Faculty IV: Science and Technology
Department Mechanical Engineering
Applied Mechanics – Prof. Dr.-Ing. C.-P. Fritzen

Investigation on Sensor Fault Effects of Piezoelectric Transducers on Wave Propagation and Impedance Measurements

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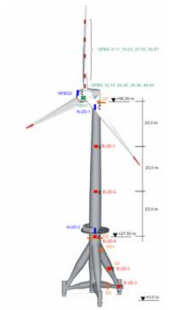
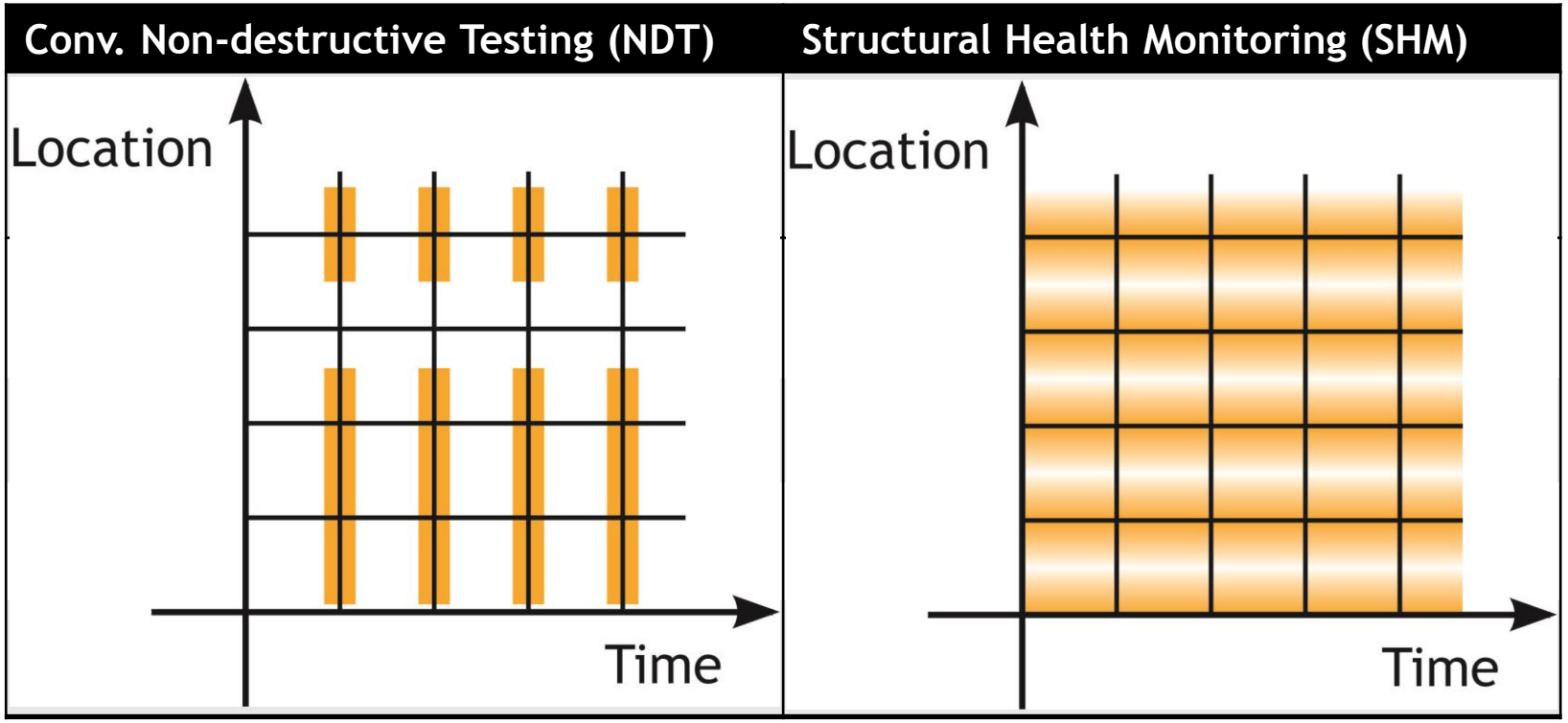
Outline

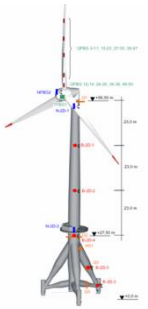
- Motivation
- FE-Model of Damaged Sensors
- Effects of Sensor Faults on the Wave Propagation (AU)
- Effects of Sensor Faults on the Electro-Mechanical Susceptance
- Comparison with Experiment
- Conclusion

Motivation

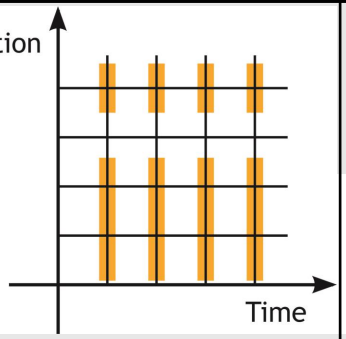


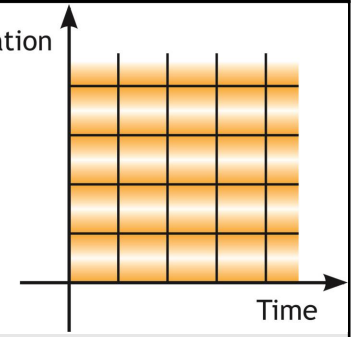

Conv. Non-destructive Testing (NDT)
Location
Time
Structural Health Monitoring (SHM)
Location
Time

Motivation



Conv. Non-destructive Testing (NDT)	Structural Health Monitoring (SHM)
Check of structure at one time at specified area	Permanent check
Some locations are inaccessible	All locations can be checked
NDT often needs downtime	SHM needs less/no downtime
NDT is time-consuming and labor-intensive	SHM is quick and runs autonomous
Scheduled testing and maintenance	Possibility of condition based maintenance
Highly skilled personnel necessary	Permanent availability of health state

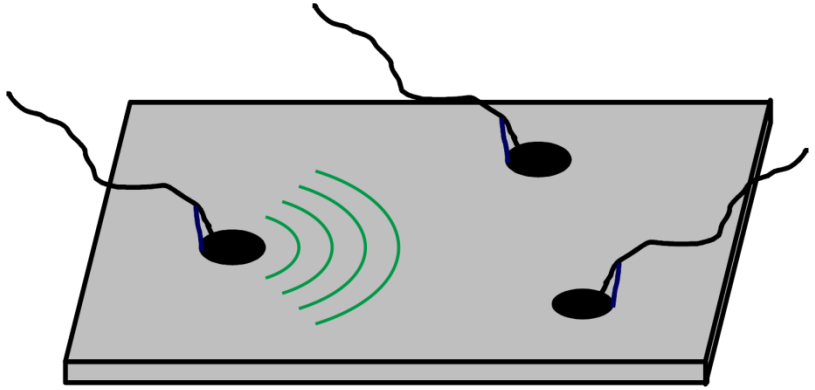


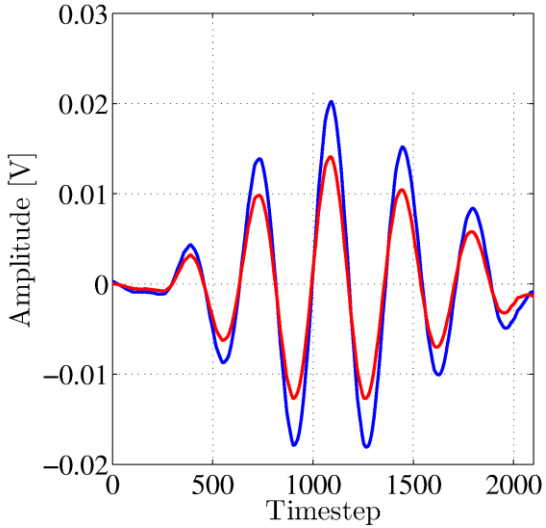


SHM is a highly versatile addition to conventional NDT

Motivation

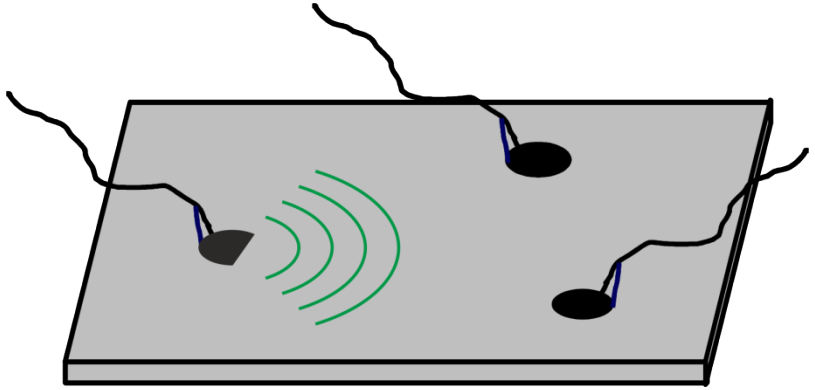
- Use of a large number of embedded sensors in advanced monitoring systems is common.
- Possible Method: Lamb Waves are excited and recorded after interaction with the structure (Acousto Ultrasonic – AU).
- Piezoelectric Wafer Active Sensors (PWAS) usage is increasing, as they can be used as actuators and sensors and are relatively cheap.
- Damage inside the structure leads to a change of the recorded signal.

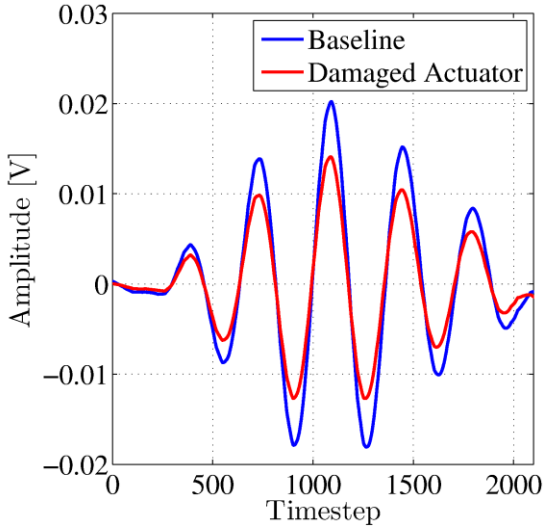




Motivation

- Sensor faults also cause different recorded wave propagation signals.
- Sensor faults must be differentiated from structural damage and detected before AU can be used.
- The electro-mechanical susceptance spectrum is used to check these defects.
- A detailed analysis of the processes during the generation of the acousto ultrasonic wave field and within the capture of the electro-mechanical impedance is necessary for different possible sensor damages.

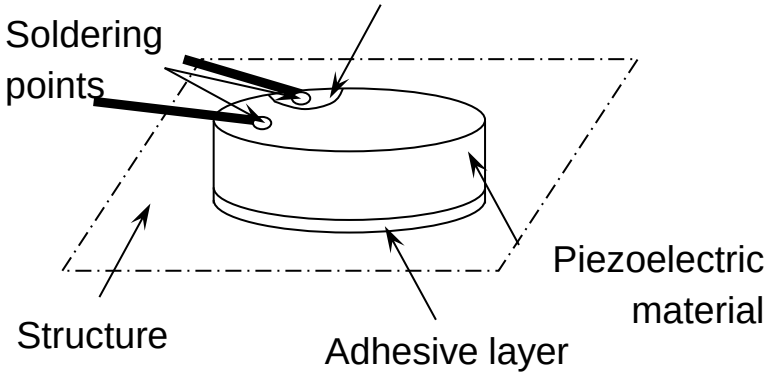




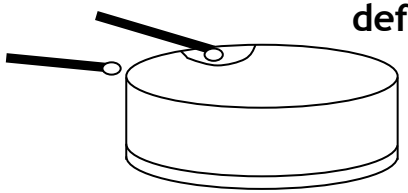
Motivation

Different Sensor Fault Types

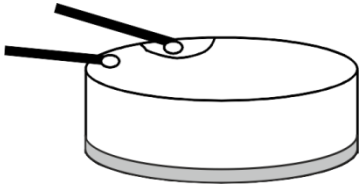
Wrapped electrode – connected to the bottom layer of the transducer



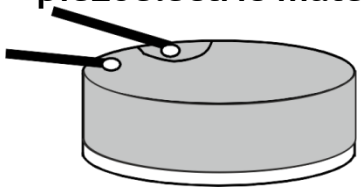
Soldering point defect



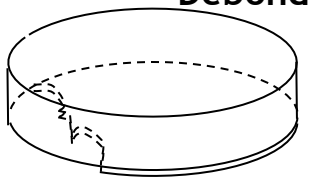
Degradation of adhesive



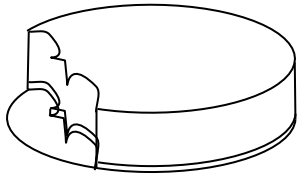
Degradation of piezoelectric material



Debonding

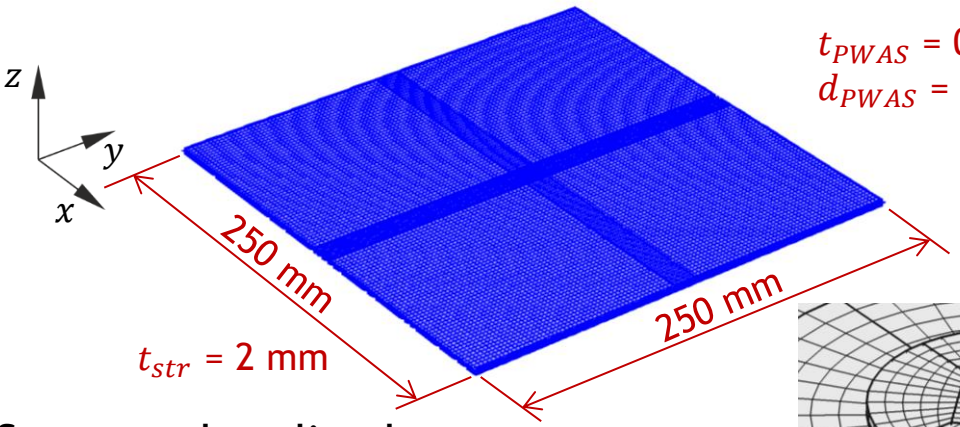


Breakage

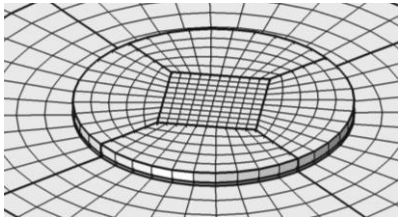


FE-Model

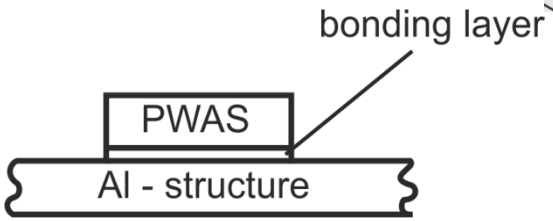
- Multiphysics - Coupled field analysis with COMSOL®



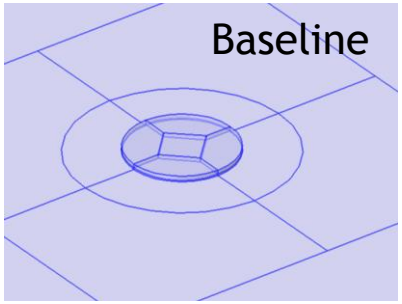
t_{PWAS} = 0.254 mm
d_{PWAS} = 6.35 mm

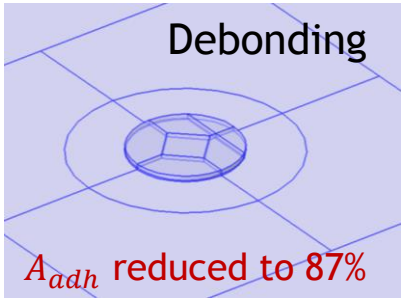


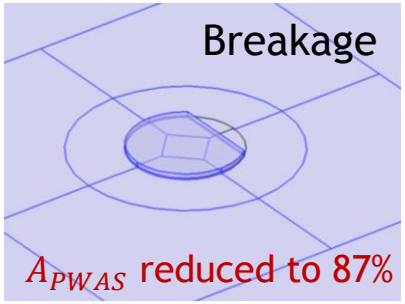
- Separate bonding layer



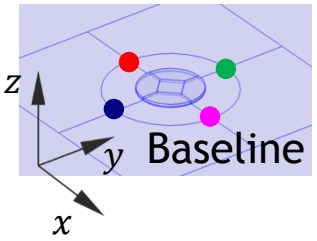
- Calculation in frequency and time domain

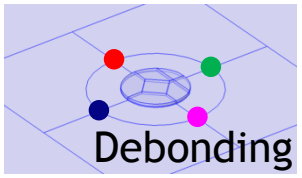


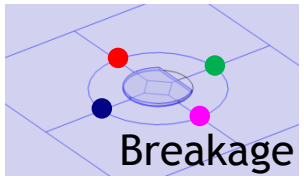


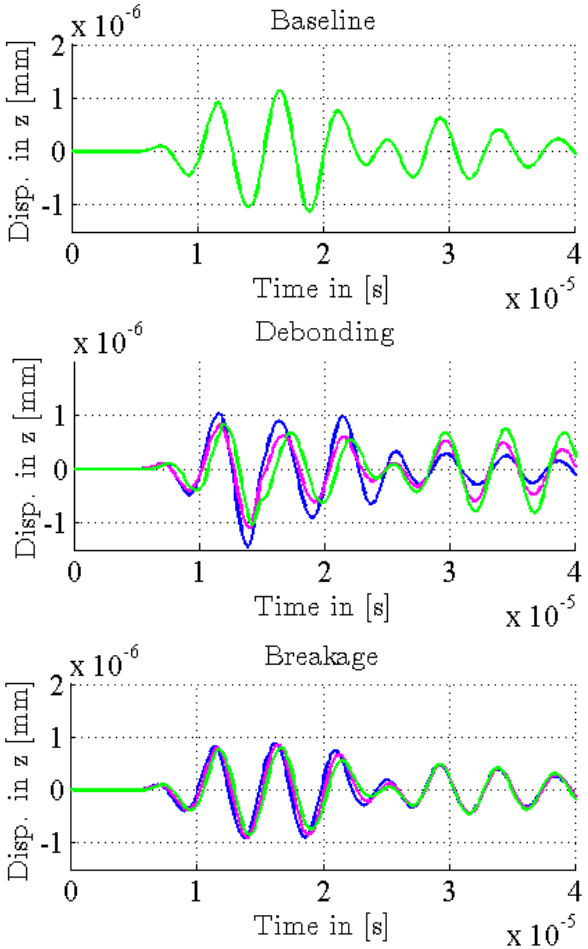


Effects of Sensor Faults on the Wave Propagation (AU)





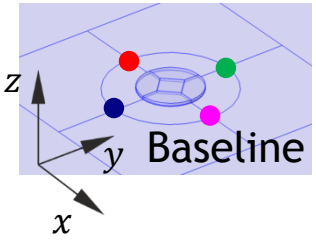


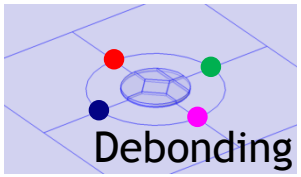


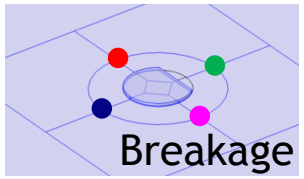
FE-model in time domain

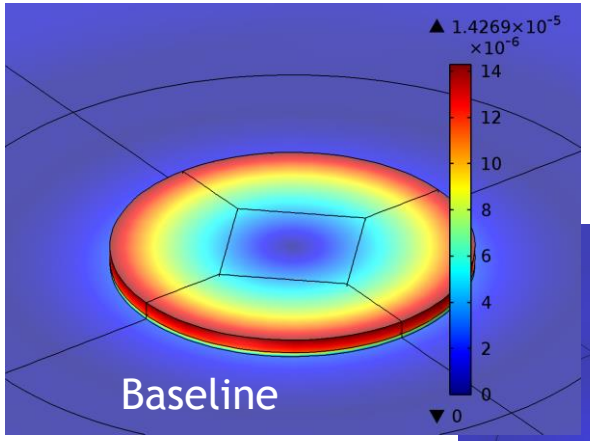
- Effects on the actuator's wave field (displacement in z-direction) have to be considered
- Debonding causes asymmetric behavior regarding time of arrival and amplitude
- Breakage causes asymmetric behavior mainly regarding time of arrival

Effects of Sensor Faults on the Wave Propagation (AU)

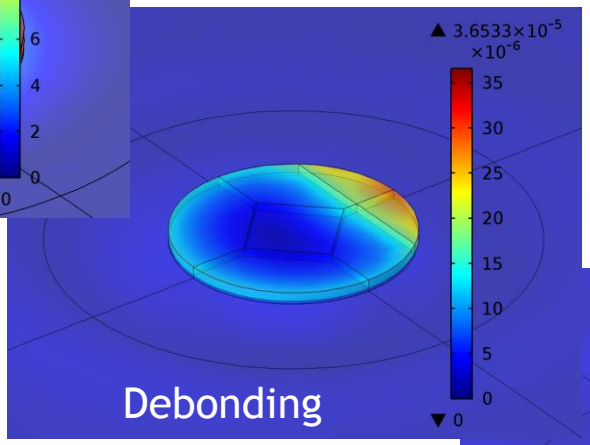








max. in-plane displacement
1.43 10^{-5} mm

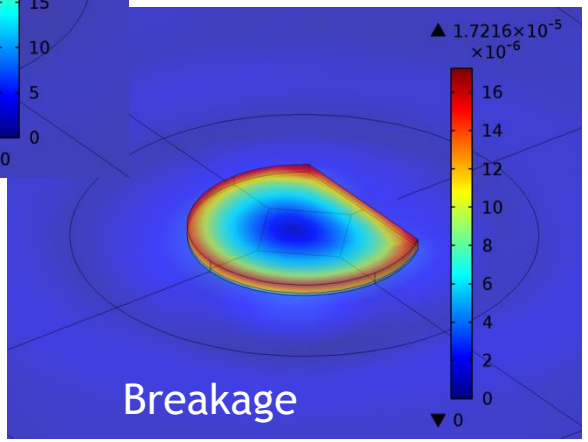


max. in-plane displacement
3.65 10^{-5} mm

FE-model in time domain

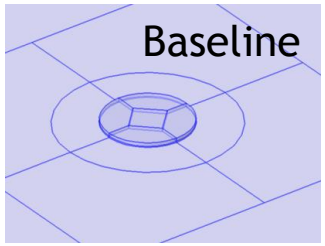
In-plane displacement at
t=1.4 10^{-5} s

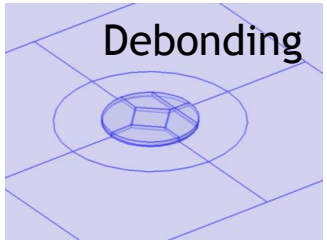
max. in-plane displacement
1.72 10^{-5} mm

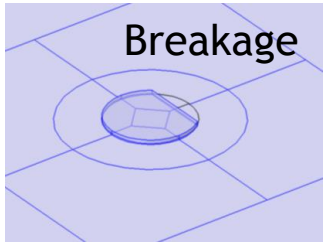


Effects of Sensor Faults on the Electro-Mechanical Susceptance

Different damages lead to different changes in the susceptance spectrum



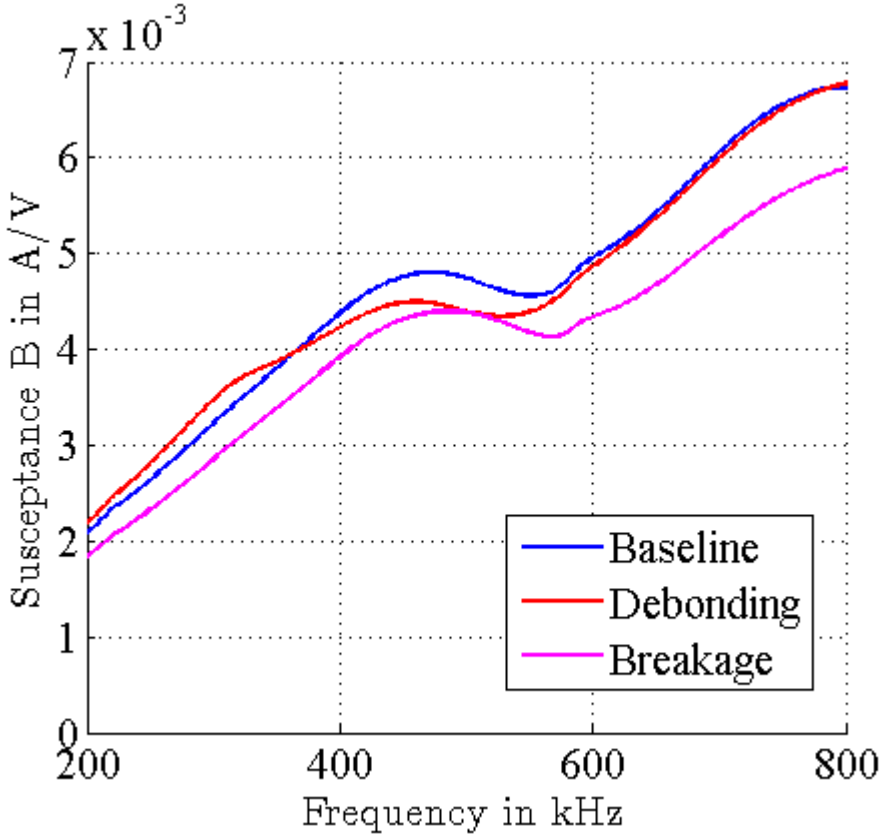




Increase of slope for lower frequencies, change of resonance behavior

General decrease of slope

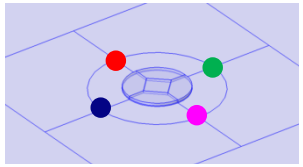
FE-model in frequency domain

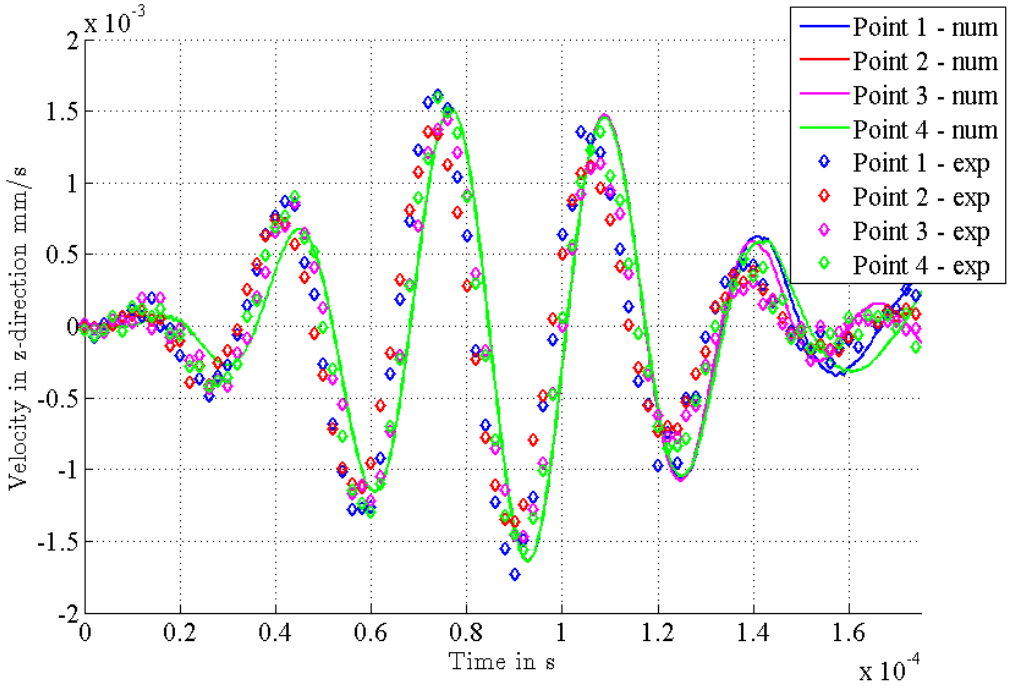


Experimental Validation

Comparison of
out-of-plane velocity

Experimental Setup:
Al-Plate 500 x 500 mm
PWAS PIC151
Ø 10 mm
t 0.25 mm
Measurement device
1-D Laser Doppler Vibrometer CLV700 (Polytec ®)

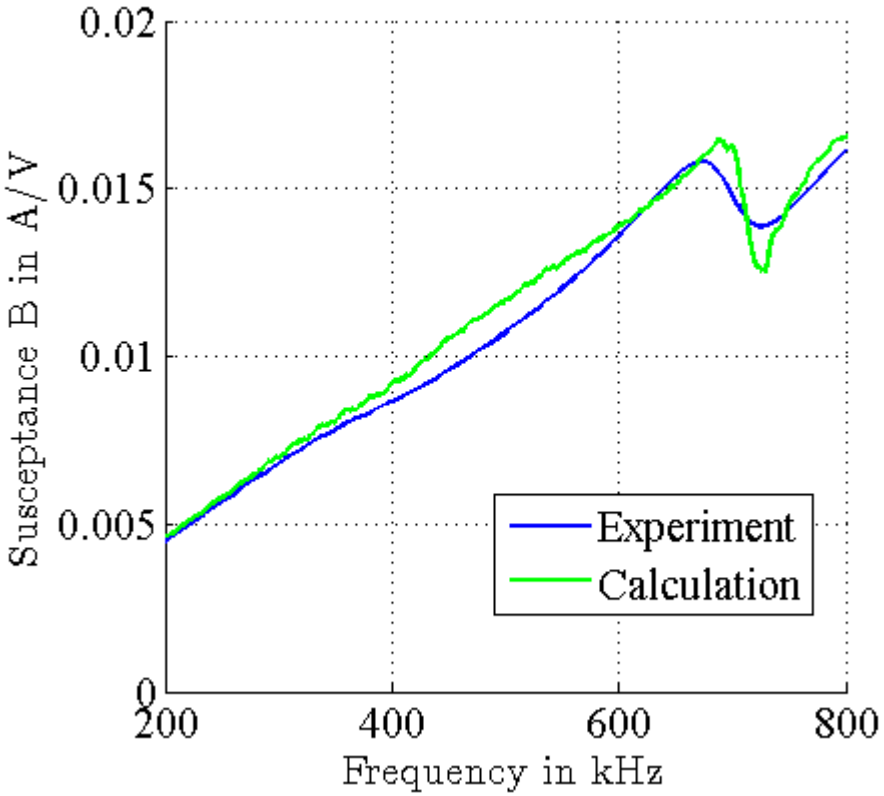




Experimental Validation

Comparison of
susceptance spectrum

Experimental Setup:
Al-Plate 500 x 500 mm
PWAS PIC151
Ø 10 mm
t 0.25 mm
Measurement device
PZT Inspector
Frequency range
200 – 800 kHz



Conclusion

- Sensor performance influences the excited field of wave propagation
- The electro-mechanical susceptance and the wave propagation field can be modeled with the help of Comsol Mulitphysics
- A comparison of experimental and numerical results on the undamaged PWAS shows good agreement
- The numerical simulations allows a deeper understanding on the sources of variation in the generated wave field due to the sensor faults

Thank you for your attention!