Chair of Vibroacoustics of Vehicles and Machines
TUM School of Engineering and Design
Technical University of Munich

Master's Thesis

Uncertainty Quantification and Correlation Analysis of Poroelastic Parameters for Porous Materials using Surrogate Modelling

Background

In vibroacoustic applications, porous materials are frequently used for noise control. Their acoustic performance is governed by a set of poroelastic parameters, including porosity, airflow resistivity, tortuosity, and viscous and thermal characteristic lengths. These parameters are extremely difficult to measure directly and are therefore typically estimated through indirect identification methods, which introduce significant uncertainties. Conventional deterministic simulations rely on fixed input values and fail to account for uncertainties arising from material variability, manufacturing tolerances, and measurement errors. Uncertainty Quantification (UQ) provides a systematic framework to move beyond deterministic assumptions toward a probabilistic and physically more realistic description of acoustic material performance. In this context, surrogate modelling techniques enable efficient uncertainty propagation and sensitivity analysis for computationally expensive numerical models.

Objectives

The objective of this thesis is to systematically assess how uncertainties in poroelastic material parameters propagate through numerical models and affect relevant Quantities of Interest (QoI), such as the average sound absorption coefficient in the frequency range from 100 Hz to 2000 Hz.

- Identify the most influential poroelastic parameters affecting sound absorption using screening methods.
- Quantify the fractional contribution of each uncertain parameter through global sensitivity analysis (e.g. Sobol indices).
- Develop efficient surrogate models to replace computationally expensive finite element method (FEM) simulations.
- Evaluate the reliability of porous sound absorbers by computing the probability that prescribed acoustic performance thresholds are met.

Your Tasks

- Study the governing equations of continuum fluids and the Helmholtz equation in the context of pressure acoustics and porous media.
- Build a three-dimensional multiphysics model using COMSOL Multiphysics, utilising the Acoustics Module for porous materials and acoustic–structure interaction.
- Apply screening techniques such as Morris sampling (MOAT) to rank the influence of uncertain poroelastic parameters.
- Develop surrogate models using Artificial Intelligence techniques, such as Deep Neural Networks (DNN), Gaussian Processes (GP), or Polynomial Chaos Expansion (PCE).
- Perform uncertainty propagation via Monte Carlo simulations on the surrogate model to obtain probability density functions (PDFs) of acoustic response quantities.
- Document the methodology and results in a scientific Master's thesis (in English).

Requirements

- Enrolment as a student at the TUM School of Engineering and Design.
- Strong background in acoustics, fluid mechanics, structural mechanics, or a related field.

- Experience with FEM software, ideally COMSOL Multiphysics.
- Interest in applied mathematics, including statistics and numerical methods.
- Ability to work independently and communicate complex scientific results effectively.

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Key references:

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