Institute of Mechanical and Electrical Engineering

PhD Defense
by
Casper Aaskov Drangsfeldt

Title:	**" A probabilistic approach for structural health monitoring of ship gearboxes under time-variant operating conditions"**
Date:	Thursday 21 May 2026
Place:	U 167
Time:	10:00
Chairperson:	Associate Professor Ulrik Borg SDU Mechanical Engineering Institute of Mechanical and Electrical Engineering, SDU
Supervisor:	Professor Marie Lützen SDU Mechanical Engineering, Institute of Mechanical and Electrical Engineering, SDU
Co-supervisor:	Associate Professor Luis David Avendaño-Valencia SDU Mechanical Engineering, Institute of Mechanical and Electrical Engineering, SDU
Evaluation Committee:	Associate Professor Jie Cai SDU Engineering Operations Management Department of Technology and Innovation, SDU Senior Lecturer David Garcia Cava School of Engineering, The University of Edinburgh Associate Professor Martin Dalgaard Ulriksen Department of Mechanical and Production Engineering – Mechatronics and Dynamics, Aarhus University

A probabilistic approach for structural health monitoring of ship gearboxes under time-variant operating conditions

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Popular Scientific Abstract

Vibration-based Structural Health Monitoring (SHM) offers the potential to enhance the reliability of engineering systems by continuously assessing their condition through the analysis of vibration data. At its core, SHM relies on establishing a reference description that represents the system in its undamaged condition and subsequently identifying consistent deviations from this reference. Such deviations may indicate deterioration, abnormal behaviour, or emerging damage. However, real-world deployment remains challenging, particularly when systems operate under discrete operating regimes, each characterized by different dynamic behaviours. In such cases, there is not a single reference condition, but multiple reference descriptions—each corresponding to normal behaviour under a specific operating regime. The situation is further complicated by environmental influences, varying loading conditions, and human decision-making, all of which introduce substantial variability. Distinguishing normal operational variability from true structural changes in such uncertain environments is essential for reliable monitoring. Yet, traditional methods often struggle, especially in early-stage conditions where available data are sparse and do not fully represent the complete range of operation.

To address these challenges, this thesis develops a probabilistic vibration-based SHM framework specifically designed for systems governed by multiple discrete operating regimes. Rather than relying on a single global reference condition, the framework separates the monitoring task into two components: (*i*) a probabilistic regime-classification model that determines the most likely operating regime for incoming measurements, and (*ii*) a regime-specific condition assessment model, where each regime is represented by its own local reference describing normal behaviour. This structure enables structural deviations to be interpreted relative to the appropriate operating regime while explicitly accounting for uncertainty arising from both operational and structural variability. The framework is designed to learn progressively as new data become available. Through a sequential updating strategy, it can operate effectively even when data are limited and uncertain, gradually refining its understanding of the system over time. Importantly, the formulation is structured to allow computationally efficient updates, ensuring that uncertainty quantification and adaptive learning can be achieved without compromising practical deployability.

The proposed framework is formulated in a general setting for systems whose behaviour can be characterized by discrete operating regimes. It is demonstrated using vibration data acquired from the gearboxes of a Crew Transfer Vessel (CTV)—a system characterized by significant operational variability, demanding environmental conditions, and cases of early gearbox failure. This case study illustrates the framework's ability to classify operating regimes, quantify uncertainty, and detect structural deviations under sparse and noisy conditions. The results show that a probabilistic, continuously updated monitoring formulation enables uncertainty-aware decision-making and supports effective early-stage deployment, even when limited prior knowledge is available.

Overall, the thesis advances data-efficient and interpretable SHM methodologies and demonstrates the value of probabilistic formulations for monitoring complex systems operating under uncertain and discrete conditions.