

Influence of Temperature and Pre-Stress on the Piezoelectric Material Behavior of Ring-Shaped Ceramics

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Motivation

- Design of new transducers: time consuming iterative process of simulation, prototyping and experiments.
- Standard determination of complete set of material parameters: 4 test samples are required.
- Manufacturer data sheets: Small signal characteristics for free vibration only.
- New approach: Measurements on a single probe (same geometry as used in device), considering driving conditions (temperature, pre-stress, high power, vibration under load).



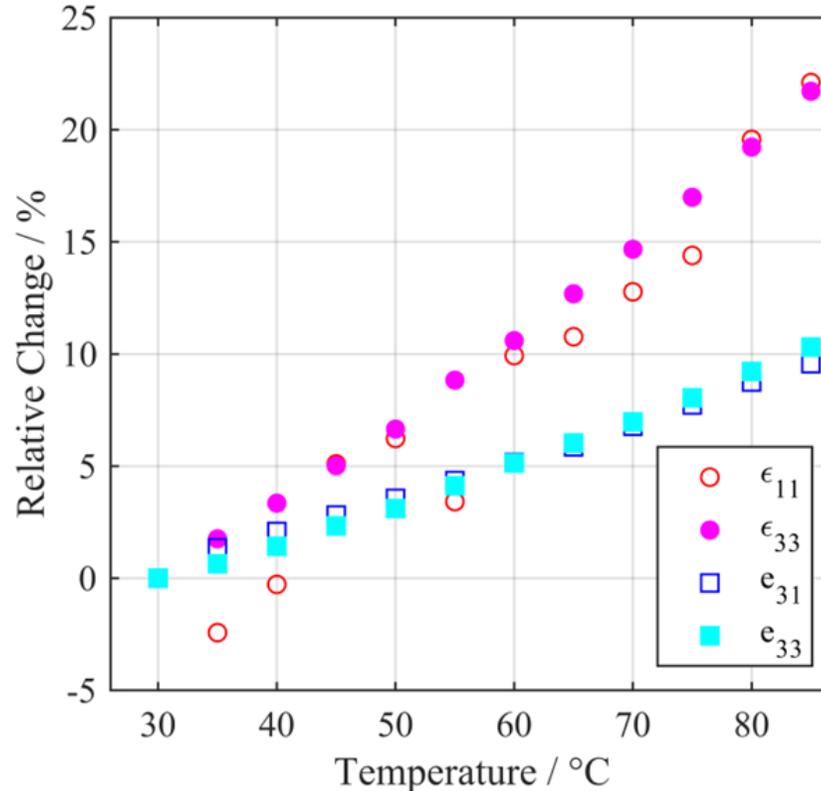
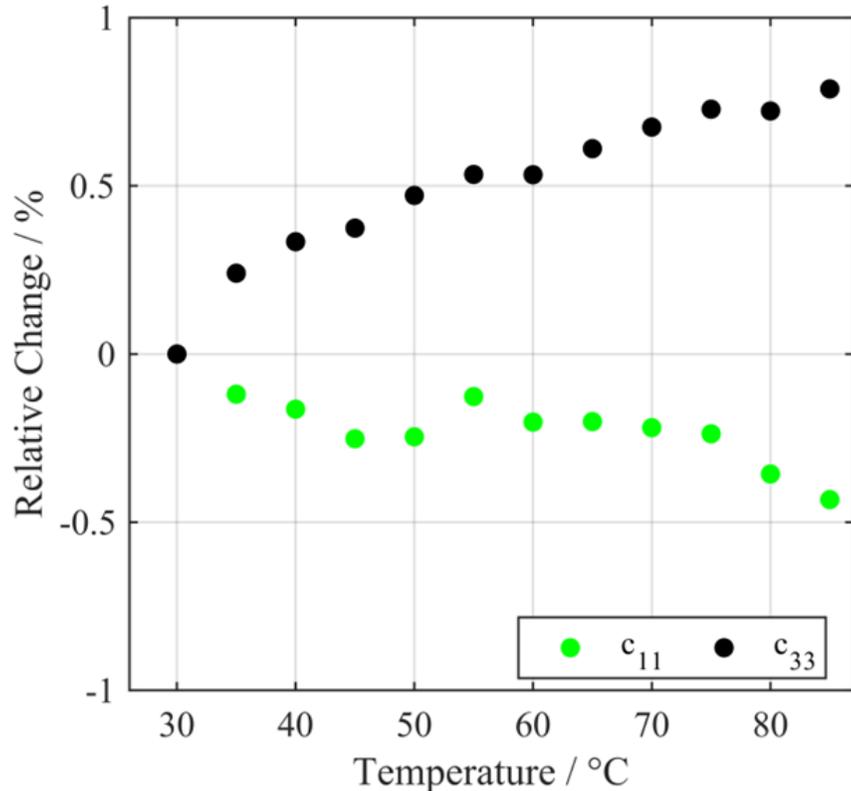
Experimental Setup for Temperature Dependence Investigations

- Hard ring ceramics of type PIC 181.
- Temperature-controlled chamber (30 °C to 85 °C)
- Impedance analyzer Keysight E4990A





Temperature Dependence Results



- Mechanical stiffnesses nearly constant
- Piezoelectric stress constant and permittivity change linear and significantly

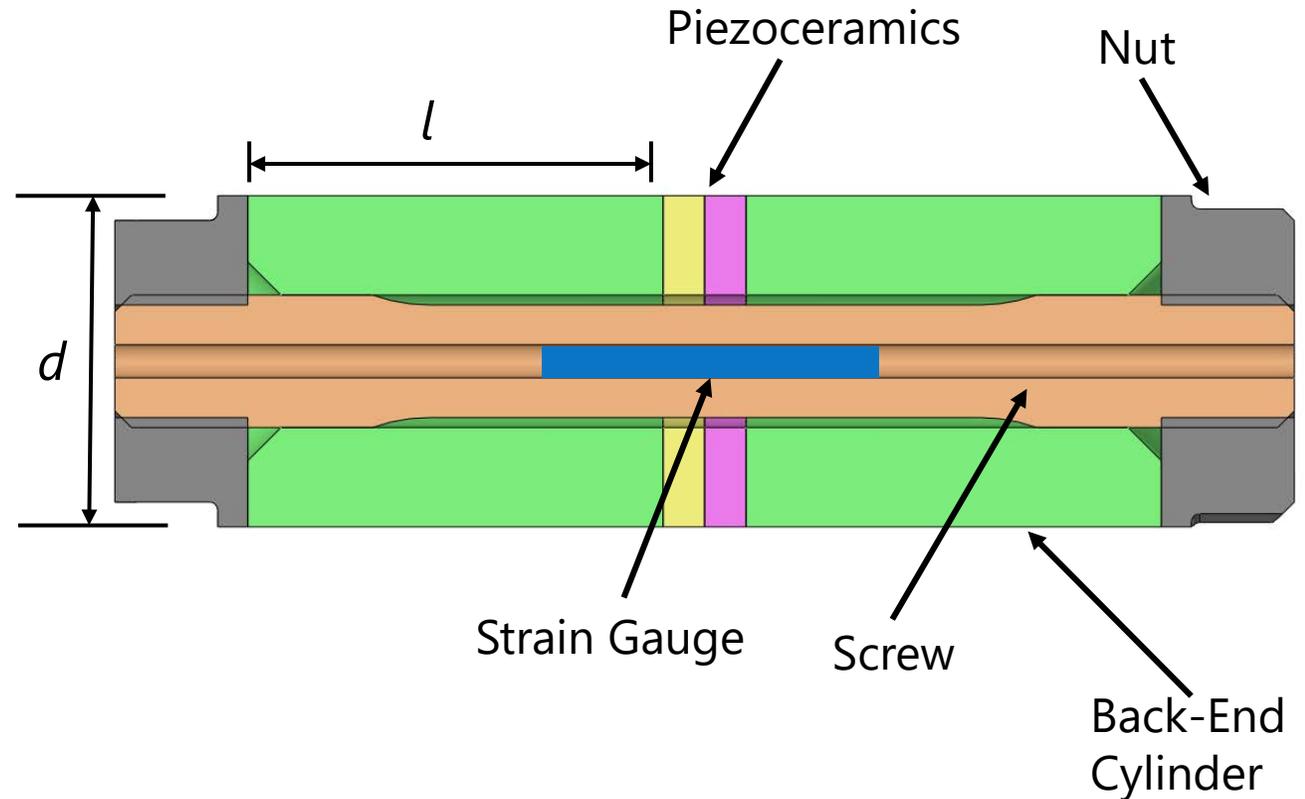
[O Friesen *et al* 2024 *J. Phys.: Conf. Ser.* **2822** 012125]





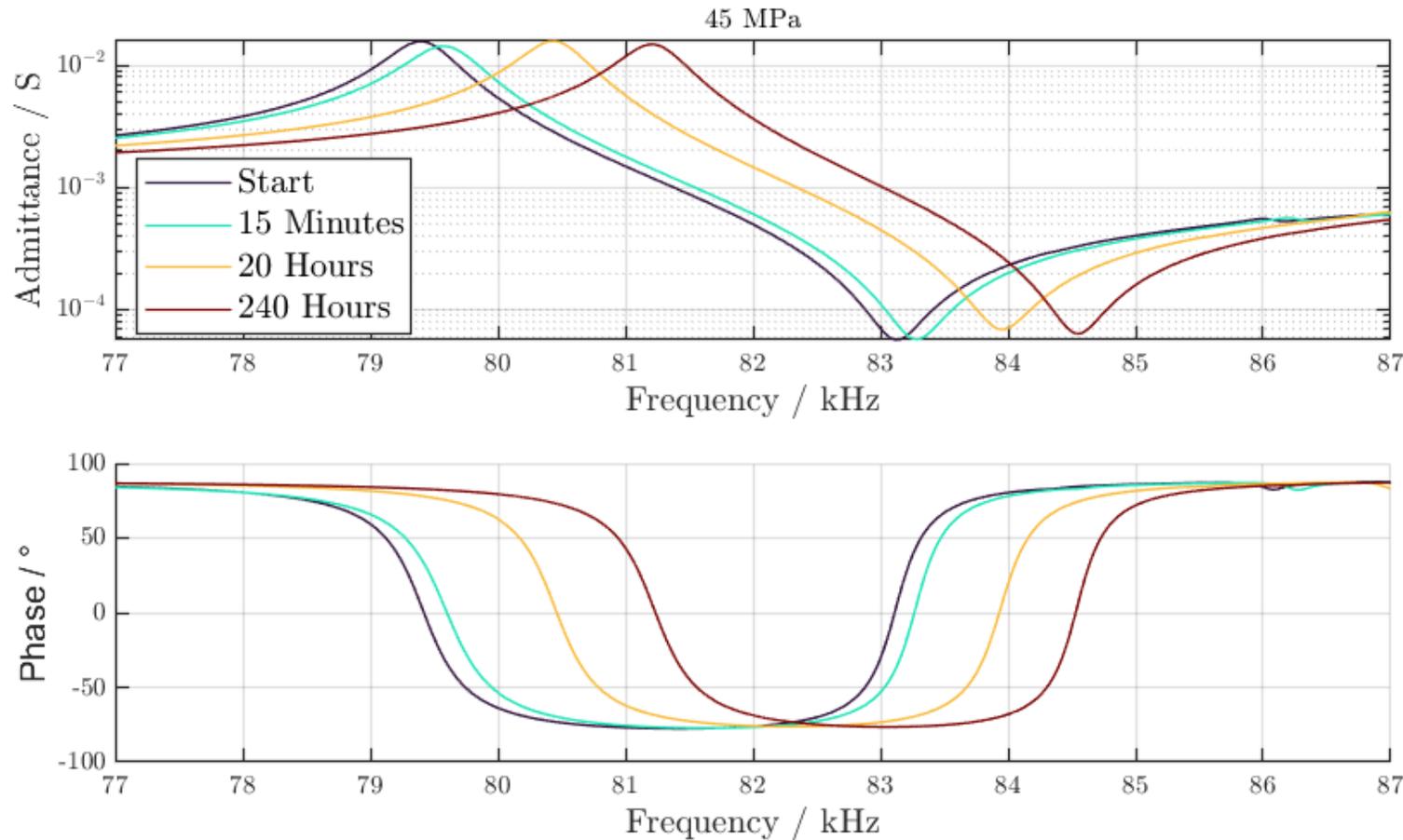
Experimental Setup for Pre-Stress Dependence Investigations

- Symmetrical transducer with integrated sensor.
- d and l optimized to achieve a homogeneous normal stress distribution in the piezoceramics.





Pre-Stress Dependence Results

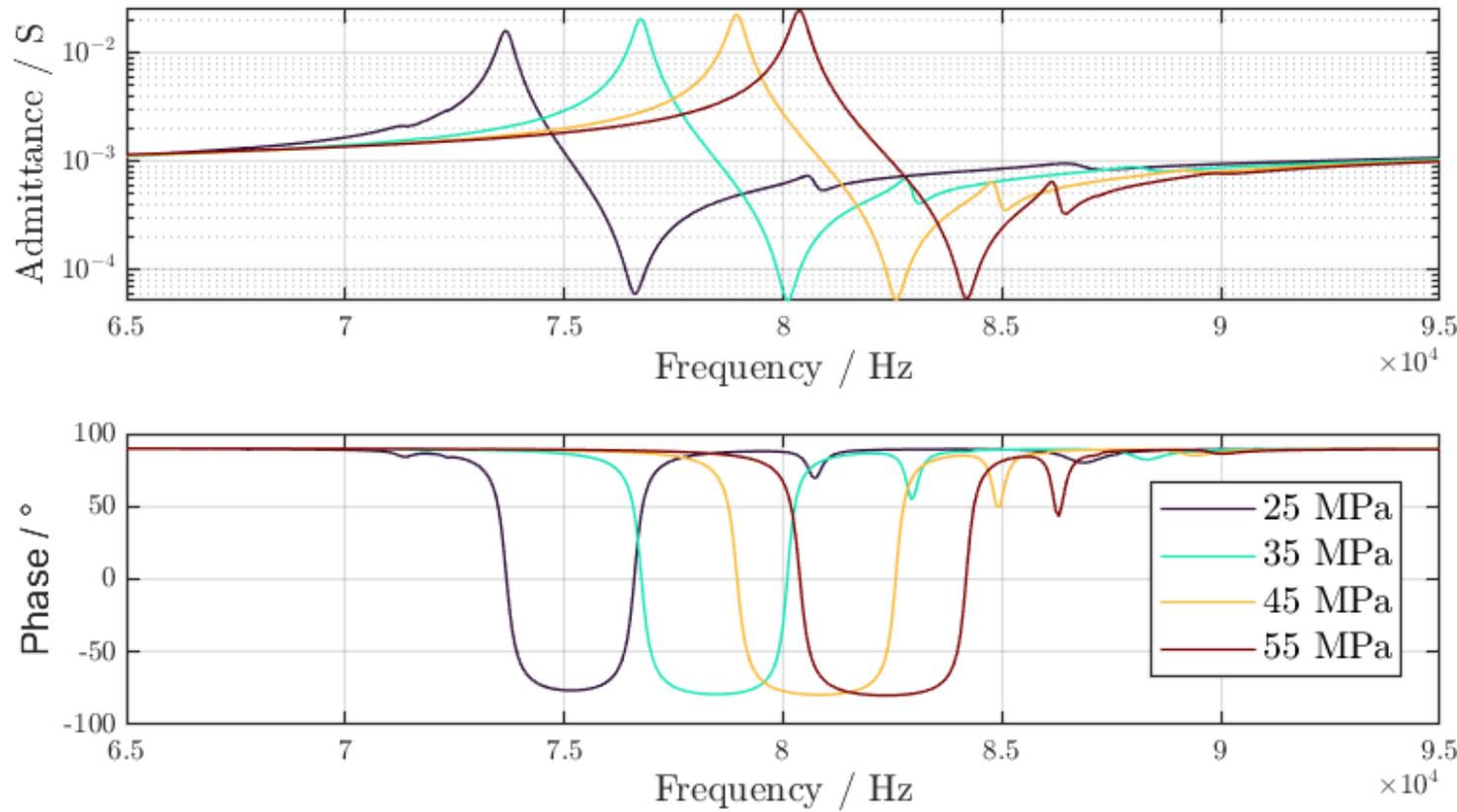


- Measurement results depend on waiting time after application of pre-stress:
- Frequency shift in total
 - Distance of resonance and anti-resonance frequency decreases with time
 - Resonance amplitude and permittivity remain almost constant
- ➔ Rather long waiting time for reliable parameter identification!





Pre-Stress Dependence Results



- Resonance frequency increases with pre-stress
 ➔ Stiffness increases by 6.5 %
- Distance of resonance and anti-resonance frequency grows with pre-stress
 ➔ Coupling factor increases by 4 %
- Resonance amplitude increases with pre-stress
- Permittivity remains constant





Summary and Outlook

- Development of a set-up for the investigation of the temperature dependency of ring ceramics
- Determination of material parameters in a two-stage optimization for temperature dependency
 - Approximately linear dependency of the piezoelectric stress constant and permittivity parameters
 - Almost no dependency of the mechanical stiffness parameters
- Test set-up development for the investigation of the pre-stress dependency of ring ceramics
 - Long waiting time for reliable parameter identification
 - Stiffness and coupling factor increases while permittivity stays constant

- Investigation of the time-dependent behavior of the pre-stress influence
- Determination of all piezoelectric material parameters at different pre-stress levels
- Investigation of combined pre-stress with temperature dependency



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