Analyse der Vibrationsausbreitung mit der Strukturintensität

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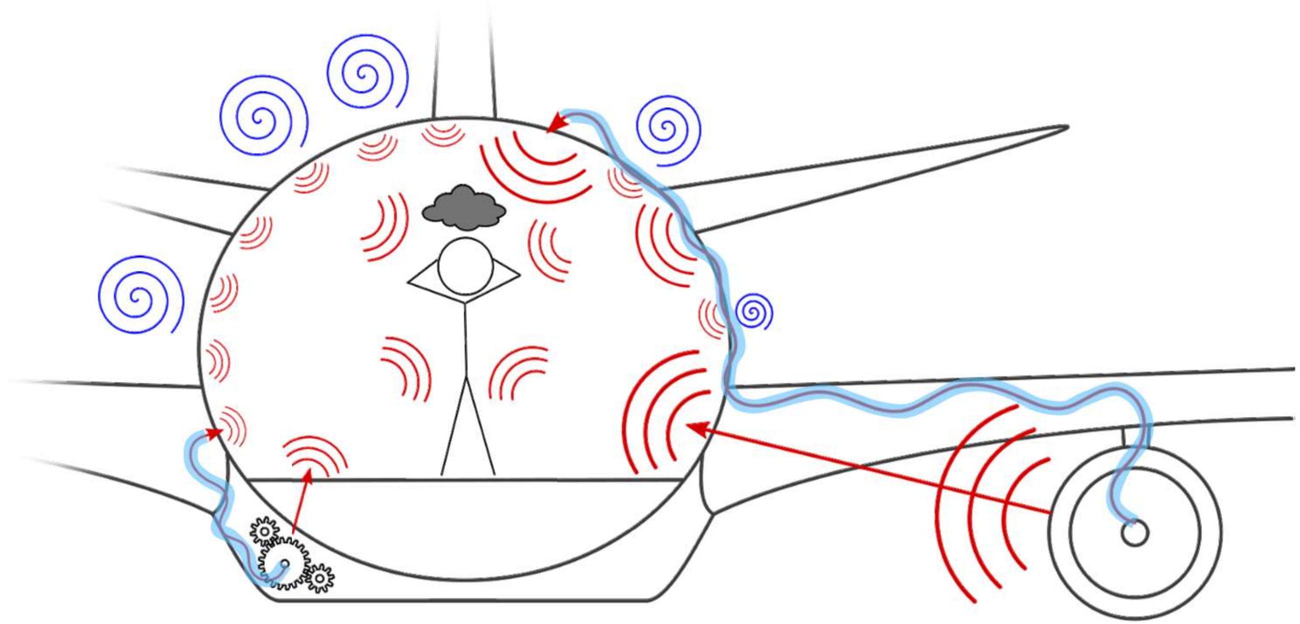
DLR

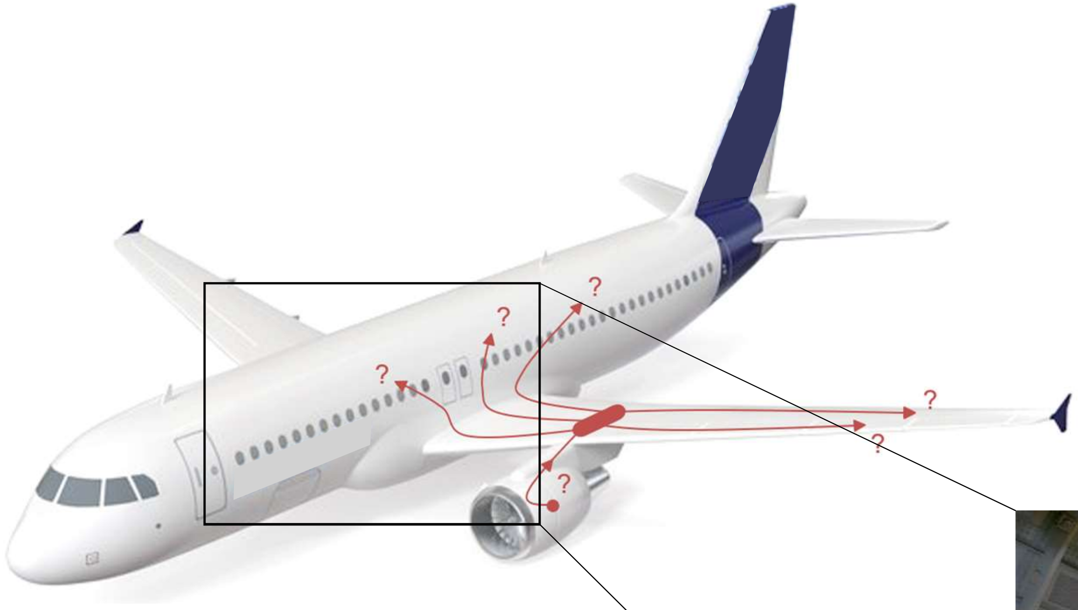
Motivation
Cabin acoustics

Noise sources

- Turbulent boundary layer
- Engines & Subsystems
  - Noise transmission
  - Vibration induced noise



Motivation
Unknown paths in aircraft fuselages



- Which fuselage areas lead to noise emission into the cabin cavitiy?
- Which paths does vibrational energy take?
- Where to consider counter measure installation?

Content

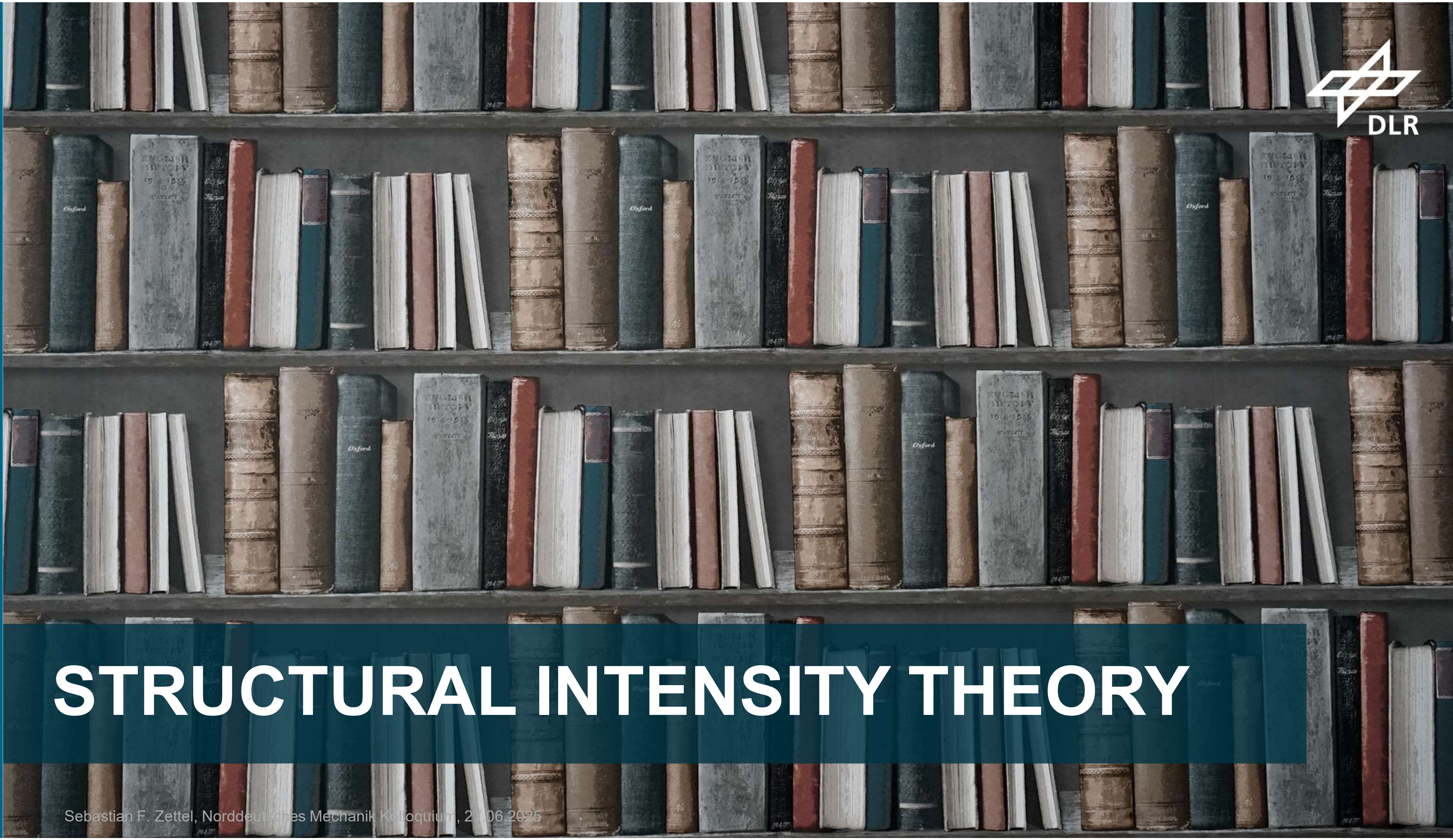
Fundamentals of structural intensity and estimation challenges

Assessing structural intensity based on structural response measurements

Relevant post-processing methods for identifying sources, sinks and paths

State-of-the-art

Ongoing



STRUCTURAL INTENSITY THEORY

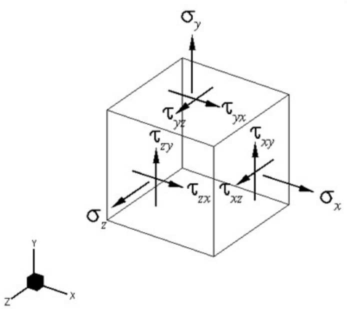
Structural intensity at a glance

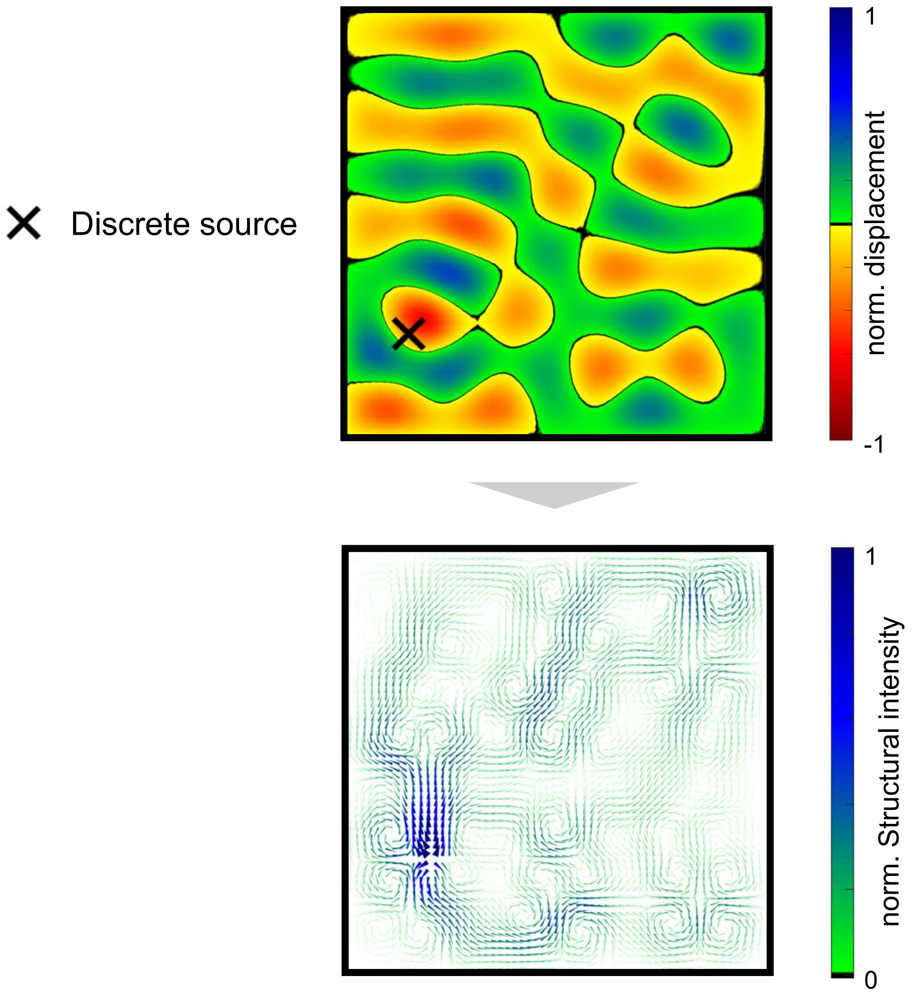
Fundamental idea

Vector quantity indicating the wave power per area in propagation direction $\left[\frac{W}{m^2}\right]$

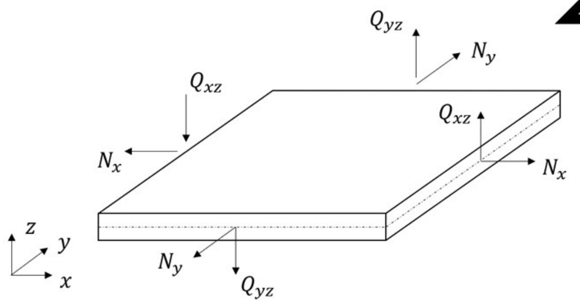
Structural Intensity (STI)

$$\vec{I} = -\Re\{\boldsymbol{S} \cdot \vec{v}\} = -\Re\left\{\begin{bmatrix} \sigma_{xx} & \tau_{xy} & \tau_{xz} \\ \tau_{yx} & \sigma_{yy} & \tau_{yz} \\ \tau_{zx} & \tau_{zy} & \sigma_{zz} \end{bmatrix}\begin{bmatrix} v_x \\ v_y \\ v_z \end{bmatrix}\right\}$$



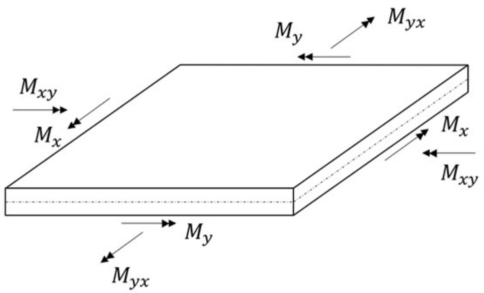


Estimating Structural Intensity from measurement data



$$\vec{I}_{Shell} = -\frac{1}{A}\Re\left\{\begin{bmatrix} N_x & N_{xy} & Q_{xz} \\ N_{yx} & N_y & Q_{yz} \\ 0 & 0 & 0 \end{bmatrix}\begin{bmatrix} v_x \\ v_y \\ v_z \end{bmatrix} + \begin{bmatrix} M_{xy} & M_x & 0 \\ M_y & M_{yx} & 0 \\ 0 & 0 & 0 \end{bmatrix}\begin{bmatrix} \omega_x \\ \omega_y \\ 0 \end{bmatrix}\right\}$$

Unit $[\frac{W}{m^2}]$



1) Assuming thin walled structures (z-components neglected)
2) Measurement values v_x, v_y, v_z
3) Values necessary to estimate

ESTIMATION FROM MEASUREMENT DATA

FUSELAGE VIBRATION

Structural intensity analysis

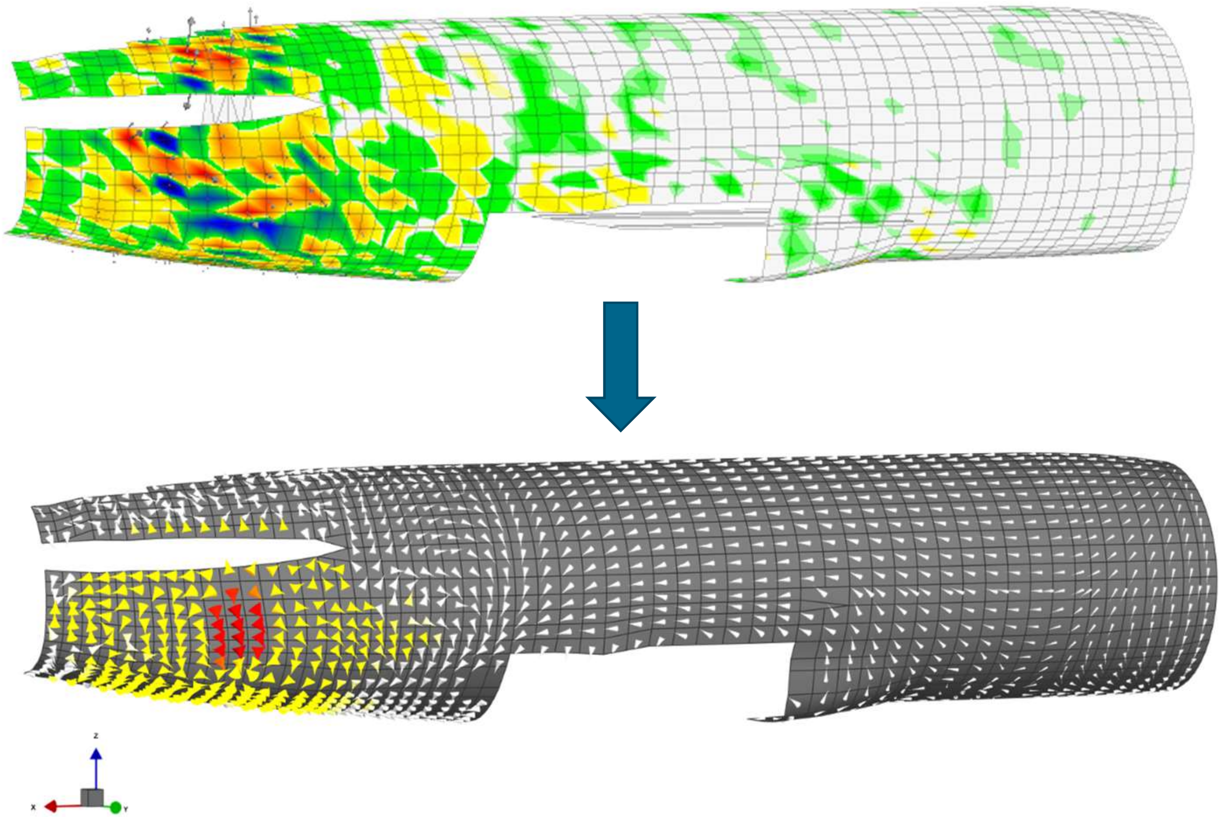
Shaker excitation on pylon

Winter, R., Norambuena, M., Sinske, J., Zettel, S.F. (2023). "High-resolution vibroacoustic characterization of DLR's Falcon 2000LX ISTAR aircraft." CEAS Aeronautical Journal.

Structural intensity analysis

Shaker excitation on pylon

274 Hz



Winter, R., Norambuena, M., Sinske, J., Zettel, S.F. (2023). "High-resolution vibroacoustic characterization of DLR's Falcon 2000LX ISTAR aircraft." CEAS Aeronautical Journal.

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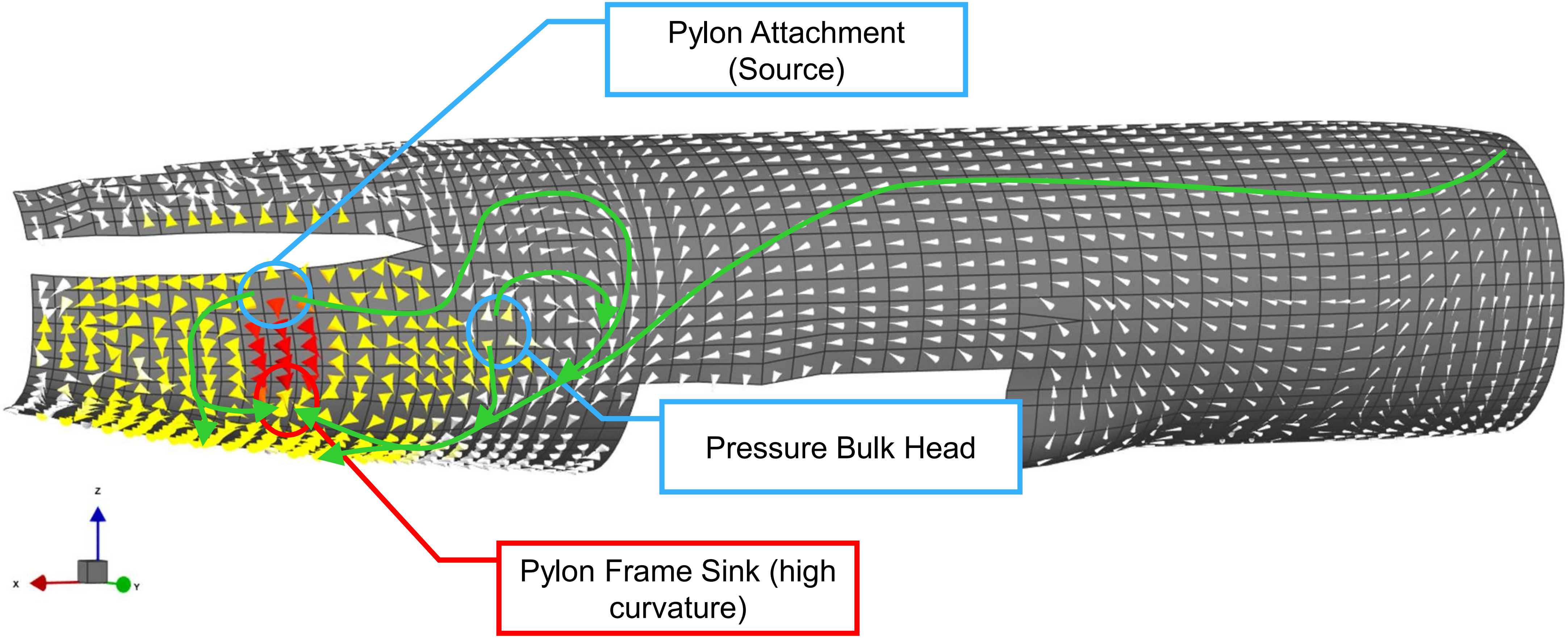

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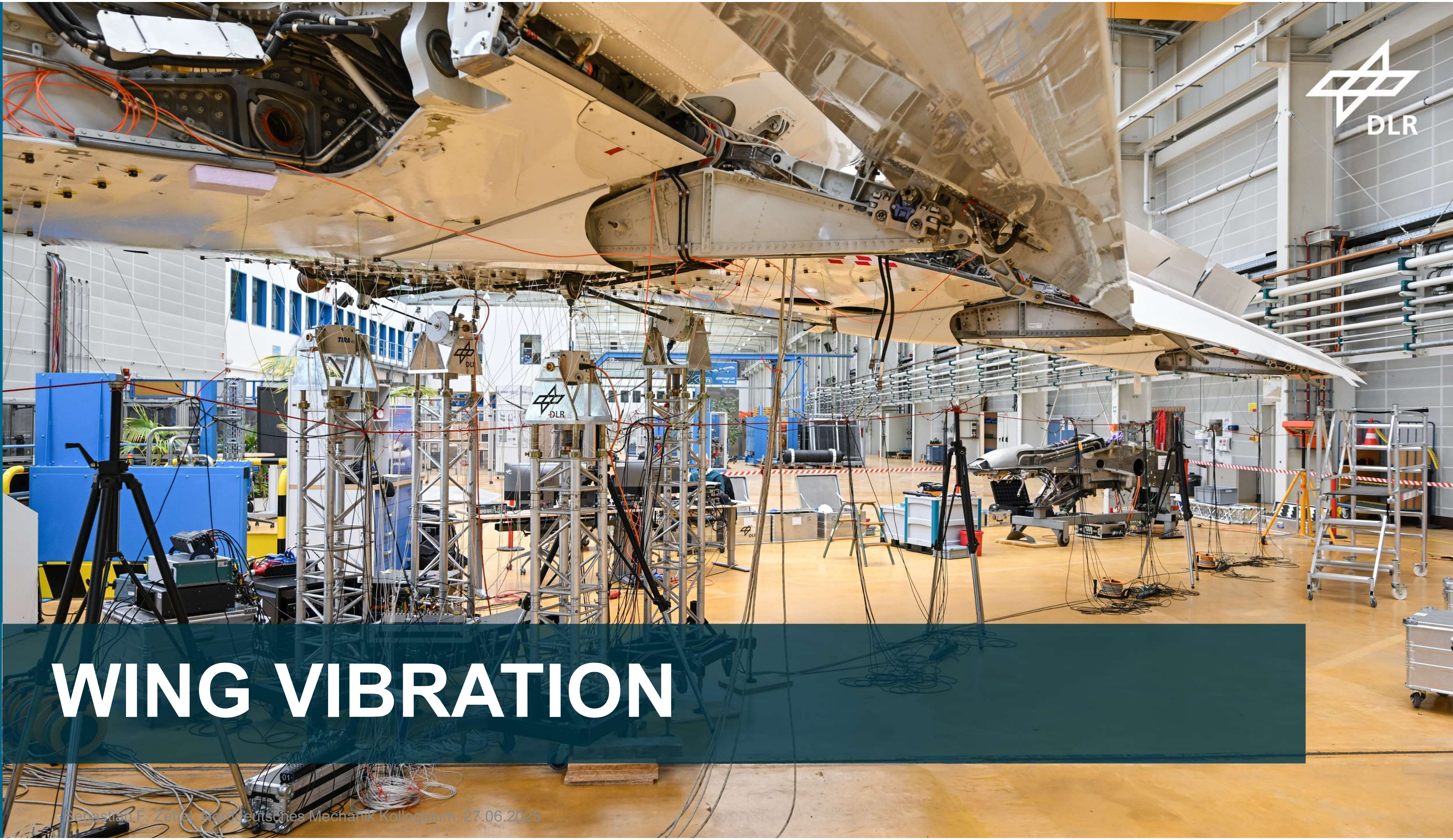
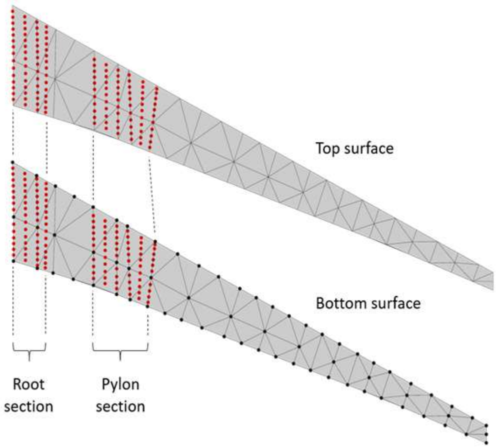
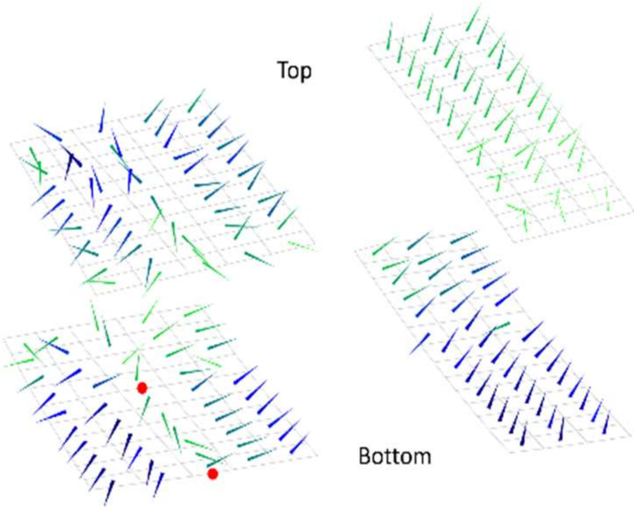


WING VIBRATION

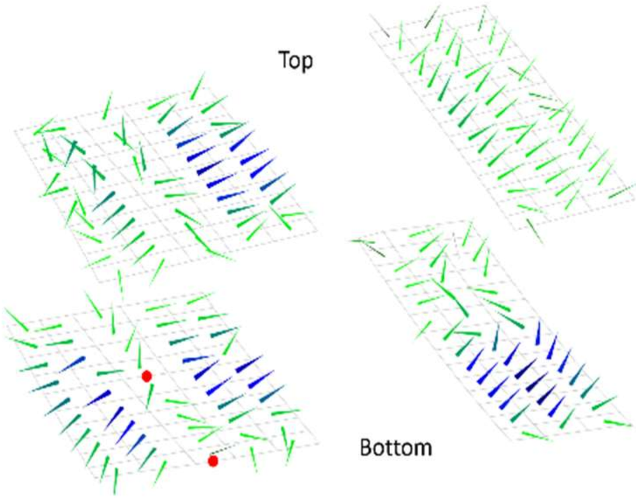
A320 wing on support structure

Structural intensity field





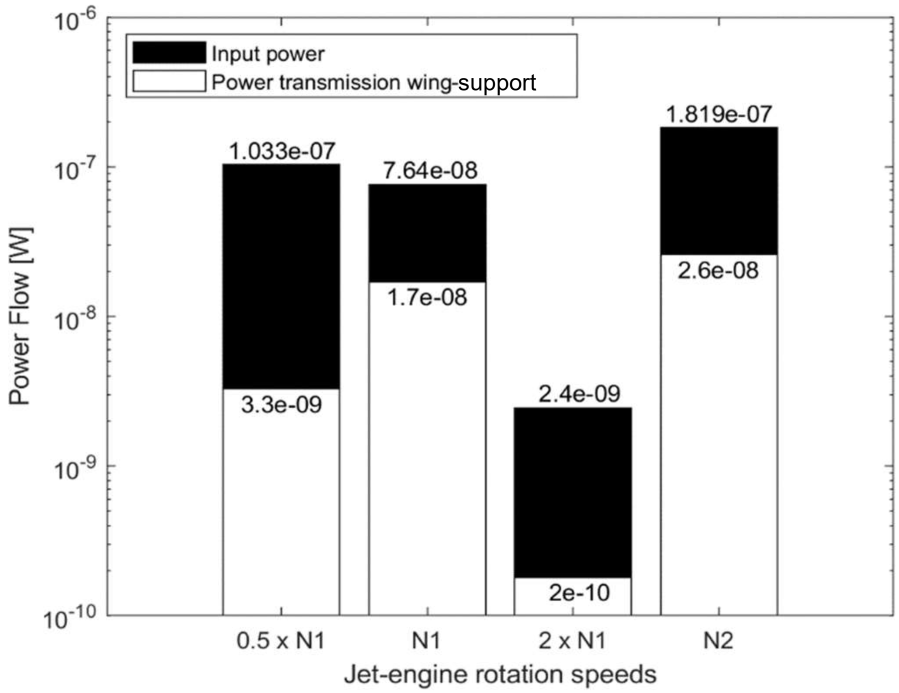
Jet engine N1 frequency
(71 Hz)



Jet engine N2 frequency
(407 Hz)

M. Norambuena, S. Zettel, R. Dewald und R. Winter, „Experimental Vibroacoustic Characterization of an A320 Wing Utilizing a Controlled Shaker System for Artificial Engine-Vibration Excitation,“ in Numerical Methods and Experimental Means for the Integration of Future Propulsion Systems - A Resumé of the Achievements Made within the CleanSky 2 XDC Demonstrator, Springer Nature Switzerland AG, 2025.

Power transmission into wing-support



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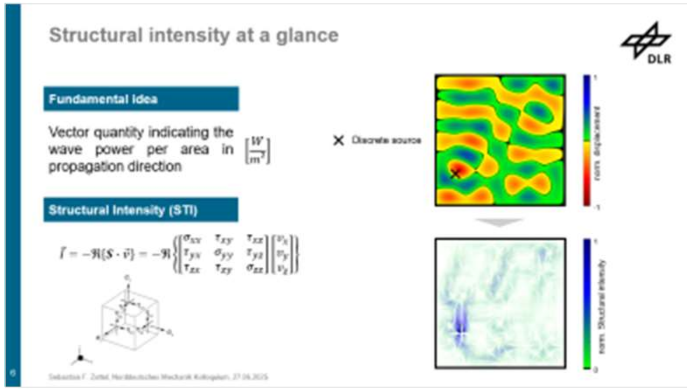
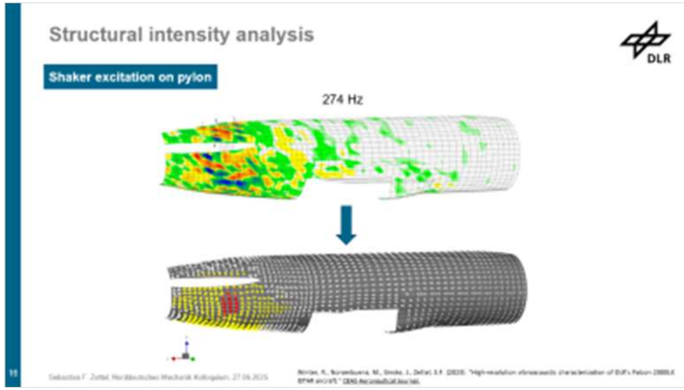
Summary

- Hybrid method allows to estimate structural intensity on complex surfaces
- Successfull evaluation of experimental response data of aircraft structures
- Post-processing methods help to acquire insights on STI vector fields
  - Source and sink identification with divergence component
  - Path identification





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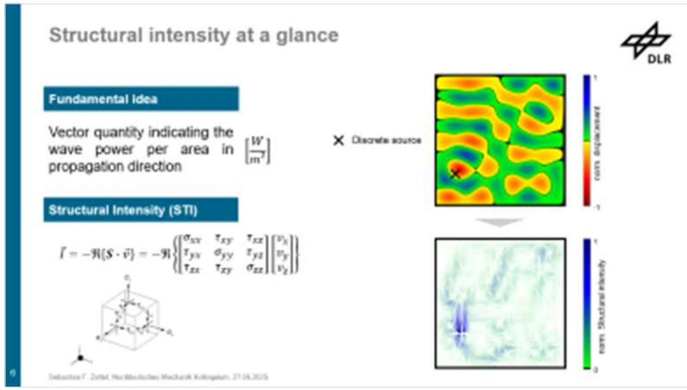

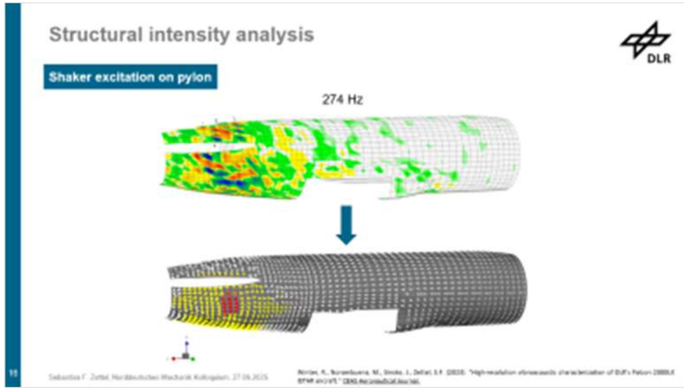

Imprint

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Institute: Institute of Aeroelasticity