

Master's Thesis

Uncertainty Quantification and Correlation Analysis of Poroelastic Parameters for Fibrous Materials

Background

Porous fibrous materials play a critical role in noise control applications. Their acoustic behavior is governed by coupled interactions between the air in the pores and the solid frame of the material. For soft and low-density materials such as wool or silk, the solid frame exhibits significant elastic contributions that must be accounted for explicitly. Poroelastic models such as the Biot model and the Biot–Johnson–Champoux–Allard (BJCA) model are commonly used to describe this behavior. These models involve both transport parameters (e.g., airflow resistivity, tortuosity, viscous and thermal characteristic lengths, permeability) and elastic parameters (e.g., frame bulk modulus, shear modulus, loss factors). Many of these parameters are obtained indirectly through inversion from acoustic measurements. Recent research has shown that these parameters are not independent, and that their statistical dependencies can strongly affect predicted absorption performance. Advanced uncertainty quantification (UQ) workflows — including copula modeling, Monte Carlo sampling, and global sensitivity analysis — offer an efficient way to evaluate how these dependencies impact the acoustic response. This enables more robust material characterization and model-based design.

Objectives

The objective of this thesis is to analyze the interdependencies of poroelastic parameters in fibrous absorbers and to quantify their influence on acoustic absorption using UQ and sensitivity analysis based on Biot and BJCA models.

- Quantify linear and nonlinear dependencies among poroelastic parameters identified from Bayesian inversion or measurement data.
- Develop copula-based joint statistical models to capture parameter correlations.
- Propagate uncertainty through Biot or BJCA models to predict absorption and impedance uncertainty bands.
- Perform global sensitivity analysis (e.g., Morris, Sobol with correlated inputs, Shapley effects).
- Compare material-specific results and highlight the role of frame elasticity.

Your Tasks

- Study Biot and BJCA poroelastic models for fibrous sound absorbers.
- Analyze parameter posterior distributions or measurement data to determine inter-parameter dependencies.
- Implement copula-based statistical modeling, uncertainty propagation, and sensitivity analysis in Matlab/Python or COMSOL.
- Optionally develop surrogate models (e.g., Gaussian Process or Polynomial Chaos Expansion) to speed up UQ.
- Document your methodology, implementation, results, and scientific insights in a formal Master's thesis (in English).

Requirements

- Interest in acoustics, poroelastic modeling, and uncertainty quantification.
- Experience with MATLAB or Python for statistical modeling and simulation.
- Familiarity with COMSOL or multiphysics simulation tools is a plus.

Contact

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Key references:

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- Lafarge, D., Lemarinier, P., Allard, J.-F., Tarnow, V. (1997). "Dynamic compressibility of air in porous structures at audible frequencies." JASA, 102(4), 1995–2006.
- Cuenca, J. et al. (2022). "Deterministic and statistical methods for the characterisation of poroelastic media from multi-observation sound absorption measurements." MSSP.