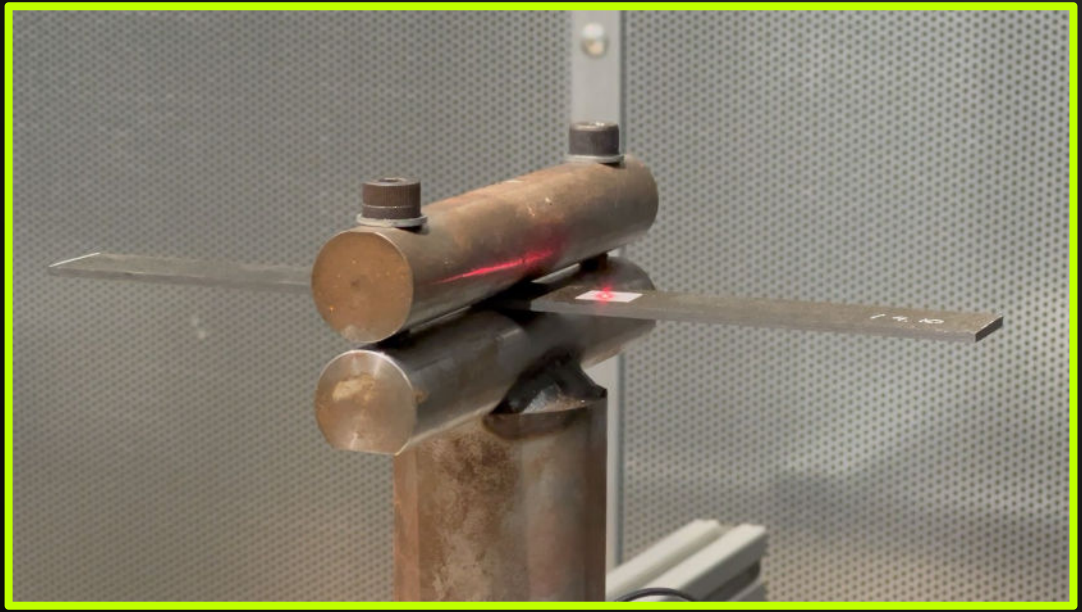
- Alignment
- Applying torque

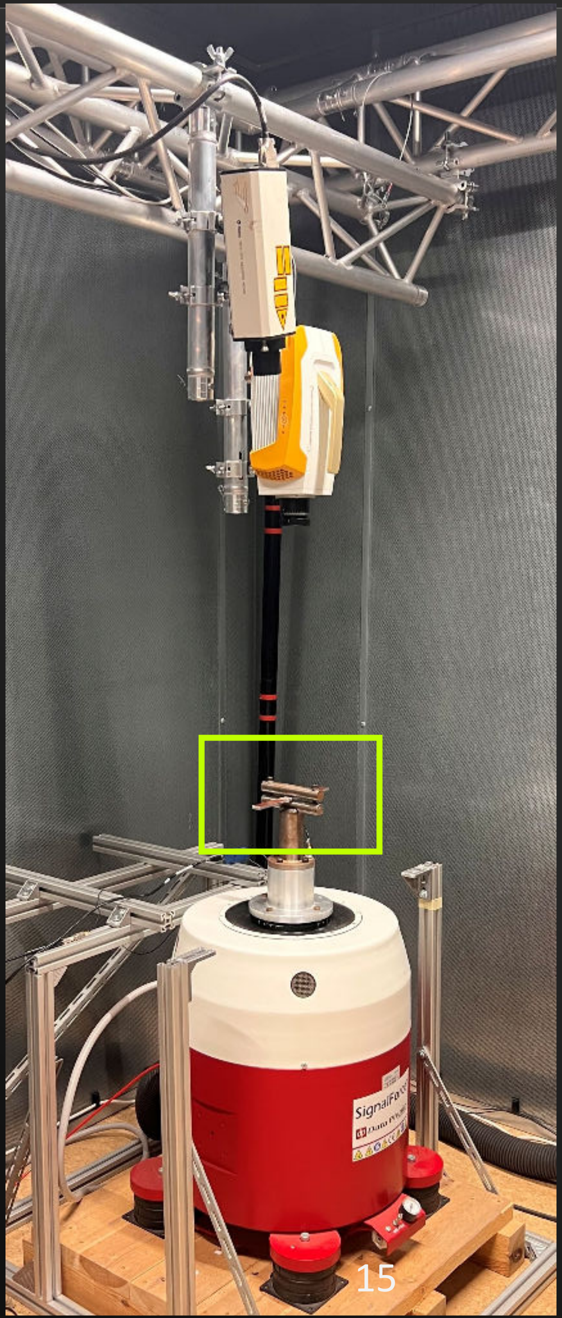
THE SETUP



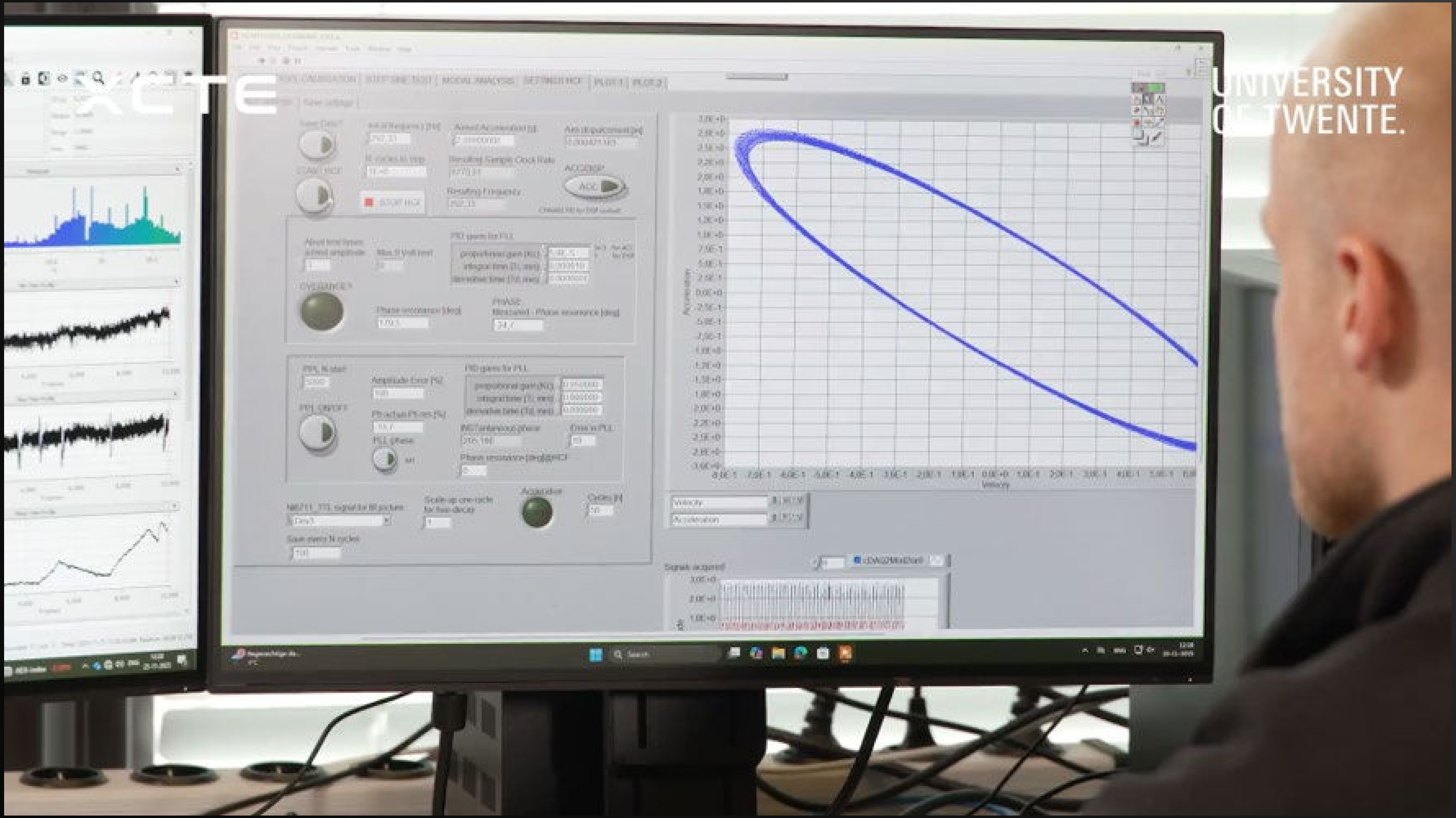
THE SETUP

1. LDV
2. Accelerometer
3. Shaker
4. Thermal Camera
5. (Environmental Chamber)



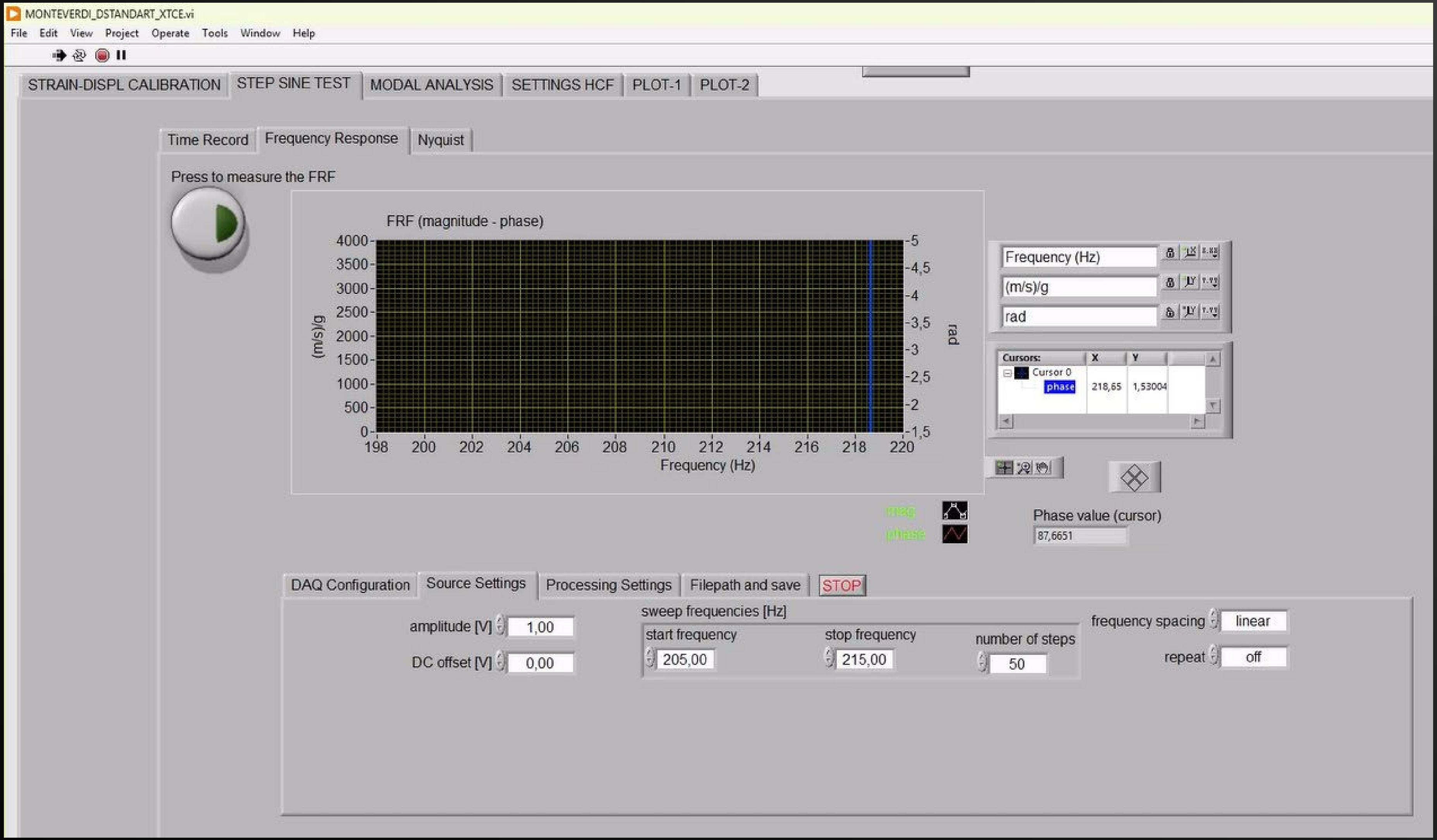


TESTING

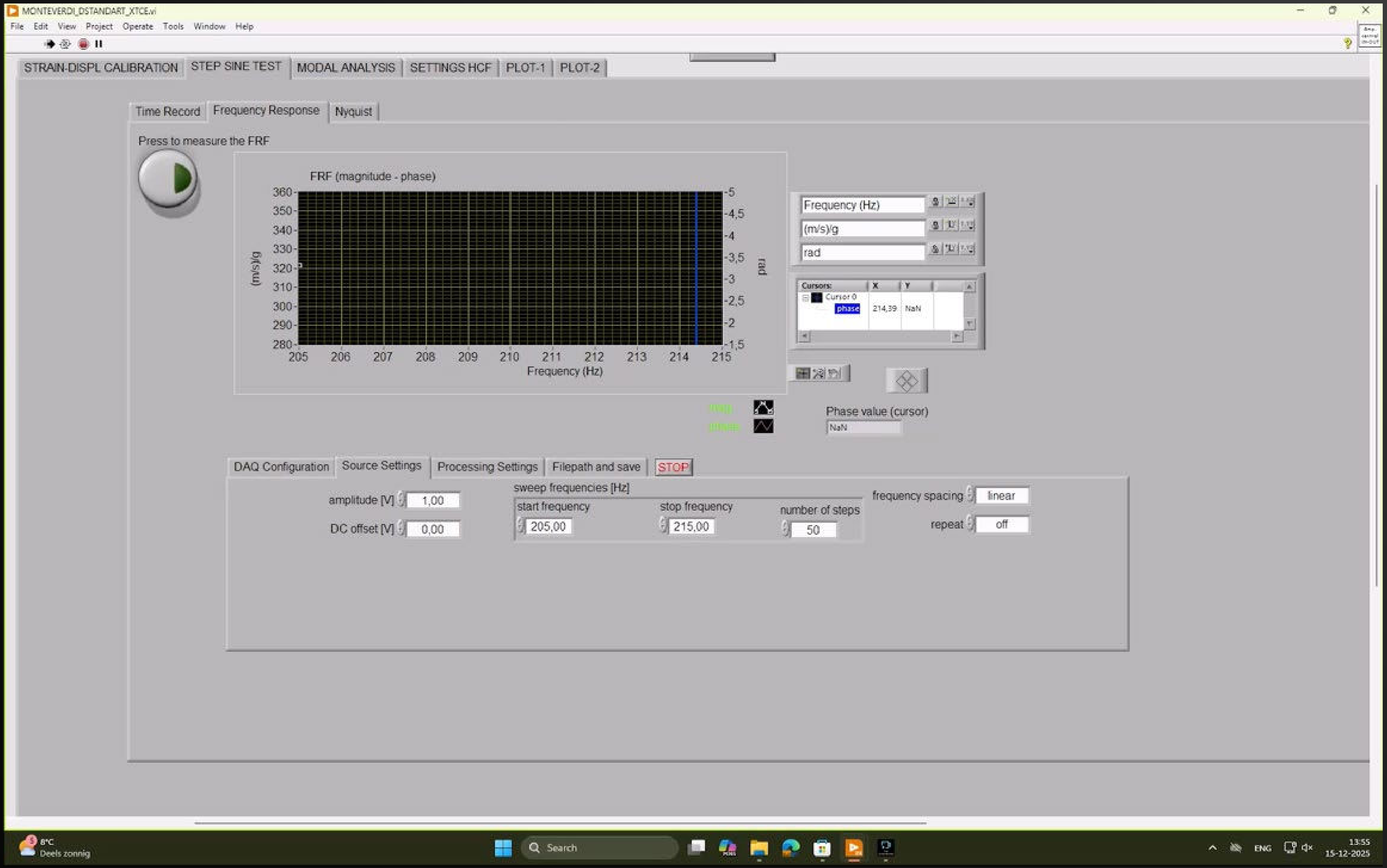


FRF

- Find natural frequency



FRF


MONTEVERDI_DSTANDART_XTCE.vi
File Edit View Project Operate Tools Window Help
STRAIN-DISPL CALIBRATION
STEP SINE TEST
MODAL ANALYSIS
SETTINGS HCF
PLOT-1
PLOT-2
Time Record
Frequency Response
Nyquist
Press to measure the FRF
FRF (magnitude - phase)
(m/s)/g
rad
Frequency (Hz)
(m/s)/g
rad
Phase value (cursor)
NaN
DAQ Configuration
Source Settings
Processing Settings
Filepath and save
STOP
amplitude [V] 1,00
DC offset [V] 0,00
sweep frequencies [Hz]
start frequency 205,00
stop frequency 215,00
number of steps 50
frequency spacing linear
repeat off
Search
Deels zonnig
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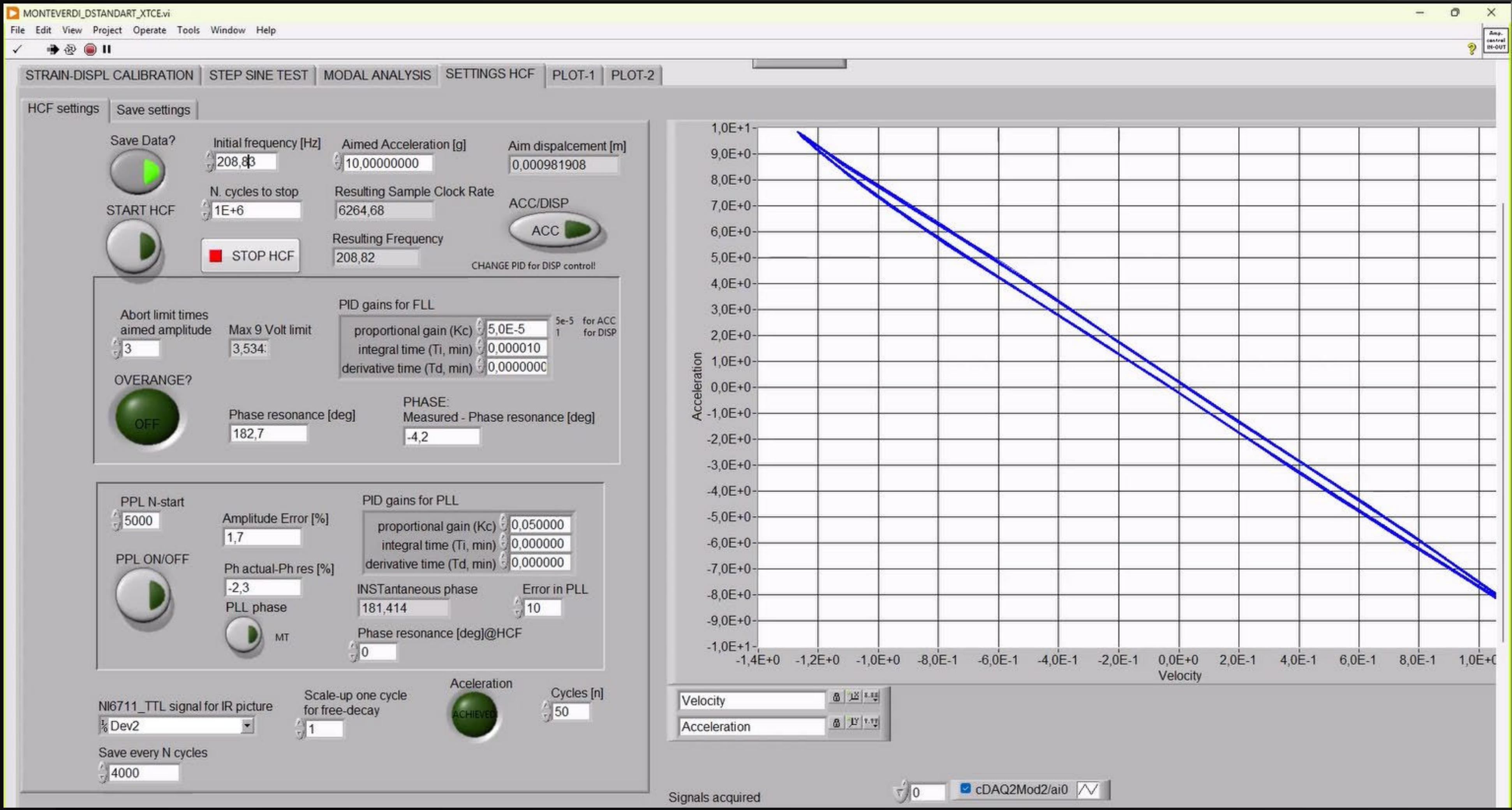
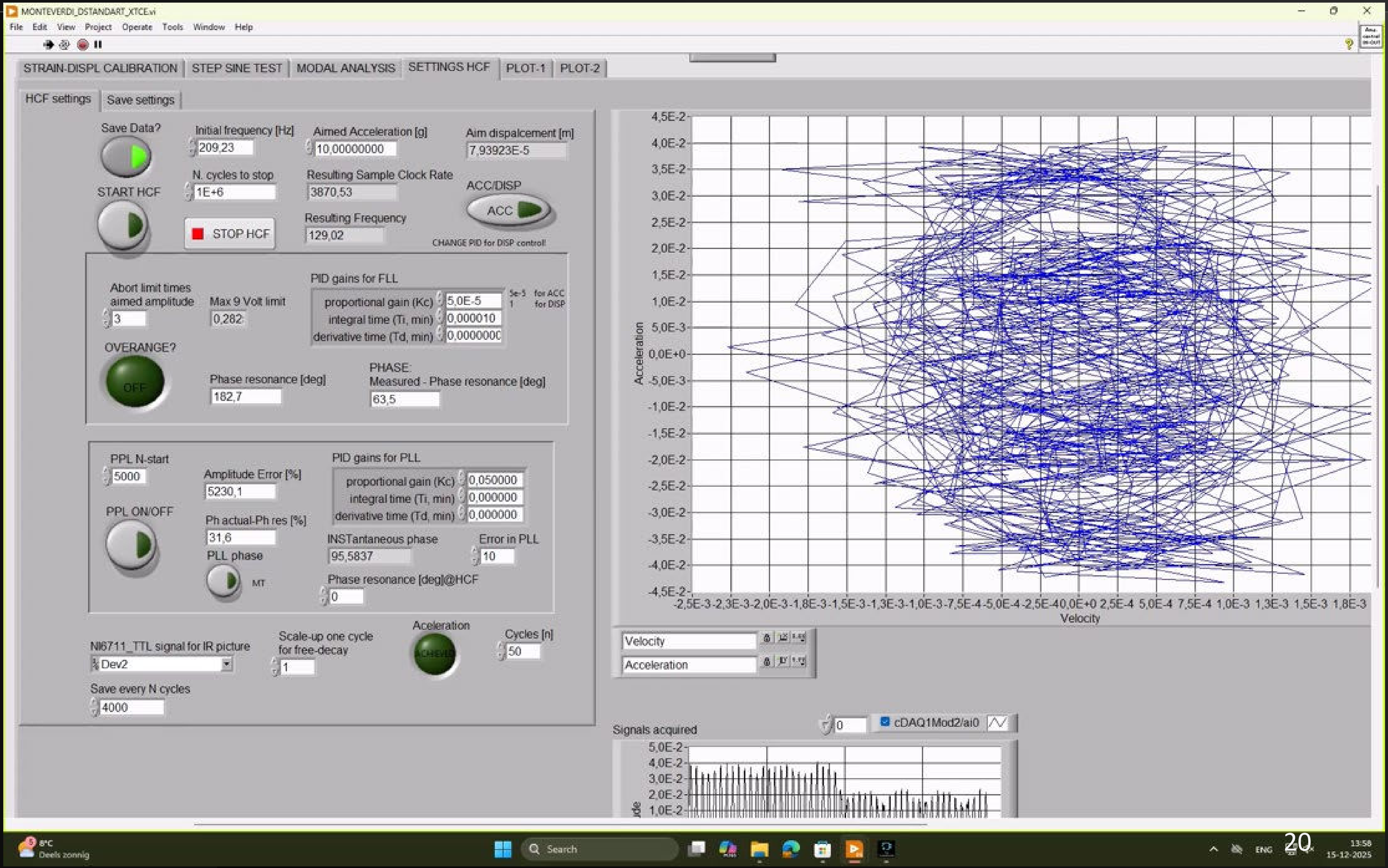
HCF

- Control:
  - Acceleration
  - Displacement
  - Force
  - Phase



HCF



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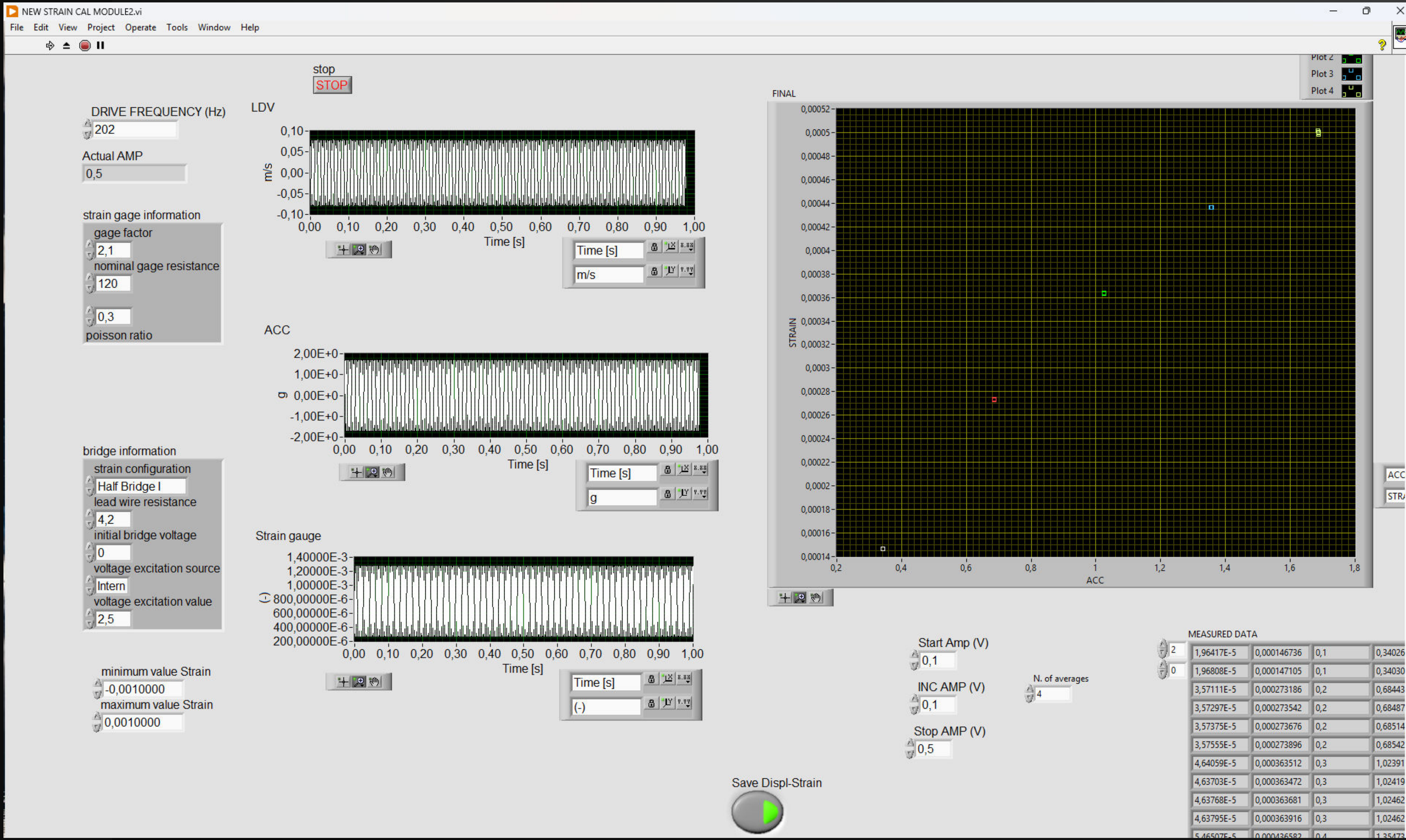
File Edit View Project Operate Tools Window Help
STRAIN-DISPL CALIBRATION
STEP SINE TEST
MODAL ANALYSIS
SETTINGS HCF
PLOT-1
PLOT-2
HCF settings
Save settings
Save Data?
Initial frequency [Hz]
209,23
Aimed Acceleration [g]
10,00000000
Aim dispalcement [m]
7,93923E-5
N. cycles to stop
1E+6
Resulting Sample Clock Rate
3870,53
ACC/DISP
ACC
START HCF
STOP HCF
Resulting Frequency
129,02
CHANGE PID for DISP control!
Abort limit times aimed amplitude
3
Max 9 Volt limit
0,282
PID gains for FLL
proportional gain (Kc)
5,0E-5
integral time (Ti, min)
0,000010
derivative time (Td, min)
0,0000000
5e-5 for ACC
1 for DISP
OVERANGE?
OFF
Phase resonance [deg]
182,7
PHASE:
Measured - Phase resonance [deg]
63,5
PPL N-start
5000
Amplitude Error [%]
5230,1
PID gains for PLL
proportional gain (Kc)
0,050000
integral time (Ti, min)
0,000000
derivative time (Td, min)
0,000000
PPL ON/OFF
Ph actual-Ph res [%]
31,6
PLL phase
MT
INSTantaneous phase
95,5837
Error in PLL
10
Phase resonance [deg]@HCF
0
NI6711_TTL signal for IR picture
Dev2
Scale-up one cycle for free-decay
1
Aceleration
Cycles [n]
50
Save every N cycles
4000
Acceleration
Velocity
Signals acquired
cDAQ1Mod2/ai0
Search

THERMAL CAM

- Nucleation location

Calibration

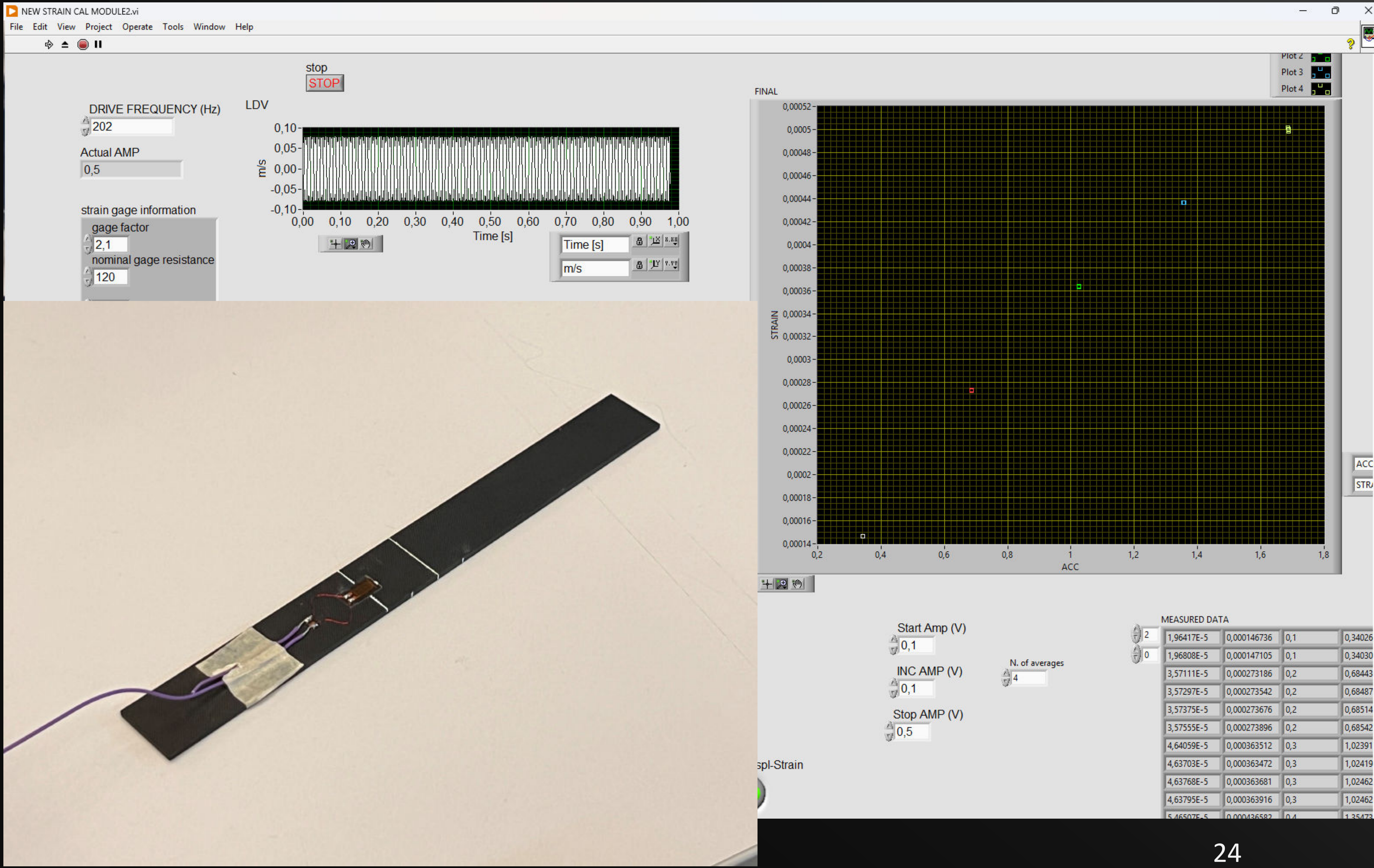
- Strain



XCTE

Calibration

- Strain

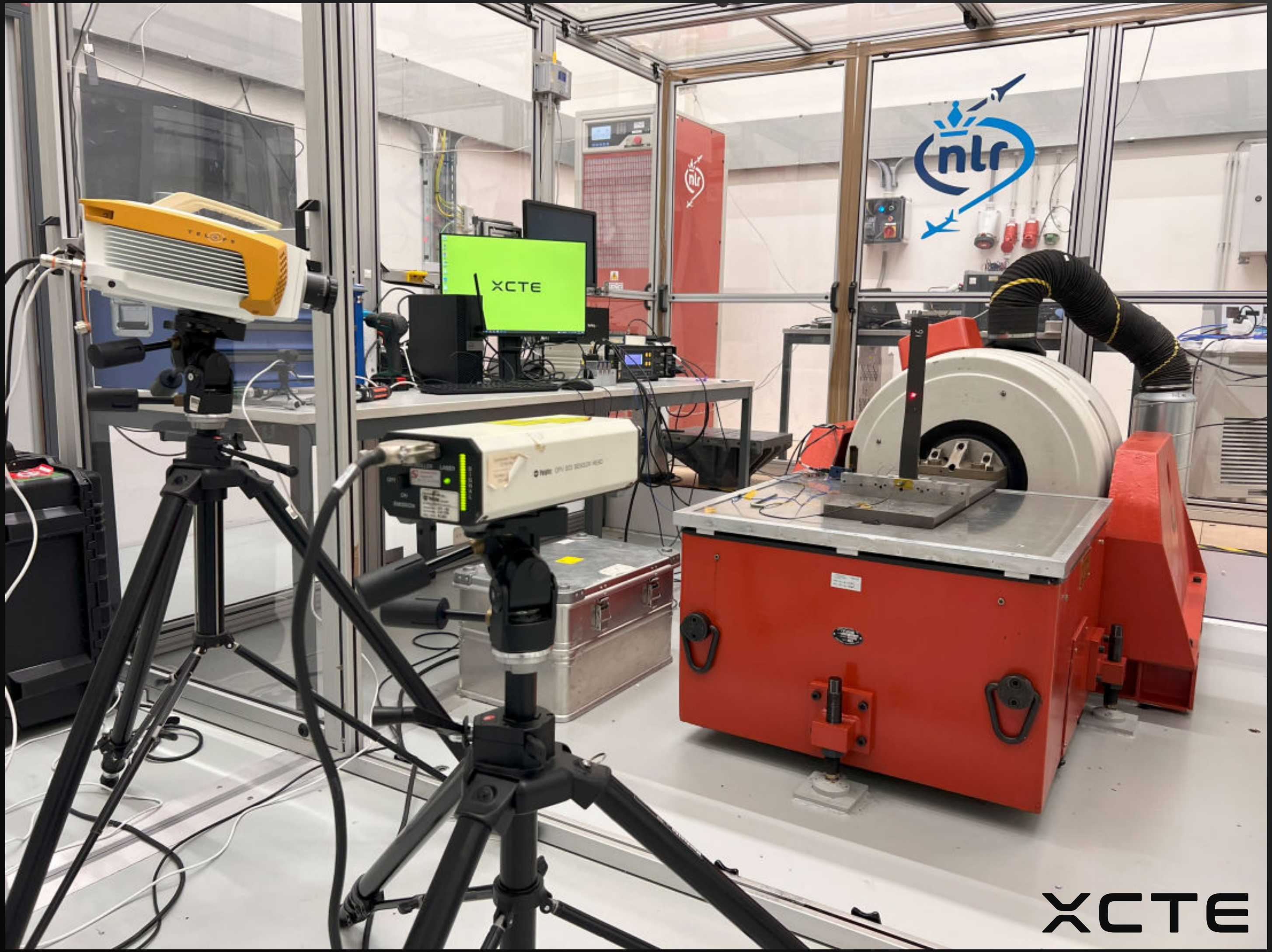


OTHER LABS

NLR (2025) >

Aerospace Demo >

Strain calibration >



OTHER LABS

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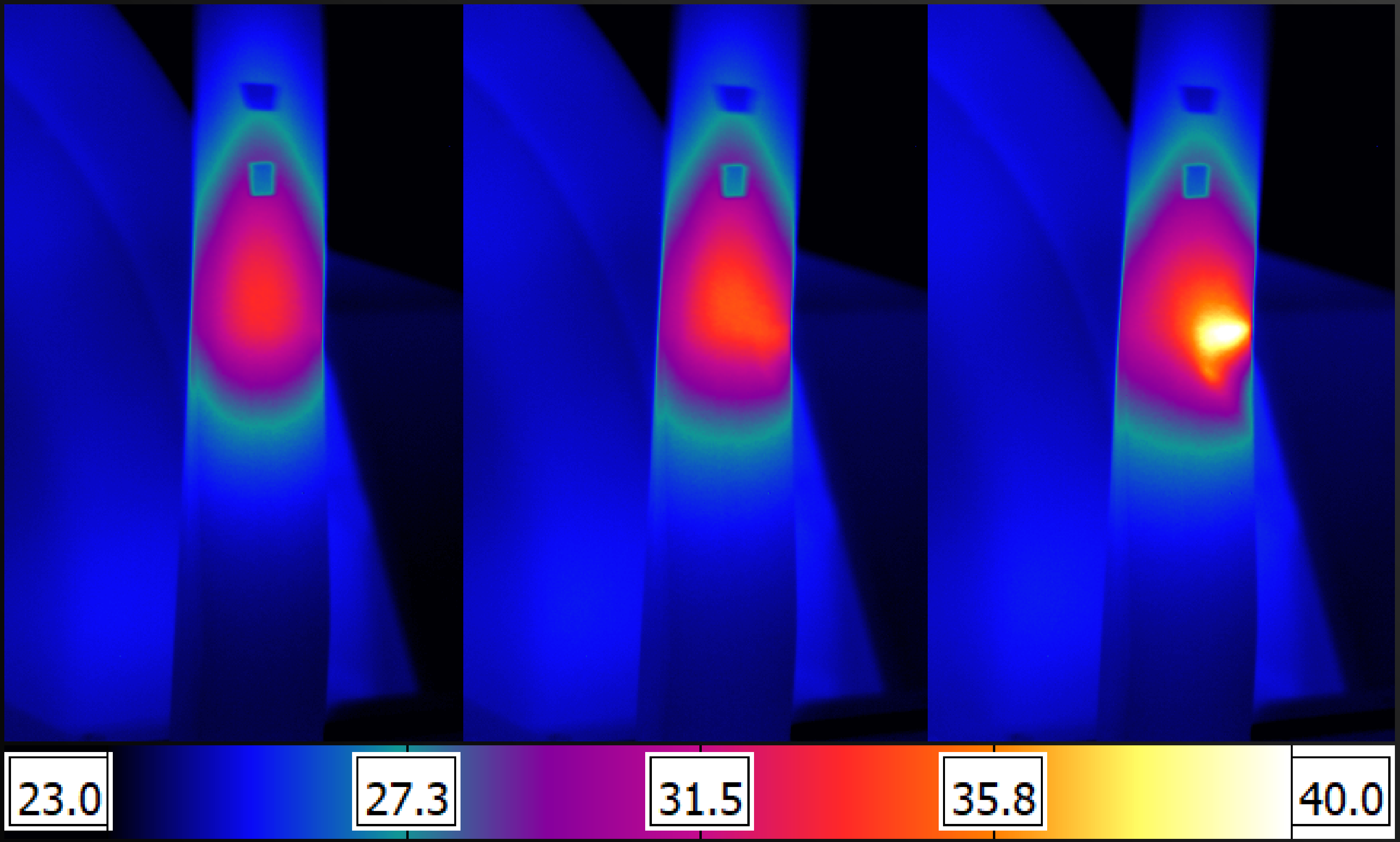
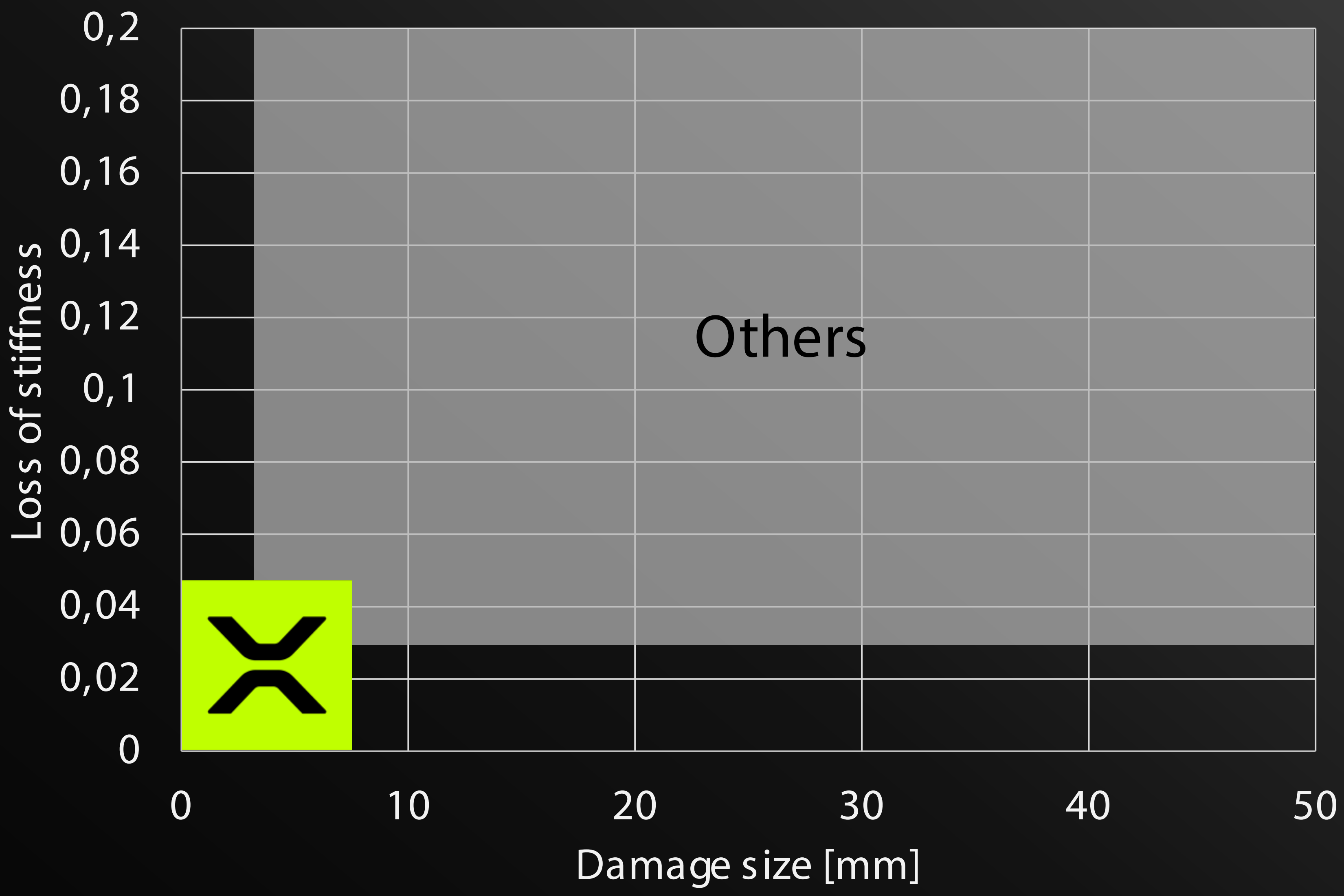
OTHER LABS

Thermal images >



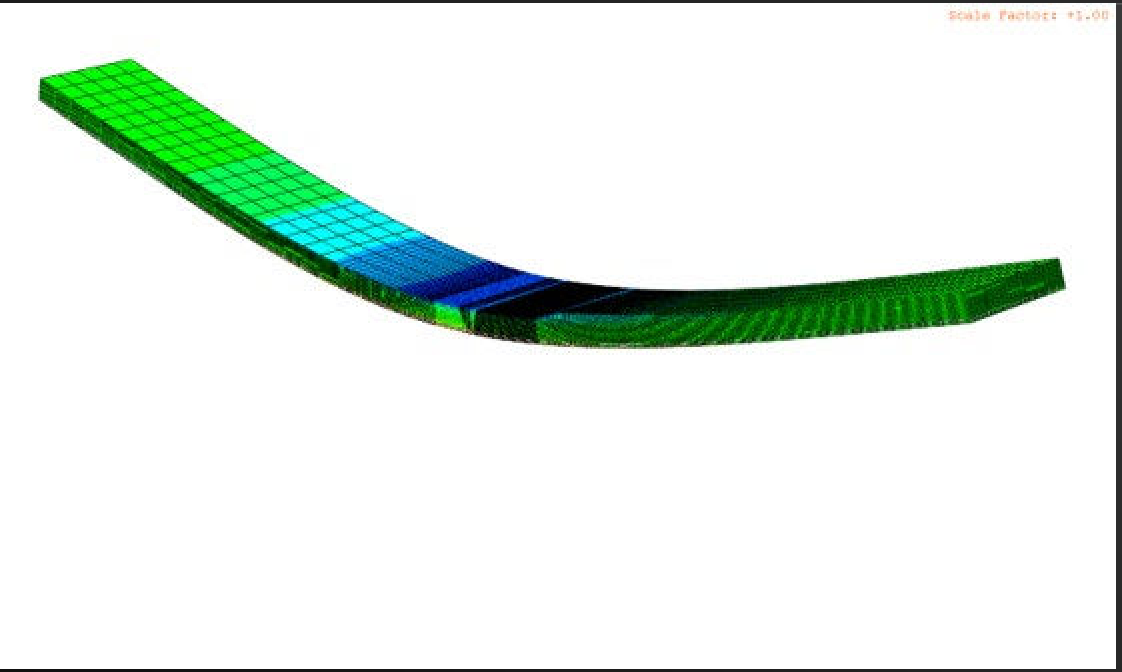
DATA ANALYSIS & EXPLOITATION

OUR BUSINESS OPERATION



PHASE TRACKING

- The rotational stiffness depends on the second moment of area and the length.
- The ATAN function transforms an extremely small change (I and L) into a large phase shift (ϕ).
- Any damage onset is detected.



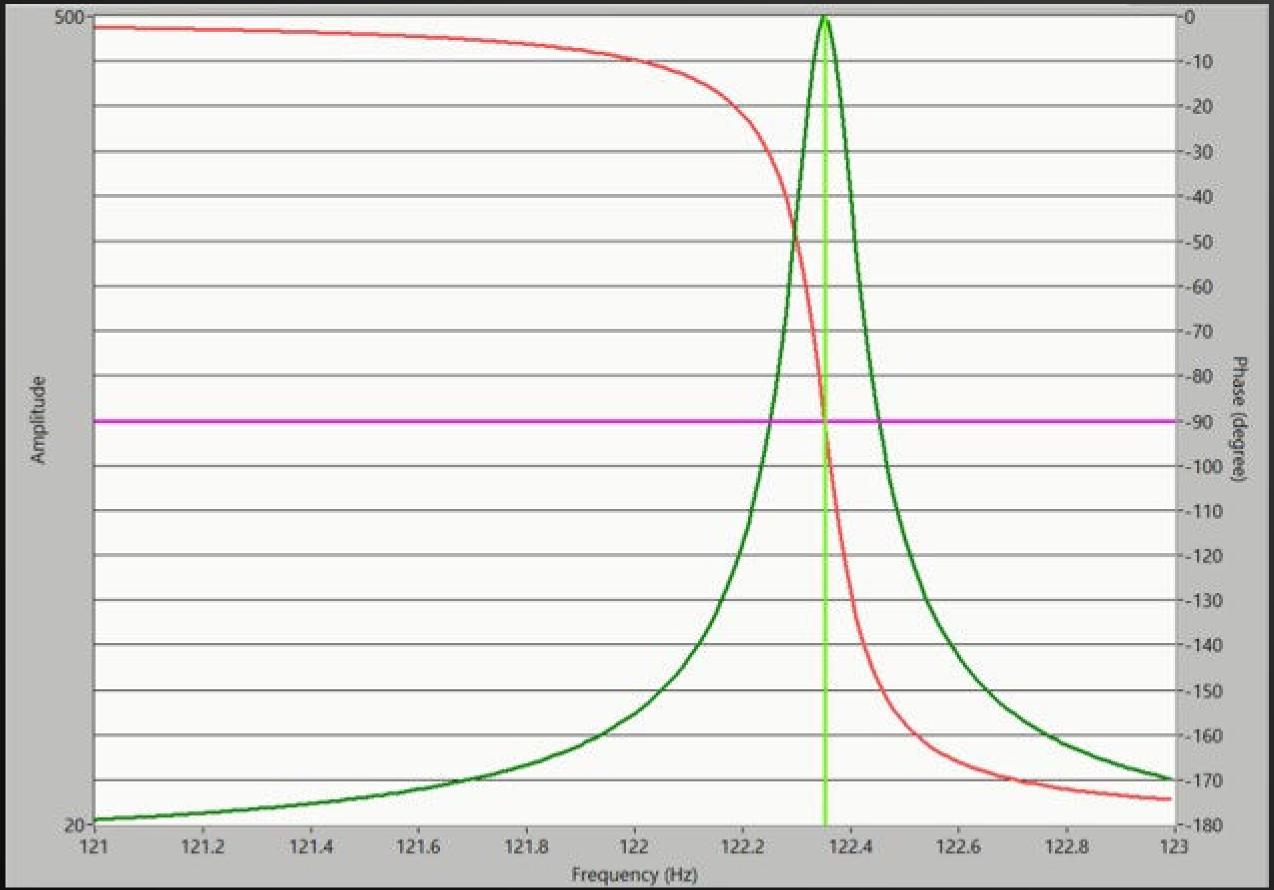
$$k_\theta = \frac{2EI_1 I_2 I_3}{(L - L_2)I_2 I_3 + 2L_2 I_1 I_3 + (L - L_2)I_1 I_2}$$

$$\omega_n^2 = \frac{k_\theta}{m_{eff}}$$

$$\phi(\bar{\omega}) = \arctan\left(-\frac{\eta\omega_n^2}{\omega_n^2 - \bar{\omega}^2}\right) \qquad \bar{\omega} = \text{const}$$

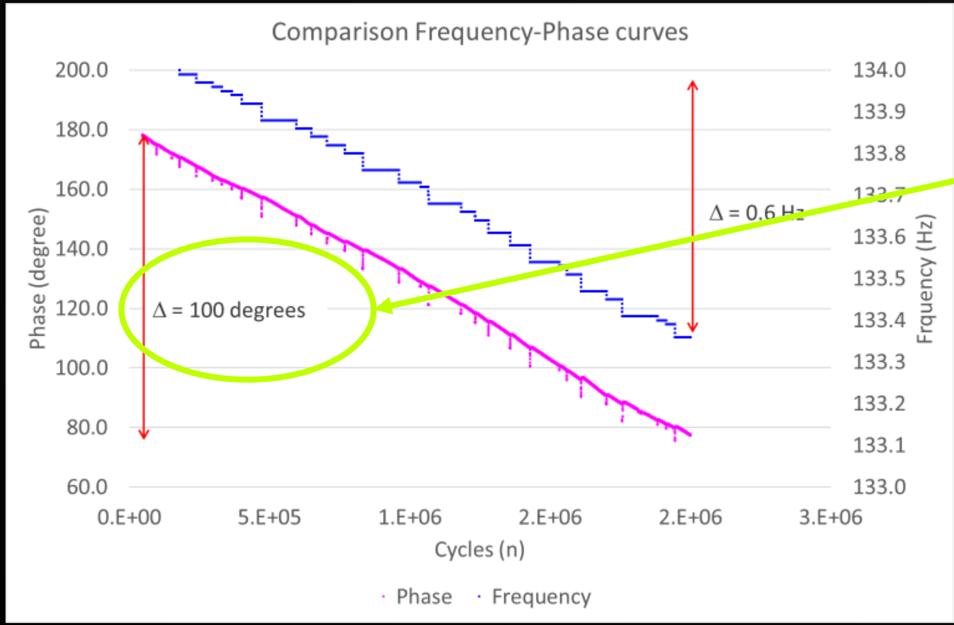
PHASE TRACKING

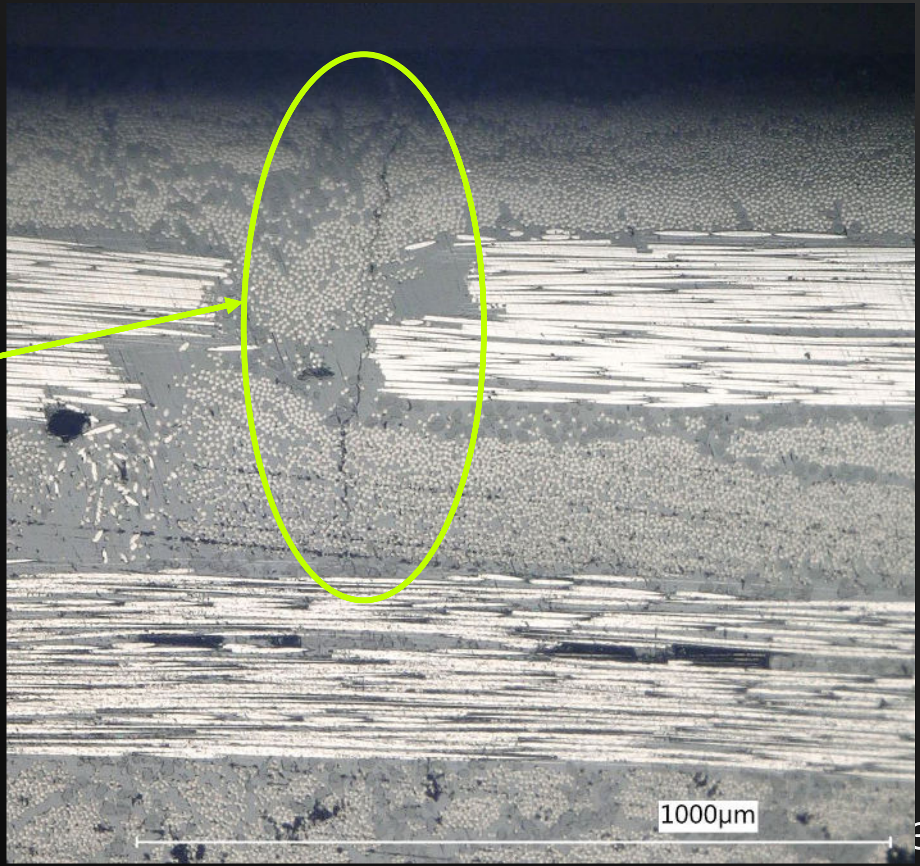
- The green line is the fixed excitation frequency $\overline{\omega} = \text{const.}$
- The system dynamics changes because of the fatigue damage.
- The phase curve is very steep around the resonance, and so sensitive.



SENSITIVITY TO FATIGUE DAMAGE ONSET

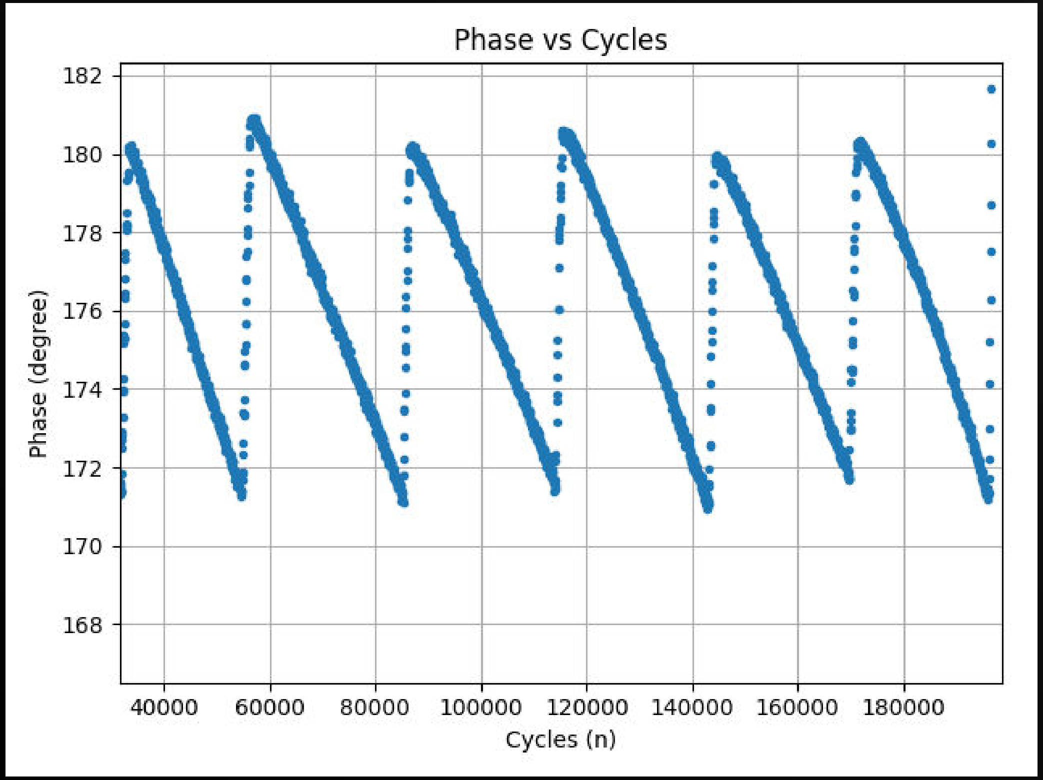
- An example of phase data shows the damage accumulation over the number of cycles.
- Experimental case (M21T700 sample)

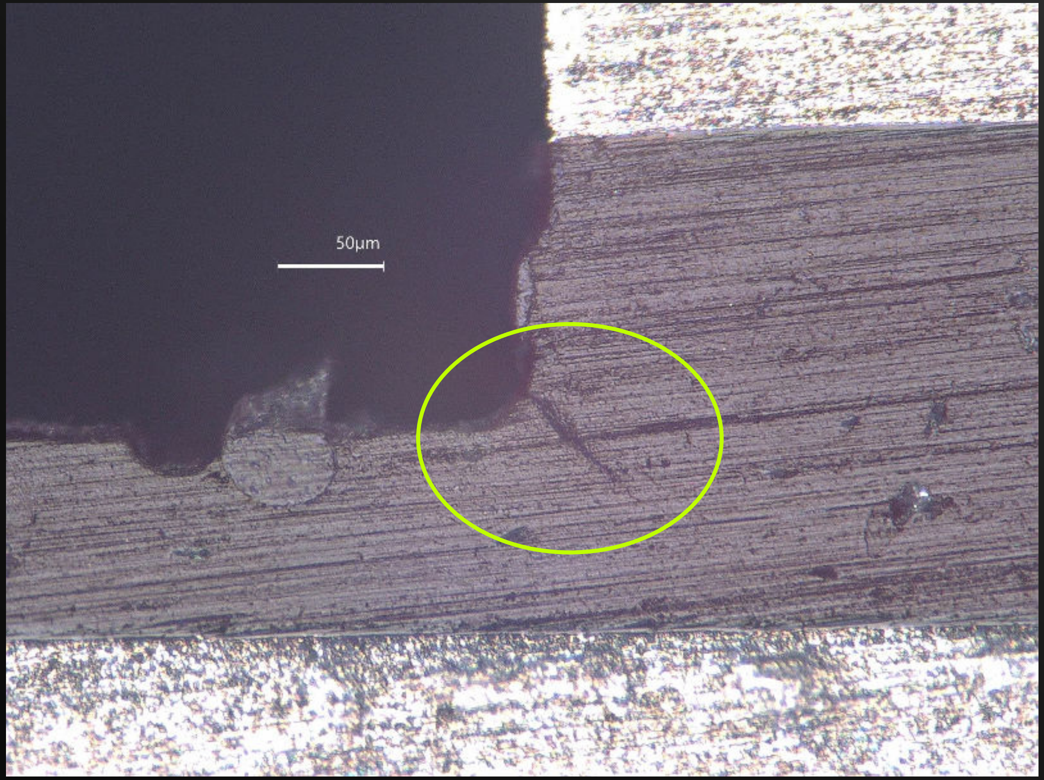




SENSITIVITY TO FATIGUE DAMAGE ONSET

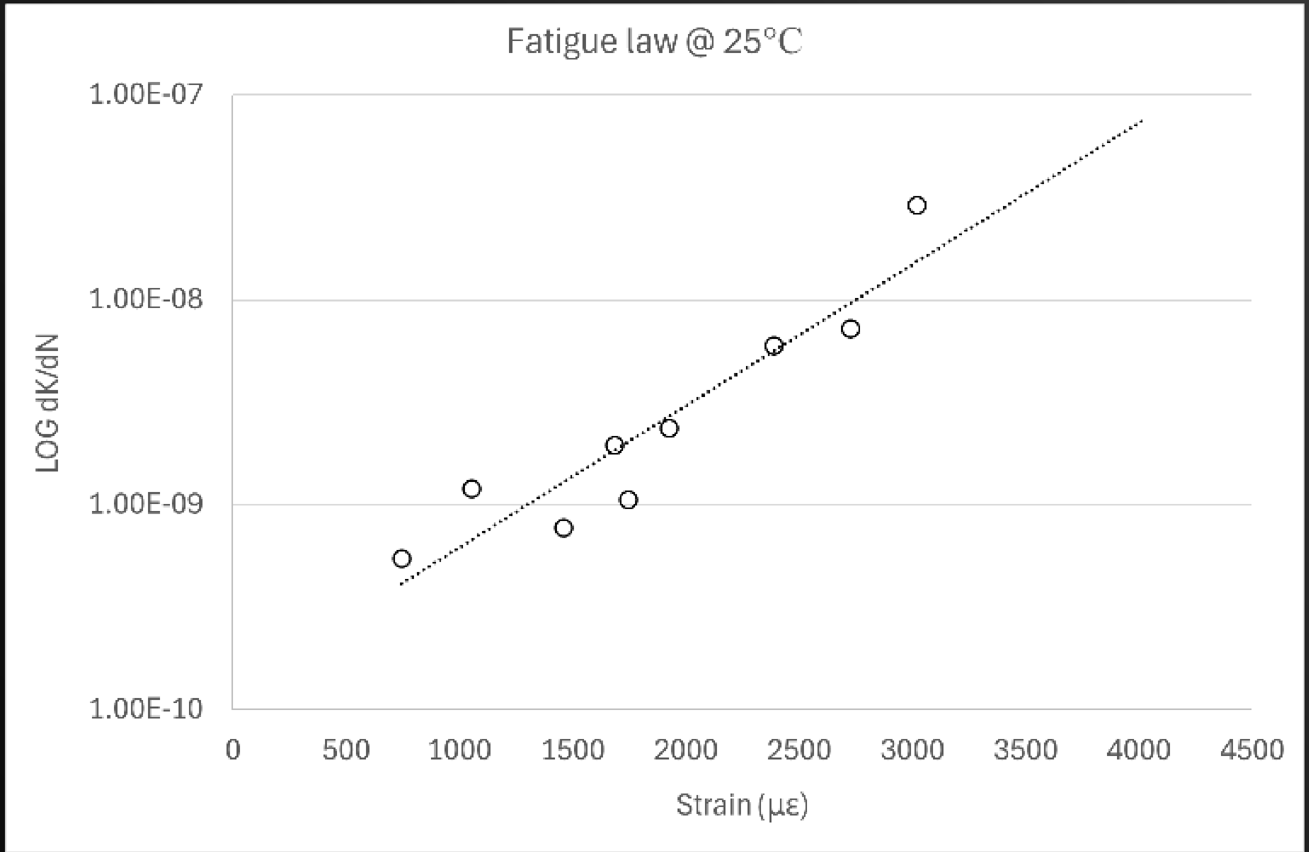
- Lap-joint with adhesive shows a small damage 50 microns after several frequency adjustments for phase tracking.





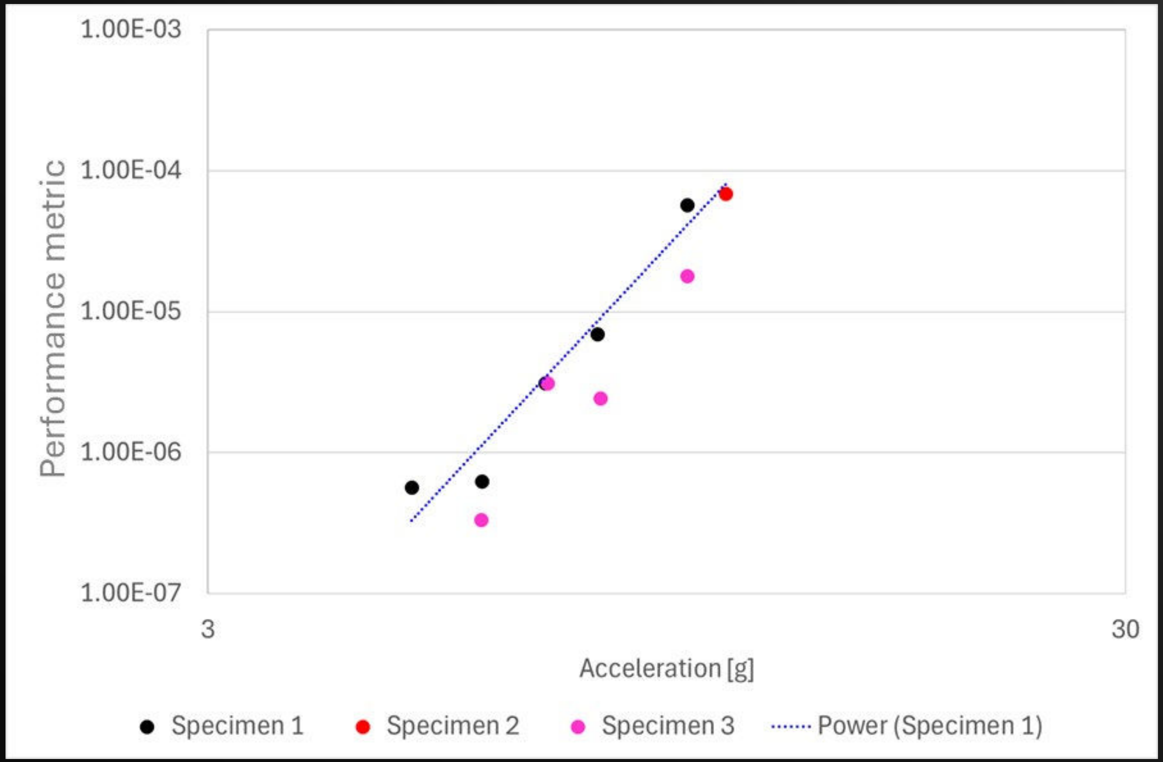
FATIGUE LAW

- The raw data are processed to produce a relationship between the input load and the output loss of stiffness.
- Note that the loss of stiffness is small because of onsets.



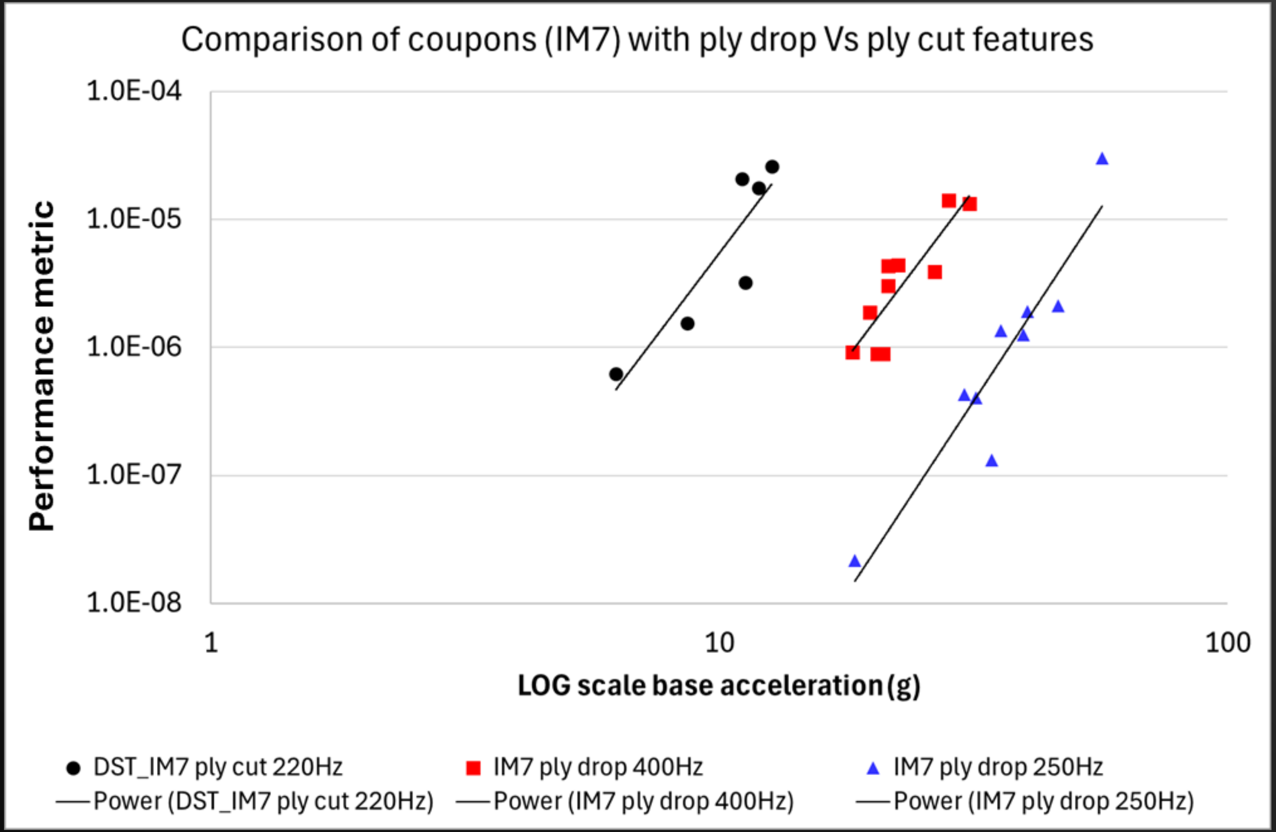
FULL SCALE TESTING

- An incremental step test can be sufficient to define the fatigue law.
- The specimen-2 (red) follows the same power law of specimen-1.



FATIGUE BEHAVIOUR OF STRUCTURES

- Fatigue of different structures can be compared.
- Based on the performance metric, being that measure by stiffness loss or else.



THE APPLICATIONS

The Impact

Fast design comparison

Unlock full material potential

Reduced time to market

XCTE.eu

Testing at the speed of innovation

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Linkedin: www.linkedin.com/company/xcte/