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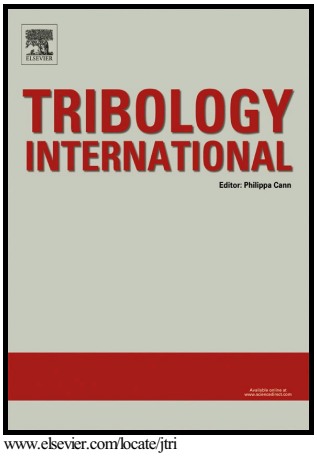
Xiaoliang Zhu, Chong Zhong, Jiang Zhe



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Xiaoliang Zhu, Chong Zhong, Jiang Zhe

Department of Mechanical Engineering, University of Akron, Akron, OH, 44325, USA

*Correspondence: Jiang Zhe, ; Tel: 1-330-972-7737; Fax: 1-330-972-6027. Email: jzhe@uakron.edu

Abstract

Analysis of lubricating oil is an effective approach in judging machine's health condition and providing early warning of machine's failure progression. Many studies from both academia and industry have been conducted. This paper presents a comprehensive review of the state-of-the-art online sensors for measuring lubricant properties (e.g. wear debris, water, viscosity, aeration, soot, corrosion, and sulfur content). These online sensors include single oil property sensors based on capacitive, inductive, acoustic, and optical sensing and integrated sensors for measuring multiple oil properties. Advantages and disadvantages of each sensing method, as well as the challenges for future developments, are discussed. Research priorities are defined to address the industry needs of machine health monitoring.

Keywords: oil condition monitoring; wear debris; lubricant properties; online sensor

1. Introduction

Machine condition monitoring has become essential in maintaining and extending the health of high speed rotating and reciprocating machinery used in many of the nation's key industries including aerospace, manufacturing, and energy [1]. The real time condition monitoring of a machine's health status can significantly reduce the operation cost by eliminating the need for costly machine shutdowns for inspection, which would otherwise be needed to avoid the possibility of catastrophic component failure during operation. Accurate condition monitoring methodologies are being sought to facilitate the effective scheduling of maintenance and repair downtime, particularly in military and the air transport industries, to ensure the safety of long-range operations. Although vibration analysis [2] and thermography [3] have been used in detecting severe faults of rotating machinery, these methods require sophisticated data acquisition and computational procedures, which are difficult to implement. In addition, little or no vibration/temperature change can be noticed at the early stage of a fault developing. More importantly, these methods are usually ineffective in identifying machine's wear conditions and providing a prognosis of pending machine failure [4].

Lubricating oil analysis has become an effective mean to provide early warnings in the failure progression because it contains valuable information regarding the aging and damage of oil-wetted moving components [5]. For lubricating oil property sensors, offline sensors require a physical sample of the lubricating oil be taken from the lubrication system and then be analyzed in the laboratory (away from the machine). In comparison, online sensors, installed on the machine, monitor a portion of the lubricating oil from the continuously circulated lubricant flow *in-situ* during operation. Currently, off-line measurement methods including spectrography and ferrography still remain the most commonly used strategy for diagnosing oil conditions [1]. Although offline methods can provide comprehensive and detailed information about oil conditions, the test procedures are time-consuming and often require expensive equipment and skilled analysts [2]. Furthermore, this method cannot provide real-time information about machine health that could be used for avoiding the catastrophic component failure during operation and providing a prognosis of pending machine fault. Online, portable devices that can perform real time analysis of lubricating oil with no need for complicated setup and skilled analysts are highly desired.