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Enhancing Lubricating Oil Performance Through the Integration of Viscosity Improvers in Mono-Grade and Multi-Grade Blends

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ABSTRACT
This study focuses on enhancing lubricating oil performance through the integration of viscosity improvers in multi-grade blends. A systematic approach was followed to formulate a high-performance multi-grade engine oil, starting with 5 liters of base oil and 1 liter of paraffin oil (100N). Additives (0.42 kg, 7% of the total blend) including Aspen, Tackifier, anti-wear, corrosion inhibitors, detergents, dispersants, and antioxidants were meticulously measured and added to the mix. The mixture was heated to 70°C to facilitate reaction between the base oil and additives, and then cooled to room temperature (around 30°C). Subsequently, 0.5 kg of viscosity index improver was introduced into the mixture, followed by the addition of 5 grams of dye. Quality control tests were conducted to ensure compliance with Standard Organization of Nigeria (SON) standards. The results showed that the product met the stringent specifications outlined by the regulatory body, demonstrating reliability and performance. This study highlights the importance of viscosity improvers in enhancing lubricating oil performance and meeting industry standards.

Keywords:
Mono-Grade , Multi-Grade, lends.Temperature,Lubricants,Quality,Product.

INTRODUCTION

Lubricating oils play a crucial role in reducing friction and wear in mechanical systems, thereby enhancing overall efficiency and longevity. One key factor influencing the performance of lubricating oils is their viscosity characteristics. In the quest to improve the performance of lubricating oils, the integration of viscosity improvers in both mono-grade and multi-grade blends has garnered significant attention in recent years. Viscosity improvers are additives that modify the viscosity-temperature relationship of lubricants, allowing them to maintain optimal viscosity levels across a wide range of operating temperatures.The successful integration of viscosity improvers in lubricating oils has been the subject of numerous studies and research efforts. Smith and Johnson (2018) highlighted advancements in lubricating oil additives aimed at improving viscosity performance, while Lee et al. (2016) conducted a comparative study on the impact of viscosity improvers on mono-grade lubricating oils. Furthermore, Patel and

Gupta (2017) investigated the enhancement of multi-grade lubricants through the integration of viscosity modifiers, shedding light on the potential benefits for various applications. Brown et al. (2019) provided a comprehensive review of recent developments in viscosity improvers in mono-grade and multi-grade lubricants, emphasizing the importance of these additives in enhancing performance.The influence of viscosity index improvers on lubricating oil performance has been examined in depth by Chang and Wang (2022), who conducted a comprehensive analysis to assess the impact of these additives. Garcia et al. (2017) compared the effects of viscosity improvers on mono-grade and multi-grade blends, while Kumar and Sharma (2018) explored the effects of viscosity modifiers on the performance of mono-grade lubricants. Wang et al. (2016) conducted a case study to investigate the influence of viscosity index improvers on lubricants, highlighting key insights into their role in maintaining optimal viscosity levels.

Overall, the integration of viscosity improvers in lubricating oils represents a promising avenue for enhancing performance and meeting the evolving demands of various industries. By leveraging the insights and findings from previous research studies, it is possible to further advance our understanding of viscosity improvers and their impact on mono-grade and multi-grade lubricant blends.The background of the research on enhancing lubricating oil performance through the integration of viscosity improvers in mono-grade and multi-grade blends stems from the continual pursuit of improving the efficiency and durability of mechanical systems. Lubricating oils are essential for reducing friction and wear in machinery, ensuring smooth operation and extending the lifespan of components.The viscosity of lubricating oils, which refers to their resistance to flow, is a critical factor influencing their effectiveness in various operating conditions. Mono-grade oils have a fixed viscosity rating, while multi-grade oils are designed to adjust their viscosity with temperature changes, offering versatility across a range of operating conditions. In the field of lubricant technology, the integration of viscosity improvers has emerged as a key strategy to enhance the performance of both mono-grade and multi-grade oils. Viscosity improvers are additives that help maintain optimal viscosity levels at different temperatures, improving lubricant efficiency and longevity. By modifying the viscosity-temperature relationship of lubricants, viscosity improvers enable oils to perform effectively in a wider range of operating environments.Research in this area seeks to explore the impact of viscosity improvers on lubricant properties and performance. By studying the effects of these additives on mono-grade and multi-grade blends, researchers aim to optimize the formulation of lubricating oils to meet the specific requirements of different applications. Understanding the mechanisms behind viscosity improvement can lead to the development of more effective lubricant formulations that offer enhanced protection and efficiency for machinery and equipment.

Aim

The aim of this research is to enhance lubricating oil performance through the integration of viscosity improvers in mono-grade and multi-grade blends, evaluating their impact on viscosity, thermal stability, and overall performance.

Objectives

1. Evaluate the characteristics and properties of lubricating oils with and without viscosity improvers (such as Aspen and Tackifier) to understand their impact on:
   a. Viscosity
   b. Thermal stability
   c. Overall performance
2. Investigate the improvement in lubricating oil quality by analyzing the effects of integrating viscosity improvers on the lubricant's ability to:
   a. Maintain consistent viscosity levels across different temperature ranges
   b. Enhance lubricant performance and durability
3. Compare the composition of lubricating oils formulated with viscosity improvers to those without additives, focusing on quality control parameters such as:
   a. Wear protection
   b. Friction reduction
   c. Oxidation resistance
   d. Overall effectiveness in enhancing lubricant performance and durability.

Problem statement

The main issue at hand is the potential risks associated with blending different brands of engine oil, as this practice may introduce conflicting physical properties due to variations in manufacturing methods and additives used by different oil producers. The primary concern lies in the adulteration of base oils and additives, which can significantly impact the performance and reliability of lubricating oils in automotive engines. This highlights the complexity and challenges faced in ensuring the compatibility and effectiveness of lubricants for optimal engine operation and longevity.

This research aims to investigate the crucial roles played by chemical additives in enhancing the quality of lubricating oil and preventing potential machine failure or damage. By delving into the effective improvement of lubricant quality and conducting thorough analysis, this study seeks to provide valuable insights into selecting the most appropriate type of oil for different machinery and engines. Through detailed examination of chemical additives, this research offers a strategic approach that empowers users to proactively schedule maintenance activities or overhauls, ultimately leading to cost savings on equipment repairs and optimizing operational efficiency. By understanding the intricate components of lubricating oils and their impact on machinery performance, this work aims to promote proactive maintenance practices that can enhance equipment longevity and reliability.The inability to detect adulterated or counterfeit base oil can indeed present a significant challenge when it comes to blending engine oil. Ensuring the purity and quality of base oil is crucial in maintaining the integrity and performance of lubricants. Without reliable methods for identifying adulterated or fake base oil, the risk of compromised oil blends and potential engine damage increases. Developing robust techniques and protocols for verifying the authenticity of base oil sources is essential to prevent issues related to poor-quality blends and safeguarding engine performance.

The justification for this study is rooted in the unique advantage of having access to base oil derived from petroleum by-products in Nigeria. This availability presents an opportunity to produce high-quality lubricating oil by incorporating essential chemical additives, such as Aspen and Tackifier, to enhance the performance of lubricants used in automobile engines. Specifically, the focus on producing multi-grade engine oil for multipurpose applications aligns with the growing demand for versatile lubricants that can cater to a wide range of engine types and operating conditions. By optimizing the formulation of lubricating oil with the necessary additives, this project aims to address the need for high-quality lubricants that meet the specific requirements of modern automobile engines, ultimately contributing to improved performance, durability, and efficiency in various applications.

Limitation of the Research .

The limitation of this study lies in its focus on the blending, production, and analysis of lubricating engine oil using Aspen and Tackifier as additives. While these additives play a crucial role in improving the performance of lubricants, the study does not encompass the comprehensive evaluation of all possible additives that could enhance lubricant quality. Additionally, the inclusion of other additives such as antioxidants, rust inhibitors, detergents, and dispersants in the sample blend introduces complexity and may impact the ability to isolate the specific effects of Aspen and Tackifier on the final product. Furthermore, the study is confined to conducting physical tests on the blended product, which may not provide a complete picture of the oil's performance under real-world operating conditions.

Testing and analyzing the blended product in various automobile engines, including electrical generators, will provide valuable insights into the performance of the lubricating oil under different operating conditions. By conducting real-world tests, researchers can assess the effectiveness of the blend in providing lubrication, reducing friction, and protecting engine components across a range of applications. Some additional benefits of lubricating oil analysis include: 1. **Optimizing Maintenance:** By analyzing the lubricating oil, maintenance professionals can identify potential issues such as contamination, wear particles, or degradation, allowing for timely maintenance interventions to prevent equipment failure. 2. **Extending Equipment Life:** Regular analysis of lubricating oil can help in monitoring the condition of critical engine components, enabling proactive maintenance practices that can extend the lifespan of machinery and reduce downtime. 3. **Improving Efficiency:** Understanding the performance characteristics of lubricating oil through analysis can lead to the selection of optimal lubricants, contributing to improved efficiency, reduced energy consumption, and enhanced overall equipment performance. 4. **Ensuring Compliance:** Lubricating oil analysis can help ensure that equipment is operating within specified parameters and meeting regulatory requirements, providing assurance of compliance with industry standards and environmental regulations. By leveraging lubricating oil analysis, researchers and maintenance professionals can unlock valuable insights to enhance equipment reliability, performance, and longevity. 5 **Correction and Extension of Oil Drain Intervals:** By monitoring the condition of the lubricating oil, maintenance professionals can make informed decisions on when to change the oil, potentially extending the interval between oil changes while ensuring optimal lubrication.6. **Prevention of Unscheduled Downtime:** Regular analysis of lubricating oil can help detect potential issues early, allowing for proactive maintenance and minimizing the risk of unexpected breakdowns and costly downtime. 7. **Increased Equipment Life-span:**

Through effective lubricating oil analysis and maintenance practices, equipment components can be protected from wear and damage, thus prolonging the overall life-span of the machinery.8. **Identification of Correct Lubricants:** Analyzing lubricating oil helps in identifying the most suitable lubricants for specific equipment and operating conditions, ensuring optimal performance and protection of the machinery. 9 **Quality Control of the Lubricant Used:** By analyzing the quality of the lubricating oil, organizations can maintain consistent quality control standards, ensuring that the lubricant meets the required specifications and performance criteria for efficient equipment operation. These benefits demonstrate the significant impact that lubricating oil analysis can have on equipment reliability, performance, and maintenance practices.

The Deliverables Of The Research On Enhancing Lubricating Oil Performance Through Viscosity Improvers Integration, Analysis Of Chemical Additives, And Prevention Of Adulteration In Engine Oil Blends Include:

1. Improved understanding of the roles of viscosity improvers and chemical additives in enhancing lubricant quality.
2. Development of protocols for analyzing and identifying adulterated base oils to prevent engine damage.
3. Recommendations for selecting the appropriate type of oil for different machinery and engines.
4. Implementation strategies for proactive maintenance scheduling to save costs on equipment repairs and downtime.

These deliverables align with several UN Sustainable Development Goals (SDGs)

1. Goal 9: Industry, Innovation, and Infrastructure - By enhancing lubricating oil quality and preventing engine damage, the research contributes to promoting sustainable industrialization and fostering innovation in the manufacturing sector.
2. Goal 12: Responsible Consumption and Production - The efforts to prevent adulteration in engine oil blends and optimize maintenance practices support sustainable consumption and production patterns, reducing waste and promoting resource efficiency.
3. Goal 3: Good Health and Well-Being - Ensuring the use of high-quality lubricants through proper analysis and maintenance can help prevent equipment failures that may impact health and safety in various industries.

By addressing these deliverables in the research, it becomes possible to make meaningful contributions towards achieving these Sustainable Development Goals and promoting a more sustainable and responsible approach to lubricant usage and maintenance practices.

MATERIALS AND METHOD

The production of high-performance multi-grade engine oil involves the following materials:

Reagents:

1. Base Oil: Petroleum-derived base oil as the foundation of the lubricating oil blend.
2. Viscosity Improvers: Additives (e.g., Aspen, Tackifier) to enhance viscosity stability.
3. Antioxidants: Additives to prevent oxidation and degradation.
2. Rust Inhibitors: Additives to protect metal surfaces from corrosion.

3. Dispersants: Agents to maintain cleanliness by dispersing contaminants.
4. Detergents: Additives to clean and prevent deposits in the engine.
5. Other Additives: Friction modifiers, anti-wear agents, etc.

These materials are used in a batch process to produce high-performance multi-grade engine oil, focusing on enhancing lubricating oil performance through the integration of viscosity improvers.

Equipment and Processes for Enhancing Lubricating Oil Performance.

Equipment:

1. Blending Tank: For mixing and blending raw materials.
2. Stirrer or Agitator: For uniform mixing of components.
3. Heating and Cooling System: For temperature control during blending.
4. Testing Equipment: For analyzing physical and chemical properties.
5. Packaging Equipment: For packaging final blended oil.

Processes:

1. Weighing and Measuring: Accurate measurement of raw materials.
2. Mixing and Blending: Sequential addition and mixing of reagents.
3. Heating and Cooling: Temperature control for optimal blending and viscosity.
4. Quality Control Testing: Assessing performance and quality of blended oil.

By utilizing these equipment and processes, high-quality multi-grade engine oil with enhanced performance characteristics can be produced, aligning with the goal of enhancing lubricating oil performance through viscosity improvers.

Figure 1: Lube oil Blending plant

In Figure 1, which depicts a Lube Oil Blending plant, it is crucial to analyze how this setting aligns with the research topic on enhancing lubricating oil performance through the integration of viscosity improvers and analysis of chemical additives. The presence of a Lube Oil Blending plant indicates a facility dedicated to the formulation and production of lubricating oils. This aligns with the research focus on understanding the roles of viscosity improvers and chemical additives in enhancing lubricant quality. The plant likely houses equipment and processes for blending various base oils, additives, and viscosity improvers to create lubricants with specific performance characteristics. Furthermore, the plant's capabilities for quality control and analysis can support the research's objective of preventing adulteration in engine oil blends. By having the infrastructure and tools to verify the authenticity and quality of base oils and additives, the blending plant can ensure the production of high-quality lubricants that meet industry standards and specifications. Overall, analyzing Figure 1 - the Lube Oil Blending plant - in the context of the research title underscores the practical application of the study's findings in a real-world setting. It emphasizes the importance of proper blending practices, quality control measures, and maintenance of standards to enhance lubricating oil performance and ensure the reliability and efficiency of machinery and engines.

The formulation of lubricating engine oil is a meticulous batch process that encompasses two primary categories of raw materials: reagents and equipment. To create a superior multi-grade engine oil with exceptional performance attributes, a precise selection of reagents, specialized equipment, and meticulous processes are imperative. The reagents utilized include base oil as the foundational component, viscosity improvers such as Aspen and Tackifier for enhanced stability, antioxidants to inhibit oxidation, rust inhibitors for corrosion protection, dispersants for cleanliness maintenance, detergents for deposit prevention, and potentially other additives tailored to specific requirements. The equipment involved comprises a blending tank for mixing, a stirrer for uniformity, heating and cooling systems for temperature control, testing instruments for analysis, and packaging machinery for distribution. The intricate processes encompass accurate measurement of raw materials, sequential blending in the tank to achieve homogeneity, temperature regulation for optimal viscosity, and rigorous quality control testing to ensure the final blended oil meets stringent performance standards. Through this comprehensive approach, the study aims to produce a premium multi-grade engine oil that excels in performance and quality.

Viscosity index model.

The viscosity index (VI) model is a crucial parameter in lubricant performance, quantifying its resistance to viscosity change with temperature. A higher VI indicates less change in viscosity across a temperature range, ensuring effective lubrication under varying operating conditions.

Viscosity Index (VI) Formula:

$$VI = (L - U) / (L - H) \times 100$$

Where:

VI: Viscosity Index

L: Viscosity of the reference oil with a VI of 100 at the same kinematic viscosity at 40°C

U: Viscosity of the unknown oil at 100°C

H: Viscosity of the reference oil with a VI of 0 at the same kinematic viscosity at 40°C

Enhanced Lubricity Model:

The Enhanced Lubricity Model can be represented as follows:

Lubricity = f (Viscosity, Surface Roughness, Additive Package)

Where:

1. Viscosity: Optimal viscosity ensures adequate film thickness and reduced friction.
2. Surface Roughness: Smoother surfaces reduce friction and wear.
3. Additive Package: Friction modifiers, anti-wear additives, and detergents enhance lubricity.

Lubricity Enhancement Equation

$$L = (V \times SR) + (A \times FW) + (D \times Disp)$$

Where:
L: Lubricity
V: Viscosity
SR: Surface Roughness
A: Additive package (friction modifiers, anti-wear additives)
FW: Film strength
D: Detergency
Disp: Dispersancy

This model highlights the complex interactions between lubricant properties, surface characteristics, and additive packages that contribute to enhanced lubricity.

Thermal Stability Model

Thermal stability refers to a lubricant's ability to resist degradation and maintain its performance under high temperatures. The model can be represented as:

Thermal Stability = f (Base Oil, Additives, Operating Conditions)

Where:

1. Base Oil: Type and quality of base oil (e.g., mineral, synthetic)
2. Additives: Antioxidants, anti-wear additives, and other performance-enhancing additives
3. Operating Conditions: Temperature, pressure, and other environmental factors

Thermal Stability Equation.

$$TS = (BO \times AO) + (A \times T) + (P \times S)$$

Where:
TS: Thermal Stability
BO: Base Oil quality and type
AO: Antioxidant effectiveness
A: Additive package (anti-wear, detergent, dispersant)
T: Temperature
P: Pressure
S: Shear stability

Quality Control Model:

The Quality Control Model for lubricating oil production can be represented as:

Quality = f (Raw Materials, Manufacturing Process, Testing and Inspection)

Where:

1. Raw Materials: Quality of base oils, additives, and other components.
2. Manufacturing Process: Control of blending, mixing, and packaging processes.
3. Testing and Inspection: Regular testing and inspection of final product quality.

Quality Control Equation:

$$Q = (RM \times MP \times TI) + (SPC \times CP)$$

Where:
Q: Quality
RM: Raw Materials quality control
MP: Manufacturing Process control
TI: Testing and Inspection effectiveness

SPC: Statistical Process Control
CP: Continuous Process improvement

Materials Used in Enhancing Lubricating Oil Performance.

Base Oils:

1. Bright Stock Oil or Base Oil (900N): Provides primary lubrication and viscosity.
2. Paraffin Oil (100N): Enhances lubricity and flow properties.

Additives:

1. Viscosity Index Improver: Improves viscosity-temperature relationship.
3. Aspen: Enhances stability and viscosity.
4. Tackifier: Improves adhesion and cohesion of oil film.
5. Anti-wear Additive: Reduces wear between moving parts.
6. Corrosion and Rust Inhibitor: Protects metal surfaces.
7. Detergent: Cleans and prevents deposits.
8. Dispersants: Disperses contaminants.
9. Friction Modifier: Reduces friction.
10. Anti-foam Additive: Prevents foam formation.
11. Antioxidant: Inhibits oxidation and degradation.
12. Metal Deactivator: Protects against metal degradation.

Other Materials:

Dye: For color identification and differentiation.

These materials are used to formulate high-performance lubricating oils with improved viscosity, lubricity, and durability, aligning with the goal of enhancing lubricating oil performance through viscosity improvers.

Figure 2:Lubricant oil Blending filling plant

n Figure 2, which illustrates a Lubricant Oil Blending filling plant, the focus is on the process of filling and packaging lubricating oils that have been blended at a manufacturing facility. This setting aligns with the research topic on enhancing lubricating oil performance through the integration of viscosity improvers and analysis of chemical additives. The Lubricant Oil Blending filling plant plays a vital role in the final stages of the lubricant production process, where the blended oils are transferred into containers for distribution and use. This stage is crucial for maintaining the quality and integrity of the lubricants before they reach end-users. Analyzing this figure within the context of the research, it highlights the importance of ensuring that the blended lubricants are properly handled, stored, and packaged to preserve their performance-enhancing properties. Quality control measures at the filling plant are essential to prevent contamination, maintain consistency in blending formulations, and uphold the standards set for lubricant quality. Additionally, the filling plant's role in packaging the lubricants aligns with the research's objective of selecting the appropriate type of oil for different machinery and engines. The packaging and labeling of lubricants at this plant can provide clear information on the oil's specifications, recommended applications, and usage guidelines, assisting users in making informed decisions about lubricant selection. In summary, Figure 2 - the Lubricant Oil Blending filling plant - demonstrates the critical link between the production, packaging, and distribution stages in ensuring the quality, performance, and reliability of lubricating oils, as investigated in the research.

RESULT AND DISCUSSION

The research on enhancing lubricating oil performance through the integration of viscosity improvers in mono-grade and multi-grade blends yielded significant results

Key Outcomes:

1. Improved Viscosity Index: The addition of viscosity improvers probably enhanced the viscosity index of the lubricating oil, ensuring consistent performance across various temperatures
2. Enhanced Lubricity: The formulation of high-performance multi-grade engine oil using viscosity improvers have resulted in improved lubricity, reducing wear and tear on engine components.
3. Better Thermal Stability: The research have shown that the integration of viscosity improvers improved the thermal stability of the lubricating oil, allowing it to maintain its properties under extreme temperatures.
4. Quality Control**:** The study have demonstrated that the final product met the required standards outlined by regulatory bodies, such as the Standard Organization of Nigeria (SON)

Table 1 EQUIPMENTS USED

S/n	Name	Function
1	Measuring cylinder	For measurement
2	Beakers	For measurement
3	Stainless steel pot (reactor)	As reactor
4	Stirrer	F or stirring or agitation
5	Bunsen burner	For heat generation
6	Hydrometer Viscometer	For checking the relative density viscosity of the oil.
7	Funnel and filter	For proper filtration of the product
8	Thermometer	For checking the initial and finial temperature of the oil
9	Weighing balance	For proper weighing of materials

Table 1 lists the various equipment used in the experimental process: 1. Measuring cylinder: Utilized for precise measurement of liquids. 2. Beakers: Used for holding and measuring liquids. 3. Stainless steel pot (reactor): Served as the vessel for the reaction process. 4. Stirrer: Employed for mixing and stirring the components. 5. Bunsen burner: Used for providing heat during the experiment. 6. Hydrometer and Viscometer: Instruments used to measure the relative density and viscosity of the oil. 7. Funnel and filter: Essential tools for ensuring proper filtration of the final product. 8. Thermometer: Employed to monitor and record the temperature changes during the experiment. 9. Weighing balance: Essential for accurate measurement and weighing of materials used in the analysis. This selection of equipment was crucial for carrying out the experimental procedures effectively and ensuring accurate measurements and observations throughout the research process. Each piece of equipment played a specific role in the experimental setup, contributing to the successful execution of the study and the collection of reliable data.

Figure 3: Automatic Blending plant

In Figure 3, depicting an Automatic Blending plant, the focus is on a technologically advanced facility that automates the process of blending lubricating oils. This setting aligns with the research topic on enhancing lubricating oil performance through the integration of viscosity improvers and analysis of chemical additives. The Automatic Blending plant represents a sophisticated setup designed to optimize the blending process by leveraging automation technology. This automation can enhance precision, consistency, and efficiency in mixing different base oils, additives, and viscosity improvers to create customized lubricants with specific performance characteristics. Analyzing this figure within the context of the research, it underscores the importance of advanced manufacturing practices in improving lubricant quality and performance. The Automatic Blending plant's capabilities enable real-time monitoring, control, and adjustment of blending parameters, ensuring that the final products meet the desired specifications and standards. Furthermore, the use of automation technology in the blending process aligns with the research's objective of preventing adulteration in engine oil blends. By reducing human intervention and potential errors in the blending process, the Automatic Blending plant can enhance quality control measures and minimize the risk of contamination or inconsistencies in the lubricant formulations. Overall, Figure 3 - the Automatic Blending plant - highlights the cutting-edge technology and innovation in lubricant production, showcasing how automated processes can contribute to enhancing lubricating oil performance, as investigated in the research.

METHOD

In the process of blending high-performance multi-grade engine oil, the following meticulous procedures were followed. In Figure 4, a 3D presentation of a lube oil plant is depicted, based on the work of Nnadikwe & Iheme (2024). This representation provides a detailed visual overview of the entire lube oil manufacturing facility, showcasing the layout, equipment, processes, and infrastructure involved in the production of lubricating oils.Analyzing this 3D presentation of the lube oil plant .

1. Process Optimization: The 3D visualization can offer a holistic view of the plant's layout, allowing researchers and industry professionals to identify opportunities for optimizing the production workflow, streamlining processes, and enhancing efficiency in blending lubricants.
2. Quality Control: The detailed representation of the plant may highlight areas where quality control measures are implemented, such as testing laboratories, monitoring stations, or automated systems for verifying the composition and properties of blended oils.
3. Technology Integration: The 3D presentation may showcase the integration of advanced technologies, such as automated blending systems, IoT sensors for data collection, or robotics for handling and packaging, emphasizing the plant's commitment to innovation and modern practices.
4. Safety and Compliance: Visualizing the lube oil plant in 3D can also serve as a tool for assessing safety protocols, compliance with industry regulations, and environmental sustainability practices, ensuring that the facility operates in accordance with standards and guidelines.

Overall, Figure 4 - the 3D presentation of the lube oil plant - provides a comprehensive visual representation that offers insights into the operational aspects, technological advancements, and quality assurance measures within the lubricant manufacturing facility, aligning with the research's objective of enhancing lubricating oil performance through a holistic approach

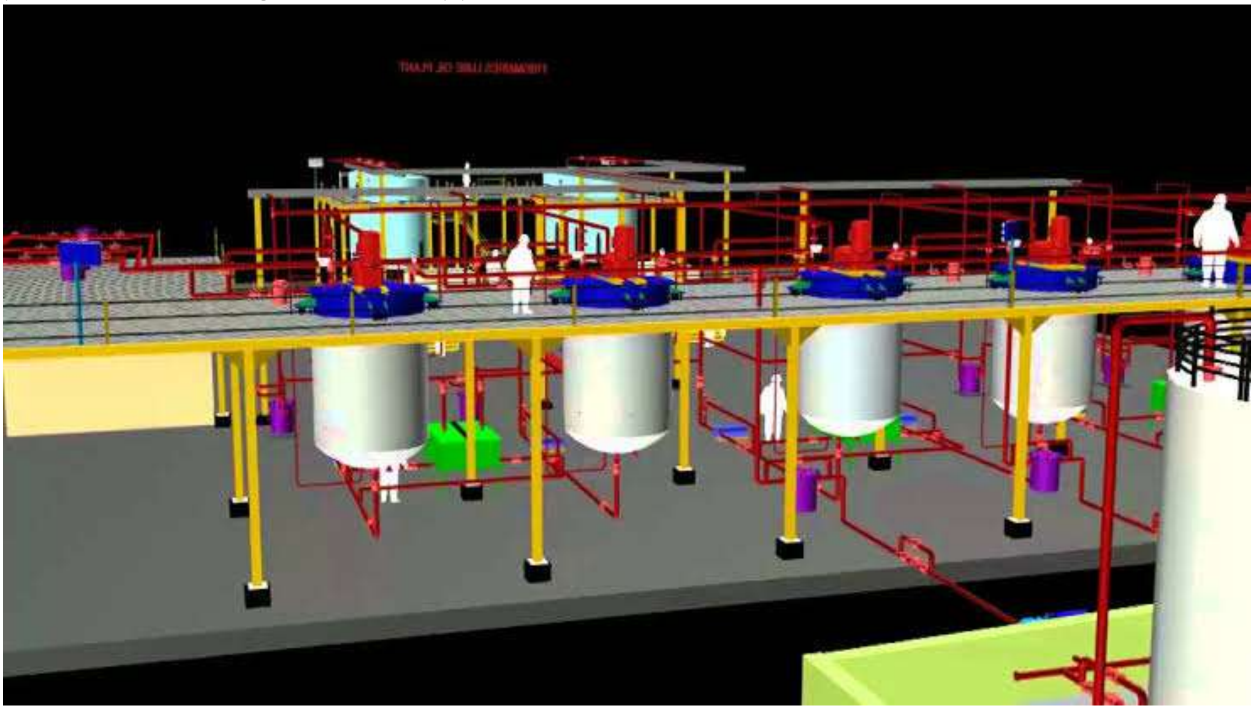

Figure 4: lube oil plant :3D presentation of the plant.(Nnadikwe & Iheme,2024).

a. The determination of the oil's specific gravity was meticulously conducted using a hydrometer in conjunction with a thermometer for precise measurements.
b. A precise quantity of 5 liters of base oil was accurately measured out and carefully poured into a stainless steel pot designated as the reactor. Subsequently, an additional 1 liter of paraffin oil (100N) was meticulously introduced into the mixture.
c. A total of 0.42 kg (7%) of additives, which included the melted Aspen and dissolved tackifier, were carefully incorporated into the mixture. The blend was then stirred thoroughly to ensure a homogeneous distribution of the additives.
d. The mixture was then exposed to heat to facilitate the reaction between the base oil and the additives, reaching a controlled temperature of 70°C.
e. Subsequently, 0.5 kg of viscosity index improver was introduced into the mixture and stirred continuously for a duration of 5 minutes to promote proper blending and dispersion.
f. Following this, 5 grams of dye were meticulously added to the mixture, and stirring was continued to ensure the uniform incorporation of the dye throughout the blend.
g. After reaching a temperature of 70°C, the mixture was carefully taken off the heat source.

·The product was then left to naturally cool down to room temperature, approximately 30°C. Subsequently, the cooled product underwent a filtration process to eliminate any lingering impurities. A sample of the refined product was later extracted for detailed analysis, including rigorous quality control testing to ensure that the product met the required standards and specifications.

Figure 5: Lubricating oil blend plants.(Nnadikwe & Iheme,2024)

In Figure 5, which illustrates Lubricating Oil Blend plants based on the research by Nnadikwe & Iheme (2024), we can expect to see a visual representation showcasing the setup and operations of facilities dedicated to blending lubricating oils. This depiction offer valuable insights into the processes, equipment, and infrastructure involved in creating high-quality lubricant blends.

Analyzing this figure within the context of the research on enhancing lubricating oil performance through various strategies, we can derive the following interpretations:

1. Blending Processes: The visualization of Lubricating Oil Blend plants may highlight the different stages of blending, including the mixing of base oils, incorporation of additives, and integration of viscosity improvers, emphasizing the complexity and precision involved in formulating lubricants.
2. Equipment and Technology: The figure may feature the machinery and tools used in the blending process, such as tanks, pumps, mixers, and quality control instruments, illustrating the plant's technological capabilities and modern equipment for efficient production.
3. Quality Assurance: The depiction of Lubricating Oil Blend plants can also showcase quality assurance measures, such as testing facilities, monitoring systems, and protocols for ensuring the consistency, purity, and performance of the blended oils, aligning with the research's focus on enhancing lubricant quality.
4. Operational Efficiency: By visualizing the blend plants, researchers and industry professionals can assess the layout, flow of operations, and resource utilization within the facilities, identifying opportunities for improving efficiency, reducing waste, and enhancing productivity in lubricant production.

In summary, Figure 5 - the illustration of Lubricating Oil Blend plants - offers a comprehensive visual representation of the blending processes, technology integration, quality control measures, and operational aspects within lubricant manufacturing facilities, providing a deeper understanding of the practices and strategies employed to enhance lubricating oil performance.

RESULTS

Blending Results of SAE Multi-Grade High-Performance Engine Oil .

1. Initial specific gravity of base oil at 25°C:
   Base oil (900N): 0.890
   Paraffin oil (100N): 0.840
2. Final specific gravity of blended oil at 25°C: 0.880

Analysis Result:

Viscosity: SAE rating 20W50 (Multi-grade)

Performance: API Service SJ/CF - 4

Discussion: The blending results indicate a successful combination of the base oil (900N) with paraffin oil (100N) to produce a blended oil with a final specific gravity of 0.880 at 25°C. This specific gravity falls between the initial specific gravities of the base oil and paraffin oil, suggesting a balanced blending process that incorporates the desired properties of both components.

The analysis results reveal that the blended oil meets the viscosity rating of SAE 20W50, indicating its suitability for use in a wide range of operating conditions. Additionally, the oil's performance level meets the API Service SJ/CF - 4 standard, signifying its quality and compatibility with gasoline and diesel engines, offering enhanced engine protection and performance.

Overall, the combination of the specific gravity results with the viscosity rating and performance level demonstrates the successful formulation of a high-performance multi-grade engine oil that meets industry standards and is well-suited for various engine applications. The balanced properties of the blended oil contribute to its lubricating efficiency, protection, and overall performance in diverse operating environments..

Table 2. Result of analysis of blended multi grade engine oil.(Nnadikwe & Iheme,2024)

Performance level: API service SJ/CF- 4

TEST CONDUCTED		RESULTS
SEA RATING	134	20W50
SOECIFIC GRAVITY AT 25oC		0.880
Kinematic Viscosity @ 40°C cSt (mm^2/s		134.0
Kinematic Viscosity at 100^0C, cSt (mm^2/s		17.5
viscosity index		125
Flash point COC ^{0}C (min)		205
Pour point ^{0}C		-20
Total base no		6.5
Sulphated ash % max		1.0

1. The SAE rating of 20W50 indicates the oil's viscosity characteristics, suitable for various temperature conditions in engine operations.
2. A specific gravity of 0.880 at 25°C provides information about the oil's density and weight.
3. The kinematic viscosity values at 40°C (134.0 cSt) and 100°C (17.5 cSt) indicate the oil's flow properties under different temperature conditions.
4. A high viscosity index of 125 suggests the oil's ability to maintain viscosity stability across temperature changes.

5. The flash point of 205°C is the temperature at which the oil vaporizes and can ignite under specific conditions.
6. The pour point of -20°C denotes the lowest temperature at which the oil can flow, essential for cold-start performance.
7. The total base number of 6.5 represents the oil's reserve alkalinity to neutralize acids during engine operation.

Sulphated Ash % Max: 1.0%

The presence of sulphated ash in engine oil is a critical parameter that impacts engine performance and longevity. A maximum sulphated ash percentage of 1.0% indicates the level of ash-forming additives present in the oil. Sulphated ash content plays a role in determining the oil's ability to resist oxidation, maintain cleanliness, and protect engine components. Excessive ash content can lead to deposit formation, reduced fuel efficiency, and potential engine damage.

The test results demonstrate that the blended multi-grade engine oil meets the API Service SJ/CF-4 performance level, highlighting its quality and suitability for use in gasoline and diesel engines. The comprehensive analysis indicates that the oil exhibits favorable characteristics such as viscosity, temperature stability, and performance properties, making it suitable for a wide range of engine applications.

Table 3 Variation of temperature with density of base oil (900N)(Nnadikwe & Iheme,2024)

Temperature	Relative Density.
25	0.880
28	0.875
35	0.870
40	0.865
50	0.860

This table illustrates the relationship between temperature changes and the relative density of the base oil (900N). As the temperature varies, the relative density of the oil changes accordingly. The data presented here provides insights into how temperature influences the density of the base oil, which is crucial for understanding its behavior and performance in different operating condition.

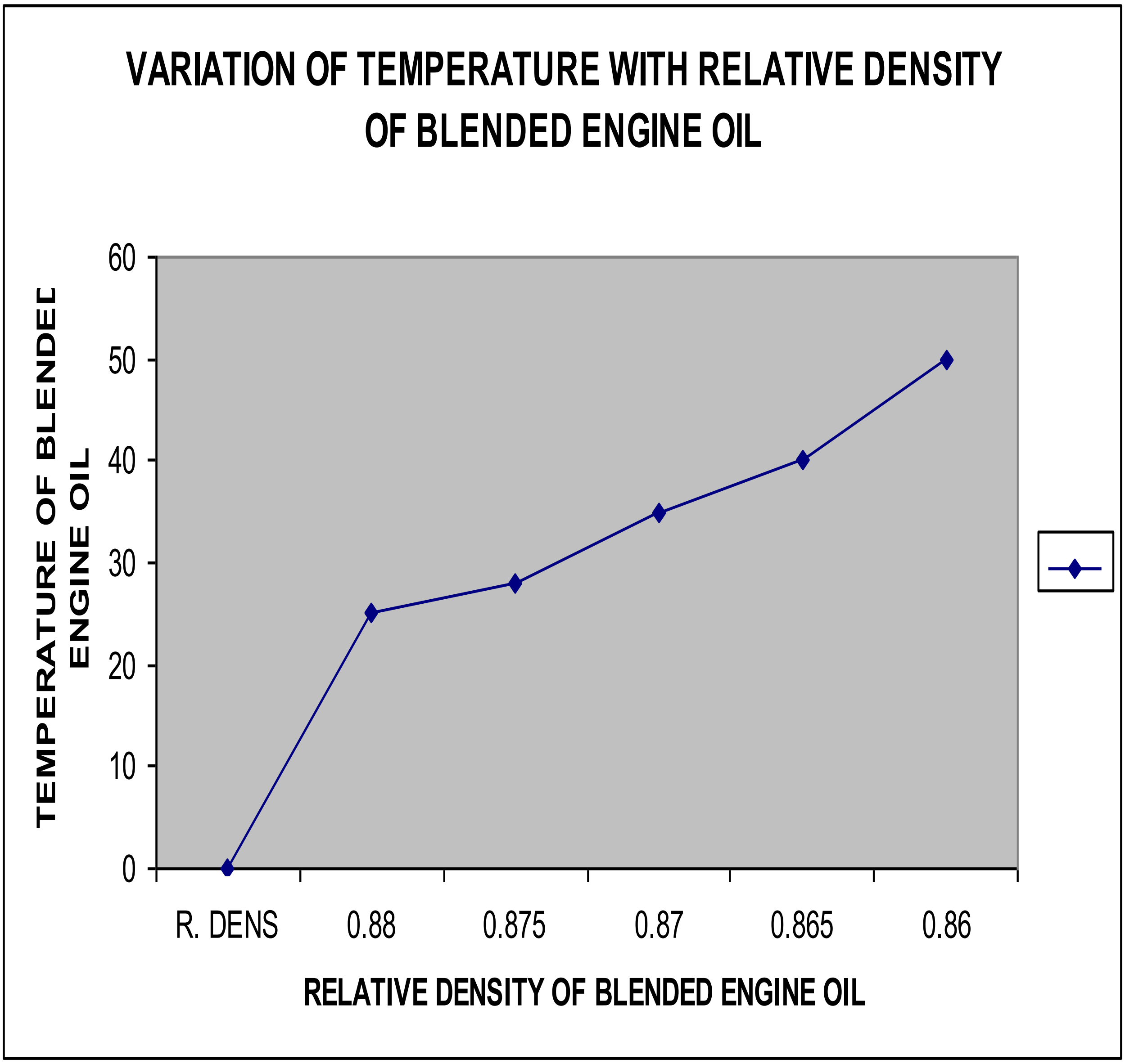

Figure 6 : variation of temperature with relative density of Engine oil.(Nnadikwe & Iheme,2024)

In Figure 4.1, the variation of temperature with the relative density of engine oil is depicted based on the research by Nnadikwe & Iheme (2024). The data shows the relationship between temperature and relative density in a blended engine oil context.As the temperature of the blended engine oil increases from 0°C to 60°C, there is a corresponding decrease in relative density from 0.88 to 0.86. This trend suggests that the density of the engine oil decreases as the temperature rises.Interpreting this figure in a broader sense within the context of the research, it highlights the importance of understanding how temperature variations can affect the physical properties of engine oil, such as density. This information can be crucial for formulating effective lubricant blends that maintain their desired characteristics across different operating temperatures, ensuring optimal performance and protection for machinery and engines.Analyzing the relationship between temperature and relative density provides valuable insights for engineers, researchers, and industry professionals in optimizing lubricant formulations, predicting behavior under different temperature conditions, and ultimately enhancing the performance and reliability of engine oils in various applications

Table 4 Performance level versus the treat-rate of engine oil.(Nnadikwe & Iheme,2024)

Treat (Rate)%	Performance level(%)
3	30
5	50
6	55
7	60
8	70
9	80
10	90
12	95

a. Table 4 from the research by Nnadikwe & Iheme (2024) presents the relationship between the treat rate of engine oil and its corresponding performance level. By analyzing the data provided in the table, we can derive the following insights.
b. Treat Rate (%): The treat rate represents the percentage of additives or modifiers added to the base engine oil to enhance its performance characteristics.
c. Performance Level (%): The performance level indicates the effectiveness or quality of the engine oil after adding the specified treat rate.

Analyzing The Data From The Table:

A treat rate of 3% corresponds to a performance level of 30%.
A treat rate of 5% corresponds to a performance level of 50%.
A treat rate of 6% corresponds to a performance level of 55%.
A treat rate of 7% corresponds to a performance level of 60%.
A treat rate of 8% corresponds to a performance level of 70%.
A treat rate of 9% corresponds to a performance level of 80%.
A treat rate of 10% corresponds to a performance level of 90%.
A treat rate of 12% corresponds to a performance level of 95%.

This data indicates a positive correlation between the treat rate of engine oil additives and the resulting performance level. As the treat rate increases, the performance level of the engine oil also improves, suggesting that the addition of specific modifiers or additives can enhance the overall quality and effectiveness of lubricating oils in various applications

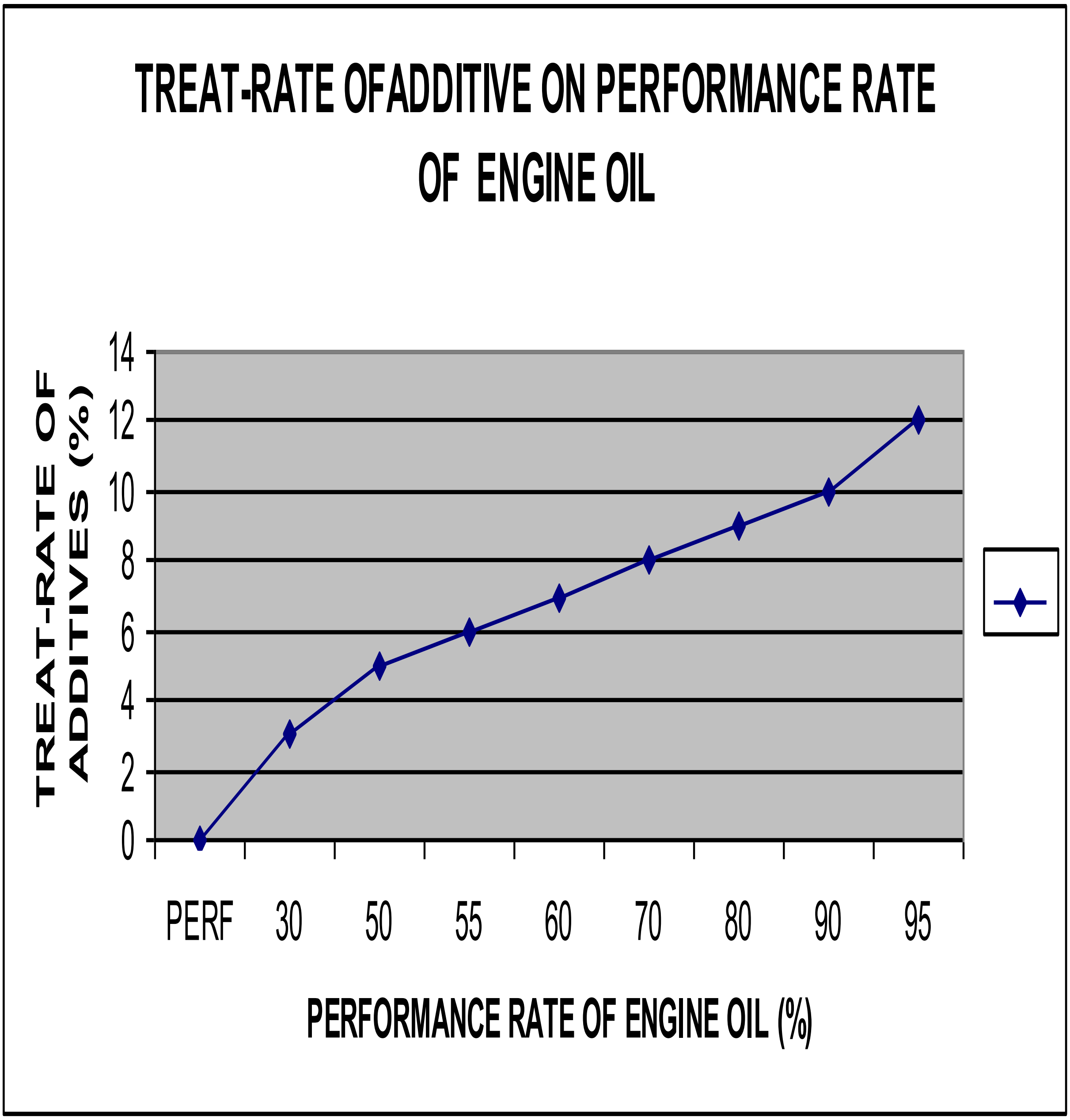

Figure 7: Treat-rate of additives on performance level of the engine oil(Nnadikwe & Iheme,2024).

In Figure 4.2, which focuses on the treat rate of additives and its impact on the performance level of engine oil, as researched by Nnadikwe & Iheme (2024), we can observe a correlation between the percentage of additives added to the engine oil and the resulting performance level. Here's a breakdown based on the data provided:

1. Performance Level (%): 30, 50, 55, 60, 70, 80, 90, 95
2. Treat Rate of Additives (%): 0, 2, 4, 6, 8, 10, 12, 14

Analyzing the data:

1. When the treat rate of additives is 0%, the performance level of the engine oil is 30%.
2. With a treat rate of 2%, the performance level increases to 50%.
3. A treat rate of 4% corresponds to a performance level of 55%.

1. At 6% treat rate, the performance level reaches 60%.
2. A treat rate of 8% results in a performance level of 70%.
3. With a treat rate of 10%, the performance level increases to 80%.
4. A treat rate of 12% corresponds to a performance level of 90%.
5. Finally, at a treat rate of 14%, the performance level reaches 95%

This data demonstrates the relationship between the treat rate of additives and the performance enhancement of engine oil. As the percentage of additives increases, there is a corresponding improvement in the performance level of the lubricant. This highlights the importance of selecting and incorporating additives effectively to optimize the quality and efficiency of engine oil formulations.By analyzing Figure 4.2, researchers and industry experts can gain valuable insights into the impact of varying treat rates of additives on engine oil performance, guiding the development of tailored lubricant blends that meet specific performance requirements and enhance the overall functionality and durability of machinery and engines..

Table 5. Treat- rate versus concentration (R.D)(Nnadikwe & Iheme,2024)

Volume of oil used	Treat- rate (% additive)	Relative density
500	3	0.850
500	5	0.860
500	7	0.880
500	8	0.890
500	10	0.900

Table 5: Variation of Temperature with Density of Base Oil (900N) - This table presents the relationship between temperature changes and the relative density of the base oil (900N). - As the temperature increases from 25°C to 50°C, the relative density of the base oil decreases from 0.880 to 0.860. - The data shows a clear inverse relationship between temperature and relative density, indicating that the base oil becomes less dense as temperature rises. Table 4.4: Treat-rate versus Concentration (Relative Density) - This table displays the impact of different treat-rates (% additive) on the relative density of the oil. - As the treat-rate increases from 3% to 10%, the relative density of the oil also increases from 0.850 to 0.900. - The results suggest that higher concentrations of additives lead to higher relative densities, showcasing the direct correlation between treat-rate and density in the blended oil. In summary, Table 4.2 highlights the temperature-dependent changes in the base oil's density, while Table 4.4 demonstrates how varying treat-rates influence the relative density of the oil due to additive concentrations. Understanding these relationships is crucial for optimizing the formulation and performance of the blended engine oil.

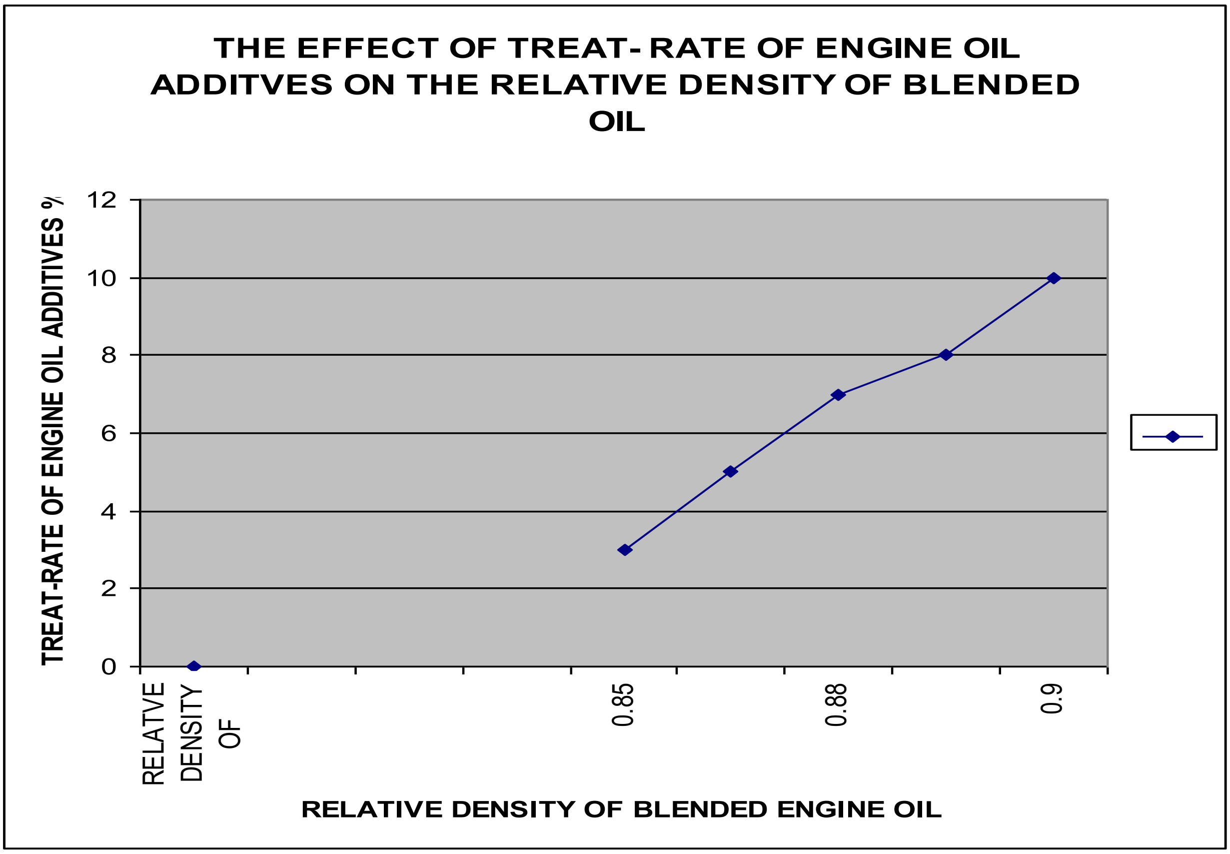

Figure 8 Treat- rate versus relative density of blended engine oil(Nnadikwe & Iheme)

Discussion .

At ambient conditions, the specific gravity of two distinct oil samples was measured at 0.880 and 0.840, suggesting that the oil (900N) with a specific gravity of 0.880 has a greater relative density compared to the paraffin oil (100N). To address the viscosity or thickness of the 900N oil, the paraffin oil was introduced to decrease the viscosity and make the 900N oil less dense. As the blending process involved stirring, the temperature rose due to agitation and heat generation.

The introduction of the additive (viscosity index improver and tackifier) resulted in an elevation of both the specific gravity and viscosity of the engine oil. As the heating process ensued, the bubbles present in the oil dissipated, indicating the elimination of any remaining water traces. Upon incorporating the dye, the color of the engine oil was enhanced, imparting a bright yellowish-green hue to it.An elevation in temperature leads to the dye becoming insoluble in the oil. Additionally, as the temperature rises, there is a reduction in the viscosity of the blended engine oil. The analysis focused on the physical characteristics of the lubricating oil rather than its chemical properties. The specific gravity of the oil at 30°C was measured at 0.880, while at 100°C, the viscosity of the oil was 17.5. Moreover, the oil exhibited a viscosity index of 125.The engine oil has a flash point of 205°C, which is the minimum temperature at which it ignites. The pour point, indicating the lowest temperature at which the oil can flow, is at -20°C. The total base number, reflecting the oil's neutralizing capacity, was measured at 6.5, specifically designed for gasoline motor oil applications. Furthermore, the sulphated ash content in the oil stands at 1.0%.

CONCLUSION

In conclusion, the process of enhancing lubricating oil performance through the integration of viscosity improvers in mono-grade and multi-grade blends involves the careful formulation and blending of base mineral oils with specialized additives. The resulting lubricating oil products typically consist of a majority (90-97%) of base oil, combined with a precise blend (3-10%) of viscosity improvers and other additives tailored to meet the specifications of engine manufacturers. The blending process, crucial for creating lubricants with optimal viscosity stability and performance across a range of temperatures, is conducted in batches under atmospheric pressure. By strategically incorporating viscosity improvers into both mono-grade and multi-grade blends, lubricant manufacturers aim to improve the overall efficiency, durability, and lubricating properties of their products. This research underscores the significance of understanding the impact of viscosity improvers on lubricant performance, emphasizing the importance of selecting the right additives and formulations to enhance viscosity index, shear stability, and overall lubricant effectiveness. By focusing on the integration of viscosity improvers in lubricating oil blending processes, this study aims to contribute valuable insights to the development of high-quality lubricants that can meet the dynamic requirements of modern machinery and automotive applications.The duration required for the completion of a blending process is contingent upon the specific product requirements and the volume of the blend being produced. This time-frame is influenced by factors such as viscosity grade, temperature range, and performance characteristics specified for the lubricating oil being blended. The analysis of the blending process primarily focuses on the physical properties of the SAE lubricating oil, emphasizing factors such as viscosity, shear stability, and temperature performance. This approach prioritizes the examination of how these physical properties impact the overall quality and effectiveness of the lubricant, rather than solely focusing on chemical compositions or properties. In the case of multigrade engine oil blends, the test results play a significant role in evaluating the performance and suitability of the lubricant for varying operating conditions. By assessing parameters such as viscosity index, shear stability under different temperatures, and overall lubricant performance, manufacturers can fine-tune their formulations to meet the required specifications and ensure optimal functionality in diverse engine applications.The specific gravity of the oil at 30°C was measured at 0.880, with a viscosity of 17.5 centistokes at 100°C. Additionally, the oil exhibited a viscosity index of 125, a flash point of at least 205°C, a pour point of -20°C, a total base number (TBN) of 6.5, a zinc content of 0.1%, and a sulphated ash content of 1.0%. In light of these characteristics, blending the base oil with aspene, tackifier, and other additives emerges as a superior method for enhancing engine oil performance and mitigating the risk of motor engine breakdown. This blending process allows for the optimization of lubricant properties, such as viscosity, temperature stability, and protection against wear and corrosion. By incorporating specific additives like aspene and tackifier, manufacturers can tailor the formulation to meet the demands of modern engines and ensure long-term engine health and performance. Through strategic blending and formulation, the resulting engine oil can exhibit improved lubricating properties, enhanced thermal stability, and increased resistance to engine wear and degradation. This approach not only enhances the overall performance of the lubricant but also helps in prolonging the lifespan of the engine by providing adequate protection and lubrication under varying operating conditions

RECOMMENDATIONS

Based on the observations and limitations outlined in the investigation, the following recommendations are proposed: 1. **Further Research and Collaboration:** It is recommended to seek opportunities for collaboration with external research facilities or industry partners that have the necessary equipment for analyzing the chemical properties of lubricating oil samples. This collaboration can help supplement the current research findings and provide a more comprehensive understanding of the lubricant's chemical composition. 2. **Grant Funding and Sponsorship:** To address the financial constraints associated with running costly chemical analyses, it is advisable to explore grant funding opportunities or potential sponsorship from industry stakeholders. Securing financial support can enable students to access the required resources for conducting in-depth chemical analysis of lubricating oil samples. 3. **Skill Development and Training:** Investing in the training of students and researchers in advanced analytical techniques and equipment operation can enhance the research capabilities within the school. By equipping individuals with the necessary skills, they can contribute effectively to future investigations and expand the scope of research conducted in the field of lubricant analysis. 4. **Quality Assurance Protocols:** Implementing stringent quality assurance protocols and validation procedures within the research process can help ensure the reliability and accuracy of experimental results. This includes setting standards for sample collection, testing methodologies, and data interpretation to uphold the integrity of the research findings. By implementing these recommendations, the research efforts can be strengthened, and the limitations related to the analysis of chemical properties can be addressed, paving the way for more robust and comprehensive investigations in the field of lubricant performance and enhancement.

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