

Characteristic behavior of lead-free and lead-containing piezo ring ceramics in ultrasonic transducers

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IWPMA 2024, Hannover, Germany, 24th July 2024





Outline

- Motivation
- Experimental and Measurement Setup
- Long Term Measurement
- Large Signal Behavior
- Conclusion and Outlook



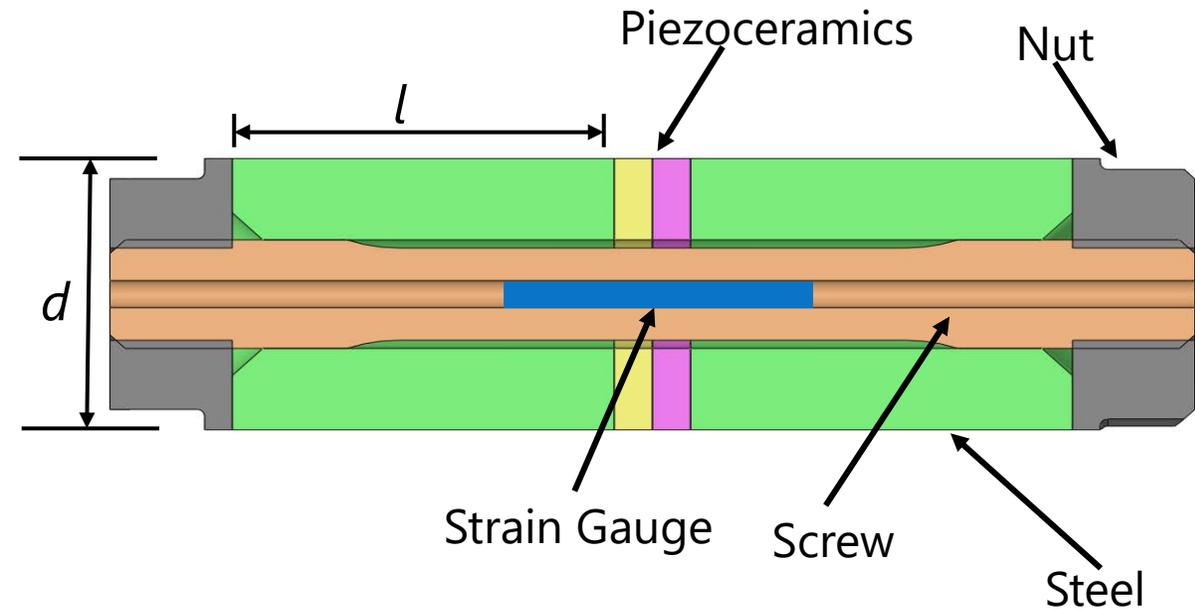
Motivation

- Restriction of Hazardous Substances Directive (RoHS).
- Can PZT ceramics be replaced by lead-free ceramics in ultrasonic transducers?
- “Known” obstacles:
 - Rapid and intense heating → higher degradation
 - Increased anisotropy (reduced planar coupling)
 - Higher Curie temperature?
 - Higher mechanical damping (?)
- Many research results for lead-free ceramic material available
- Very few information for the use of lead-free ceramics in pre-stressed ultrasonic transducers



Experimental Setup

- Symmetrical transducer
- d and l optimized to achieve a homogeneous normal stress distribution in the piezoceramics
- Impedance analyzer (HP4194A), ultrasound generator (Athena GmbH)
- Strain Gauges Amplifier (HBM MGC-Plus)
- Laser vibrometer (Polytec OFV 302)
- PZT (PIC 181) and lead-free (PIC 758) piezo ceramics (PI Ceramic)

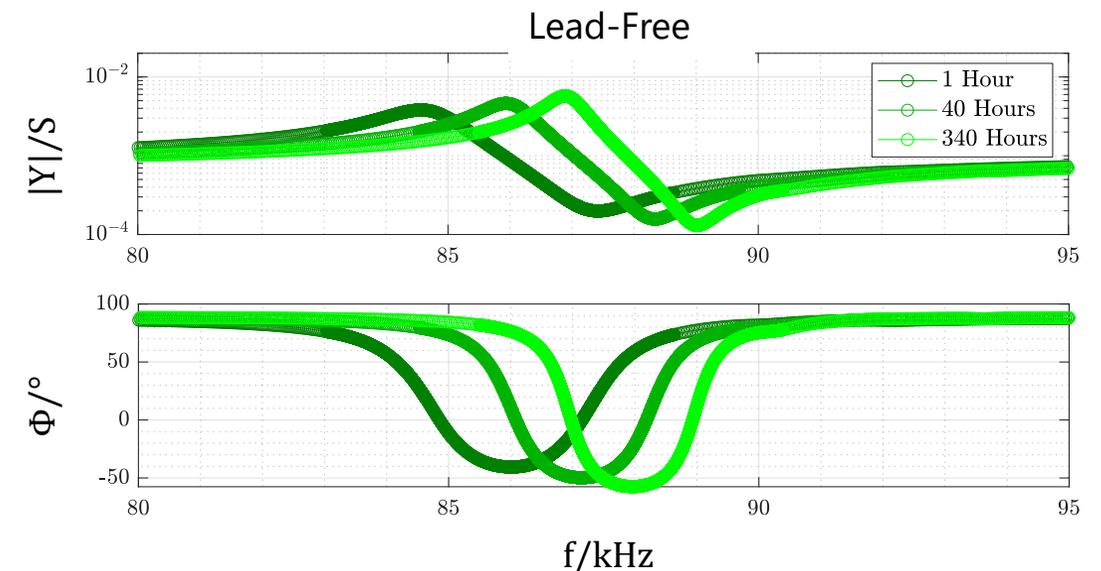
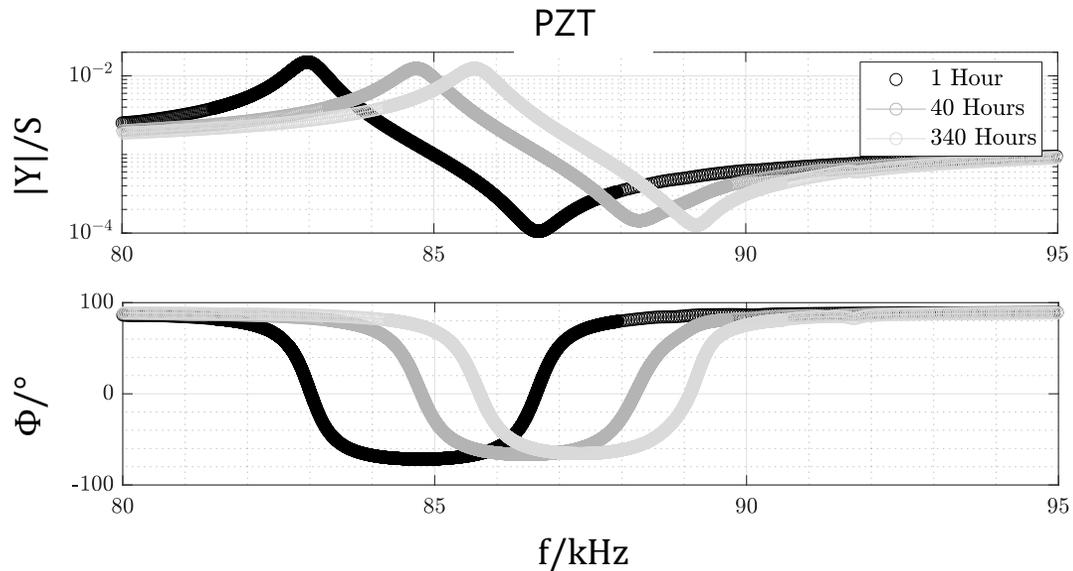




Measurement Setup

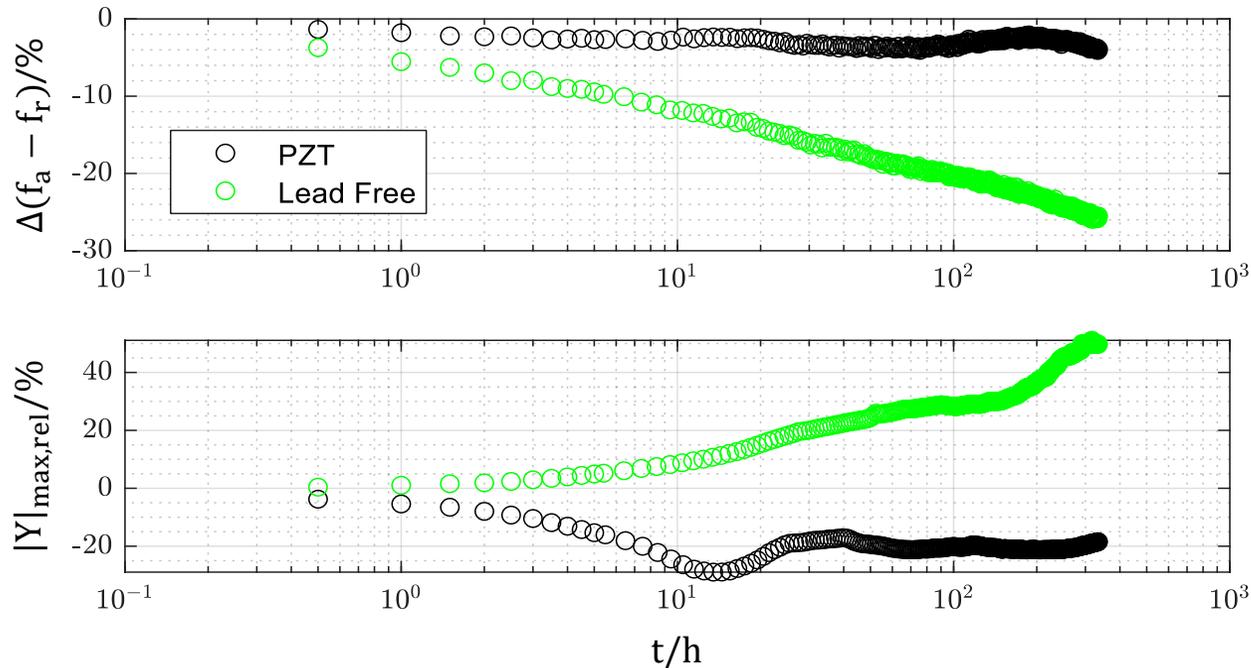
General Conditions

- Measurement of electrical admittance at different points of waiting time
- 50 MPa pre-stress
- Small signal excitation, free vibration
- Ceramic rings 12.7 x 5.2 x 1 mm³





Long Term Measurement



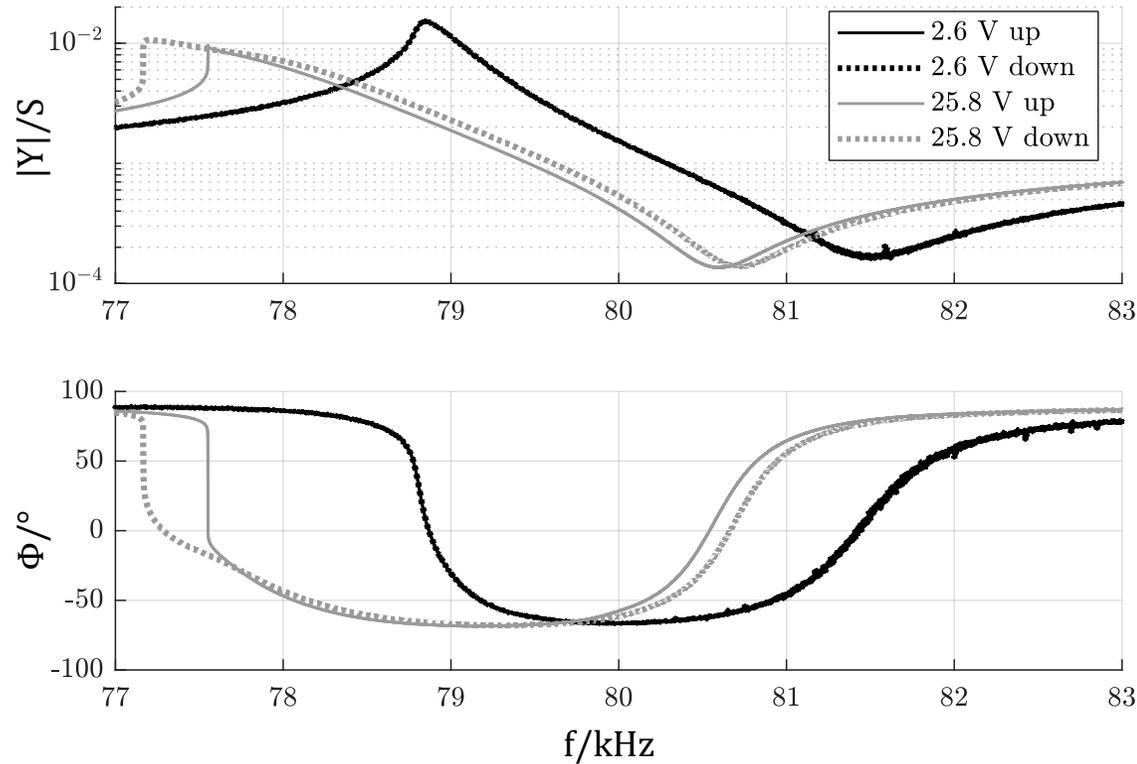
- Resonance and anti resonance frequencies increase by 1-3 %
 - Electro-mechanical coupling decreases up to 25 % for the lead free material
 - Maximum admittance remains almost constant for PZT and increases for the lead-free material
- ➔ For reliable parameter identification the decadal time behavior must be considered!



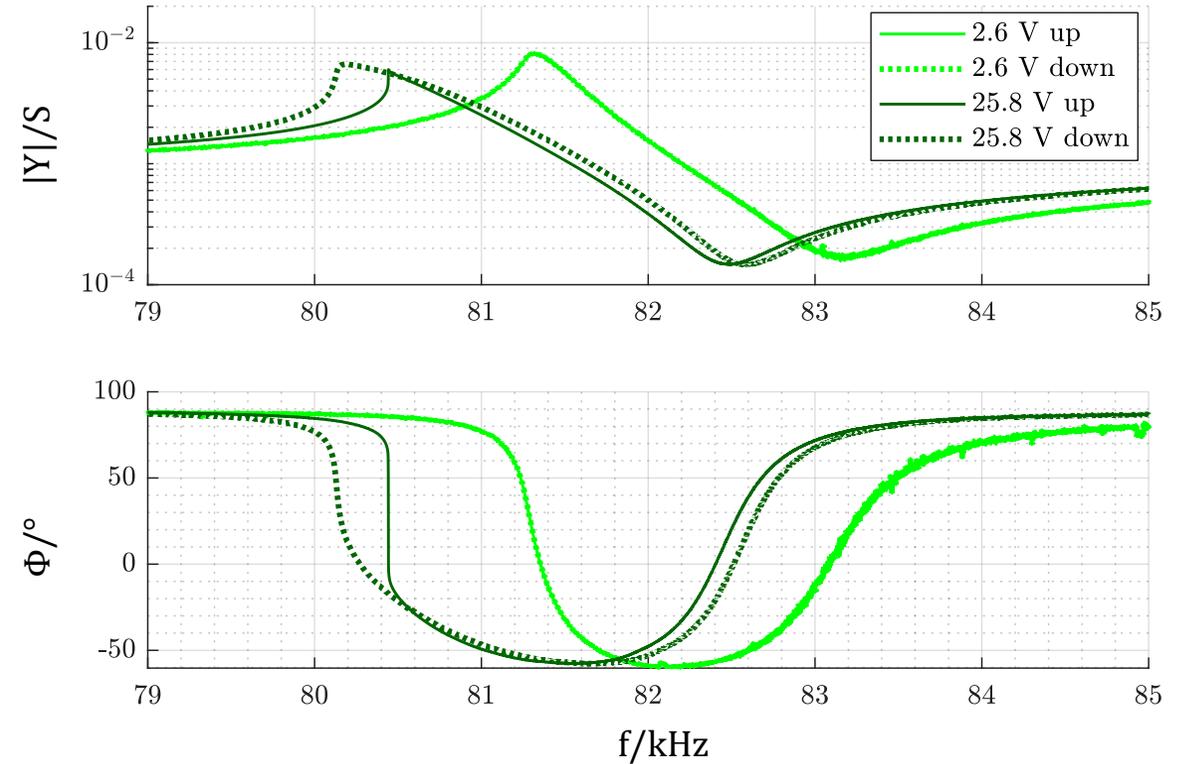


Large Signal Behavior

PZT



Lead-Free

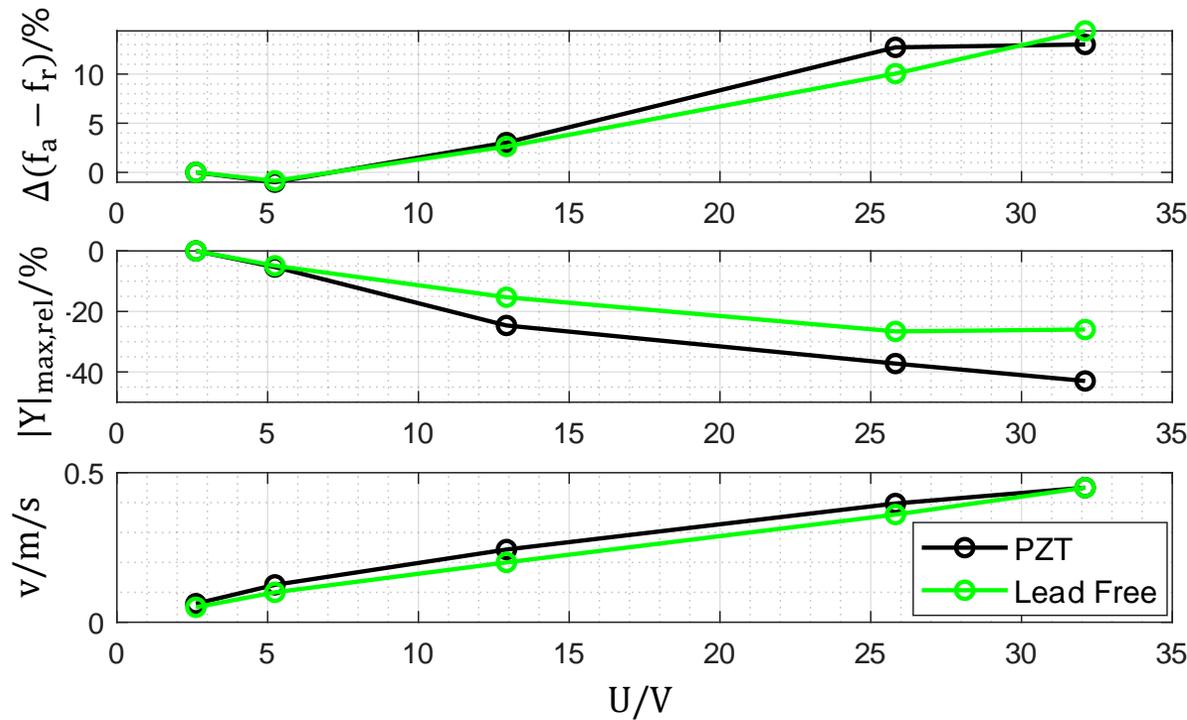


➔ Non-linear behavior occurs slightly stronger in PZT than in lead-free ceramics.





Large Signal Behavior

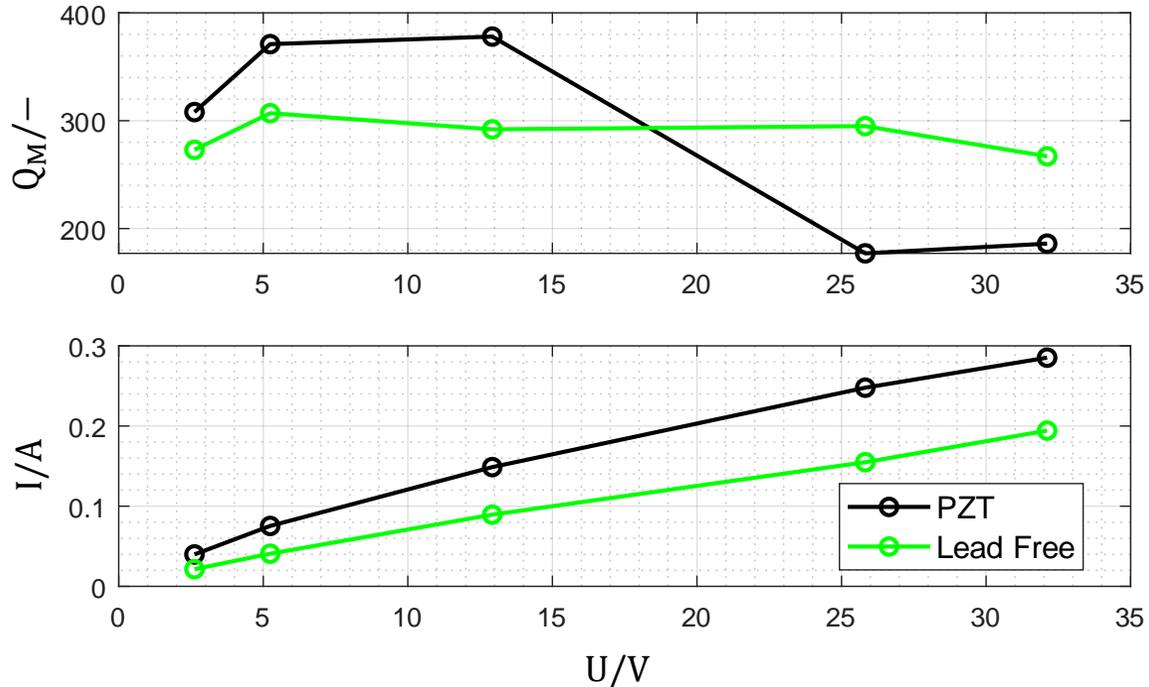


- Resonance and anti resonance frequencies decrease by 2-3 %
- The change in distance of resonance and anti-resonance frequency is similar for both ceramics
- The decrease of maximum admittance is significantly higher for PZT
- Lead-free material achieves the same velocity amplitudes at the same voltage, but at lower current





Large Signal Behavior



- The mechanical quality factor of lead-free ceramics remains constant with increasing voltage, while PZT's decreases significantly.
 - Lead-free ceramics have a higher mechanical quality factor combined with lower current.
- ➔ No excessive heating during permanent operation is expected!





Conclusion and Outlook

- Long-term measurements showed significant differences between PZT and lead-free ceramics
 - Admittance of lead-free ceramics increases over time, while the electro-mechanical coupling factor decreases
- Large signal measurements:
 - PZT ceramics have a slightly higher non-linearity: stronger drop of resonance frequency and maximum admittance
 - Lead-free ceramics achieve the same velocity amplitudes as PZT ceramics
 - Excessive heating up in permanent operation mode is not expected for lead free ceramics

➔ **Lead-free piezoceramics demonstrate the potential to replace PZT ceramics!**

- Investigation of the behavior under load
- Determination and comparison of piezoelectric material parameters at different conditions



Thank you for your attention



PI

Supported by:



on the basis of a decision
by the German Bundestag

Grant no. KK5011523AB3



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