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Advancements in Engine Oil Durability, Performance, and Diagnostics

Neha Sahu[1], Rizwan Arif[2,*]

Abstract

The depletion of fossil fuels and environmental concerns have driven the search for alternative fuels and enhanced lubricants. This article explores advancements in machine oil durability, focusing on vegetable oil modifications, synthetic lubricants, and diagnostic methods for marine engine oils. A study comparing Karanja oil blends with mineral diesel in direct injection compression ignition engines revealed comparable wear characteristics and reduced metallic debris for Karanja oil-fueled engines. Investigations on synthetic and semi-synthetic oils demonstrated viscosity changes under various operating conditions, emphasizing the importance of timely oil replacement. The aging of engine oils, caused by oxidation and other physicochemical processes, impacts engine performance and emissions. Modern lubrication solutions, including high-viscosity base oils and advanced additives, have been developed to meet the demands of modern engine designs. Diagnostics using high-resolution Nuclear Magnetic Resonance (NMR) methods show potential for non-destructive evaluation of oil conditions. The findings highlight the critical role of quality control in improving engine reliability and efficiency while reducing environmental impact. The depletion of fossil fuels has spurred advancements in durable lubricants, including vegetable oil modifications, synthetic blends, and marine engine oil diagnostics. Studies show Karanja oil blends reduce wear and debris, while synthetic oils emphasize timely replacement for optimal performance. High-viscosity base oils, advanced additives, and NMR diagnostics improve engine efficiency and reduce environmental impact.

Keywords: Engine oil durability, vegetable oil blends, viscosity, oil aging, NMR diagnostics, marine engine lubrication

INTRODUCTION

The growing scarcity of fossil fuels and associated environmental concerns necessitate advancements in alternative fuels and lubricants. Engine oils are essential for reducing wear, enhancing performance, and meeting modern automotive demands. This study delves into modifications of vegetable oils, viscosity characteristics, and diagnostics of aging oils to improve performance and environmental sustainability [1].

***Author for Correspondence**
Rizwan Arif
E-mail: rizwan@lingayasvidyapeethedu.in

[1]Research Scholar, Department of Chemistry School of Basic & Applied Sciences, Lingaya's Vidyapeeth, Faridabad, Hariyana, India
[2]Assistant Professor, Department of Chemistry School of Basic & Applied Sciences Lingaya's Vidyapeeth, Faridabad, Hariyana, India

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Durability of Machine Oil

Modification of Vegetable Oil

The search for alternative transportation fuels has been motivated by the depletion of fossil fuel resources and the associated environmental degradation. One of the simplest solutions that can be used right away is blending a small amount of Karanja oil (vegetable oil) with mineral diesel. Two identical Direct Injection Compression Ignition (DICI) engines were put through a long-term endurance test to compare the performance of mineral diesel versus a 10% blend of Karanja oil. Over 512 hours of engine operation, a long-term endurance test was conducted to examine carbon deposits, wear on critical engine components, and the impact of a new fuel (oil blend) on lubricating oil. It was discovered that the wear of the K10-fueled engine's liner, piston, piston rings, valves, gudgeon pin, crank pin, bearings, etc. was comparable to that of a mineral diesel-fueled engine. Aluminum content in the lubricating oil of K10 engines was slightly higher than that of diesel engines, but iron, lead, chromium, and zinc metal debris were found to be lower for K10 fueled engines than for diesel fueled engines. Without making significant hardware modifications, respect oil has proven to be a potential partial substitute for mineral diesel in engines [2,3].

The search for alternative fuels for internal combustion engines has been heavily influenced by the depletion of fossil fuel resources and the environmental damage caused by their combustion. In the current context, new resources being considered as potential alternative fuels for DICI engines include plant-based Straight Vegetable Oil (SVO) and fatty acid methyl esters derived from SVOs, animal fats, and other triglyceride molecules. For Compression Ignition (CI) engines, biodiesel has already proven to be the best renewable fuel. The production of biodiesel locally in rural areas is very challenging and difficult because it involves the chemical processing of SVOs, which requires chemical and thermal energy input. The descriptive issue demonstrated that biodiesel produces more energy as a fuel than is consumed in its cultivation, processing, and production, in contrast to the alternative version that claimed the energy required for the cultivation, processing, and production of biodiesel is greater than the energy that is ultimately produced as a fuel. Respect came to the conclusion that the most cost-effective method of producing biofuel from biological renewable resources is the on-form utilization of oilseed crops using the SVO production route. A rapeseed oil life cycle impact assessment study was conducted to compare the environmental impacts of SVO and biodiesel. The results showed that SVO was more environmentally friendly, with an emphasis on its localized production and use [4,5].

Proportioned Deterioration

The descriptive issue involved testing different synthetic and semi-synthetic engine oils to determine how their viscosity changed at various temperatures and how much wear they experienced. Descriptive issue contrasted fresh and used oils. The reliability of motor vehicles, anticipated repairs, and maintenance all depend on this issue. Engine oils undergo physicochemical changes as a result of the extraction process. High pressure, temperature, pollution, and oil oxidation are a few factors that can cause lubricating liquid to degrade. As a result, the engine oil must be changed after the manufacturer's suggested mileage. These suggestions might not be sufficient for the actual liquid consumption, which depends on the technical state of the engine and how the operation is carried out. The best replacement interval must be determined in order to reduce operating expenses and emissions of exhaust that are harmful to the environment. For this, different oils with varying degrees of deterioration and obsolescence had their viscosities based on temperature measured. A mathematical model describing these changes was made after characteristic points were identified. It was found that for all oils, the viscosity changes appear in a smaller range and are less pronounced below a temperature of 40 °C, where the greatest changes in viscosity occur. Evaluation of the change in their lubricating properties was one of the outcomes of comparing the new and used oil. This study's objective was to use a rotational viscometer to perform viscosity tests on a selection of engine oils in order to measure how much engine oil was being used and how much it was being consumed.

Chariot wheel axes were already lubricated with animal fat in ancient Egypt. Up until the middle of the 19th century, these kinds of oils and vegetable oils were employed. Then, mineral oils that were produced by refining crude oil and having their properties enhanced with enhancing additives were used. Today, synthetic oils of various grades are most frequently used. The requirement to continually enhance the properties of lubricating oils is related to the evolution of automotive engine construction techniques. The reliability of motor vehicles, anticipated repairs, and maintenance all depend on this issue. Engine oils undergo physicochemical changes as a result of the extraction process. High pressure, temperature, pollution, and oil oxidation are a few factors that can cause lubricating liquid to degrade. As a result, the engine oil must be changed after the manufacturer's suggested mileage. These suggestions might not be sufficient for the actual liquid consumption, which depends on the technical state of the engine and how the operation is carried out [5,6].

The best replacement interval must be determined in order to reduce operating expenses and emissions of exhaust that are harmful to the environment. For this, different oils with varying degrees of deterioration and obsolescence had their viscosities based on temperature measured. The purpose of this context was to use a rotational viscometer to conduct viscosity tests on a selection of engine oils in order to measure how much engine oil was being used and how much it was being consumed. Studies that accurately reflect how motor oils actually function in automobile engines are the most desirable tests of viscosity changes of motor oils. They enable the observation of changes in the viscosity of these liquids during the intensive operation of the cold engine and when the oil operates at over 100 °C. The context tests different synthetic and semi-synthetic engine oils for viscosity change at various temperatures and degree of wear. We contrasted fresh and used oils. The viscosity-temperature characteristics, which allow for the observation of changes in the viscosity value under the influence of exploitation, were used to present the results [7].

Aging

Engine oils that can handle more demanding conditions, primarily with greater loads and higher temperatures, are needed for new internal combustion engine designs. Modern base oils and specially created additive packages are now more widely used as a result of recent requirements. This prevents the shearing of the viscosity additives under heavy loads, which can lead to the formation of impurities and changes in viscosity. The article addresses the significant issue of oil aging while operating and how it affects internal combustion engine performance. Research findings on the impact of oil service life on changes in their viscosity were presented along with a discussion of the impact of oil service life and its replacement on the emission of toxic exhaust gas components.

The recent rapid growth of the modern automotive industry necessitates the development of new automobile designs, particularly those with novel, ground-breaking drive systems. Let's just say that by 2010, there were more than a billion cars on the road worldwide, compared to 7.2 billion people. And in the not too distant year of 1970, Poland had about 0.5 million vehicles, or about 80 of their own countrymen to every single car. Around 7 people worldwide are connected to one vehicle today. Due to the abundant supply of vehicles, automakers compete with one another to satisfy customer expectations. As a result, consumers today choose models not only based on price, brand, and color, as they did in the past, but also on factors like engine power, fuel efficiency, and driving comfort. Additionally, the engine's operating conditions are very unfavorable: combustion temperatures that can exceed 2000°C, and rotational speeds of 6000 rpm, or 100 rpm, for a typical engine. The piston must move 100 times per second across the space between the so-called cylinder blind spots at these revolutions! It can move at a speed of 20 m/s. Without the proper lubrication, an engine degrades rapidly or even fails. As a result, oil companies have been working on developing engine oil technology for many years in order to protect the engine against wear and enable it to last for years and hundreds of thousands of kilometers. If the oil completes the tasks assigned to it, it will be possible. Engine oils that can handle more demanding conditions, primarily with greater loads and higher temperatures, are needed for new internal combustion engine designs. The manufacturers' plan calls for advanced combustion process control, exhaust gas cleaning, and boost pressure increases among other things. As a result, the engine accessories become very complex and are put under a lot of stress. All of this has an impact on dependability and durability. Engine oils face more challenging circumstances as a result of this. Modern base oils and specially created additive packages are now more widely used as a result of recent requirements. Reducing the amounts of viscose-depressants is possible by using oil bases with a higher viscosity index. This prevents the shearing of the viscosity additives under heavy loads, which can lead to the formation of impurities and changes in viscosity. The choice of shear-resistant viscosity enhancing compounds and lubricating additives, compatible with exhaust gas treatment systems and simultaneously performing their functions in high pressure and high temperature conditions, are the most significant changes in newly produced engine oils. Additionally, the mechanical consumption of the gear accounts for about 7% of total fuel consumption. To cut down on energy losses in rolling bearings, new varieties of seals and specialized plastic greases are used. Resistance to motion savings of 30 to 50 percent have been made. Use of gear or engine oils with correspondingly lower viscosities is the solution for mechanisms that cooperate without rolling bearings. The friction surfaces of synchronizers are increasingly made of carbon fiber rather than molybdenum and light metal alloys, which on the one hand reduces the weight of the mechanism but on the other hand makes them more susceptible to vibration transmission. Less frequently used synthetic oils are also used in gearboxes.

The oxygen in the air, which reacts fairly quickly with the hydrocarbons, is what causes the used oil to continually age. On the internal surfaces of the engine, compounds with the chemical make-up of alcohols, aldehydes, and organic acids are produced as a result of their oxidation. These resin products then go through secondary condensation reactions to form difficult-to-remove lacquers. Parallel polymerization processes are brought on by the simultaneous detachment of hydrogen atoms from hydrocarbon chains, which results in the formation of double bonds in those chains. After extremely long runs, the oil transforms into thick, black tar that cannot lubricate anything and, in severe cases, even solidifies. High temperatures speed up the oxidation process because they cause the thermal decomposition of base oil hydrocarbons, viscosity modifiers, and some improvers. Engine oil is consumed both quantitatively and qualitatively based on the operating conditions (specifically, the operating temperature influences the intensity of physicochemical changes, such as oxidation). Engine oil quality, composition, and physicochemical characteristics are crucial engine operating factors that can have a significant impact on the makeup and emissions of toxic components created in the engine. Engine oil aging and its effects on how an internal combustion engine operates wear. This indicator's response to oil is a complicated and poorly understood phenomenon. Engine oil has an impact on the effectiveness of catalytic exhaust gas treatment systems, which has an impact on the emission of toxic exhaust gas components. The engine's operating conditions, distance traveled, time spent running, technical state of the engine, and the condition of its cooperating parts all affect the engine's oil parameters, which are not constant. Beyond the lower and upper limit ranges established for them, lubricating oil properties can change negatively, increasing the emission of toxic exhaust components and possibly causing damage [8,9].

Assessment

By using high-resolution Nuclear Magnetic Resonance (NMR) and NMR relaxometry with Laplace transform inversion, this work will examine both new and used marine engine oil. Used 10W40 engine oil showed the largest drop in the molar content of CH_3 groups, from 37.7% to 27.3%, and the largest rise in the molar content of CH groups, from 8.8% to 11.5%. The distribution of relaxation times was obtained using the inversion method based on standard deviation minimization and regularization (RILT). It is shown that there are practically no differences between fresh and used oils in terms of the bimodal distributions of the longitudinal relaxation times. This suggests that a change in the viscosity of the used oil has affected the mobility of the functional groups of macromolecules. It is suggested that marine engines with used motor oil be diagnosed using the proton relaxometry NMR method and distributions of relaxation times.

Enhancing the dependability, longevity, and efficiency of equipment is one of the main responsibilities of the maritime sector. The experience of operating marine diesel power plants around the world shows that, in addition to improvements in engine design and manufacturing technology, the quality of the fuels and oils used is the most crucial factor affecting engine technical life. Under typical operating conditions, improving the lubrication oil's quality is one of the few free ways to significantly improve an engine's durability and efficiency. Typically, information on the aging of marine engine oils is discovered through a thorough laboratory analysis that pinpoints changes in the primary metrics commonly used to gauge the oil's quality. Flash point in an open crucible, density, water-soluble acids and alkalis, acidity, acid and alkaline numbers, water content, kinematic viscosity, conditional viscosity, coking capacity, the presence of mechanical impurities and their composition, and ash content are the main physical and chemical properties that are determined in the lab. Lubricating, thermal control, detergent, sealing, and anti-corrosion properties are all provided by motor oils. All of these are supplied by motor oil. While the engine is running, the lubricating oil is affected by numerous factors, such as high temperatures and fuel entering. In order to increase the service life of the engine, it is essential to study the processes of oil aging and mechanical impurity dispersion. the lubrication system, the air's oxygen content, foreign impurities, and the lubrication temperature. The numerous physical and chemical processes that the oil undergoes cause its properties to change as it ages. As a result of operation, viscosity changes, flash point shifts, acidity shifts, and molecular capability. Using high-resolution 1 H nuclear magnetic resonance (NMR) and NMR relaxometry with Laplace transform inversion, this work aims to investigate both new and used marine engine oil. Used 10W40 engine oil showed the largest drop in the molar content of CH_3 groups, from 37.7% to 27.3%, and the largest rise in the molar content of CH groups, from 8.8% to 11.5%. The distribution of relaxation times was obtained using the inversion method based on standard deviation minimization and regularization (RILT). It is shown that there are practically no differences between fresh and used oils in terms of the bimodal distributions of the longitudinal relaxation times. This suggests that a change in the viscosity of the used oil has affected the mobility of the functional groups of macromolecules. It is suggested that marine engines with used motor oil be diagnosed using the proton relaxometry NMR method and distributions of relaxation times.

Engine wear is increased and reliability is decreased by oil oxidation products. The engine ages in the engine much more quickly than it does in a lab setting with artificial oxidation. Studies of the group chemical composition of the oil in relation to the length of engine operation revealed that while the contribution of resinous substances increases as a result of the oxidation of alkanic and naphthenic compounds, that of aromatic hydrocarbons remains essentially unchanged. The relationship between changes in the fundamental physicochemical properties of oils and part wear has been the subject of numerous studies. This article examines diagnostic and forecasting techniques as well as the creation of systems for keeping track of lubricating oil condition. The outcomes of these studies are, however, quite ambiguous. The situation is complicated by the variety of oils and additives used to enhance its quality. Because it has an impact on both transportation safety and the safety of operating environments, the issue of petroleum product quality control is crucial. The current control methods either don't clearly identify the quality of petroleum products or are complicated and expensive. Additionally, conventional techniques for evaluating the quality of petroleum products typically require a sizeable time commitment. The development of new, quick techniques for counterfeit detection and quality control using small devices is essential. Consistent quality control is necessary for ships to use fuel and lubricants efficiently. Their quality also affects how judiciously they are used and how well they protect the environment. Their quality also affects how judiciously they are used and how well they protect the environment. As a new express method for non-destructive quality control, the method of proton NMR relaxometry with the inversion of the Laplace transform can be suggested. Radiofrequency spectroscopy is one of many physical and chemical techniques used to examine the characteristics of petroleum products. However, the majority of these techniques are quite expensive, time-consuming, and complicated. The topic is focused on the development of online marine motor oil analysis techniques and intelligent sensor systems for diagnostics. The handbook presents a variety of techniques for analyzing oils while they are in operation [10].

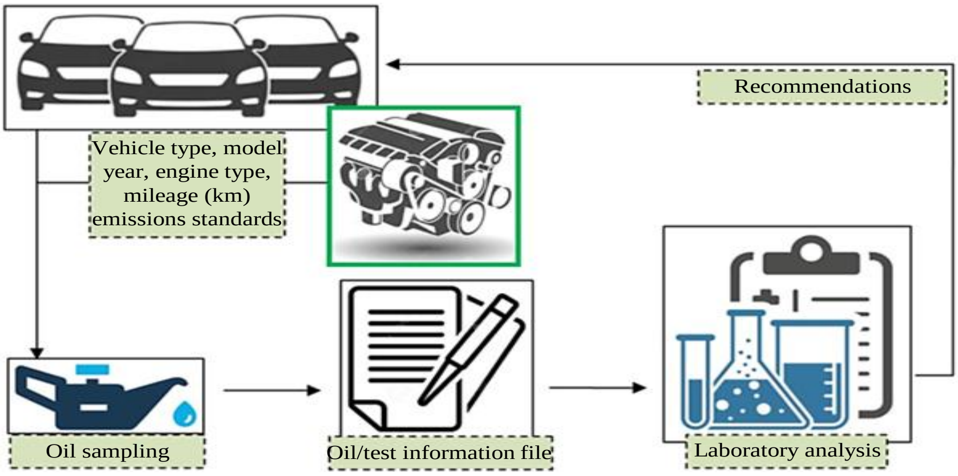

Figure 1. Flowchart representing the oil sampling process for vehicle analysis and maintenance recommendations.

1. *Vehicles*
   - Represents different types of vehicles being analyzed (e.g., cars, trucks, etc.).
   - Includes details like vehicle type, model year, engine type, mileage (km), and emissions standards.
2. *Engine Analysis*
   - Central focus on the vehicle's engine as the subject of oil sampling and performance evaluation.
3. *Oil Sampling*
   - Collection of oil samples from the engine for testing purposes.
4. *Oil Test Information File*
   - Documentation of essential vehicle and sample data (e.g., vehicle details, test parameters).
5. *Laboratory Analysis*
   - Detailed examination of the oil sample to evaluate its properties and detect any issues.
6. *Recommendations*
   - Based on test results, actionable recommendations are provided for engine maintenance or optimization. Figure 1.

Discussion

The study underscores the potential of vegetable oil blends like Karanja oil as partial replacements for diesel, emphasizing their comparable performance and reduced metallic debris. Viscosity studies revealed the significant influence of temperature and degradation on oil properties, advocating regular replacements. Aging oils negatively impact engine efficiency and emissions, necessitating advanced additives. NMR-based diagnostics offer precise, non-destructive methods to monitor oil conditions, paving the way for real-time quality control in marine engines.

CONCLUSION

Advancements in lubricants, including alternative fuels and improved diagnostic techniques, are crucial for sustainable transportation. Enhanced engine oil quality and innovative monitoring solutions can improve engine reliability and reduce environmental impact, emphasizing the need for continued research in this domain.

REFERENCES

1. Avinash Kumar Agarwala and Atul Dhar: Wear, durability, and lubricating oil performance of a straight vegetable oil (Karanja) blend fueled direct injection compression ignition engine; *J. Renewable Sustainable Energy*; 4 (2012) 063138–1.
2. N Wierzbicka et al.: Evaluation of deterioration of engine oil properties in the function of mileage; *[Proc. Conf.]*; Int. Conf.: *Appl. Sci. J. of Phy.*; 1426 (2020) 012004.
3. Idzior, M. Aging of engine oils and their influence on the wear of an internal combustion engine; *Combustion Engines*; 185 (2) (2021) 15.
4. Nikolay Sinyavsky, Ivan Mershiev: Marine engine oil diagnostics by means of NMR spectroscopy and relaxometry of protons; *J. of ETA Maritime Sci.*; 10 (3) (2022) 195.
5. Mehta PS, Anand K. Estimation of a lower limit of brake thermal efficiency for biofuel engines. Renew Energy. 2019;138:389–396.
6. Bhale PV, Deshpande NV, Thombre SB. Improving the low temperature properties of biodiesel fuel. Renew Energy. 2009;34(3):794–800.
7. Srinivasan GR. Vegetable oils as fuels for compression ignition engines: A review. Renew Sustain Energy Rev. 2021;136:110421.

8. Rajagopal D, Zilberman D. Environmental, economic, and policy aspects of biofuels. Found Trends Microecon. 2007;4(5):353–468.
9. Zhu J, He D, Bechhoefer E. Survey of lubrication oil condition monitoring, diagnostics, and prognostics techniques and systems. Journal of chemical science and technology. 2013 Jul;2(3):100–15.
10. Tahan M, Tsoutsanis E, Muhammad M, Karim ZA. Performance-based health monitoring, diagnostics and prognostics for condition-based maintenance of gas turbines: A review. Applied energy. 2017 Jul 15;198:122–44.

