Experimental Analysis on Performance, Emission and Vibration Characteristics of a Biodiesel CI Engine fueled with Diesel-Methanol blend

Mustefa Seyida Feto

A Thesis submitted to the department of mechanical engineering

School of mechanical, chemical and materials engineering

Presented in Partial Fulfillment of the Requirement for the Degree of Master's in Automotive Engineering

Office of Graduate Studies

Adama Science and Technology University

May, 2024

Adama, Ethiopia

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DECLARATION

I hereby declare that, this Master Thesis entitled "Experimental Analysis on Performance, Emission and Vibration Characteristics of a Biodiesel CI Engine fueled with Diesel-Methanol blend" is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

Mustefa Seyida Feto	____________	____________
Name of the student	Signature	Date

RECOMMENDATION

I, the advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled “Experimental Analysis on Performance, Emission and Vibration Characteristics of a Biodiesel CI Engine fueled with Diesel-Methanol blend” prepared under my guidance by Mustefa Seyida Feto submitted in partial fulfillment of the requirements for the degree of Mater’s of Science in Automotive engineering. Therefore, I recommend the submission of revised version of the thesis to the department following the applicable procedures.

Getachew Alemayehu (PHD)	______________________	____________________
Major Advisor	Signature	Date

APPROVAL

I, the advisors of the thesis entitled **“**Experimental Analysis on Performance, Emission and Vibration Characteristics of a Biodiesel CI Engine fueled with Diesel-Methanol blend” and developed by Mustefa Seyida; hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

Major Advisor	Signature	Date

We, the undersigned, members of the Board of Examiners of the thesis by Mustefa Seyida have read and evaluate the thesis entitled **“**Experimental Analysis on Performance, Emission and Vibration Characteristics of a Biodiesel CI Engine fueled with Diesel-Methanol blend**”** and examine the candidate during the open defense. This is, therefore, to certify that the thesis accepted for partial fulfillment of the requirement of the degree of Master of Science in Automotive Engineering.

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Internal examiner	Signature	Date
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Final approval and acceptance of the thesis is contingent upon submission of its final copy to the Office of Postgraduate Studies (OPGS) through the Department Graduate Council (DGC) and School Graduate Committee (SGC).

Department head	Signature	Date
School Dean	Signature	Date
Office of Postgraduate Studies, Dean	Signature	Date

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Abstract

In this thesis, an experimental analysis of diesel/methanol engine performance, emissions, and vibration characteristics using ratio blends of B10, B20, B25, and B30 at various engine load conditions is presented. According to the performance analysis, the addition of methanol resulted in a minor drop in brake power, which was mostly caused by methanol's lower energy content than diesel. The power of blended fuels (D90M10), (D80M20), and (D70M30) was lower than that of pure diesel by 2.76%, 5.04%, and 8.08%, respectively. On the other hand, when the amount of methanol increased, thermal efficiency improved by 0.031% to 0.056% as methanol concentration is increasing, suggesting better fuel economy and increased combustion efficiency. The experimental analysis showed that, especially at lower engine loads, methanol blending significantly reduced emissions of hydrocarbons (HC) and carbon monoxide (CO). Particulate matter (PM) emissions also showed a declining trend with increasing methanol content, indicating the potential for cleaner combustion and less environmental impact. Nitrogen oxide (NOx) emissions showed only slight increment variations across different loads. The addition of methanol affected engine vibrations, according to vibration analysis, with the effects becoming more noticeable at higher engine loads. The fact that the vibrations were still within tolerable bounds for engine operation highlights the significance of carefully adjusting and optimizing engine settings in order to reduce any potential unfavorable effects. All things considered, the results of this experimental investigation offer insightful information about how a diesel/methanol engine behaves under various blend ratios and engine load scenarios. The findings show that brake power and thermal efficiency must be traded off for better fuel economy and lower emissions of PM, HC, and CO. The continued efforts to provide internal combustion engine fuel alternatives that are more sustainable and cleaner are aided by these findings. The research's conclusions have an impact on the energy and transportation industries, opening the door to a future that is greener and more ecologically friendly.

Keywords: Diesel Fuel, Emission, Fuel Blend, Methanol, Performance, Vibration.

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LIST OF ACRONYMS AND ABBREVIATIONS

CH_3OH	Methyl Alcohol
NOx	Nitrogen Oxide
PM	Particulate Matter
CO	Carbon Monoxide
HC	Hydrocarbon
ASTM	American Standard for Testing and Materials
FEM	Finite Element Method
DOE	Department of Energy
NREL	National Renewable Energy Laboratory
SO_x	Sulphur Oxides
DMDF	Diesel-Methyl Dual Fuel
RCR	Ramsbottom Carbon Residue
CCR	Conradson Carbon Residue
MCR	Micro Carbon Residue
HP	Horsepower
BTE	Brake Thermal Efficiency
RPM	Revolution Per Minutes
RMS	Root mean square

CHAPTER ONE

INTRODUCTION

1.1 Background

The increasing worries regarding environmental contamination and the necessity for sustainable energy sources have stimulated extensive research on alternative fuels for internal combustion engines. Methanol is a fuel that has attracted attention due to its ability to enhance combustion properties and decrease emissions. The objective of this study project is to evaluate the merits and drawbacks of utilizing methanol as a fuel. This will be achieved by conducting an experimental investigation of engine performance, emission levels, and vibration characteristics on an engine that is powered by a combination of diesel and methanol. Methyl alcohol, sometimes known as methanol, is a renewable oxygenated fuel that has attracted attention as a potential substitute for conventional fossil fuels. Prior research has demonstrated that when employed as a fuel in internal combustion engines, it possesses the capability to reduce emissions and enhance combustion efficiency.

For instance, (S0306261922014520, no date)**,** examined a diesel/methanol blend's combustion properties and emission output in a compression-ignition engine. When compared to traditional diesel fuel, their research revealed a substantial decrease in nitrogen oxides (NOx) and particulate matter (PM) emissions. Methanol has environmental benefits, but its unique combustion features may significantly impact engine vibration characteristics. Engine wear and tear, engine lifetime, and noise levels can all be impacted by vibrations in engines induced by combustion. Thus, establishing whether methanol is a feasible fuel source requires an understanding of how it impacts engine vibrations. On the other hand, not much research has been done particularly on the vibrational qualities of engines fueled by methanol or diesel. The proposed study proposes to bridge this research gap by undertaking a complete experimental examination of engine performance, emission, and vibration characteristics on an engine driven by diesel and methanol. In order to find out how varied fuel blend ratios of methanol and diesel effect engine characteristics, emissions, and vibrations, the research will change these ratios. This research will give valuable insights into the probable advantages and difficulties of using methanol as a fuel in internal combustion engines by monitoring the engine's performance, emissions, and vibration levels. It is predicted that the study's findings will add to the body of knowledge already available on alternate fuels and how they affect engine performance. The data will assist regulators, automakers, and engine designers make well-informed decisions about the use of methanol as a possible sustainable fuel source (Huang et al., 2020). The experimental examination of the diesel-methanol engine's vibration characteristics at varying engine loads using blends B0, B10, B20, and B30 offers important new information about how fuel blends affect engine vibrations.

Diesel engines have various advantages, including excellent thermal efficiency and lower emissions of CO and HC when compared to gasoline engines. However, they also have downsides, such as the creation of smoke, particulate matter, and NOx. It is tough to concurrently lower both NOx and smoke density in diesel engines due to the tradeoff between these two pollutants. Consequently, enormous efforts have been committed to discovering ways to alleviate these difficulties. One successful strategy to lowering smoke emissions in diesel engines is the utilization of oxygenated fuels. The addition of oxygen-containing compounds to diesel fuel has been proposed as a technique to accelerate the oxidation of carbonaceous particulate matter and related hydrocarbons. Moreover, many oxygenates feature high cetane numbers, which, when coupled with diesel fuel, result in higher cetane numbers and subsequently lower CO and HC emissions. Notably, the influence on NOx emissions is relatively minimal. These advantages have generated considerable interest in the introduction of oxygenates into diesel fuel (S. Chockalingam & Ganapathy, 2012).

In recent years, there has been an increasing interest in studying alternative fuels for internal combustion engines as a strategy to minimize greenhouse gas emissions and increase overall engine performance. Among these possibilities, the use of methanol as a blend with diesel fuel has shown encouraging results due to its potential to boost combustion efficiency and minimize emissions. However, the impact of diesel-methanol fuel mixtures on engine vibration characteristics remains relatively unknown. Engine vibration is a crucial component impacting the performance, longevity, and comfort of internal combustion engines. Diesel fuel qualities and combustion characteristics have a direct influence on engine vibration levels. The addition of methanol to diesel fuel modifies its physicochemical properties, potentially altering engine vibration behavior. Understanding and assessing the comparative vibration characteristics of diesel fuel and diesel-methanol fuel blends is vital for optimizing engine design and performance in the context of alternative fuel use (S. R. Chockalingam et al., 2017).

Many academics have recently concentrated on alternative fuels such as biodiesel, natural gas, alcohol fuels, dimethyl ether, and natural gas because of their potential to minimize pollution emissions and lessen the depletion of fossil fuel resources. One of these alternatives, methanol, has a variety of potential uses and research value, especially for China, a country with an abundance of coal resources. Methanol fuel has several practical applications in China due to its ease of manufacturing from coal and coke oven gas. Methanol is a feasible alternative to diesel since it is less expensive and can simultaneously cut emissions of both NOx and soot.(Li et al., 2019).

Because of their excellent thermal efficiency, diesel engines are widely used in power generation, transportation, agriculture, and irrigation systems in modern times. However, because of the recent strict regulations on fuel consumption and pollutant emissions, the development of diesel engines is severely limited by the high emissions of NOx and soot as well as the rapid depletion of fossil fuel resources. Biofuels have garnered increasing attention globally over the past twenty years as supplemental or alternative fuels for mobile vehicles because of their potential to lower pollution emissions and increase energy security(Ma et al., 2017).

The continuous increase in the global population, coupled with rapid industrial growth, poses a threat to the availability and affordability of crude oil and petroleum products in the foreseeable future. This concern is exacerbated by the significant rise in the number of vehicles worldwide, which has led to a surging demand for fuel regardless of advancements in fuel economy. As petrol and diesel prices continue to soar, the prominence of biodiesel derived from alternative sources has emerged as a notable renewable fuel option.

According to the ASTM D7467 standards, blending biodiesel with diesel up to a 20% ratio has been defined as the normal practice for its utilization in diesel engines without requiring any prior modifications to the engine. Biodiesel, which is both biodegradable and clean-burning, is manufactured from numerous natural resources and possesses similar fuel qualities to normal diesel. In comparison to diesel, biodiesel utilized in modern diesel engines demonstrates fewer emissions of carbon monoxide (CO), hydrocarbons (HC), and particulate matter (PM), with the exception of nitrogen oxide (NOx) emissions. It is vital to understand that there are three basic methods by which NOx is formed: thermal, immediate, and N2O pathways.(Dey et al., 2021)

NOx emissions result from the elevated combustion temperature and the ample oxygen content within the cylinder. Under 75% and 100% load conditions, all fuels display higher NOx emissions due to the increased combustion temperatures. Fuel B1, characterized by a higher oxygen concentration, displays enhanced NOx emissions across all load circumstances. Conversely, the utilization of B2 fuel leads to reduced emissions compared to B1, attributable to the cooling effect of methanol, which lowers cylinder combustion temperatures.

When operating at full load, blended fuels consisting of diesel-biodiesel-methanol (B1 and B2) demonstrate 60.7% and 36.4% greater NOx emissions, respectively, compared to diesel and NME (Non-Methanol Extract). Notably, larger levels of smoke were recorded for NME and B2 up to a 75% load state, whereas B2 demonstrated higher smoke density at no load. In contrast, B1 displayed decreased smoke density compared to other fuel types up to a 50% load. However, at full load, the smoke density of blend B1 grew, surpassing diesel, NME, and B2 by 8.98%, 0.6%, and 8%, respectively.

In terms of CO (carbon monoxide) emissions, it is commonly noted that emissions drop with an increase in load for all fuels, thanks to more complete combustion. However, at full load situation, gasoline B2 exhibits CO emissions that are 100% higher compared to diesel fuel. This can be due to B2's lower total cetane number, which leads to higher ignition delay and incomplete combustion, resulting in elevated CO emissions. CO2 (carbon dioxide) emissions, on the other hand, decrease with increasing load for all fuels.

As for HC (hydrocarbon) emissions, they decrease with increasing load for all fuels, indicating more complete combustion at higher loads. Fuel B1 showed decreased HC emissions across all loads. Notably, B2 exhibits greater HC emissions at no load and full load, surpassing diesel fuel by 120% and 200% respectively. The engine operated with NME also generates greater HC emissions, particularly up to a 50% load. Overall, these findings give light on the behavior of various fuels in terms of CO, CO2, and HC emissions under varied load circumstances.(Budharaju et al., 2019)

1.2 Statement of the problem

The need for sustainable energy sources and environmental concerns have drawn a lot of attention to the use of alternative fuels in internal combustion engines in recent years. With the potential for improving combustion characteristics and reducing emissions, methanol has become a more attractive alternative fuel. On the other hand, when methanol is used as a fuel in diesel engines, there is a dearth of thorough experimental analysis concerning how it affects engine performance, emission, and vibration characteristics.

A few studies have particularly examined the vibration characteristics of diesel/methanol-fueled engines, despite the fact that earlier research has examined the combustion and emission properties of diesel/methanol blends. Increased wear and tear, a shorter engine life, and higher noise levels can all be caused by engine vibrations. Therefore, determining whether methanol is a viable fuel option and guaranteeing optimal engine operation require an understanding of how methanol affects engine vibrations. Moreover, it is still unknown how different diesel and methanol fuel blend ratios affect engine characteristics, emissions, and vibrations. It is still unknown what the ideal blend ratio is to maximizes engine performance and minimize vibrations and emissions. To maximize engine performance and strike the ideal balance between emissions, vibration characteristics, and performance, this information is crucial. This proposed study intends to perform a thorough experimental analysis of engine performance, emission, and vibration characteristics on a diesel/methanol fueled engine in order to fill in these research gaps.

1.3 Objectives

1.3.1 General Objective

The General Objective of this research was to perform an experimental analysis to look into the vibration, emission, and engine performance of a diesel/methanol-fueled engine.

1.3.2 Specific objectives

In order to accomplish the primary goal of this thesis, the following particular goals were designed:

1. To evaluate the impact of methanol as a fuel on engine performance in terms of power output, fuel consumption, and thermal efficiency.
2. To quantify the emissions characteristics, including particulate matter (PM), nitrogen oxides (NOx), and sulfur compounds, of a diesel/methanol fueled engine and compare them to those of conventional diesel fuel.
3. To analyze the vibration characteristics of the engine when operated on diesel/methanol fuel and identify any changes or reductions in vibration levels.
4. To find out how different diesel and methanol blend ratios affect engine characteristics, emissions, and vibrations, this research varies these ratios.

1.4 Significance of the Study

The research on experimental analysis of performance, emission, and vibration characteristics of diesel-methanol fueled engine holds considerable significance in several domains. The findings and outcomes of this study contribute to the advancement of knowledge and have practical implications in the following areas:

A. *Environmental Sustainability:* The study addresses the critical need for sustainable transportation systems by studying the feasibility of employing methanol as a blending agent in diesel engines. By researching the performance and emission characteristics of the diesel/methanol fuel mixes, the research intends to provide valuable insights into decreasing hazardous pollutants such as nitrogen oxides (NOx), particulate matter (PM), carbon monoxide (CO), and hydrocarbons (HC). The findings of this study can contribute to the development of cleaner and more environmentally friendly combustion technologies.

B. *Energy Security and Resource Management:* As the globe faces difficulties connected to energy security and the depletion of fossil fuel supplies, the study on alternative fuels grows significance. By examining the performance of a diesel/methanol fueled engine, this study analyses the possibilities of employing methanol, which may be generated from numerous sources such as natural gas, coal, or biomass. This diversification of fuel sources can boost energy security and encourage efficient resource management.

C. *Engine Efficiency:* Understanding the impact of methanol mixing on engine performance is vital for maximizing the efficiency of diesel engines. The study provides insights into the impact of different diesel/methanol fuel blends on measures such as brake power, torque, specific fuel consumption (SFC), and brake thermal efficiency (BTE). The findings can contribute in the development of methods to improve the overall performance and efficiency of diesel engines, resulting to lower energy consumption and operational expenses.

D. *Emission Control and Compliance*: The experimental investigation of emission characteristics in this study leads to the development of emission control techniques for diesel engines. By quantifying and analyzing the emissions of nitrogen oxides (NOx), particulate matter (PM), carbon monoxide (CO), and hydrocarbons (HC) for different diesel/methanol fuel blends, the research provides valuable data for understanding the environmental impact and compliance of alternative fuel usage. The findings can inform the development of emission control technology and assist meet rigorous emission standards

E. *Vibration Mitigation and Engine Durability:* Vibration analysis is vital for assuring the durability and performance of internal combustion engines. By analyzing the vibration characteristics of a diesel/methanol powered engine, this study attempts to discover the impact of methanol mixing on engine vibrations. The findings can help to the development of vibration mitigation measures, resulting to improved engine durability, decreased maintenance costs, and enhanced passenger comfort.

F. *Technological Advancements and Innovation:* The research on experimental examination of a diesel/methanol fueled engine comprises the employment of advanced measurement techniques, sensors, and data gathering systems. The work adds to the progress of experimental procedures and instruments in the field of internal combustion engines.

Generally, the significance of this study lies in its contribution to environmental sustainability, energy security, engine efficiency, emission control, vibration mitigation, and technological advancements. The findings and outcomes of this research can inform policymakers, engine manufacturers, and researchers in their endeavors to develop greener and more sustainable transportation systems, optimize engine performance, and meet stringent emission regulations.

1.5 Scope of the study

The scope of this research, focusing on the comparative analysis of engine vibration, performance and emission characteristics on diesel fuel versus diesel-methanol fuel blends, encompasses the fuel type, performance analysis, engine type, emission analysis, vibration analysis, experimental setup, vibration analysis and blend ratios. The research focuses solely on the experimental analysis of engine performance, emission, and vibration characteristics.

1.6 limitation of the research work.

The limitations of this study are listed as follows:

1) The limitation of time,
2) Shortage of budget and
3) Engine design modification

1.7 Organization of the thesis chapters

The organization of the thesis begins with an introduction to the research topic and delves into a comprehensive literature review that explores existing research, studies, and scholarly articles related to diesel/methanol blends, engine performance, emissions, and vibrations. It critically analyzes previous works to identify gaps in knowledge and provides a theoretical foundation for the experimental analysis conducted in the subsequent chapters. The literature review chapter establishes the current state of knowledge in the field and highlights the research advancements made by other scholars.

In Chapter 3, the experimental setup and methodology employed in the research are thoroughly described. This chapter explains the selection and preparation of the diesel/methanol blend, the engine specifications, and the instrumentation used for data collection. It provides a detailed account of the experimental procedures, including the test conditions, measurement techniques, and data acquisition methods. The chapter also discusses any limitations or constraints encountered during the experimental process and outlines the steps taken to mitigate them.

Chapter 4 presents the results obtained from the experimental analysis and provides a comprehensive discussion of the findings. The chapter includes the analysis of performance parameters such as brake power, thermal efficiency, and specific fuel consumption, along with the assessment of emission levels (NOx, CO, HC, PM) and vibration characteristics. The results are presented in tables, graphs, and figures, and are compared with those obtained from the conventional diesel fuel. The discussions interpret the results, analyze the trends, and highlight any significant observations or correlations between variables.

The final chapter of the thesis presents the conclusions drawn from the experimental analysis and provides recommendations for future research and practical applications. It summarizes the key findings, emphasizes their significance, and relates them back to the research objectives. The chapter also discusses the implications of the research and highlights potential areas for further investigation. Additionally, it offers recommendations for engine optimization, emission reduction strategies, and the utilization of diesel/methanol blends in real-world scenarios. The conclusion chapter serves as a culmination of the thesis, summarizing the research journey and its contributions to the field of alternative fuels and engine performance.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Vibration is a sort of movement displayed by a body or system around its equilibrium point. It can be classed as either periodic or random. Periodic vibrations occur in a repetitive and predictable fashion, such as the movement of a pendulum in a grandfather clock. On the other hand, random vibrations are unpredictable and occur in irregular patterns, like the movement of an object passing across an uneven surface. In the context of machinery or engines, vibrations are generally undesired as they might lead to different negative outcomes. These include increased stress levels, accelerated wear and tear, heightened sound levels, material fatigue, energy losses, and increased bearing loads (Örn, 2014). Over time, these factors can result in mechanical failure and breakdown.

Vibrations can be classed into two types: free vibrations and forced vibrations. Free vibrations occur when a mechanical system is started in motion and left to oscillate until it comes to a stop naturally, comparable to letting go of a swing. On the other hand, forced vibrations occur when an external force or load is given to a mechanical system, forcing it to vibrate. For example, an unequal load of clothes in a washing machine can create forced vibrations. When an internal combustion engine is functioning, it generates several types of excitations. Despite being engineered to be balanced, vibrations nevertheless originate from rotating engine parts, gas pressures, and the firing of the engine itself. Therefore, it is vital to design the engine in a way that avoids any vibrations that are close to its natural frequency. If the running engine's vibrations align with its natural frequency, they can amplify one other, resulting to increased forces and premature mechanical breakdown.

Determining the natural frequency of an engine can be performed by finite element method (FEM) simulations or direct measurements. Accelerometers are often used to measure the entire vibration of a running engine, capturing movement in three directions: longitudinal, transversal, and vertical along the axis. Since vibration levels can vary across different regions of the engine, a predefined grid of measurement locations is designed for installing the accelerometers. The measurement findings must be compared to normal values for each spot on the engine and for each engine type. Exceeding these usual limits indicates significant vibration, demanding further study to find the underlying reason. Vibrations can have both negative and good impacts. In the case of engines, vibrations are generally undesired yet inevitable. However, vibrations are purposely exploited in applications such as compactors, eccentric grinders, and the vibrators found in mobile phones, among other gadgets, where they serve a practical purpose (Örn, 2014).

Transportation frequently uses diesel engines. power generation as well as a variety of other uses, such as in the agricultural and industrial sectors (Erdiwansyah et al., 2018) conducted vibration experiments on small engines running on diesel biodiesel fuel; the findings of the tests revealed that all engine that correspond to the engine piston's stroke frequency and the size of the engine vibration based on the fuel mixture, speed, and growth rate. Notably, the forwarding speed has a substantial impact on the engine vibration, which is raised as a result of the acceleration of vibration. The outcomes of many studies done utilizing the B100, B5, and B20 gasoline blends demonstrated the least amount of vibration. Microcars employ ultra-low Sulphur diesel with quantities up to 40% and mixed fuel biodiesel from refined cooking oil, which shows vibro-acoustic behavior at small engine displacements.

All gasoline combinations had an increase in index noise, according to the experimeon analysis on a diesel engine running on a blend of biodiesel and petroleum diesel fuel The lowest vibration was at D100 compared to B100, according to experimental results employin g gasoline blends of(B5),(B10)(B15),(B20),(B30),(B40), and(B50) at 1,800 and 2,000 rpm engin e speeds.On a generator set, vibration and noiseinduced fuel vibration between JB100 and JB20 as well as diesel minerals have been examined.

All gasoline mixtures had an increase in index noise, according to the experimental data, with the B10 mix having the highest level for the majority of the engine loads that were assessed. has looked at a vibration analysis on a diesel engine running on a blend of biodiesel and petroleum diesel fuel. On a generator set, vibration and noise-induced fuel vibration between JB100 and JB20 as well as diesel minerals have been investigated. The experimental findings indicated a high association between the measurement of vibration and noise in the combustion engine and the length of fuel combustion and variation in HRR max. The fuel blend of petrol and ethanol on the spark ignition engine was triggered by vibration characteristics and noise emissions (Aydin &

Bayindir, 2010). Between 25% E-70% G-5% O and 50% E-45% G-5% O, the mixed volume is operated at 1,500, 2,000, and 2,500 rpm engine speeds. Experiments conducted out at engine speeds of 1,500 and 2,500 rpm revealed considerable variations in the vibration characteristics of the engine. This is owing to the fact that it contains more oxygen and latent heat than ethanol. A analogous analysis of vibration and noise in compression engines running on biodiesel fuel has also been undertaken by (Erdiwansyah et al., 2018).

According to (Campos-Fernández et al., 2012) experiment's findings, the engine's noise and vibration can be lessened by raising the biodiesel ratio. For vibration and noise, the coefficient of correlation (R) is 0.784 and 0.741, respectively was done in diesel engines using 20%, 50%, and 100% quantities of fuel and biodiesel. According to the data, B20 reaches 100 Nm at 35% of its maximum load. When engine vibration is compared to diesel fuel, its amplitude grows.

Numerous researchers worldwide are now exploring this fascinating subject as a result of prior studies' discoveries about the impact of noise and vibration on machinery. Similarly, the goal of this study is also to explore how different fuel blends and engine loads effect vibration and noise levels in the engine.

This analysis covers the machines utilized in the experiment as well as a variety of fuels. The examination of fuel qualities is dependent upon the volume of ratios employed. The production and utilization of biodiesel as an alternative fuel for compression-ignition engines and boilers have undergone tremendous expansion in recent years. Biodiesel acts as an instant option to decrease the impact of damaging greenhouse gases, while also lowering dependence on fossil fuels. Biodiesel is a renewable fuel generated through a chemical reaction between alcohol (methanol or ethanol) and vegetable or animal oils, fats, or greases. Compared to petroleum diesel, biodiesel offers a safer and cleaner alternative, displaying various advantages.

Biodiesel is a renewable fuel noted for its energy efficiency and compatibility, as it can be used as a 20% blend in most diesel equipment with little to no modifications necessary. By utilizing biodiesel, global warming gas emissions can be minimized, making it an environmentally favorable alternative. Additionally, biodiesel is non-toxic, biodegradable, and suited for delicate areas.

The synthesis of biodiesel involves a chemical interaction between vegetable oil or animal fat and alcohol, assisted by a catalyst such as sodium or potassium hydroxide. Glycerin is created as a co-product. Various oil feedstocks, including soybean oil, corn oil, canola oil, cottonseed oil, mustard oil, palm oil, restaurant waste oils, animal fats, trap grease, and float grease, can be turned into biodiesel using a transesterification reaction. The most frequent approach involves combining vegetable oil with methanol in the presence of sodium hydroxide.

This reaction provides methyl esters (biodiesel) and glycerin as a byproduct. Biodiesel can be utilized in its pure form, called as B100, however engine modifications are necessary to prevent any degradation of plastic components. Due to the high level of care necessary, the National Renewable Energy Laboratory (NREL) and the U.S. Department of Energy (DOE) do not promote the use of high-level biodiesel mixes. Instead, biodiesel is often used as a blend (e.g., B5, B10, B20), where a specified percentage of biodiesel is combined with petroleum fuel. No engine adjustments are needed when using biodiesel blends, up to 5% (B5) content, which meets the ASTM D975 diesel fuel specification. For home heating oil, B5 complies with the D396 home heating oil specification (Biodiesel Handling and Use Guide, 2009). Biodiesel blends ranging from 6% to 20% can be employed in many applications with few or no equipment modifications. B20, a blend of 20% biodiesel and 80% petroleum diesel, is the most generally used biodiesel blend in the United States because to its advantageous balance between material compatibility, cold weather performance, pollution benefits, and prices (Biodiesel Handling and Use Guide, 2009). Equipment compatible with B20 comprises compression-ignition engines, fuel oil and heating oil boilers, and turbines. In-depth research has addressed the analysis, fuel quality, and production monitoring of biodiesel (Knothe, 2005; Mittelbach and Remschmidt, 2004; Knothe, 2001; Mittelbach, 1996; Komers et al., 1998). These research provide new insights into the properties and monitoring of biodiesel fuel.(Ghenai, 2011)

Diesel fuel plays a major role in the transportation and heavy-duty engine industries, contributing significantly to the worldwide economy. Its broad use is motivated by its excellent combustion efficiency, reliability, adaptability, and cost-effectiveness. However, the recent dramatic spike in crude oil prices on the international market has had a detrimental impact on the economies of many countries, particularly those strongly reliant on oil-producing nations for their energy production and transportation needs. This predicament has generated interest in researching non-fossil and sustainable energy options as alternative fuels to decrease or replace the dependence on crude oil imports. On the other hand, the emissions released by diesel engines constitute a substantial threat to the environment and are regarded a major contribution to the greenhouse

effect and air pollution. These pollutants have been demonstrated to alter ecological processes, leading to environmental concerns, and the carcinogenic substances in the emissions represent considerable dangers to human health. Consequently, there is an increasing global urgency to develop cleaner-burning diesel fuels. One viable technique to lowering gaseous and particle emissions is adjusting the chemical composition and physical properties of the fuel. Studies have indicated that oxygenating diesel fuels with oxygenated additives and using fuels with reduced aromatic content are two effective strategies for primarily reducing soot and particle emissions. As a result, several oxygenated fuel additives have been examined in research focused on reformulated diesel fuels. Certain glycol ethers, alcohol esters, and carbonates have proven potential and favorable impacts on particle emissions from diesel engines. (Guo et al., 2011)
There is a growing concern about the escalating prices of oil, the rapid depletion of fossil fuels, heightened pollution levels, and the ozone impacts that threaten emissions. Recent estimates from the United States Agency for International Development (USAID) predict that energy demand will surge by over 50% by 2040 compared to 2018. Adapting to global changes requires significant energy conservation and the development of sustainable alternatives. Consequently, researchers are actively exploring renewable energy sources. Among these options, biofuels emerge as a promising alternative, offering practical, political, and environmental benefits. Biofuels are hailed as alternative fuels that can address various issues, such as the global surge in energy costs due to the depletion of traditional fuels, the increasing energy demands in industries, agriculture, and transportation heavily reliant on petroleum-based fuels, the environmental impacts of burning fossil fuels, and the national energy security concerns (Bhan et al., 2022).

Biofuels have emerged as a viable energy alternative aimed at lessening dependence on fuel imports and meeting regulatory emission standards. Among the commonly used biofuels like ethanol and biodiesel, ethanol has garnered significant attention due to its production from more environmentally sustainable sources. It can be derived from sugar cane, sugar beets, wood, corn, and various grains, offering substantial potential as a fuel for both Spark Ignition (SI) and Compression Ignition (CI) engines owing to its unique physicochemical properties. In the automotive sector, there is a continual drive to enhance passenger comfort, efficiency, and eco-friendliness. Achieving these goals necessitates a comprehensive analysis of fuel usage and engine maintenance to address issues like reducing vibration, noise, and engine spray characteristics. Engine noise and vibrations are not only influenced by combustion properties but also by moving engine parts. The combustion behavior is intricately tied to factors such as fuel type, engine load, and speed. Engine vibrations contain valuable insights into the engine's physical attributes and operational status, with both noise and vibration serving as indicators of an engine's health and performance (Mogal et al., 2023).

Mounting expenses, diminishing fossil fuel reserves, and inadequate sustainability efforts have raised significant concerns regarding alternative fuel sources. Presently, extensive research is concentrating on the utilization of biodiesel as a sustainable alternative fuel for compression ignition (CI) engines. This shift is prompted by the rapid depletion of crude oil, escalating greenhouse gas emissions, and soaring fuel prices. With fossil fuels leading to detrimental gas emissions and diminishing availability, fuel researchers are emphasizing the adoption of renewable and eco-friendly energy sources like biodiesel and ethanol. Within the realm of energy solutions, diesel engines boast notable features such as high thermal efficiency, efficient air-fuel mixture utilization, reduced fuel consumption, higher compression ratios (CR), and reliability. However, a key drawback of diesel engines lies in their substantial emissions output, including carbon monoxide (CO), unburnt hydrocarbons (UHC), unburnt nitrogen oxides (NOx), and particulate matter. Given that road transportation vehicles consume significant amounts of fuel and generate substantial exhaust emissions compared to other modes of transport, the Indian road transport sector, a vast and intricate network, releases significant exhaust pollutants. Numerous investigations have explored the impact of biodiesel and its blends on the environmental lifecycle. Consequently, biodiesel emerges as a promising alternative feedstock for diesel engine applications. As a superior oxygenated fuel with an enhanced cetane number, biodiesel is poised to offer improved combustion characteristics, making it a favorable substitute in diesel engine operations (Jaikumar et al., 2020).

There exists a robust global initiative towards exploring the integration of renewable fuels in gasoline engines. In response to the energy demands of the worldwide transportation sector, the investigation into low-carbon fuels, particularly primary alcohols like methanol derived from biomass, municipal solid waste (MSW), and non-edible agricultural resources, is gaining momentum for extensive production and adoption. Methanol, in particular, is being increasingly considered as an alternative fuel in many nations due to its relatively higher-octane rating in comparison to the gasoline it seeks to replace. Methanol and blends of methanol with gasoline (known as gasohol) exhibit reduced emissions of particulate matter (PM) mass and sulfur dioxide (SO_2) when contrasted with standard gasoline. Studies by Sharma et al. have explored the impact of alcohol-gasoline blends on particulate emissions from gasoline direct injection (GDI) test engines, reporting a decrease in emissions. Masum et al., on the other hand, have noted that oxygenated fuels yield higher torque and peak in-cylinder pressure compared to gasoline, despite having similar energy content. Given the significant influence of noise and vibration characteristics on the market reception of an engine, their assessment has been integral since the early stages of engine development. Engine vibrations are crucial in terms of durability as excessive vibrations can lead to structural failures. Therefore, it is imperative that thorough evaluations of methanol and gasohol fuels be conducted to ascertain their noise and vibration profiles relative to those of conventional gasoline (Sharma et al., 2019).

The increasing awareness of global warming and greenhouse gas (GHG) emissions has spurred widespread focus on reducing CO_2 emissions. The European Commission has put forth proposals for mandatory CO_2 regulations for new heavy-duty trucks, suggesting a 15% reduction standard by 2025 and a 30% reduction by 2030, based on the 2019 benchmarks. Similarly, targets have been set for light commercial vehicles, aiming for a 15% reduction in average CO_2 emissions by 2025 and a 31% reduction by 2030. Concerning passenger cars, agreed-upon targets include a 15% reduction by 2025 and a 37.5% reduction by 2030, relative to the 2021 baseline.

Simultaneously, the escalating global energy demand and apprehensions regarding fossil oil depletion are amplifying the necessity for renewable and clean energy sources. Among these sources, alcohol fuels are often hailed as "green" from a life cycle perspective. The CO_2 emissions from alcohol fuels when utilized in vehicles can be counterbalanced by the CO_2 absorbed during the crop growth utilized in their production. Consequently, vehicles powered by alcohol fuel blends emit less net CO_2 per mile traveled compared to conventional fossil fuel vehicles. Bio-alcohol fuels offer a substantial CO_2 reduction potential ranging from 35% to 80%, contingent on the biomass and processing technology employed.

Alcohols like methanol, ethanol, and butanol present intriguing alternatives for the low-temperature combustion (LTC) concept due to their high-octane ratings, oxygenated fuel structures, and liquid form. While methanol faces challenges in internal combustion (IC) engines due to its toxicity and low energy density, the primary sources of methanol currently stem from natural gas or coal through gasification and subsequent synthesis. Hence, ethanol and butanol derived from biomass are better-suited options for IC engine applications, given their diverse production technologies and source materials (Han et al., 2020).

2.2 Fuel that is frequently used

2.2.1 Diesel fuel

The process of creating a suitable mixture has also involved researching the effects of noise and vibration. According to the test results, there is a noticeable difference when employing combinations like biodiesel, ethanol, methanol, and petrol compared to using pure diesel(Seifi et al., 2016).

2.2.2 The Biodiesel fuel

One sustainable energy source that can be created domestically is biodiesel, much like animal material, vegetable oil, and waste cooking oil. Fuels derived from biomass, such as biodiesel, are able to fulfil all specifications for renewable biofuel. Fuels that are liquid, like biodiesel Pure biodiesel, also referred to as B100, is appropriate for use in compression combustion engines. The. Table 2.1 outlines the features of biodiesel. Blends of biodiesel, diesel Their performance in cold conditions is largely impacted by their features and raw materials. In chilly conditions, biodiesel B5 is particularly precise. Diesel No. 2 and biodiesel B5 crystallize at low temperatures in ways that are comparable. Agricultural materials like sunflower, soybeans, vegetable oil waste, hemp, canola, jatropha, and sawn oil can all be used to make biodiesel.

Table2.1: Physical characteristics of biodiesel fuel (Miller et al., 2022).

Oxygens, by dif. Wt.%	11.01	Sulfurs, wt.%	0.0-0.00150
Flash points (^{0}C)	100-171	Kinematic viscosities at 40 (^{0}C)	4.0-6.00
Densities 1b/gal at 15.5	7.31	Lower heating values, Btu/gal	119,550.0
Specific gravities	0.880	Pour points, (^{0}C)	-5-11
Cetane numbers	47-66	Cloud points, (^{0}C)	-3 to 15.5

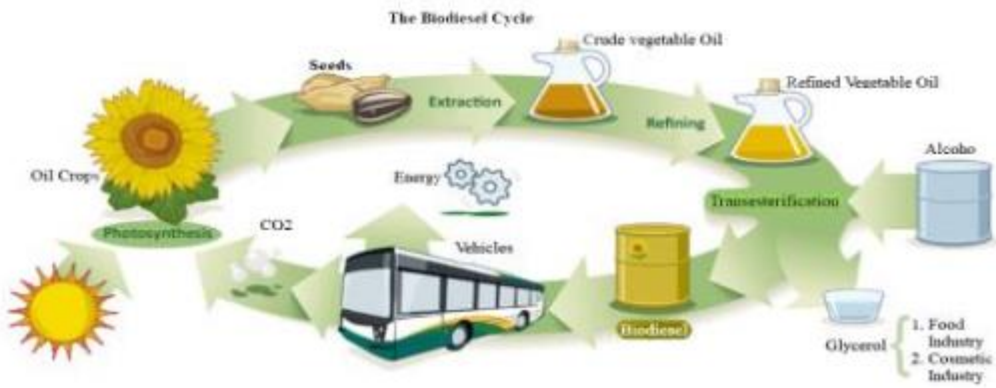


Figure 2.1 The Biodiesel and transesterification process

Biodiesel is a promising renewable fuel produced from different plant oils, animal fats, waste oils and microbial lipids. However, the feedstocks used to produce biodiesel are relatively costly, and these feedstocks are often derived from crops that are also used for food. The replacement of food crops by energy crops has led to an increase in food prices. So, biodiesel producers are seeking technologies that promises to reduce feedstock costs and enable the use of plant materials from non-food sources and a typical biodiesel and transesterification process is shown in Figure 2.1. The development of cost-effective feedstock coupled with judicious usage of waste substrates may be available option to reduce the process of costs.

The fermentation process for producing different biodiesel from the feed-stock, but the pre-fermentation is similar. An efficient fermentation process is a pre-request for the production of biofuels in a larger quantity and makes the production economically competitive with the prices of crude oil.

2.2.3 Ethanol fuel

Biomass is the general term for a variety of plant materials that can be used to make renewable fuels like ethanol. In the US, petrol fuels have 98% ethanol, which is an excellent combination to oxidize fuel and lower air pollution (90% petrol and 10% ethanol). Flexible fuels, like ethanol (also known by E85), can be used interchangeably for vehicle fuels because they are made to run on an 85% ethanol to petrol fuel mixture.

- ✓ authorized as a new fuel for automobiles with a different fuel blend, such as E15. Many steps are involved. devoted to producing alcohol that can be used as a fuel for cars: Grown, gathered, Materials transferred to an ethanol producing facility are biomass feedstocks.
- ✓ After being delivered by rail, truck, or barge to a hydrocarbon terminal or an end user, feedstocks are converted back into grain alcohol at a production facility.
- ✓ At the petrol terminal, ethanol is combined with petrol to create E10, E15 or E85, which is then distributed to fueling stations using trucks.

2.2.4 The Methanol fuel

Methanol is a safe, affordable substitute for marine gas. Methanol is a potential marine petrol that helps ships meet more stringent emission regulations, which is in line with the growing demand for cleaner marine petrol. Particulate particles, Sulphur oxides (SOx), and nitrogen oxides (NOx) are all significantly reduced by methanol emissions. Worldwide access to methanol fuel is made possible by current global infrastructure. The cost of building new vessels and converting existing ones to run on methanol is significantly lower than that of converting to other gases. In recent decades, methanol fuels for automobiles have been extensively studied. Methanol fuel was used in the experiments carried out by (Tomassetti et al., 2017).

A study was conducted by some researchers on a variety of machines, with varying outcomes. The differences between the properties that ethanol and methanol fuel have are shown in Table 2.2

Table:2.2 physiochemical properties methanol, ethanol, diesel and gasoline (Yusri et al., 2017)

Properties	Methanol	Ethanol	Diesel	Gasoline
Heat Of Vaporizations (kJ/kg	1162.640	918.420	243.0	349
Boiling Points(^{0}C)	65.0	78.0	180-370	27-225
Autoignition Temperatures(^{0}C)	463.0	420.0	Up to 300.	257
Low Heating Values (MJ/kg)	20.10	26.90	42.50	42.70
Stochiometric Air/Fuel Ratios	6.470	9.010	14.30	14.70
Flash Points(^{0}C)	12.0	13.0	65-88	-13 to 45
RON	136.0	129.0	20-30	80-99
Cetane Numbers	3.80	5-9	40-55	0-10

Methanol is a renewable energy, which can be created from hydrogen and carbon dioxide by solar energy and reach carbon neutrality. In addition, methanol can be produced on a big scale. Its unique physical and chemical features can efficiently decrease the generation of particles, nitrogen oxides, and unburned hydrocarbons in the combustion process. Due to the high latent heat of evaporation, methanol can reduce the cylinder temperature in the combustion process, resulting in minimal NOx emission. Methanol has no C-C bond and will not form soot during combustion. In addition, diesel–methanol fuel can be put directly in the cylinder and does not affect the engine's fuel system. Moreover, due to the micro-explosion phenomena, the spray characteristic of a diesel engine can be improved. Therefore, methanol has become a possible clean alternative fuel for engines. In recent years, numerous researchers have researched diesel–methanol dual-fuel engines. For example, Li et al. evaluated the impact of diesel injection parameters on quick combustion and emission of diesel–methanol dual-fuel (DMDF) engines. The results revealed that with the increase in the methanol premixing ratio, the NOx and soot emissions were decreased, while the HC and CO emissions were raised. However, a greater injection pressure and advanced injection time can improve the BTE and lower the HC and CO emissions. In addition, Panda et al. evaluated the effect of injection technique on the combustion, performance, and emission characteristics of DMDF engines. The results showed that the NOx and soot emissions had good combustion stability and low cycle index. Liang et al. examined the combustion and emission characteristics of diesel-ethanol mixtures. The results revealed that the

BTE could be enhanced, and the NOx and PM emissions could be lowered in the combustion process.

(Chen et al., 2021)have researched he combustion and exhaust characteristics of diesel engine powered with different biodiesel blends. They observed that the fuel-rich area and the maximum in-cylinder temperature of the dual-fuel engines were much lower, leading to a simultaneous reduction in NOx and PM emissions.

2.3 General Characteristics of Diesel

A few characteristics that apply to all diesel fuels are color, density, kinematic viscosity, Sulphur content, flash point, pour point, total acid number, water content, ash content, carbon residue, cetane number, and so on.

- ✓ *Specific gravity and density (ASTM D1298).* The mass to volume ratio of a substance is known as its density. The standard for specific gravity is defined as the density of pure water at 4 degrees Celsius. The density of a substance divided by the density of pure water at the same temperature is known as specific gravity. A hydrometer (Leimco, Range 0.8000 to 0.9000, Serial No.: 809303) is used to measure it. At 60°F, the density was measured and the value was noted.(Pillai & Ansari, n.d.).
- ✓ *Color (ASTM D1500).* Petroleum products' color is a crucial aspect of their quality and can be used to identify contamination. The source of the crude, the refinery processes, and the use of dyes all affect the color of diesel fuel. In the past, regular petrol stations sold clear diesel, or diesel fuel without any coloring added to it.(Pillai & Ansari, n.d.). These days, very small amounts of red, blue, and green coloring dyes are added to diesel to distinguish between different uses. In the United Arab Emirates, all petrol stations sell diesel with a pale green dye added. The diesel sample is compared to standard color discs in the Petroleum Colorimeter (Koehler, light source: Tungsten halogen lamp) to determine ASTM color.
- ✓ *Viscosity (ASTM D445).* The resistance a fluid offers to flow is called viscosity. Usually, it is stated as the amount of time needed for a standard amount of the fluid to pass through a standard orifice at a standard temperature. The fluid is more viscous the higher the value. Viscosity's value is meaningless without the temperature at which it is measured because it varies inversely with temperature. The kinematic viscosity, which

can be measured with a viscometer (Visco den plus, Martechnic, Hamburg, serial no. 2011/0643), is the ratio of the fluid's dynamic viscosity to its density.(Pillai & Ansari, n.d.).

- ✓ *Content of Sulphur (ASTM D4294).* The first feature of diesel fuel that is extensively regulated by law in an effort to reduce exhaust emissions is its Sulphur content. Every refined product, including crude oils, contains Sulphur. Burning diesel fuel releases Sulphur and oxygen (SOx) emissions that are harmful to the environment and human health in addition to lowering air quality. Two of the primary environmental issues associated with Sulphur emissions are particulate matter formation and acid rain. Vehicles emit Sulphur in the form of sulfurate particles (SO4). These particles aid in the production of particulate matter (PM) along with nitrogen oxides (NOx). Over the world, low- and ultra-low-sulfur diesel (500 and 15 ppm) are now used in on-road diesel fuel engines to prevent the negative effects of Sulphur compounds on the environment. Using an Oxford Benchtop Lab X3500 X-ray fluorescence analyzer, the amount of Sulphur in diesel is measured and recorded.(Pillai & Ansari.)
- ✓ *Flash point (ASTM D93).* The lowest temperature at which the oil vapor created by heating it produces a transient in the presence of an ignition source, flame. The engine's ignition characteristics and performance are unaffected by the flash point. It is managed to satisfy safety standards for the handling and storage of fuel. Pensky-Martens Closed Cup Tester (TANAKA Flash point tester, APM-8, serial no: 33626) is used to measure flash point. This test requires a minimum of 75 milliliters. In a closed cup, the sample is stirred and heated gradually and steadily. Periodically, the cup is opened and an ignition source is shifted to cover the top of the cup. The lowest temperature at which the vapors above the liquid ignite due to an ignition source is known as the flash point.
- ✓ *Total acid number (ASTM D 664).* The amount of acid content in the diesel is indicated by the Total Acid Number (TAN). A diesel sample is prepared by dissolving a mixture of toluene, isopropyl alcohol, and water in it. After that, an auto titrator is used to titrate it against a potassium hydroxide solution. The TAN is the quantity of potassium hydroxide needed to counteract one gramme of diesel's acidity. Using a motor-driven dispenser, a stirred reaction vessel, and electrodes that detect the reaction's completion by measuring

the potential difference between two electrodes, the Auto titrator (KEM, Japan, and AT-710B) carries out this analysis.

- ✓ *Water Content (ASTM D 6304).* Because diesel fuel is made from crude oil, it will always include some water in it. Diesel fuel's ability to ignite quickly is significantly impacted by the presence of moisture. Fuels' water content can be determined by utilizing the coulometric and volumetric Karl Fischer titration instruments. Karl Fischer states that the fundamental idea behind the water determination process is the reaction of iodine and water in an alcoholic solution that contains a base and sulphureous acid. Iodine can be precisely added using a piston burette or a coulometric directly produced in the reaction vessel when using the volumetric method. The method used to dose the iodine for the titration is the primary distinction between volumetry and coulometry. All of the diesel samples' water content was determined using a KF volumetric titrator (Kem, Japan, MKV-710B).(Pillai & Ansari.)
- ✓ *Ash content (ASTM D 482).* Diesel fuel ash content can lead to deposits in the combustion chamber and harm the fuel injection system. The technique for calculating the sample's ash content is put inside a crucible, lit, and left to burn. To turn all of the carbon in the carbonaceous residue into carbon dioxide and all of the mineral salts into oxides (ash), the furnace is modified to a temperature of up to 1200 degrees Celsius using a muffle furnace (LSC, casline). After cooling, the ash is weighed. Carbon Residue (10% MCRT) *(ASTM D 4530).* the amount of carbon residue that remains after thermal degradation of a diesel sample. It is primarily thought of as a fuel byproduct that is produced during combustion. Excessive residue concentrations have the potential to harm both the environment and living things. For instance, carbon monoxide is released into the exhaust when diesel is burned and used in a motor vehicle engine. Ramsbottom Carbon Residue (RCR) is the test method used to determine the amount of carbon residue. This test measures the amount of residue that fuel is expected to leave behind. It also aids in determining the fuel's propensity to burn or combust. Conradson Carbon Residue (CCR) and Micro Carbon Residue (MCR) are other ways to calculate residue.(B, 2023) The carbon residue for each diesel sample was measured using a micro carbon residue tester (stanhope-seta). 90% (V/V) of the flask charge should be removed from the samples through distillation. This test method is then used to check for carbon residue in the 10%

of the bottom that remains. An exact amount of diesel is weighed and then heated to 500°C in a controlled manner for a predetermined amount of time in a glass container with an inert (nitrogen) atmosphere. Micro carbon residue, or the carbonaceous-type residue that is still present, is expressed as a percentage of the initial sample**.**(Omar et al., 2017)

- ✓ *Pour point (ASTM D 97).* The lowest temperature at which a petroleum product will start to flow is known as the pour point. Wax and paraffin are found in diesel oil, which solidifies and becomes hazy at lower temperatures and begins to stop the fuel from flowing. The pour point is measured using the Koehler, K46100 Pour Point Apparatus. Paraffin wax crystals are formed by cooling the diesel sample in a cooling bath. The test jar is taken out and tilted to look for surface movement at roughly 9 °C above the predicted pour point, and for each additional 3 °C after that. The jar is held horizontally for five seconds if tilting the specimen does not cause it to flow. The pour point temperature of the corresponding sample is obtained by adding 3 °C to the corresponding temperature in the event that it does not flow.(Jiaqiang et al., 2019)
- ✓ *Cetane number (ASTM D 613).* The cetane number of diesel fuel measures the ignition delay and indicates the speed of combustion. It is measured in a single-cylinder test engine with a variable compression ratio known as the CFR Engine, or cooperative fuel research engine. The reference fuels utilized are blends of alpha methyl naphthalene (CN: 0), which has a long ignition delay, and cetane, which has a very short ignition delay (CN: 100). A diesel test typically yields a cetane number between 30 and 65 (the range for biodiesel is 46–52 CN). The cetane number scale spans from zero to hundred. The above parameters were tested for each of the five diesel samples in accordance with ASTM standard.(Ali et al., 2015)

The torsional vibrations observed in engine systems have showcased unusual phenomena in their oscillations. These outcomes stem from the geometric intricacies of the reciprocating mechanism and can be identified through kinematic and dynamic analyses. Furthermore, the system's inertia fluctuates with crankshaft rotation, impacting the vibrations as evidenced by the influence of friction between the cylinder and piston. Piston slap, a prevalent occurrence in reciprocating engines, stands as a primary factor contributing to the intricate transient vibration responses linked to the induced impacts within the cylinder.

Various aspects of diesel and gasoline engine vibrations have been extensively researched. The sound and vibration stemming from the engine's combustion process can directly impact users. Diesel engine noise and vibrations can pose risks to both the ears and the overall health of users, particularly in engines with high compression ratios and rapid combustion pressures. Numerous experiments have been conducted on the vibration of cylinder blocks in diesel and gasoline engines. Factors such as injection timing, number of injections, and fuel quantity greatly influence cylinder block vibration in diesel engines. An investigation involving spectrum analysis examined the impact of cooling water temperature on engine vibration, revealing that reducing the water temperature leads to an increase in mean vibration frequencies between 500 and 2000 Hz, underscoring the need for precise temperature control. Additionally, piston slap is a significant contributor to engine cylinder block vibration, while valve malfunctions in diesel engines can also escalate vibration levels (Taghizadeh-Alisaraei et al., 2012)

2.4 Research Gap

While there is existing research on engine vibration characteristics and studies on individual fuel types, there is a lack of comprehensive comparative analysis specifically focused on comparing diesel fuel to diesel-methanol fuel blends. The research gap lies at the absence of in-depth investigations that directly compare the vibration behavior between these two fuel types, considering parameters such as amplitude, frequency, and distribution. Although there is some research available on the effects of methanol as an addition in diesel fuel, there is still a research gap in understanding its specific influence on engine vibration characteristics. The existing literature often focuses on emissions, combustion, and performance aspects, whereas the engine vibration remains relatively unexplored.

Another research gap lies in the specific examination of different methanol concentrations in diesel-methanol fuel blends and their effect on engine vibration characteristics. The literature may lack detailed investigations that systematically explore the effects of varying blend ratios and the corresponding changes in vibration parameters. While some studies may touch upon the relations between fuel properties, combustion characteristics and engines vibration, there is often an incomplete correlation analysis between these factors (Taghizadeh-Alisaraei et al., 2012).

By addressing these research gaps, the study can contribute can provide insights into the specific effects of fuel composition and blend ratios on engine vibration, bridging the existing knowledge gap and informing future research and development in the field.

Table 2.3. summary of the literature review

Authors	Approach	Key findings	Parameter
Ali, O. M., Mamat, R., Najafi, G., & Yusaf, T. (2015	Statistical Analysis and Response Surface Methods	Optimization of Biodiesel-Diesel Blended Fuel Properties and Engine Performance with Ether Additive	Fuel properties and engine performance
Aydin, H., & Bayindir, H. (2010)	Experimental Study	Exhaust emissions of a partially loaded compressed ignition engine fueled with biodiesel derived from cottonseed oil	Exhaust emissions
B, O. B. B. (2023)	Comparative Experimental Study	Performance and emission characteristics of a diesel engine fueled with Tung	Performance and emissions
Campos-Fernández, J., Arnal, J. M., Gómez, J., & Dorado, M. P. (2012)	Experimental Study	Performance of higher alcohols/diesel fuel blends in a diesel engine	Performance
Chockalingam, S., & Ganapathy, S. (2012)	Experimental Study	Performance and emission analysis of a single cylinder constant speed diesel engine fueled with diesel-methanol-isopropyl alcohol blends	Performance and emissions
Chockalingam, S. R., Kumar, M., & Pauldoss, P. (2017)	Experimental Study	Effective application of ethanol in diesel engines	Engine performance and emissions
Erdiwansyah, E., Sani, M. S., Mamat, R., Khoerunnisa, F., Rajkumar, A., Razak, N. F. D., & Sardjono, R. E. (2018)	Review	Vibration Analysis of the Engine Using Biofuel Blends	Engine vibration
Huang, J., Xiao, H., Yang, X., Guo, F., & Hu, X. (2020)	Experimental Study	Effects of methanol blending on combustion characteristics and various emissions of a diesel engine fueled with soybean biodiesel	Combustion characteristics and emissions
Jiaqiang, E., Liu, G., Zhang, Z., Han, D., Chen,	Thermodynamic Mode	Cold starting performance enhancement of a diesel engine fueled with biodiesel fuel	Cold starting performance

J., Wei, K., Gong, J., & Yin, Z. (2019)			
Li, Z., Wang, Y., Geng, H., Zhen, X., Liu, M., Xu, S., & Li, C. (2019)	Experimental Study	Parametric study of a diesel engine fueled with directly injected methanol and pilot diesel	Engine performance and emissions
Ma, Y., Huang, S., Huang, R., Zhang, Y., & Xu, S. (2017)	Experimental Study	Ignition and combustion characteristics of n-pentanol-diesel blends	Ignition and combustion characteristics
McCormick, R. L., Graboski, M. S., Alleman, T. L., Herring, A. M., & Tyson, K. S. (2001)	Experimental Study	Impact of biodiesel source material and chemical structure on emissions of criteria pollutants from a heavy-duty engine	Emissions of criteria pollutants
Omar, F. K., Selim, M. Y. E., & Emam, S. A. (2017)	Experimental Study	Time and frequency analyses of dual-fuel engine block vibration	Engine block vibration
Örn, J. (2014	Guideline	Vibration guideline for large diesel engines	Vibration guidelines
Pillai, S., & Ansari, T	Comparative Study	Comparative Studies of Diesel Fuel Properties with Biodiesel and Recycled Diesel	Diesel fuel properties

CHAPTER THREE

METHODS AND MATERIALS

3.1 Introduction

To find out what happens when methanol is added to diesel engine fuel, an experiment called "Experimental Analysis on Performance, Emission, and Vibration Characteristics of a Diesel/Methanol Fueled Engine" is conducted. A thorough explanation of the supplies and techniques used in the experimental investigation is provided in this section. Because they can improve engine performance, lower emissions, and diversify fuel sources, alternative fuels have drawn a lot of attention to internal combustion engine use. The addition of methanol to diesel fuel has demonstrated potential because of its high-octane rating, favorable combustion characteristics, and reduced emissions when compared to traditional hydrocarbon fuels. Nevertheless, in order to assess how diesel-methanol blends affect engine performance, emissions, and vibrations, a thorough experimental analysis is required.

A diesel engine was chosen as the test platform for this investigation, and its fuel system was altered to allow methanol to be added to the combustion process. Using various diesel-methanol blends, the engine's performance, emissions, and vibrations were assessed through a battery of controlled tests conducted within the experimental setup. The diesel engine, methanol fuel, and a number of measurement and data collection tools and sensors were the materials used in the experimental analysis. The engine specs, including displacement, cylinder count, and maximum power rating, were recorded to give a clear picture of the test engine's features.

To accommodate the addition of methanol, changes were made to the engine's fuel system. In order to guarantee the regulated delivery of the diesel-methanol blends, these modifications included the installation of fuel injectors, pressure regulators, and fuel storage systems. Diesel and methanol were blended in different ratios to prepare test fuels, and the mixing process had to be carefully carried out to produce blend compositions that were reliable and accurate. Throughout the experiments, a variety of sensors and instruments were used to measure and keep an eye on a number of parameters. These included vibration (such as amplitude and frequency spectrum analysis), emissions (such as CO, NOx, and particulate matter concentrations), and engine performance (such as brake power and torque). The selection of the instruments was predicated upon their calibration, accuracy, and suitable measurement ranges procedure.

3.2 Methodology

This study aims to conduct an experimental analysis on a diesel/methanol fueled engine to investigate its performance, emission, and vibration characteristics. The methodology begins with an extensive review of existing literature on dual-fuel engines, focusing on studies related to performance, emissions, and vibrations. Subsequently, a suitable diesel engine is selected for the experimental analysis, considering factors such as size, power output, and availability. The chosen engine is then modified to enable dual-fuel operation with diesel and methanol, incorporating necessary components like injectors, fuel lines, and control systems. Rigorous fuel preparation is conducted by procuring high-quality diesel fuel and methanol, followed by fuel characterization tests to ensure compliance with required specifications. A range of fuel blend ratios is developed by systematically varying the proportion of diesel and methanol.

For instance, the experiment was conducted at Addis Ababa science and technology university.
For the experimental setup, appropriate sensors, transducers, and data acquisition systems are installed to measure relevant parameters. Instrumentation is set up to capture engine performance parameters, emissions, and vibration characteristics. Calibration and validation of measurement equipment are performed to ensure accurate and reliable data collection. A series of controlled experiments is designed, considering engine load, speed, and fuel blend ratios as variables. A standardized testing procedure is implemented to ensure consistency and reproducibility. During the experiments, measurements of engine performance parameters such as power output, torque, fuel consumption are collected and thermal efficiency is calculated. Exhaust emissions including nitrogen oxides (NOx), carbon monoxide (CO), carbon dioxide (CO2), and particulate matter (PM) are also measured. Additionally, engine vibrations are captured using VIBEXPERTEX.

A comparison is made between the performance, emissions, and vibration characteristics of the diesel/methanol-fueled engine and a conventional diesel-fueled engine. The results obtained from the analysis are presented in an organized manner using tables, graphs, and charts. The observed effects of methanol fuel on the engine's performance, emissions, and vibration characteristics are discussed, and interpretations are provided to offer insights into the impact of different fuel blend ratios on the engine's behavior. Future research directions in the field are also highlighted. In general, this section outlines the methodology employed in the research, including the experimental setup, fuel blend preparation, data collection, and analysis techniques.

Figure 3.1: Making the experimental set up and checking the device for the experiment at AASTU laboratory with the technicians

The flowchart which is a diagrammatic representation of the steps that are going through is shown in the following figure 3.2. more importantly this flow chart provides a breakdown of the essential steps to the stated experimental analysis. In this experimental process, if the collected data from previously existing literatures and the experimental results are inline with, depending on the flow chart the path follows yes and directly delves in to results and discussion. If the experimental result is contradictory with existing data, the path will follow no and turns back to experimental design part.

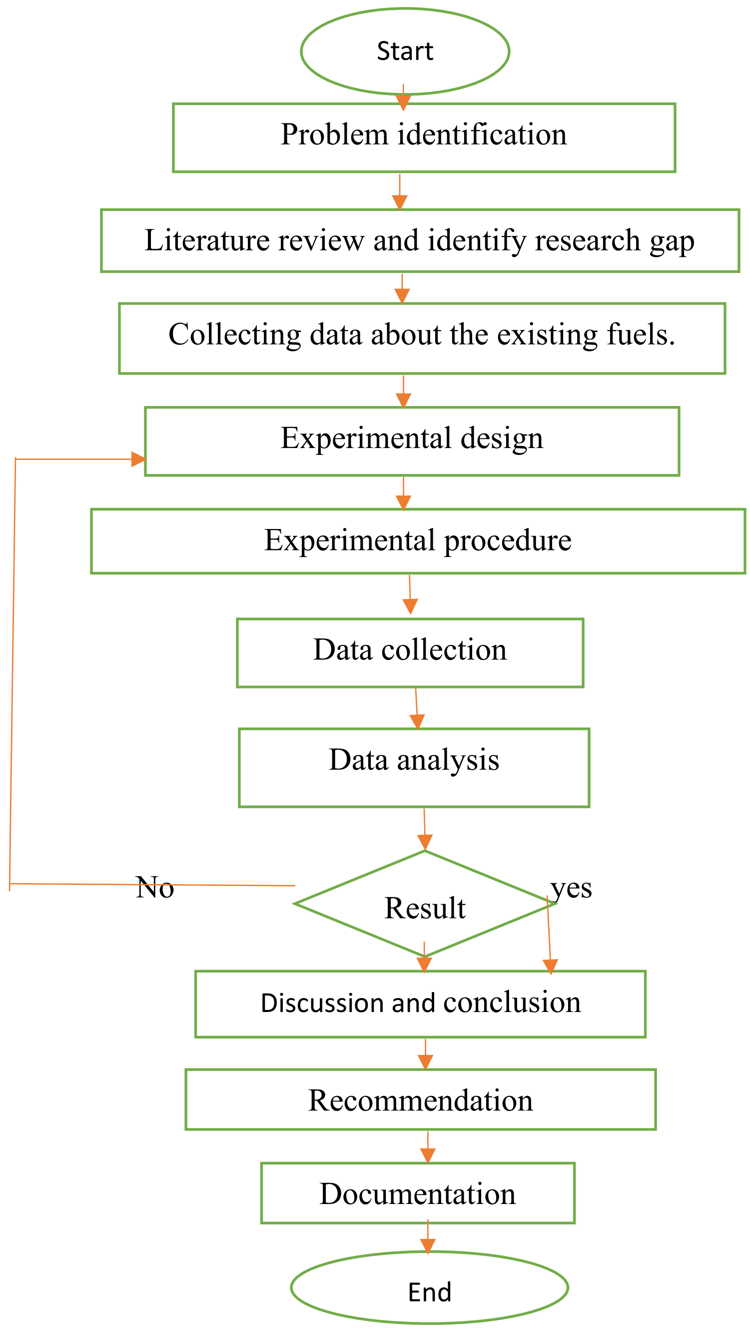


Figure 3.2: Flowchart of the methodology

3.3 Materials

3.3.1 Test Engine

The selected engine is TM3-02 air-cooled, four-stroke, single-cylinder diesel test engine. Here is a description of its key features and specifications:

- ✓ *Type*: The TM3-02 is a single-cylinder diesel engine, meaning it has a single combustion chamber where the fuel is burned.
- ✓ *Cooling System*: It features an air-cooling system, which uses airflow to dissipate heat generated during engine operation. This eliminates the need for a separate liquid cooling system, simplifying the engine design and reducing maintenance requirements.
- ✓ *Stroke Cycle:* The engine operates on a four-stroke cycle, which includes intake, compression, combustion, and exhaust strokes. This cycle allows for more efficient power generation and reduced emissions compared to two-stroke engines.
- ✓ *Displacement*: The displacement refers to the total volume swept by the piston during its movement inside the cylinder. The TM3-02 may have a specific displacement value, such as 250cc or 500cc, which determines the engine's power output potential.
- ✓ *Fuel System*: The engine is equipped with a fuel injection system. Depending on the specific model, it might employ direct injection or indirect injection technology. Fuel injectors precisely deliver fuel into the combustion chamber according to the engine's operating conditions, ensuring efficient combustion.
- ✓ *Ignition*: As a diesel engine, the TM3-02 relies on compression ignition rather than spark ignition. The high compression ratio generates enough heat to ignite the air-fuel mixture without the need for a spark plug.
- ✓ *Power Output*: The power output of the TM3-02 can vary depending on its specific configuration and tuning. It is typically measured in horsepower (HP) or kilowatts (kW). The power output is influenced by factors such as engine displacement, compression ratio, and fuel injection system efficiency.
- ✓ *Applications*: The TM3-02 diesel engine is commonly used as a test engine in research and development settings. It serves as a platform for conducting experiments, evaluating fuel and additive performance, studying combustion characteristics, and assessing engine parameters.

Figure 3.3: the engine used for the experiment

Additionally, the TM3-02 includes additional features such as an electric starter motor, lubrication system, air filtration system, and exhaust system for emissions control.

Table 3.2: Test engine specification and experimental conditions (Iliev & Mitev, 2019).

TM3-02. Air-cooled.	Single-cylinder Four-stroke diesel
Bore (mm)	69
Stroke (mm)	60
Speed(rpm)	3600
Power (kW) Hp	3.5(4.8); N 180/1269/EEC-ISO 1585
Maximum torque	10.4 Nm at 2400rpm

3.3.2 VIBXPERT II FFT Data Collector & Signal Analyzer

High-quality vibration sensors capable of measuring engine vibrations accurately. specifically, VIBEXPERT with tachometer is used in measuring the vibration of the Engine. It is a product manufactured by PRÜFTECHNIK, a company specializing in condition monitoring and reliability solutions. some the general features of the device include: Vibration Measurement, Frequency Range, FFT Analysis, Data Collection, Data Storage, Signal Analyze, Balancing and Alignment, Display and Interface and so on.

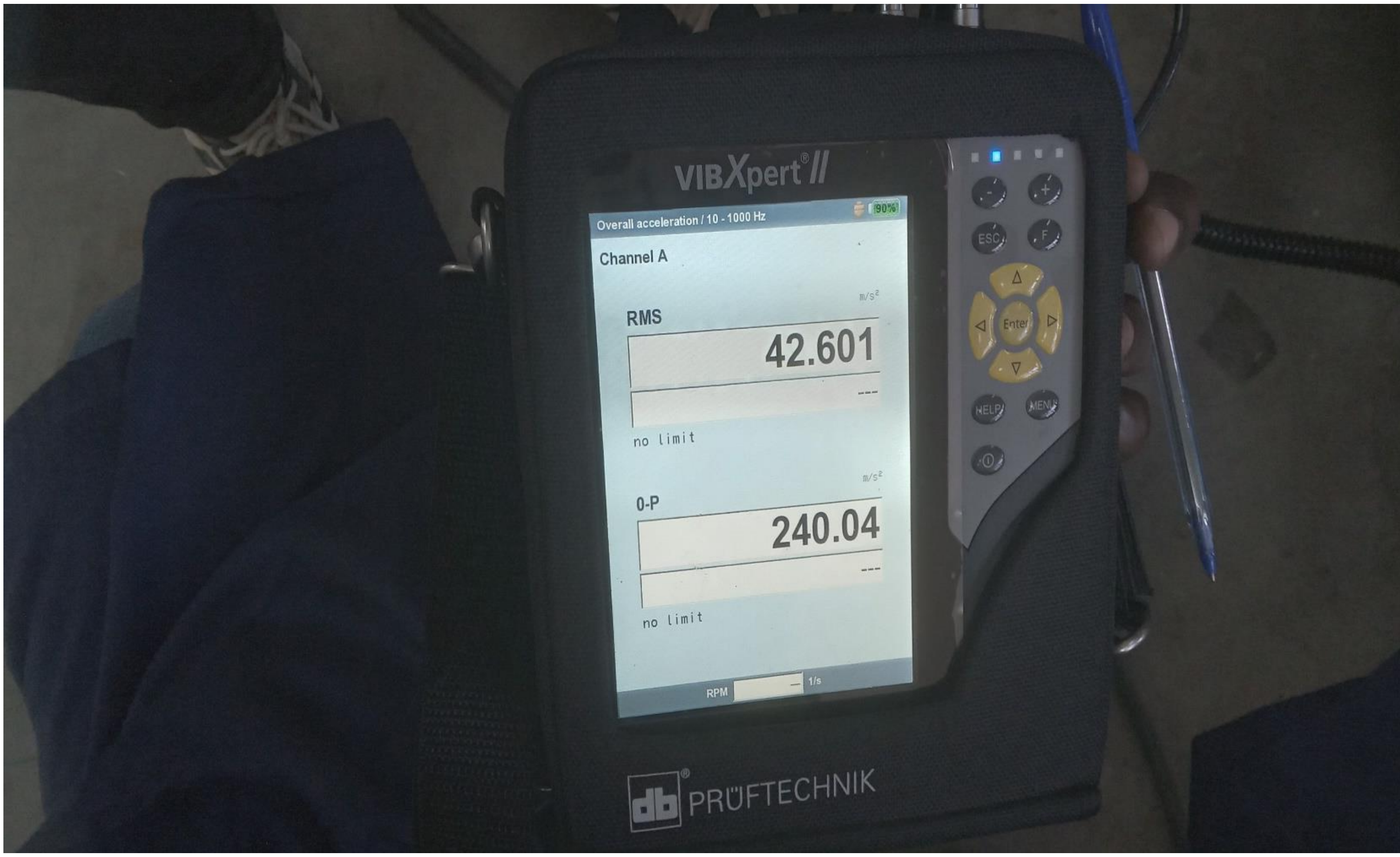


Figure 3.4: VIBERTEX used for vibration measurement

Figure 3.5: Description of the VIBERTEX used for the experiment

Description of its main parts VIBEXPERTEX

1. Full color display
2. Light sensor controls key board illuminations
3. LEDs indicate
   - ✓ Alarm condition
   - ✓ Measurement error
   - ✓ Battery charge status
4. Thumb keyboard
5. A/B measuring channels
6. Temperature
7. Digital input
8. Communication via internet.

Table 3.3: Specifications of the vibration measuring device (Guo et al., 2011)

	PARAMETER	VIB 5.310
Input Channels	Analog, 2x	Voltage (AC/DC, ±30 V max.) Current (AC/DC, ±30 mA max.) ICP-type accelerometer (2 mA, 24 V max.) Current Linedrive (CLD) accelerometer (10 V, 10 mA max.)
	Frequency range	DC ... 51.2 kHz (Acceleration from 0.5 Hz)
	Dynamic range	96 dB (measurement) / 136 dB (total)
	Sampling frequency	up to 131 kHz per channel
	Impedance	90 kOhm, w/ cable VIB 5.433
	Analog, 1x	Thermocouple (type K)
	Digital (1+1 Pulse/ Tacho), 1x	RPM, Trigger, Keyphaser with pulse and AC signals: 0 V ... +26 V or -26 V ... 0 V
	Max. input voltage	± 26 V
	Switching threshold for 0 V ...+26 V signal	max. 2.5 V rising, min. 0.6 V falling
	Switching threshold for -26 V ...0 V signal	min. -8 V rising, max. -10 V falling
	Pulse width	< 0.1 ms
Output Channels	Stroboscope control	TTL output
	Frequency range	0 ... 500 Hz
	Resolution	0.05 Hz
	Signal-Out	Connection for headphones to listen to the analog input signal; signal processing (oscilloscope)
	Frequency range	0.5 Hz ... 40 kHz
	Output impedance	100 Ohm
Meas. range / Accuracy	Vibration acceleration	depends on the transducer connected
	Shock pulse	-10 ...80 dBsv / ± 3dBsv
	RPM	10 ... 200 000 min^{-1} / ±0.1‰ or ± 1 min^{-1} (the lower accuracy is applicable)
	Temperature type K	-50 ... +1000°C / 1% or ±1°C (the lower accuracy is applicable)
	Standards fulfilled	Frequency response according to ISO 2954
Display	Type	TFT-LCD, backlit
	Pixel area	116 x 87 mm
	Resolution	VGA (640 x 480 pixel) with 140 ppi
	Color depth	18 bit (262144 colors)
Power supply	Battery type	Li Ion rechargeable battery pack (7.2V / 4.8Ah - 34 Wh)
	Charging time	< 5 hours in the device or external with optional charging station
	Charger, input	110-240 V / 50-60 Hz
	Charging temperature	0°C ... +50°C
Computer	Processor	Marvell PXA320 806 MHz
	Keyboard	1 navigation pad and 7 keys (Zoom, Escape, Function, Help, Menu, On/Off); Keyboard illumination controlled by ambient light.
	Memory	Internal: 128 MB DDR RAM; Compact Flash: 2 GB ... 8 GB
	Serial interface	RS 232, <115 kBaud
	USB interface	USB host for printing; USB slave for data exchange with OMNITREND
	Ethernet interface	100 Mbit (100Base T), 10 Mbit (10Base T)
	Printing	Direct printing of measurement reports via the USB port Compatible printer types: HP, Epson and other printers with USB connection
Environment / General	Connectors	Analog / Digital channels: MiniSnap socket Thermocouple (type K): QLA socket; all compatible to VIBSCANNER
	Housing	ABS plastics
	Dimensions	186 x 162 x 52 mm (LxWxH)
	Weight	approx. 1.1 kg
	IP rating	IP65, dust and splash-proofed
	Temperature range	-10°C ... +60°C (Operation) -20°C ... +60°C (Storage)

3.3.3 Diesel Fuel

Diesel fuel that meets the required specifications and standards as shown in the following table 3.4 was used for the experiment (Dey et al., 2021).

Specifications	Diesel
Chemical formulas	$C_{10.8}H_{18.7}$
Mole weights (g)	148.3
Densities (g/cm^3 at 20ºC	0.84
Boiling points ºC	180-330
Heat of evaporations (KJ/Kg)	280
Lower heat values (MJ/Kg)	42.5
Liquid viscositie (cP at 20ºC)	3.03
Surface tension (mN/m at 20ºC)	34.1
Flash points (ºC)	78
Stochiometric air-fuel ratio	14.4
Cetane number	49
Auto-ignitions (ºC)	235
Carbon contents (wt%)	87.4
Oxygen contents (wt%)	0

Figure 3.6: Pure diesel fuel used for the experiment

3.3.4 Methanol

Methanol, which is the most basic form of alcohol with the molecular formula CH3OH, serves as a fundamental component in numerous common items such as plastics, paints, automotive components, and construction materials. Methanol is a versatile fuel that may be used to power various vehicles and appliances, such as cars, trucks, buses, ships, fuel cells, boilers, and cook stoves. It is also considered a clean energy resource. The diesel-methanol fuel blends utilize a mixture of 99% methanol and diesel fuel.

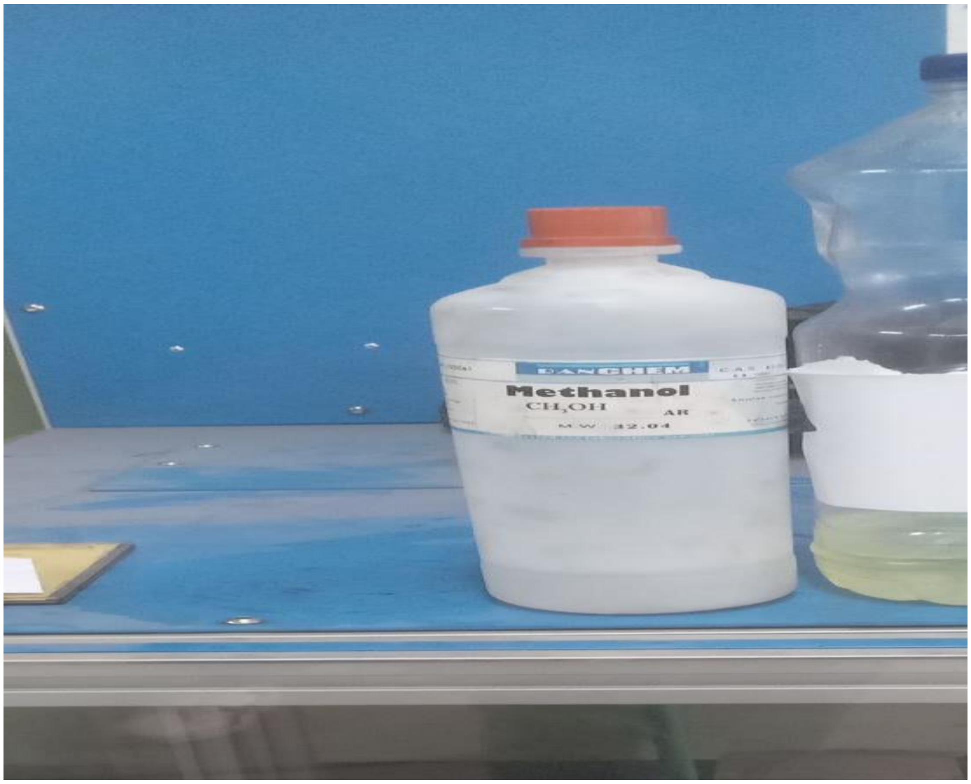


Figure 3.7: 99% methanol fuel used for the experiment

Table 3.4: Chemical properties of methanol (Iliev & Mitev, 2019)

Density	kg/m^3	796.0
Boiling points	k	338.0
Lower heating values	MJ/Kg	19.670
Stoichiometric air-fuel ratios	-	6.450
Heat of evaporations	KJ/Kg	1100.0
Viscosity	cSt	0.65
Auto ignition temperatures	K	736.0
Carbon content by mass	%	37.50

Hydrogen content by mass	%	12.50
Oxygen content by mass	%	50.0
Specific carbon dioxide emission	g/MJ	68.440

Fuel Blending and preparation

Here's an outline of the steps involved in fuel blending and preparation for the experimental analysis:

- ✓ *Selection of Diesel and Methanol*: The specific types of diesel and methanol fuels to be used in the study were determined. Which was done by Considering factors such as fuel quality, availability, and compatibility with the engine and experimental setup.
- ✓ *Fuel Property Analysis*: A comprehensive analysis of the properties of the diesel and methanol fuels, including characteristics such as density, viscosity, flash point, cetane number (for diesel), and methanol content (for methanol) were performed.
- ✓ *Blend Ratio Determination*: The desired blend ratio of diesel to methanol based on the research objectives and the range of blends to be investigated were determined. such as 10%, 20%, denoting the proportion of methanol in the blend.
- ✓ *Fuel Mixing*: The diesel and methanol fuels in the determined proportions to create the desired blend were mixed. Which is done by measuring the volumes of each fuel component and thoroughly mixing them in a suitable container.
- ✓ *Fuel Homogenization*: The blend halogenation to achieve a consistent mixture were ensured. This was achieved by stirring blend to ensure that the diesel and methanol are uniformly distributed.
- ✓ *Fuel Handling and Storage*: The blended fuel handled with care, following appropriate safety protocols. The fuel stored in a suitable container that preserve its quality and prevent contamination.
- ✓ *Fuel Delivery to the Engine*: A proper fuel was delivered to delivery system that allows controlled and precise injection of the blended fuel into the engine.

Figure 3.8: During blend preparation and conducting the experiment

CHAPTER FOUR

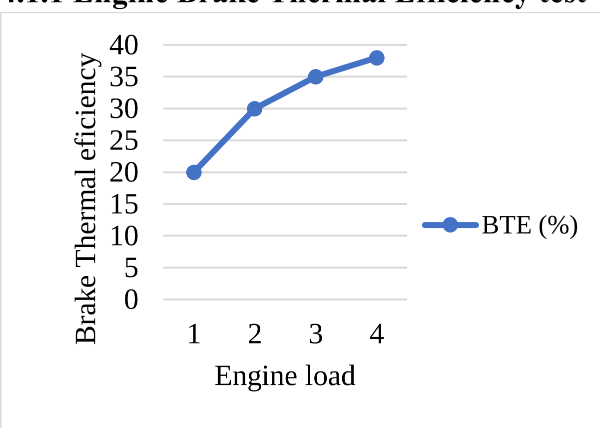
RESULTS AND DISCUSSION

4.1 Performance analysis

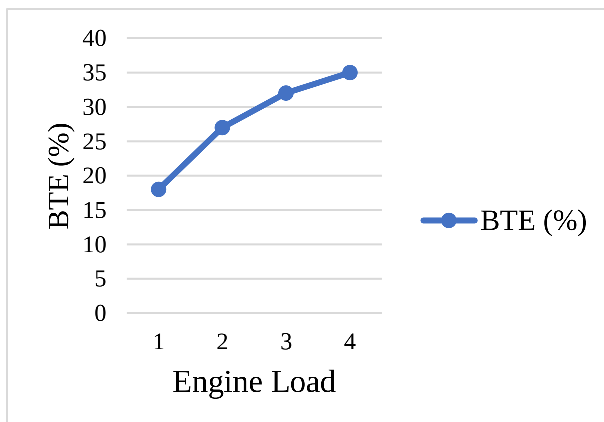
Diesel engines have long been a cornerstone of various industries, powering a wide range of vehicles and machinery. Analyzing the performance of diesel engines is crucial for understanding their efficiency, reliability, and overall effectiveness in meeting the desired power requirements. Performance analysis involves assessing various parameters and characteristics of the engine to evaluate its operational efficiency, fuel consumption, emissions, and power output.
Performance analysis is crucial in optimizing the evaluation of diesel engines, identifying areas for improvement, and ensuring compliance with environmental regulations.

Here below are the experimental data and graph that shows diesel engine performance at various load without and with blend.

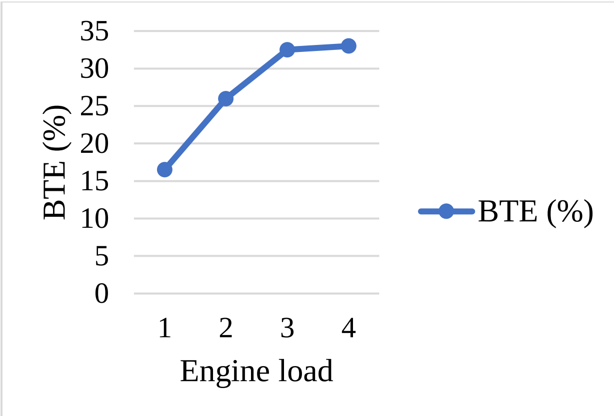
4.1.1 Engine Brake Thermal Efficiency test



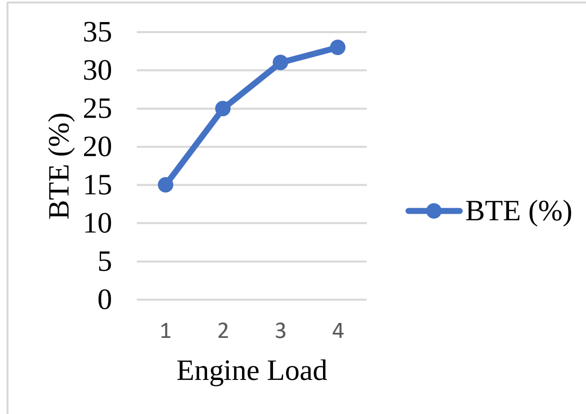
(a)



(b)



(c)



(d)

Figure 4.1 (a), (b), (c) and (d) shows the results of brake thermal efficiency variations with pure diesel, M10%, M20% and M30% respectively.

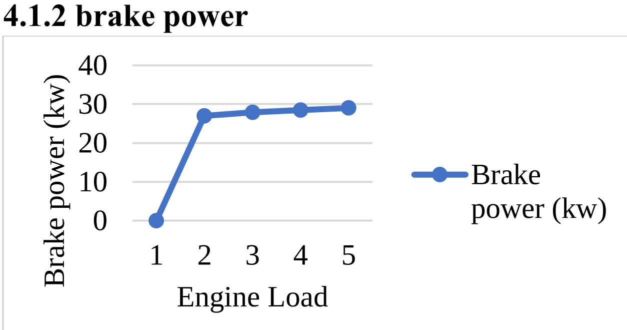
Brake thermal efficiency is a term commonly used in the context of internal combustion engines to describe how effectively an engine converts the energy from fuel into useful work output.

Mathematically, brake thermal efficiency (η_{th}) is defined as:

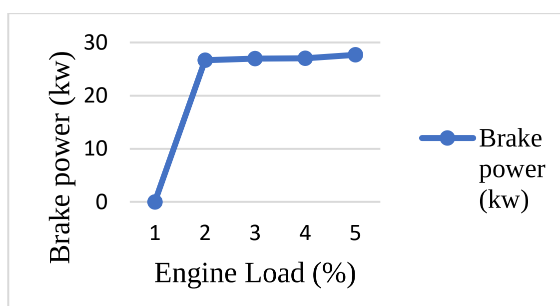
$$\eta_{\text{th}} = \frac{\text{Brake Power Output}}{\text{Fuel Power Input}} \times 100\%$$

The brake thermal efficiency of several combinations of diesel and methanol fuel at different load circumstances are shown in Figures (12a–12d). As the concentration of methanol in the fuel blend grew, the brake thermal efficiency (BTE) also improved. The brake thermal efficiency (BTE) of the engine improves when the concentration of methanol in diesel-methanol blended fuel is increased, because methanol's oxygen content increases fuel combustion efficiency and enhances spray characteristics. This experimental result is in line with (Chen et al., 2021).

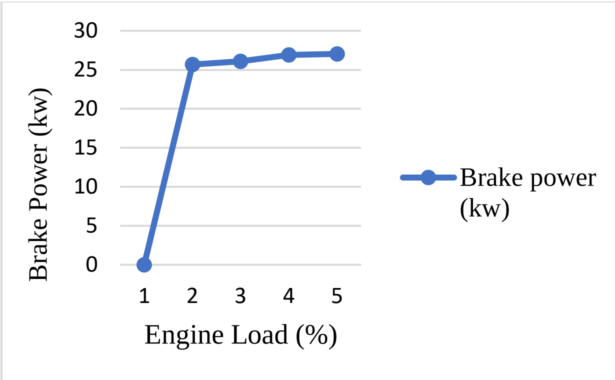
4.1.2 brake power

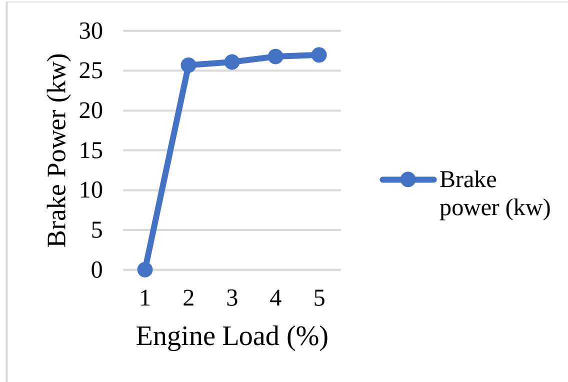


(a)



(b)



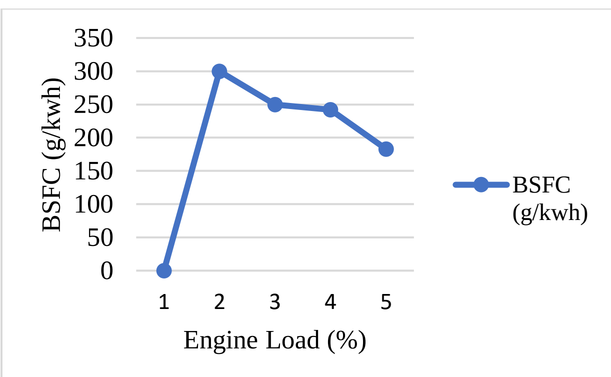


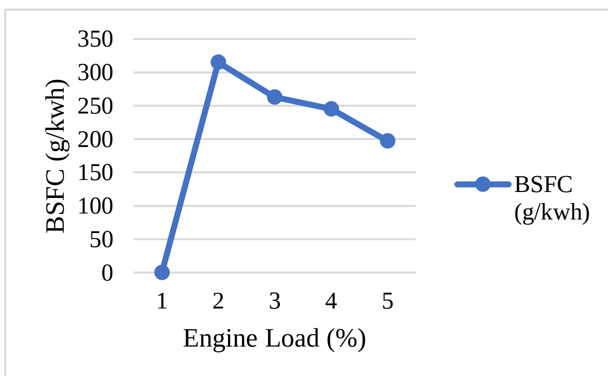
(c)

(d)

Figures 4.1.2 (a, b, c and d) displays brake power for multiple mixtures of diesel fuel and methyl fuel with varied conditions of load. The brake power progressively declined as the combined fuel's methanol content climbed. Furthermore, the loss in brake power is exactly proportional to the amount of methanol included in the blended fuel. The power of mixed fuels D90M10, D80M20, and D70M30 was lower compared to that derived from pure diesel fuel by 2.76%, 5.04%, and 8.08%, respectively. This is why the combined fuel has a lower calorie content than pure diesel, which means that it will burn with less power than diesel. Research has also suggested that the rise in the ratio of methanol resulted in a drop in the engine's power performance. Which is also stated by (Mohanty et al., 2011).

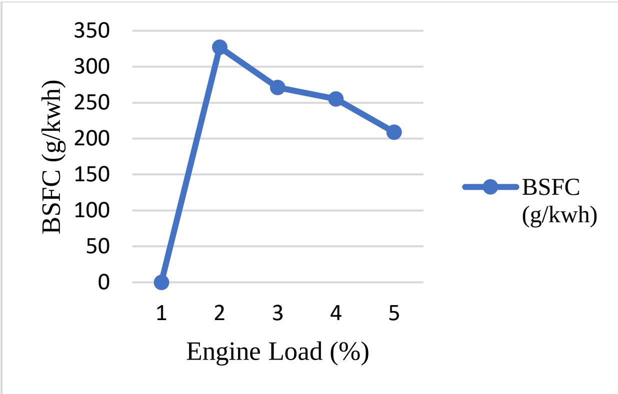
4.1.3 The brake specific fuel consumption

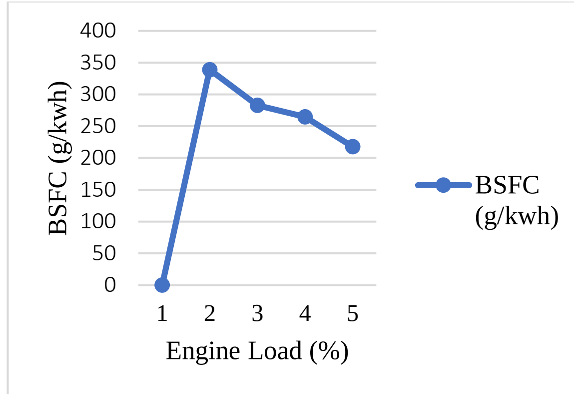




(a)

(b)



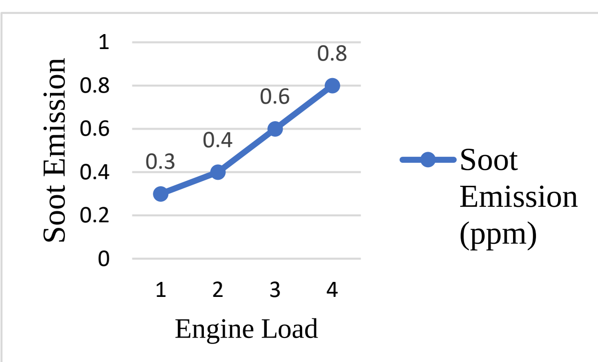


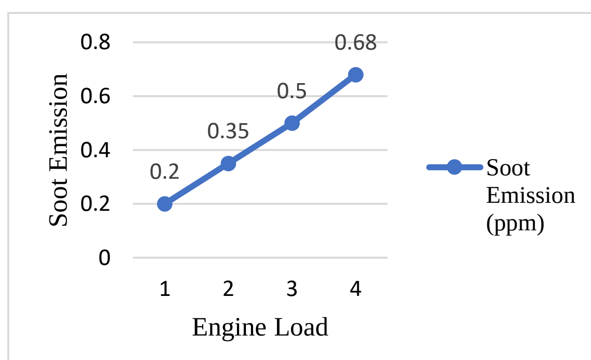
(c) (d)

The Brake specific fuel consumption (BSFC) is a critical measure to determine an engine's economic attributes. The engine's economy improves with reducing fuel usage. Under varied load situations, the BSFCs of various percentages of blended diesel and methanol fuel are illustrated in Figures 4.1.3 (a, b, c and d). It is apparent that as the percentage of methanol in mixed fuel raised, so did the fuel consumption of diesel engines. For instance, at 15% load and pure diesel engine fuel, the BSFC was 300.19 g/(kWh). The highest cylinder temperatures of (D100), (D90M10), (D80M20), and (D70M30) had BSFCs of 315.37 g/(kWh), 327.06 g/(kWh), and 339.16 g/(kWh) respectively. This is owing to the fact that methanol has a substantially lower calorific value (19.1 MJ/kg) than diesel (41.5 MJ/kg). A rise in BSFC is the effect of the mixed fuel's overall calorific value being decreased due to the greater methanol content. This result also agreed with the findings of (Hasan et al., 2021)

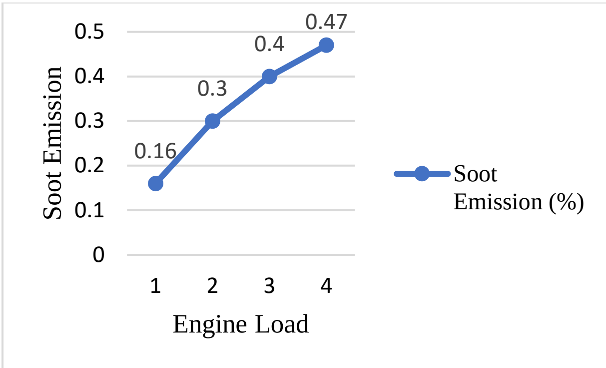
4.2 Emission analysis

4.2.1 Soot Emission

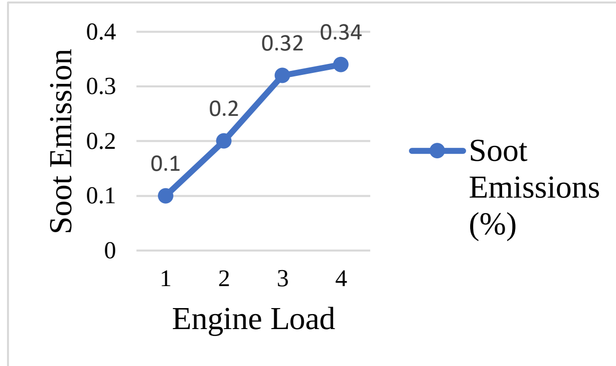




(a) (b)



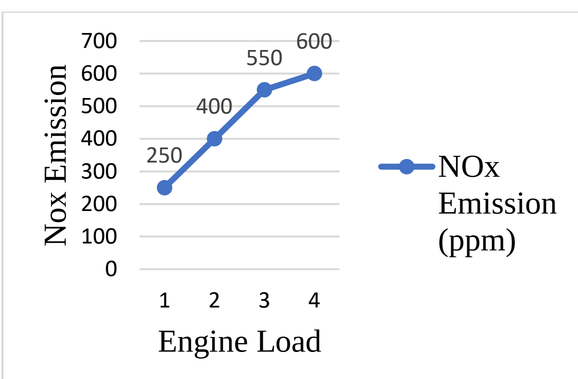
(c)



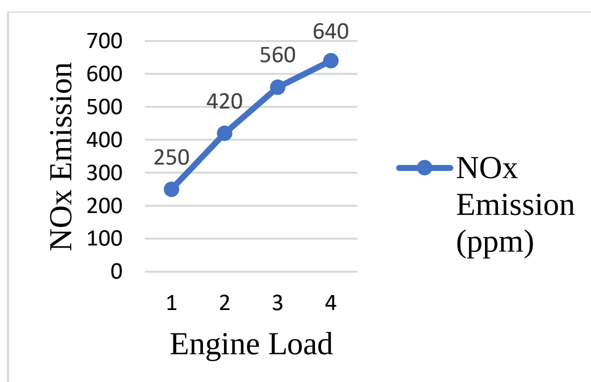
(d)

As we can understand from Figure 4.2.1(a, b, c and d), the use of diesel/methanol blends has shown promising characteristics in reducing soot emissions. When methanol is blended with diesel fuel, it introduces a greater oxygen content, that helps in complete combustion. The presence of methanol leads to improved atomization and fuel vaporization mixture, resulting in better fuel-air mixing. This enhanced mixing promotes a more efficient and homogeneous combustion process, reducing the formation of soot particles. Additionally, methanol's higher cetane number enhances diesel fuel's ignition properties, leading to shorter ignition delays and lower soot formation. The blending of diesel with methanol can thus be an effective strategy to mitigate soot emissions and improve the overall environmental performance of diesel engines.

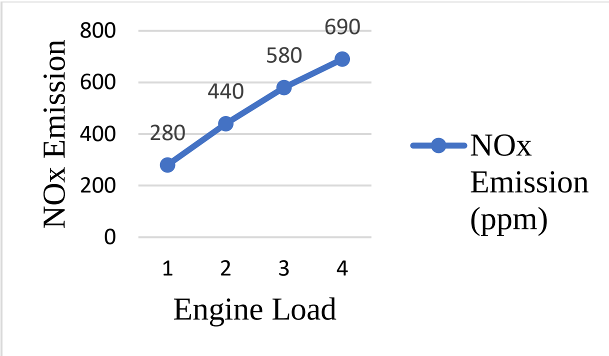
4.2.2 NOx Emission



(a)



(b)



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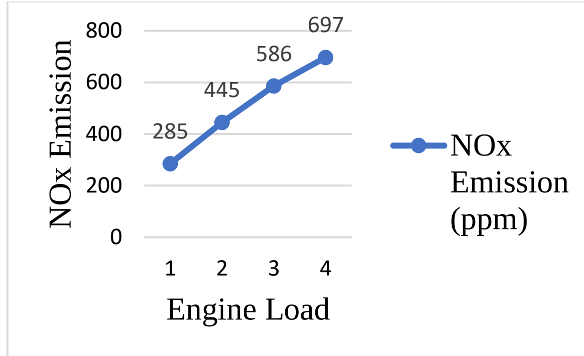
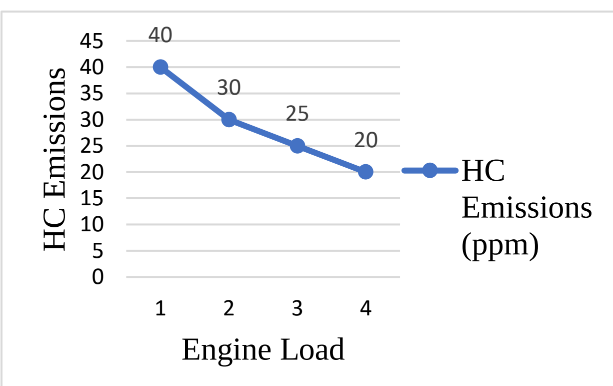


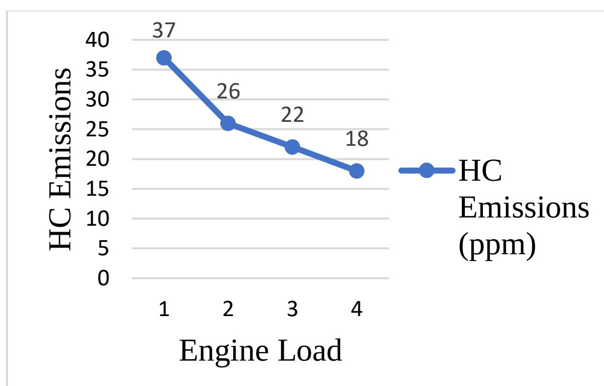
(d)

The nitrogen oxides (NOx) emissions of diesel-methanol mixed fuels having varied fractions over various load situations are illustrated in Figures 4.2.2(a, b, c, and d). As engine load increased, so did NOx emissions. The temperature of the cylinder will rise in accordance with an increase in engine load. High temperatures enhance NOx production. Furthermore, as the percentage of methanol in the blended fuel grows, so does the quantity of NOx emitted. This is because the increased methanol's oxygen concentration favors better burning. Similar to pure diesel, blended diesel has a lower cetane content than pure diesel, which causes already mixed combustion and an increase in ignition time for delay. Further NOx thus will be created. This is also stated by (Chen et al., 2021)

4.2.3 Hydro Carbon (HC) Emissions



(a)



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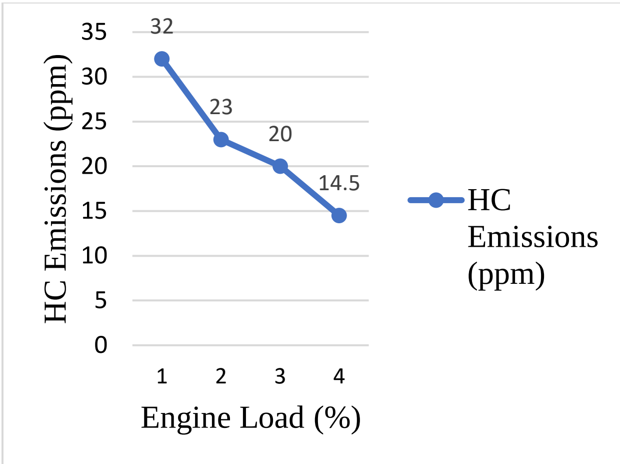

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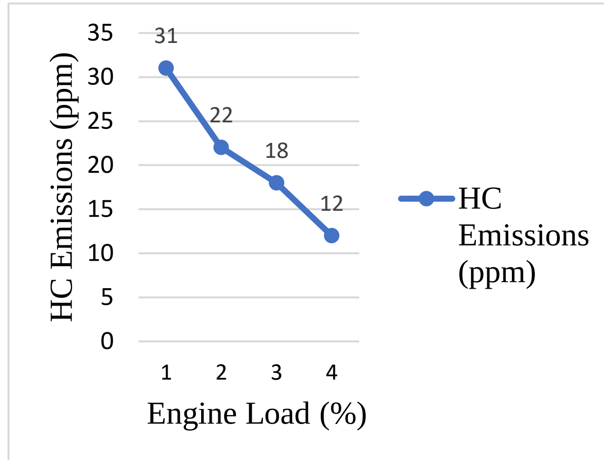
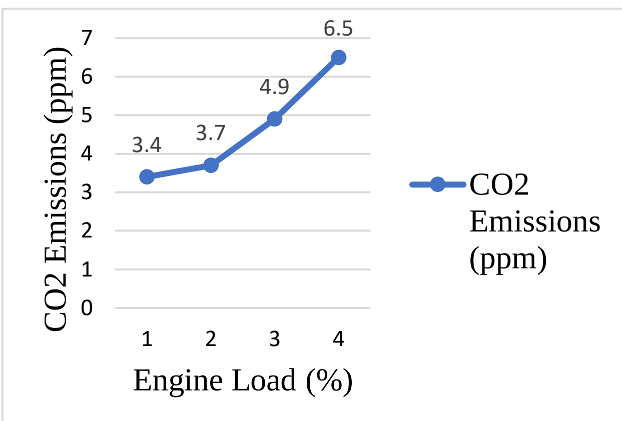
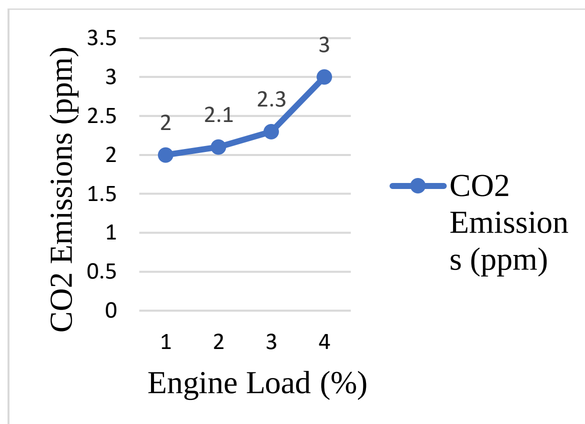


(d)

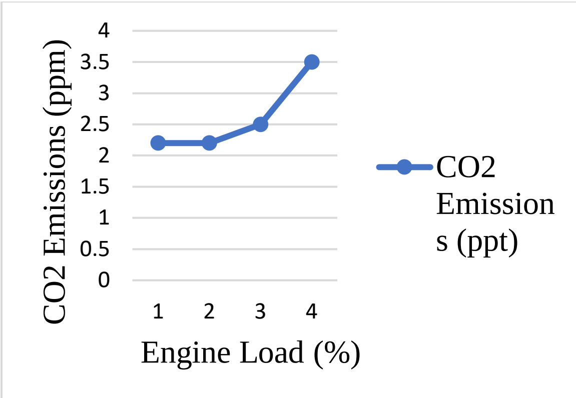
4.2.4 CO_2 Emissions

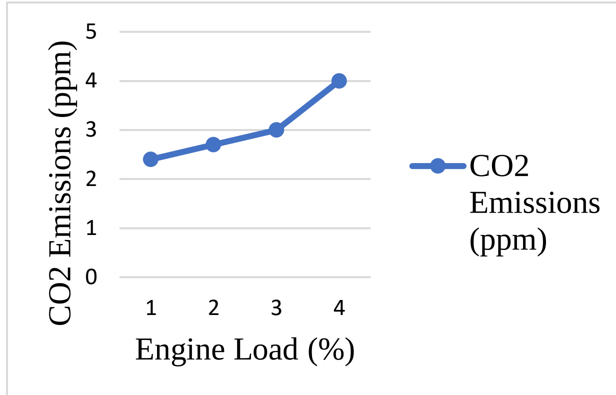


(a)



(b)

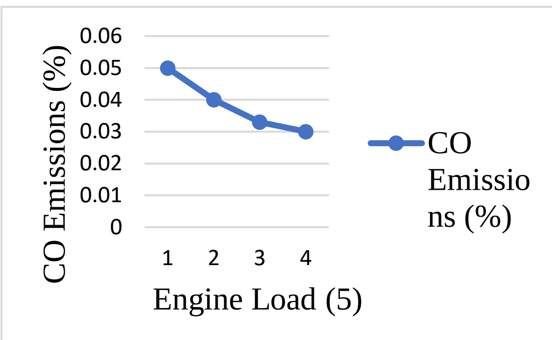


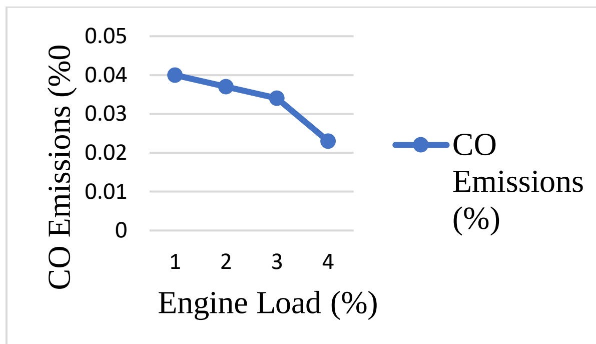


(c) (d)

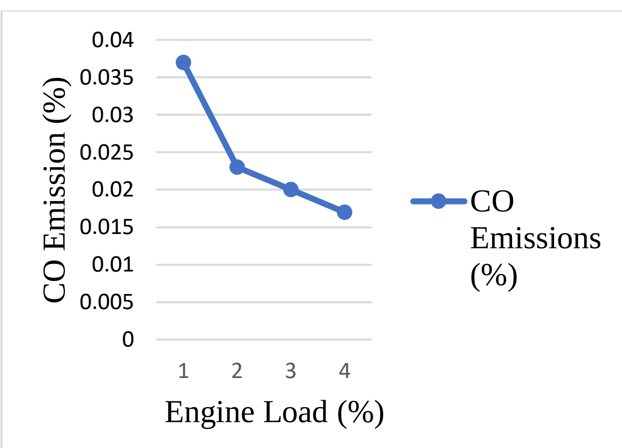
4.2.5 CO Emissions

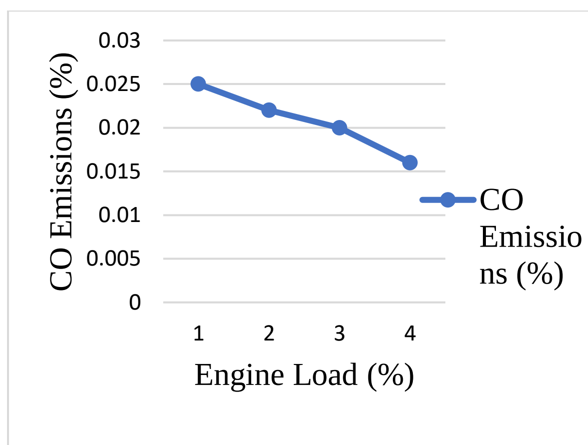
Test 1&2: CO emissions with (0%M) left and (10%M) right





(a) (b)





(c) (d)

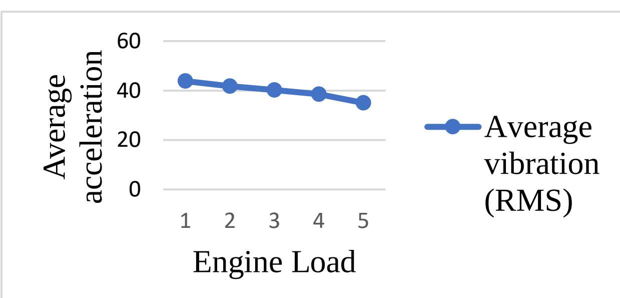
Figure 4.2.5(a, b, c and d) illustrates the CO emissions of various blends of diesel with methyl fuel under varying load levels. As engine load increased, CO emissions progressively rose. Nonetheless, as the mixed fuel's methanol content rose, CO emissions progressively dropped. Higher CO emissions were the result of the cylinder's oxygen becoming less available due to a raise in engine load, which prevented the fuel from burning all the way through. Methanol, on the other hand, improved combustion in the cylinder by raising the mixed fuel's oxygen content. The CO emission decreased as a result. This result also matches with (Hasan et al., 2021).

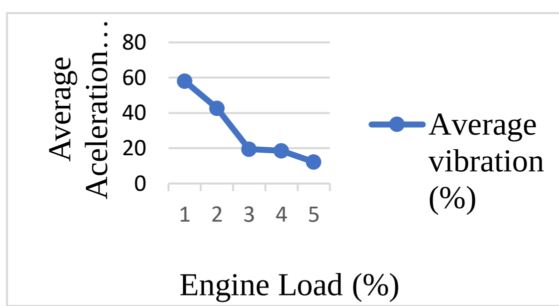
4.3 Vibration Analysis

The automotive sectors compete to increase efficiency, comfort, and environmental friendliness for passengers. Both fuel consumption and combustion engine repairs require a detailed analysis in order to minimize vibration, noise, and engine spray characteristics. In addition to contributions from moving engine parts, engine combustion characteristics also affect engine noise and vibrations. The type of fuel, engine load, or speed are just a few of the engine operating variables that determine the combustion characteristics. An engine's physical attributes and operating conditions can be inferred from signals originating from vibrations in the engine body, and an engine's condition can also be ascertained from noise (Mogal et al., 2023)

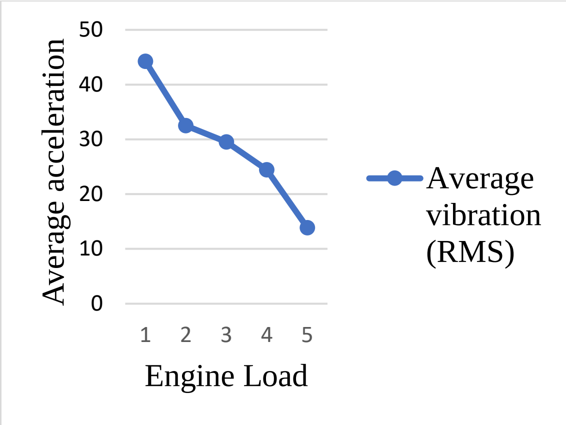
Diesel engines have higher end-of-combustion pressures than spark-ignition engines because of their high compression ratio. Diesel engines vibrate more as a result of this. Both the engine and users should not experience excessive vibration. Numerous studies looked into how various blends affected vibration and noise levels in engines. The result is in line with (Mogal et al., 2023)

4.3.1 mechanical vibration test procedures and results

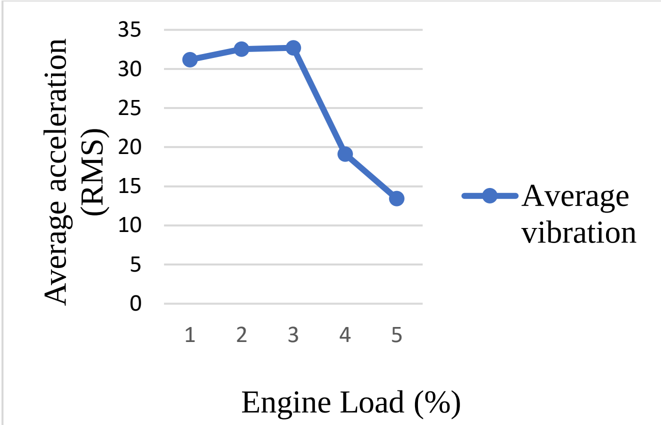




(a) (b)



(c)



(d)

Considering the experimental results from the above Figure 4.3.1(a, b, c and d), the high vibration reduction and better engine performance is at the ratio of B10-B25. So, it has been concluded that, the better blend ratio of methanol with diesel fuel is B10-B25. Because beyond this proportion, the engine vibration is rising significantly.

Important information about how the diesel/methanol blends affect engine dynamics was found through vibration analysis performed at various engine loads. Engine vibrations affection with the addition of methanol into the fuel blend and the results changed based on the engine's load circumstances. The addition of methyl created relatively slight modifications in the vibrations at smaller engine loads. This can be explained by the reality that, lighter loads have a lower energy requirement and a lower combustion intensity. Engine vibrations vary less as a result of a generally smoother and less vigorous combustion process. Nevertheless, it is important to remember that due to the modified combustion characteristics brought about by the addition of methanol, minor variations in certain frequency ranges may still be noticed, even at low loads.

Overall, the experimental analysis of the diesel/methanol engine's vibration characteristics at various engine loads shows that adding methanol to the fuel blend can affect engine vibrations, especially when the engine is running at a higher engine load. It's crucial to remember that the vibrations were still within tolerable bounds for engine operation. These results emphasize the necessity of additional investigation and engine parameter optimization to reduce any possible adverse effects of vibration brought on by the addition of methanol. These insights can be used by engine researchers and manufacturers to create vibration mitigation strategies and guarantee dependable and effective operation of diesel/methanol-fueled engines under a variety of engine load conditions.

CHAPTER FIVE

CONCLUSION AND RECOMENDATION

5.1 Conclusion

In the end, this thesis presented an experimental analysis undertaken to investigate the performance, emission, and vibration properties of a diesel/methanol powered engine. The study aims to evaluate the possible benefits and obstacles associated with using methanol as a partial substitute for diesel fuel in internal combustion engines. Through rigorous testing and analysis, several major findings emerged. Firstly, the performance characteristics of the diesel/methanol fueled engine were assessed, including metrics such as brake power, torque, and fuel consumption. The results demonstrated that the engine attained comparable performance levels, proving the possibility of methanol as an alternate fuel.

The emission characteristics were also comprehensively studied, focusing on emissions of nitrogen oxides (NOx), particulate matter (PM), carbon monoxide (CO), and unburned hydrocarbons (HC). The experimental data demonstrated that the addition of methanol in the fuel blend led to reductions in NOx and PM emissions, but CO and HC emissions were within allowed values. The quantitative findings showed in previous chapter imply that methanol has the potential to contribute to improved air quality and lower environmental impact.

Furthermore, the study studied the vibration characteristics of the engine, attempting to analyze the impact of methanol on engine vibrations and its consequences for total engine performance and durability. The results indicated that the addition of methanol in the fuel blend resulted in slight modifications in vibration characteristics, with no substantial deleterious impacts identified.

Overall, this experimental investigation provides useful insights into the performance, pollution, and vibration characteristics of a diesel/methanol powered engine.

The findings support the assumption that methanol can serve as a viable alternative fuel choice, delivering potential benefits in terms of lower emissions without affecting engine performance or durability. The conclusions of this thesis contribute to the growing body of information on alternative fuels and their impact on internal combustion engines. The findings can influence additional research and development efforts in the pursuit of sustainable and environmentally friendly transportation alternatives.

By studying the possibilities of methanol as a partial substitute for diesel fuel, this study lays the way for future breakthroughs in engine technology and alternative fuel consumption, ultimately encouraging a greener and more sustainable future for the automobile industry.

Recommendations

According to the findings and results gained from the experimental analysis on performance, emissions, and vibration properties of a diesel/methanol fueled engine, the following recommendations are proposed:

- ✓ *Further Investigation*: While this study provides valuable insights, there is still room for further investigation. Future research should focus on conducting long-term durability tests to measure the engine's performance and emission characteristics over extended periods of operation. Additionally, exploring the effects of varying methanol blend ratios and optimizing engine parameters could provide a more comprehensive understanding of the engine's behavior.
- ✓ *Optimal Methanol Blend*: Conduct a detailed analysis to determine the optimum methanol blend ratio that balances performance, emissions, and vibration characteristics. This can be achieved by conducting a series of tests with different blend ratios to identify the ideal combination that maximizes fuel efficiency, minimizes emissions, and maintains acceptable vibration levels.
- ✓ *Engine Calibration*: Develop an optimized engine calibration specifically tailored for diesel/methanol operation. This includes adjusting injection timing, fuel pressure, and air-fuel ratios to achieve the best possible performance and emission outcomes. Fine-tuning the engine parameters can help ensure optimal combustion and minimize any potential issues related to vibration or engine durability.
- ✓ *Emission Control Technologies*: Investigate The incorporation of emission control technology, such as selective catalytic reduction (SCR) or diesel particulate filters (DPF), with diesel/methanol powered engines. These technologies could further cut emissions, particularly nitrogen oxides (NOx) and particulate matter (PM), to meet and exceed regulatory requirements.
- ✓ *Fuel Infrastructure and Standards*: Assess the feasibility and implications of developing an infrastructure for methanol fuel distribution. This includes evaluating the compatibility of existing fueling stations, storage facilities, and transportation networks with methanol. Additionally, establishing standardized fuel quality and safety regulations for methanol blends would ensure consistent performance and enable widespread adoption.

- ✓ *Environmental and Economic Impact*: Conduct a detailed examination of the environmental and economic consequences of utilizing diesel/methanol fueled engines on a larger scale. This includes evaluating the life cycle emissions, energy efficiency, and cost-effectiveness of methanol production, distribution, and utilization. Understanding the broader implications will provide valuable insights for policymakers, industry stakeholders, and researchers.
- ✓ *Alternative Fuel Integration*: Explore the potential for integrating other alternative fuels, such as biodiesel or hydrogen, in combination with methanol to further enhance engine performance, reduce emissions, and diversify the fuel portfolio. Investigate the compatibility, combustion characteristics, and overall system performance when using blended fuels.
- ✓ The result of this investigation advances our understanding of alternative fuels and how they affect engine performance. Regarding engine performance, emissions reduction, and vibration characteristics, this result helps engine designers, automakers, and legislators make well-informed decisions about how to use of methanol as a potential sustainable fuel option.

By implementing these recommendations, researchers, engineers, and policymakers can continue to advance the development and utilization of diesel/methanol fueled engines. This will contribute to the goal of achieving sustainable transportation solutions and lowering the negative ecological effects of internal combustion engines.

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