

**EFFECTS OF CONTAMINANTS ON DEMULSIBILITY AND FOAM  
LEVELS OF ENGINE LUBRICANTS**



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**DECLARATION**

I, **JOHNSON ANTWI**, hereby declare that this research work was carried out by me; and I would like to further affirm that the work is my original work. All information from other sources are duly acknowledged.

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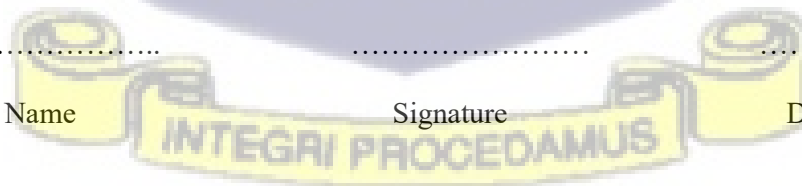
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## ABSTRACT

Lubricants, such as engine oils and hydraulic oils, are a critical component in many industrial applications, and its quality directly affects equipment performance and lifespan. However, their performance can be severely compromised when water mixes with the oil due to poor separation. The presence of contaminants in lubricating oils can lead to demulsibility failure, allowing water to become miscible with the oil, thereby causing it to foam.

The propensity of lubricating oils to foam poses a significant challenge in applications like high-speed gear transmissions, high-volume pumping, and spray lubrication systems. Foaming leads to intermittent lubrication, lubricant loss through overflow, and potentially catastrophic consequences, including mechanical damage, cavitation, reduced product lifespan, and increased maintenance expenses.

This study investigates the effects of common contaminants - grease, used oil, dust and fuel - on the demulsibility and foam levels of fresh lubricating oils. Testing was conducted using ASTM D1401 demulsibility test procedure and ASTM D892 foam test procedure. The results show that grease has the most significant impact, causing a substantial increase in emulsion layer volume. Dust and used oil also negatively affect demulsibility and foam levels in lubricants, while fuel has no significant impact. There is a correlation between demulsibility and foam levels, with poor demulsibility often leading to excessive foaming. The findings highlight the importance of controlling contamination to maintain the performance and lifespan of lubricants. Regular oil analysis and contamination control measures are essential to maintaining optimal oil quality.

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## CHAPTER ONE

### 1.0: INTRODUCTION

#### 1.1: BACKGROUND OF THE STUDY

Lubricants are a crucial component in the efficient operation of internal combustion engines and mechanical systems, playing a multifaceted role in reducing friction and wear, acting as coolants, protecting against corrosion, and cleaning and suspending contaminants (Tailor, 2021). Petrol and diesel engine oils are among the most widely used lubricants globally, and their performance is vital to vehicle operation, fuel economy, and engine longevity. However, over time, the performance of these lubricants deteriorates due to thermal breakdown, oxidation, additive depletion, and contamination.

Contamination is a major issue, and can originate from both internal sources, such as combustion by-products and metal wear particles, and external sources, including dust, water, and foreign oils. The presence of contaminants in engine oil accelerates degradation and significantly alters the physical and chemical properties of the lubricant (Kurre et al., 2017). Among the various performance characteristics of lubricants, demulsibility and foam tendency are particularly important in maintaining the functional integrity of the oil during service, and are critical parameters affected by contamination. Demulsibility, or water-separating ability, refers to a lubricant's capacity to release water introduced through condensation, leaks, or environmental exposure. In practical scenarios, especially in humid or wet environments, water entry into an engine's oil system is inevitable. If the oil does not effectively separate water, emulsions can form, leading to corrosion, reduced lubricity, sludge formation, and engine failure (Robinson, 2024).

Foaming, another undesired phenomenon in lubricants, occurs when air becomes entrained in the oil during operation, forming bubbles that accumulate into foam. Foaming can be triggered or worsened by contamination, especially from surfactant-like substances or incompatible fluids such as dispersants, detergents, and corrosion inhibitors (Ren et al., 2023). Persistent foam formation interferes with oil film formation, increases the risk of cavitation in pumps, impairs heat dissipation, and may result in overflow or spillage in the oil reservoir.

Modern lubricants are formulated with additives to enhance demulsibility and suppress foaming, but these properties can be compromised when the oil becomes contaminated. The additives frequently exhibit surfactant-like properties, concentrating at oil-water or air-oil interfaces and reducing interfacial tension. This behavior enables them to effectively suspend contaminants or emulsify water, which is crucial for maintaining lubricant performance and preventing equipment damage (Rosen & Kunjappu, 2012). However, the amphiphilic nature of these additives can also have unintended consequences, such as promoting foam formation or stabilizing emulsions, which can compromise lubricant functionality and overall system reliability.

In contrast, demulsifiers are specifically designed to disrupt emulsions and promote phase separation. These surfactant-like molecules selectively adsorb to oil-water interfaces, raising interfacial tension and facilitating the separation of water from the lubricant. By controlling emulsion formation and stability, demulsifiers play a critical role in maintaining lubricant performance, preventing corrosion, and ensuring the overall reliability of equipment and machinery.

For surface chemistry mechanisms, surfactants play a crucial role in influencing foam and emulsion behaviors through their dynamic interfacial adsorption and film stabilization properties. Specifically, ionic surfactants enhance foam stability by forming electrostatic

repulsion between bubble films, whereas nonionic surfactants rely on steric stabilization mechanisms to achieve similar effects (Koreh et al., 2022). In complex lubricant systems, particles such as dust can unexpectedly act as pickering stabilizers, adsorbing at interfaces and stabilizing foam films, which can have significant implications for lubricant performance and longevity.

Furthermore, factors such as viscosity, surface rheology, and additive depletion can substantially alter foam drainage rates and stability, highlighting the intricate relationships between lubricant formulation, contamination, and performance. Demulsifiers, on the other hand, work by deactivating surfactant effects, often through competitive adsorption at the oil-water interface and altering interfacial rheology. The effectiveness of demulsifiers depends on critical properties like hydrophilic-lipophilic balance (HLB), critical aggregation concentration (CAC), and molecular weight, which underscores the importance of carefully selecting and formulating demulsifiers for specific applications (Dhandhi et al., 2023).

In regions with high dust exposure, poor fuel handling, or inconsistent maintenance practices, lubricant contamination is frequent and often unmanaged. Despite this reality, there is limited local research on how specific contaminants affect lubricant performance in typical operating environments. This study focuses on the effects of four common contaminants—dust, grease, fuel, and used engine oil—on two critical parameters: demulsibility and foam level. These substances represent practical, real-world contaminants introduced through air filtration leaks, cross-contamination during servicing, fuel dilution from incomplete combustion, or reuse of spent oil due to cost constraints. This research aims to provide insights into the effects of contamination on lubricant performance, informing strategies for improved lubricant management and engine maintenance.

## 1.2: PROBLEM STATEMENT

According to Usman et al. (2020), the condition of lubricating oil has a profound impact on engine performance, fuel efficiency, and maintenance costs. In real-world operating environments, contaminants are unavoidable, particularly in harsh or dusty regions, or where economic constraints lead to extended service intervals. While numerous studies have examined the effects of contaminants on oil viscosity changes, wear metal content, and oxidation stability, the impact of these contaminants on foam formation and demulsibility has received relatively less attention. These two properties are crucial for ensuring oil system reliability and overall equipment performance.

Contaminants such as dust can significantly affect lubricant performance by acting as nucleation sites for bubbles or interfering with surfactants in the oil, thereby promoting foam formation. Additionally, grease, which is often used in other mechanical assemblies, can be inadvertently introduced into the engine oil during maintenance, affecting the oil's ability to release air or water due to its thick and sticky composition. Fuel dilution, a common issue in engines with poor combustion or leaking injectors, not only lowers oil viscosity but also alters the oil's interfacial tension and miscibility with water. Furthermore, used engine oil, which is sometimes mixed with fresh oil due to topping off or cost-saving practices, carries degraded additives, oxidation products, and soot, further complicating the oil's behavior and performance.

The lack of empirical data on the specific effects of these contaminants on oil performance creates a significant knowledge gap for maintenance personnel and engineers. Without this information, it is challenging for them to make informed decisions about critical aspects such as oil change intervals, contamination thresholds, and additive selection. This study aims to address this knowledge gap by investigating the impact of these common contaminants on demulsibility and foam behavior in widely used petrol and diesel engine oils, providing

valuable insights for improving lubricant performance, maintenance practices, and overall equipment reliability.

### 1.3: RESEARCH AIM

The main aim of this research is to investigate the impact of selected contaminants on the demulsibility and foam levels of engine lubricants, specifically petrol and diesel engine oils.

### 1.4: SPECIFIC OBJECTIVES

1. To examine the changes in demulsibility properties of petrol and diesel engine oils when contaminated with dust, grease, fuel, and used engine oil, and to determine the extent to which these contaminants affect the oil's ability to separate water.
2. To evaluate the foam-forming tendencies of these lubricants under the same contamination conditions, and to assess the impact of contaminants on foam stability and drainage.
3. To compare the degree of impact across the two lubricant types, and to determine if petrol and diesel oils respond differently to specific contaminants, which will help identify potential differences in lubricant formulation or handling practices.

### 1.5: RESEARCH QUESTIONS

This research seeks to answer the following key questions:

1. To what extent do dust, grease, fuel, and used oil affect the demulsibility of petrol and diesel engine oils, and what are the implications for lubricant performance and equipment reliability?
2. How do these contaminants influence foam levels and stability in the lubricants, and what are the potential consequences for equipment operation and maintenance?

3. Are the effects of the contaminants more pronounced in one lubricant type over the other, and what are the potential reasons for any observed differences?

#### 1.6: SIGNIFICANCE OF THE STUDY

The findings of this study are expected to make significant contributions to both academic knowledge and industrial practice, with far-reaching implications for various stakeholders. Specifically, the study's results will:

- Inform Lubricant Manufacturers: By providing insights into the effects of contamination on lubricant performance, the study can inform the formulation of more robust additive packages that can resist contamination-induced performance degradation, leading to improved lubricant quality and reliability.
- Guide Maintenance Engineers and Mechanics: The study's findings can guide oil inspection protocols, contamination tolerance levels, and early warning indicators of oil degradation, enabling maintenance personnel to take proactive measures to prevent equipment damage and optimize maintenance schedules.
- Support Policy Makers and Standards Bodies: The data generated by this study can support the development of guidelines and regulations for lubricant quality control and contamination management in developing regions, promoting best practices and standards for lubricant handling and maintenance.
- Advance Academic and Research Communities: The research provides a basis for further studies into the interactions between oil additives and contaminants under varying operating conditions, contributing to a deeper understanding of lubricant chemistry and performance.

In the broader context of environmental sustainability, minimizing lubricant contamination and extending oil service life can have significant environmental benefits, including reducing waste

oil generation, improving engine efficiency, and contributing to lower emissions and reduced resource use. By providing insights into the effects of contamination on lubricant performance, this study can help promote more sustainable practices in lubricant use and maintenance, ultimately contributing to a more environmentally friendly and resource-efficient industry.

### **1.7: SCOPE AND LIMITATIONS**

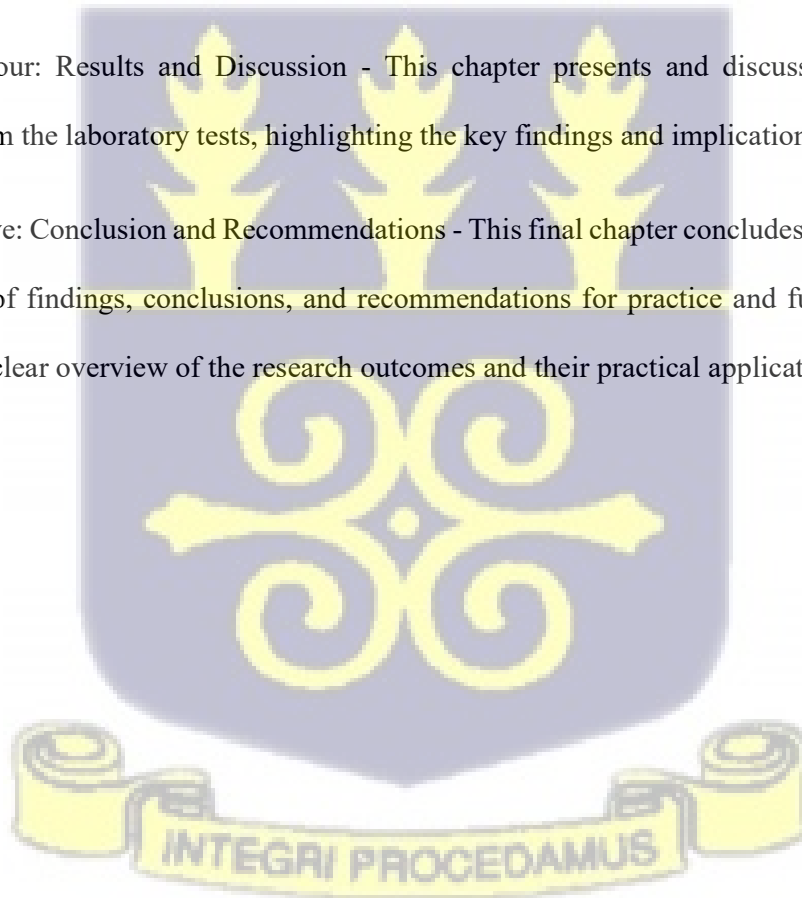
This study will focus on investigating the effects of selected contaminants on the demulsibility and foam levels of two commercially available engine lubricants: one petrol engine oil and one diesel engine oil. The contaminants considered in this study are dust, grease, fuel (petrol/diesel), and used engine oil, which will be added to the lubricants under controlled laboratory conditions at defined concentrations. The performance testing will be limited to evaluating the demulsibility and foam levels of the lubricants, following standard protocols such as ASTM D1401 for demulsibility and ASTM D892 for foam testing.

It is essential to note that this study does not include long-term engine testing, full-scale field trials, or analysis of other oil properties such as viscosity, Total Base Number of other oil properties, which could provide a more comprehensive understanding of the lubricant's behavior under contamination conditions. All tests will be carried out in laboratory settings using available equipment at Tema Lube Oil Company Limited and the University of Ghana Chemistry Department, ensuring controlled and consistent experimental conditions.

### **1.8: ORGANIZATION OF THE THESIS**

This thesis is organized into five chapters, each addressing a specific aspect of the research. The chapters are structured as follows:

- Chapter One: Introduction - This chapter introduces the background, problem statement, objectives, significance, and scope of the study, providing an overview of the research and its relevance.
- Chapter Two: Literature Review - This chapter presents a comprehensive review of literature related to lubricants, contaminants, demulsibility, foaming, and relevant testing methods, providing a foundation for the research and identifying gaps in existing knowledge.
- Chapter Three: Materials and Methods - This chapter describes the materials, sample preparation procedures, contamination protocols, and testing methodologies employed in the study, outlining the experimental approach and ensuring transparency and reproducibility.
- Chapter Four: Results and Discussion - This chapter presents and discusses the results obtained from the laboratory tests, highlighting the key findings and implications of the study.
- Chapter Five: Conclusion and Recommendations - This final chapter concludes the study with a summary of findings, conclusions, and recommendations for practice and future research, providing a clear overview of the research outcomes and their practical applications.



## CHAPTER TWO

### 2.0: LITERATURE REVIEW

#### 2.1: OVERVIEW OF LUBRICANTS

Crude oil's most stable and non-volatile form is lubricants, which are also the rarest. (Mang & Dresel, 2007) As petroleum products, lubricants are composed of hydrocarbons with 20-70 carbon atoms per molecule. (Ekejuiba, 2021) These molecules can be categorized into three main types: paraffinic, naphthenic, and aromatic. Paraffinic molecules are typically straight chains with a waxy texture, high water content, and superior viscosity and temperature performance. Naphthenic molecules have straight chains with mostly five-ring structures, a low pour point, and are often used as refrigerants due to their low pour point. However, they are highly carcinogenic and rarely used in engine oil. Aromatic molecules feature straight chains with six-ring benzene structures. In actuality, the boundaries between lubricant categories are blurred, as most lubricants are composed of a mix of various hydrocarbon types (Hsu & Liu, 2011). Lubricants, including engine oil, gear oil, and hydraulic oil, perform multiple functions such as:

- Reducing friction between moving parts
- Cooling machine components by dissipating heat
- Forming a protective barrier on metals to prevent corrosion
- Sealing metal surfaces to increase mechanical efficiency
- Filtering out dirt and debris to ensure proper equipment function (Mang, 2018).

These functions are crucial for maintaining machine performance, and contaminants are typically removed through engine oil or transmission filters. To enhance performance and extend lifespan, lubricants are frequently blended with various additives, enabling machines to operate efficiently in demanding conditions. Nevertheless, the long-term effectiveness of lubricants declines due to additive degradation and contamination resulting from physical and chemical reactions, ultimately leading to a buildup of impurities in the oil (Cecelia et al., 2020).

### 2.1.1 Production of Lubricants

Lubricants are formulated by blending base oils with additives to enhance performance and ensure quality. Base oils can be derived from petroleum, synthetic materials, or, less commonly, vegetable sources. Paraffinic oils, which contain paraffin wax, are the most widely used and offer superior lubrication properties, including:

- Greater resistance to oxidation
- Lower volatility
- Higher viscosity indices (Mang & Dresel, 2007).

In contrast, naphthenic oils do not contain wax, resulting in lower viscosity. Synthetic lubricants, on the other hand, are created through chemical reactions that produce predictable and consistent properties. Synthetic lubricants often outperform petroleum-based lubricants, but their significantly higher cost, sometimes several times more, limits their use to specialized or demanding applications (Pichler et al., 2023). Typically, lubricants are formulated with a base oil, usually petroleum or mineral oil (90%), and a smaller proportion of additives (less than 10%). Alternatively, vegetable oils or synthetic liquids like hydrogenated polyolefins, esters, silicones, fluorocarbons, and others may be used as base oils. Additives play a crucial role in enhancing lubricant performance by:

- Reducing friction and wear
- Increasing viscosity
- Improving viscosity index
- Preventing corrosion, oxidation, and degradation.

Solid lubricants, which don't have a liquid form, include:

- Powders like graphite, PTFE, molybdenum disulfide, and tungsten disulfide
- PTFE tape, used in applications like piping and air cushions (Singh et al., 2021).

These dry lubricants offer high-temperature lubrication capabilities, outperforming liquid and oil-based lubricants, with operating temperatures reaching up to 350°C. Additionally, researchers are exploring the potential of oxide varnish layers, which exhibit low friction when compressed at high temperatures (hundreds of degrees Celsius) in metal sliding systems. However, their practical application has been hindered by physical instability issues for many years (Zielinski et al., 2024).

#### 2.1.1.1 Lubricant Additives

Additives are specialized compounds that are blended with lubricating oils to enhance their performance and impart unique properties (Singh et al., 2021). These additives can:

- Introduce new and beneficial characteristics to the lubricant
- Enhance existing properties
- Mitigate undesirable changes that occur over time.

The development of high-performance additives has significantly contributed to advancements in technology and strength. Various modern devices, including:

- Passenger car engines
- Automatic transmissions
- Hypoid gears
- Rail and marine diesel engines
- High-speed gas and steam turbines
- Industrial processing machines

rely on additives to achieve optimal performance. The functional benefits provided by additives have been extensively discussed in research (Rizvi, 2009; Li et al., 2022). Essentially, all lubricants are formulated with additives to either enhance their existing characteristics or impart new ones. Lubricant additives serve three primary functions:

1. Surface protection: guarding against wear and tear on bearings and surfaces
2. Performance enhancement: tailoring lubricant properties for specific applications
3. Lubricant protection: preventing degradation and extending lubricant lifespan

As highlighted by Li et al. (2022), these additive roles are crucial for maintaining optimal lubricant performance and protecting equipment.

#### 2.1.1.1.1 Lubricity Additives

Lubricity, a key property of oil-based lubricants, refers to their capacity to minimize friction between moving components. Lubricating additives, typically derived from vegetable or animal fats, enhance lubricity by:

- Bonding to metal surfaces
- Forming thin, high-performance films that reduce friction

As noted by Celik et al. (2013), these additives play a crucial role in optimizing lubricant performance and reducing wear on moving parts.

#### 2.1.1.1.2 Antiwear Additives.

Anti-corrosion additives function by forming a protective coating on metal surfaces. When metal-to-metal contact occurs, the friction-generated heat melts the additives, creating a lubricating layer that prevents wear and damage to the metal surface. This molten layer, softer than steel, acts as a barrier against corrosion and wear (Li et al., 2022).

Phosphorus derivatives are widely used as anti-wear agents, but the demand for additional solutions has grown. During engine startup, when loads are light, preventing bearing metal corrosion is a top priority for engine oils. Fortunately, many bearing protectants also offer anti-wear properties, such as salts of long-chain carboxylic acids, often combined with sulfur. Other effective anti-wear agents include oil-soluble sulfur, phosphorus, and chlorine compounds. However, the most significant breakthrough in anti-wear technology came with the discovery of zinc dialkyl dithiophosphate (ZDDP) in the 1930s and 1940s, revolutionizing wear protection in engines (Masabumi et al, 2008). Initially used as a corrosion inhibitor, zinc dialkyl dithiophosphate (ZDDP) was later found to possess excellent antioxidant and anti-aging properties. Its antioxidant capabilities play a crucial role in preventing corrosion by inhibiting peroxide formation, thereby protecting Cu or Pb bearings from organic acid corrosion. ZDDP's anti-wear and friction-reducing properties are activated through thermal decomposition, forming compounds that react with metal surfaces to create a thin, boundary lubrication layer. Since its discovery, ZDDP has become the most widely used anti-wear additive in lubricants, prompting extensive research into its anti-aging and antioxidant mechanisms, with numerous proposals and studies exploring its properties (Spikes, 2008).

#### 2.1.1.1.3 Extreme Pressure Additives

Extreme pressure (EP) additives function by chemically reacting with metal surfaces to form a protective layer, which is softer than the underlying metal. This sacrificial layer wears away preferentially under extreme conditions, shielding the metal from damage. As the layer is removed, the EP additive promotes the formation of a new protective layer, thereby controlling wear rather than preventing it entirely (Li et al., 2022). However, some EP additives can corrode copper or brass alloys due to their reactivity. To mitigate this, most EP additives are designed to activate only under high-temperature and high-friction conditions, remaining inert at room temperature. Through thermochemical reactions, EP additives create a robust protective film on metal surfaces, capable of withstanding high temperatures, mechanical stress, and surface contact, thus preventing scratches and damage (Rizvi, 2009).

The first extreme pressure (EP) additives were formulated with lead salts of fatty acids, "active sulfur" compounds like thiols and elemental sulfur, and chlorine compounds. However, in the 1950s, lead was replaced by zinc and phosphorus-based compounds, such as zinc dithiophosphate (Alqahtani et al., 2022). EP additives are polar molecules, consisting of a head and a tail. The head is drawn to the metal surface, while the tail is compatible with the lubricating oil, allowing the additive to effectively interact with both. Under high temperatures and loads, the metal-to-metal interaction intensifies, causing increased stress on the lubricating film. As the metal surfaces draw closer, friction arises, and the risk of metal contact increases (Opia et al., 2021).

Conventional lubricants have limitations and cannot entirely prevent friction, wear, and machine damage under extreme conditions. However, advanced additives can still provide benefits in such situations. Extreme pressure (EP) additives have two main categories: temperature-dependent and non-temperature-dependent. The most common temperature-dependent types include boron, chlorine, phosphorus, and sulfur-based additives. These

additives react with the metal surface at high temperatures, triggered by friction-generated heat, to form a protective layer. This heat-activated reaction enables the additive to adapt to changing conditions and provide enhanced protection (Alqahtani et al., 2022).

When metal surfaces come into contact, friction and pressure generate heat, similar to when you rub your hands together. In response, extreme pressure (EP) additives react with the metal surface to form new compounds like iron chloride, iron phosphide, or iron sulfide, depending on their composition. This reaction creates a chemical film, akin to a soap, that acts as a barrier, reducing friction, wear, and scratches on the metal surface while preventing soldering (Ali et al., 2022). In contrast, non-temperature-dependent additives like perbasesulfonates work differently. They contain colloidal carbonates dispersed in sulfonates, which form a protective film on the metal surface without requiring heat activation. This film can act as a barrier, depending on the temperature (Thampi et al., 2021).

In essence, EP additives kick in when the lubricant's adhesive properties are insufficient to protect the work area, providing an extra layer of defense against wear and damage. With EP lubricants in place, you can have peace of mind knowing your machinery is better protected (Guan et al., 2022).

#### 2.1.1.1.4 Corrosion and Rust Inhibitors

Corrosion inhibitors are specialized compounds that, when added to liquids or oils, significantly reduce the corrosion of materials, particularly metals and alloys (Raja et al, 2016).

Rust inhibitors, specifically, protect iron and steel surfaces by forming a water-resistant film, while corrosion inhibitors extend this protection to non-ferrous materials and neutralize acidic substances containing crucial elements like calcium carbonate (Aljamali 2019).

Rust inhibitors typically consist of compounds with strong polar attraction to metal surfaces, forming a continuous, protective film through physical or chemical interaction. This barrier

prevents water from reaching the metal surface, and common materials used for this purpose include amines, alkaline earth succinates, and sulfonates. While anti-rust chemicals can be incorporated into most lubricants, careful selection is crucial to avoid issues like corrosion of stainless steel or unwanted emulsions with water (Palanisamy, 2019).

Rust inhibitors in lubricants adsorb onto metal surfaces, leading to their gradual depletion over time. Machines using lubricants can experience various types of corrosion, with two primary concerns being:

1. Corrosion caused by organic acids present in the oil itself.
2. Corrosion caused by contaminants absorbed and carried by the oil.

For instance, internal combustion engines may experience corrosion due to organic acids, which can attack metals like lead in copper or lead-bronze. To combat this, corrosion inhibitors form a protective film on bearing surfaces, preventing corrosive substances from reaching or attacking the metal. This film can be either adsorbed onto the metal or chemically bonded to it. Additionally, incorporating highly alkaline chemicals into oil has been shown to reduce corrosion and corrosive wear by neutralizing strong acids as they form (Costello, 2017).

#### 2.1.1.1.5 Detergents and Dispersants

Engine oil relies on detergents and dispersants to prevent deposit formation and distribute contaminants throughout the lubricant. These additives play a crucial role in extending equipment life by maintaining lubricant integrity (Kan, 2022). A key function of automotive lubricants, particularly engine oil, is to neutralize harmful substances generated by thermal and oxidative decomposition. During fuel combustion, byproducts like hydrogen peroxide and free radicals can enter the lubricant through piston rings, causing reactive oxidation. This leads to

the formation of thermally unstable products that decompose into polar compounds, which can separate from the lubricant and form deposits, clogging pores (Farahani & Zheng, 2022).

To address this, oxidation inhibitors, detergents, and dispersants - collectively known as sediment stabilizers and control agents - work together to:

- Inhibit oxidative damage to the lubricating oil
- Eliminate harmful contaminants present in the lubricating oil

These additives help control deposit formation, ensuring the lubricant remains effective and equipment longevity is maintained (Mammadova et al., 2023).

#### 2.1.1.1.6 Viscosity Index Improvers

Viscosity index improvers are additives that minimize the impact of temperature on viscosity, making them essential for producing multigrade automotive oils. These additives, along with thickeners, are polymers that stabilize viscosity levels, preventing extreme changes in response to temperature fluctuations. Mineral oil-based lubricants struggle at high temperatures, as heat reduces their viscosity and film-forming capabilities (Gori et al., 2024). Traditionally, this issue is addressed by periodic oil changes in certain applications, making viscosity improvers unnecessary. However, when combined with low-viscosity oil, viscosity improvers enhance the oil's performance at elevated temperatures. This enables mineral oil to maintain its lubricating properties even in extreme heat conditions (Khalafvandi et al., 2022). When producing viscosity improvers, a crucial balance must be struck between the polymer's thickening effectiveness and its resistance to mechanical shear. While higher molecular weight polymers excel at thickening, they tend to be more susceptible to shear degradation. Conversely, lower molecular weight polymers offer better shear stability but provide limited high-temperature viscosity improvement, requiring more frequent use (Patil & Tyagi, 2024).

The viscosity index (VI) measures the rate of change in viscosity with temperature fluctuations. A lower VI indicates a greater variation in oil viscosity with temperature. VI is used to assess the temperature-dependent viscosity changes in lubricating oils, with a lower viscosity generally preferred to minimize friction between moving parts. However, if the lubricant is too thin, it may not provide adequate friction reduction, while an excessively thick lubricant requires more energy to operate effectively. A lubricant that is too thick requires significant energy to move, similar to honey, while a lubricant that is too thin fails to prevent surface contact and friction (Méheust et al., 2022). Various lubricant applications demand specific performance characteristics. For instance, automotive lubricants must reduce friction in engine components across a temperature range, from startup to operating temperatures reaching 200°C (392°F). The ideal oil exhibits a high viscosity index (VI), ensuring stability and consistent engine performance without excessive viscosity at high temperatures.

The Society of Automotive Engineers (SAE) developed the VI scale, using 38°C and 99°C (100°F and 210°F) as reference temperatures. Initially, the VI range spanned from 0 (naphthenic oil) to 100 (paraffinic oil), but advancements in oil development have led to lubricants with VI values exceeding 100 (Hata & Tamoto, 2021).

#### **2.1.1.1.7 Pour Point Depressant**

The boiling point of a liquid is the minimum temperature at which it flows freely. In lubricants, the pour point is the temperature at which the liquid's flowability is impacted. For paraffin oils, this is due to the crystallization of wax particles, while in naphthenic oils, it's caused by a temperature-induced decrease in viscosity. These characteristics are crucial when selecting a lubricant for use in cold weather conditions (Shi et al., 2024). Pour point depressants are additives that enable lubricants to flow at lower temperatures by reducing the pour point. These depressants are specifically designed polymers that control wax crystal formation, improving cold-weather performance. The selection of a pour point depressant depends on the lubricant's

base oil, additives, and viscosity index improver, as determined by the ASTM D 5950 method. By using pour point depressants, lubricants can maintain their flowability and effectiveness even in extremely cold temperatures (Kurniawan et al., 2022).

Most mineral oils contain waxy substances that melt and then crystallize as the oil cools, forming a structure that traps the oil in small pockets. When enough crystals form, the oil ceases to flow. However, mechanical stress can break down these wax crystals, allowing oil to leak even below the pour point. The rate of cooling also influences wax crystallization. Rapid cooling can cause oil to remain fluid even below its pour point. Typically, pour point issues are related to wax crystallization, but some wax-free oils have a pour point due to increasing viscosity with decreasing temperature, making them non-flowable at certain temperatures. In these cases, pour point depressants (PPD) are ineffective, as they facilitate crystal growth and connection, rather than addressing viscosity-related pour point issues (Steckel et al., 2022).

#### 2.1.1.1.8 Oxidation Inhibitors/Antioxidants

The primary cause of oil thickening is the oxidation process, which leads to the formation of sludge and varnish on engine surfaces. This results in engine wear, reduced lubrication, and decreased fuel efficiency. Antioxidants are crucial additives in lubricants, as they delay and reduce oxidative degradation. During oxidation, acidity and viscosity increase due to a chain reaction, producing high-molecular-weight polymers that precipitate and raise oil viscosity. Oxidation inhibitors (antioxidants) counteract this by binding free oxygen or neutralizing metal catalysis, extending lubricant life. To assess oxidation stability, it's essential to monitor the rate of acidity and viscosity increase during the oxidation process. Lubricating oil is highly susceptible to decomposition by oxygen (Abdulla et al., 2021).

#### 2.1.1.1.9 Metal deactivators, or metal deactivating agents (MDA)

Metal deactivators (MDAs) are additives used in oils to stabilize liquids by neutralizing metal ions, typically through sequestration. These ions are often introduced by acids naturally present in the oil or formed during the oxidation process with metal components (Hussain, 2021). For instance, desulphurized oil with copper sweetener may contain high levels of copper, which can be problematic even at concentrations as low as 0.1 ppm. MDAs inhibit the catalytic effects of these ions, particularly copper, and delay the formation of adhesive residues like copper mercaptide-containing gels. Examples of MDAs include N,N-disalicylidene-1,2-propanediamine, used in gasoline, jet fuel, diesel, fuel oil, and gas, as well as benzotriazole and its derivatives, which are used in lubricants (Youseffi et al., 2023).

#### 2.1.1.1.10 Foam Inhibitors.

Foaming in lubricants is a highly undesirable phenomenon, as it can accelerate oxidation due to extensive air mixing. Insufficient oil transport in tanks and damage to oil tanks and lubrication cavitation can occur due to inadequate lubrication. The tendency of a lubricant to foam depends on its inherent properties, including the surface tension of the base oil and the presence of surface-active substances like detergents, corrosion inhibitors, and other ionic compounds (Chang et al., 2024). In some applications, oil agitation and foaming may be tolerated, but in others, even minor bubble formation can be problematic. In such cases, antifoaming agents can be added to the oil. These agents are believed to attach to bubbles, creating unstable bonds or spreading, which can merge smaller bubbles into larger ones. This facilitates their rise to the surface, where they can break and release air, thereby reducing foaming (Rizvi, 2009; Tiso et al., 2024).

Foam inhibitors work by reducing the surface tension of air bubbles in lubricants, enabling them to merge into larger bubbles and preventing excessive foaming. To ensure effective dispersion of antifoam additives, high mixing efficiency is necessary, breaking down the

additives into small particles. Therefore, test samples require processing with a Waring-type mixer to distribute the antifoam agents evenly before conducting the foam test. This step is crucial to guarantee uniform distribution of the antifoam agent throughout the oil, allowing for accurate test results (Al-Darweesh et al., 2023).

#### 2.1.1.2 Lubricant Base Oils

The term "base oil" refers to the primary oil produced from either refined petroleum (mineral base oil) or chemical synthesis (synthetic base oil). Base oils are typically characterized by their hydrocarbon content, molecular weight, and carbon atom count, ranging from 18 to 40 atoms. They can be classified into two main categories: paraffinic or naphthenic, depending on their molecular structure. Base oils are further categorized into various grades, including Neutral, Solvent, and Group III, with viscosity indicators such as 4cst, 6cst, and 8cst. These grades are defined by their viscosity and other properties (Zhang et al., 2021).

##### 2.1.1.2.1 Mineral Base Oil

Modern mineral oil is produced through an intricate process of distillation and refining, starting with crude oil as the raw material. Crude oil is a complex mixture of thousands of hydrocarbon compounds, each consisting of carbon and hydrogen atoms. Hydrocarbons can be categorized into three primary groups: paraffinic, naphthenic, and aromatic. Paraffinic hydrocarbons can be further divided into two subgroups: normal paraffins and isoparaffins. Paraffinic hydrocarbons are considered the superior oils. During the refinery distillation process, the hydrocarbons in crude oil are separated and classified based on their molecular size, resulting in various oil fractions (Jasim & Kashmoula, 2022).

During the production of mineral oil, impurities like sulfur, aromatic hydrocarbons, and paraffin wax are removed as much as possible. This refining process purifies the oil, yielding paraffin base oil as the final product. Although primarily composed of paraffinic hydrocarbons,

the base oil also contains smaller amounts of naphthenic and aromatic molecules. To create finished lubricants like engine oil, various additives are blended with the base oil to enhance its performance. Alternatively, the final product may be designated as naphthenic base oil, characterized by a predominantly naphthenic hydrocarbon content. This type of base oil exhibits exceptional properties (Joshi et al., 2023).

#### 2.1.1.2.2 Synthetic base oil

In scientific contexts, "synthetic" typically implies human creation rather than natural occurrence. For petroleum engineers in the 1980s, synthetic oil referred to oil whose molecules were constructed through chemical reactions from purified precursor materials, rather than being directly extracted from petroleum. In other words, synthetic oil's molecular composition is not derived from crude oil, but rather created through a process of breaking down crude oil into individual chemicals, refining them, and then reassembling them. This differs from the production process for Group I, II, and older Group III base oils, which utilize molecules commonly found in traditional oils (Sulima et al., 2021).

#### 2.1.2 Types of Lubricants

While automotive applications are a significant sector, lubricants are also widely used in various industrial, marine, and metallurgical applications. Although alternative lubricants like air and oil-based options (such as liquid bearings) exist, liquid and solid lubricants remain the dominant choice, particularly in the electronics industry. Lubricants typically consist of an oil base combined with various additives to achieve the desired properties. Usually, lubricants are formulated with a single type of oil base, but blended oils are also utilized to meet specific requirements (Hamnas & Unnikrishnan, 2023).

#### 2.1.2.1 Hydraulic Oils

Hydraulic oil serves as a medium for transmitting power through fluid flow and pressure in pipes or pipelines, similar to how air functions in pneumatic systems. To achieve optimal efficiency and precision, hydraulic oil must maintain its performance across various temperatures. Its primary function is to transmit power effectively, requiring a low-viscosity fluid that flows easily through the system while still providing sufficient viscosity to seal and lubricate components. Among various options, oil remains the most widely used hydraulic fluid due to its suitability for these tasks (Pabsetti et al., 2023).

#### 2.1.2.2 Gear Oils

For most gear applications, gear oil serves as the ideal adhesive. In contrast, gear oil is a specialized lubricant designed for the transmissions, gear shifts, and differentials of vehicles and machinery (Baumann & Bertsche, 2022). It has a higher viscosity to provide enhanced protection, but often comes with an unpleasant odour. Open gear lubricants should resist stripping caused by centrifugal forces or gear tooth action. Typically, these lubricants are heavy, asphalt-based, or mild oils with high viscosity to maintain lubrication throughout the gear. This is necessary because the equipment requiring these heavy oils relies on the lowest gear submerged in the oil pan, without a pump for oil circulation. However, these heavy oils can create viscous drag, negatively impacting vehicle performance. Notably, some modern automatic transmissions (combination and differential) have shifted away from using heavy oil, instead utilizing high-viscosity hydraulic fluids that can withstand high pressure (Ghosh et al., 2021).

Depending on the specific application, lubricants may be formulated with antioxidants to enhance their performance. However, these lubricants' sticky nature can attract dust and dirt, potentially leading to contamination if not regularly cleaned. The design and lubrication requirements of gears vary widely, making it crucial to select the right lubricant based on

factors like gear type, operating speed, load, and temperature. In the case of glass blocks, such as those used in oil-tight buildings, mineral oil is often used, supplemented with additives like rust, oxidation, and foam inhibitors. In high-load applications, air release additives may also be included to ensure optimal performance (Yan et al., 2024).

#### 2.1.2.3 Heat Transfer/Transformer Oils

Transformer oil, also known as insulating oil, is a specialized oil that exhibits thermal stability and exceptional electrical properties. It is utilized in various applications, including oil transformers, high-voltage capacitors, fluorescent lamp ballasts, and certain high-voltage switches and circuit breakers. Its primary functions are to provide protection, prevent corona effects and electric arcs, and serve as a coolant. The oil plays a crucial role in cooling the transformer while also offering electrical insulation to internal components. To ensure long-term stability at high temperatures, the oil must maintain its properties. Additionally, oil tanks can facilitate cooling through natural convection, while large or high-power generators (up to thousands of kVA capacity) may employ oil cooling fans, pumps, and even oil-water heat exchangers to enhance cooling efficiency (Elele et al., 2022).

#### 2.1.2.4 Engine/Motor Oils

Engine oil is typically formulated from thicker, heavier petroleum hydrocarbon products refined from crude oil, supplemented with additives to enhance specific properties. In contrast, gasoline is primarily composed of hydrocarbons with 18 to 34 carbon atoms per molecule. A crucial characteristic of engine oil is its viscosity, which enables it to maintain a lubricating film on moving parts. Viscosity can be understood as a measure of a liquid's "thickness" or resistance to flow. Engine oil must strike a balance between high enough viscosity to maintain the lubricating film and low enough viscosity to flow freely through engine components under various conditions. The viscosity index measures how much oil viscosity changes with

temperature, with a higher index indicating less variation in viscosity across different temperatures (Sulima et al., 2021).

Engine oil, also known as motor oil or engine lubricating oil, refers to a range of specially designed lubricants, often enriched with additives, used to facilitate the smooth operation of internal combustion engines. The primary purpose of these lubricants is to minimize wear and tear on moving parts, while also serving to remove heat, clean, prevent corrosion, enhance seals, and cool the engine (Khan et al., 2021). Unlike synthetic petroleum, motor oil is derived from petroleum and typically consists of a blend of base oils containing hydrocarbons, polyalphaolefins (PAO), and polyinternal olefins (PIO), which are organic compounds composed of carbon and hydrogen. Notably, some high-performance oils may contain up to 20% esters in their base oils (Armioni et al., 2024).

#### 2.1.2.4.1 Engine/Motor Oil Grades

The Society of Automotive Engineers (SAE) has established a mathematical formula to classify engine oils based on their viscosity properties, resulting in a rating system ranging from 0 to 60, with lower numbers indicating lower viscosity. The ratings are further distinguished by the prefix "W" (denoting "winter" or lower cold-start viscosity) for grades 0, 5, 10, 15, and 25, while the number 20 can be used with or without the "W" designation depending on whether it refers to cold or hot viscosity. The SAE J300 document provides the specific viscosity parameters for each grade. It's important to note that SAE has a separate viscosity rating system, SAE J306, for gear, axle, and manual transmission fluids, which should not be confused with engine oil viscosity ratings. Additionally, a higher rating in gear oil (e.g., 75W-140) does not necessarily indicate higher viscosity than engine oil (Chybowski et al., 2023).

To prepare for forthcoming lower viscosity levels in new oils and avoid confusion with existing "winter" oil classifications, the Society of Automotive Engineers (SAE) introduced SAE 16 as

the new standard, succeeding SAE 20, rather than adopting SAE 15. Michael Covitch, president of SAE Lubrizol, explained that the International Engine Oil Viscosity Classification (EOVC) Working Group aimed to alleviate consumer confusion surrounding low-temperature viscosity, particularly with designations like SAE 10W, SAE 5W, and SAE 0W. By establishing SAE 16 as the new viscosity level, the group set a precedent for future levels, which will increment by 4 (e.g., SAE 12, SAE 8, and SAE 4) rather than 5, to avoid further confusion (Galpaya et al., 2024).

According to SAE J300, a specific grade of engine oil cannot utilize polymer additives that enhance viscosity index or modify viscosity. SAE J300 defines 11 viscosity grades, with 6 designated as winter grades (0W to 25W) and the remaining 5 as non-winter grades (20 to 60). These numbers are often misinterpreted as the "weight" of the engine oil, with lower grades commonly referred to as "light" oils (Joni et al., 2021). For premium winter oils, dynamic viscosity is measured at various temperatures specified in J300, depending on the viscosity grade. The oil's classification into SAE viscosity grades (0W to 25W) is determined by the coldest temperature it can pass through. A lower viscosity level indicates the oil can perform at lower temperatures. For instance, if an oil meets the 10W and 5W specifications but fails at 0W, it should be labeled SAE 5W, and cannot be labeled 0W or 10W (Galpaya et al, 2024).

For non-winter oil grades, kinematic viscosity is measured in millimeters per square second ( $\text{mm}^2/\text{s}$ ) or centistokes (cSt) at a temperature of  $100^\circ\text{C}$  ( $212^\circ\text{F}$ ). Based on the oil's viscosity loss at high temperatures, it is classified into SAE viscosity grades 20, 30, 40, 50, or 60. Furthermore, for SAE grades 20, 30, and 1000, an additional requirement is a minimum viscosity at  $150^\circ\text{C}$  ( $302^\circ\text{F}$ ) and high shear rates. The classification system is hierarchical, with higher viscosities corresponding to higher SAE viscosity grades (Chybowski, 2023).

#### 2.1.2.4.1.1 Multigrade Engine Oils

Multigrade engine oil is a specially designed oil that maintains its performance across a broad range of temperatures and viscosity levels, typically indicated by the "W" designation. By incorporating polymers into the base oil, multigrade oil prevents excessive thinning at high temperatures and thickening at low temperatures (Rostamian et al., 2022). This type of oil is specifically designed to minimize excessive wear and tear in internal combustion engines, which can experience temperature fluctuations of over 100°C, from cold starts to operating temperatures. Multigrade oil ensures optimal flow and protection by maintaining a suitable consistency, neither too thick to flow initially nor too thin at operating temperatures, thereby keeping metal parts separated and properly lubricated (Johnson & Chigozie, 2022).

SAE designations for oils typically consist of two viscosity grades, such as 10W-30, which represents a range of oils. The first number, "10W", indicates the oil's viscosity at low temperatures, while the second number, "30", represents the viscosity at 100°C (212°F). According to SAE J300, each oil is assigned two-part numbers, and oils labeled 10W-30 must meet the viscosity requirements for both grades, subject to any applicable limitations. If an oil does not exhibit viscosity index improvement and can pass multiple grades, it may be labeled with one of the two SAE viscosity grades. For instance, oil that can be easily produced from regular base oils without enhancing the viscosity index may be labeled 20W-20, 20W, or 20. However, if the viscosity index is improved, the oil cannot be registered as a single grade (Rostamian et al., 2022). Failure to improve viscosity index in shear forces is a problem in motorcycle applications where the transmission will supply lubricant to the engine. For this reason, synthetic oils or special motorcycle oils are recommended. The demand for expensive motorcycle fuel is also contested by at least one consumer group (Holdmeyer, 2022).

#### 2.1.2.4.2 Diesel Engine Oils

Diesel engine oil typically contains a high volume of additives, with detergents being the most crucial component. These additives play multiple roles, primarily neutralizing and cleaning acids generated by diesel engines, which produce more pollutants and waste than gasoline engines. The detergent additive helps to clean cylinder walls, but if used in a gasoline engine, it can compromise the seal between the ring and liner, leading to reduced compression and efficiency. To determine if an oil is designed for gasoline or diesel engines, check the American Petroleum Institute (API) donut on the label. The top of the donut indicates the service designation, starting with "S" for gasoline engines (service or spark ignition) and "C" for diesel engines (compression ignition or economy) (Victorovych & Olexandrovich, 2021).

In contemporary diesel engines, oil plays a vital role in the lubrication process. However, the removal of sulphur from diesel fuel, as mandated by regulations in countries like the US and EU, has also eliminated the naturally occurring lubricating compounds found in diesel fuel. As a result, hydrotreated diesel fuel, unless blended with biodiesel, exhibits poor lubricity and necessitates the addition of lubricity-enhancing additives to prevent excessive engine wear (Wang & Bai, 2024).

#### 2.1.2.4.3 Petrol/Gasoline Engine Oils

SINOPEC offers two premium gasoline engine oils: SM and SL. The SM oil is a high-performance blend of ultra-high viscosity index synthetic oil, mineral oil, and advanced additives, making it suitable for both new drivers and racing enthusiasts. The SL oil is specifically designed to provide all-around protection for engines, safeguarding against start-up friction, heat, and deposit buildup (Agocs et al., 2023). Additionally, the API SL-certified oil is a top-tier, shear-stable multigrade lubricant designed for various passenger and light commercial vehicles. By using this oil, drivers can enjoy extended engine life, reduced wear

and tear, maintained power and performance, improved fuel efficiency, and lower maintenance costs.

SINOPEC offers three high-performance engine oils: SM/CF 0W-50, SJ, and SF. The SM/CF 0W-50 Full Synthetic Engine Oil is formulated with a synthetic hydrocarbon base and premium materials, making it suitable for OEM vehicles, military, and civilian vehicles operating in extreme conditions. The SJ gasoline engine oil provides comprehensive engine protection against friction, heat, and deposits, promoting extended engine life, reduced wear, maintained power, improved fuel efficiency, and lower maintenance costs. The SF gasoline engine oil is a potent engine cleaner for passenger cars and trucks, blending high-quality base oil with advanced technology. Its exceptional oxidation stability ensures optimal engine protection under harsh working conditions, preventing wear and tear (Agocs et al., 2021).

### 2.1.3 Functions of Lubricant

The primary role of a lubricant is to create a protective layer on metal surfaces within an engine, preventing contact and subsequent damage, thereby minimizing friction and wear. Lubrication is essential for most mechanical components, including automobile engines with moving parts like pistons and gears. At its core, lubrication involves the movement of a fluid between two moving parts in relative motion (Singh et al., 2021). The main objective of a lubricant is to reduce friction and wear between moving parts. Additionally, lubricants often serve multiple purposes, such as heat dissipation, corrosion prevention, sealing, and contaminant removal from bearing surfaces. To achieve this, a lubricant must maintain a continuous fluid film on the moving surface, a condition known as fluid film lubrication (Shah et al., 2021).

## 2.2 CONTAMINANTS LUBRICANTS

Contamination is a major contributor to lubricant degradation and mechanical failure in engines and machinery, highlighting the importance of maintaining a clean and controlled environment

for lubricant operation. Lubricants are designed to function optimally in relatively clean systems; however, in real-world applications, they are often exposed to a wide range of foreign substances that can compromise their chemical and physical stability. These substances, referred to as contaminants, can enter the system through various means, including environmental exposure, internal sources such as wear debris, or during maintenance activities (Ratiu et al., 2021).

Common categories of contaminants that can affect lubricant performance include solid particulates, such as dust, fluids like fuel and water, and semi-solids like used oil and grease. Even small quantities of these contaminants can significantly impact lubricant properties, including viscosity, demulsibility, foaming tendency, and additive in the lubricant formulation. The presence of these contaminants can lead to a range of problems, including increased wear, corrosion, and degradation of the lubricant's chemical and physical properties (Rameshkumar et al., 2024).

The impact of contaminants on lubricant performance can be significant, and it is essential to understand the sources and effects of contamination to develop effective strategies for mitigating its impact. By identifying the types and sources of contaminants, lubricant manufacturers and users can take steps to minimize their impact and ensure optimal lubricant performance (Sentanuhady et al., 2021).

### 2.2.1 The Impact of Dust on Lubricants

Dust is a common and pervasive contaminant in lubricating systems, particularly in off-road and industrial applications where equipment is often exposed to harsh environments. It can enter the system through various means, including air intake systems, seals, or during open maintenance procedures. Dust particles, typically composed of abrasive materials such as

silica, metal oxides, and organic matter, can have a detrimental impact on lubricant performance (Kh et al., 2021).

The presence of dust can lead to three-body abrasive wear, especially in boundary lubrication regimes where the protective lubricant film is thin. This type of wear can result in increased surface roughness, damage to equipment components, and ultimately, premature failure. Furthermore, dust can also influence oil emulsification behavior, with fine particulates serving as stabilization agents for water-in-oil emulsions. This can impede demulsibility, leading to increased corrosion, sludge formation, and filter clogging (Zhang et al., 2023).

The effects of dust contamination on lubricant performance can be significant, highlighting the importance of proper maintenance and filtration systems to minimize the impact of dust and other contaminants on equipment operation. By understanding the mechanisms of dust contamination and its effects on lubricant performance, equipment operators and maintenance personnel can take steps to mitigate its impact and ensure optimal equipment performance (Olimjonov & Gulmatov, 2022).

### 2.2.2 The Impact of Grease Contamination on Lubricants

Grease can sometimes be inadvertently introduced into lubricant systems during relubrication or part replacement, posing a significant risk to lubricant performance. Although grease is itself a lubricant, its thickening agents, such as lithium or calcium soaps, are often incompatible with engine oils, which are specifically formulated for high-temperature, high-shear conditions. When grease is mixed with engine oils, it can cause a range of problems, including additive separation, thickening or thinning of the oil, and instability in emulsion behaviour (Pazskowski et al., 2023).

The incompatibility of grease with engine oils can lead to a range of issues, including changes in viscosity, reduced lubricity, and increased risk of equipment damage. Furthermore, residual

greases can also interfere with the foam control properties of lubricants due to their surface-active components, which can stabilize foam and lead to increased foam formation (Gil et al., 2021). This can result in reduced lubricant performance, increased equipment wear, and potentially even equipment failure.

The impact of grease contamination on lubricant systems highlights the importance of proper maintenance practices, including careful handling and storage of lubricants and greases, and ensuring that all equipment components are properly cleaned and flushed before introducing new lubricants. By minimizing the risk of grease contamination, equipment operators and maintenance personnel can help ensure optimal lubricant performance and extend equipment life (Board, 2023).

### 2.2.3 The Impact of Fuel Dilution on Lubricant Performance

Fuel dilution is a common issue in engines, where petrol or diesel fuel enters the crankcase oil due to ring blow-by or injector leaks. This can lead to a significant reduction in the oil's viscosity, compromising its load-carrying ability and boundary lubrication properties. As a result, the oil's capacity to maintain film strength under pressure is diminished, leading to increased wear and potentially premature equipment failure (Zhang et al., 2023).

Diesel fuel, in particular, can introduce additional contaminants like sulfur and unburned hydrocarbons into the oil, which can promote oxidation and acidic degradation of the lubricant (Kaminski, 2022). This can further exacerbate the negative effects of fuel dilution, leading to increased wear, corrosion, and lubricant degradation.

Fuel dilution can also have a significant impact on foam characteristics, as it lowers the surface tension of the oil, making foam formation more likely during mechanical agitation. This can lead to increased foam levels, which can compromise lubricant performance and equipment operation. The effects of fuel dilution on lubricant performance highlight the importance of

regular oil analysis and maintenance practices to detect and prevent fuel dilution, ensuring optimal equipment performance and longevity (Tailor, 2021).

#### 2.2.4 The Impact of Used Engine Oil on Lubricant Systems

Recycling or reusing used engine oil without proper reconditioning can introduce a complex mixture of degraded additives, oxidation products, soot, and metallic particles into the lubricant system. These contaminants can drastically affect the oil's ability to perform under thermal and mechanical stress, leading to a range of problems (Wang et al., 2021).

The oxidation products present in used oil can increase oil acidity, causing corrosion and rust formation on metal surfaces. Additionally, carbonaceous materials such as soot and sludge can increase viscosity, leading to poor flow and excessive energy consumption. Furthermore, used oil may already contain entrained air and water, which can increase its foaming tendency and reduce its demulsibility due to the presence of polar degradation byproducts (Armioni et al., 2024).

The consequences of lubricant contamination extend far beyond the loss of lubricity. Contaminants can alter the oil's chemical equilibrium, destabilize additive packages, increase wear rates, and reduce overall equipment reliability. They can also interfere with filtration efficiency, accelerate the need for oil replacement, and increase operational costs and downtime. Effective contamination control and monitoring are therefore essential components of lubricant management programs, helping to ensure optimal equipment performance, reduce maintenance costs, and extend equipment life. By prioritizing contamination control, equipment operators and maintenance personnel can help prevent a range of problems and ensure reliable equipment operation (Seikorovo et al., 2021).

### 2.3 DEMULSIBILITY OF LUBRICANTS

Demulsibility is a vital property of lubricants, particularly engine oils, that refers to their ability to separate from water after becoming contaminated. In real-world mechanical systems, such as internal combustion engines, hydraulic systems, and gearboxes, water ingress is a common occurrence. Water can enter the lubricant system through various means, including condensation, coolant leaks, seal failures, or exposure to humid operating environments (Hartyanyi et al., 2024).

When water contaminates the lubricant, it can form a stable emulsion, making it challenging to separate the two liquids. The ability of a lubricant to quickly release water is crucial for maintaining its performance, protecting equipment, and preventing corrosion and wear. If water is not separated from the lubricant, it can lead to a range of problems, including reduced lubricity, increased wear, and corrosion of metal surfaces.

Effective demulsibility is essential for ensuring the reliability and longevity of equipment, particularly in applications where water contamination is likely. Lubricant manufacturers often formulate their products with additives that enhance demulsibility, allowing the lubricant to quickly separate from water and maintain its performance characteristics. By understanding the importance of demulsibility and selecting lubricants with good demulsibility properties, equipment operators can help prevent equipment damage and ensure optimal performance (Xiong et al., 2023).

The presence of stable emulsions in lubricants can have detrimental effects on their performance and equipment longevity. When water forms a stable emulsion with the lubricant, it can compromise the protective film strength, reduce load-carrying capacity, and interfere with the action of additives. Furthermore, water in emulsified form can accelerate oxidation,

promote microbial growth (especially in biodegradable oils), and lead to the formation of sludge and acids that damage metallic surfaces (Agah et al., 2022).

As a result, high demulsibility is a desirable property for most lubricants, allowing them to quickly separate from water and maintain their performance characteristics. Lubricants with good demulsibility properties can help prevent equipment damage, reduce maintenance costs, and ensure optimal performance.

### 2.3.1 Types of Emulsions in Lubricants

Emulsions in lubricants can be broadly classified into two types:

- Oil-in-Water (O/W) Emulsions: These emulsions are less common in engine oils but may occur in water-based or soluble cutting fluids. They form when small oil droplets are dispersed within a continuous water phase.
- Water-in-Oil (W/O) Emulsions: These emulsions are more typical in engine and hydraulic oils, where water is dispersed within the oil. They are more stable due to the continuous oil phase and are harder to separate without proper formulation (Lim & Stokes, 2021).

The stability of an emulsion depends on multiple factors, including the type and concentration of emulsifiers (such as additives or contaminants), temperature, shear conditions in the system, and the presence of particulate matter like dust or sludge, which can act as emulsifying agents. Understanding these factors is crucial for developing effective strategies to prevent or mitigate emulsion formation in lubricants (Liu et al., 2024).

### 2.3.2 The Role of Additives and Contaminants

Modern lubricants contain complex additive packages that play a crucial role in their performance. However, some of these additives can inadvertently stabilize emulsions, reducing the lubricant's demulsibility. Detergents, dispersants, and anti-wear agents often contain

surfactants, which are molecules that reduce surface tension and stabilize oil-water interfaces. While these additives are essential for lubricant performance, they can compromise demulsibility if not properly balanced (Li et al., 2022).

Contaminants such as dust, grease, and used oil can significantly worsen the demulsibility of lubricants. Dust particles can act as physical stabilizers, while grease - especially if chemically incompatible - can introduce additional emulsifiers into the system. Used engine oil, which contains oxidized hydrocarbons, degraded additives, and metal particles, can further enhance emulsion stability by altering the interfacial properties between oil and water.

The combined effect of additives and contaminants can lead to a significant reduction in demulsibility, making it challenging to separate water from the lubricant. This can result in a range of problems, including reduced lubricant performance, increased wear, and corrosion of metal surfaces. Therefore, it is essential to carefully balance additive packages and minimize contamination to ensure optimal demulsibility and lubricant performance (Seikorova, 2022).

### 2.3.3 Factors Affecting Demulsibility

The demulsibility of lubricants is influenced by several key factors. These include:

- Oil Composition: The type of base oil used, whether mineral or synthetic, can significantly impact demulsibility. Synthetic oils often exhibit better water separation properties due to their tailored molecular structure. Additionally, the polarity and additive content of the oil can also play a crucial role in determining its demulsibility.
- Temperature: Temperature can have a complex effect on demulsibility. Elevated temperatures can reduce viscosity, which may help break emulsions and improve water separation. However, in some cases, heat can stabilize emulsions by accelerating additive breakdown, leading to the formation of emulsifying agents that worsen demulsibility.

- Water Quality: The hardness, pH, and ion content of water can significantly affect emulsion stability. Soft or deionized water tends to form more stable emulsions, making it more challenging to separate water from the lubricant.
- Contaminant Type and Concentration: As previously noted, solid particles and polar contaminants can act as emulsifying agents, stabilizing emulsions and reducing demulsibility. The type and concentration of contaminants can have a significant impact on lubricant performance (Soliman, 2020).

#### 2.3.4 Importance of Demulsibility

Demulsibility is a critical property in various lubricant applications, including engines and hydraulic systems. In engines, poor demulsibility can lead to bearing corrosion, reduced film strength, and cavitation, ultimately compromising equipment performance and longevity. In hydraulic systems, poor demulsibility can impair fluid power transmission and damage pumps and valves (Ameye & Sitton, 2008). To address these concerns, lubricants used in these environments are required to meet specific demulsibility standards, such as those outlined in test methods ASTM D1401 and ASTM D2711. Demulsibility also has significant implications for maintenance practices. Oils with poor demulsibility may require more frequent replacements, and oil purification can be challenging. In contrast, high-demulsibility oils can be centrifuged or filtered to remove water, extending oil life and improving cost-efficiency. By selecting lubricants with good demulsibility properties, equipment operators can help ensure optimal performance, reduce maintenance costs, and extend equipment life.

Demulsibility is a critical property of lubricants that not only determines their ability to separate from water but also plays a significant role in their overall longevity and the health of mechanical systems. The presence of contaminants such as dust, grease, fuel, and used oil can significantly impair demulsibility, leading to reduced lubricant performance and equipment

damage. Therefore, assessing demulsibility under various contamination conditions is essential in evaluating the suitability of lubricants for real-world applications. By understanding how different contaminants affect demulsibility, lubricant manufacturers and users can develop and select lubricants that meet the demands of specific applications and operating conditions. In practice, this means testing lubricants with various contaminants and under different conditions to determine their demulsibility characteristics. By doing so, lubricant manufacturers can formulate products that maintain their demulsibility properties even in the presence of contaminants, ensuring optimal equipment performance, reduced maintenance costs, and extended equipment life (Agah et al., 2022).

## 2.4 FOAMING IN LUBRICANTS

Foaming in lubricants refers to the formation and accumulation of air bubbles within the oil during operation. Although foam is primarily composed of air, its presence in a lubricant system can be highly detrimental to equipment performance and longevity (Suja et al., 2020). The primary function of a lubricant is to form a continuous film between moving surfaces, and this function is compromised when air is entrained or foam develops on the surface of the oil.

Foaming is particularly problematic in high-speed, high-pressure systems, such as internal combustion engines, hydraulic circuits, and gearboxes. In these systems, the disruption of the oil film can lead to metal-to-metal contact, increased wear, heat generation, and eventual system failure (Prolic & Lepusic, 2012).

Foam in lubricants typically forms in two stages:

1. Foam Tendency (Initial Foaming): This refers to the formation of foam when the oil is agitated or aerated. Foam tendency is a measure of how easily foam forms in the lubricant.

2. Foam Stability (Foam Persistence): This refers to the length of time the foam remains before collapsing. Foam stability is a measure of how long the foam persists in the system.

An ideal lubricant will exhibit low foam tendency and rapid foam collapse, ensuring that the oil film remains intact and equipment performance is not compromised. Persistent or excessive foam, on the other hand, can indicate a problem with the oil formulation or contamination, highlighting the need for careful lubricant selection and maintenance (Suja et al., 2020).

#### 2.4.1 Causes of Foaming in Lubricants

Several factors can contribute to foaming in lubricants, including:

- Aeration: Agitation of the lubricant, especially in turbulent systems, can introduce air into the oil. If the entrained air is not quickly released, it may form stable foam, leading to equipment problems.
- Contaminants: Various substances can increase the oil's surface activity, promoting foam formation and stability. Examples of contaminants that can contribute to foaming include:
  - Dust: Acts as a stabilizer for foam bubbles by interfering with bubble coalescence, making it more difficult for the foam to collapse.
  - Fuel: Lowers the oil's surface tension, making bubble formation easier and increasing the likelihood of foaming.
  - Used oil: Contains oxidation products and degraded additives that act as surfactants, stabilizing foam bubbles and promoting foam persistence.
- Additive Incompatibility: Some additives, particularly detergents and dispersants, can act as foaming agents if not properly balanced in the formulation. If these additives are not carefully selected and formulated, they can contribute to excessive foaming.

- Base Oil Characteristics: The chemical structure and viscosity of the base oil can affect its air release and foam characteristics. For example:

- Low-viscosity oils: Tend to entrain more air, increasing the likelihood of foaming.
- High-viscosity oils: May retain bubbles longer, leading to persistent foam and equipment problems (Chandran, 2020).

Understanding these factors is essential for developing effective strategies to prevent or mitigate foaming in lubricants. By carefully selecting the base oil and additive package, and minimizing contamination, lubricant manufacturers can formulate products with improved foam resistance and reduced susceptibility to foaming-related problems.

#### 2.4.2 Effects of Foam in Lubricants

Foaming can have several adverse effects on lubricant performance and machinery health, including:

- Loss of Lubrication: Foam disrupts the oil film, preventing it from effectively separating metal surfaces and leading to increased wear and tear.
- Cavitation: Entrapped air bubbles collapse under pressure, causing localized high temperatures and pitting of metal surfaces, which can lead to equipment failure.
- Oxidation Acceleration: Increased air exposure due to foaming can speed up oxidation of the oil, leading to the formation of sludge, varnish, and acids, which can compromise lubricant performance and equipment longevity.
- Pump Damage: Foam can cause pumps to run dry or lose prime, especially in hydraulic systems, leading to equipment damage and downtime.

- False Level Readings: Excessive foam may distort oil level measurements, leading to overfilling or underfilling, which can compromise equipment performance and safety (Ren et al., 2023).

#### 2.4.3 Foam Control and Testing

To counteract foaming, lubricants are formulated with antifoam agents, typically silicone-based compounds or organic polymers that reduce surface tension and promote bubble coalescence (Chandran, 2022). These additives are used in low concentrations due to their powerful effects.

The industry-standard test method for foam is ASTM D892, which evaluates lubricants at two temperatures:

- Sequence I (24°C): Foam tendency and stability are observed at ambient temperature.
- Sequence II (93.5°C): High-temperature foam performance is tested.
- Sequence III (24°C Re-test): A final check for stability after heat exposure.

By using antifoam agents and testing lubricants for foam performance, manufacturers can develop products that minimize foaming-related problems and ensure optimal equipment performance and longevity.

#### 2.4.4 Impact of Contaminants on Foaming

Contaminants can severely impair a lubricant's foam resistance, leading to increased foaming and equipment problems (Obisesan, 2023). Some common contaminants that can affect foaming include:

- Water: Acts as a stabilizer by lowering surface tension and enabling foam formation, making it more difficult to control foam.

- Dust and soot particles: Hinder bubble coalescence, prolonging foam life and increasing the risk of equipment damage.
- Used engine oil: May contain surfactants formed through additive degradation, which can dramatically increase foam persistence and compromise lubricant performance.
- Fuel dilution: Changes the volatility and surface tension of the oil, increasing the risk of foaming and equipment problems.

Understanding the effects of these contaminants on foaming characteristics is essential for predicting field performance and ensuring reliability in engine operation. By studying the impact of contaminants such as dust, grease, fuel, and used oil on the foaming characteristics of petrol and diesel engine lubricants, manufacturers can develop products that are more resistant to foaming and better suited for real-world applications. This knowledge can also inform maintenance practices and help equipment operators take steps to minimize contamination and prevent foaming-related problems.

## **2.5 TESTING METHODS FOR DEMULSIBILITY AND FOAMING**

Evaluating the performance of lubricants under real-world conditions requires standardized testing methods. Demulsibility and foaming behavior are two critical properties that affect lubricant reliability and service life. Accurate and reproducible testing is essential to determine a lubricant's suitability for various applications, particularly where exposure to contaminants or extreme mechanical stress is likely.

### **2.5.1 Demulsibility Testing**

Demulsibility testing assesses a lubricant's ability to separate from water after mixing. This property is crucial for lubricants used in engine, hydraulic, and gear systems where water ingress can occur due to condensation, environmental exposure, or coolant leakage.

a) ASTM D1401 – Water Separation Characteristics of Lubricants:

ASTM D1401 is the most widely used standard for evaluating demulsibility. The procedure involves mixing the lubricant with water and then observing the separation of the two liquids over time. This test provides valuable information on the lubricant's ability to shed water and maintain its performance characteristics.

The ASTM D1401 test procedure involves:

1. Mixing 40 mL of the oil sample with 40 mL of distilled water in a graduated cylinder.
2. Stirring the mixture at 54°C (or 82°C for high-viscosity oils) for 5 minutes.
3. Allowing the mixture to settle for up to 30 minutes.
4. Recording the volumes of water, oil, and emulsion layers.

The results are reported in the format: Oil-Water-Emulsion (mL) at the time (e.g., 40-40-0 at 30 min indicates complete separation). A high-quality lubricant should demonstrate rapid separation with minimal emulsion formation (Hartyanyi, 2024).

b) ASTM D2711 – Demulsibility of Lubricating Oils:

ASTM D2711 is a suitable test method for lubricants with higher viscosities or those containing additives that may affect water separation. The test uses a stirrer and heating bath to simulate mechanical agitation, which can help to:

- Evaluate the demulsibility of lubricants under more severe conditions
- Assess the impact of additives on water separation
- Determine the amount of emulsion formed after mixing and the time it takes to separate

By using these standardized testing methods, lubricant manufacturers and users can evaluate the demulsibility performance of lubricants and ensure that they meet the required standards for various applications.

### 2.5.2 Foaming Testing

Foaming tests are critical in evaluating a lubricant's tendency to form and retain foam when agitated. This is particularly important in applications involving high-speed components or oil recirculation systems, where excessive foam can lead to equipment damage and performance issues (Cui et al., 2022).

#### a) ASTM D892 – Foaming Characteristics of Lubricating Oils:

ASTM D892 is the primary industry test for foam tendency and stability. The test evaluates the oil's response under controlled aeration at specified temperatures:

- Sequence I: Conducted at 24°C (room temperature) to assess foam tendency and stability under normal operating conditions.
- Sequence II: Conducted at 93.5°C (high temperature) to evaluate foam performance under elevated temperatures.
- Sequence III: Repeat of Sequence I after heating to assess the oil's foam characteristics after thermal stress.

For each sequence, the test involves:

1. Aerating 200 mL of oil with dry air at 94 mL/min for 5 minutes.
2. Measuring the foam volume immediately after aeration (foam tendency).
3. Measuring the volume remaining after 10 minutes of settling (foam stability).

Acceptable results for most applications are typically less than 50 mL foam tendency and 0 mL foam stability. Higher values may indicate the need for improved formulation or the presence of contaminants.

#### b) ASTM D6082 – High Temperature Foam Test:

For oils used in high-speed or high-temperature applications, ASTM D6082 provides a more rigorous test:

- Conducted at 150°C using a specialized air-injection apparatus.

- Measures foaming under extreme thermal conditions, simulating the high temperatures encountered in diesel engines or industrial gearboxes.
- Suitable for testing diesel engine oils or industrial gear lubricants that require exceptional foam control properties.

By using these standardized testing methods, lubricant manufacturers and users can evaluate the foaming characteristics of lubricants and ensure that they meet the required standards for various applications.

### 2.5.3 Factors Affecting Test Results

Several factors can influence the outcome and interpretation of demulsibility and foam tests, including:

- Presence of contaminants: Dust, fuel, used oil, and grease can significantly worsen both demulsibility and foaming behavior, leading to reduced lubricant performance.
- Additive formulation: Detergents, dispersants, and anti-foam agents must be properly balanced to avoid skewing test results. Imbalances can lead to inaccurate assessments of lubricant performance.
- Oil viscosity: High-viscosity oils tend to retain air and water more, affecting separation and foam collapse rates. This can impact the lubricant's ability to perform effectively in various applications.
- Temperature: Elevated temperatures can either enhance or impair water separation and foam collapse, depending on the oil composition. This highlights the importance of testing lubricants under simulated operating conditions.

To accurately assess lubricant performance, testing must consider potential contamination scenarios and simulate expected operating conditions. This ensures that the results are relevant and applicable to real-world situations.

#### 2.5.4 Relevance to Current Study

In this research, standardized methods will be employed to systematically evaluate the effects of selected contaminants (dust, grease, fuel, and used engine oil) on the demulsibility and foaming behavior of both petrol and diesel engine oils. By comparing contaminated samples against uncontaminated controls, this study aims to:

- Determine the sensitivity of demulsibility and foaming properties to real-world contaminant exposure
- Inform formulation and maintenance decisions
- Provide valuable insights into the impact of contaminants on lubricant performance

The findings of this study will contribute to a better understanding of lubricant behavior in contaminated environments, ultimately helping to improve lubricant formulation and equipment maintenance practices.

#### 2.6 SUMMARY OF LITERATURE REVIEW

The literature review highlights the complex nature of lubricant performance and the significant impact of contaminants on critical properties such as demulsibility and foaming behavior. Modern engine oils are sophisticated blends of base oils and additives designed to provide lubrication, heat transfer, wear protection, and system cleanliness. However, these formulations are highly susceptible to external influences, particularly contamination.

Contaminants like dust, grease, fuel, and used engine oil are common in practical operating environments, especially in internal combustion engines and industrial machinery. These substances can enter the lubricant system through various means, including poor maintenance, fuel dilution, aging oil, or environmental exposure. Each contaminant poses distinct challenges:

- Dust particles promote emulsification and foam stabilization by acting as solid emulsifiers and disrupting fluid dynamics.

- Grease, especially when incompatible, can alter oil chemistry and destabilize additive interactions, leading to increased emulsion formation and foaming.
- Fuel contamination reduces oil viscosity and alters its surface tension, exacerbating foaming and hindering effective demulsibility.
- Used engine oil contributes oxidized products, degraded additives, and insoluble contaminants, compounding the lubricant's instability and degrading its functional properties.

The literature emphasizes demulsibility and foaming as crucial lubricant properties that ensure water separation and prevent equipment failure. Standard testing methods like ASTM D1401 and ASTM D892 provide well-established frameworks for assessing lubricant quality. However, there is a notable gap in understanding the interactive effects of multiple contaminants on lubricant emulsion stability and foam performance, particularly in petrol and diesel engine oils.



## CHAPTER THREE

### 3.0 METHODOLOGY

#### 3.1 INTRODUCTION

The methodology chapter outlines the experimental framework for investigating the impact of selected contaminants on the demulsibility and foam characteristics of lubricants, specifically petrol and diesel engine oils. This study aims to provide a comprehensive understanding of how common contaminants affect lubricant performance in real-world operating environments. Lubricants play a critical role in maintaining the efficient operation of mechanical systems. Their degradation or performance impairment due to contamination can have significant consequences for engine protection, efficiency, and service life. Demulsibility and foaming tendency are two essential properties that determine lubricant performance. Demulsibility refers to a lubricant's ability to separate from water, while foaming behavior pertains to its tendency to form stable foam under agitation.

The contaminants selected for this research are dust, grease, fuel, and used engine oil, which are commonly encountered in practical operating environments. These contaminants can enter the lubricant system through various means, including:

- Dust: air intake leaks, maintenance lapses, or dusty operating environments
- Grease: cross-contamination between lubricants, especially during servicing
- Fuel: leakage past piston rings or fuel system malfunctions, particularly during cold starts
- Used engine oil: degraded and oxidation-prone fluid that may remain in the system after incomplete drainage or mixing during top-up.

This study will compare the behavior of petrol and diesel engine oils under identical contamination scenarios. The formulation differences between these two oil types, such as detergent and dispersant levels, may lead to varied responses to the same contaminants.

The methodology follows a comparative experimental design guided by ASTM standards, specifically:

- ASTM D1401 for demulsibility
- ASTM D892 for foaming

These protocols ensure uniformity, repeatability, and industry relevance. Each oil sample will be exposed to one contaminant at a time, under measured concentrations, to isolate and compare effects. Results will be analyzed using descriptive and inferential statistics to identify trends and significant differences.

The experimental approach taken in this chapter is grounded in the need for applied knowledge that informs lubricant formulation, machinery maintenance, and contamination control. By simulating practical contamination scenarios and quantifying their impact using recognized testing methods, this research aims to produce actionable insights for the lubricant industry, equipment operators, and maintenance professionals.

### **3.2 RESEARCH DESIGN**

This research employed a quantitative experimental design to investigate the effects of selected contaminants on the demulsibility and foaming behavior of petrol and diesel engine lubricants. The design focused on controlled laboratory-based experiments using standardized testing procedures, allowing for precise manipulation of variables and accurate measurement of responses.

The study involved two independent variables:

1. Type of lubricant: Petrol engine oil and diesel engine oil
2. Type of contaminant: Dust, grease, fuel (petrol), and used engine oil

The dependent variables were:

- Demulsibility (measured as the rate and extent of water separation from the oil-water mixture)
- Foaming tendency and stability (measured as the volume of foam generated and retained at specified conditions).

Each lubricant type was tested under five conditions:

- Control (uncontaminated)
- Contaminated with dust
- Contaminated with grease
- Contaminated with fuel
- Contaminated with used engine oil.

This full factorial design allowed for the comparison of how each contaminant affected the lubricant's demulsibility and foaming properties, and how petrol and diesel engine oils responded differently to similar contamination.

The testing was performed under consistent laboratory conditions, with temperature and agitation rates closely monitored to mimic real-world operating conditions, where relevant.

Standardized test protocols were adopted:

- ASTM D1401 for demulsibility, which involves mixing the oil with water and observing the separation over time
- ASTM D892 for foaming, which measures both the formation and collapse of foam under controlled air flow and temperature conditions.

Control samples (i.e., uncontaminated oils) were used as baselines to evaluate the relative impact of each contaminant. This comparative approach enabled the study to isolate the effect of each contaminant and draw valid conclusions on its influence.

The experimental research design was structured to provide measurable, objective, and comparable results. It enabled the quantification of performance changes in lubricants subjected to contamination and contributed to identifying the most detrimental contaminants in terms of demulsibility and foaming, thereby filling an important knowledge gap in applied lubrication science. The chosen methods were selected based on their relevance and established application in similar studies. The rationale behind their selection is grounded in their proven ability to generate reproducible and reliable data under similar conditions.

### 3.3 MATERIALS AND EQUIPMENT

This section outlines the materials, reagents, equipment, and instrumentation used to evaluate the effects of contaminants on the demulsibility and foam levels of petrol and diesel engine lubricants. The selection of materials was guided by their relevance to real-world contamination scenarios, while equipment and testing procedures adhered to standardized protocols to ensure accuracy and consistency.

#### 3.3.1 Lubricant Samples

Two commercially available engine lubricants representing common formulations were selected:

- Petrol Engine Oil: SAE 10W-30 multigrade motor oil, formulated with detergent, dispersant, anti-wear, antioxidant, and antifoaming additives.
- Diesel Engine Oil: SAE 15W-40 multigrade motor oil, typically with higher base number and stronger detergency to handle soot and fuel residues from diesel combustion.

These oils served as the base fluids for control and contamination tests.

### 3.3.2 Contaminants

To simulate common field contaminants encountered during engine operation and maintenance, the following materials were selected:

- Dust: Collected ambient dust filtered through a 75  $\mu\text{m}$  sieve to ensure fine particle size representative of airborne particulate contamination.
- Grease: Standard lithium-based automotive grease used in chassis and bearing lubrication, chosen to represent cross-contamination from maintenance operations.
- Fuel (Petrol): Commercial-grade gasoline, used to simulate fuel dilution in crankcase oil due to piston ring blow-by or injector leakage.
- Used Engine Oil: Oil drained from a diesel engine after ~2000 km of use, representing a contaminant rich in oxidation products, soot, and degraded additives.

### 3.3.3 Reagents and Chemicals

The following reagents and supporting chemicals were used throughout the experimental procedures to ensure consistency and reliability:

- Distilled Water: Employed as the aqueous phase in the demulsibility (ASTM D1401) tests.
- Isopropyl Alcohol (99%): Used for cleaning glassware and apparatus before and after each test.
- Hexane: A non-polar solvent employed in degreasing and ensuring complete removal of hydrocarbon residues from test columns and mixing vessels.
- Compressed Air: Clean, dry, oil-free compressed air was used for generating foam during ASTM D892 tests.

- Laboratory Cleaning Detergent: A neutral-pH detergent was used for deep cleaning glassware, followed by thorough rinsing with distilled water.

### 3.3.4 Equipment and Instruments

To achieve accurate and replicable results, all experimental setups were based on ASTM-specified equipment and calibrated instruments:

- Graduated Cylinders (100 mL and 500 mL): Precision borosilicate cylinders used in demulsibility tests.
- Foam Test Column (ASTM D892-compliant): A tall cylindrical glass vessel fitted with air inlets and foam volume markings.
- Air Diffuser Tubes: Glass or stainless-steel sintered tubes with fine pores for uniform air bubble dispersion.
- Air Pump/Flow Controller: Calibrated to deliver air at  $94 \pm 5$  mL/min, as specified in ASTM D892.
- Thermostatic Water Bath: Used to maintain consistent sample temperatures at 24°C and 93.5°C.
- Analytical Balance ( $\pm 0.001$  g accuracy): For weighing precise amounts of contaminants.
- Magnetic Stirrer with Heating Plate: Ensured uniform mixing of contaminants into base oils.
- Stopwatches and Timers: Used to track mixing time, air bubbling duration, and phase separation intervals with precision.

These materials and instruments collectively provided the foundation for a controlled, repeatable, and standards-based investigation of how contaminants impact lubricant performance.

### 3.4 SAMPLE PREPARATION

Proper sample preparation is essential to ensure consistency, reliability, and reproducibility in experimental investigations. For this study, a structured approach was followed in preparing lubricant samples for the evaluation of demulsibility and foaming behavior under varying contamination conditions.

#### 3.4.1 Selection and Handling of Base Oils

Two types of commercial engine lubricants were used as the base fluids:

- Petrol Engine Oil (SAE 10W-30)
- Diesel Engine Oil (SAE 15W-40)

Both oils were obtained in sealed containers to avoid prior contamination. Upon opening, the oils were stored in clean, airtight amber bottles to prevent oxidation or moisture uptake. Each lubricant was gently stirred before sampling to ensure homogeneity without introducing air bubbles.

#### 3.4.2 Contaminant Measurement and Mixing Ratios

The study focused on four real-world contaminants: dust, grease, petrol (fuel), and used engine oil. These were added to the base oils at concentrations intended to reflect moderate contamination scenarios:

- Dust: Added at 1.0% w/w
- Grease: Added at 3.0% w/w, blended slowly into the oil to simulate cross-contamination
- Fuel (Petrol): Added at 5.0% v/v, representing mild-to-moderate fuel dilution from engine blow-by
- Used Engine Oil: Added at 10.0% v/v, to reflect cases where oil was topped up without full drainage

Each contaminant was weighed or measured accurately using an analytical balance or volumetric cylinder, depending on its physical state.

### 3.4.3 Mixing Procedure

For each contaminated sample:

1. A 100 mL aliquot of the base oil was transferred into a clean, dry 250 mL beaker.
2. The contaminant was added gradually while stirring the oil with a magnetic stirrer at moderate speed (300-500 rpm) for 15 minutes to ensure even distribution.
3. For grease and dust, mild heating ( $\sim 40^{\circ}\text{C}$ ) was applied where necessary to enhance dispersion without affecting oil properties.
4. After mixing, the samples were allowed to stand for 30 minutes to reach thermal equilibrium and for any trapped air to escape.
5. Each contaminated sample was transferred to labeled, airtight containers, minimizing exposure to light and air until testing commenced.

Control samples (uncontaminated oils) underwent the same mixing and resting procedures to ensure uniform handling across all test conditions.

### 3.4.4 Sample Conditioning for Testing

Prior to testing:

- All samples were brought to the required test temperature (e.g.,  $24^{\circ}\text{C}$  or  $93.5^{\circ}\text{C}$ ) using a thermostatic water bath.
- Samples were gently agitated to resuspend any settled contaminants, especially dust or grease, just before pouring into test vessels.
- Care was taken to avoid entrainment of air during transfer, as air bubbles could artificially affect both demulsibility and foaming results.

By maintaining strict control over sample preparation procedures, this research ensured that observed differences in demulsibility and foaming behavior could be confidently attributed to the presence and type of contaminant, rather than inconsistencies in sample handling or preparation.

### 3.5 TEST PROCUDURES

This section describes the standardized procedures followed to evaluate the demulsibility and foaming behavior of the prepared lubricant samples, both contaminated and uncontaminated. All tests were conducted in accordance with ASTM (American Society for Testing and Materials) standards to ensure scientific validity, repeatability, and comparability of results.

#### 3.5.1 Demulsibility Testing (ASTM D1401)

The demulsibility test assesses the lubricant's ability to separate from water after mixing under controlled conditions.

- Equipment Used:

- 100 mL graduated cylinders
- Magnetic stirrer
- Water bath (set to 54°C)

- Stopwatch

- Thermometer

- Test Procedure:

1. Sample preparation: 40 mL of the lubricant sample and 40 mL of distilled water were introduced into a clean 100 mL graduated cylinder.

2. The cylinder was tightly stoppered and placed in a water bath preheated to 54°C for 30 minutes, allowing the fluids to equilibrate.

3. The contents were then mechanically stirred using a paddle stirrer for 5 minutes at a controlled speed ( $1500 \pm 50$  rpm).

4. After stirring, the cylinder was placed upright and left undisturbed in the water bath.
5. Phase separation was observed at intervals of 5 minutes up to 30 minutes.
6. The volumes of separated oil, water, and the emulsion layer were recorded.

- Parameters Measured:

- Time taken for clear phase separation
  - Volume (mL) of water separated at 5, 10, 15, 20, 25 and 30 minutes
  - Stability and thickness of the emulsion layer
- Interpretation: A lubricant with high demulsibility will show a clear, sharp interface with minimal emulsion remaining. Poor demulsibility indicates strong water-lubricant bonding or contamination effects that promote stable emulsions.

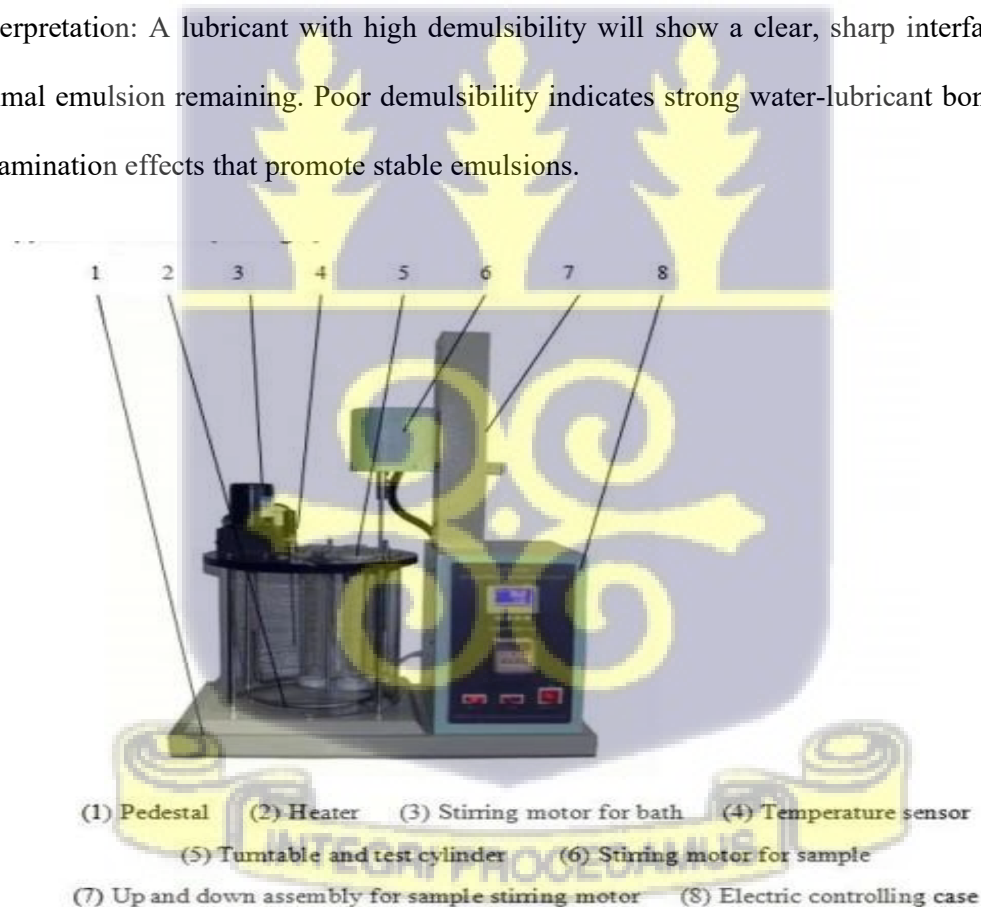


Figure 3.1: ASTM D1401 Demulsibility Test Equipment.

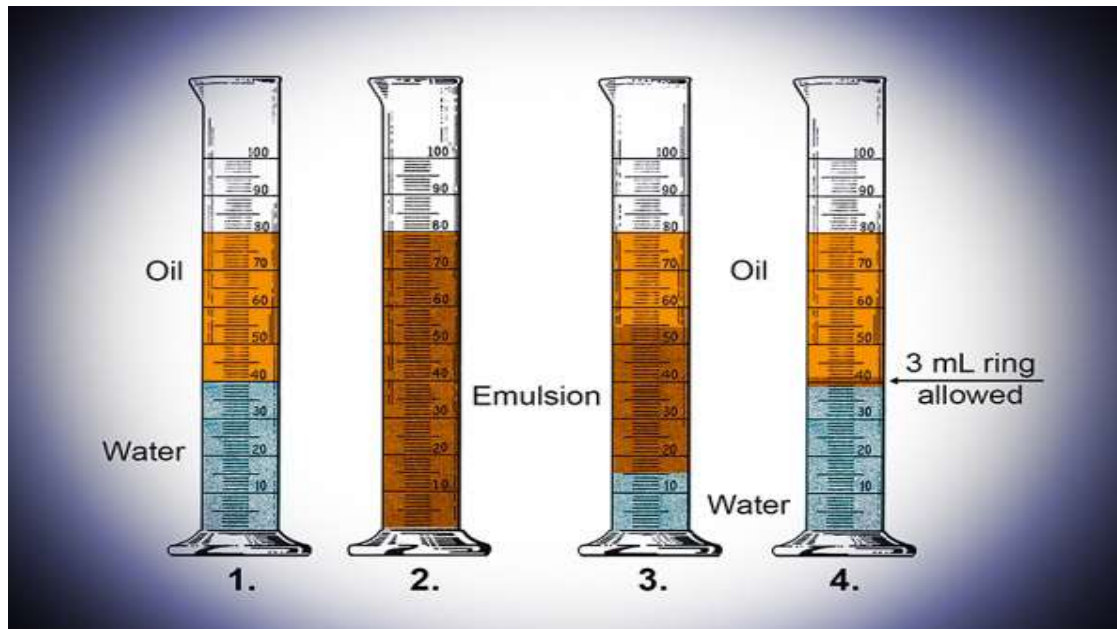


FIGURE 3.2: Sample status: (1) after preparation (2) after stirring (3) during separation process (4) at final stage

### 3.5.2 Foaming Testing (ASTM D892)

The foaming test determines the tendency of a lubricant to form foam and its ability to dissipate it under various temperature conditions.

- Equipment Used:

- Foam test apparatus (graduated foam cylinder, air diffuser)
- Dry air source (flowrate:  $94 \pm 5$  mL/min)
- Water bath (for  $24^{\circ}\text{C}$  and  $93.5^{\circ}\text{C}$  stages)
- Thermometer and timer

- Test Procedure: Three test sequences were carried out for each sample:

- Sequence I: Foam at Room Temperature ( $24^{\circ}\text{C}$ )

- Sequence II: Foam at Elevated Temperature (93.5°C)

- Sequence III: Foam at Room Temperature (Repeat)

Sequence I:

- Approximately 200 mL of the sample was decanted into a beaker.
- The sample was poured into the 1000-mL cylinder until the liquid level is at the 190-mL mark, and the level was visually estimated to be within 5 mL.
- The cylinder was immersed at least to the 900-mL mark in the bath maintained at 24°C.
- The gas diffuser and the air-inlet tube were inserted into the volume measuring device while the air source was disconnected.
- The gas diffuser was allowed to soak for about 5 minutes in the oil when the oil has reached the bath temperature.
- The air-outlet tube was then connected to the air volume measuring device.
- At the end of 5 min, the air source was connected, and the air flow rate was adjusted to 94 mL/min, and clean dry air was forced through the gas diffuser into the oil sample for 5 minutes.
- Timing was done from the first appearance of air bubbles rising from the gas diffuser up to five minutes and the volume of foam generated was recorded as foam tendency.
- At the end of the five minutes, the air flow was shut off by disconnecting the hose from the flow meter.
- The cylinder was then allowed to stand for 10 minutes, and again the volume of foam was recorded as foam stability; that is, the volume between the oil level and the top of the foam.

Sequence II:

- A second portion of sample was poured into a cleaned 1000mL cylinder until the liquid level was at the 180-mL mark.
- The level was visually estimated to be within 5 mL.
- The cylinder was immersed at least to the 900-mL mark in the bath maintained at 93.5°C.
- When the oil has reached a temperature of 93.5°C, a clean gas diffuser and air-inlet tube were inserted into the oil contained in the cylinder and proceeded as described in Sequence I
- The volume of foam at the end of the blowing and settling periods were recorded as foam tendency and foam stability respectively.

Sequence III:

- Any foam remaining after the test at 93.5°C (Sequence II) was allowed to collapse.
- The sample was cooled to a temperature below 43.5°C by allowing the test cylinder to stand in air at room temperature.
- The cylinder was then placed in the bath maintained at 24°C.
- After the oil has reached bath temperature, a cleaned air-inlet tube and gas diffuser were inserted into the oil contained in the cylinder and proceeded as described in sequence I
- The volume of foam at the end of the blowing and settling periods were recorded as foam tendency and foam stability respectively
- After testing the foam tendency and stability on each type of diesel and petrol engine oils, increasing amounts of dust, grease, fuel, water and aeration were introduced into the engine oils separately and their foam levels were determined as described earlier.

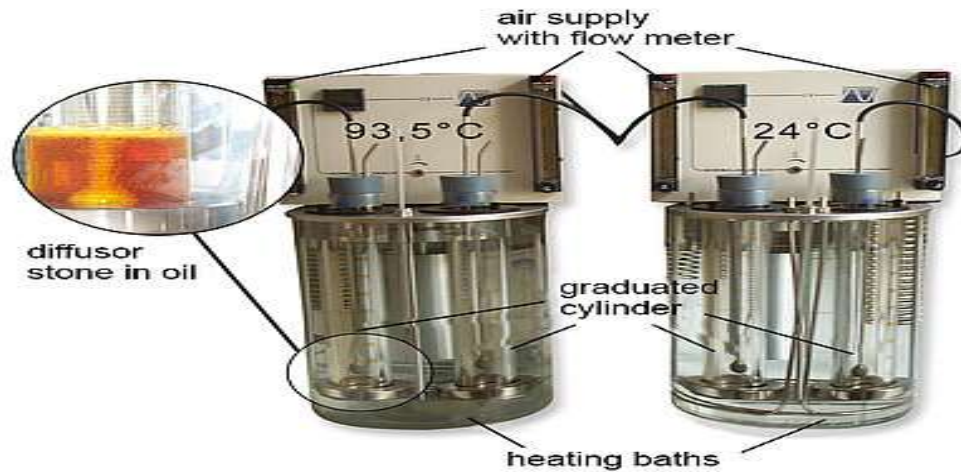


FIGURE 3.3: ASTM D892 SetaFoil Dual Twin Test Baths.

- Parameters Measured:

- Initial foam volume (after 5 min of air bubbling)
- Foam stability (residual foam after 10 min rest)
- Comparative foam volumes before and after heating

- Interpretation: Oils with high foaming tendencies may indicate contamination or additive imbalance. Stable foam can cause pump cavitation, air entrapment, and lubrication failure.

All data collected during testing were recorded systematically and tabulated for further statistical analysis in Chapter 4. Observations regarding unusual behavior (e.g., persistent emulsions or excessive foaming) were also noted for qualitative interpretation.

The standard engine oil foam specification is shown below;

Sequence I: 20/0 max

Sequence II: 50/0 max

Sequence III: 20/0 max

## CHAPTER FOUR

### 4.0 RESULTS AND DISCUSSIONS

#### 4.1 INTRODUCTION

This chapter presents and interprets the results obtained from experimental evaluations of the demulsibility and foaming characteristics of uncontaminated and contaminated petrol and diesel engine oils. Data were generated from tests conducted according to ASTM D1401 and ASTM D892 standards. The results are organized into sections that address the impact of each contaminant type—dust, grease, petrol(fuel), and used engine oil—on lubricant performance. The discussion focuses on the practical implications for engine operation and maintenance, highlighting the potential consequences of contamination on lubricant functionality and engine reliability.

#### 4.1 DEMULSIBILITY RESULTS

Table 4.1: Demulsibility results for the uncontaminated oil + water only (Control).

| Time / mins | Oil / mL | Water / mL | Emulsion / mL |
|-------------|----------|------------|---------------|
| 5           | 0        | 0          | 80            |
| 10          | 0        | 0          | 80            |
| 15          | 16       | 7          | 57            |
| 20          | 30       | 15         | 35            |
| 25          | 40       | 27         | 13            |

|    |    |    |   |
|----|----|----|---|
| 30 | 40 | 40 | 0 |
|----|----|----|---|

Reported results; 40/40/0 (30)

Table 4.2: Demulsibility results of oil + water + 1 ml diesel

| Time / mins | Oil / mL | Water / mL | Emulsion / mL |
|-------------|----------|------------|---------------|
| 5           | 0        | 0          | 80            |
| 10          | 10       | 2          | 68            |
| 15          | 20       | 8          | 52            |
| 20          | 33       | 17         | 30            |
| 25          | 39       | 30         | 11            |
| 30          | 40       | 39         | 1             |

Reported results; 40/39/1 (30)

Table 4.3: Demulsibility results of oil + water + 2 ml diesel

| Time / mins | Oil / mL | Water / mL | Emulsion / mL |
|-------------|----------|------------|---------------|
| 5           | 0        | 0          | 80            |
| 10          | 12       | 3          | 65            |
| 15          | 28       | 13         | 39            |
| 20          | 40       | 25         | 15            |
| 25          | 40       | 40         | 0             |

|    |  |  |  |
|----|--|--|--|
| 30 |  |  |  |
|----|--|--|--|

Reported results; 40/40/0 (25)

Table 4.4: Demulsibility results of oil + water + 5 ml diesel

| Time / mins | Oil / mL | Water / mL | Emulsion / mL |
|-------------|----------|------------|---------------|
| 5           | 3        | 0          | 77            |
| 10          | 16       | 6          | 58            |
| 15          | 33       | 16         | 31            |
| 20          | 40       | 37         | 3             |
| 25          |          |            |               |
| 30          |          |            |               |

Reported results; 40/37/3 (20)

Table 4.5: Demulsibility results of oil + water + 1 ml petrol

| Time / mins | Oil / mL | Water / mL | Emulsion / mL |
|-------------|----------|------------|---------------|
| 5           | 0        | 0          | 80            |
| 10          | 12       | 3          | 65            |
| 15          | 23       | 10         | 47            |
| 20          | 35       | 20         | 25            |
| 25          | 40       | 34         | 6             |

|    |    |    |   |
|----|----|----|---|
| 30 | 40 | 40 | 0 |
|----|----|----|---|

Reported results; 40/40/0 (30)

Table 4.6: Demulsibility results of oil + water + 5 ml petrol

| Time / mins | Oil / mL | Water / mL | Emulsion / mL |
|-------------|----------|------------|---------------|
| 5           | 9        | 2          | 69            |
| 10          | 34       | 18         | 28            |
| 15          | 40       | 40         | 0             |
| 20          |          |            |               |
| 25          |          |            |               |
| 30          |          |            |               |

Reported results; 40/40/0 (15)

Table 4.7: Demulsibility results of oil + water + 0.2g dust

| Time / mins | Oil / mL | water / mL | Emulsion / mL |
|-------------|----------|------------|---------------|
| 5           | 1        | 0          | 79            |
| 10          | 15       | 5          | 60            |
| 15          | 25       | 15         | 40            |
| 20          | 38       | 26         | 16            |
| 25          | 40       | 35         | 5             |

|    |    |    |   |
|----|----|----|---|
| 30 | 40 | 40 | 0 |
|----|----|----|---|

Reported results; 40/40/0 (30)

Table 4.8: Demulsibility results of oil + water + 0.5g dust

| Time / mins | Oil / mL | Water / mL | Emulsion / mL |
|-------------|----------|------------|---------------|
| 5           | 1        | 0          | 79            |
| 10          | 10       | 4          | 66            |
| 15          | 21       | 11         | 48            |
| 20          | 32       | 20         | 28            |
| 25          | 39       | 30         | 11            |
| 30          | 40       | 38         | 2             |

Reported results; 40/38/2 (30)

Table 4.9: Demulsibility results of oil + water + 0.8g dust

| Time / mins | Oil / mL | water / mL | Emulsion / mL |
|-------------|----------|------------|---------------|
| 5           | 0        | 0          | 80            |
| 10          | 11       | 3          | 66            |
| 15          | 22       | 9          | 49            |
| 20          | 32       | 17         | 31            |
| 25          | 38       | 24         | 18            |

|    |    |    |   |
|----|----|----|---|
| 30 | 40 | 33 | 7 |
|----|----|----|---|

Reported results; 40/33/7 (30)

Table 4.10: Demulsibility results of oil + water + 1g dust

| Time / mins | Oil / mL | water / mL | Emulsion / mL |
|-------------|----------|------------|---------------|
| 5           | 0        | 0          | 80            |
| 10          | 12       | 2          | 66            |
| 15          | 22       | 9          | 49            |
| 20          | 32       | 15         | 33            |
| 25          | 37       | 20         | 23            |
| 30          | 40       | 28         | 12            |

Reported results; 40/28/12 (30)

Table 4.11: Demulsibility results of oil + water + 1.5g dust

| Time / mins | Oil / mL | water / mL | Emulsion / mL |
|-------------|----------|------------|---------------|
| 5           | 0        | 0          | 80            |
| 10          | 10       | 5          | 65            |
| 15          | 20       | 14         | 46            |
| 20          | 25       | 19         | 36            |
| 25          | 33       | 20         | 27            |

|    |    |    |    |
|----|----|----|----|
| 30 | 38 | 28 | 15 |
|----|----|----|----|

Reported results; 38/27/15 (30)

Table 4.12: Demulsibility results of oil + water + 0.1g of grease

| Time / mins | Oil / mL | Water / mL | Emulsion / mL |
|-------------|----------|------------|---------------|
| 5           | 0        | 0          | 80            |
| 10          | 0        | 0          | 80            |
| 15          | 0        | 0          | 80            |
| 20          | 2        | 0          | 78            |
| 25          | 2        | 0          | 78            |
| 30          | 3        | 0          | 77            |

Reported results; 3/0/77 (30)

Table 4.13: Demulsibility results of oil + water + 0.2g of grease

| Time / mins | Oil / mL | Water / mL | Emulsion / mL |
|-------------|----------|------------|---------------|
| 5           | 0        | 0          | 80            |
| 10          | 0        | 0          | 80            |
| 15          | 0        | 0          | 80            |
| 20          | 0        | 0          | 80            |
| 25          | 0        | 0          | 80            |

|    |   |   |    |
|----|---|---|----|
| 30 | 1 | 0 | 79 |
|----|---|---|----|

Reported results; 1/0/79 (30)

Table 4.14: Demulsibility results of oil + water + 0.2g of grease

| Time / mins | Oil / mL | Water / mL | Emulsion / mL |
|-------------|----------|------------|---------------|
| 5           | 0        | 0          | 80            |
| 10          | 0        | 0          | 80            |
| 15          | 0        | 0          | 80            |
| 20          | 0        | 0          | 80            |
| 25          | 0        | 0          | 80            |
| 30          | 0        | 0          | 80            |

Reported results; 0/0/80 (30)

Table 4.15: Demulsibility results of oil + water + 1mL of used oil

| Time / mins | Oil / mL | Water / mL | Emulsion / mL |
|-------------|----------|------------|---------------|
| 5           | 0        | 0          | 80            |
| 10          | 8        | 1          | 71            |
| 15          | 20       | 9          | 51            |
| 20          | 34       | 18         | 28            |
| 25          | 39       | 29         | 12            |

|    |    |    |   |
|----|----|----|---|
| 30 | 40 | 38 | 2 |
|----|----|----|---|

Reported results; 40/38/2 (30)

Table 4.16: Demulsibility results of oil + water + 2mL of used oil

| Time / mins | Oil / mL | Water / mL | Emulsion / mL |
|-------------|----------|------------|---------------|
| 5           | 0        | 0          | 80            |
| 10          | 8        | 1          | 71            |
| 15          | 19       | 7          | 54            |
| 20          | 32       | 15         | 33            |
| 25          | 39       | 25         | 16            |
| 30          | 40       | 37         | 3             |

Reported results; 40/37/3 (30)

Table 4.17: Demulsibility results of oil + water + 3mL of used oil

| Time / mins | Oil / mL | Water / mL | Emulsion / mL |
|-------------|----------|------------|---------------|
| 5           | 1        | 0          | 79            |
| 10          | 7        | 0          | 73            |
| 15          | 17       | 4          | 59            |
| 20          | 30       | 12         | 38            |
| 25          | 38       | 23         | 19            |

|    |    |    |   |
|----|----|----|---|
| 30 | 40 | 35 | 5 |
|----|----|----|---|

Reported results; 40/35/5 (30)

Table 4.18: Demulsibility results of oil + water + 4mL of used oil

| Time / mins | Oil / mL | Water / mL | Emulsion / mL |
|-------------|----------|------------|---------------|
| 5           | 0        | 0          | 80            |
| 10          | 5        | 0          | 75            |
| 15          | 14       | 1          | 65            |
| 20          | 23       | 8          | 49            |
| 25          | 35       | 20         | 25            |
| 30          | 39       | 33         | 8             |

Reported results; 39/33/8 (30)

Table 4.19: Demulsibility results of oil + water + 5mL of used oil

| Time / mins | Oil / mL | Water / mL | Emulsion / mL |
|-------------|----------|------------|---------------|
| 5           | 0        | 0          | 80            |
| 10          | 1        | 0          | 79            |
| 15          | 8        | 0          | 72            |
| 20          | 20       | 3          | 57            |
| 25          | 31       | 16         | 33            |

|    |    |    |    |
|----|----|----|----|
| 30 | 38 | 32 | 10 |
|----|----|----|----|

Reported results; 38/32/10 (30)

#### Summary of Demulsibility Results:

Table 4.20: Effects of grease on engine oil's demulsibility.

| MASS OF GREASE/g | VOLUME OF EMULSION/mL |
|------------------|-----------------------|
| 0.1              | 77                    |
| 0.2              | 79                    |
| 0.3              | 80                    |
| 0.4              | 80                    |
| 0.5              | 80                    |

Table 4.21: Effects of dust on engine oil's demulsibility.

| MASS OF DUST/g | VOLUME OF EMULSION/mL |
|----------------|-----------------------|
| 0.2            | 0                     |
| 0.5            | 2                     |
| 0.8            | 7                     |
| 1.0            | 12                    |
| 1.5            | 15                    |

Table 4.22: Effects of used oil on engine oil's demulsibility.

| VOLUME OF USED OIL/mL | VOLUME OF EMULSION/mL |
|-----------------------|-----------------------|
| 1                     | 2                     |
| 2                     | 3                     |
| 3                     | 5                     |
| 4                     | 8                     |
| 5                     | 10                    |

Table 4.23: Effects of diesel on engine oil's demulsibility.

| VOLUME OF DIESEL/mL | VOLUME OF EMULSION/mL |
|---------------------|-----------------------|
| 1                   | 1                     |
| 2                   | 0                     |
| 3                   | 0                     |
| 4                   | 0                     |
| 5                   | 0                     |

Table 4.24: Effects of petrol on engine oil's demulsibility.

| VOLUME OF PETROL/mL | VOLUME OF EMULSION/mL |
|---------------------|-----------------------|
|---------------------|-----------------------|

|   |   |
|---|---|
| 1 | 0 |
| 2 | 0 |
| 3 | 0 |
| 4 | 0 |
| 5 | 0 |

## 4.2 FOAM TESTING RESULTS

Table 4.25: Effects of Different Weights of Grease on Foam Levels of Petrol Engine Oils at Different Sequences

| Foam (ml)      | Weight of grease (g) |      |      |       |       |       |
|----------------|----------------------|------|------|-------|-------|-------|
|                | 0                    | 1    | 2    | 3     | 4     | 5     |
| <b>SEQ I</b>   | 0/0                  | 20/0 | 20/0 | 20/0  | 20/0  | 20/0  |
| <b>SEQ II</b>  | 20/0                 | 55/0 | 75/0 | 100/0 | 125/0 | 150/0 |
| <b>SEQ III</b> | 0/0                  | 20/0 | 20/0 | 20/0  | 20/0  | 20/0  |

Table 4.26: Effects of Different Weights of Grease on Foam Levels of Diesel Engine Oils at Different Sequences

| Foam (ml) | Weight of grease (g) |      |      |       |       |      |
|-----------|----------------------|------|------|-------|-------|------|
|           | 0                    | 1    | 2    | 3     | 4     | 5    |
| SEQ I     | 0/0                  | 20/0 | 20/0 | 20/0  | 20/0  | 20/0 |
| SEQ II    | 20/0                 | 50/0 | 80/0 | 105/0 | 120/0 | 155  |
| SEQ III   | 0/0                  | 20/0 | 20/0 | 20/0  | 20/0  | 20/0 |

Table 4.27: Effects of Different Weights of Dust on Foam Levels of Petrol Engine Oils at Different Sequences

| Foam (ml) | Weight of dust (g) |      |      |      |       |       |
|-----------|--------------------|------|------|------|-------|-------|
|           | 0                  | 1    | 2    | 3    | 4     | 5     |
| SEQ I     | 0/0                | 20/0 | 20/0 | 20/0 | 20/0  | 20/0  |
| SEQ II    | 20/0               | 45/0 | 60/0 | 95/0 | 100/0 | 120/0 |
| SEQ III   | 0/0                | 20/0 | 20/0 | 20/0 | 20/0  | 20/0  |

Table 4.28: Effects of Different Weights of Dust on Foam Levels of Diesel Engine Oils at Different Sequences

| Foam (ml) | Weight of dust (g) |   |   |   |   |   |
|-----------|--------------------|---|---|---|---|---|
|           | 0                  | 1 | 2 | 3 | 4 | 5 |
|           |                    |   |   |   |   |   |

|                |      |      |      |      |      |       |
|----------------|------|------|------|------|------|-------|
| <b>SEQ I</b>   | 0/0  | 20/0 | 20/0 | 20/0 | 20/0 | 20/0  |
| <b>SEQ II</b>  | 20/0 | 45/0 | 70/0 | 85/0 | 95/0 | 120/0 |
| <b>SEQ III</b> | 0/0  | 20/0 | 20/0 | 20/0 | 20/0 | 20/0  |

Table 4.29: Effects of Different Volumes of Water on Foam Levels of Petrol Engine Oils at Different Sequences

| <b>Foam (ml)</b> | <b>Volume of water (mL)</b> |          |          |          |          |          |
|------------------|-----------------------------|----------|----------|----------|----------|----------|
|                  | <b>0</b>                    | <b>1</b> | <b>2</b> | <b>3</b> | <b>4</b> | <b>5</b> |
| <b>SEQ I</b>     | 0/0                         | 20/0     | 20/0     | 20/0     | 20/0     | 20/0     |
| <b>SEQ II</b>    | 20/0                        | 30/0     | 45/0     | 60/0     | 75/0     | 95/0     |
| <b>SEQ III</b>   | 0/0                         | 20/0     | 20/0     | 20/0     | 20/0     | 20/0     |

Table 4.30: Effects of Different Volumes of Water on Foam Levels of Diesel Engine Oils at Different Sequences

| <b>Foam (ml)</b> | <b>Volume of water (mL)</b> |          |          |          |          |          |
|------------------|-----------------------------|----------|----------|----------|----------|----------|
|                  | <b>0</b>                    | <b>1</b> | <b>2</b> | <b>3</b> | <b>4</b> | <b>5</b> |
| <b>SEQ I</b>     | 0/0                         | 20/0     | 20/0     | 20/0     | 20/0     | 20/0     |
| <b>SEQ II</b>    | 20/0                        | 35/0     | 50/0     | 60/0     | 75/0     | 100      |

|                |     |      |      |      |      |      |
|----------------|-----|------|------|------|------|------|
| <b>SEQ III</b> | 0/0 | 20/0 | 20/0 | 20/0 | 20/0 | 20/0 |
|----------------|-----|------|------|------|------|------|

Table 4.31: Effects of Different Volumes of Petrol on Foam Levels of Petrol Engine Oils at Different Sequences

| <b>Foam (ml)</b> | <b>Volume of Petrol (mL)</b> |          |          |          |          |          |
|------------------|------------------------------|----------|----------|----------|----------|----------|
|                  | <b>0</b>                     | <b>1</b> | <b>2</b> | <b>3</b> | <b>4</b> | <b>5</b> |
| <b>SEQ I</b>     | 0/0                          | 20/0     | 20/0     | 20/0     | 20/0     | 20/0     |
| <b>SEQ II</b>    | 20/0                         | 30/0     | 40/0     | 55/0     | 70/0     | 90/0     |
| <b>SEQ III</b>   | 0/0                          | 20/0     | 20/0     | 20/0     | 20/0     | 20/0     |

Table 4.32: Effects of Different Volumes of Diesel on Foam Levels of Diesel Engine Oils at Different Sequences

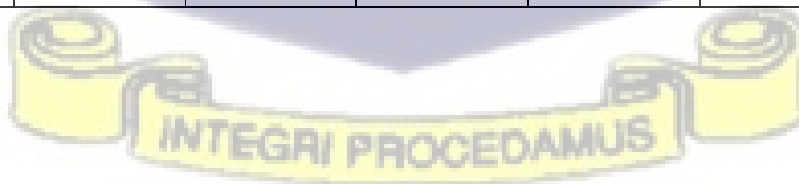
| <b>Foam (ml)</b> | <b>Volume of Diesel(mL)</b> |          |          |          |          |          |
|------------------|-----------------------------|----------|----------|----------|----------|----------|
|                  | <b>0</b>                    | <b>1</b> | <b>2</b> | <b>3</b> | <b>4</b> | <b>5</b> |
| <b>SEQ I</b>     | 0/0                         | 20/0     | 20/0     | 20/0     | 20/0     | 20/0     |
| <b>SEQ II</b>    | 20/0                        | 30/0     | 40/0     | 60/0     | 70/0     | 95/0     |
| <b>SEQ III</b>   | 0/0                         | 20/0     | 20/0     | 20/0     | 20/0     | 20/0     |

Table 4.33: Effects of Increasing Aeration on Foam Levels of Petrol Engine Oils at Different Sequences

| Foam (ml) | Aeration (mL/min) |      |      |      |      |      |
|-----------|-------------------|------|------|------|------|------|
|           | 94                | 95   | 96   | 97   | 98   | 99   |
| SEQ I     | 0/0               | 20/0 | 20/0 | 20/0 | 20/0 | 20/0 |
| SEQ II    | 20/0              | 30/0 | 30/0 | 30/0 | 30/0 | 30/0 |
| SEQ III   | 0/0               | 20/0 | 20/0 | 20/0 | 20/0 | 20/0 |

Table 4.34: Effects of Increasing Aeration on Foam Levels of Diesel Engine Oils at Different Sequences

| Foam (ml) | Aeration(mL/min) |      |      |      |      |      |
|-----------|------------------|------|------|------|------|------|
|           | 94               | 95   | 96   | 97   | 98   | 99   |
| SEQ I     | 0/0              | 20/0 | 20/0 | 20/0 | 20/0 | 20/0 |
| SEQ II    | 20/0             | 30/0 | 30/0 | 30/0 | 30/0 | 30/0 |
| SEQ III   | 0/0              | 20/0 | 20/0 | 20/0 | 20/0 | 20/0 |



### 4.3 DISCUSSION OF RESULTS

4.3.1: The Figures below present the effects of contaminants on demulsibility of lubricants, showing the relationship between the amounts of contaminants added and the volume of emulsion formed. Here is an interpretation of the data:

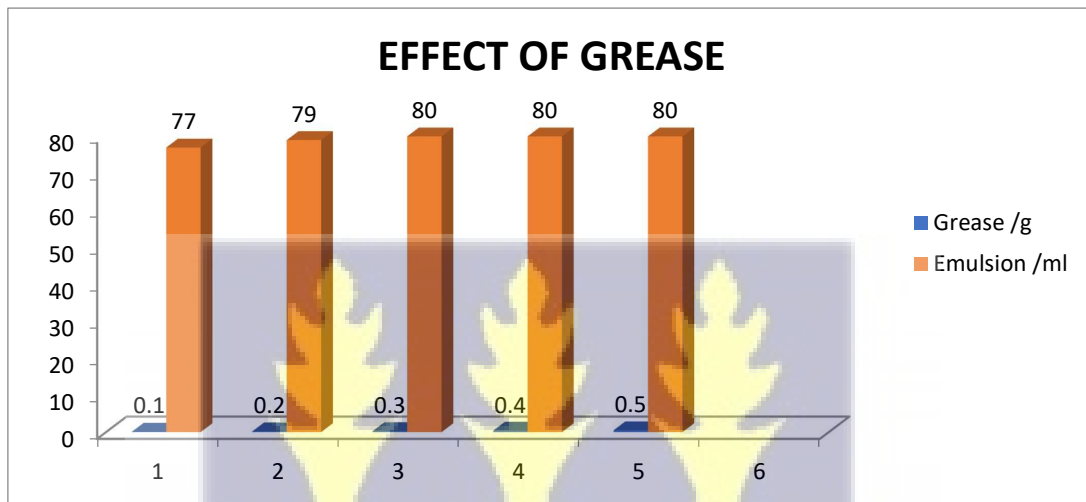


Figure 4.1: Effect of increasing weights of grease on oil's demulsibility at a specified time of 30 minutes.

As the mass of grease increases from 0.1g to 0.5g, the volume of emulsion formed increases slightly from 77mL to 80mL. The volume of emulsion remains relatively constant at 80mL for grease masses between 0.3g and 0.5g. Adding small amounts of grease (up to 0.5g) greatly reduces the demulsibility of the engine oil, as indicated by the high increase in emulsion volume. The effect of grease on demulsibility appears to plateau beyond 0.3g, as further increases in grease mass do not significantly increase the emulsion volume beyond that level.

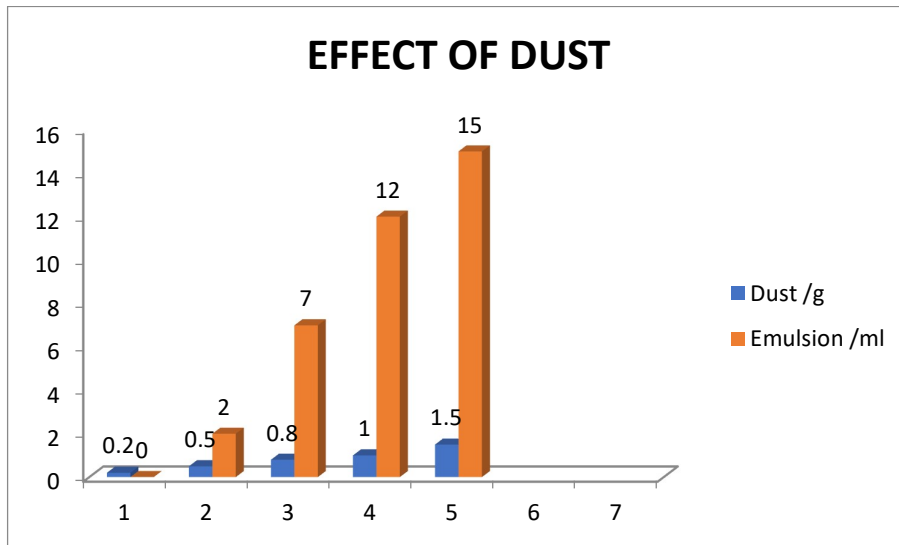


Figure 4.2: Effect of different weights of dust on engine oil's demulsibility at a specified time of 30 minutes.

As the mass of dust increases from 0.2g to 1.5g, the volume of emulsion formed increases significantly from 0mL to 15mL. The volume of emulsion remains at 0mL for the lowest dust mass (0.2g), indicating complete separation of oil and water. Beyond 0.2g, the volume of emulsion increases steadily with increasing dust mass, indicating reduced demulsibility.

In summary, the data suggests that adding small amounts of dust (up to 0.2g) does not affect the demulsibility of hydraulic oil. Increasing dust content beyond 0.2g significantly reduces the demulsibility of engine oil, leading to increased emulsion formation. The demulsibility of engine oil deteriorates steadily with increasing dust content.



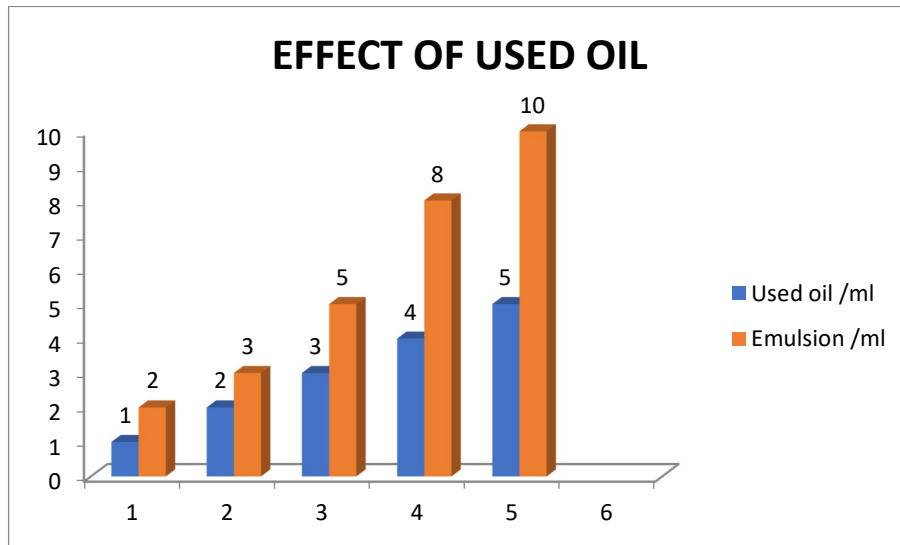


Figure 4.3: Effects of different volumes of used oil on engine oil's demulsibility at a specified time of 30 minutes.

As the volume of used oil increases from 1mL to 5mL, the volume of emulsion formed increases steadily from 2mL to 10mL. The volume of emulsion increases linearly with the volume of used oil added, indicating a direct relationship between the two. The data suggests that adding used oil beyond 3ml to engine oil reduces its demulsibility, leading to increased emulsion formation. In summary, the data indicates that used oil contaminates engine oil and reduces its ability to separate from water. The amount of emulsion formed increases directly with the amount of used oil added. Engine oil's demulsibility deteriorates steadily with increasing used oil content.



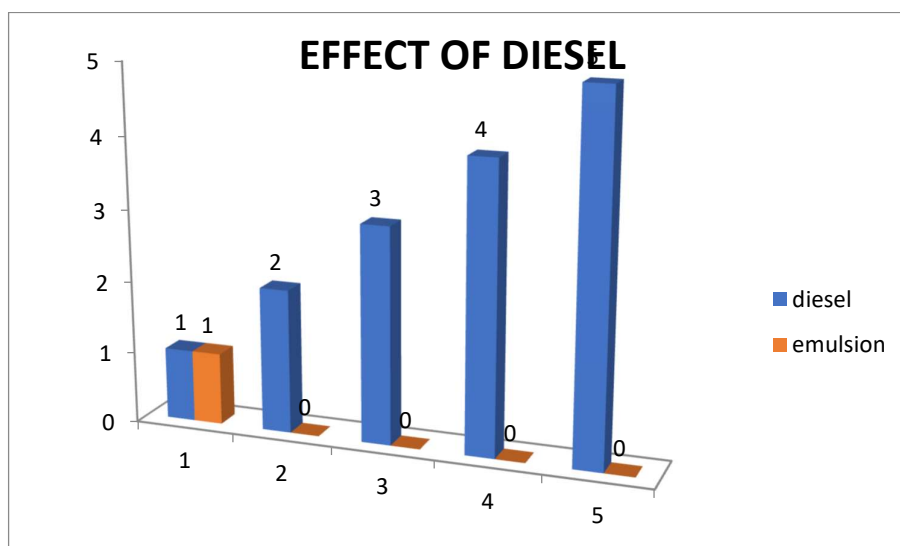
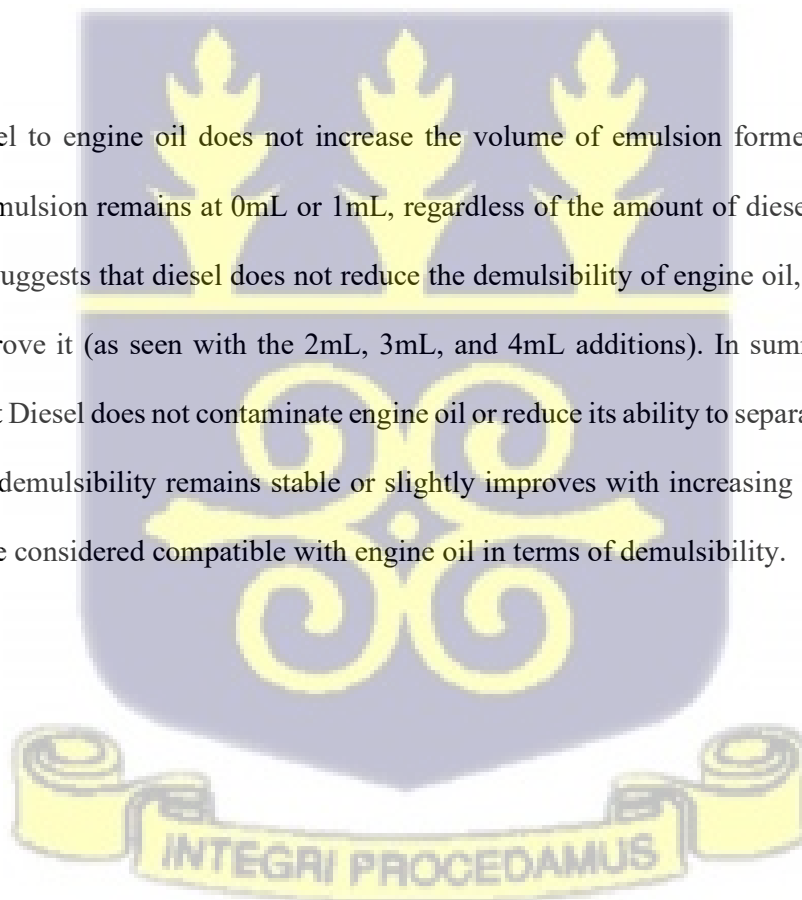


Figure 4.4: Effect of different volumes of diesel on engine oil's demulsibility at the end of 30 minutes.

Adding diesel to engine oil does not increase the volume of emulsion formed. In fact, the volume of emulsion remains at 0mL or 1mL, regardless of the amount of diesel added (up to 5mL). This suggests that diesel does not reduce the demulsibility of engine oil, and may even slightly improve it (as seen with the 2mL, 3mL, and 4mL additions). In summary, the data indicates that Diesel does not contaminate engine oil or reduce its ability to separate from water. Engine oil's demulsibility remains stable or slightly improves with increasing diesel content. Diesel can be considered compatible with engine oil in terms of demulsibility.



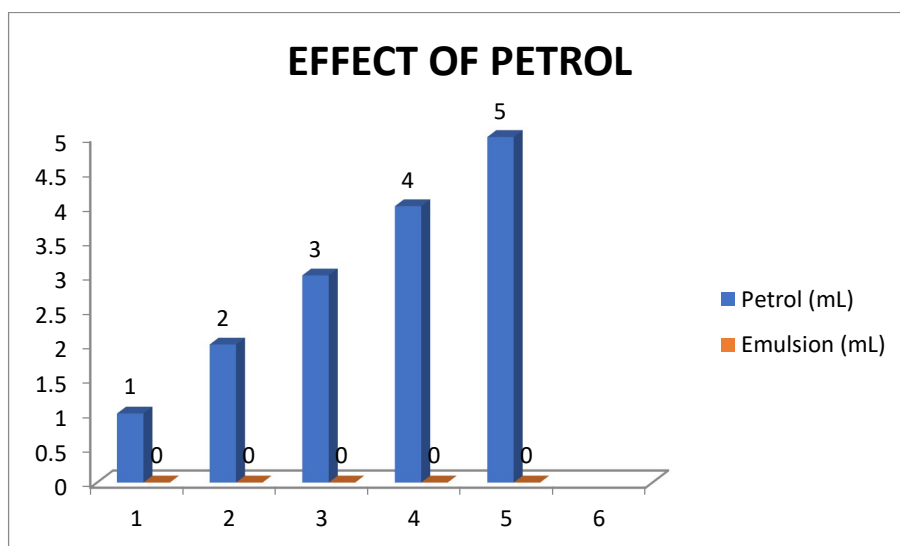


Figure 4.5: Effect of different volumes of petrol on engine oil's demulsibility at a specified time of 30 minutes.

Adding petrol to engine oil does not increase the volume of emulsion formed. The volume of emulsion remains at 0mL, regardless of the amount of petrol added (up to 5mL). This suggests that petrol does not reduce the demulsibility of engine oil and is fully compatible with it. In summary, the data indicates that Petrol does not contaminate engine oil or reduce its ability to separate from water. Engine oil's demulsibility remains stable with increasing petrol content. Petrol can be considered fully compatible with engine oil in terms of demulsibility.

In general, when demulsibility is lost, the oil will either cloud or foam; and this confirms (Klüber Lubrication, edition 11-04) that "Foaming may be caused by the penetration of lubricating greases, dust or water" and (Evans and Hunt, 2008) who also said "Particulates act as seeds or nucleation points on which bubbles grow. Not only does the dust act as a nucleation site for bubbles, but also calcium seems to bind the antifoam additive, rendering it less effective. In practice, dirty oil can foam more than clean"

4.2.2: The Figures below present the effects of contaminants on foam levels of lubricants, showing the relationship between the amounts of contaminants added and the volume of foam formed. Foam Results= Foam Tendency/ Foam Stability. Foam stability (the denominator value) was zero (0) for all the samples, hence only Foam Tendency graph was plotted.

Here is an interpretation of the data:

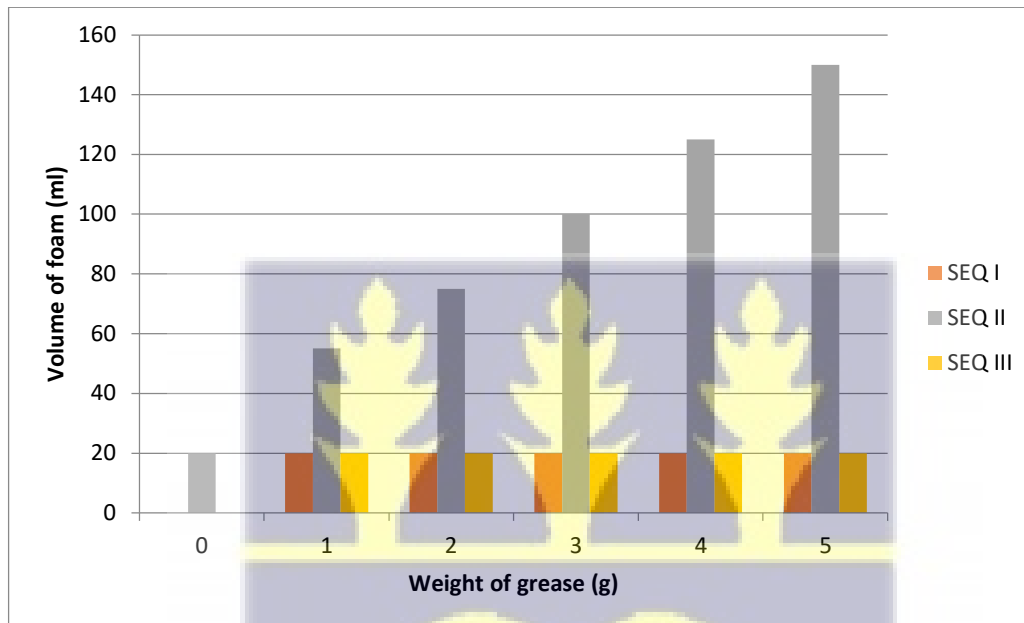


Figure 4.6: Effects of different weights of grease on foam levels (tendency) of petrol engine oils.

SEQ I: No grease (0g): No foam (0/0). Adding grease (1-5g): Foam level remains constant at 20/0. In Sequence I, adding grease up to 5g does not increase the foam level, which remains at 20/0.

SEQ II: No grease (0g): Initial foam level of 20/0. Adding grease (1-5g): Foam level increases steadily with increasing grease weight (55/0, 75/0, 100/0, 125/0, 150/0). In Sequence II, adding grease increases the foam level, with a more significant increase beyond 1g.

SEQ III: No grease (0g): No foam (0/0). Adding grease (1-5g): Foam level remains constant at 20/0. In Sequence III, the foam level remains constant at 20/0, regardless of the grease weight

added. In summary: SEQ I and SEQ III show no significant impact of grease on foam levels. SEQ II shows a direct relationship between grease weight and foam level, with increasing grease weight leading to higher foam levels.

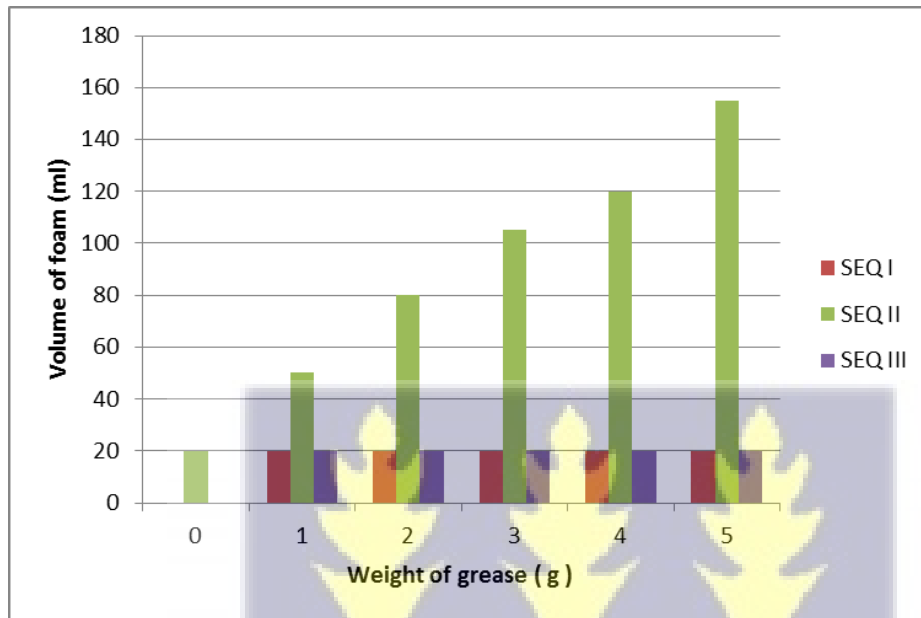


Figure 4.7: Effects of different weights of grease on foam levels (tendency) of diesel engine oils.

In Sequence I, adding grease up to 5g does not increase the foam level, which remains at 20/0. This suggests that the grease has no significant effect on foam levels in this sequence.

In Sequence II, adding grease increases the foam level, with a more significant increase beyond 1g. This suggests a direct relationship between grease weight and foam level in this sequence.

In Sequence III, the foam level remains constant at 20/0, regardless of the grease weight added. This suggests that the grease has no significant effect on foam levels in this sequence, similar to Sequence I. Overall, the data suggests that: Grease addition has a minimal impact on foam levels in Sequences I and III.

In Sequence II, grease addition increases foam levels, with a more significant increase beyond 1g.

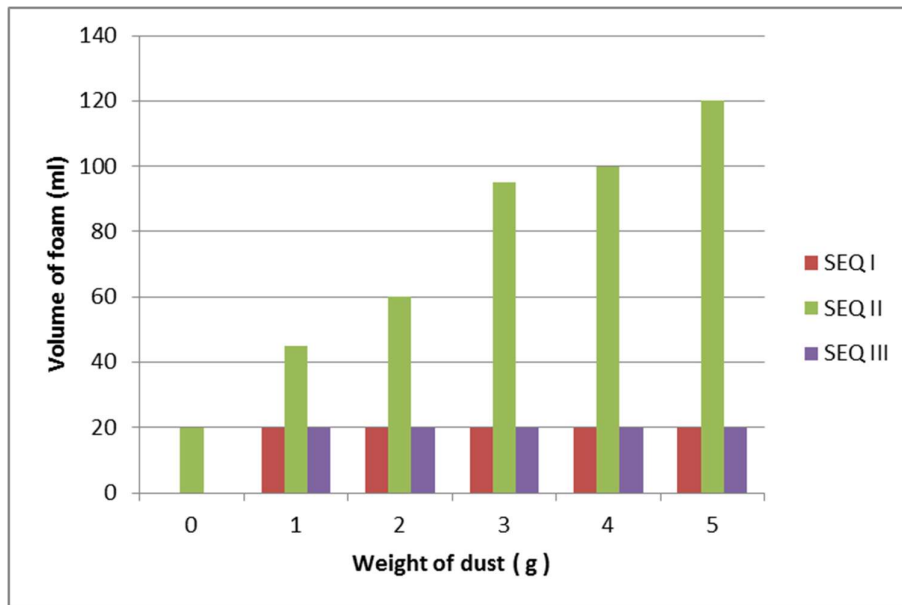


Figure 4.8: Effects of different weights of dust on foam levels (tendency) of petrol engine oils. In Sequence I, adding dust up to 5g does not increase the foam level, which remains at 20/0. This suggests that dust has no significant effect on foam levels in this sequence. In Sequence II, adding dust increases the foam level, with a more significant increase beyond 2g. This suggests a direct relationship between dust weight and foam level in this sequence. In Sequence III, the foam level remains constant at 20/0, regardless of the dust weight added. This suggests that dust has no significant effect on foam levels in this sequence, similar to Sequence I. Overall, the data suggests that: Dust addition has a minimal impact on foam levels in Sequences I and III. In Sequence II, dust addition increases foam levels, with a more significant increase beyond 2g.



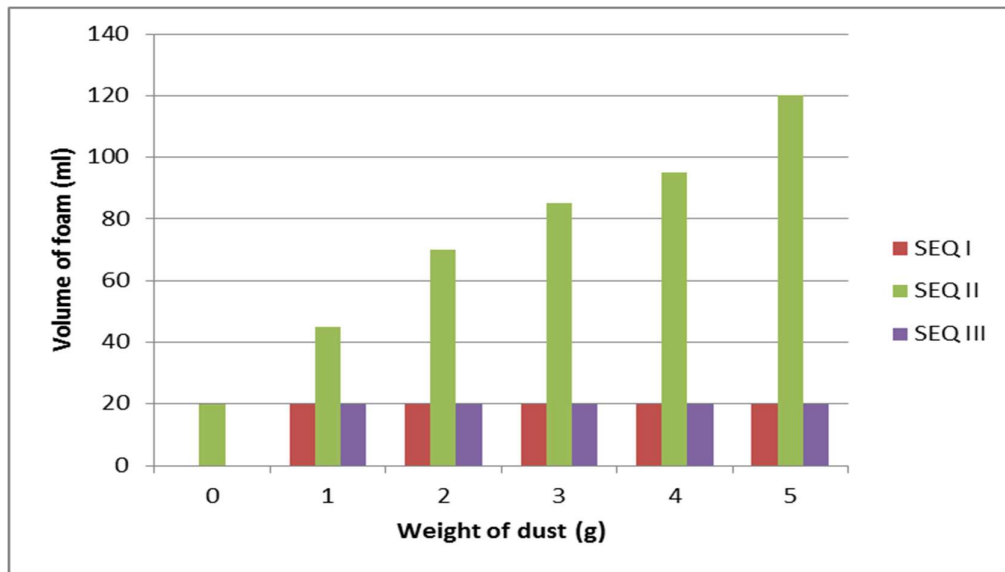


Figure 4.9: Effects of different weights of dust on foam levels (tendency) of diesel engine oils.

In Sequence I, adding dust up to 5g does not increase the foam level, which remains at 20/0.

This suggests that dust has no significant effect on foam levels in this sequence.

In Sequence II, adding dust increases the foam level, with a more significant increase beyond 2g. This suggests a direct relationship between dust weight and foam level in this sequence.

In Sequence III, the foam level remains constant at 20/0, regardless of the dust weight added.

This suggests that dust has no significant effect on foam levels in this sequence, similar to Sequence I.

Overall, the data suggests that: Dust addition has a minimal impact on foam levels in Sequences I and III.

In Sequence II, dust addition increases foam levels, with a more significant increase beyond 2g.



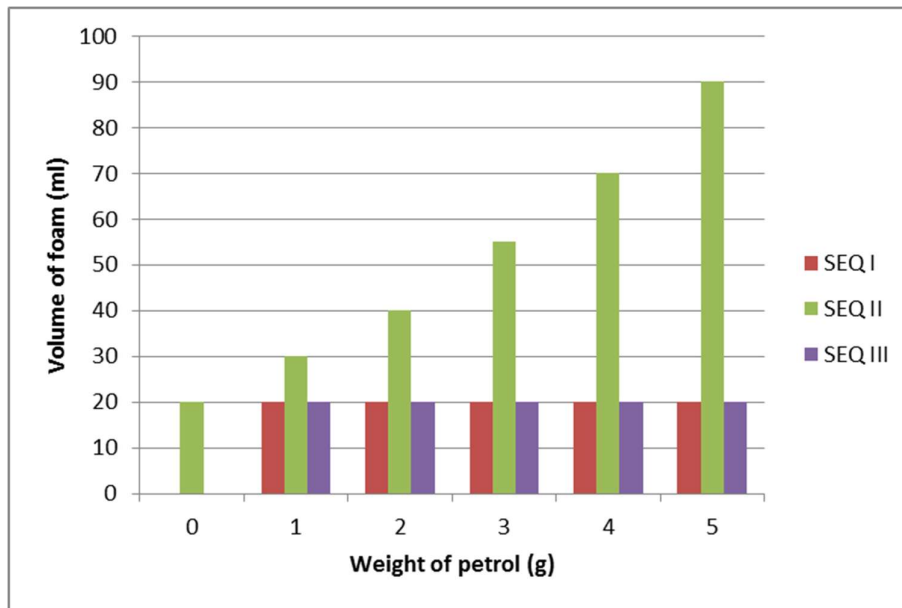


Figure 4.10: Effects of different weights of petrol on foam levels (tendency) of petrol engine oils.

In Sequence I, adding petrol up to 5g does not increase the foam level, which remains at 20/0. This suggests that petrol has no significant effect on foam levels in this sequence.

In Sequence II, adding petrol increases the foam level, with a more significant increase beyond 2g. This suggests a direct relationship between petrol weight and foam level in this sequence.

In Sequence III, the foam level remains constant at 20/0, regardless of the petrol weight added. This suggests that petrol has no significant effect on foam levels in this sequence, similar to Sequence I.

Overall, the data suggests that: Petrol addition has a minimal impact on foam levels in Sequences I and III. In Sequence II, petrol addition increases foam levels, with a more significant increase beyond 2g.

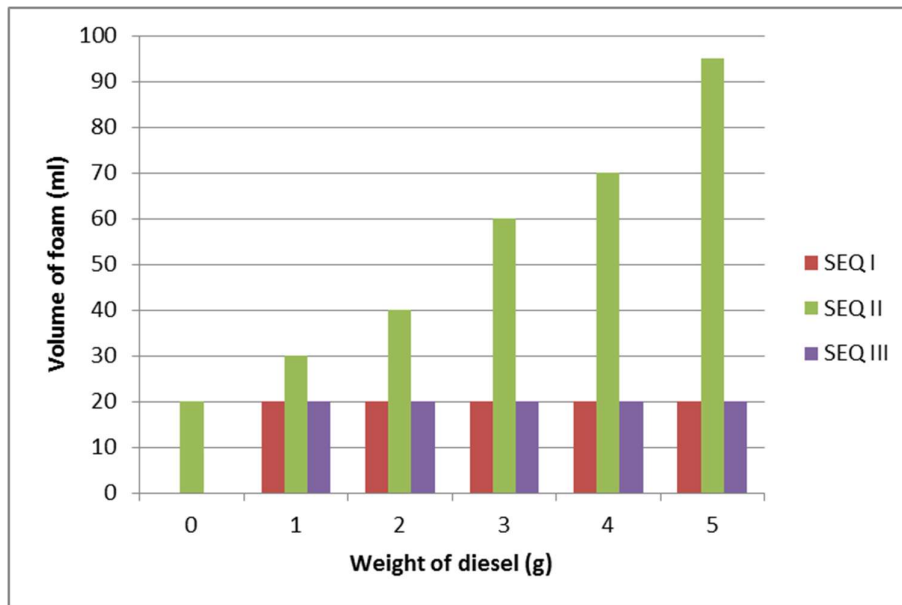


Figure 4.11: Effects of different weights of diesel on foam levels (tendency) of diesel engine oils.

In Sequence I, adding diesel up to 5ml does not increase the foam level, which remains at 20/0. This suggests that diesel has no significant effect on foam levels in this sequence.

In Sequence II, adding diesel increases the foam level, with a more significant increase beyond 2ml. This suggests a direct relationship between diesel volume and foam level in this sequence.

In Sequence III, the foam level remains constant at 20/0, regardless of the diesel volume added. This suggests that diesel has no significant effect on foam levels in this sequence, similar to Sequence I.

Overall, the data suggests that: Diesel addition has a minimal impact on foam levels in Sequences I and III. In Sequence II, diesel addition increases foam levels, with a more significant increase beyond 2ml.

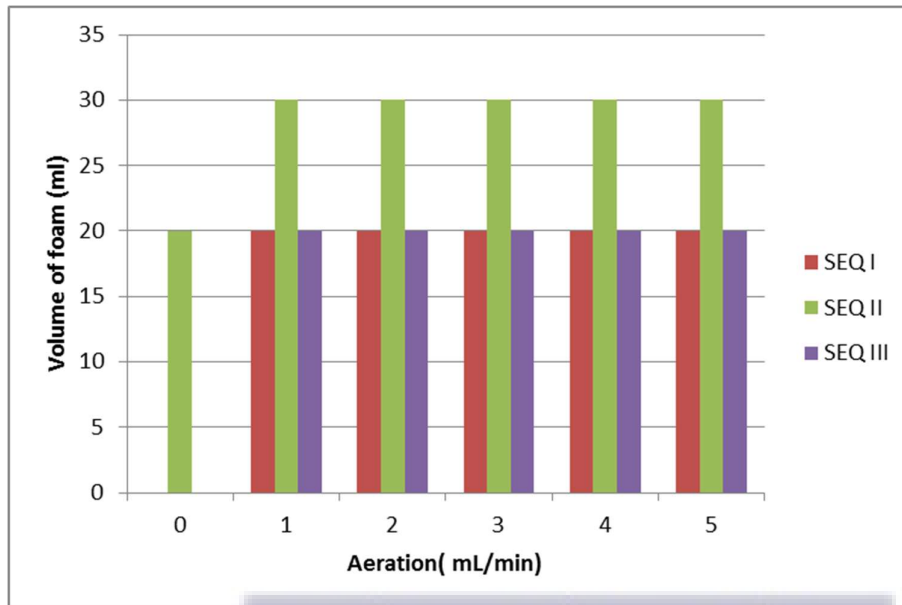


Figure 4.12: Effects Aeration on foam levels (tendency) of petrol engine oils.

In Sequence I, increasing aeration from 94 to 99 mL/min does not affect the foam level, which remains at 20/0. This suggests that aeration has no significant impact on foam levels in this sequence. In Sequence II, increasing aeration from 94 to 99 mL/min also does not affect the foam level, which remains at 30/0. This suggests that aeration has no significant impact on foam levels in this sequence. In Sequence III, increasing aeration from 94 to 99 mL/min does not affect the foam level, which remains at 20/0. This suggests that aeration has no significant impact on foam levels in this sequence.

Overall, the data suggests that:

- Increasing aeration has no significant impact on foam levels in any of the sequences (I, II, and III). This data indicates that aeration, within the tested range, does not affect foam levels in petrol engine oils, regardless of the sequence of addition.

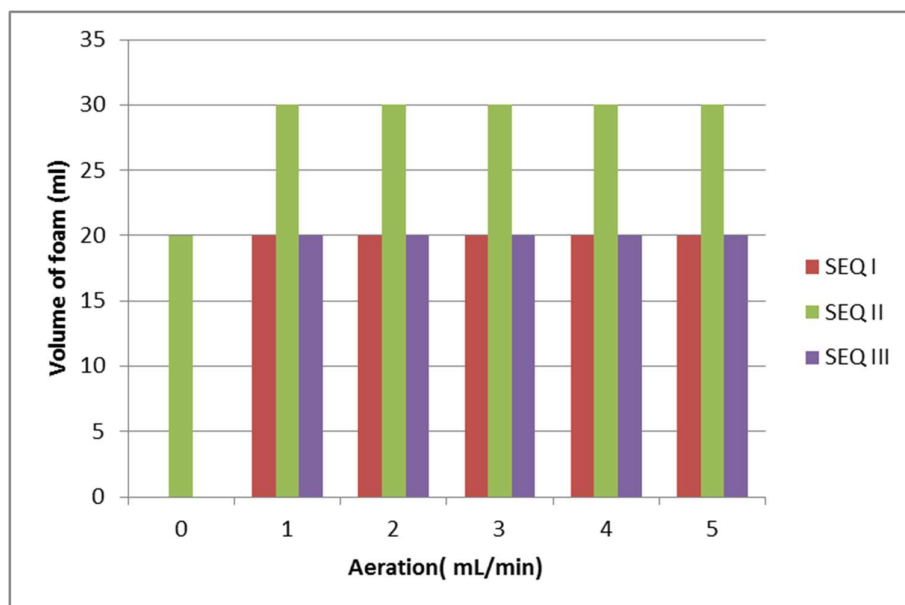


Figure 4.13: Effects Aeration on foam levels (tendency) of diesel engine oils.

In Sequence I, increasing aeration from 94 to 99 mL/min does not affect the foam level, which remains at 20/0. This suggests that aeration has no significant impact on foam levels in this sequence. In Sequence II, increasing aeration from 94 to 99 mL/min also does not affect the foam level, which remains at 30/0. This suggests that aeration has no significant impact on foam levels in this sequence. In Sequence III, increasing aeration from 94 to 99 mL/min does not affect the foam level, which remains at 20/0. This suggests that aeration has no significant impact on foam levels in this sequence.

Overall, the data suggests that increasing aeration has no significant impact on foam levels in any of the sequences (I, II, and III) for diesel engine oils.

## SUMMARY OF FINDINGS

This study explored the influence of four common contaminants—dust, grease, fuel, and used engine oil—on the demulsibility and foaming behavior of petrol and diesel engine oils. The

findings reveal significant insights with both academic and practical implications, particularly in lubricant formulation, contamination control, and machinery maintenance practices.

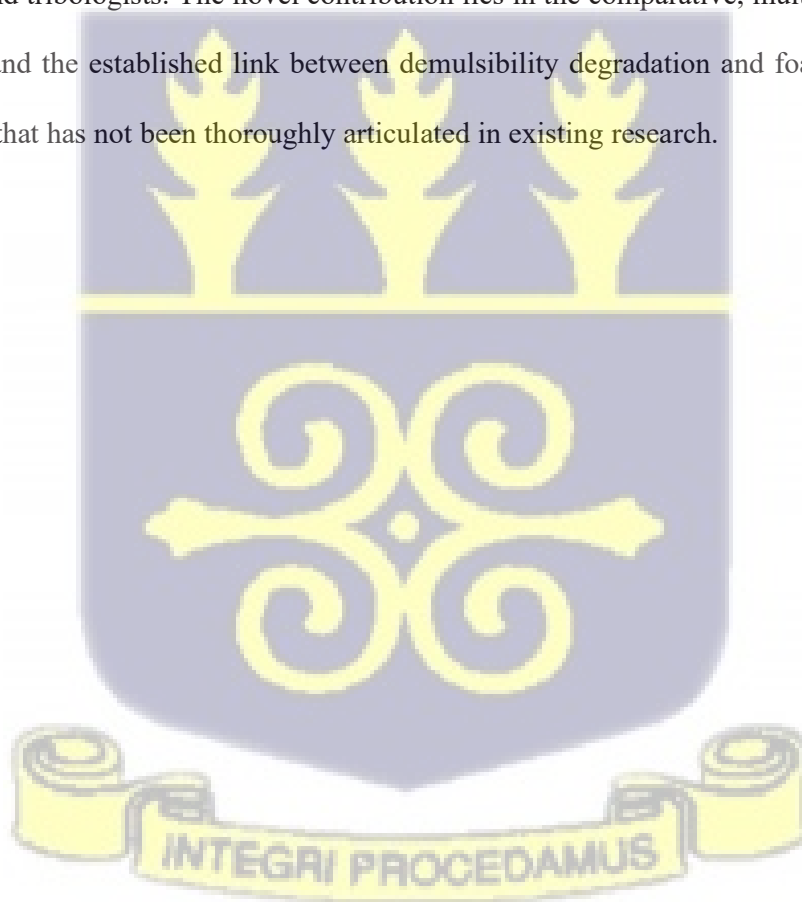
Consistent with Objective 1, the results demonstrated that all tested contaminants, aside from fuel, adversely affected the demulsibility of both petrol and diesel engine oils. Among them, grease exhibited the most severe impact, likely due to its hydrophobic and viscous nature, which inhibits water separation. This observation aligns with prior studies (e.g., Ren et al., 2023; Koreh et al., 2022), which reported that high-molecular-weight and oil-soluble contaminants hinder coalescence of water droplets at the oil-water interface. However, this study advances the field by systematically comparing multiple contaminant types and their differential impact across lubricant classes, which has been less extensively studied in the literature.

For Objective 2, the foaming tests revealed increased foam formation and stability in contaminated samples, with grease again producing the most persistent foam. This suggests that certain contaminants may act as unintentional surface-active agents, stabilizing the foam. This phenomenon is consistent with findings in the work of Rosen & Kunjappu (2012), who reported that contaminants with surfactant-like properties can prolong foam drainage. Notably, this study uniquely contributes to the field by relating foam behaviour with demulsibility outcomes, revealing a strong inverse relationship between water-separation efficiency and foam stability.

Addressing Objective 3, a comparative analysis between petrol and diesel oils showed that diesel engine oils generally exhibited better resistance to contamination effects, particularly in demulsibility. This may be attributed to differences in additive packages and base oil viscosity, as noted in existing lubricant performance studies (Usman et al., 2020). These findings suggest that lubricant formulation plays a crucial role in contamination resilience, and opens up possibilities for tailoring formulations to specific environmental or operational risks.

Despite the strengths of this work, there are limitations. The study was conducted under controlled laboratory conditions, which may not fully replicate field environments where temperature fluctuations, shear forces, and complex mixtures of contaminants may influence results. Future studies should consider real-time monitoring of contaminated systems and explore broader classes of contaminants.

Overall, the findings underscore the importance of contamination management in maintaining lubricant functionality and equipment longevity. By demonstrating how specific contaminants alter key lubricant properties and identifying the relative vulnerability of different lubricant types, this study provides actionable insights for lubricant manufacturers, maintenance engineers, and tribologists. The novel contribution lies in the comparative, multi-contaminant assessment and the established link between demulsibility degradation and foam stability, a relationship that has not been thoroughly articulated in existing research.



## CHAPTER FIVE

### CONCLUSION AND RECOMMENDATIONS

#### 5.1. CONCLUSION

This study examined how common contaminants like dust, grease, fuel, and used engine oil affect the demulsibility and foaming characteristics of petrol and diesel engine oils. The research aimed to determine the impact of these contaminants on oil performance and identify differences in response between petrol and diesel oils:

1. Grease and dust contaminants: Grease and dust contaminants have a significant impact on both demulsibility and foam levels in engine oils. They can lead to poor demulsibility and excessive foaming, particularly in Sequence II.
2. Used oil contamination: Used oil contamination have a moderate impact on demulsibility, but a minimal impact on foam levels.
3. Diesel and petrol contaminants: Diesel and petrol contaminants have no impact on demulsibility, but can lead to excessive foaming in Sequence II.
4. Aeration: Aeration has a minimal impact on foam levels in all sequences.
5. Sequence II sensitivity: Sequence II is more sensitive to contaminants than Sequences I and III, particularly for grease, dust, and petrol/diesel contaminants.
6. Demulsibility and foam level correlation: There is a correlation between demulsibility and foam levels, with poor demulsibility often leading to excessive foaming.
7. Contaminant interactions: The interactions between contaminants can impact demulsibility and foam levels, with some contaminants exacerbating the effects of others.

8. Importance of contamination control: The results highlight the importance of controlling contamination in hydraulic oils to maintain optimal performance and prevent damage to equipment.

The conclusions drawn from this study are directly aligned with the objectives stated in the research, and highlight critical insights for lubricant formulation, application, and maintenance. Objective 1 sought to investigate the dynamics in demulsibility properties of both petrol and diesel engine oils under various contamination conditions. The findings clearly show all contaminants, with the exception of fuel, reduced the oils' ability to separate from water, with grease causing the most significant decline in demulsibility. This highlights a critical risk to lubricant performance and system reliability when exposed to such contaminants.

Objective 2 examined the foam-forming tendencies and foam stability of the lubricants. The results show that contamination increased both the formation and persistence of foam, especially in grease-contaminated samples. Foam drainage was delayed, suggesting that contamination compromises the oil's ability to maintain operational stability under dynamic conditions. Objective 3 focused on comparing the extent of impact across petrol and diesel engine oils. While both oils showed similar trends, diesel engine oils generally exhibited slightly better resistance to demulsibility reduction and foam instability. This implies formulation-based differences that could inform tailored handling or additive strategies for each lubricant type.

In summary, the study confirms that lubricant contamination significantly impairs oil performance by compromising water separation and promoting foam stability. These effects are contaminant-specific and vary with lubricant type. The findings highlight the need for contamination control and inform strategies for improving lubricant formulation, maintenance practices, and system design.

## 5.2 RECOMMENDATIONS

Based on the findings from the analysis, here are some recommendations:

1. Equipment Operators are advised to implement effective contamination control measures:

- Regularly clean and maintain equipment and storage containers.
- Use filters and separators to remove contaminants.
- Monitor oil condition and perform regular oil analysis.

2. Regulatory Agencies and Standard Organizations like ASTM should select appropriate contaminants for testing:

- Consider the impact of contaminants on demulsibility and foam levels.
- Test with relevant contaminants for specific applications.

3. Industrial Maintenance Teams must optimize equipment performance:

- Minimize contamination during oil changes and maintenance.
- Use high-quality oils and filters.
- Monitor equipment performance and adjust maintenance schedules accordingly.

4. Lubricant Manufacturers should develop strategies to mitigate contaminant effects:

- Use additives or treatments to improve demulsibility and foam levels.
- Implement oil recycling or re-refining programs.
- Consider using synthetic oils or alternative lubricants.

5. Industrial Maintenance Teams should regularly review and update maintenance schedules:

- Adjust schedules based on oil analysis and equipment performance.
- Consider implementing condition-based maintenance.

6. Regulatory Agencies and Standards Organizations like ASTM and ISO must provide training and education:

- Educate personnel on contamination control and oil maintenance best practices.
- Ensure understanding of the impact of contaminants on hydraulic oil's properties.

7. Organizations must consider using advanced oil analysis techniques:

- Use techniques like spectroscopy or chromatography to detect contaminants and monitor oil condition.

8. Lubricant Manufacturers must develop a comprehensive oil management program:

- Include procedures for oil storage, handling, and disposal.
- Establish a system for tracking oil usage and maintenance.

Mechanics must make sure that grease does not get into lubricating oils during overhauling. For a situation where the head gasket leaks, there is the possibility for water to enter the hydraulic system. This enables contamination between the various parts of the hydraulic system. Overheating is the most probable cause of a leaking head gasket. Head gasket and overheating must be checked regularly, as well as cracks in the cylinder head or block. Also, another way in which water can enter and get mixed with the lubricating oil is through failure of seal around bottom of the wet liner. Many hydraulic systems are fitted with water to oil heat exchangers which can leak fluids between the systems. This must be checked frequently.

Since when traces of used lubricating oil in contact with new lubricating oil affects lubricity, the maintenance department in industries and those responsible for changing oils in hydraulic systems in other areas of work, must ensure that the hydraulic tank/system is thoroughly cleansed and free from any traces of used oil before the introduction of the fresh lubricant into the system. Industrial machineries, construction equipment, and other machines that use hydraulic oils in their operations should be free from dusty environments, if possible, or should be well checked to block any possible exposures that may allow dust to enter the hydraulic system.



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## APPENDIX

### Appendix I: API SPECIFICATION FOR CAR ENGINE OILS

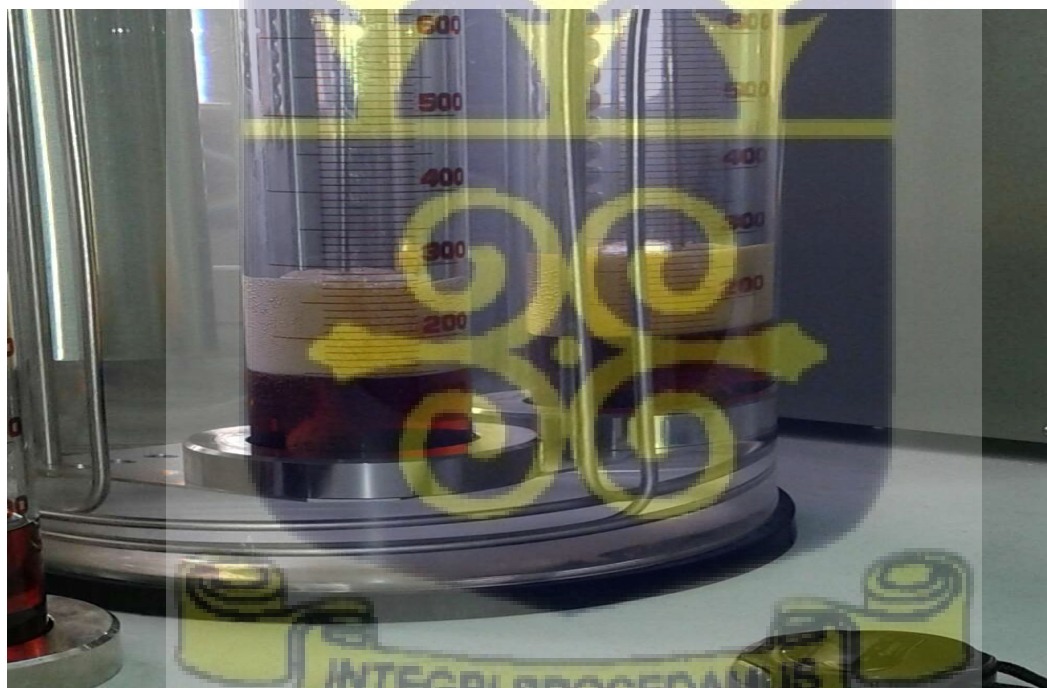
| Requirements     | Test Method | Properties                                                                                            | Unit  | specification                    |
|------------------|-------------|-------------------------------------------------------------------------------------------------------|-------|----------------------------------|
| Viscosity grades | SAE J300    | All Monogrades and Multigrades                                                                        |       |                                  |
| Foam Test        | ASTM D 892  | Sequence tendency/stability I,<br>Sequence tendency/stability II,<br>Sequence tendency/stability III, | ml/ml | 20/0 max<br>50/0 max<br>20/0 max |



Appendix II: Sampling of Engine Oils for Demulsibility and Foam Testing.



Appendix III: Aeration Control in Foam Measurement of Engine Oils Using the Foaming Bath.



Appendix IV: Timing for the blowing and settling periods.