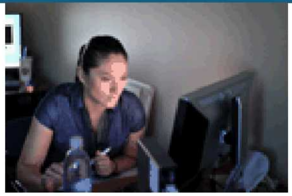
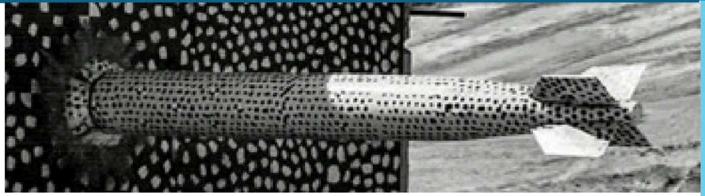
SAND2019-10178C

Detection of Precursors to Damage in Aerostructures





PRESENTED BY

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Collaborators University of Twente

Laura Cordova Gonzalez, Dario Di Maio, Kasper van Loobergen, Tiedo Tinga

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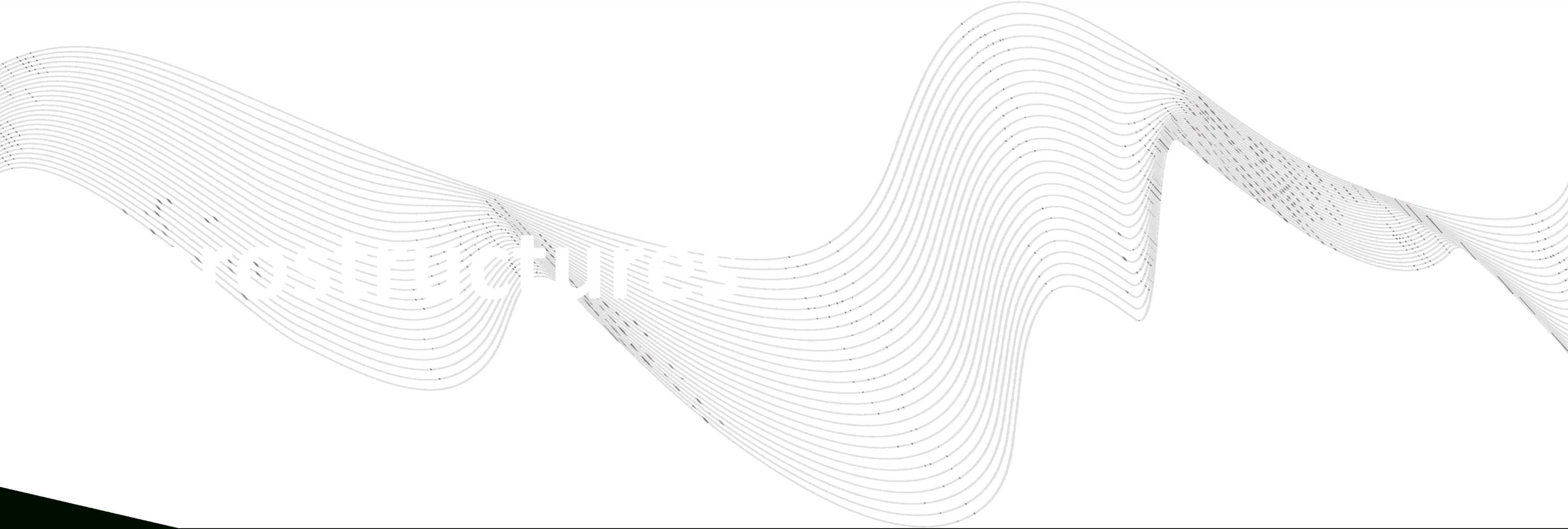
ostructures

Aerostructures: Additive Manufacturing

Advantages:
- Optimized structures
- Multifunctionality

Consequences:
- Nonlinearities
- Fatigue
- Complexity

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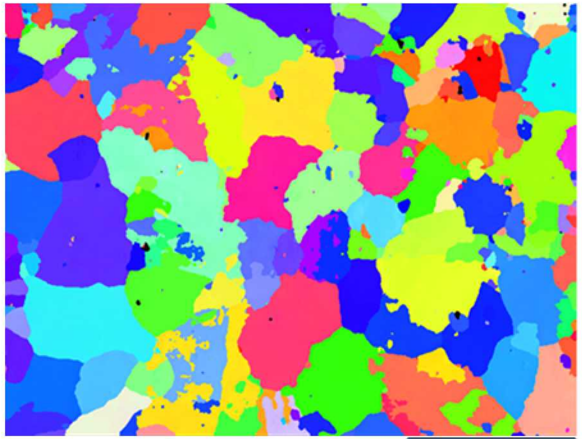
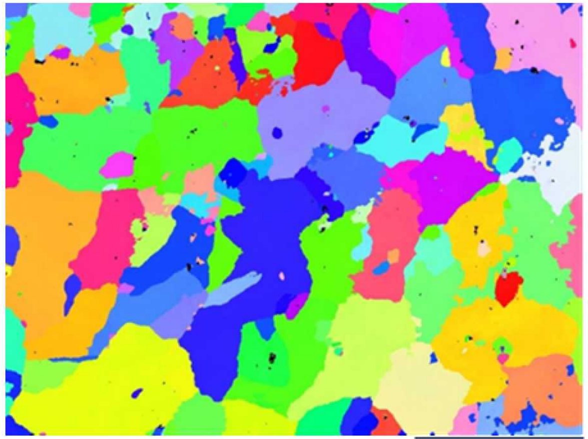
Technical Gaps: Material Behavior Due to Vibration

Al7075

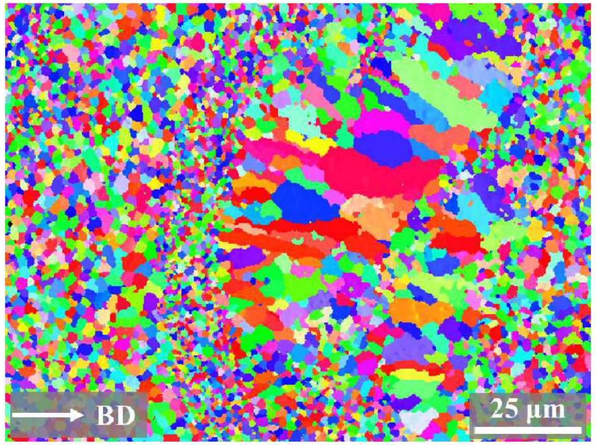


Non fatigued 250µm

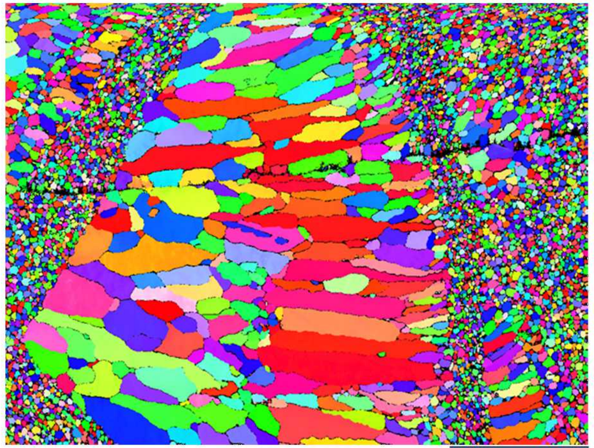


fatigued 250µm

Scalmalloy



Non fatigued



fatigued mini-crack 25 µm

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MATERIALS — STRUCTURES — DYNAMICS

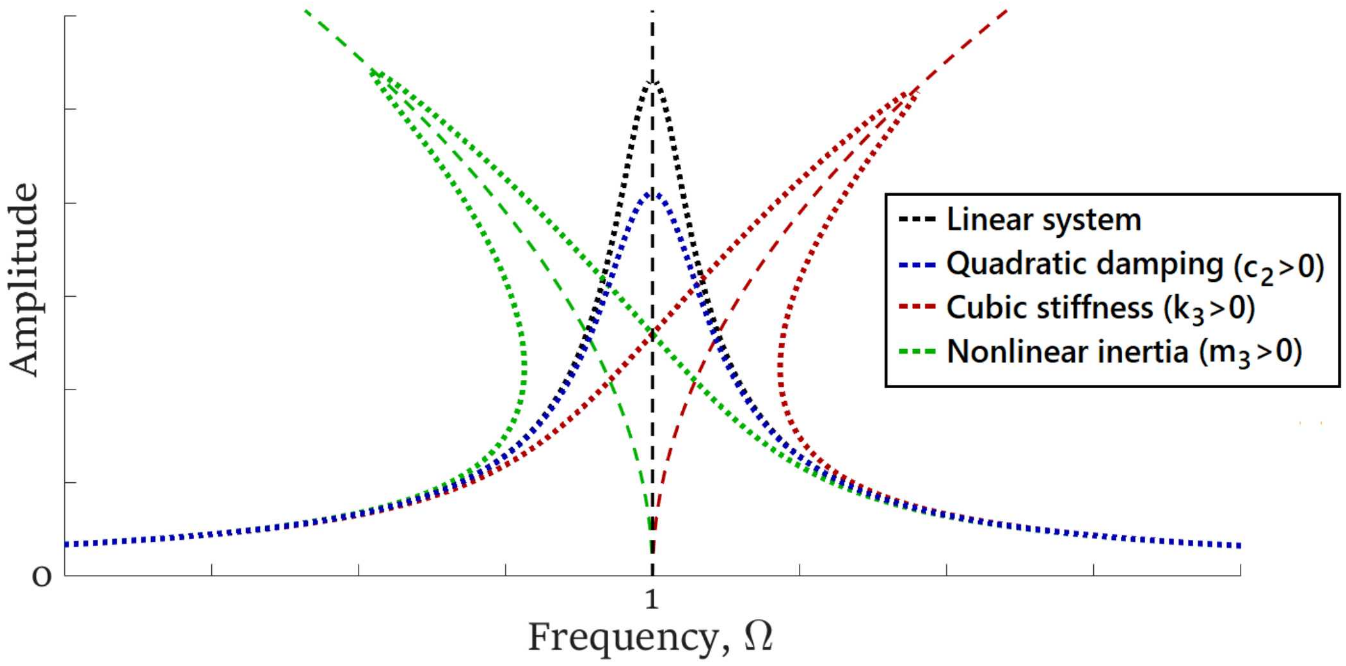
Technical Gaps: Global Manifestation

$$\ddot{y} + c_1\dot{y} + k_1 y + F_n(y, \dot{y}, \ddot{y}) = F_e + F_b$$

$$F_n(y, \dot{y}, \ddot{y}) = F_{ni} + F_{nd} + F_{nr}$$

F_{ni} : inertial, F_{nd}: damping, F_{nr}: Stiffness

- Most SHM assume linear behavior
- Nonlinear parameters sensitive to damage precursors



Carrella & Ewins, *Mechanical Systems and Signal Processing,* 2011
Haynes et al., *IMAC*, 2019

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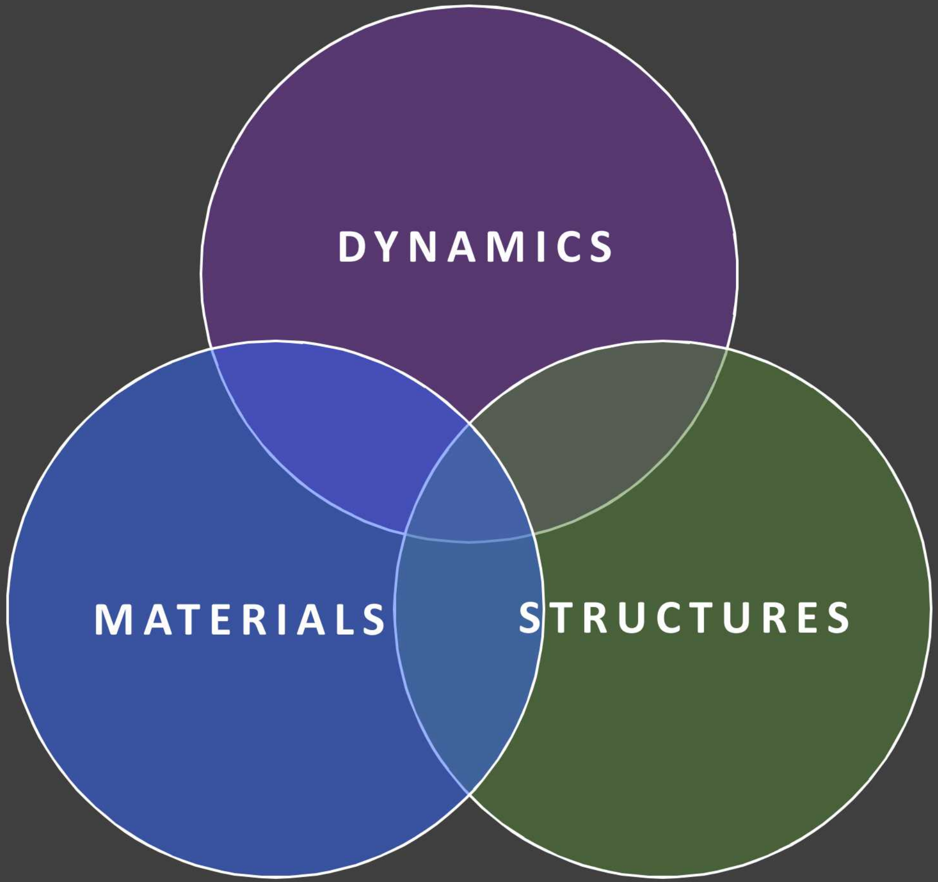
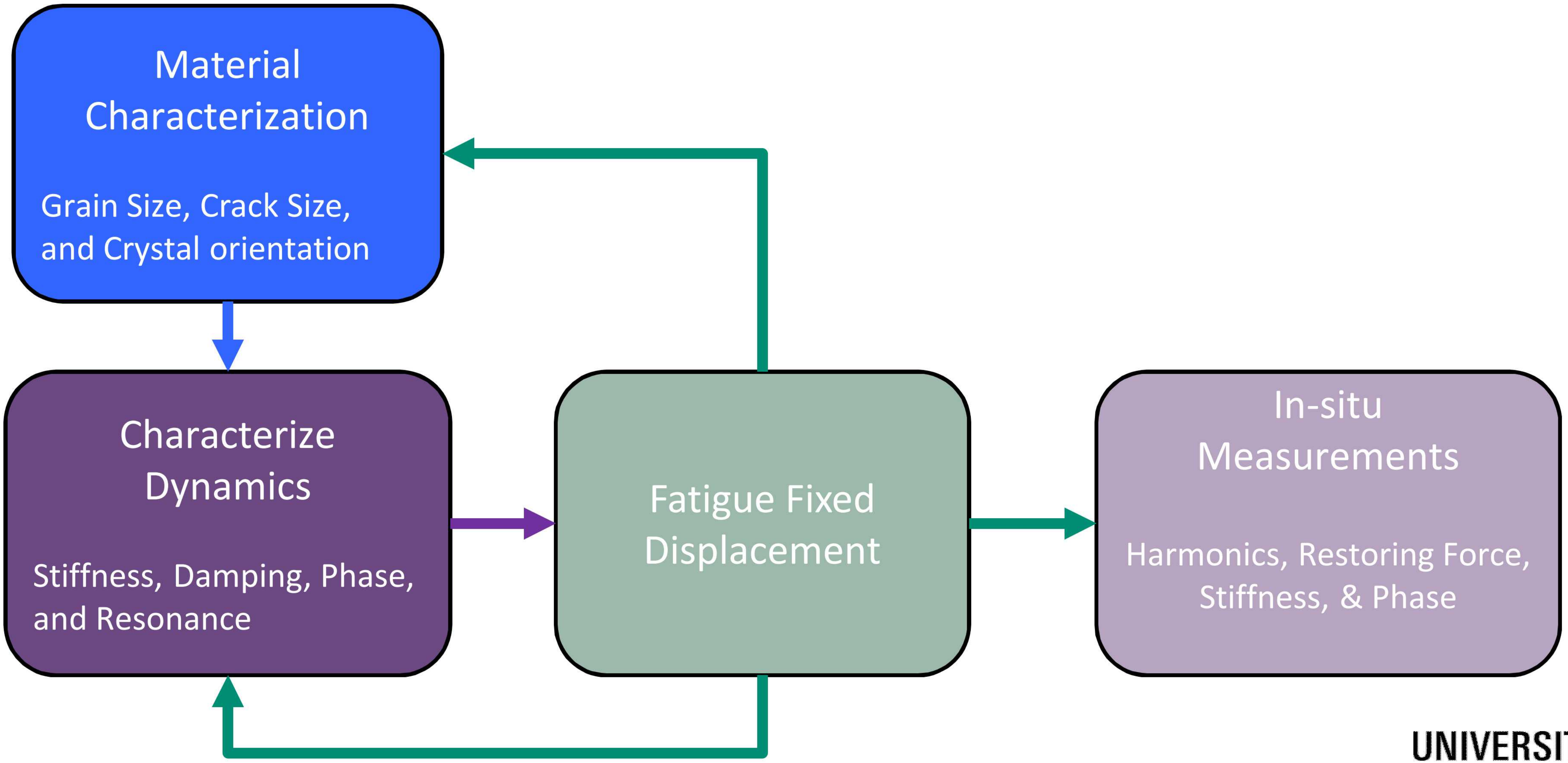
MATERIALS STRUCTURES DYNAMICS

PPROACH



Approach: Connecting Nonlinearities

Approach



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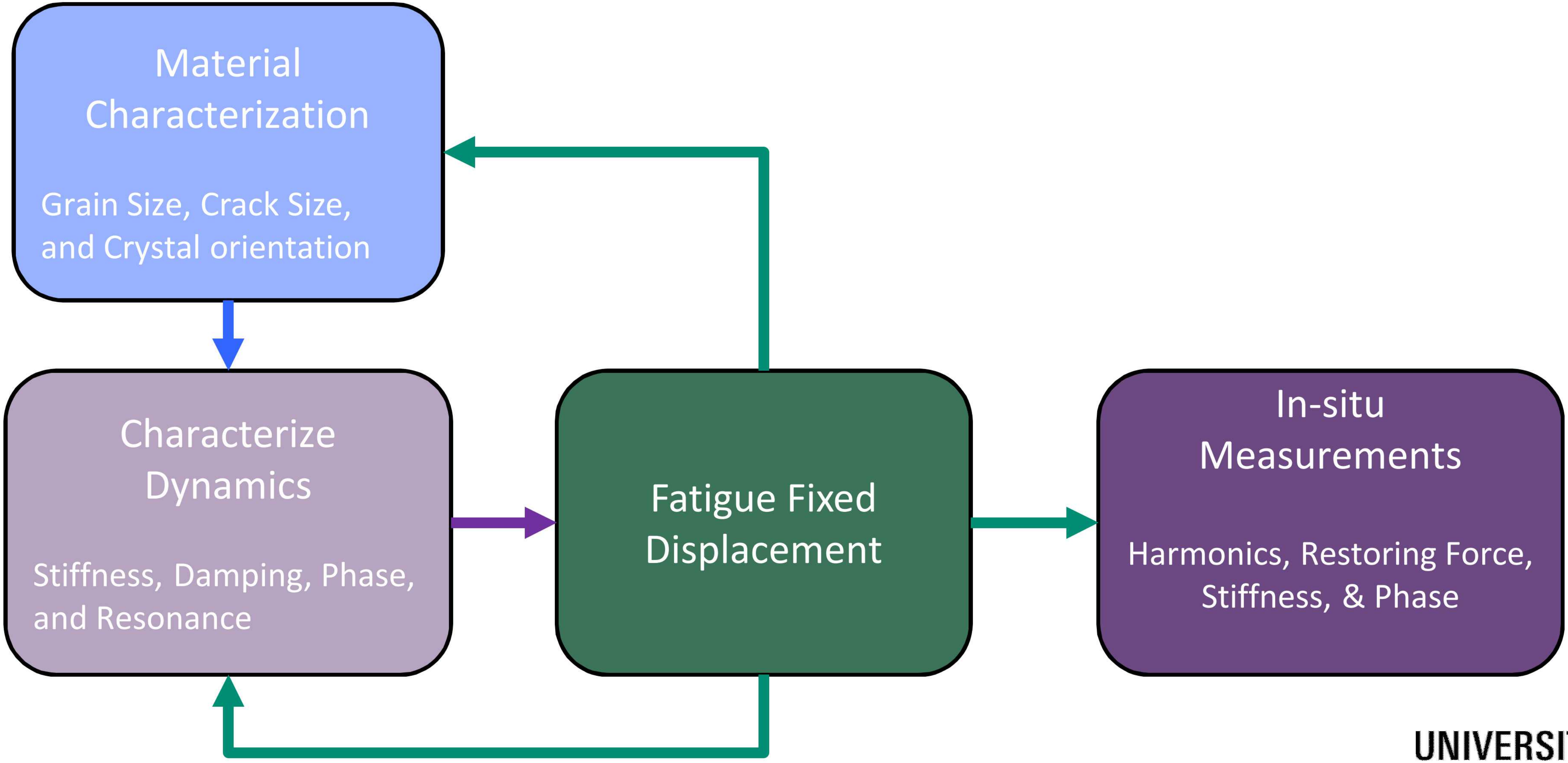
Approach



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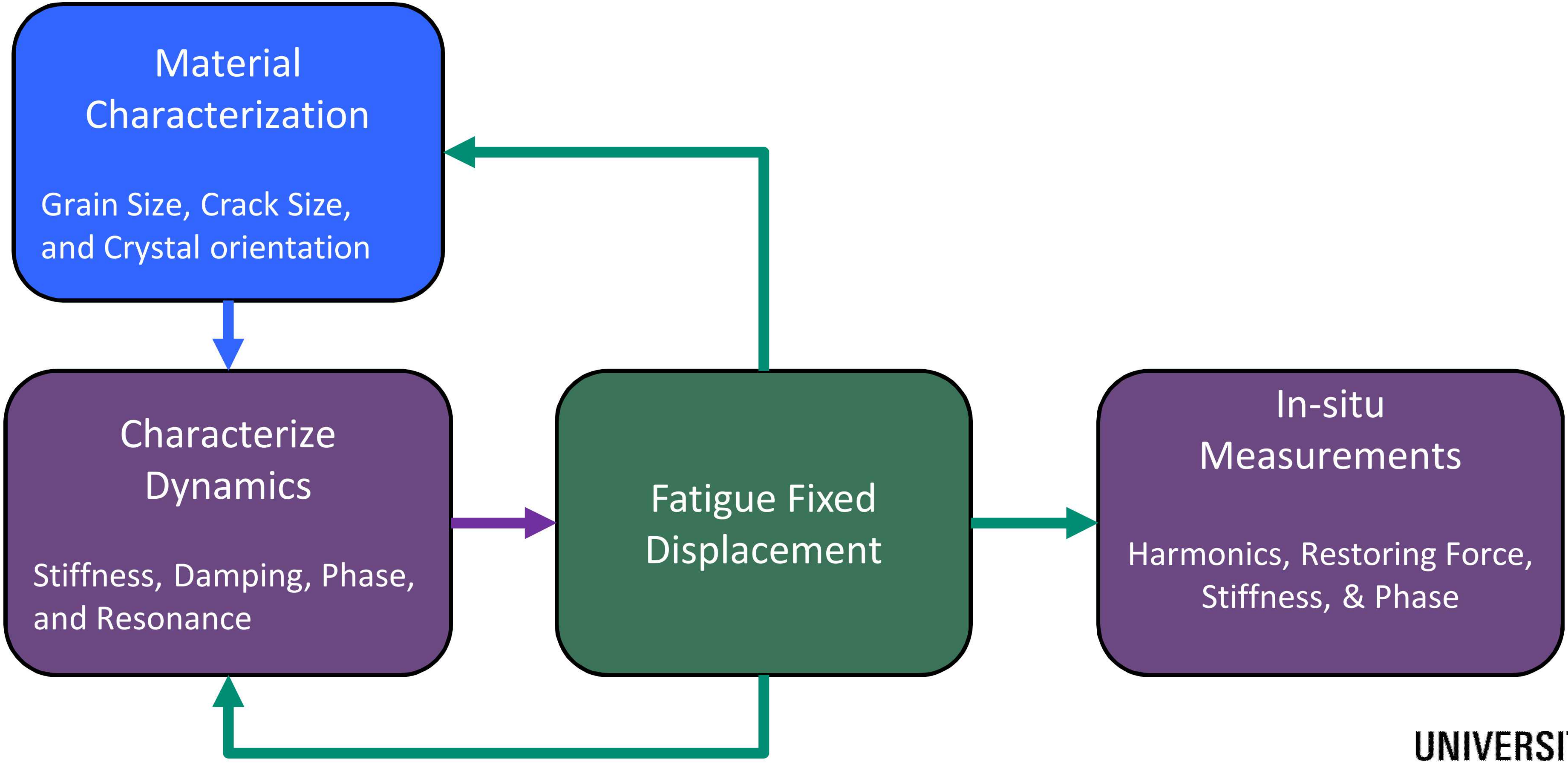
Approach



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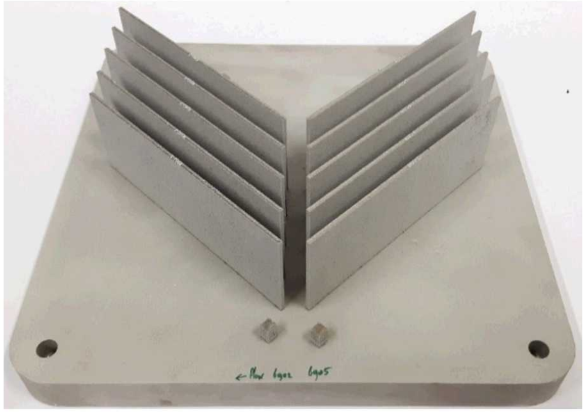
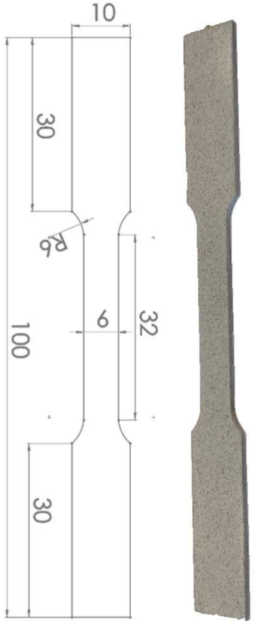
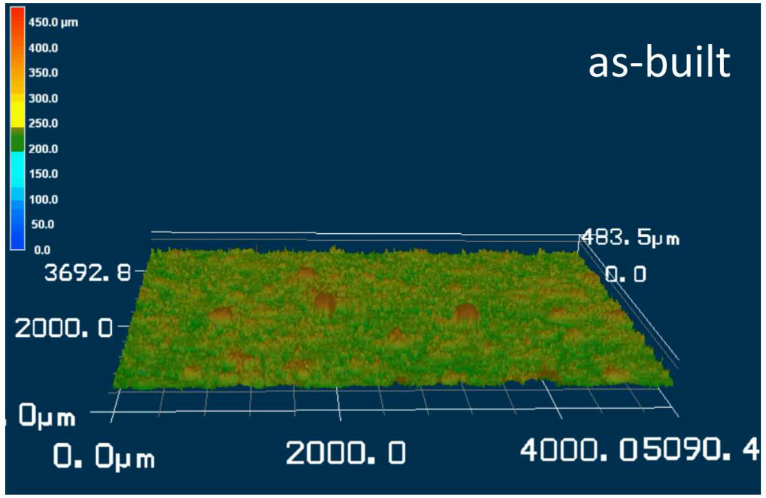
XPERIMEN

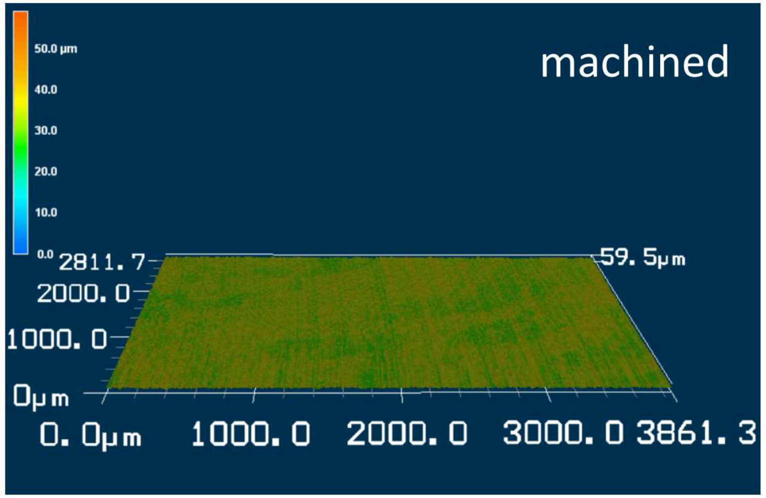
Experiments: Materials Characterization





Macro-specimens
ASTM standard
Sub-sized





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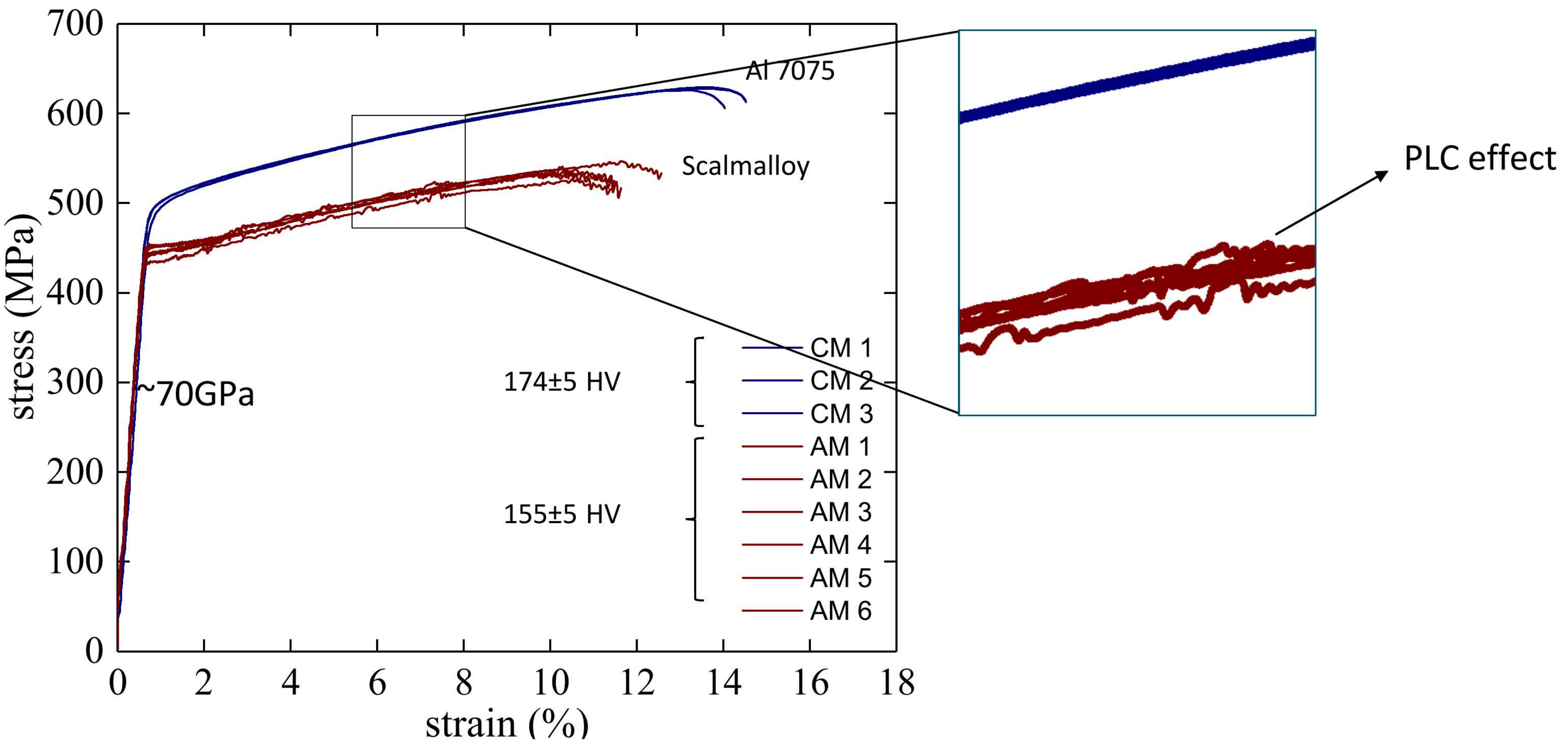
Experiments: Materials Characterization



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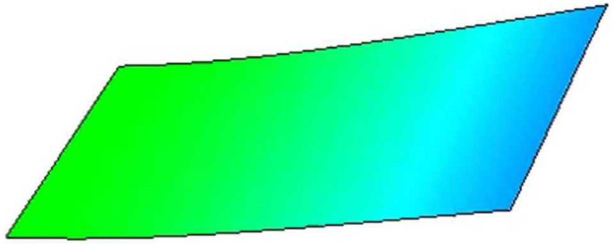
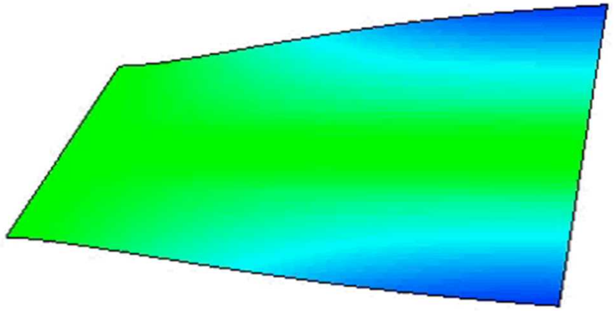
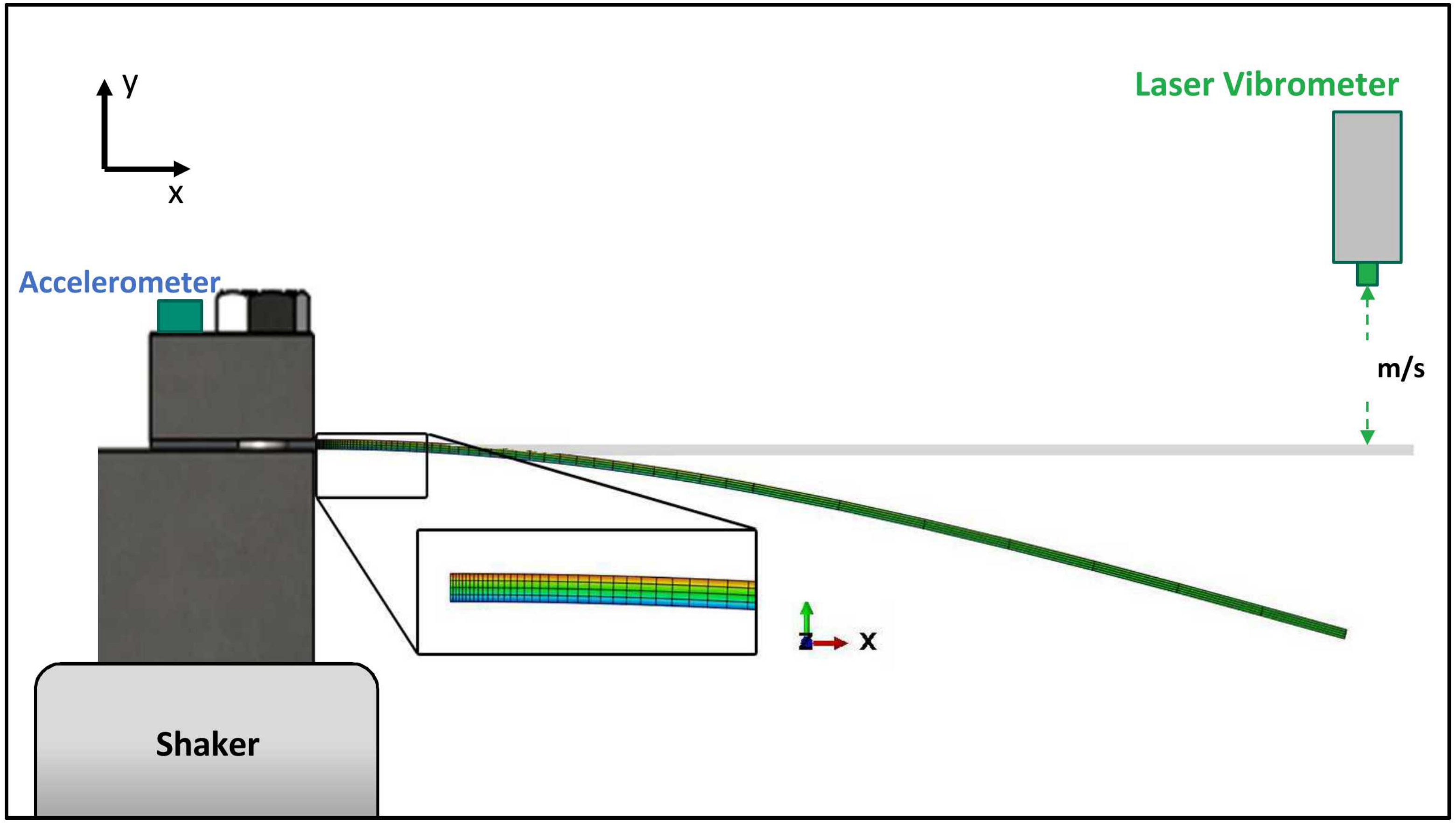
Experiments: Setup



Mode I ω_1



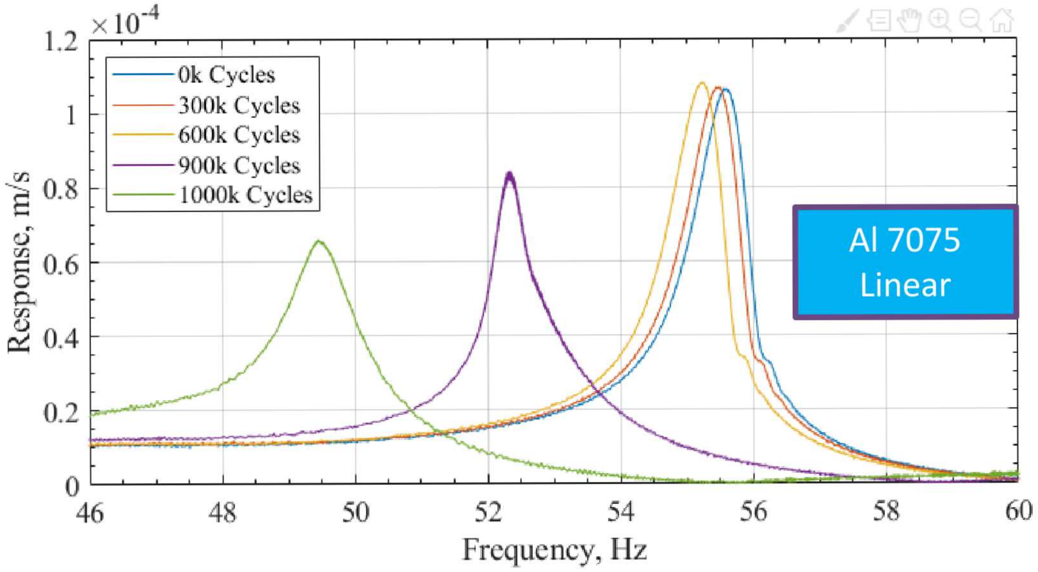
Mode II $5.0 \cdot \omega_1$

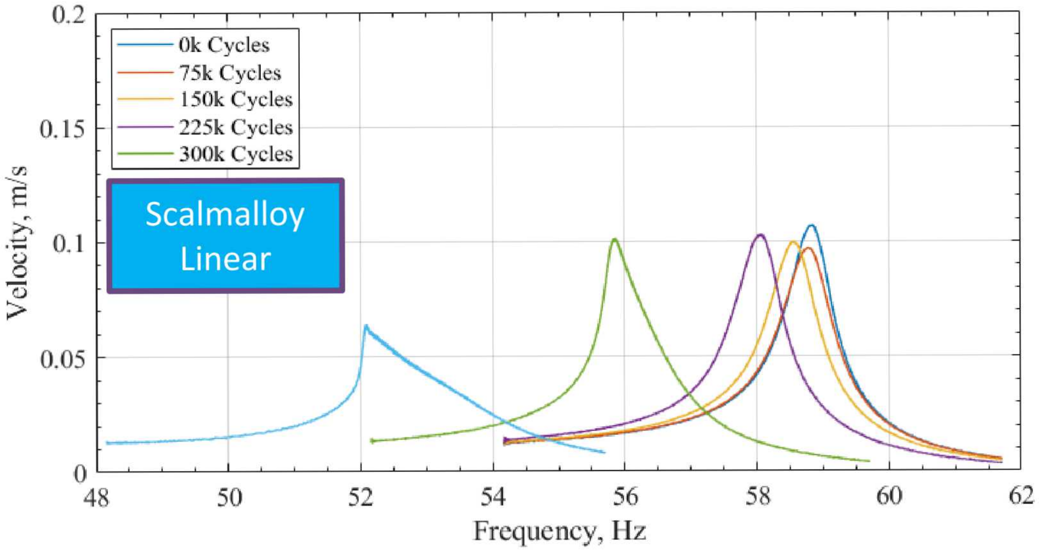


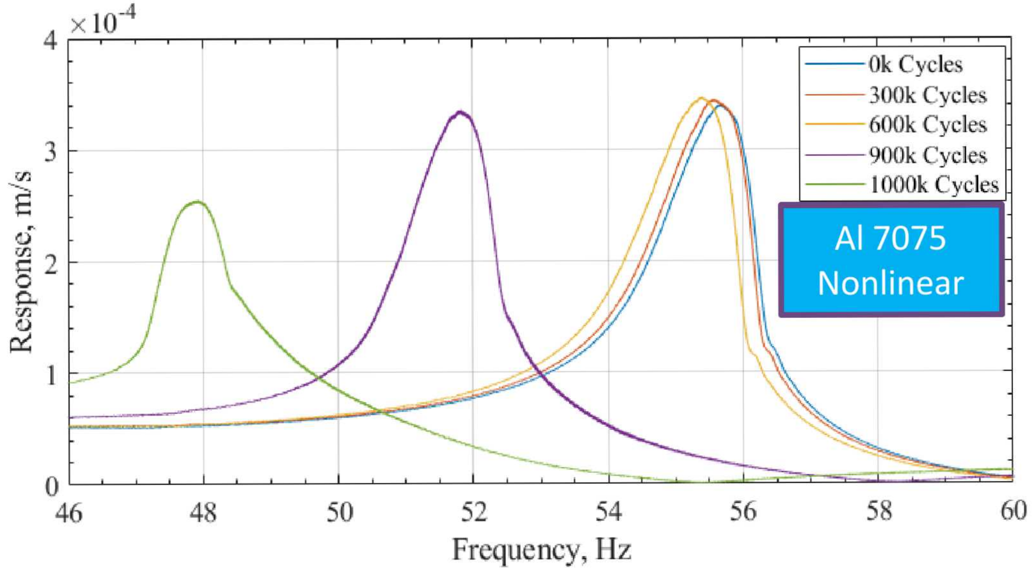
Habtour et al., *ISMA*, 2018

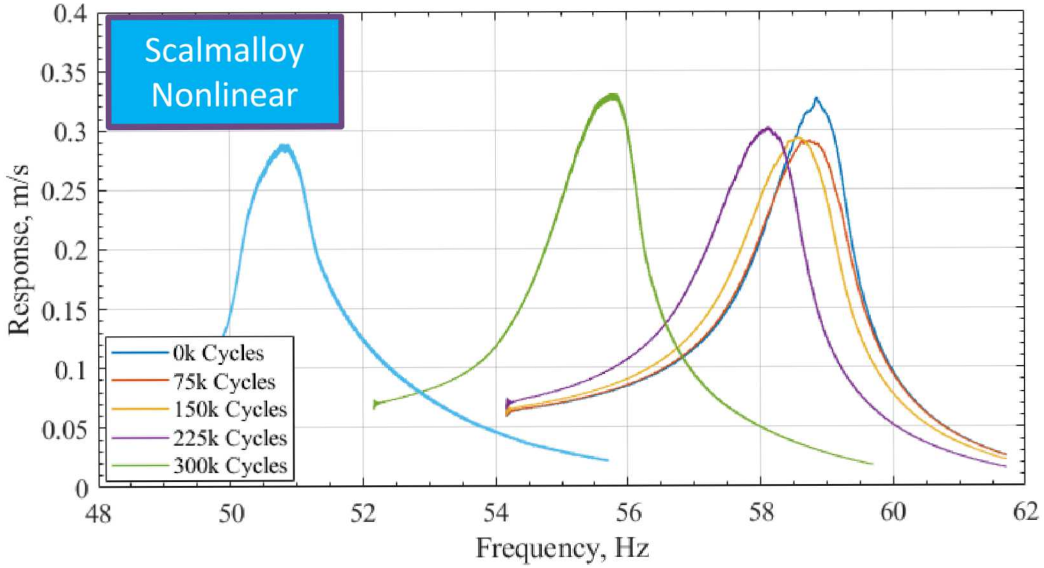
SULTS

Results: Linear vs Nonlinear Dynamics









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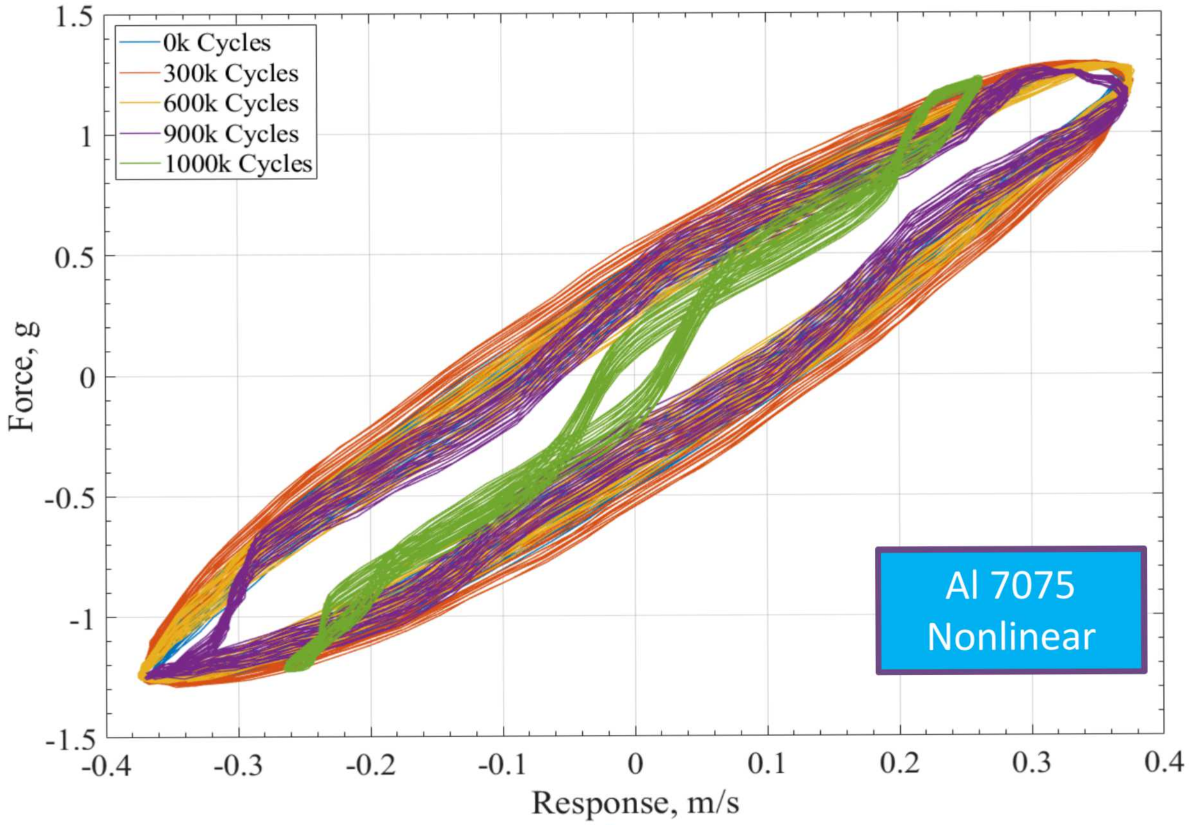
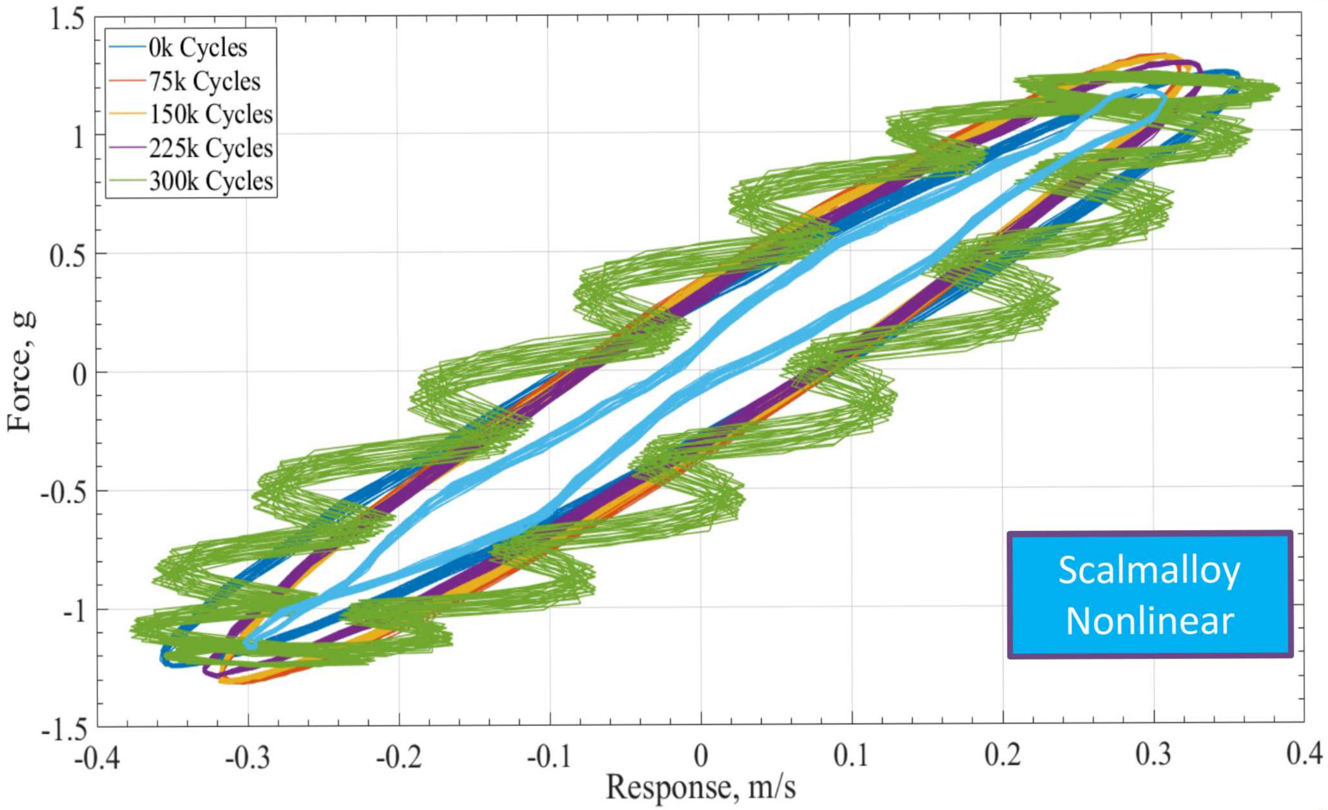
Results: Energy Dissipation

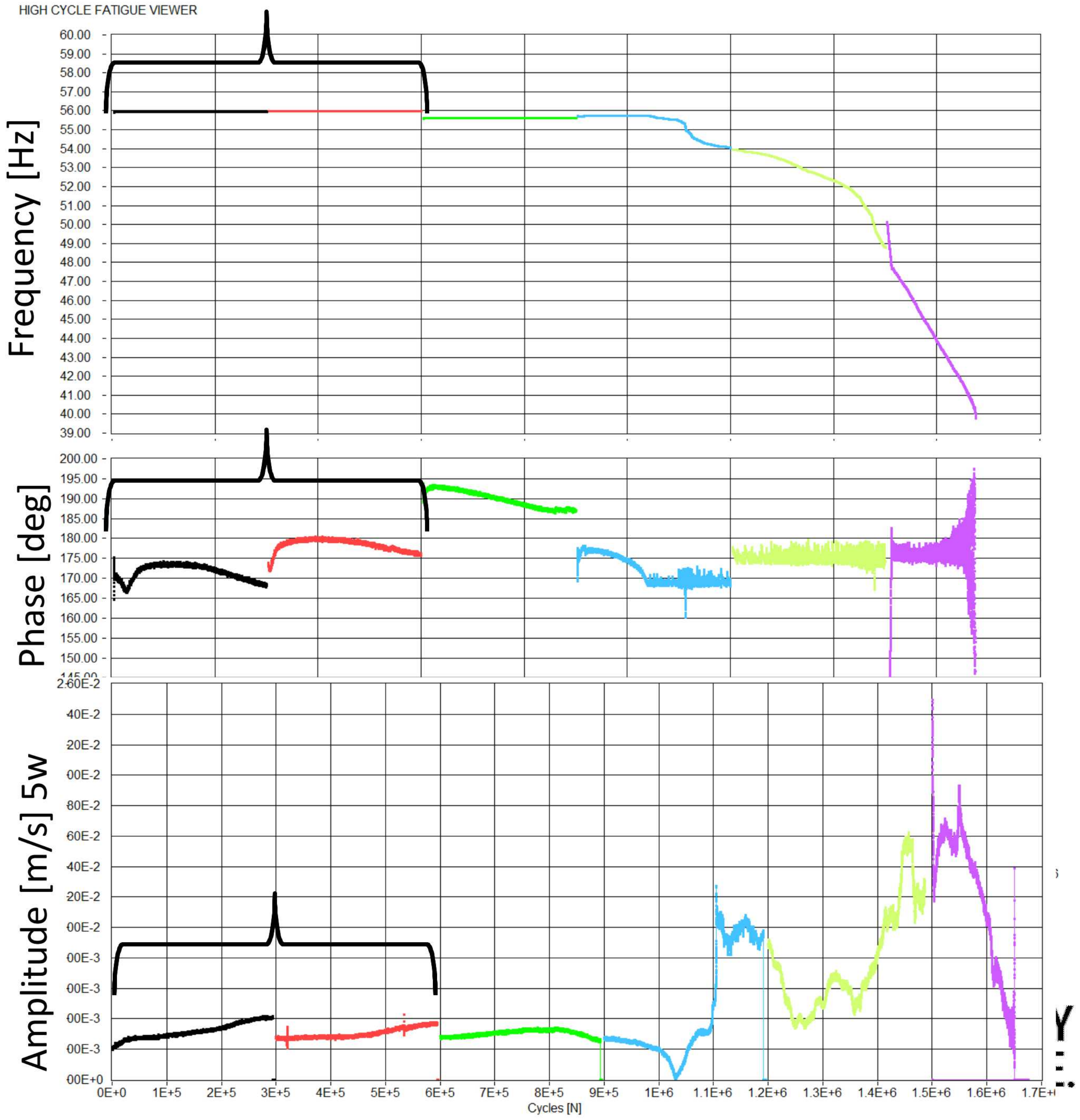




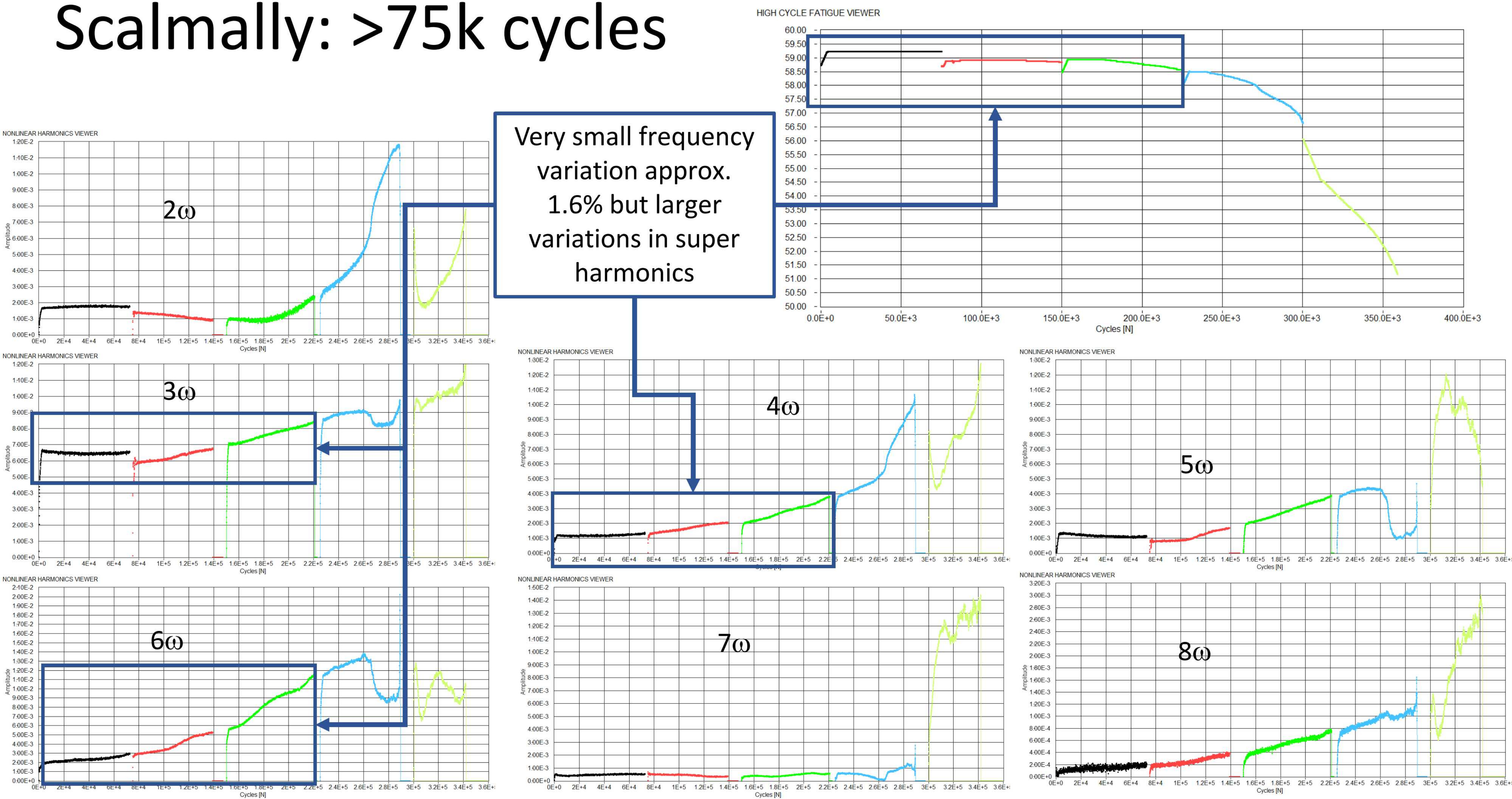
Results: Harmonics Al7075

high order harmonics show changes from the pristine conditions, but no resonance change

Super-harmonics can be used to track damage precursors



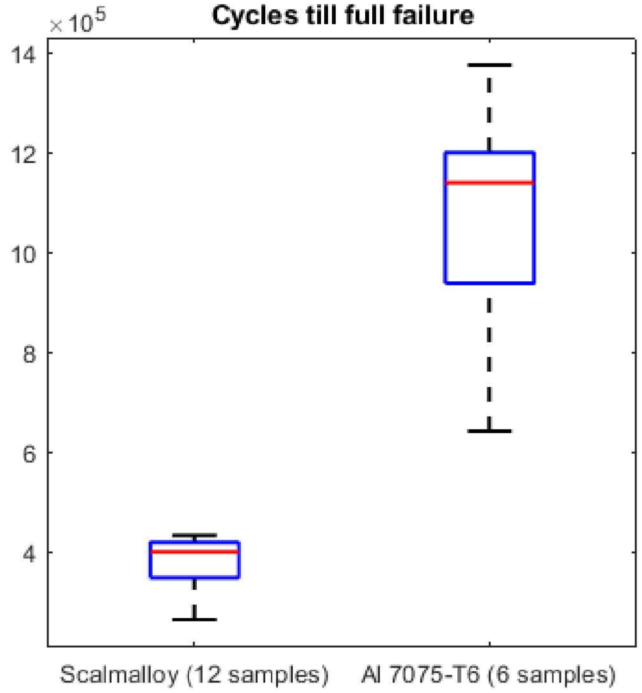
Scalmally: >75k cycles

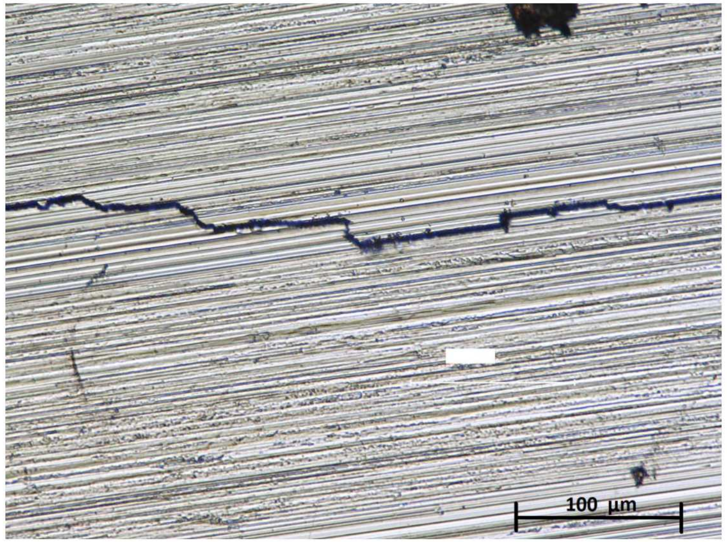


Very small frequency variation approx. 1.6% but larger variations in super harmonics

Results: Material Degradation

- Al 7075-T6: minor fatigue cracking around ~ 300.000 cycles
- Scalmalloy: beginning fatigue cracks around ~ 150.000 cycles
- Crack initiated at surface could be due to boundary conditions
- Machining pattern in Scalmalloy may influenced direction of crack growth





Scalmalloy after ~ 350k cycles

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CONCLUSION

Conclusions

Nonlinear parameters are sensitive to evolution of fatigue damage:

- Effective stiffness, high harmonics, phase
- Energy dissipation can be calculated

Al 7075 fatigue life is much higher than Scalmalloy, but:

- Scalmalloy results are more repeatable
- Nonlinear parameters can be more effective
- Prior understanding of the mechanics is required

Future Work:

- Relate parameters to materials micromechanics, mathematically
- Additional material characterization: AFM, nano-indentation, …

Reference

[1] Habtour, E. M., Cole, D. P., Kube, C. M., Henry, T. C., Haynes, R. A., Gardea, F., Sano, T., Tinga, T. (2019). “Structural state awareness through integration of global dynamic and local material behavior”. *Journal of Intelligent Material Systems and Structures*.

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[6] Habtour, E., Cole, D. P., Stanton, S. C., Sridharan, R., & Dasgupta, A. (2016). Damage precursor detection for structures subjected to rotational base vibration. *International Journal of Non-Linear Mechanics, 82, 49-58.*

[7] Habtour, E., Dragman, T., Masmeijer, T., Di Maio, D., Haynes, R., Homborg, A. M., & Tinga, T. (2018). Connecting nonlinearities: Damage precursors detection and control methodology. *In 28th International Conference on Noise and Vibration Engineering (ISMA 2018) (pp. 3597-3605). KU Leuven.*

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