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Poroacoustics Model for Waveguide Thermometer Damping

May 2022

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Poroacoustics Model for Waveguide Thermometer Damping

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Poroacoustics Model Configuration

Model Dimension Selection

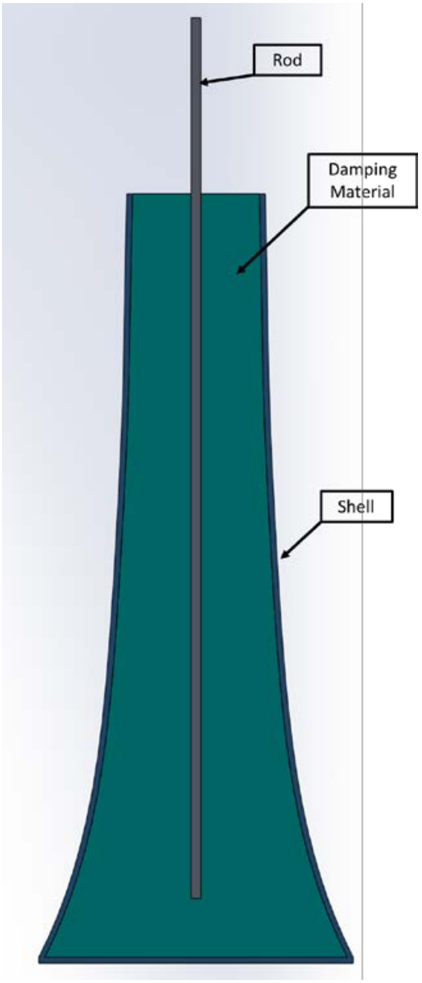
- Full 3D model: computational expensive
- 2D axisymmetric: frequency analysis with the "Port" feature is not available in 2D axisymmetric COMSOL model
- Half 3D model: Simulate 50% of the 3D model and apply the symmetry boundary condition at the cross section (selected)

Components and Materials

- Rod: Galfenol
- Damping material: steel wool
- Shell: structural steel

Physics and Key Features

- *Solid Mechanics* and *Acoustics* with **Port** feature and **Poroacoustics** feature
- The Poroacoustics was originally set to **Delany-Bazley-Miki** (the default) but was later changed to **Three parameter approximation JCAL model** due to the range of frequencies being tested
- The **Port** feature was used to record the Reflection coefficients (S_{11}) at the top surface or the rod for different frequencies.
- A Parametric sweep was used to calculate mainly a range of frequencies, but also some acoustic parameters as well.



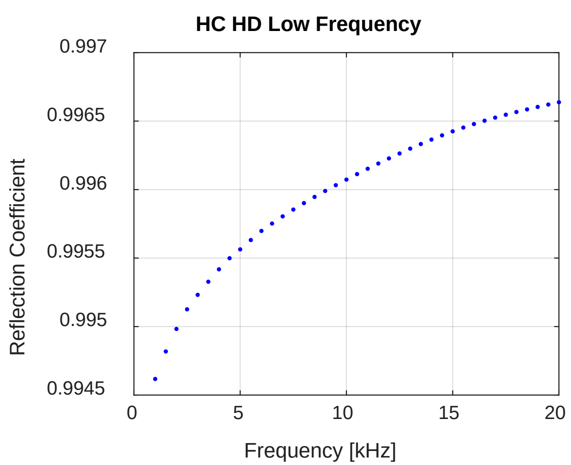
Results

Material Properties
- **Hard Core (HC) Galfenol:** 70 GPa and 8000 kg/m^3
- **Hard Damping (HD) steel wool**: Median Pore Size (MPS): 50um, Porosity: 0.05, Standard Deviation: 1

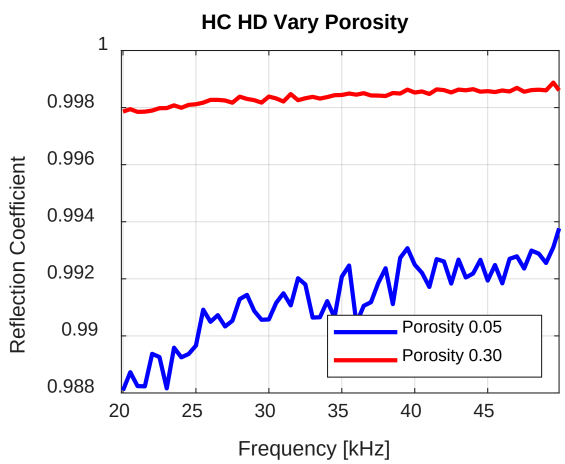
Simulation Results
(a) Hard Core, Hard Damping at a **Porosity** of 0.30 and 0.05 from 20 kHz to 50 kHz, with a **MPS** of 10 um
(b) Hard Core, Hard Damping at a **Porosity** of 0.05 from 1 kHz to 20 kHz, with a **MPS** of 50 um
(c) Hard Core, varying **MPS**, varying **Porosity**, at a constant 20 kHz.

Observations
- The overall damping is very low (<2%); Extremely small pore size is required
- The best damping occurs at a low **Porosity** and low **MPS**

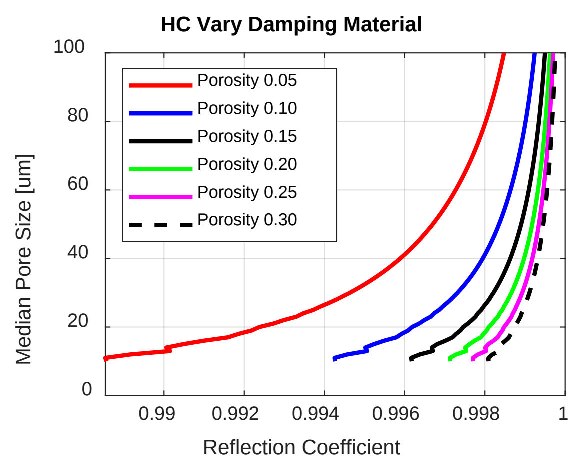
Conclusions
According to literature, the porous media should offer better damping at high frequency, which is opposite to the trend we saw. We hypothesize that our material properties settings are off.



(a)



(b)



(c)

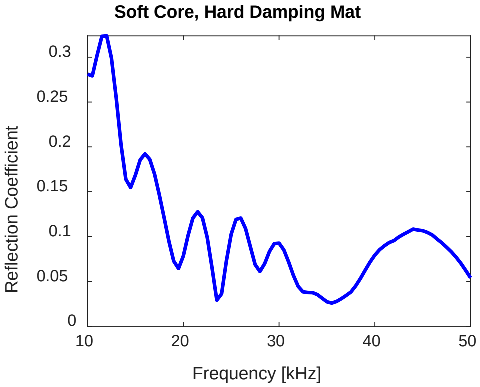
Impact of Material Properties

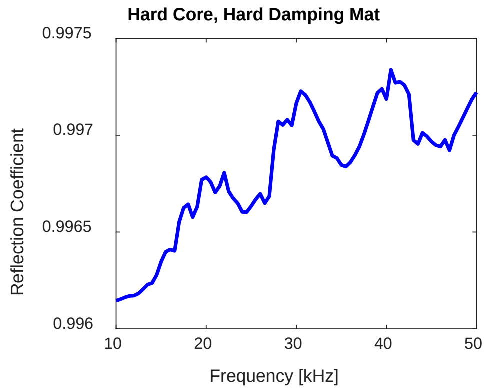
Material Options

- **Hard Core (HC) Galfenol:** 70 GPa and 8000 kg/m^3
- **Soft Core (SC) material:** 10 MPa and 10 kg/m^3
- **Hard Damping (HD) material:** Median Pore Size: 50um, Porosity: 0.05, Standard Deviation: 1
- **Soft Damping (SD) material:** Median Pore Size: 1000um, Porosity: 0.05, Standard Deviation: 1

Results

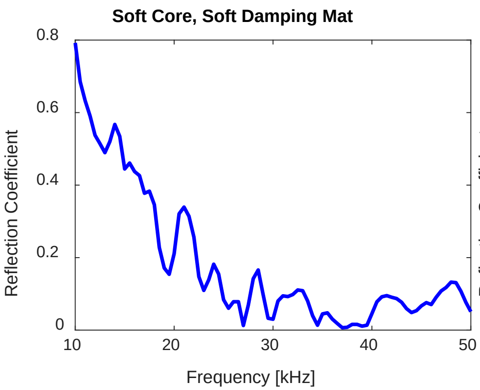
- The steel wool damping mechanism is more effective for **Soft Core**
- **Hard Damping** is more effective than the **Soft Damping**
- Only **Hard Core** and **Hard Damping** combination results in the "wrong" trend

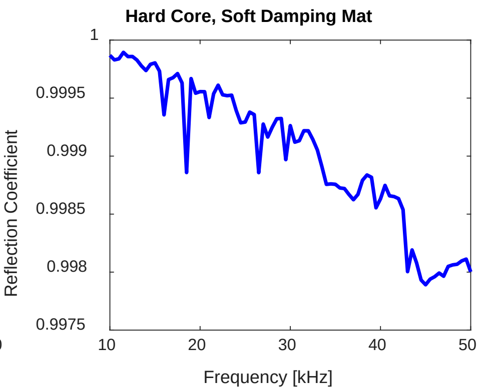




Remaining Questions & Proposed Solutions

- We are currently not sure if the modeling results are correct or not (experimentally characterize the steel wool damping mechanism when the new Galfenol waveguide arrives next month)
- If the model is incorrect, we will make two modifications:
  (a) The model inaccuracy may be caused by the parameters that we used in the **Three parameter approximation JCAL model**. We currently selected our model parameters based on a couple of COMSOL examples, in which the porous media are soft foams. We will conduct an experiment and use the experimental results to update the JCAL model parameters.
  (b) The JCAL model may not be effective for wave propagation in stiff media. If this is the case, we will investigate other Poroacoustics model options in COMSOL.





Proposed Follow-On Activities

- Perform experiment with modelled geometry to validate model findings
- Refine model inputs based on experimental data
- Update damper design via parametric study using refined model
  - Study sensitivities to frequency, damper shape, damper fill material properties