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## Abstract

The failure diagnosis of critical components in rotating mechanical systems is a pivotal challenge in maintaining operational efficiency and reducing downtime in industrial settings. Among the various components, bearings are particularly vulnerable to failure, significantly impacting the performance of motors and other high-speed machinery. This chapter explores advanced methodologies for the early detection of bearing failures using thermal monitoring and acoustic emission techniques. By leveraging sensor technology and signal processing methods, these diagnostic approaches provide real-time, non-invasive insights into the health of bearings, enabling proactive maintenance strategies. Thermal monitoring focuses on identifying temperature anomalies indicative of friction and wear, while acoustic monitoring captures high-frequency noise generated by bearing degradation. The integration of both techniques allows for a comprehensive fault diagnosis, enhancing the accuracy and reliability of predictive maintenance systems. The chapter also discusses the advantages of combining these monitoring methods with advanced machine learning algorithms for continuous, automated health assessments. The implementation of these diagnostic strategies can significantly improve the lifespan, reliability, and efficiency of rotating mechanical systems, ultimately contributing to reduced maintenance costs and increased operational uptime. This research highlights the critical role of multi-sensor fusion in modern failure diagnosis and its potential to revolutionize maintenance practices in industrial machinery.

Keywords: bearing failure detection, thermal monitoring, acoustic emission, predictive maintenance, machine learning, sensor technology.

## Introduction

The reliability of rotating mechanical systems, such as motors, turbines, and compressors, is paramount in industries where continuous operation is essential [1]. Bearings, as key components in these systems, are particularly vulnerable to wear and failure, making their condition a critical factor in maintaining overall system performance [2]. Bearing failures, if left undetected, can lead to catastrophic machinery breakdowns, extended downtime, and costly repairs [3]. In traditional maintenance practices, bearing condition is often assessed using manual inspection methods, vibration monitoring, or scheduled maintenance cycles [4]. These methods are frequently reactive, detecting failures only after significant degradation has occurred. As industries seek to reduce maintenance costs and improve operational efficiency, more advanced diagnostic techniques are being developed to detect bearing failures at earlier stages, enabling predictive maintenance strategies that address issues before they lead to failure [5].

Thermal monitoring and acoustic emission are two of the most promising diagnostic techniques for early detection of bearing failure [6]. Thermal monitoring involves tracking temperature fluctuations in bearings and related components [7]. When bearings begin to fail due to friction, misalignment, or inadequate lubrication, excessive heat is generated [8]. By using temperature sensors, it is possible to detect these anomalies in real-time, identifying potential failure conditions before they escalate [9]. Infrared thermography, a technique often used in thermal monitoring, allows for the non-invasive measurement of temperature variations across bearing surfaces, providing critical insights into the health of the bearings and identifying areas of potential concern [10].