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Artificial Intelligence-Enhanced Multivariate Process Control for Gearbox Failure Monitoring via Principal Components Analysis and Machine Learning.

This work presents a methodology for condition monitoring of spur gearboxes based on AI-enhanced multivariate statistical process control. Gearboxes are critical components in rotating machinery, and early fault detection is essential to minimize downtime and optimize maintenance strategies. Vibration signals are a non-invasive means to assess gearbox conditions under varying load and rotational speed conditions.

Condition indicators (CIs) are extracted from the time, frequency, and time-frequency domains to capture relevant features of the vibration signals. These indicators are fused into a multivariate data matrix and analyzed using Principal Component Analysis (PCA). Control limits are established using Hotelling's T_A^2 and Squared Prediction Error (SPE) statistics to identify deviations from healthy behaviour.

To enhance diagnostic capabilities, simulated faults with different degrees of severity are introduced and classified using a Random Forest model. This hybrid approach enables early fault detection and severity assessment by combining multivariate control charts with machine learning-based classification.

All signal processing, statistical analysis, and machine learning modelling were performed in R software, an open-source environment suited for multivariate and predictive analytics.

The results demonstrate that the proposed methodology effectively detects incipient faults and distinguishes between different fault levels, providing a valuable tool for smart maintenance in industrial applications.

Special/ Invited session

Classification

Both methodology and application

Keywords

Predictive maintenance, Gearbox condition monitoring, Fault detection, Multivariate statistical process control (MSPC), Condition indicators, Vibration signal analysis.

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Track Classification: Statistical Process Monitoring