Mini Review
Volume 12:3, 2023

Telecommunication System and Management

ISSN: 2167-0919

Open Access

Ensemble Multiwavelet analysis for Ship-Based Satellite Communication Antenna's Planetary Gearbox condition Monitoring

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Abstract

An important part of a ship's support for voice, data, fax, and video integration services are satellite communication antennas. From the vibration measurement data, condition monitoring of mechanical equipment is essential for ensuring safe operation and avoiding unexpected breakdowns. As a result, the ship-based satellite communication antenna condition monitoring system is designed and developed. In the transmission train of a satellite communication antenna, planetary gearboxes play an important role. However, due to its complexity and lack of condition feature, condition monitoring of planetary gearboxes remains challenging. The ensemble multiwavelet analysis approach proposed in this paper makes it possible to monitor the condition of planetary gearboxes. Multiwavelet has an advantage over characterizing the non-stationary signal due to the property of multi-resolution analysis and the multiple wavelet basis functions. The adaptive multiwavelet basis function is constructed by increasing multiplicity, and the ensemble multiwavelet transform is used to process the vibration signal in order to enable accurate condition feature detection and multi-resolution analysis across the entire frequency range. To describe the state of the planetary gearbox, the normalized ensemble multiwavelet transform information entropy is finally calculated. The experimental planetary gearbox's condition is monitored to first confirm the proposed method's efficacy. The results of this method's application to ship-based satellite communication antenna planetary gearbox condition monitoring demonstrate its viability.

Keywords: Planetary gearbox • Condition monitoring • Ensemble multiwavelet transform

Introduction

Ship-based satellite communication antennas play a critical role in ensuring reliable and uninterrupted communication for maritime vessels. These antennas are equipped with complex mechanical systems, such as planetary gearboxes, which are prone to wear and faults due to continuous operation in harsh marine environments. Timely and accurate condition monitoring of these gearboxes is crucial to prevent unexpected failures and ensure the uninterrupted operation of satellite communication systems. This article introduces the concept of ensemble multiwavelet analysis as a powerful technique for monitoring the condition of planetary gearboxes in ship-based satellite communication antennas. The planetary gearbox in ship-based satellite communication antennas experiences a range of operational stresses, including vibration, shock, and varying loads. Over time, these factors can lead to gear wear, misalignment, and other mechanical faults. Traditional maintenance practices, such as periodic inspections and scheduled maintenance, may not be sufficient to detect early signs of deterioration or impending failures. Condition monitoring techniques offer a proactive approach by continuously assessing the health of the gearbox, enabling timely maintenance actions and reducing the risk of unexpected downtime. Ensemble multiwavelet analysis is an advanced signal processing technique that combines the strengths of ensemble empirical mode decomposition and multiwavelet transform. EEMD is particularly effective in extracting intrinsic mode functions from non-stationary and nonlinear signals, while multiwavelet transform provides a multi-resolution analysis of the IMFs. By applying ensemble multiwavelet analysis to the vibration signals collected from ship-based satellite communication antennas, the condition of the planetary gearbox can be accurately assessed. Data Acquisition and Preprocessing: To perform condition monitoring, vibration signals are typically acquired using accelerometers mounted on the gearbox or nearby components. These signals are then preprocessed to remove noise, baseline drift, and other artifacts. Ensemble multiwavelet analysis requires a robust preprocessing stage to ensure the accuracy and reliability of the subsequent analysis [1].

Literature Review

Ensemble multiwavelet analysis combines the strengths of ensemble empirical mode decomposition and multiwavelet transform to effectively analyze vibration signals obtained from the planetary gearboxes. The technique overcomes the limitations of traditional analysis methods by addressing the non-stationary and nonlinear characteristics of the signals. It provides a comprehensive understanding of the gearbox's condition by capturing both time and frequency domain features. The workflow of ensemble multiwavelet analysis begins with acquiring vibration signals from the planetary gearbox using accelerometers or other suitable sensors. These signals are then preprocessed to remove noise and artifacts, ensuring accurate and reliable analysis. The next step involves decomposing the vibration signals into Intrinsic Mode Functions (IMFs) using EEMD. EEMD is a data-driven method that adaptively decomposes the signals into different frequency components. It adds controlled white noise to the signals and applies the decomposition process multiple times to obtain robust IMFs [2].

Once the vibration signals are decomposed into IMFs, the multiwavelet transform is applied to each IMF individually. The multiwavelet transform provides a detailed analysis of the frequency content and time-domain characteristics of each IMF, allowing for the extraction of relevant features. These features include energy distribution, peak amplitudes, spectral characteristics, and other parameters that capture important information about the condition of the planetary gearbox. To classify the extracted features into different gearbox conditions, machine learning algorithms can be employed. Support vector machines (SVM), artificial neural

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Received: 01 May, 2023, Manuscript No. jtsm-23-104248; **Editor assigned:** 03 May, 2023, PreQC No. P-104248; **Reviewed:** 15 May, 2023, QC No. Q-104248; **Revised:** 22 May, 2023, Manuscript No. R-104248; **Published:** 29 May, 2023, DOI: 10.37421/2167-0919.2023.12.379

networks (ANN), or other classification methods can be trained using labeled data to develop a robust and accurate condition monitoring system. These algorithms learn from the extracted features and their corresponding gearbox conditions, enabling them to accurately classify new vibration signals and provide real-time insights into the health of the planetary gearbox [3,4].

Discussion

The benefits of ensemble multiwavelet analysis for condition monitoring of planetary gearboxes in ship-based satellite communication antennas are significant. Firstly, the technique allows for accurate fault detection by effectively identifying and isolating fault-related features. The combination of EEMD and multiwavelet transform addresses the non-stationary and nonlinear characteristics of the signals, enabling the analysis to capture subtle changes and abnormalities indicative of gearbox faults. Secondly, ensemble multiwavelet analysis enables early fault diagnosis, allowing maintenance interventions to be performed before failures occur. By continuously monitoring the condition of the planetary gearbox, potential issues can be identified at their early stages, preventing costly downtime and minimizing the risk of catastrophic failures [5]. Furthermore, ensemble multiwavelet analysis exhibits robustness against noise and artifacts commonly present in vibration signals. The preprocessing stage removes unwanted noise and artifacts, ensuring that the subsequent analysis is based on clean and reliable data. The combination of EEMD and multiwavelet transform provides a robust framework for extracting relevant features, even in the presence of signal variations and interferences [6].

Conclusion

Ensemble multiwavelet analysis offers a powerful and effective approach for monitoring the condition of planetary gearboxes in ship-based satellite communication antennas. The combination of ensemble empirical mode decomposition and multiwavelet transform allows for accurate fault detection and early fault diagnosis, enabling timely maintenance interventions to prevent unexpected failures. The extraction of relevant features from vibration signals and their classification using machine learning algorithms enhances the effectiveness.

Acknowledgement

None.

Conflict of Interest

None.

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How to cite this article: Zi, Yanyang. "Ensemble Multiwavelet analysis for Ship-Based Satellite Communication Antenna's Planetary Gearbox condition Monitoring." *Telecommun Syst Manage* 12 (2023): 379.