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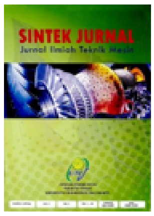

ANALYSIS OF THE USE OF FINE FILTERS ON LUBRICATING OIL CONTENT WITH CONTAMINANT TESTS IN DIESEL ENGINES

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ABSTRACT

Lubricating oil is a critical component in the operation of diesel engines, functioning to reduce wear and dissipate heat generated by friction in moving engine components. Compared to gasoline engines, diesel engines produce higher levels of carbon during combustion, necessitating the use of lubricating oil filters to remove combustion residues. Additionally, fine filters are employed to minimize contaminants present in the lubricating oil. This study aims to analyze the contaminant levels in different states of lubricating oil: new, unused oil; oil used for 500 hours without a fine filter; oil used for 500 hours with a CJC fine filter; and oil used for 1,336.5 hours with a CJC fine filter. The testing methods employed were ASTM D5185-18 and ASTM E2412-10, with all analyses conducted at the PT Petrolab Services Laboratory. The results demonstrate that the use of a CJC fine filter significantly reduces contaminants, with sodium levels at 1 ppm, silicon levels at 7 ppm, and Fuel Dilution, Water Content, and Glycol levels consistently at 0%.

Keywords: lubricating oil; fine filter; contaminant testing; diesel engine

ABSTRAK

Oli pelumas merupakan komponen penting dalam pengoperasian mesin diesel, berfungsi untuk mengurangi keausan dan membuang panas yang ditimbulkan oleh gesekan pada komponen mesin yang bergerak. Dibandingkan dengan mesin bensin, mesin diesel menghasilkan tingkat karbon yang lebih tinggi selama pembakaran, sehingga membutuhkan penggunaan filter oli pelumas untuk menghilangkan residu pembakaran. Selain itu, filter halus digunakan untuk meminimalkan kontaminan yang ada di dalam minyak pelumas. Penelitian ini bertujuan untuk menganalisis tingkat kontaminan pada berbagai kondisi oli pelumas: oli baru yang belum pernah digunakan; oli yang digunakan selama 500 jam tanpa filter halus; oli yang digunakan selama 500 jam dengan filter halus CJC; dan oli yang digunakan selama 1.336,5 jam dengan filter halus CJC. Metode pengujian yang digunakan adalah ASTM D5185-18 dan ASTM E2412-10, dengan semua analisis dilakukan di Laboratorium PT Petrolab Services. Hasilnya menunjukkan bahwa penggunaan filter halus CJC secara signifikan mengurangi kontaminan, dengan kadar natrium pada 1 ppm, kadar silikon pada 7 ppm, dan tingkat Pengenceran Bahan Bakar, Kadar Air, dan Glikol secara konsisten pada 0%.

***Kata Kunci**: minyak pelumas; filter halus; pengujian kontaminan; mesin diesel*

1. Introduction

Contamination testing of lubricating oil is essential for determining whether the oil contains foreign materials or contaminants that may compromise the lubrication system's performance [1,2]. Contaminants, including solid particles, water, gas, and chemical substances, can originate from both internal and external sources [3,4]. These contaminants can degrade the physical and chemical properties of the lubricant, resulting in reduced efficiency and increased wear on engine components [5-7]. For example, contamination can cause abrasion and scratching of metallic surfaces by disrupting the oil film, leading to significant mechanical damage [8,9]. Monitoring and controlling contamination levels are crucial to maintaining lubricant quality and preventing damage to machinery and equipment [10-13].

Effective contamination prevention involves minimizing the ingress of potential contaminants during both the lubricant's storage and application stages

[14,15]. Additionally, utilizing advanced filtration systems can enhance the lubricating oil's quality and extend its operational lifespan [16,17]. Diesel engines, in particular, are highly susceptible to contamination due to their higher carbon output during combustion, necessitating the use of effective filters to maintain lubricant performance [18-20].

The use of fine filters, such as the CJC type fine filter, represents a significant advancement in lubricant filtration technology. However, there is limited research on the comparative performance of lubricating oil when filtered using CJC fine filters versus traditional filtration systems. This study addresses this gap by focusing on the quality of lubricating oil in diesel engines. Typically, diesel engines require oil changes every 500 operational hours, which is both frequent and economically burdensome. By employing CJC fine filters, this research aims to extend the operational life of lubricating oil, reduce maintenance costs, and improve overall efficiency.

2. Methods

The data variables in this study include four samples: (1) new unused lubricating oil, (2) lubricating oil without a CJC type fine filter, (3) lubricating oil with a CJC type fine filter after 500 hours of use, and (4) lubricating oil with a CJC type fine filter after 1,336.5 hours of use. The primary test indicators are contaminants and wear metals. Contaminants refer to foreign particles or residues that may compromise oil quality, while wear metals include elements such as iron, aluminum, and copper, which result from engine component wear.

The study aims to compare the quality of these lubricating oil samples after they have been used for different durations (500 hours and 1,336.5 hours). The analysis focuses on assessing the effectiveness of the CJC fine filter in removing contaminants and reducing wear metal content over time.

The data analysis method used in this research is descriptive analysis. Laboratory test results will be presented in the form of bar charts and line diagrams, which will visually demonstrate the differences between the four samples. Each sample consists of 150 ml of lubricating oil, and the laboratory tests will examine the presence of contaminants and wear metals. The bar charts will highlight differences in contaminant levels and wear metal content, enabling a comparative analysis of each sample.

The laboratory tests conducted on the lubricating oil samples include the physical tests following ASTM D445-21e2 (for viscosity) and ASTM D2896 (for total base number). These tests are essential for determining the lubricating oil’s ability to maintain proper lubrication and its resistance to contamination and degradation. The results will be analyzed to identify significant variations in the oil quality between the samples, particularly with respect to the use of CJC type fine filters.

3. Results and Discussion

Diesel Engine

The main engine used on fishing vessels in supporting shrimp fishing operations and ship motion can be seen in Figure 1.

Figure 1. Main Engine Ship KM. Binama 11
(Source: KM. Binama 11, 2023)

Fine Filter CJC Type

CJC stands for C.C. JENSEN, a company renowned for providing filtration solutions across various industries. C.C. JENSEN (CJC) specializes in the development and production of filtration systems designed to maintain the cleanliness of industrial oils and fluids.

CJC's primary products include oil filters and filtration systems for a wide range of industrial applications, such as hydraulic oils, lubricating oils, and coolants. These systems are engineered to remove contaminant particles and ensure that the working fluids remain clean, thereby protecting equipment and machinery from damage caused by particulate contamination.

To perform the lubricating oil filtration function and minimize the presence of contaminants, specialized filtration is required through a fine filter component. The lubricated sliding components of machinery require a clean, contaminant-free lubricant to minimize wear on the surface of moving joints. Studies on industrial maintenance procedures indicate that contamination of circulating lubricants leads to increased friction and wear, failure of machine components, and elevated maintenance costs.

One of the fine filter components used in the main engine lubrication system of the KM. Binama 11 is a

CJC (CC Jensen A/S) type fine filter. The CJC filter is capable of filtering contaminants as small as 2 microns, which is 40 times smaller than the diameter of a human hair.

Figure 2. CJC KM Filter. Binama 11
(Source: KM. Binama 11, 2023)

Specification of Lubricating Oil

The figure 2 shows Pertamina Meditran S lubricating oil with SAE 40 used on board KM Binama 11. The unused lubricating oil 0 hours of operation) has a viscosity of 13.75 cSt (centistokes) and a Total Base Number (TBN) of 11.08 mg KOH/g. These physical properties will be the standard comparison values for lubricating oil after use in the engine. To compare the quality of lubricating oil after use, the author took oil samples from the main engine on KM Binama 11. Four samples were taken according to the research parameters: 1) new lubricating oil, 2) lubricating oil after 500 hours of use without CJC type fine filter, 3) lubricating oil after 500 hours of use with CJC type fine filter, and 4) lubricating oil after 1336.5 hours of use with CJC type fine filter. The samples were tested in the laboratory of PT Petrolab Service. The test results of these samples can be seen in the following data:

Contaminant Test Results

Contamination testing of lubricating oils has significant impacts and benefits depending on the test results, and it plays a crucial role in engine maintenance and performance. The impacts include assessing the condition of the lubricating oil, detecting harmful contaminants, enhancing energy efficiency, and monitoring engine health. The benefits derived from contamination testing are as follows: it helps assess oil performance and determine when replacement or maintenance is needed, prevents engine or component damage, improves operational reliability, and avoids losses due to contaminants. Clean and high-performance oil enhances engine energy efficiency, reduces friction, and prevents unnecessary wear. Furthermore, it aids in planning preventive maintenance and reduces the risk of engine failures that could result in production downtime. It is important to understand that contamination testing in lubricating oil is not just about detecting issues but also about taking appropriate actions to prevent further damage and maintain machine performance. Preventing contamination in lubricants involves minimizing the potential for contaminant ingress from all possible external sources, both before and during lubricant usage [21].

Sodium Content (Na)

Various sources of sodium can be found in diesel engine oil. Based on the type of equipment and operating environment, these sources can be narrowed down. Potential sources include coolants, brines, additives, grease thickeners, base materials, dirt, and road salt. These sources can generally be categorized into two types: sodium as an additive and sodium as a contaminant [22,23].

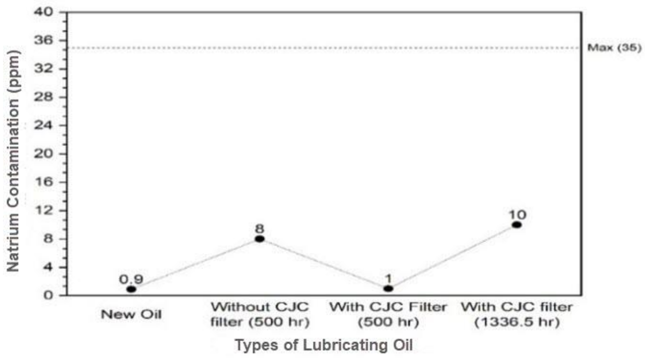

Figure 3. Sodium Content Chart

The sodium content in lubricating oil is typically measured through the Total Base Number (TBN). TBN indicates the amount of base (including sodium) present in the oil, which neutralizes the acids produced during the oxidation process. TBN can also provide insight into the oil's ability to protect against corrosion. The bar graph below illustrates how the TBN test results vary for lubricating oils with and without a filter.

From the figure 3, the sodium (Na) content in new lubricating oil is 0.9 ppm, which serves as a standard for comparison with used lubricating oil. An increase in sodium content in used lubricating oil indicates contamination by other substances, such as water, fuel, or other materials within the engine system, suggesting a potential leak in one of these systems. The graph shows that the sodium content of lubricating oil used for 500 hours without a fine filter is 8 ppm, while the sodium content in oil used for 500 hours with a fine filter is 1 ppm. Additionally, lubricating oil used for 1336.5 hours has a sodium content of 10 ppm.

When comparing the test results of new lubricating oil with those of used oil—both without a fine filter (after 500 hours) and with a fine filter (after 1336.5 hours)—the values exceed the standard. This indicates excessive sodium content, possibly due to leakage from seawater (seawater cooling system) or incomplete combustion in the engine. According to [24], sodium sources in diesel engine oil can be traced to various contaminants, depending on the operating environment and equipment type. Potential sources include coolants, brine, additives, grease thickeners, base oils, dirt, and road salt. The line graph below illustrates the variations in sodium content across each sample.

Silicon Content (Si)

Silicon in lubricating oils can originate from additives or the base oil itself. Silicon is a chemical element commonly used in lubricating oils to impart specific properties. An increase in silicon (Si) levels in oil analysis results is generally indicative of dust contamination. However, this is not always the case, as silicon can also originate from other sources, both external and internal to the machinery or units themselves. Additionally, silicon can be present in fresh oil as an antifoam additive, typically in concentrations around 10 ppm [25]. Lubricating oils with silicon content are frequently used in applications that require resistance to high temperatures, high pressures, or extreme operating conditions. While silicon can offer certain benefits, its use and presence must adhere to the specifications and requirements set for specific types of machinery or equipment.

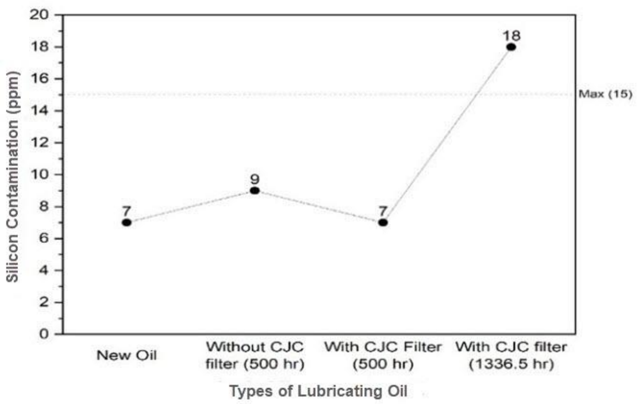

Figure 4. Silicon Content Chart

From the figure 4, it can be concluded that there is an abnormal increase in silicon content in the lubricating oil used with a filter for 1336.5 hours on the KM Binama 11 main engine, with a test value of 18 ppm. Several factors could contribute to the increase in silicon, including environmental contamination, equipment conditions, use of incorrect lubricants, manufacturing processes, and the use of spare parts containing incorrect materials. Excessive silicon content in lubricating oils can lead to several issues, such as reduced lubrication performance, deposit formation, and damage to engine components. It is crucial to identify the causes of elevated silicon content and take appropriate measures to address the contamination in order to maintain the health and performance of the lubrication system. Below is a line graph depicting the test results.

Metal Content Test Results

According to [26], machining involves mechanical contact between components, which inevitably leads to wear. The wear metal test on lubricating oil is a method used to determine the amount of metal particles present in the oil, serving as an indicator of wear or abrasion on engine components. This abrasion process occurs when machine parts move against each other, such as in gear teeth, shafts, and bearings. The testing was conducted by collecting oil samples from the main engine lubrication system on the KM Binama 11 and analyzing the concentration of specific metals that may originate from worn engine parts. The analysis was performed using the ASTM D5185-18 method with the ICP-OES 5100 VDC instrument (PT. Petrolab Services). According to [27], the engine block is composed of aluminum, iron, and tin. As a result, metal wear occurs within the engine, which is quantified in units of ppm. The levels of mixed heavy metals in used oil range from 0.05 to 1,300 ppm. The following are some of the metal contents that were tested, including:

Iron Content (Fe)

The iron content in used lubricating oil can originate from several sources, primarily due to friction and wear of engine components. Factors that contribute to the increase in iron content in lubricating oils include:

- Wear of Engine Components: Engine components that move against each other, such as shafts, bearings, and gears, experience wear over time. Iron particles detached from these metal surfaces can enter the lubricating oil.
- Corrosion: The corrosion of metal components in machinery can release iron particles into the lubricating oil. Corrosion may result from moisture, acidity, or other environmental conditions.
- Use of Lubricating Materials: Some lubricating oils contain additives or base materials that may have iron content. Although the amount is typically small, it can still contribute to the overall iron content in the oil.
- Dust and Foreign Particles: Dust, dirt, or foreign particles from the surrounding environment can also enter the lubrication system, increasing the iron content of the oil.

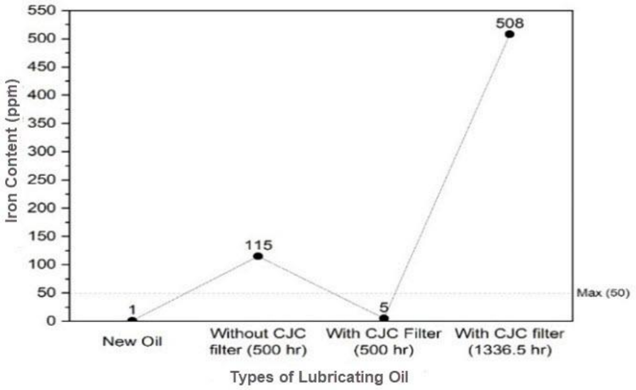

Figure 5. Iron Content Chart

The figure 5 illustrates the presence of iron content in lubricating oil without a filter, with a test value of 115 ppm, compared to lubricating oil that has been used for 1336.5 hours with a filter, which has a test value of 508 ppm. According to the sample test results from PT Petrolab Services, the source of the iron content in the lubricating oil without a filter may stem from components such as the timing gear, camshaft, cam follower, rocker arm, gear oil pump, and cylinder liner. Meanwhile, in the lubricating oil that has been used for 1336.5 hours, the likely sources of the iron content are wear on the piston ring and cylinder liner, which may lead to high blow-by. According to [28], a common issue in diesel engines is high blow-by pressure. This condition occurs when the pressure in the oil pan becomes too high or exceeds the standard. It is caused by excessive pressure leakage from the combustion chamber into the oil pan through gaps in the liner. The most noticeable effect of high blow-by pressure is a reduction in engine power, necessitating an overhaul to restore the engine's performance. Below is a line graph showing the iron content test results for the lubricating oil in the KM Binama 11 main engine.

Copper Content (Cu)

Copper content in lubricating oils can originate from several sources, including contact with engine components or certain additives in the oil formulation. Copper levels can increase significantly if there is a coolant leak into the crankcase oil. These leaks can be detected through routine oil analysis using Gas Chromatography, which confirms the presence of coolant components such as ethylene and propylene glycol. A common source of copper contamination is the chemical leaching of the coolant core, caused by the interaction between ZDDP (Zinc Dialkyl Dithiophosphate) and copper coolant tubes. This chemical process can result in high concentrations of copper in the oil, often exceeding 500 ppm [29,30].

It is crucial to monitor the copper content, along with other metals, in lubricating oil to identify potential issues, assess the level of wear, and determine when engine replacement or further maintenance is required.

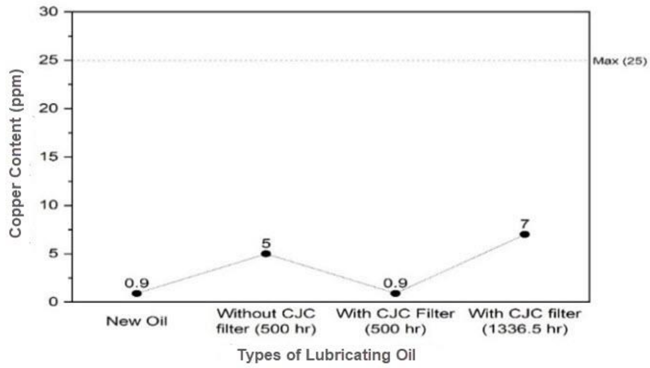

Figure 6. Copper Content Chart

Based on the two graphical representations above, the values are the same, with the only difference being the graphical model—bar and line graphs. In the lubricating oil without a filter, the copper content has a test value of 5 ppm. However, in the lubricating oil that has been used for 1336.5 hours with a filter, there is a slight increase in the test value to 7 ppm. This increase in copper content in the test results of both samples does not significantly affect the quality of the lubricating oil, as it remains well below the attention threshold, which is set at a maximum of 25 ppm. This indicates that the quality of the lubricating oil with respect to copper content is still considered very good.

Aluminum Content (Al)

There should be no aluminum content in lubricating oils, as it is neither a common nor desirable component in oil formulations. Lubricating oils typically consist of a base oil and specific additives that provide the oil with special properties. Aluminum is generally not used as an additive in lubricating oils because it can lead to issues such as undesirable oxidation or other chemical changes that negatively impact the oil's performance. Additives in lubricating oils are typically designed to enhance viscosity, clean the engine, prevent corrosion, and improve lubrication properties.

The figure 7 presents the test results of lubricating oil samples taken from the KM main engine, Binama 11. The new lubricating oil has a value of 1 ppm, while the lubricating oil used for 500 hours without a fine filter is measured at 2 ppm. For lubricating oil used for 500 hours and 1336.5 hours with a fine filter, both show a value of 1 ppm. Based on the test results, there is no excessive aluminum content. Even if the content exceeds the standard, further research or analysis is needed. Aluminum content in lubricating oils may arise from several factors, although aluminum is generally not an intended ingredient in lubricating oil formulations.

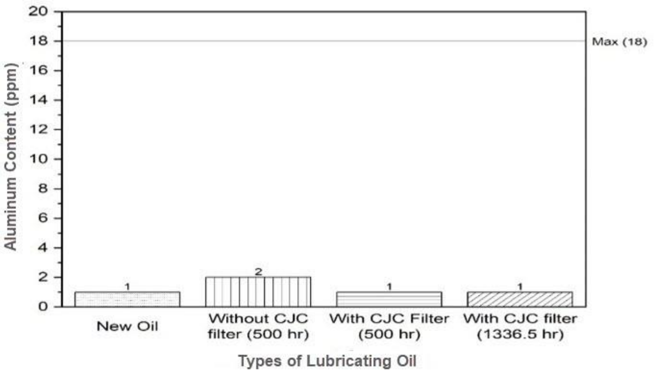

Figure 7. Aluminum Content Chart

Some possible causes of excessive aluminum content in the lubricating oil used in the KM main engine, Binama 11, include:

- Contamination During the Production Process: If the equipment or tanks used during the production process contain aluminum, it could lead to contamination of the oil.
- Use of Equipment Containing Aluminum: The presence of aluminum in equipment used for production, storage, or packaging of the lubricating oil may result in contamination.
- Use of Additives Containing Aluminum: Some additives may contain aluminum, though this is uncommon. The use of inappropriate additives or incorrect formulations can cause contamination.
- Condition of Engine or Lubrication System: If engine components made of aluminum or aluminum alloys experience wear or corrosion, aluminium particles could enter the lubrication system.
- Errors in the Testing or Analysis Process: The detected aluminum content may also be a result of errors during laboratory testing or analysis.

Chromium Content (Cr)

Chromium is generally undesirable in lubricating oils, and high-quality lubricating oils should not contain significant amounts of chromium. Chromium is neither a standard component nor a common additive in lubricating oil formulations. Based on the graph below, lubricating oil used for 500 hours without a fine filter and lubricating oil used for 1336.5 hours with a fine filter in the KM main engine, Binama 11, show an abnormal or excessive chromium content. The sample test results suggest an unusual source of chromium content, possibly originating from components such as the timing gear, camshaft, cam follower, rocker arm, gear oil pump, and cylinder liner.

It is important to note that chromium is not a desirable component in lubricating oil, and its presence may indicate issues in the lubrication system or the production process. If unusual chromium content is found in lubricating oil, such as in the lubrication of the KM. Binama 11, the cause should be identified and addressed to prevent damage to the engine or system. Referring to product datasheets or consulting with lubricating oil manufacturers and machinists can provide valuable insight into the specific situation.

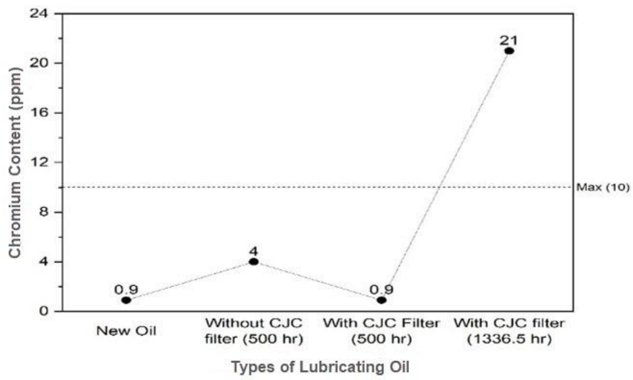

Figure 8. Chromium Content Chart

The figure 8 shows the results of the lubricating oil test from KM. Binama 11, where the lubricating oil used for 1336.5 hours with a filter shows a very high chromium content, with a test value of 21 ppm. This value exceeds the maximum attention limit of 10 ppm.

Chromium is a wear metal found in the linings of parts such as valves, stems, rings, and bearings. Typically, increased levels of chromium, and possibly nickel (which is not comparable to iron), indicate wear of these linings, while proportional increases suggest wear of steel alloys [31,32]. According to [33], high levels of silicon and aluminum, which are key components of dirt, are clear indicators of air intake filtration leaks that allow dirt to enter the combustion chamber. High chromium levels suggest that abrasion has eroded the chrome on the piston rings.

Nickel Content (Ni)

Nickel content in lubricating oils is generally uncommon and undesirable. High-quality lubricating oil should not contain significant amounts of nickel. It is important to note that the unusual presence of nickel in lubricating oil can indicate an issue in the lubrication system or production process. If unnatural nickel content is detected, it is crucial to identify the cause and take the necessary corrective actions.

Based on the figure 9, the test results from the lubricating oil sample of the KM main engine, Binama 11, show consistent values across all samples, including both new lubricating oil and oil that has been used for up to 1336.5 hours with a fine filter, all measuring 0.9 ppm. This indicates that the nickel content is within the acceptable standard, and the quality of the lubricating oil can be considered normal, as confirmed by the line graph.

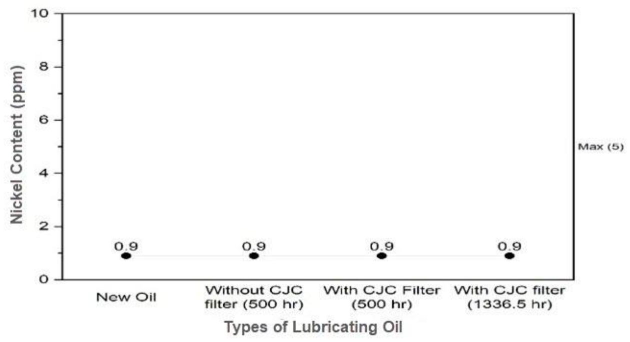

Figure 9. Nickel Content Chart

Tin Content (Sn)

Lubricating oils typically consist of a base oil and various additives. Tin content in lubricating oils usually originates from special additives added during the formulation process. Tin-based additives can serve various purposes, depending on the type of oil and its specific application.

Referring to the figure 10, the test results of lubricating oil samples from the KM main engine, Binama 11, show the following values: for new lubricating oil, the test result is 0.9 ppm; for lubricating oil used for 500 hours without a fine filter, the value increases to 3 ppm, representing a 2.3% increase from the standard value. This indicates an unnatural increase in tin content. For lubricating oil used for 500 hours with a fine filter, the test value remains at 0.9 ppm, the same as that of new lubricating oil, indicating no excess tin content. However, for lubricating oil used for 1336.5 hours with a fine filter, the test value rises significantly to 10 ppm. This marks a substantial increase of about 10%, which is highly unusual and suggests an abnormal tin content.

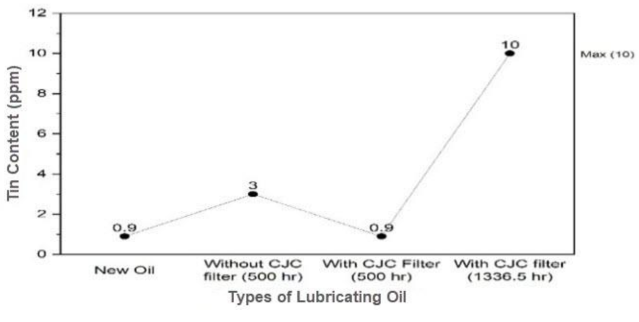

Figure 10. Tin Content Chart

Some possible common causes of the presence of tin in the lubricating oil of the KM main engine, Binama 11, involve the use of certain additives that serve the following functions:

- Anti-Wear: Tin can be added as an anti-wear additive to protect metal surfaces from friction and wear. These additives form a protective layer on metal surfaces, helping to extend the life and performance of engine components under high stress.
- Extreme Pressure (EP): In some applications, such as engine gears, tin-based additives can enhance the oil's ability to withstand extreme pressure, preventing wear caused by heavy loads.
- Anticorrosion: Tin is sometimes used as an anticorrosion additive in lubricating oils to protect metals from corrosion. This is particularly useful in applications exposed to corrosive environments or machinery frequently exposed to water or moisture.
- Oxidation Stabilizer: Tin in specific additives can improve the oxidative stability of the oil, reducing the formation of deposits and chemical changes that may degrade the lubricating oil during use.
- Viscosity Index Enhancer: Tin can be part of additives that enhance the viscosity index of the oil, helping the oil maintain stability over a wide range of operational temperatures.

Content of Lead (Pb)

Modern lubricating oils are typically produced with reduced or eliminated lead content due to its harmful impact on human health and the environment. However, certain specialty lubricating oils or those designed for specific applications may still contain lead. Lead-based additives may be included for particular purposes, such as enhancing oxidative stability or providing additional lubricating properties.

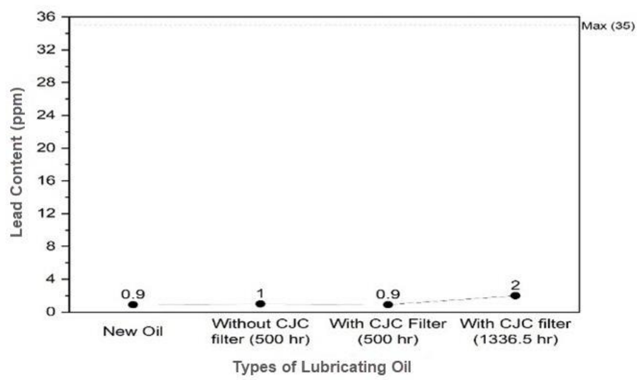

Figure 11. Lead Content Chart

Judging from the figure 11, the test results from four lubricating oil samples taken from the KM main engine, Binama 11, show the following values: The new lubricating oil has a test value of 0.9 ppm. The lubricating oil that has been used for 500 hours without using a fine filter has a value of 1 ppm, which is an increase of 0.1 ppm from the standard value and can still be tolerated. The lubricating oil that has been used for 500 hours with a fine filter maintains a value of 0.9 ppm, the same as the new lubricating oil, indicating that using a fine filter at 500 hours significantly helps maintain the quality of the lubricating oil. For lubricating oil used for 1336.5 hours with a fine filter, the test value increases to 2 ppm, which is an increase of 1.1 ppm compared to the new oil value and is still considered reasonable.

4. Conclusion

Based on the results of the testing and analysis of the diesel engine lubricating oil samples, it can be concluded that:

The lubricating oil used for 500 hours without a fine filter showed significant degradation, as evidenced by abnormal test results. The presence of iron (Fe) was detected, indicating wear, alongside the presence of unnatural soot and water content. These results suggest that the absence of a fine filter allows contaminants to accumulate, adversely affecting the oil's quality.

On the other hand, lubricating oil used for 500 hours with a CJC fine filter showed normal test results. All contaminants, including wear metals and soot, were within acceptable limits, comparable to those found in new lubricating oil. This indicates that the fine filter effectively reduced the accumulation of contaminants, preserving the oil’s integrity and performance.

The lubricating oil used for 1,336.5 hours with a fine filter showed severe degradation. Test results revealed significantly thickened viscosity, low Total Base Number (TBN), and high contamination levels, particularly with silicon, iron, chrome, and tin. Additionally, high levels of soot, sulfate, and water content were detected. These abnormal results suggest that, despite the use of the fine filter, the prolonged use of the oil exceeded its capacity to maintain performance, leading to the accumulation of harmful contaminants and a significant reduction in its protective qualities.

In conclusion, while the CJC fine filter proves effective in maintaining the quality of lubricating oil during shorter durations of use (500 hours), its effectiveness diminishes over extended periods (1,336.5 hours), highlighting the importance of timely oil changes and the potential limitations of the filtration system for long-term use.

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