Lehrstuhl Steuerung,
Regelung und Systemdynamik

Master Thesis

Programming

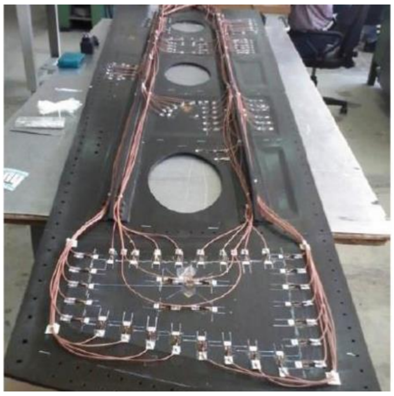
Physics-informed optimization of MSD networks to simulate the propagation of ultrasonic waves in CFRP

Keywords: Guided Waves, Machine Learning, wave simulation

Conditions:

Duration:	6 months
Requirements:	MATLAB knowledge
Language:	English or German
Target group:	Master students

Contents:



Sensor placement on the wing box [Marzani et al., 2019]

In the context of Structural Health Monitoring (SHM), guided waves are widely used as a non-destructive testing method. Ultrasonic waves are generated by actuators and propagated through the monitored structure. Damage assessment is then performed by analyzing changes in the received signals. However, the complex propagation behavior of ultrasonic waves in carbon fiber reinforced plastics (CFRP) significantly increases the difficulty of analysis.
The goal of this master thesis is to extend and optimize the Mass-Spring-Damper (MSD)-based simulation framework by analyzing and directly adjusting the system's dynamical characteristics. The MSD system will be studied through its eigenvalues and eigenfrequencies, which describe the system's natural dynamic response. The approach aims to link these dynamical properties with experimental ultrasonic wave measurements, allowing for a physics-informed parameter adjustment that enhances both interpretability and accuracy of the MSD simulation. The training and test data will be taken from an open-source dataset containing experimental guided wave measurements from a composite panel representing the lower part of an aircraft wing box. The current simulation approach is based on Particle Swarm Optimization (PSO), which adjusts the mass, spring stiffness, and damping coefficients of a double-layer MSD network. The MSD network takes the experimental excitation signal as input and produces a simulated response, which is compared against the measured sensor signal to evaluate accuracy.

Goals of the thesis:

- Analyze and extend the existing MSD–PSO framework
- Preprocess and feature-extract ultrasonic measurement data (e.g., filtering, frequency-domain analysis)
- Derive and study the eigenvalues and eigenfrequencies of the MSD network
- Develop methods for parameter adjustment based on eigenanalysis to improve model fidelity
- Validate the model against experimental CFRP measurements using multiple test cases
- Complete and detailed documentation/presentation of the research results

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