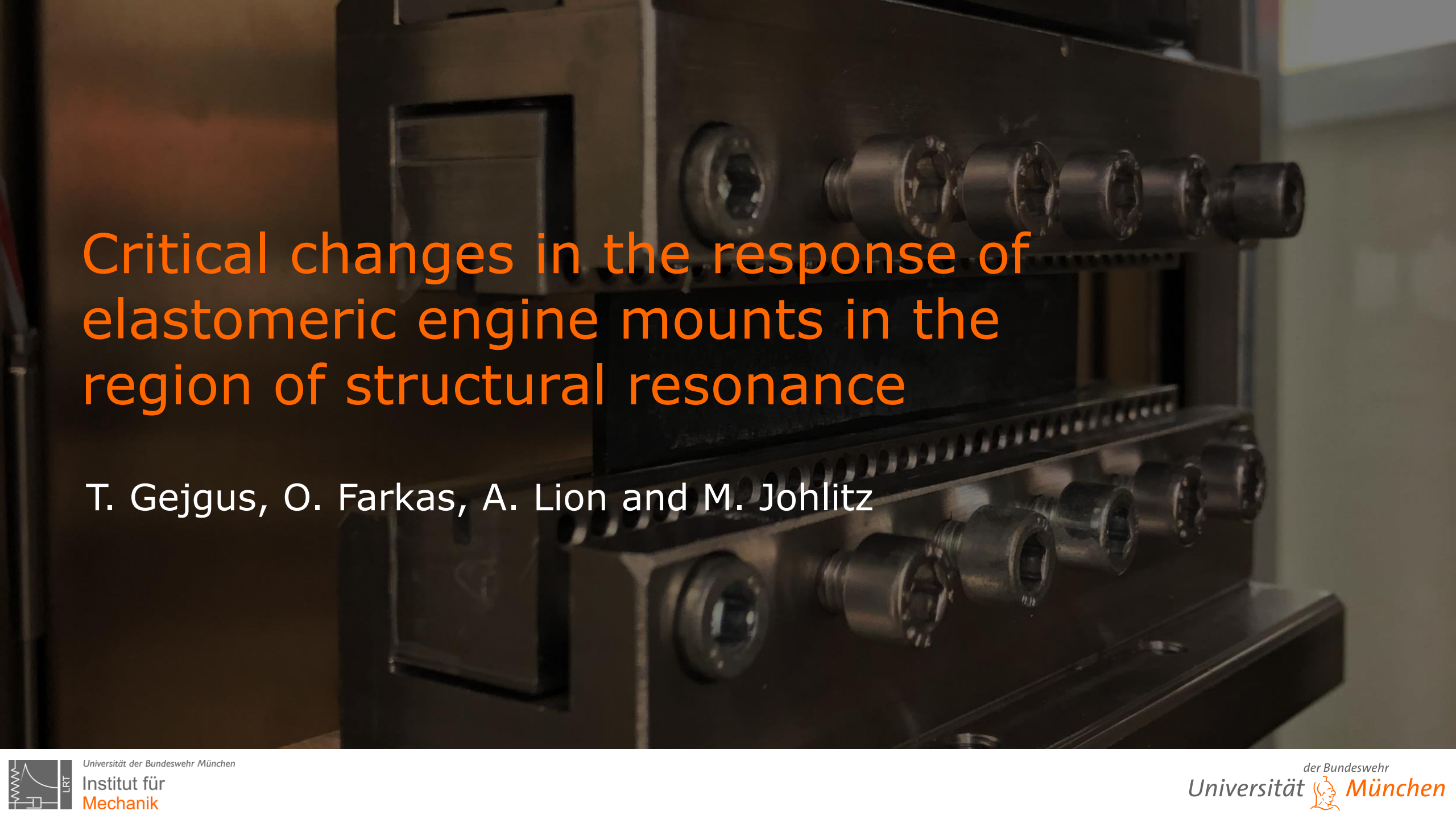
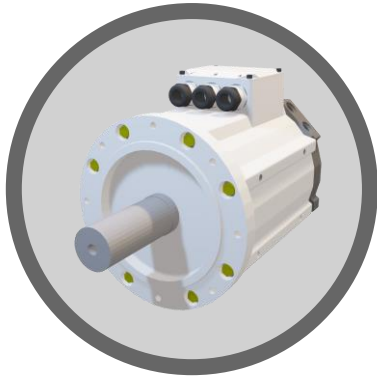




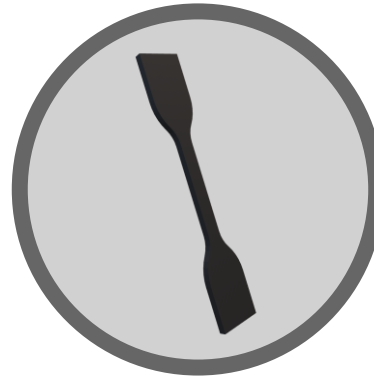
Critical changes in the response of elastomeric engine mounts in the region of structural resonance

T. Gejgus, O. Farkas, A. Lion and M. Johlitz

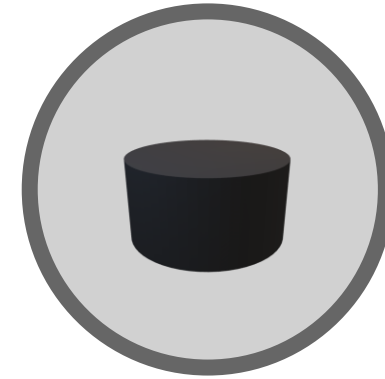
Agenda



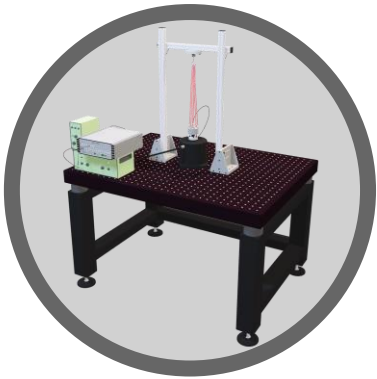
1. Motivation



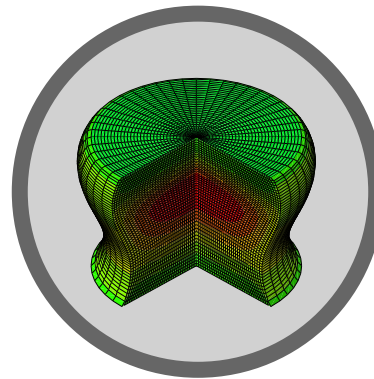
2. Hyperelastic behaviour



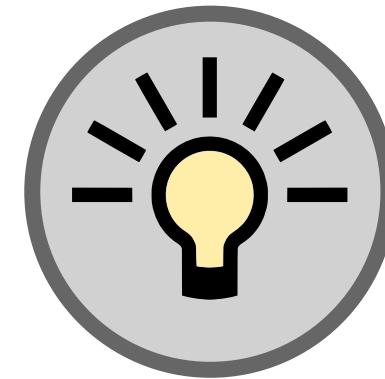
3. Viscoelastic behaviour



4. High-frequency analysis



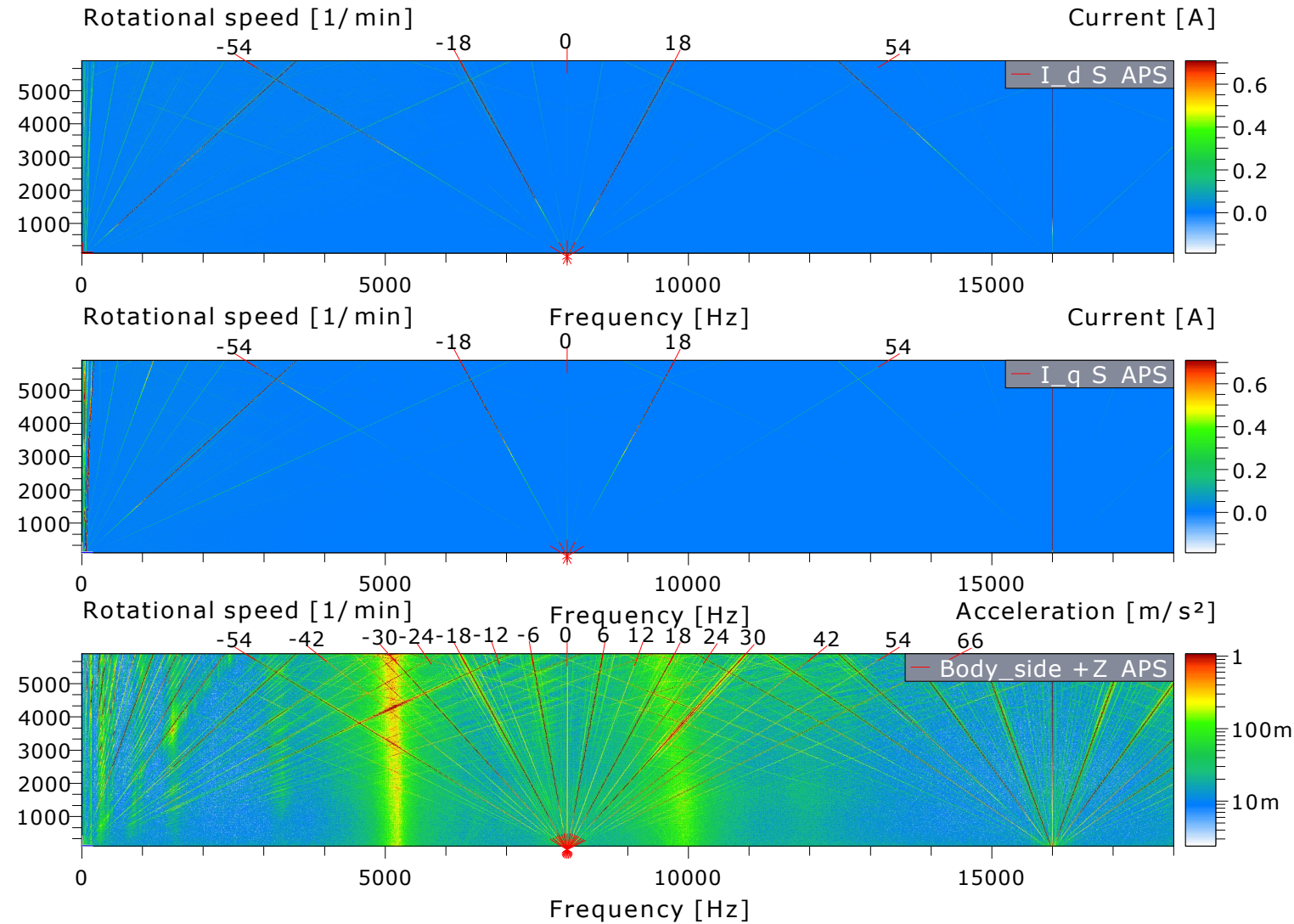
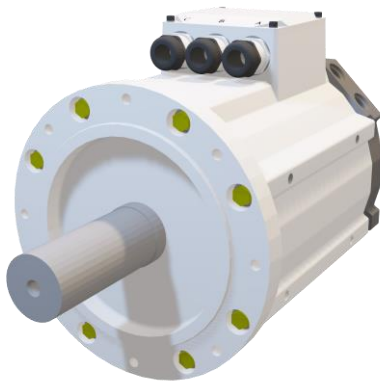
5. Frequency domain simulation



6. Conclusions and outlook

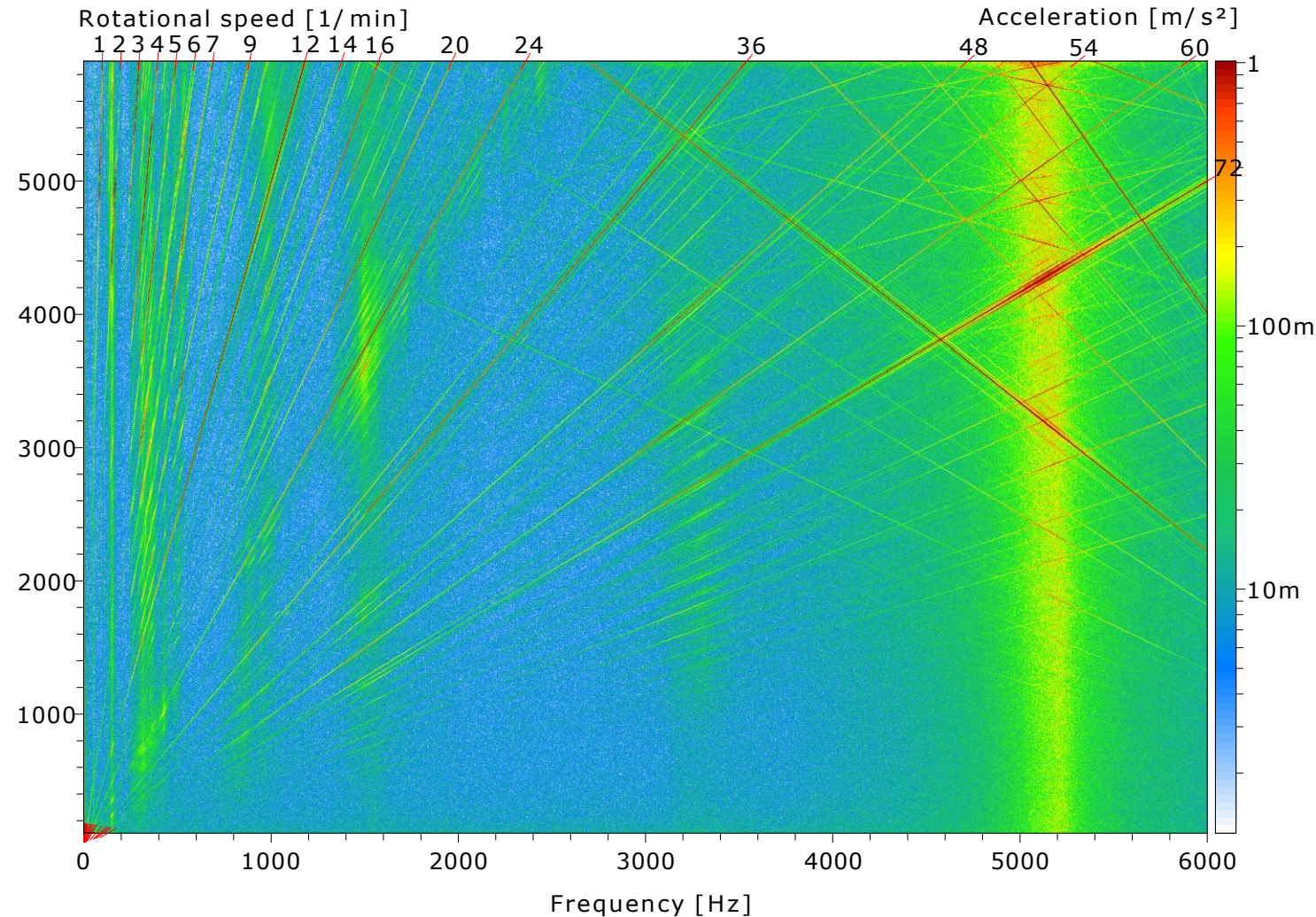
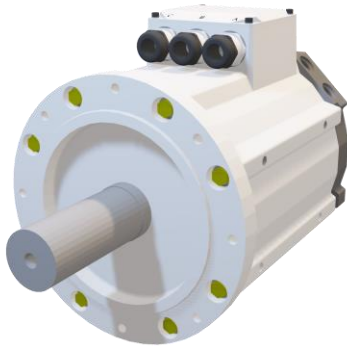
1. Motivation

- Acoustic comfort of electric vehicles
- Characteristic NVH behaviour of PMSM
- Significant high-frequency effects

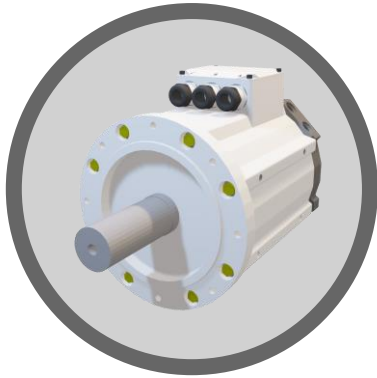


1. Motivation

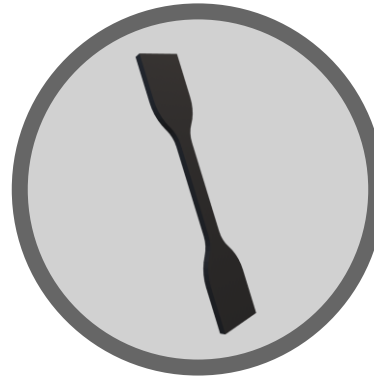
- Identification of mechanically and electrically excited orders
- Structural resonances
- Order crossing
- Uncritical areas inside the PMSM spectrum



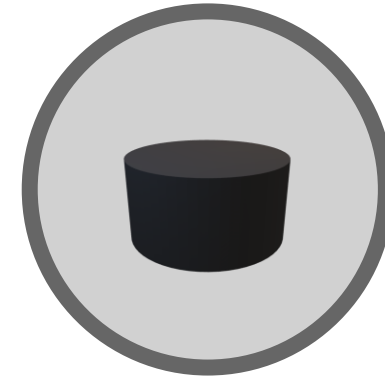
Agenda



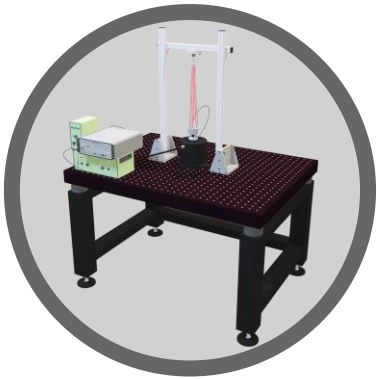
1. Motivation



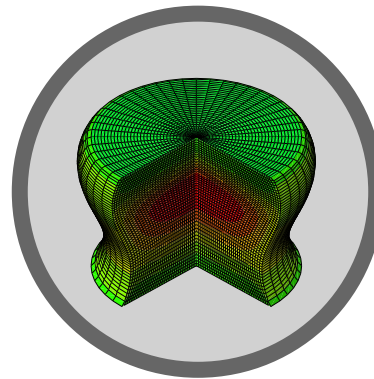
2. Hyperelastic behaviour



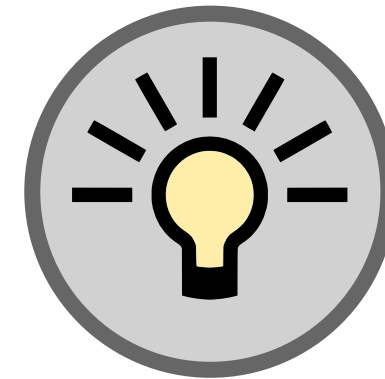
3. Viscoelastic behaviour



4. High-frequency analysis



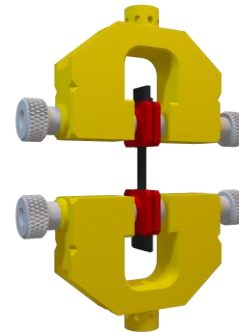
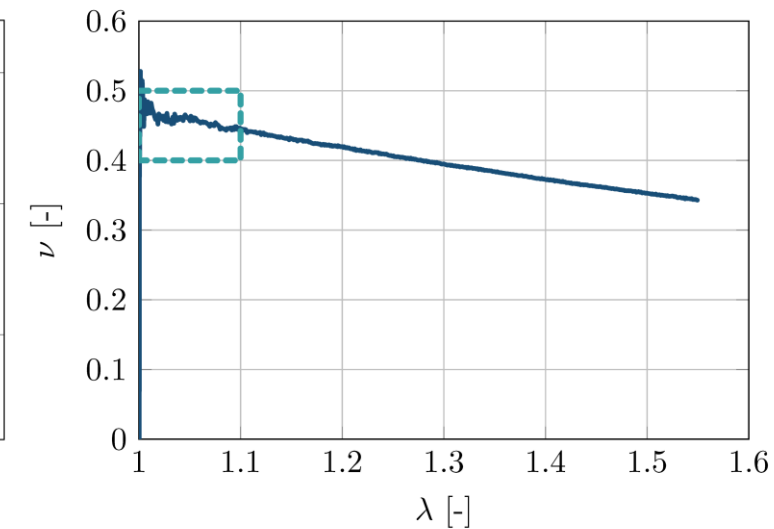
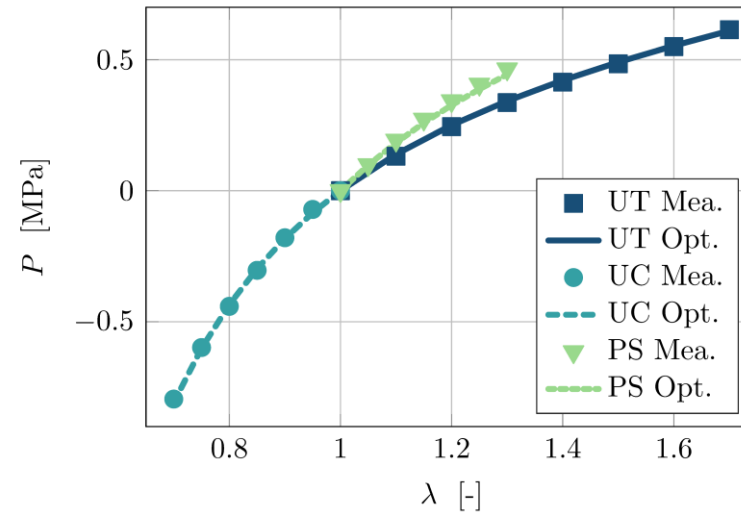
5. Frequency domain simulation



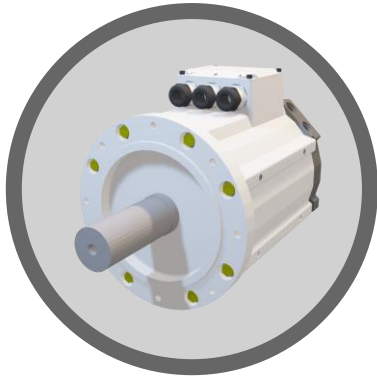
6. Conclusions and outlook

2. Hyperelastic behaviour - experiments

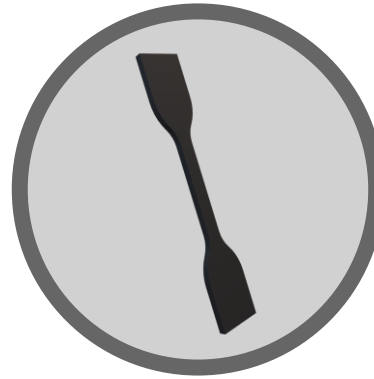
- Preconditioning to prevent Mullins effect
- 3 different load cases
- Multi-step relaxation tests in isothermal conditions at RT
- Investigation of strain dependence of the Poisson's ratio with help of DIC



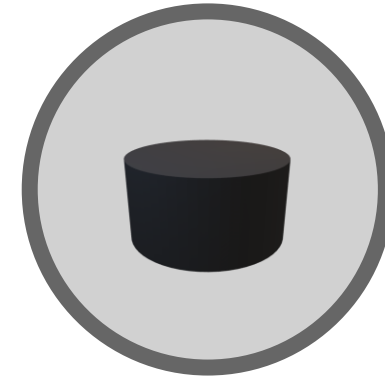
Agenda



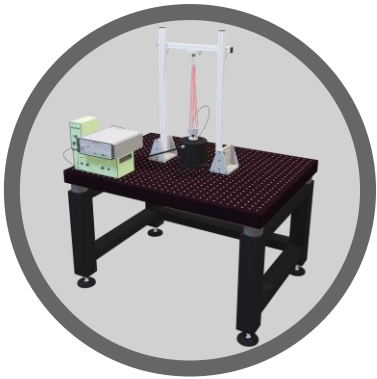
1. Motivation



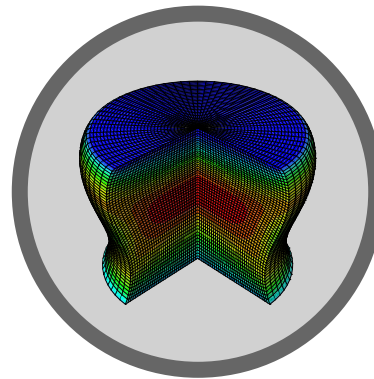
2. Hyperelastic behaviour



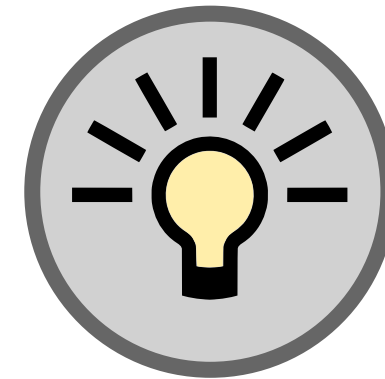
3. Viscoelastic behaviour



4. High-frequency analysis

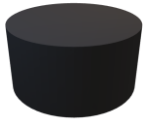


5. Frequency domain simulation

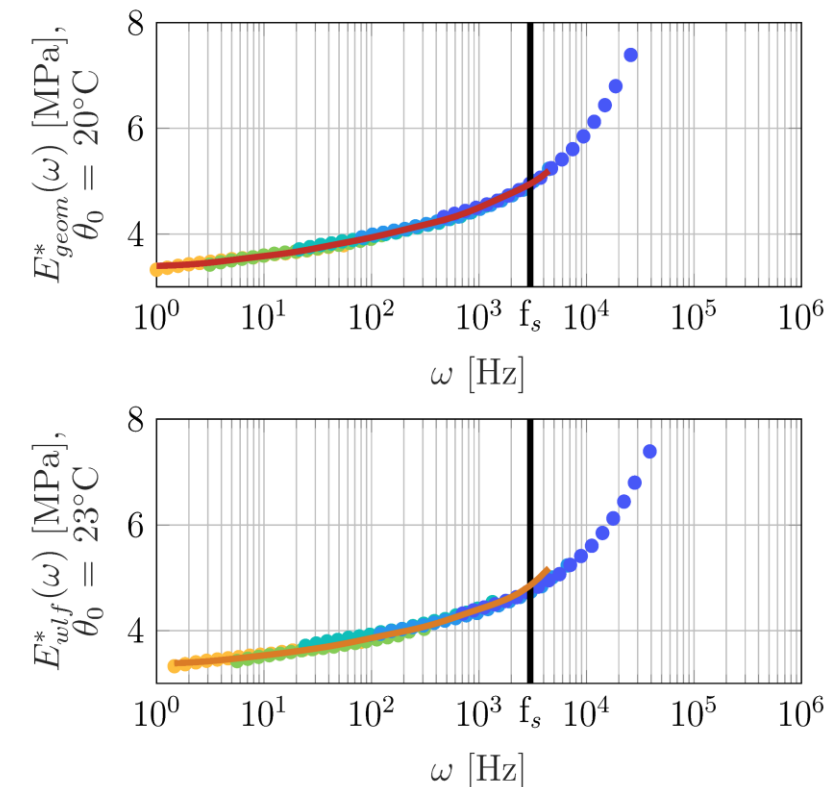
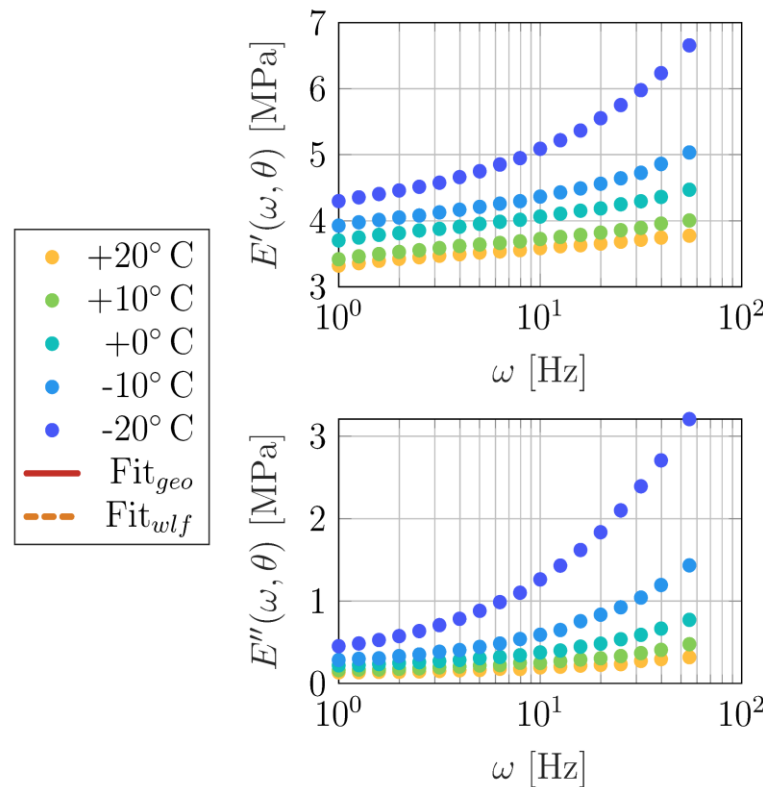


6. Conclusions and outlook

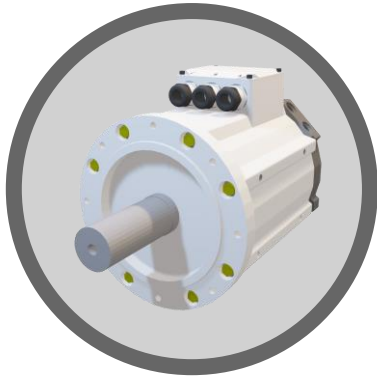
3. Viscoelastic behaviour



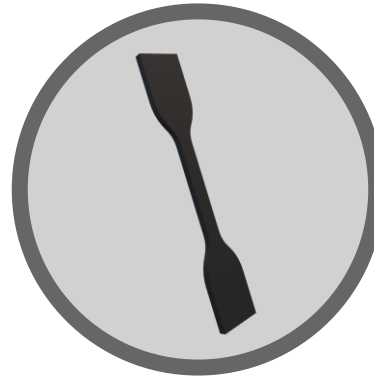
- Isothermal sweeps guaranteed by additional soak times
- Dynamic amplitude under linear viscoelastic limit
- Measurement results vertically shifted and extrapolated horizontally using geometrical shift and WLF



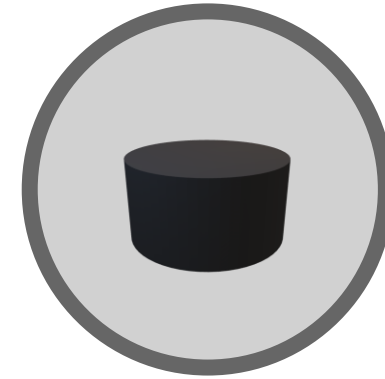
Agenda



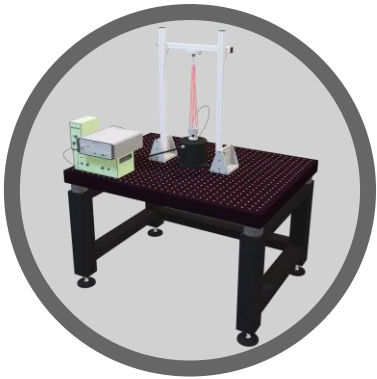
1. Motivation



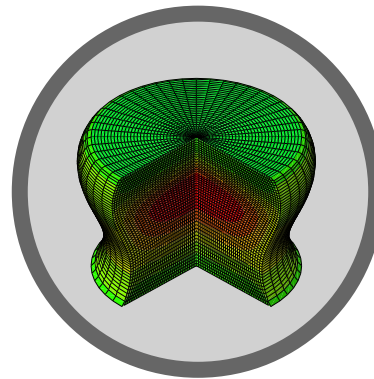
2. Hyperelastic behaviour



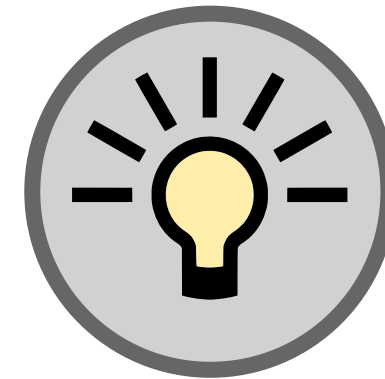
3. Viscoelastic behaviour



4. High-frequency analysis



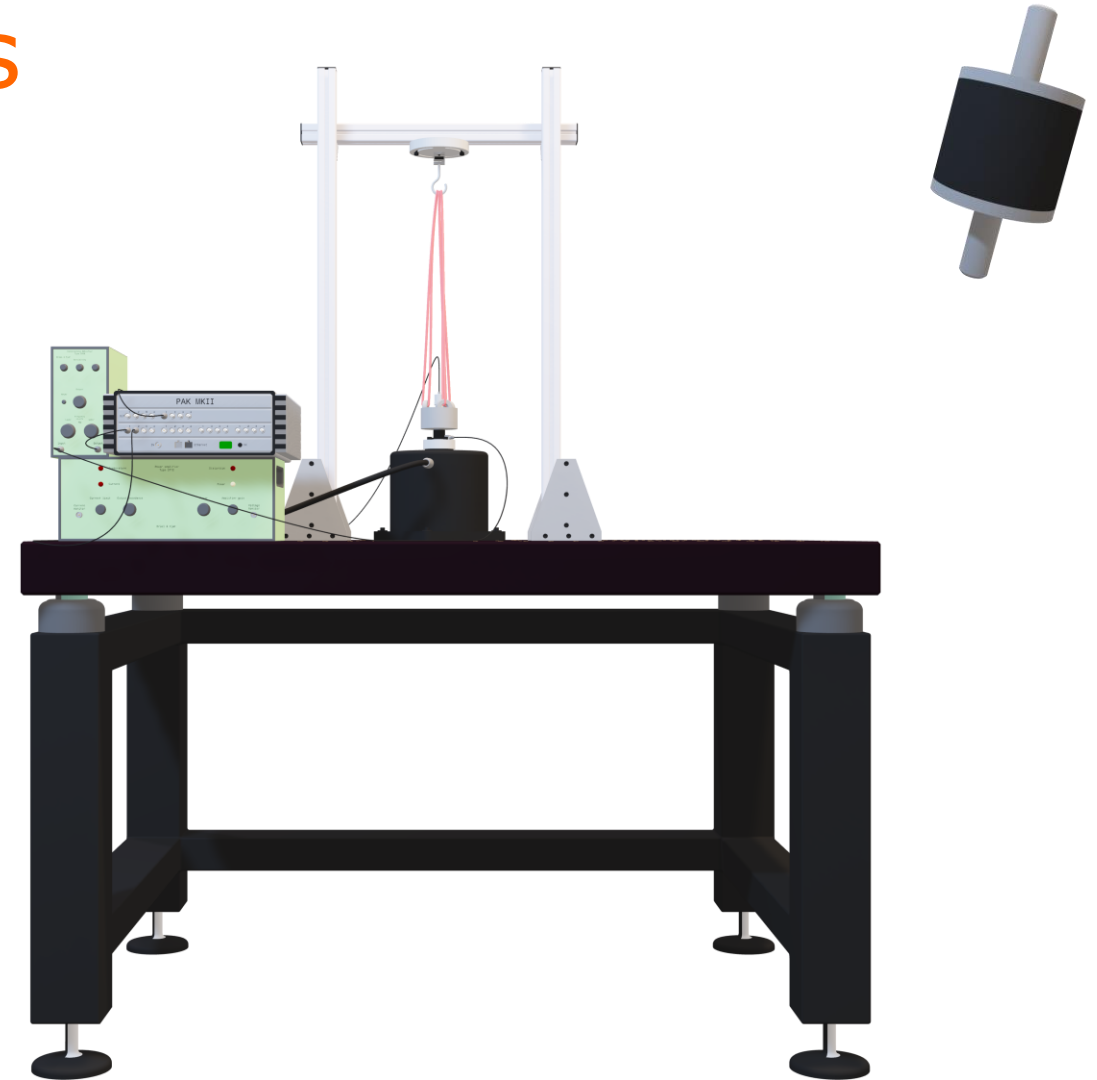
5. Frequency domain simulation



6. Conclusions and outlook

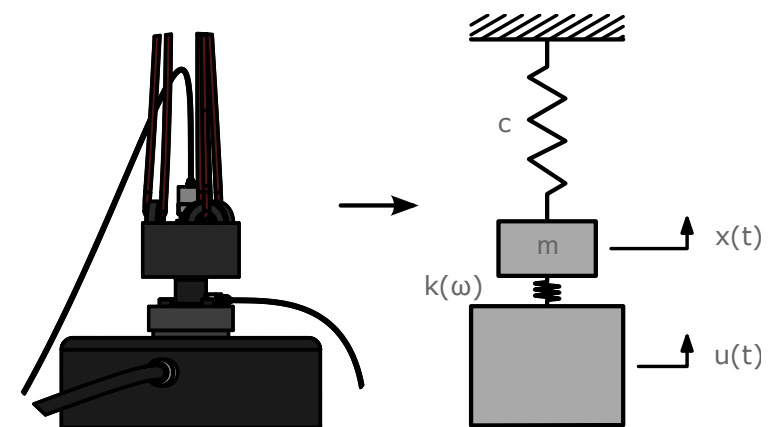
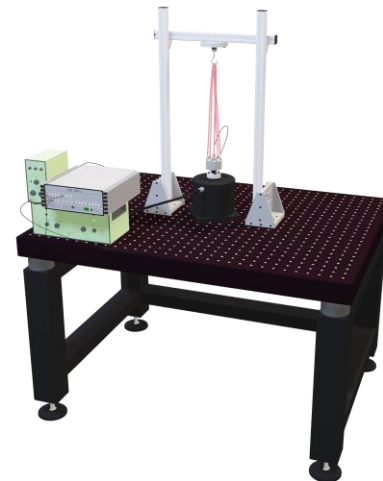
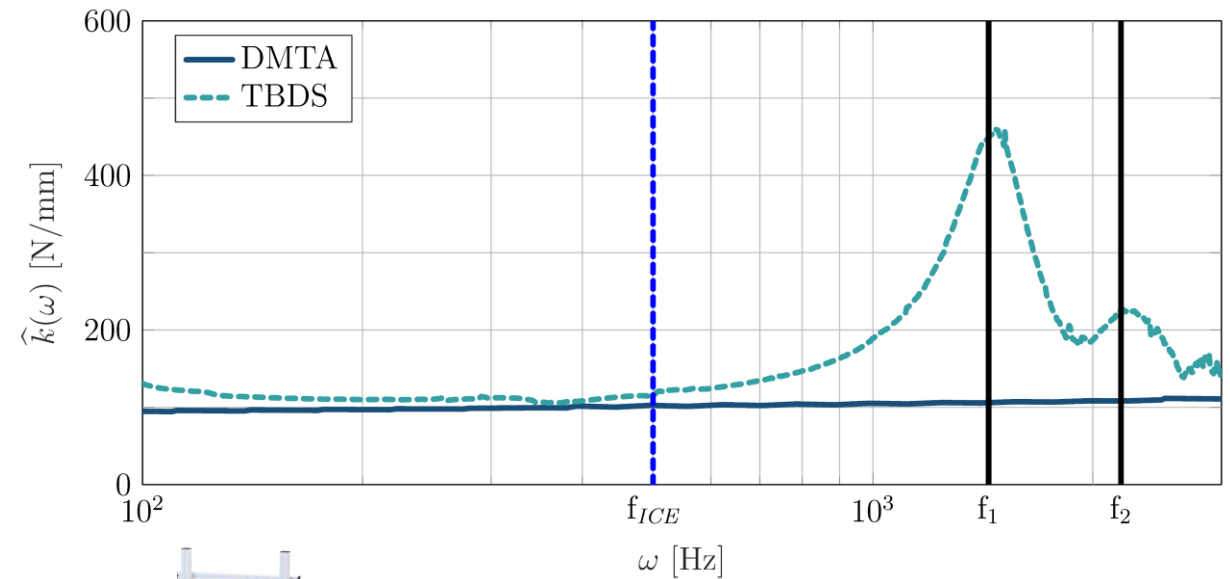
4. High-frequency analysis

- Motivated by research of NVH behaviour of engine mounts
- Measurement range of the apparatus (TBDS) well beyond 1000 Hz
- Controllable preload and dynamic amplitude
- Low level piezoelectric charge accelerometer
- Modular, yet simple and effective design



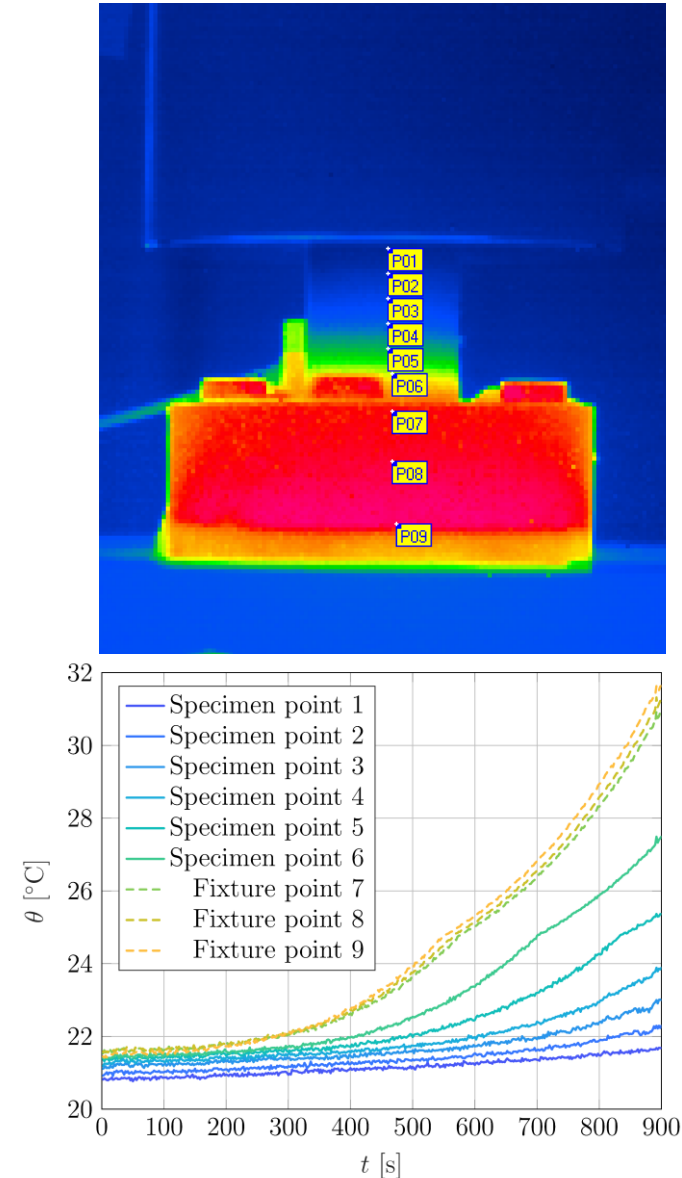
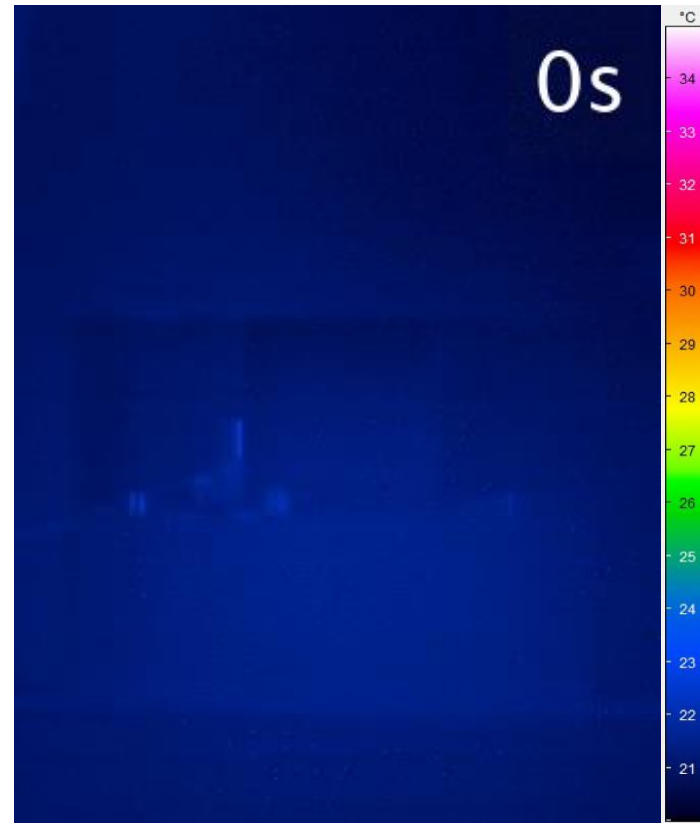
4. High-frequency analysis

- Frequency spectrum resolution of 1 Hz
- Strong correlation of both measurements up until 500 Hz
- Detection of two stiffness peaks representing structural resonances of the elastomer above 1000 Hz using TBDS

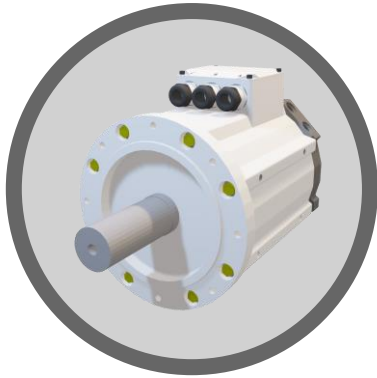


4. High-frequency analysis

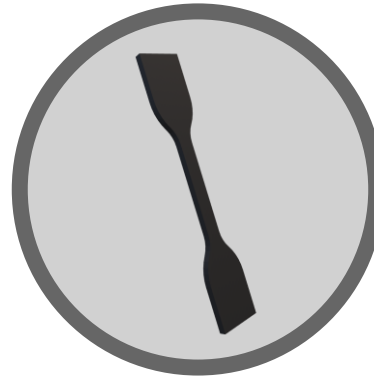
- Warm-up of the dynamic exciter was reduced by more than 50% in comparison with non-actively cooled exciter from the 2022
- Fixture temperature change is only 3.5°C in 600s
- Temperature change in the most exposed place of the specimen is only 1.5°C in 600s



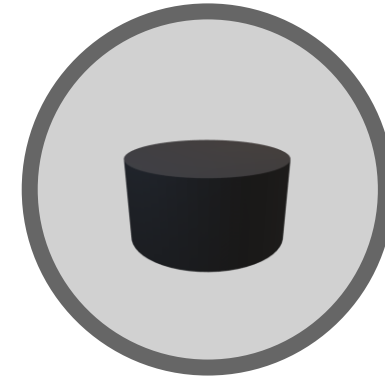
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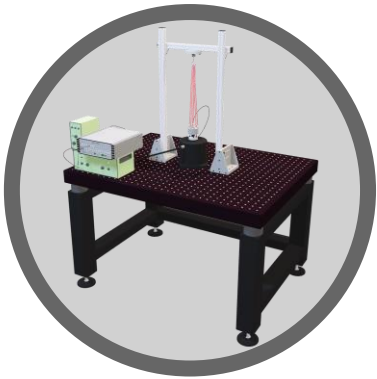
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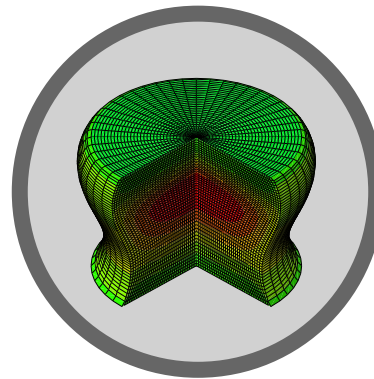
2. Hyperelastic behaviour



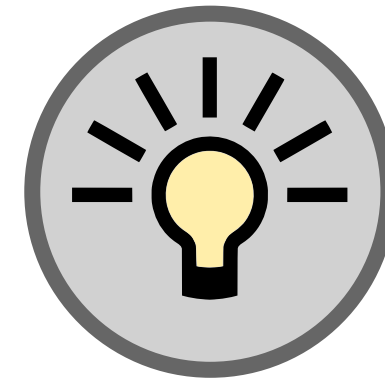
3. Viscoelastic behaviour



4. High-frequency analysis



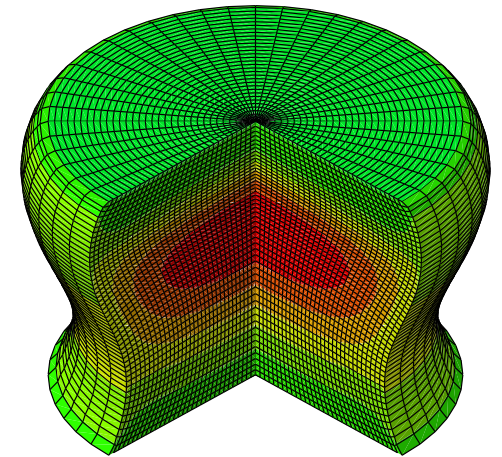
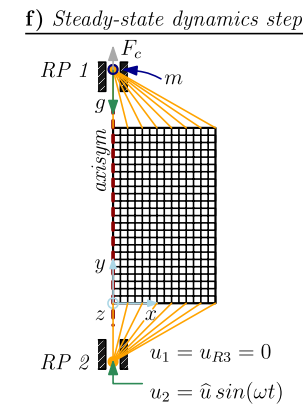
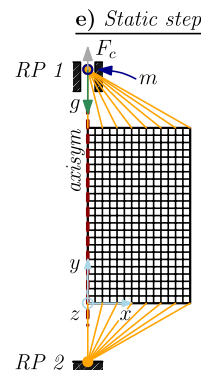
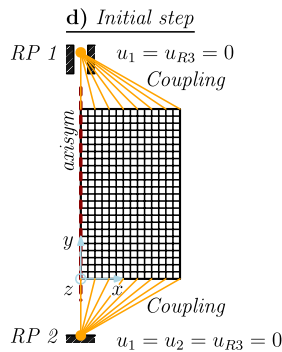
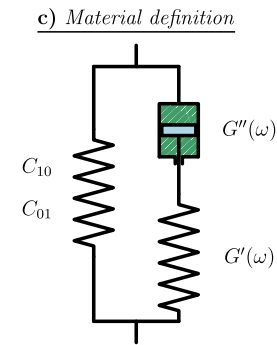
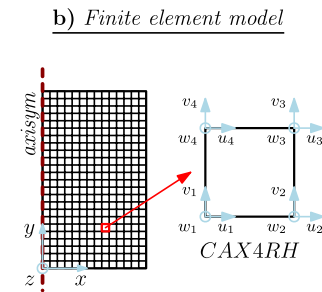
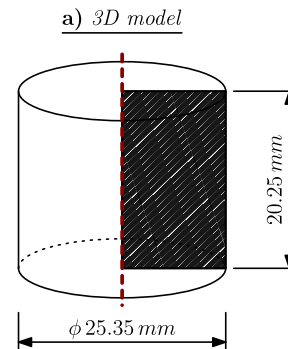
5. Frequency domain simulation



6. Conclusions and outlook

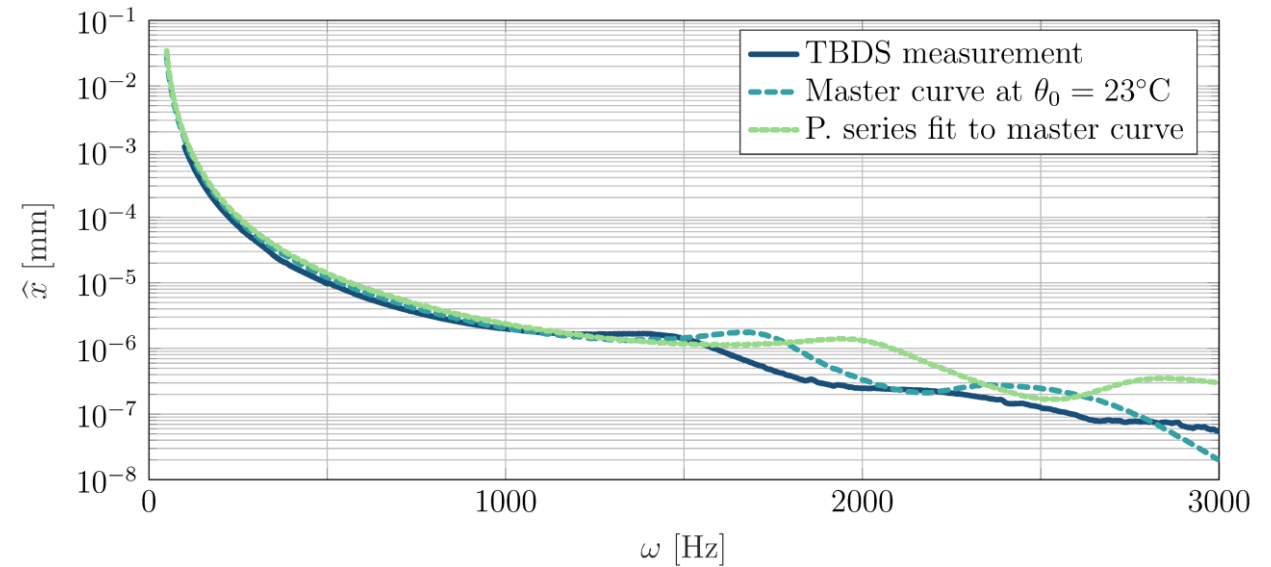
5. Frequency domain simulation

- Performed in Abaqus simulation environment
- Axisymmetric approach with precise meshing
- Results of standardised measurements used as material properties
- Boundary and loading conditions analogous to TBDS measurement
- Several Poisson's ratios were considered

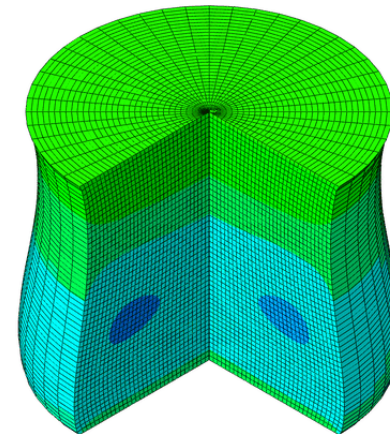


5. Frequency domain simulation

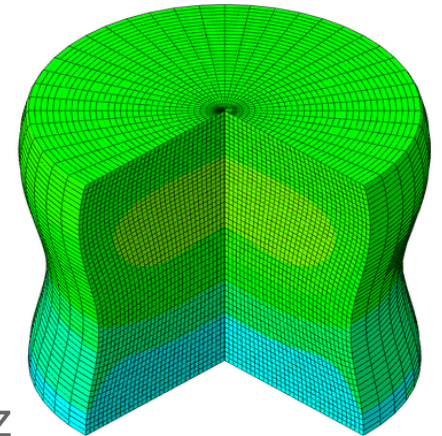
- Results qualitatively correlate with high-frequency analysis
- Numerically calculated structural resonances shifted to higher frequencies
- The model is sensitive above 500Hz to:
 - Density of the elastomer
 - Viscoelastic material definition
 - Poisson's ratio



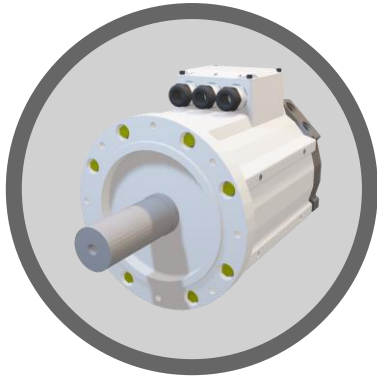
• 1680Hz



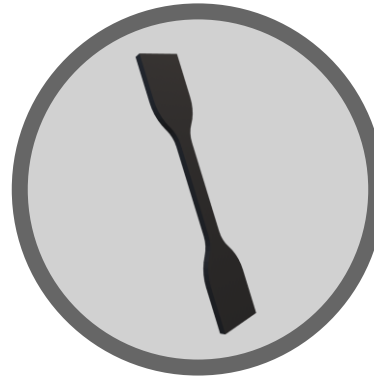
• 2346Hz



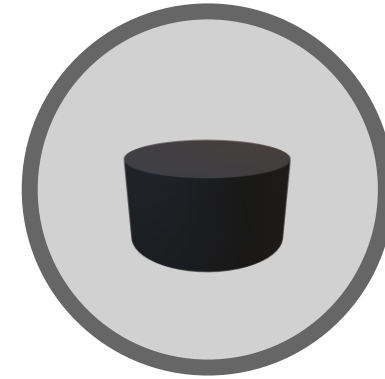
Agenda



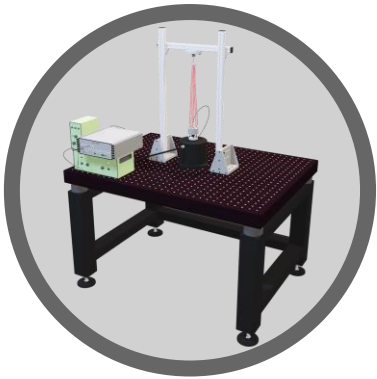
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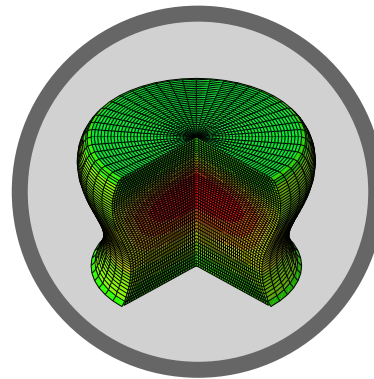
2. Hyperelastic behaviour



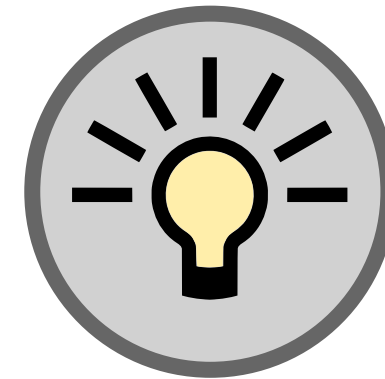
3. Viscoelastic behaviour



4. High-frequency analysis



5. Frequency domain simulation



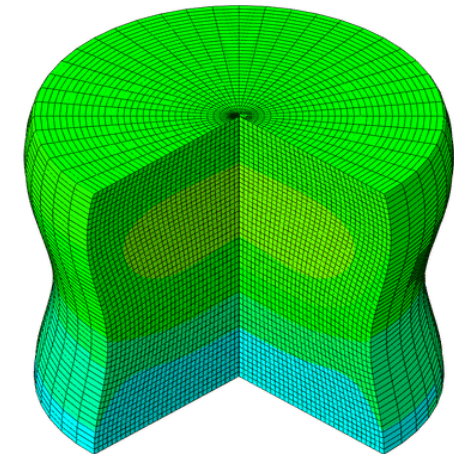
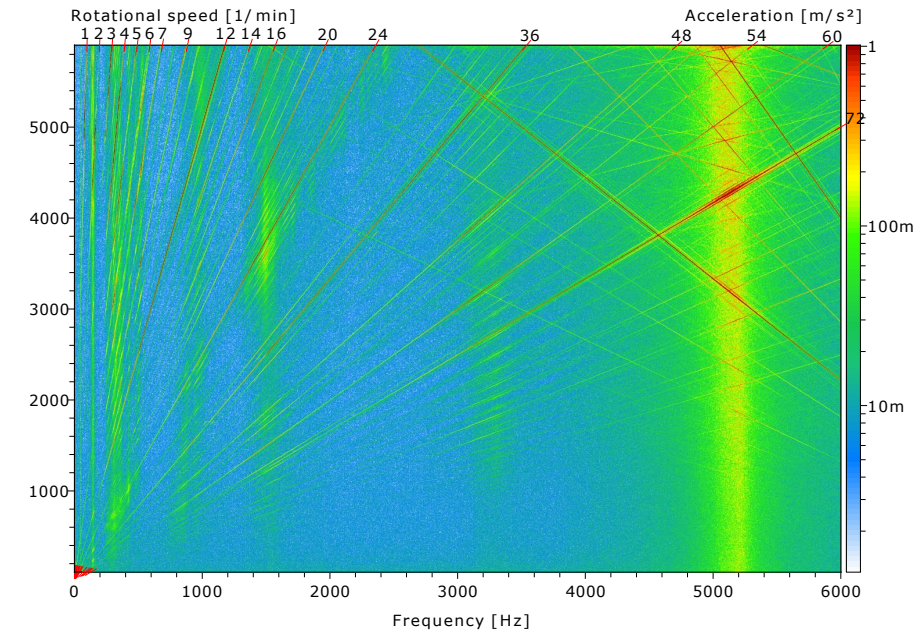
6. Conclusions and outlook

6. Conclusions and outlook

Conclusions



- Interpretation of excitation spectrum of permanent magnet synchronous motor in run-up
- High-frequency analysis is crucial when NVH behaviour is of interest
- Material modelling and simulation procedure necessary for realistic prediction of resonance behaviour of elastomeric mounts
- Mass of the elastomeric engine mount can not be neglected above 500 Hz

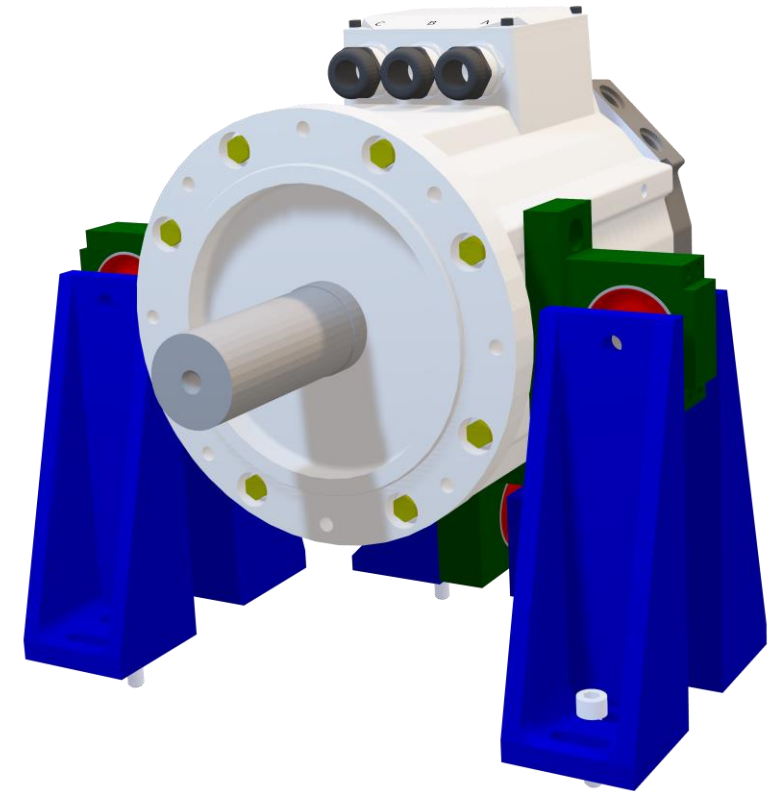


6. Conclusions and outlook

Outlook



- Experimental analysis of soft-mounted E-drive under various working conditions.
- Extraction of excitation amplitudes caused by E-drive
- FE – vibration transfer simulation based on calibrated viscoelastic material model and further material parameters validated on soft-mounted E-drive
- Simulation of different scenarios, such as changes in the geometry of the mounts or their position and orientation.





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Thank you for your attention!

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