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Automatic diagnostic of marine diesel generator lubricating oil condition

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Автоматична діагностика стану мастила суднового дизель-генератора

Abstract – Quality of a marine 4-stroke diesel generator engine oil is crucial for ensuring the reliable operation of these engines, which are essential for marine transportation and industry. Traditional methods of oil quality diagnostics can be time-consuming and require manual labour, which can lead to inaccuracies and delays. This work presents an analysis of ways of automatically diagnosing the quality of a marine 4-stroke diesel generator engine oil. The approaches involve using different algorithms to analyse data from various sensors and indicators in the engine, and to give engine operator suggestions if needed for necessary action. Data from a marine 4-stroke diesel generator engine is being collected under different operating conditions, and is being used to draw a conclusion regarding the current condition of the oil. Automatic diagnostic approach is accurate and efficient, and can provide real-time diagnostics of the engine oil quality. By utilizing automatic diagnostic one can potentially save time and reduce costs for engine operators and manufacturers, while also improving the overall reliability and safety of marine transportation and industry.

Резюме – Якість масла для чотиритактного дизель- генератора морських суден є вирішальною для забезпечення надійної роботи цих двигунів, які є необхідними для морського транспорту та промисловості. Традиційні методи діагностики якості масла можуть забирати багато часу та потребувати ручної праці вахтового механіка, що може призвести до неточностей та

затримок, не кажучи про те, що частота проведення таких тестів є недостатньою для того, щоб оперативно визначити швидку зміну якості масла через забруднення. Ця робота презентує аналіз методів автоматичної діагностики якості масла для чотиритактного дизельного генератора морського судна. Підходи полягають у використанні різних алгоритмів для аналізу даних з різних датчиків та індикаторів в двигуні, та в наданні рекомендацій для необхідних дій оператору двигуна, якщо це потрібно. Дані з чотиритактного дизель-генератора морського судна збираються в різних умовах експлуатації та використовуються для встановлення поточного стану масла. Підхід автоматичної діагностики є точним та ефективним, та може забезпечувати виявлення якості масла в реальному часі. Використання автоматичної діагностики може потенційно заощадити час та зменшити витрати для операторів та виробників двигунів, покращуючи загальну надійність та безпеку морського транспорту та промисловості.

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Marine diesel generators are crucial components of ships, providing electrical power for onboard systems and propulsion. The lubricating oil used in these generators plays a critical role in maintaining their performance and reliability [2]. However, over time, the oil can deteriorate due to factors such as oxidation, contamination, and wear.

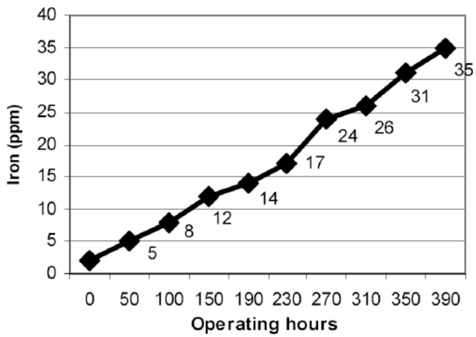

Fig. 1. Trend of iron concentration in oil [1]

Monitoring the condition of the oil is essential to prevent engine failures and downtime [1]. While manual oil analysis is a common practice, it can be time-consuming and expensive. Automatic diagnostic systems offer a potential solution to this problem, providing real-time monitoring and diagnosis of lubricating oil condition.

The use of automatic diagnostic systems for marine diesel generator lubricating oil condition monitoring offers several benefits over manual oil analysis [5]. Real-time monitoring and diagnosis can help prevent engine failures and reduce downtime, resulting in improved reliability and efficiency. Additionally, these systems can reduce the need for manual labour and equipment, leading to cost savings. However, there are challenges to implementing these systems, such as sensor malfunction and data processing requirements [3]. Advancements in technology have made automatic diagnostic systems increasingly viable, but further research is needed to validate these systems in real-world conditions. Overall, this article aims to contribute to the understanding of automatic diagnostic systems for lubricating oil condition monitoring in marine diesel generators, with the goal of improving the reliability and efficiency of these critical systems.

Physical methods such as measuring parameters like viscosity, density, particle size etc. have been used to monitor lubricating oil condition. Chemical methods involve analysing the chemical composition of the oil, while spectroscopic methods use light absorption or emission to determine the presence of specific molecules. While each method has its advantages and disadvantages, automatic diagnostic systems can integrate multiple techniques to provide a more comprehensive assessment of oil condition.

Periodic off-line oil analysis provides significant value within reliability programs, but often it is not a sufficient tool on its own for meeting the program's reliability goals. Online oil quality monitoring systems have proven to be critical, cost saving tools, providing the data necessary to make optimal maintenance decisions [5]. Poseidon Systems' Trident is a real-time, in-line sensing technology for monitoring the health state of lubricating fluids. Technology provides continuous insight to oil health, promoting condition-based maintenance practices such as optimized fluid drain intervals and reduced dependence on offline analysis. Technology utilizes electrochemical impedance spectroscopy (EIS) to measure a fluid's impedance spectrum and track its health. The impedance spectrum provides multiple condition indicators which can be used to assess the lubricant's additive package health, monitor breakdown, and identify the presence of contaminants which helps to make maintenance decisions based on real-time information [5].

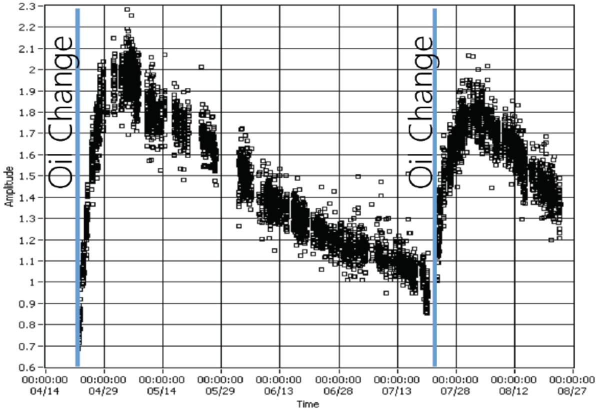

Fig. 2. Sensing method based on analyzing a fluid's electrical properties across a range of frequencies [5]

Sensor technology has played a critical role in the development of automatic diagnostic systems for lubricating oil condition monitoring. In [4] authors provide methodology for rapid analysis using Fourier-transformed infrared spectroscopy and the subsequent multivariate data analysis.

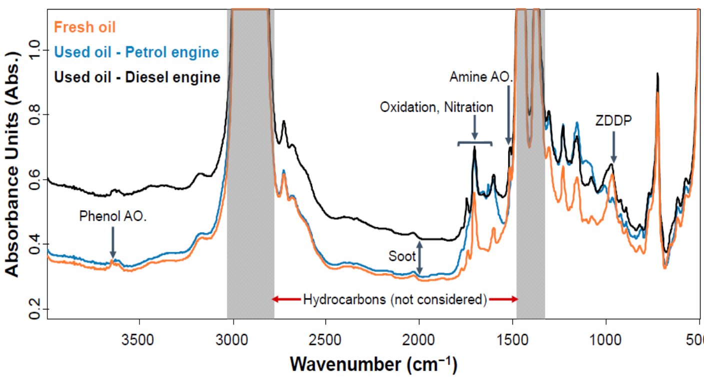

Fig. 3. Exemplary FTIR spectra of the frersh engine oil and used engine oil sample [4]

In [6] a continuous on-board diagnostic lubricant monitoring system evaluates lubricant quality and detects incipient lubricant failure due to contamination by measuring physical characteristics of the lubricant itself.

The sensors preferably include permittivity sensor, a viscosity sensor and a temperature sensor. Diagnostic testing based on the measurements can be carried out on-board via a controller running selected algorithms. A time to condemning limit for the lubricant, i.e., time until the lubricant has degraded to given quality level, is calculated based on permittivity data received by the controller. Implemented algorithm, apart from other, calculates the change in slope for the measured variables. In this way controller can give engine operator not only information about gradual oil deterioration but also quickly inform about rapid changed e.g., in permittivity, which gives information about some major malfunction (coolant contamination, excessive engine wear etc.). Patent also provides specific implementation of such system (fig. 4).

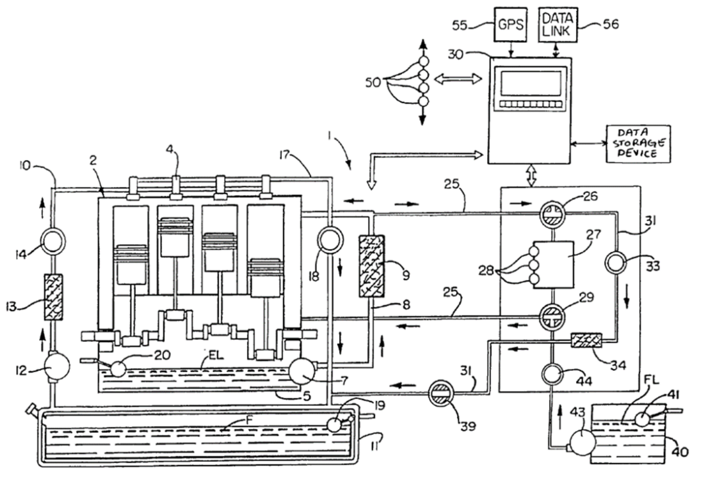

Fig. 4. Specific implementation of on-line diesel-engine lubricating oil monitoring system according to [6]

In patent [7] oil quality and contamination sensing system include a capacitive dielectric sensor and pressure sensing arrangements for measuring the dielectric constant of the oil and the pressure of the oil, respectively, with these variables being indicative of oil viscosity and contamination. The sensors take measurements as oil flows through an internal combustion engine and provide an indication of the cause of a problem with oil in an engine.

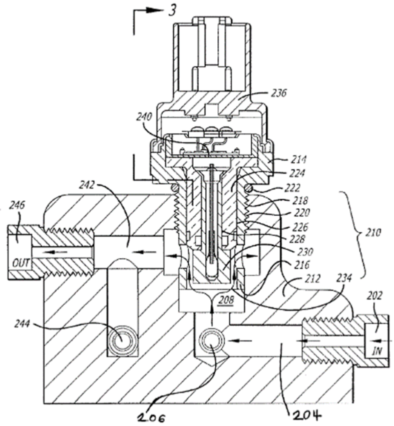

Fig. 5. A cross-sectional side view of the combined oil quality and viscosity sensing system, showing the various components of the system, including the high- and low-pressure ports, the restricted paths, the pressure sensing arrangement, the capacitive dielectric sensor and temperature sensor according to [7]

In [8] a method of detecting soot in engine oil using microwaves is described. The relative permittivity of the oil is measured in the microwave region (fig. 6).

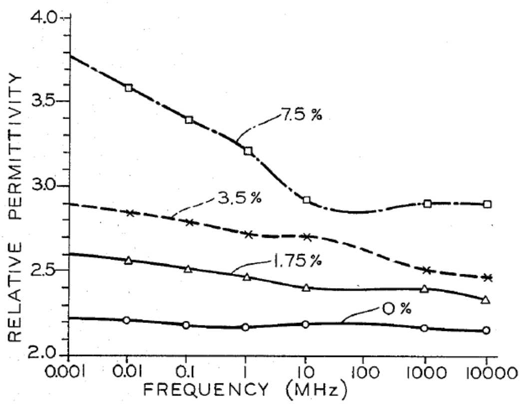

Fig. 6. Relative permittivity versus frequency for several crankcase oils at different levels of soot content [8]

In [9] a degree of deterioration of lubrication oil used in engine is detected by measuring the dielectric constantof the oil with a pair of spaced sensor capacitor electrodes placed in the oil. A voltage source of 50 – 500 kHz is a part of measuring system.

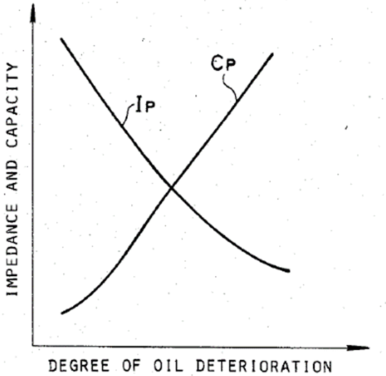

Fig. 7. Graph of variations in the impedance and capacity of the sensor capacitor as a function of lubricating oil deterioration [9]

Patent [10] describes a wear debris sensor which monitors the operation of a lubricated mechanical system. Pattern of debris concentration data indicative of damage to the mechanical system.

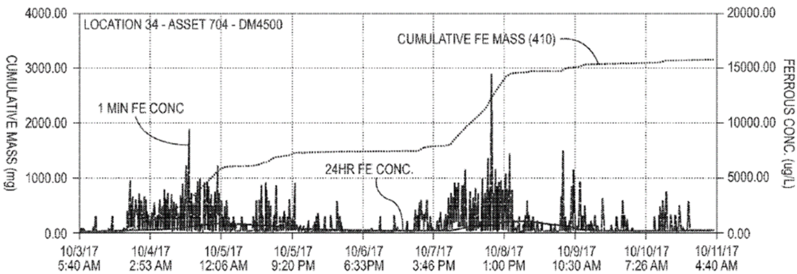

Fig. 8. Chart of the 24-hour average wear concentration and the observed cumulative wear mass over an 8-day period [10]

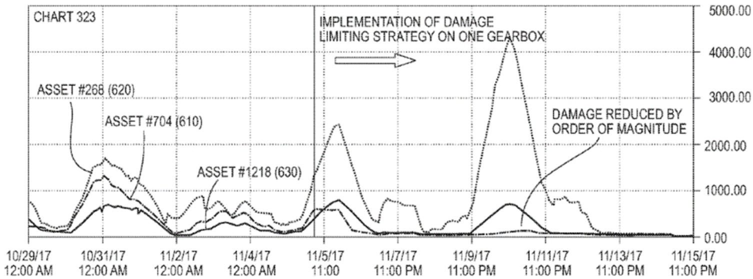

Fig. 9. Chart representing the 24-hour average wear concentration values for three lubrication systems over a 4-day period illustrating the effect of implementing a derating strategy on one of three systems with similar wear generation rates [10]

In [11] a sensor for measuring multiple porperties of an oil, including level, temperature, water contamination and dielectric properties where the sensing elements include two or more interdigitated electrodes, a capacitive relative humidity sensor and a temperature sensing element.

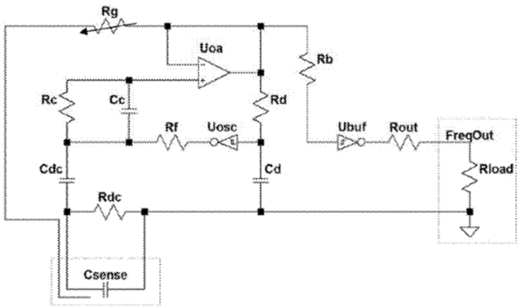

Fig. 10. Circuit diagram for use with the disclosed sensor [11]

In [12] a method and system for estimating the remaining useful life of a filter in a lubrication system includes an inductive wear debris sensor.

In [13] multi-modal fluid condition sensor platform and system are described. Real-time, simultaneous, integrated, multi-modal sensor system has been developed for early warning malfunction notification. System include temperature, magnetic, inductive, electrical impedance and optical absorption sensors.

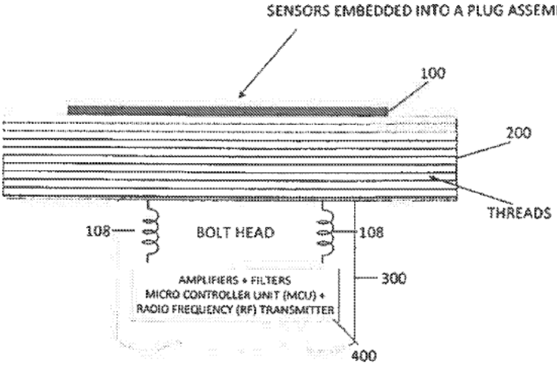

Fig. 11. A representation of an exemplary real-time multi-modal fluid sensing system described in patent [13]

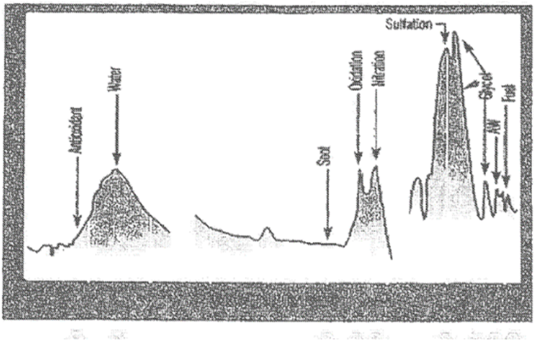

Fig. 12. A representative framework of discrete wavelengths for the various optical properties detection [13]

A Rolls-Royce Corporation patent [14] describes lubricating oil quality sensing system which applies a laser beam to the debris and detects a light signature generated by the debris in response to application of the laser beam.

A Caterpillar company patent [15] describes a system and method for activating on a user interface an indicator of a condition of a lubricant in an engine. The controller may be configured to receive a plurality of lubricant characteristics and determine a change in slope. If the change in slope exceeds a threshold – operator is being notified.

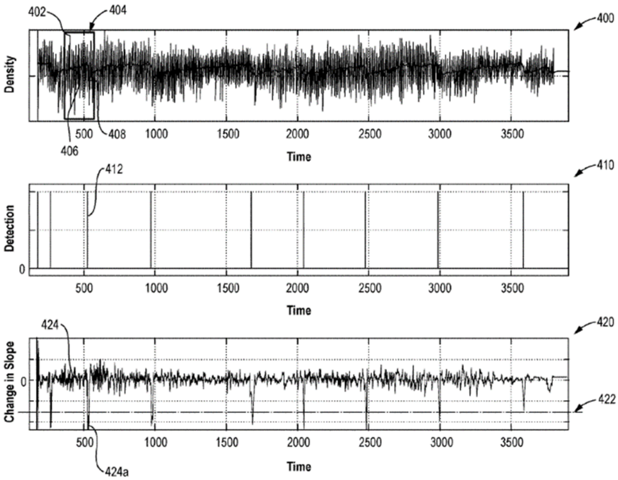

Fig. 13. Illustration exemplary related to patent [15]

In fig. 13 graphs 400, 410 and 420. Graph 400 shows the plotted lubricant characteristics 402 and the plotted slope 406 of the associated adjusted lubricant characteristics over time. The exemplary graph 420 illustrates the plotted change in slope 424 over time for the plotted slope 406. Graph 410 illustrates exemplary detection points over time associated with the change in slope 424 of graph 420 exceeding a threshold 422.

While these experimental studies have shown promising results, implementing automatic diagnostic systems for lubricating oil condition monitoring in real-world maritime environment conditions presents several challenges. The variability of engine operating conditions and oil properties can affect the accuracy and reliability of these systems.

Implementing automatic diagnostic systems for marine diesel generator lubricating oil condition monitoring requires careful consideration of various factors, such as sensor selection, data collection and processing, and choosing diagnostic algorithms.

The selection of sensors depends on several factors, such as the specific condition being monitored and the cost of the sensors. In general, a combination of sensors is used to provide a more comprehensive assessment of oil condition.

Automatic diagnostic systems collect data from the sensors in real-time and process the data using specific algorithms. The data collected includes various parameters such as viscosity, acidity, permittivity and oxidation products. Machine learning algorithms can analyze these parameters and provide real-time predictions of oil condition.

Data processing is a crucial aspect of automatic diagnostic systems. The data must be filtered and processed to remove noise and irrelevant information. Additionally, the algorithms must be trained on a large dataset of oil condition data to provide accurate predictions.

Various machine learning algorithms can be used to analyze the data collected from the sensors. Some of the commonly used algorithms include neural networks, support vector machines, and decision trees. These algorithms can be trained using supervised or unsupervised learning methods.

The selection of machine learning algorithms depends on several factors, such as the size of the dataset and the specific condition being monitored. Neural networks are commonly used for large datasets, while decision trees are useful for smaller datasets.

Implementing automatic diagnostic systems for marine diesel generator lubricating oil condition monitoring faces several challenges and limitations. Sensor malfunction and data processing requirements can pose challenges to these systems. Additionally, the accuracy of the predictions can be affected by the variability in the oil properties and the complexity of the engine components.

Moreover, the cost of implementing automatic diagnostic systems can be a limiting factor, especially for small-scale operators. The complexity of these systems can also require specialized knowledge and training, making them difficult to implement without proper expertise.

The implementation of automatic diagnostic systems for marine diesel generator lubricating oil condition monitoring offers significant benefits for the reliability and efficiency of these critical systems. The selection of sensors, data collection and processing, and machine learning algorithms are crucial aspects of implementing these systems. Despite the challenges and limitations, advancements in technology have made automatic diagnostic systems increasingly viable.

Future research directions

Potential applications of automatic diagnostic systems for marine diesel generator lubricating oil condition monitoring extend beyond the maritime industry. These systems can also be used in other industrial applications where lubricating oil is used. Future research could focus on improving the accuracy and reliability of these systems by incorporating more advanced machine learning and artificial intelligence algorithms. Additionally, investigating the potential of using these systems for predictive maintenance could lead to significant cost savings.

Conclusion

The use of automatic diagnostic systems is becoming increasingly important in the marine industry, particularly for monitoring the condition of lubricating oil in diesel generators. These systems provide a range of benefits, including early detection of faults and lubricating oil degradation, lower maintenance costs, and improved operational efficiency.

One of the most significant advantages of these systems is their ability to detect potential issues before they become major problems. By identifying problems early on, operators can take corrective action before they escalate, minimizing downtime and costly repairs.

In addition, automatic diagnostic systems can help reduce maintenance costs. By monitoring the condition of lubricating oil, these systems can identify when oil needs to be changed, ensuring that maintenance is performed only when it is necessary. This can lead to significant cost savings, as maintenance and oil changes can be expensive.

Moreover, automatic diagnostic systems can improve operational efficiency. By monitoring the condition of lubricating oil, these systems can help ensure that diesel generators are running at peak performance, reducing fuel consumption and improving overall efficiency. This can lead to lower operating costs and a smaller environmental footprint.

However, it is important to note that there are some limitations to the implementation of automatic diagnostic systems. For example, these systems may not be able to detect all types of faults or issues, and their accuracy may be affected by factors such as environmental conditions and the quality of the data used.

To ensure that these systems are accurate and reliable, it is important to carry out thorough evaluations and validations. This involves data validation, model validation, model optimization, and real-world testing. By following these steps, operators can ensure that their automatic diagnostic systems are providing accurate and reliable results.

Automatic diagnostic systems are an essential tool for marine operators and owners looking to monitor the condition of lubricating oil in diesel generators. By providing early detection of faults, reducing maintenance costs, and improving operational efficiency, these systems offer significant benefits to the industry. While there are some limitations to their implementation, advancements in technology are making it increasingly possible to overcome these challenges. As such, automatic diagnostic systems are a worthwhile investment for any marine operator or owner looking to improve the reliability and efficiency of their equipment.

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Підхід автоматичної діагностики є точним та ефективним, та може забезпечувати виявлення якості масла в реальному часі. Використання автоматичної діагностики може потенційно заощадити час та зменшити витрати для операторів та виробників двигунів, покращуючи загальну надійність та безпеку морського транспорту та промисловості. Розглянуті в роботі підходи базуються на використанні інтелектуальних алгоритмів, що дозволяє отримати достовірні результати без втручання людини. Крім того, перспективними напрямками можуть бути використання сучасних технологій інтернету речей та хмарних технологій для моніторингу якості масла. Ці технології можуть допомогти вирішити проблему обмеженої кількості даних та дозволять віддалено моніторити якість масла в режимі реального часу. Автоматична діагностика якості масла для чотиритактного дизель-генератора морських суден може допомогти покращити безпеку та надійність морського транспорту та промисловості. Застосування інтелектуальних алгоритмів та сучасних технологій може покращити ефективність моніторингу якості масла та дозволить операторам забезпечувати надійну роботу двигунів при мінімальних витратах на технічне обслуговування.