Experimental Study on Performance, Emission and Vibration Characteristics of Ethanol-Gasoline Fueled Spark Ignition Engine

Gadisa Muluneh Dadi

A Thesis Submitted to

The Department of Mechanical Engineering

School of Mechanical, Chemical and Materials Engineering

Presented in Partial Fulfillment of the Requirement for Master of Science in Automotive Engineering

Office of Graduate Studies

Adama Science and Technology University

June, 2024

Adama, Ethiopia

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DECLARATION

I hereby declare that this Master Thesis entitled **“Experimental Study on Performance, Emission and Vibration Characteristics of Ethanol-Gasoline Fueled Spark Ignition Engine”** is my original work. That is, it has not been submitted for the reward 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.

Gadisa Muluneh Dadi ______________ ______________

Name of the student Signature Date

RECOMMENDATION

I, the major advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled "**Experimental Study on Performance, Emission and Vibration Characteristics of Ethanol-Gasoline Fueled Spark Ignition Engine"** prepared under my guidance by Gadisa Muluneh Dadi submitted in partial fulfillment of the requirements for Master of Science in automotive engineering. Therefore, I recommend the submission of revised version of the thesis to the department following the applicable procedures.

Dr.Getachew Alemayehu	________________	_______________
Major advisor	Signature	Date

APPROVAL PAGE

I, the advisor of the thesis entitled "**Experimental Study on Performance, Emission and Vibration Characteristics of Ethanol-Gasoline Fueled Spark Ignition Engine"** and developed by Gadisa Muluneh Dadi; hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

Dr.Getachew Alemayehu _______________ ______________

Major advisor Signature Date

We, the undersigned, members of the Board of Examiners of the thesis by Gadisa Muluneh Dadi have read and evaluated the thesis entitled "**Experimental Study on Performance, Emission and Vibration Characteristics of Ethanol-Gasoline Fueled Spark Ignition Engine"** and examined the candidate during open defense.This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of Master of Science in Automotive Engineering.

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In closing, I would like to thank Addis Abeba Science and Technology University, Adama Science and Technology University, and all of the professional and academic staff in the mechanical engineering department for allowing me to conduct research in their workshop

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ACRONYMS

BTE	Break thermal efficiency
E0	Ethanol 0% and gasoline 100% fuel
E5	Ethanol 5% and 95% gasoline
E10	Ethanol 10% and 90% gasoline
E15	Ethanol 15% and 85% gasoline
E20	Ethanol 20% and 80% gasoline
E25	Ethanol 25% and 75% gasoline
ICE	Internal combustion engine
LPG	liquefied petroleum gasoline
M10	Methanol 10%
M15	Methanol 15%
NVH	Noise vibration harshness
PM	Particulate matter
RMS	Root mean square
SI	Spark injection

ABSTRACT

The importance of alternative fuels for both compression and spark ignition engines has increased due to growing environmental concerns and the need to lessen dependency on petroleum. This research report details an extensive investigation into the effects of gasoline and ethanol-fueled spark ignition engines on engine vibration, emissions, and performance. Based on the experiment, it can be concluded that gasoline and ethanol blends perform well and help reduce emissions. Fuel blends E0 (100% gasoline), E5 (5% ethanol and 95% gasoline), E10 (10% ethanol and 90% gasoline), E15 (15% ethanol and 85% gasoline),E20(20% ethanol and 80% gasoline) and E25(25% ethanol and 75% gasoline) are used in the experimental design. The test engine was the TBMC3 gasoline engine, which was kept at the AASTU Automotive Engineering workshop. For all fuel types, the test is run at various engine load conditions (10 kg, 15 kg, 30 kg, 45 kg, 60 kg, and 75 kg) and at constant engine speed of 1750rpm. The engine dynamo meter is used to measure power and torque, the exhaust gas analyzer is used to measure emissions, and the VIBXPERT II instrument is used to measure engine vibrations. A comprehensive analysis is carried out following the data collection phase to derive significant insights into the impact of gasoline-ethanol blends on the performance, emissions, and vibration characteristics of spark ignition engines.According to the experimental findings, the range of CO and HC emission reductions for all test fuels is 14.79% to 49.1% and 11.99% to 53.57%, respectively. The range of increases in NOx emissions is 16.23% to 48.74%. Engine power and torque rise by a range of 4.5% to 41%, and 3% to 45% respectively. BSFC exhibits a 6.95% to 26% reduction in comparison to pure gasoline. There is a rise in engine vibrations from 6.5% to 25.3%.Every test fuel's engine vibration is evaluated using international standard organization guidelines. The engine vibrations of the E0, E5, E10, and E15 do not affect this particular engine type. When the test engine was running on E25 fuel, its vibration did not affect it at low load, but at high load, it caused issues that made it unsatisfactory to operate for extended periods.

Keywords: *Compression ignition, Emission, Ethanol Gasoline blend fuel, performance, Spark ignition, , Vibration*

CHAPTER ONE

1. INTRODUCTION

1.1 Background of the study

A spark-igniting engine, referred to as a gasoline engine or petrol engine, is a form of internal combustion engine that ignites a fuel-air mixture within a combustion chamber using a spark plug. These engines are used in automobiles, motorcycles, small airplanes, and other applications that require lightweight, high power-to-weight ratio, and ease of operation. Enhancing the workings of a spark ignition engine requires considering several factors, including efficiency, performance, emissions, and dependability.

It is well-known that fossil fuels are consumed in vast amounts globally, with energy demand escalating rapidly each year. The transportation sector is a major consumer of fossil fuels, raising concerns about dwindling reserves, climate change, and air quality deterioration. Hydrogen and electrification are often proposed as potential solutions. Both are extensively researched, and electric vehicles (EVs) are already in use. However, the limited volumetric energy density of batteries and hydrogen results in a shorter range for these vehicles compared to traditional internal combustion engine (ICE) vehicles.

Automakers have incorporated new technologies to improve performance, energy efficiency, pollution reduction, safety, and comfort over the decade. To increase energy efficiency and address current international regulations.

The dual-plug ignition technique in SI engines enhances performance by enabling a leaner or more diluted fuel-air mixture, leading to better fuel economy and combustion. Besides engine configuration, such as spark plug layouts, the fuels used in SI engines are crucial. The use of alcohol fuels, also known as biofuels, and their blending with gasoline in SI engines, are popular research topics. Ethanol, in particular, stands out in many SI engine studies (Laganá et al., 2018).

Global concerns such as fossil fuel depletion and rising temperatures highlight the need for alternative energy solutions. One promising approach is the use of renewable fuels derived from plant-based products. Fuels from waste biomass are precious because they do not affect the food supply. Consequently, these biofuels are crucial for reducing dependence on fossil fuels and enhancing environmental health. The most commonly used liquid biofuels in transportation are biodiesel and bio-alcohols (Biswal et al., 2020).

Vibration noises are caused by the motion created by the engine, which is powered by fuel energy. As a result of the vibrations, a proportion of the fuel energy that could be used to produce useful work is lost.The most common problems with the vehicles are vibration and sound of burning. The automotive industry is under pressure to make vehicles that are more economical, environmentally friendly, more efficient, less polluting, and comfortable for passengers due to the growing demand for engines. To lessen vibration, noise, and engine spray characteristics in this situation, a thorough study is necessary for both fuel use and combustion engine repairs (Ding et al., 2011).

Numerous scientists have experimented with and studied the internal combustion engine's injection, vibrations, noise, and combustion features. They begin with the fuel and continue until all engine components have been added.Many studies are currently being conducted on gasoline engines to determine how fuel affects vibration in engines. In addition, a lot of research is done on vibration and noise to determine the consequences of using different fuels. Recent years have seen a number of studies exploring how spark ignition engines operate when running on alcoholic fuels like ethanol (Elnajjar et al., 2010).

1.2 Statement of the problem

Researchers invest significant effort into enhancing the performance of spark ignition engines. Their studies reveal that the use of alternative fuels, such as ethanol-gasoline blends, in spark ignition engines can yield improved engine performance (in terms of power and torque) and reduce emissions compared to conventional gasoline engines. However, the introduction of ethanol-gasoline blends in spark ignition engines leads to increase engine vibration, as concentration of ethanol in gasoline increase (Gravalos et al., 2013). Therefore, It's essential to examine which level of ethanol concentration causes engine vibration that has no impact on engine operation.

1.3 Objectives

2.3.1 General Objective

The general objective of this study is to investigate the effect of ethanol-gasoline-fueled on the performance, emission, and vibration characteristics of spark ignition engines.

2.3.2 Specific Objectives

The specific objectives are:

- ✓ To examine the engine's emission characteristics when it runs on different ethanol/gasoline combinations.
- ✓ To assess the performance characteristics of a spark ignition engine operating with different ethanol/gasoline blend.
- ✓ To investigate the impact of vibration on all test fuels.

1.4 Scope of the Study

This study focuses on experimental analysis to investigate performance, emission, and engine vibration during ethanol/gasoline-fueled spark ignition engines. The scope of this study is, operating a gasoline engine with pure gasoline fuel, 5%, 10%, 15%, 20% and 25% concentration of ethanol in a gasoline engine at engine load conditions of 10kg, 15kg, 30kg, 45kg, 60kg, and 75kg and constant engine speed of 1750rpm measure performance, emission, and engine vibration.

1.5 Motivation

The majority of research on alternative fuel is concerned only with engine performance like power, torque, and pollution like CO, HC, NOx, and particulate matter. However, the effect of vibration on engine components must be studied because vibration causes fatigue failure and damage to engine-supporting structures.

For years, researchers have investigated the impact of ethanol on the performance and emissions of spark ignition engines. However, there is limited research on how ethanol influences the vibration characteristics and noise emissions of these engines.

1.6 Significance of the Study

This study aims to contribute to the existing knowledge on alternative fuels, specifically ethanol-gasoline blends. The findings are anticipated to provide insights into the trade-offs between improved performance and increased engine vibration, with a focus on the cylinder head mount. The significance of the study is the following:

- Reduce noise and vibration
- Increase passenger comfort
- Increase engine efficiency

1.7 Limitations

The lack of project facilities at Adama Science and Technology University's automotive technology workshop had a detrimental effect on the experimental work. The inaccessibility of the relevant manuals for the tools and equipment used to measure engine vibration presented additional difficulties. Another issue is that paying for the laboratory is costly.

1.8 Organization of the Thesis

This thesis is organized into five chapters. Chapter one is an introduction to on ethanol-gasoline blend-fueled spark ignition engine. Chapter two presents a review of literature related to the study that emphasizes experimental analysis of performance, emission, and vibration characteristics of ethanol/gasoline-fueled spark ignition engines, a review summary, and a research gap. Chapter three describes the Materials and Methods used to complete this work. Chapter four contains the results and discussion of the experiment. The last chapter contains a conclusion and recommendation.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 Introduction

The integration of ethanol into gasoline as a fuel blend has been extensively studied for its potential to enhance engine performance and reduce emissions in spark ignition (SI) engines. This literature review consolidates findings from various studies that explore the impact of ethanol-gasoline blends on engine performance, emissions, vibration and other related parameters.

2.2 Performance and Emission Evaluation with Gasoline-Ethanol Fuel

(Ağbulut et al., 2018) conducted an empirical study on the impacts of ethanol-gasoline blends on pollutant emissions and performance in an SI engine. The study showed that ethanol blends reduced emissions of CO, HC, and nitrogen oxides (NOx), while also improving engine performance. These improvements were attributed to the higher oxygen content in ethanol, which promotes more complete combustion.

(Mohammed et al., 2021) studied the effects of ethanol-gasoline blends on the performance and emissions of SI engines. Their findings indicated that ethanol blends improved engine performance metrics such as power output and thermal efficiency. Emissions of CO and HC were significantly reduced with ethanol blends, though NOx emissions showed a slight increase. This study supports the use of ethanol blends for enhancing engine performance while reducing harmful emissions.

(Abdeta et al., 2015) evaluated the performance of a gasoline vehicle using a gasoline-ethanol-methanol emulsion. The study found that the emulsion improved engine performance metrics such as power output and thermal efficiency. Additionally, the emulsion blend resulted in a significant reduction in exhaust emissions, particularly carbon monoxide (CO) and unburned hydrocarbons (HC). This suggests that ethanol and methanol can synergistically enhance fuel properties and engine performance.

2.2.1 Performance and Emissions of E85 with Different Injection Approaches

(Tornatore et al., 2019) investigated the performance and emissions of a turbocharged PFI SI engine using E85 (85% ethanol, 15% gasoline) with different injection approaches.

Their experimental study showed that direct injection provided better combustion efficiency and lower emissions compared to port injection. This highlights the importance of injection strategies in maximizing the benefits of high-ethanol blends.

2.2.2 Effect of Varying Compression Ratios on Ethanol-Gasoline Blend Fuel

(Ansari et al., 2013) examined the performance and emissions of an SI engine using ethanol as a blended fuel under varying compression ratios. The results indicated that increasing the compression ratio improved engine performance and fuel efficiency when using ethanol blends. Additionally, the optimized compression ratio significantly reduced CO and HC emissions, though NOx emissions increased, necessitating further optimization.

(Ye et al., 2023) examined the effects of different ratios of gasoline-ethanol blends on combustion enhancement and emission reduction in electronic fuel injection engines. Their study demonstrated that optimal ethanol blend ratios significantly improved combustion efficiency and reduced CO and HC emissions. This research underscores the importance of finding the right blend ratio to maximize the benefits of ethanol blends.

(Costa & Sodré, 2011) investigated the effects of compression ratios on the performance of ethanol-gasoline-fueled engines. They found that increasing the compression ratio improved the thermal efficiency and power output of the engine. However, higher compression ratios also led to an increase in NOx emissions. The study emphasized the need to optimize compression ratios to balance performance gains with emission control.

(Yücesu et al., 2006) investigated the effect of ethanol-gasoline blends on engine performance and exhaust emissions at different compression ratios. Their study concluded that higher compression ratios with ethanol blends improved thermal efficiency and power output. However, NOx emissions increased with higher compression ratios, indicating the need for a balanced approach to optimize performance and emissions.

(Manikandan et al., 2013) investigated the effects of gasoline-ethanol blends and varying compression ratios on SI engine performance and emissions. The study found that higher compression ratios with ethanol blends improved thermal efficiency and power output.

However, NOx emissions increased with higher compression ratios, indicating a trade-off between performance and emission control.

2.2.3 Ternary Gasoline-Ethanol-LPO Blends

(Biswal et al., 2020) investigated the effects of using ternary gasoline-ethanol-LPO (liquid petroleum gas) blends on port fuel injection (PFI) engine performance and emissions. The study found that the ternary blend improved engine performance and reduced emissions compared to pure gasoline. The inclusion of LPO in the blend further enhanced combustion efficiency and reduced pollutant emissions, providing a promising alternative fuel strategy.

2.2.4 Emission Reduction with Ethanol-Gasoline Blends Using 1, 4 Dioxan

(Srinivasan & Saravanan, 2010) explored using 1, 4 Dioxan as an additive in ethanol-gasoline blends for emission reduction. Their study revealed that adding 1, 4 Dioxan to ethanol-gasoline blends significantly reduced CO and HC emissions. The study suggested that 1, 4 Dioxan acts as an oxygenate, promoting more complete combustion and thereby lowering emissions. This finding is crucial for developing cleaner alternative fuels for SI engines.

2.2.5 Ethanol vs. Butanol as Oxygenates in Direct-Injection Engines

(Wallner et al., 2009) compared the use of ethanol and butanol as oxygenates in a direct-injection SI engine. They found that while both alcohols improved combustion efficiency and reduced CO and HC emissions, butanol was more effective in reducing NOx emissions. This suggests that butanol could be a superior alternative to ethanol as an oxygenate in SI engines.

2.2.6 Comparative Analysis of Ethanol-Butanol-Gasoline Blends

(Taneja et al., 2018) conducted a comparative analysis of ethanol-butanol-gasoline blends, focusing on performance and emission characteristics. Their study found that both ethanol and butanol blends improved engine performance, but butanol blends had a slight edge in reducing emissions, particularly NOx. This suggests that butanol, with its higher energy density and better combustion characteristics, could be a more effective additive than ethanol for reducing emissions in SI engines

2.2.7 Effect of Cyclic Variability on Ethanol-Gasoline blend fuel

(Ceviz & Yüksel, 2005) studied the effects of ethanol-unleaded gasoline blends on cyclic variability and emissions in an SI engine. Their findings indicated that ethanol blends reduced cyclic variability, which in turn improved combustion stability and reduced emissions. The study highlighted the potential of ethanol blends to enhance engine reliability and environmental performance .

2.2.8 Cold-Start Emissions

(R. H. Chen et al., 2011) focused on cold-start emissions using ethanol-gasoline blended fuel. The study demonstrated that ethanol blends significantly reduced cold-start emissions of CO and HC, which are critical for urban air quality. The higher volatility and oxygen content of ethanol were key factors in achieving more efficient combustion during cold starts.

2.2.9 Hydrous Ethanol vs. Gasoline-Ethanol Blends

(Costa & Sodré, 2010) examined the performance and emissions of engines using hydrous ethanol versus gasoline-ethanol blends. Their study revealed that hydrous ethanol provided better performance and lower emissions than traditional gasoline-ethanol blends. Specifically, hydrous ethanol resulted in higher thermal efficiency and lower emissions of carbon monoxide (CO) and hydrocarbons (HC), though nitrogen oxides (NOx) emissions were higher compared to gasoline-ethanol blends. This suggests that hydrous ethanol could be a more sustainable alternative fuel for SI engines.

2.2.10 Advanced Combustion Techniques

(Dalla Nora et al., 2018) investigated the performance and combustion characteristics of a supercharged two-stroke DI engine using ethanol-gasoline blends. They found that ethanol blends enhanced combustion efficiency and reduced emissions, highlighting the benefits of advanced combustion techniques. Similarly, Kurji et al. (2021) demonstrated the positive impact of pure ethanol additives on gasoline in SI engines, noting improvements in emissions and performance.

2.2.11 Combustion and Idle Performance in Rotary Engines

(Pan et al., 2021) investigated the effect of ethanol blending on combustion characteristics and idle performance in gasoline rotary engines. The experimental results showed that ethanol blends improved combustion stability and reduced idle emissions, enhancing overall engine performance during idle conditions. This highlights the versatility and effectiveness of ethanol as a fuel additive for different engine types.

2.2.12 Performance Enhancement and Emission Reduction in Motorcycles

(Dinh et al., 2020) investigated the effects of flex-fuel gasoline-ethanol blends on the performance and emissions of used carburetor motorcycles. The study found that ethanol blends improved engine performance, particularly in terms of power output and fuel efficiency. Emissions of CO and HC were significantly reduced with ethanol blends, although NOx emissions showed a slight increase. This research supports the use of ethanol blends in older motorcycle engines to enhance performance and reduce emissions.

(Y. L. Chen et al., 2012) optimized the ethanol blend ratio for motorcycle engines using response surface methodology. The study identified an optimal blend ratio that maximized engine performance and minimized emissions. This approach provided a systematic method for determining the best blend ratio, taking into account multiple performance and emission parameters .

2.2.13 Effect of Ethanol-Gasoline Blends on NOx Emissions

(Masum et al., 2013) investigated the impact of ethanol-gasoline blends on nitrogen oxide (NOx) emissions in SI engines. Their study found that increasing the ethanol content in gasoline significantly reduced NOx emissions due to the lower combustion temperatures and oxygen content in ethanol. This reduction is crucial for meeting stringent emission regulations and improving air quality, making ethanol blends an attractive alternative fuel option for SI engines .

2.2.14 Comparative Study of Various Alcohol-Gasoline Blends

(Elfasakhany, 2017) conducted a comparative study on the performance and pollutant emissions of SI engines fueled with various alcohol-gasoline blends, including n-butanol, isobutanol, ethanol, methanol, and acetone. The study concluded that ethanol and methanol blends provided the best balance of improved performance and reduced emissions. Isobutanol and n-butanol blends also showed promising results but were less effective than ethanol and methanol in reducing emissions.

2.3 Detection of Ethanol-Gasoline Fuel on Engine Vibration

(Gravalos et al., 2013) explored the detection of fuel types in SI engines based on engine vibration behavior. Their study demonstrated that different fuel types, including ethanol and methanol blends, produce distinct vibration signatures. This finding is significant as it suggests that engine vibrations can be used as a diagnostic tool to determine the type of fuel being used, which can be crucial for optimizing engine performance and ensuring proper fuel use.

2.3.3 Vibration Effects of Ethanol Blends

(Gravalos et al., 2011) examined the vibration effects on SI engines fueled with methanol and ethanol-gasoline blends. They found that both methanol and ethanol blends reduced engine vibrations compared to pure gasoline. The reduction in vibrations is attributed to the smoother combustion process of alcohol fuels, which leads to a more stable engine operation.

(Keskin, 2010) investigated the influence of ethanol-gasoline blends on the vibration characteristics and noise emissions of SI engines. The study found that ethanol blends significantly reduced both engine vibrations and noise emissions. This reduction was more pronounced at higher ethanol concentrations, suggesting that ethanol not only improves combustion efficiency but also enhances driving comfort by reducing noise and vibrations.

(Sharma et al., 2019) conducted experimental investigations on the noise and vibration characteristics of gasoline-methanol blends in direct injection engines. Their study revealed that methanol blends reduced engine noise and vibrations, enhancing driving comfort. The relationship between combustion characteristics and noise/vibration behavior was also established, indicating that methanol blends can lead to a smoother and quieter engine operation.

2.4 Detonation Detection using Ion Current Signals

(Laganá et al., 2018) identified combustion and detonation events in SI engines using ion current signals. The study showed that ion current signals could effectively detect combustion anomalies, such as knock and misfire when using ethanol-gasoline blends. This method provides a reliable tool for real-time monitoring and control of engine combustion processes.

2.5 Stability of Ethanol-Gasoline Blends

(Li et al., 2020) analyzed the performance and stability factors of vehicle ethanol-gasoline blends. Their research indicated that ethanol blends improved engine performance and stability, particularly in terms of power output and fuel economy. The study also highlighted the importance of maintaining a consistent ethanol blend ratio to ensure optimal engine operation and fuel stability.

2.6 Preheating Bio Fuel

(Mourad & Noureldenn, 2019) explored the benefits of using exhaust gas energy to preheat biofuel. The study's findings are relevant for ethanol-gasoline blends. Preheating the fuel improved combustion efficiency and reduced emissions, suggesting that similar preheating techniques could enhance the performance and emission characteristics of ethanol-gasoline blends in SI engines.

2.7 Optimization Using Response Surface Methodology

(Najafi et al., 2015)optimized the performance and emission parameters of SI engines using gasoline-ethanol blends through response surface methodology. Their study identified optimal blend ratios that maximized engine performance and minimized emissions, providing a systematic approach for determining the best ethanol blend ratio. This optimization is essential for achieving a balance between performance gains and emission reductions .

2.8 Predictive Modeling Using Artificial Neural Networks

(Thakur et al., 2018) used an artificial neural network (ANN) approach to predict the performance and exhaust emissions of a gasoline engine using ethanol-gasoline blended fuels. Their model accurately predicted engine performance metrics such as power output and emissions, demonstrating the utility of ANNs in optimizing fuel blend ratios. This approach can help in identifying the most effective blend ratios for enhancing performance and reducing emissions.

2.9 Review Summary

The above review indicated that when ethanol-gasoline fuel blend is used in gasoline engines, engine performance increases, emission is improved, and vibration engine increases. This vibration comes from the high combustion pressure of the engine, camshaft/crankshaft, and high-pressure fuel system are the causes for engine vibration in ethanol-gasoline blended fuel.

Typically, engine vibration in gasoline engines is primarily attributed to the combustion process. This is because of factors such as the higher latent heat of evaporation and the increased rate of pressure, leading to elevated peak pressure values within the cylinder during combustion.

2.10 Research Gap

The above review shows, during experimental research on the performance, emission, and vibration behavior of ethanol gasoline blended fuel at different concentrations of ethanol in a spark ignition engine, the study includes changes in CO, HC, NO_x, and PM and whether the engine vibration increases or decreases.

The research does not identify the impact on individual engine vibration. However, the study has to include the impact of vibration that occurred because of this blended fuel in their study.

CHAPTER THREE

3. MATERIALS AND METHODS

3.1 Introduction

The Addis Ababa Science and Technology University's automotive engineering workshop served as the study's location. Experiments were performed on a single-cylinder, four-stroke, spark ignition engine at full load. Engine test conditions are at engine load conditions of 10kg 15kg, 30kg, 60kg, and 75kg and constant engine speed of 1750 rpm with all types of fuel.

An exhaust gas analyzer was used to measure emissions, and a dynamometer was used to measure the engine's torque and power output. For each of the six test fuel types, engine vibration is measured through VIBXPERT II.

Materials and methods used for the experiment of engine performance, emission, and vibration characteristics of Ethanol/gasoline-fueled spark ignition engines will be discussed below.

3.2 Materials

3.2.1 Fuel Types:

1. E0: 100% gasoline fuel.
2. E5: 5% ethanol and 95% gasoline
3. E10: 10% ethanol and 90% gasoline fuel.
4. E15: 15% ethanol and 85% gasoline fuel.
5. E20:20% ethanol and 80% gasoline fuel.
6. E25:25% ethanol and 75% gasoline fuel**.**

Figure 3.1 Fuel types used in the experiment

The 99% pure ethanol used in this experimental study was purchased from Addis Ababa, a chemical store located in the Kirkos sub-city. The automotive lab of Adama Science and Technology University provided the gasoline fuel for this experiment.

3.2.2 Characteristics of ethanol

Ethanol is a renewable fuel made by fermenting and distilling sugars and starches found in grains like corn and sorghum, beverage and food waste, and cellulose biomass such as corn stover and switch grass. Because of its high-octane rating, ethanol is frequently added to reformulated gasoline blends as an octane improvement. Ethanol has RON values between 105 and 109, while gasoline has RON values between 91 and 99 (Li et al., 2020).

Other properties, such as its low heat value, Reid vapor pressure, latent heat of vaporization (which is 2.4 times higher than that of gasoline), and increased laminar flame speed, ethanol is an ideal candidate for use with both PFI and DI approaches to increase efficiency gains and decrease NOx raw emission (Deresse Firew et al., 2016).

Test Engine: TBMC3 gasoline engine, one cylinder, four-stroke at AASTU Automotive Engineering Workshop was used for the experiment its picture is shown in Figure 3.2 and the engine specifications are given in Table 3.1

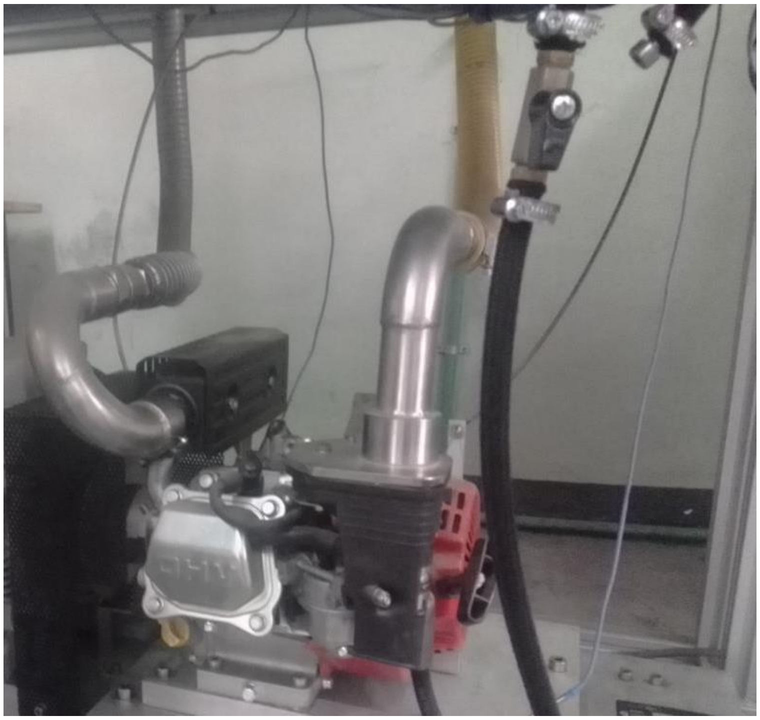


Figure 3.2 TBMC3 Test engine

Table 3.1 Technical specifications of TBMC3 gasoline engine

Type of engine	Spark injection
Fuel	Petrol
No. of cylinders	1
No. of stroke	4
Maximum torque	7.7 N·m/2400 rpm.
Maximum power	4.2 HP/3600 rpm.
Stroke	42 mm.

Operating Conditions: Engine load: 10kg, 15kg, 30kg, 45kg 60kg, and 75kg.

3.2.3 VIBXPERT II instrument for engine vibration measurement.

In terms of mobile machine and plant condition monitoring, VIBXPERT II is the industry standard. The VIBXPERT II is a fast, dependable, and highly effective data analysis tool that can also be used for operational balancing. In this experiment, VIBXPERT II is used to measure engine vibration for all types of fuels. The figure below shows VIBXPERT II used during this experimental work.

Table 3.2 General Specification of VIBXPERT II

Output	Frequency range	0-500khz
Accuracy	Vibration acceleration	±0.1%
	RPM	10 ... 200 000 min-1 / ±0.1‰ or ± 1 min-1 (the lower accuracy is applicable)
Power supply	Charging time	< 5 hours in the instrument
	Charger, input	110-240 V / 50-60 Hz
	Charging temperature	0°C ... +50°C [32 °F ... 122°F]

Figure 3.3 VIBXPERT II

3.2.4 Engine dynamo meter for performance measurements.

TBMC3 test engine is connected to a dynamometer to measure engine performance(power and torque) for all test fuel at selected engine load and constant engine speed. Figure 3.4 shows a picture of the engine connected to a dynamometer.

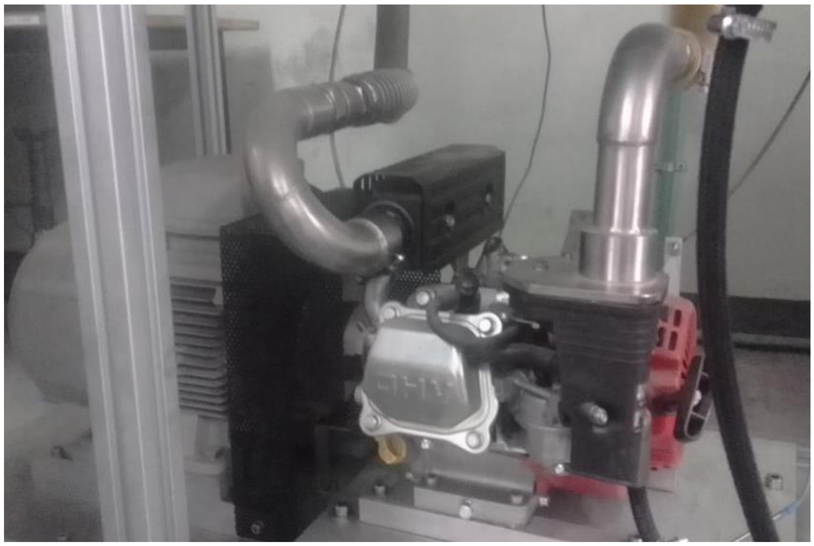


Figure 3.4 Engine connected with a dynamometer

3.2.5 Exhaust gas analyzer for emission measurements.

An automotive exhaust gas analyzer, model MQ550-4, is used to evaluate the emission of CO, HC, and NOx for all test fuels. Figure 3.5 shows a picture of an automotive exhaust gas analyzer.

Figure 3.5 Automotive exhaust gas analyzer.

3.2.6 Accuracy and Range measurement in engine emission testing

Carbon Monoxide: This parameter measures the percentage of carbon monoxide in the exhaust gas. The accuracy is 0.01% with a range of 0-10%. The over-range limit is 20%, meaning that the instrument can measure up to 20% but with reduced accuracy.

Hydrocarbon: This parameter measures the concentration of hydrocarbons in the exhaust gas. The accuracy is 1 ppm (parts per million) with a range of 0-5000 ppm. The over-range limit is 10,000 ppm, meaning that the instrument can measure up to 10,000 ppm but with reduced accuracy.

Nitric Oxide (Fuel cell): This parameter measures the concentration of nitric oxide in the exhaust gas. The accuracy is 1 ppm with a range of 0-1500 ppm. The over-range limit is 5000 ppm, meaning that the instrument can measure up to 5000 ppm but with reduced accuracy. The technical specification of the exhaust gas emissions measurement device is given in Table 3.3.

Table 3.3 The technical specification of the exhaust gas emissions measurement device

Parameter	Accuracy	Range
Carbon Monoxide (Infrared)	0.01 %	0-10 % Over-range 20 %
Hydrocarbon (Infrared)	1 ppm	0-5000 ppm Over-range: 10,000 ppm
Nitric Oxide (fuel cell)	1 ppm	0-1500ppm Over-range: 5000 ppm

3.3 Experimental Procedure

The experimental test is conducted based on ASTM D5501 which is the use of ethanol-gasoline blend fuel in spark ignition engine.

3.3.1 Fuel Preparation

Ethanol and gasoline fuel were mixed at various concentrations to produce the fuel samples. The amounts of gasoline and ethanol needed were measured using a graduated cylinder. next to preparation, the ethanol and gasoline blend samples were put through several tests in the lab, which included performance, vibration, and emission test

Step-1: Prepare ethanol-gasoline fuel blend at six different concentrations of ethanol.

E0: Pure gasoline as the base fuel 250ml.

E5: Contains 5% Ethanol and 95% Gasoline

- ✓ Measure 12.5ml of ethanol.
- ✓ Measure 237.5ml of gasoline fuel.
- ✓ Mix the measured quantities and blend ethanol and gasoline in 250ml

E10: Contains 10% Ethanol and 90% Gasoline.

- ✓ Measure 25ml of ethanol.
- ✓ Measure 225ml of gasoline.
- ✓ Mix the measured quantities and the blend of ethanol and gasoline is 250ml.

E15: Contains 15% Ethanol and 85% Gasoline

- ✓ Measure 37.5 ml of ethanol.
- ✓ Measure 212.5ml of gasoline.
- ✓ Mix the measured quantities and the blend of gasoline and ethanol is 250ml.

E20:Contains 20% Ethanol and 80% Gasoline

- ✓ Measure 50ml of ethanol.
- ✓ Measure 200ml of gasoline.
- ✓ Mix the measured quantities and the blend of gasoline and ethanol is 250ml.

E25: 25% ethanol, 75% gasoline fuel.

- ✓ Measure 62.5ml of ethanol.
- ✓ Measure 187.5ml of gasoline.
- ✓ Mix the measured quantities and the blend of ethanol and gasoline is 250ml.

3.3.2 Prepared experimental setup

The experimental set-up for this experiment contains a spark ignition engine, engine dynamometer, exhaust gas analyzer, VIBXPERT II, and desktop computer connection. A dynamometer measures engine power and torque, and an exhaust gas analyzer measures CO, HC, and NO_x emissions. VIBXPERT II is connected to the engine in three directions to measure vibration longitudinally, transversely, and axially. Figure 3.6 and Figure 3.7 below show the schematic experimental setup and experimental setup respectively.

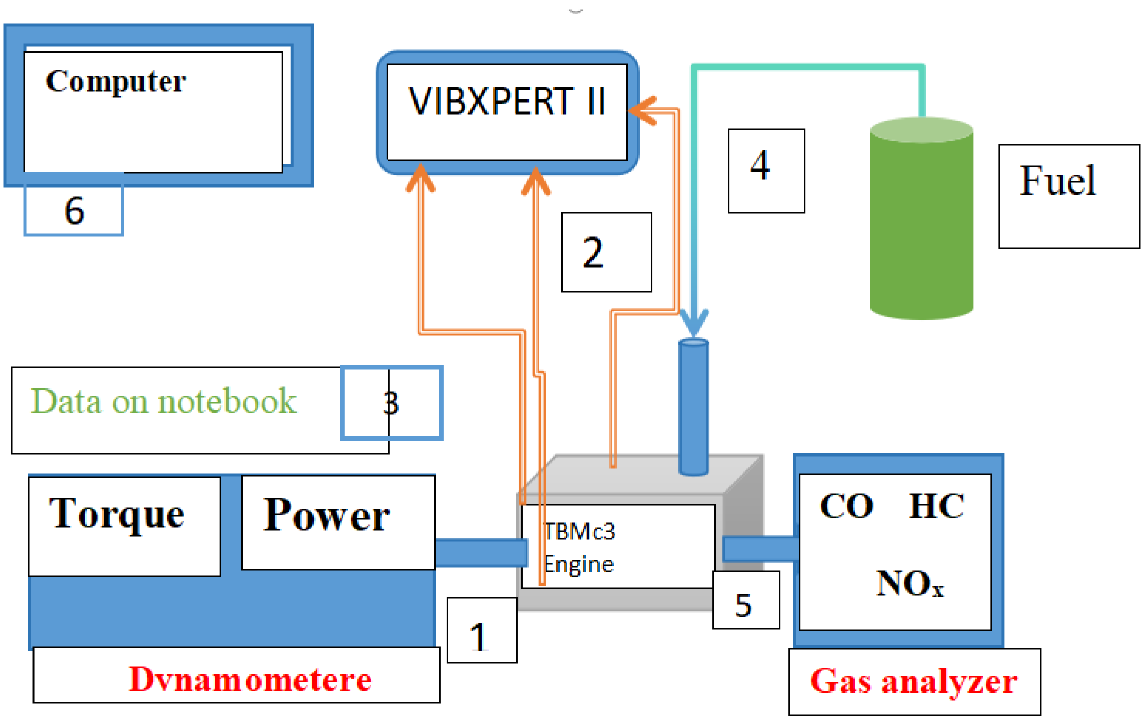


Figure 3.6 Schematic Experimental setup

1. Coupling
2. VIB 5.444-5 sensor that measures vibration
3. Data taken from VIBXPERT II to notebook
4. Fuel line
5. Exhaust gas pipe
6. Measurement quantity is taken from control board computer.

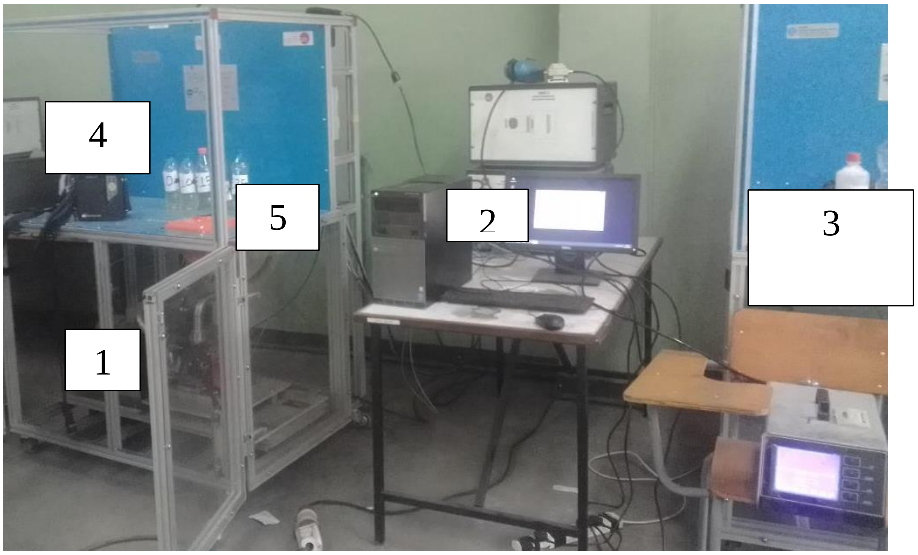


Figure 3.7 Experimental setup

1. Engine connected with a dynamometer
2. Desktop computer
3. Automotive exhaust gas analyzer
4. Vibxpert II
5. **Fuel tank**

3.3.3 Engine Warm-Up

Before starting the experiment, run the engine for 10 minutes to ensure proper engine warm-up.

3.3.4 Testing with all test Fuels

Run the engine with all test fuel at engine loads of 10kg, 15kg, 30kg, 45kg 60kg, and 75kg.

- ✓ Measure and record engine performance.
- ✓ Record emission levels using an exhaust gas analyzer.
- ✓ Measure engine vibration at all engine loads.

3.3.5 Data Collection and Analysis

- ✓ Collect and compile all data obtained during the experimental runs.
- ✓ Analyze the performance, emission, and vibration data for each fuel type and concentration.
- ✓ Identify trends, patterns, and correlations between ethanol concentration, engine performance, emissions, and vibration.

3.3.6 Error Analysis

Numerous factors, including test conditions, planning, instrument selection, reading, the variety of measurement devices, and even the connection type points and placements of the measurement probes on the experiment setup, prevent the experiments from being measured with 100% accuracy. It is advised that the research experiments be repeated at least three times to guarantee the validity of the findings and lessen the influence of these variables. confirm the repeatability under the same conditions, based on this the measurement is repeated three times the average value is taken. The error and uncertainty analysis is one of the most effective methods to evaluate and determine the experimental results. Hence, the accuracy rates of all measurement devices using the experimental section of this study are given in Table 3.4.

The total error rate (er) in this study is calculated using the following equation.

$Er = (0.01)^2 + (1)^2 + (1)^2 + (0.05)^2 + (0.01)^2 = 2.0027$

Confidence level = 97.99%

Table 3.4 The Accuracy of the experimental devices used in this study

Measurement	Accuracy in the study
CO (%)	±0.01%
HC (ppm)	±1%
NOx (ppm)	±1%
Torque	±0.05
Vibration	±0.01

CHAPTER FOUR

4. RESULTS AND DISCUSSION

4.1 Introduction

In this investigation, the experiment was conducted using various volumes of ethanol-gasoline mixtures (5% ethanol + 95% gasoline, 10% ethanol + 90% gasoline, 15% ethanol + 85% gasoline, 20% ethanol +80% gasoline, 25% ethanol +75 gasoline). The effects of carbon monoxide (CO), hydrocarbon (HC), and nitrogen oxide (NO_x) emissions, as well as the power, torque, and vibration, are to be ascertained based on the fuel types and different engine speeds. Specific fuel consumption was also looked into.

For every fuel type, the tests were run at engine load conditions of 10kg, 15kg,30kg,45kg, 60kg, and 75kg and at a constant engine speed of 1750rpm.

4.2 Carbon monoxide emission

The emission test for all test fuel is conducted based on selected engine load conditions and at constant engine speed and data is recorded.

4.2.1 Carbon monoxide emission test for E0 fuel.

The CO emission test result that was acquired from the test engine through the use of an exhaust gas analyzer is shown in Figure 4.1. When the engine is running at a load of 30 kg, it emits the most CO; when the load is lower, the engine emits less CO. The carbon monoxide emissions from pure gasoline fuel increased at higher engine loads and somewhat decreased at lower engine loads, as shown in Figure 4.1.

CO emissions from an internal combustion engine decrease at higher loads because the combustion process becomes more efficient due to higher temperatures. Conversely, CO emissions are typically highest at medium loads where the balance of air and fuel might not be optimal, and the combustion process might not be as efficient, leading to incomplete combustion and higher CO production (Hu et al., 2022).

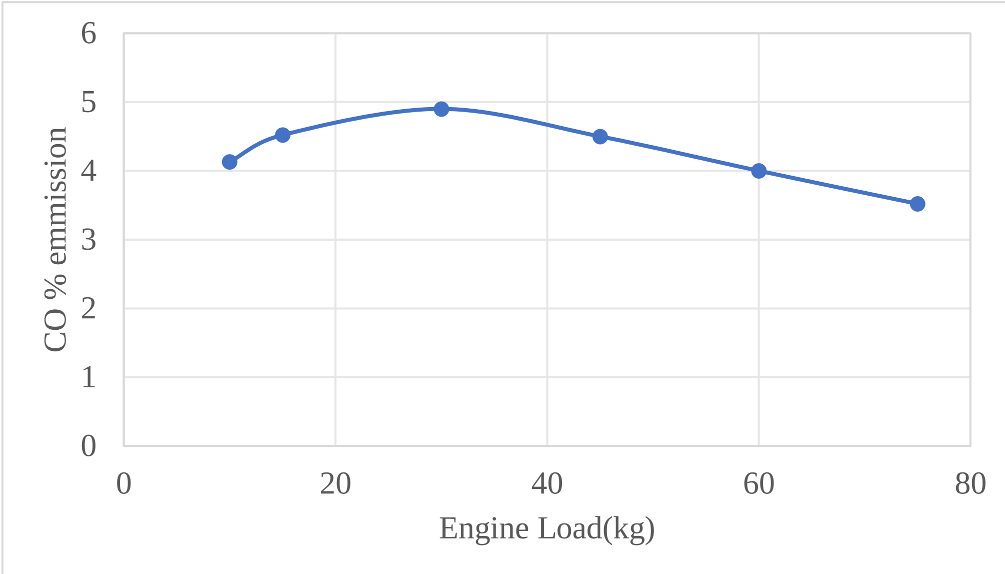


Figure 4.1 CO% Emission for E0 fuel.

4.2.2 Carbon monoxide emission test for E5 fuel.

The maximum carbon monoxide emission for E5 fuel occurs at an engine load condition of 30 kg, or 4.2%, and the minimum emission occurs at a higher engine load condition of 75 kg, or 2.7%. Figure 4.2 shows Carbon monoxide emission for E5 test fuel.

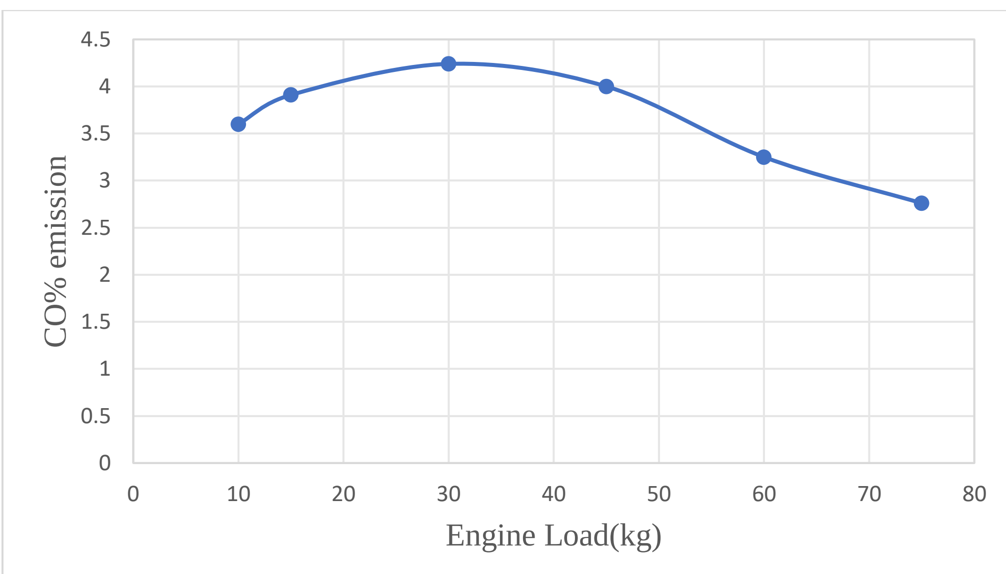


Figure 4.2 CO emission for fuel E5.

4.2.3 Carbon monoxide emission test for E10 fuel.

When using E10 fuel, the engine's carbon monoxide emission reaches its maximum at 30 kg or 3.57%, and its minimum at 75 kg, or the lowest engine load condition. After a certain load, the emission result increases before beginning to decrease. The emissions results for E5 fuel are displayed in Figure 4.3

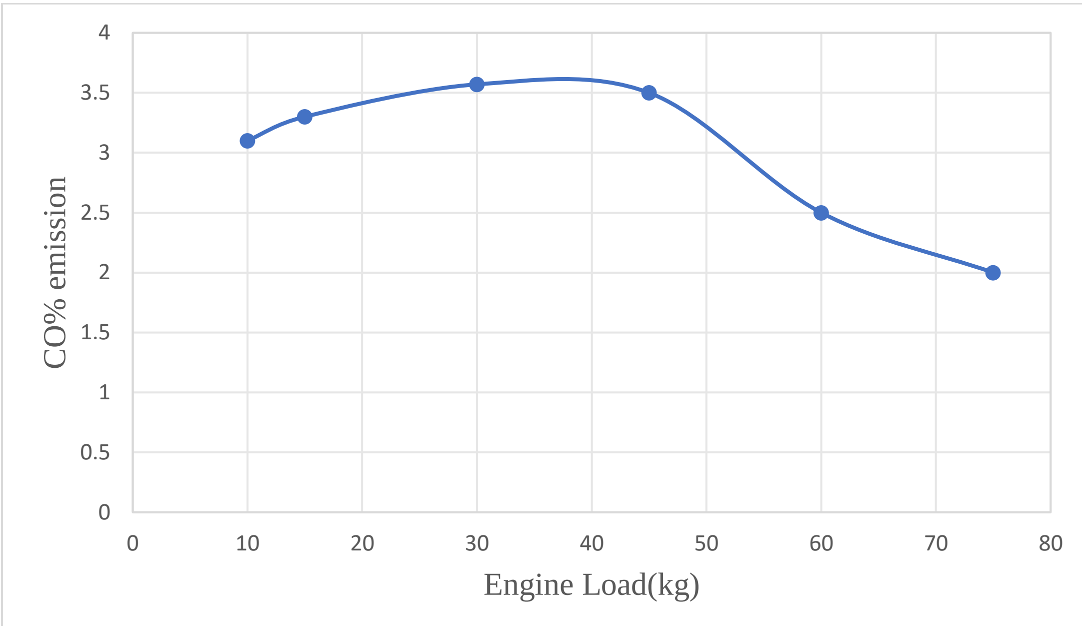


Figure 4.3 CO% emission for E10 fuel.

4.2.4 Carbon monoxide emission test for E15 fuel.

When the engine is fueled with E15, the highest carbon monoxide emission recorded is 3.25% when the load is at 10 kg, while the lowest emission is 1.68% at maximum load. There's a slight decrease in carbon monoxide emissions as engine load increases from lower to higher levels. Figure 4.4 below for detailed carbon monoxide emission data for engines running on E15 fuel.

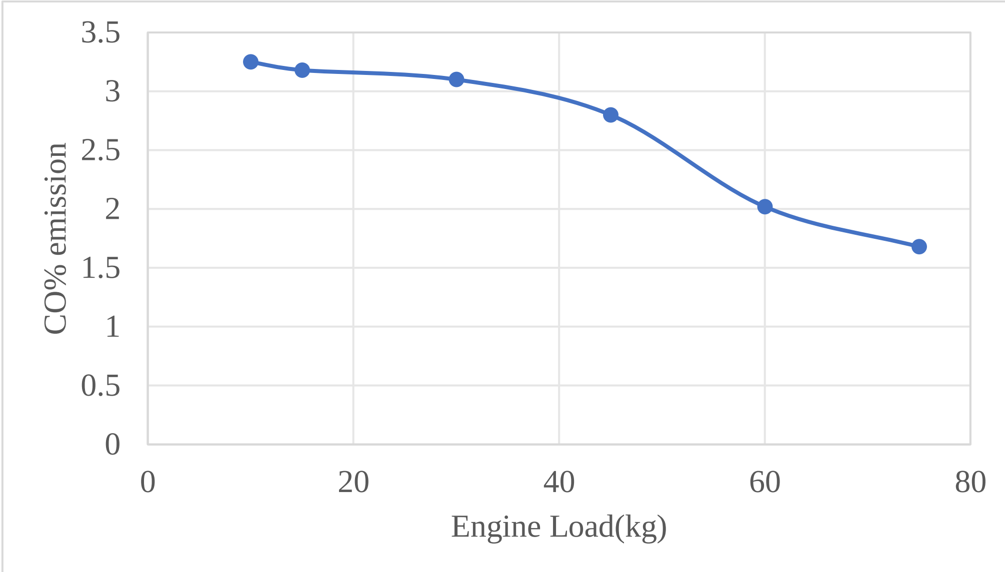


Figure 4.4 CO% Emission for E15 Fuel.

4.2.5 Carbon monoxide emission test for E20 fuel.

Under E20 fuel, the engine registers its peak carbon monoxide emissions of 3.2% at a load of 10 kg, while the lowest emissions of 1.4% are observed at a load of 75 kg. There seems to be a declining trend in emission levels with increasing engine load. For detailed data on carbon monoxide emissions with E20 fuel, refer to Figure 4.5

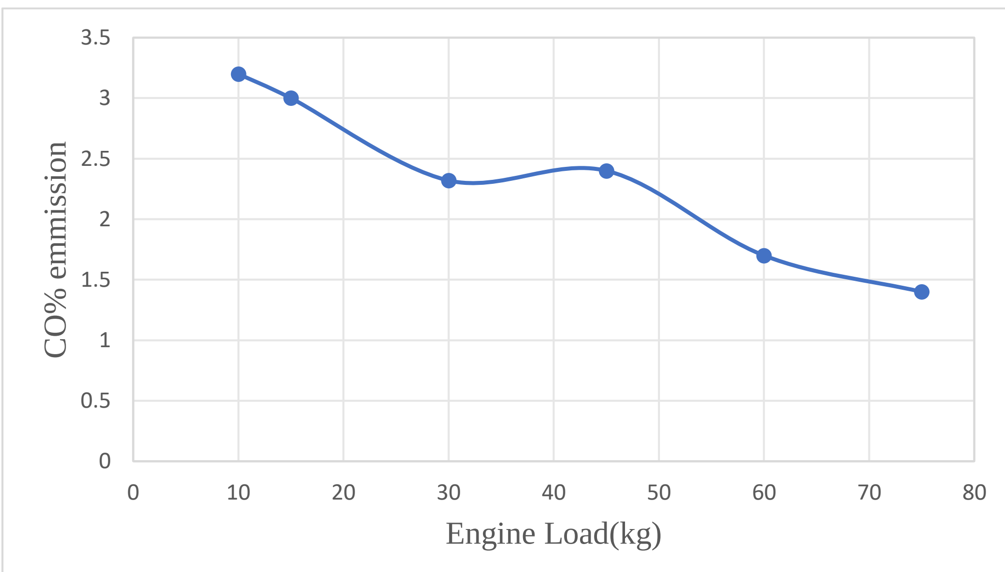


Figure 4.5 CO% emission for E20 fuel.

4.2.6 Carbon monoxide emission test for E25 fuel.

For engines running on fuel type E25, the maximum carbon monoxide emission occurs at engine load conditions of 10 kg, or 3.1%, and the lowest emission occurs at engine load conditions of 75 kg, or 1.3%. Figure 4.6 shows that when engine load increases, carbon monoxide emissions slightly decrease.

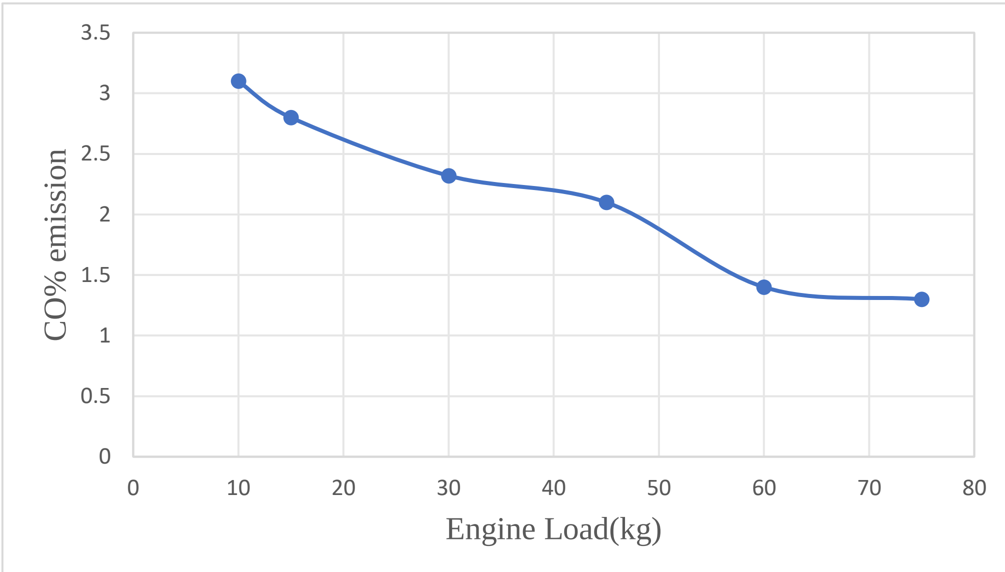


Figure 4.6 CO % emission for E25 fuel.

4.2.7 Summary of CO emission for fuel E0, E5, E10, E15, E20 and E25

The carbon monoxide emission in Figure 4.7 shows that the E0 engine produces slightly more at low engine load and 3.52 at 75kg engine load condition.

According to studies, E25 fuel emits fewer carbon monoxide gases into the atmosphere than E0, E5, E10, E15 and E20 fuels. This is because gasoline with a 25% ethanol content produces less carbon monoxide. After all, it has a lower carbon-to-hydrogen ratio than pure gasoline.

For the fuel types E0, E5, E10, E15, E20, and E25, the average CO emissions are 4.26%, 3.63%, 2.995%, 2.67%, 2.33%, and 2.17%, in that order. In comparison to pure gasoline fuel, the average CO emissions of the E5, E10, E15, E20, and E25 show reductions of 14.79%, 29.69%, 37.26%, 45.31%, and 49.1%, respectively.

The decrease in carbon monoxide (CO) emissions as ethanol concentration in gasoline increases can be attributed to several factors related to the chemical properties and combustion characteristics of ethanol such as high oxygen content of ethanol, more complete combustion and higher flame temperature (Mehra et al., 2017).

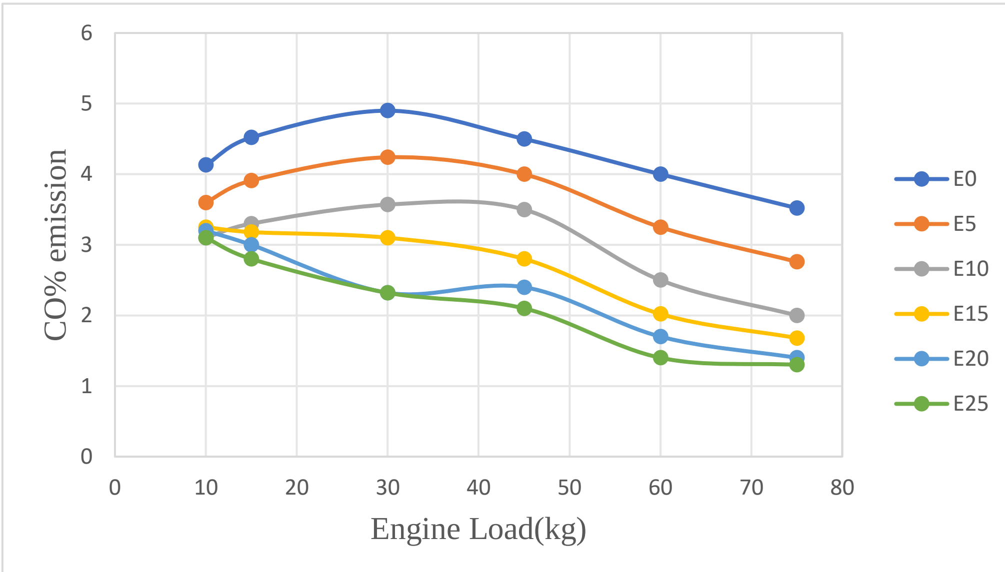


Figure 4.7 Comparison of CO% emission for E0, E5, E10, E15, E20 and E25 fuel

4.3 Evaluation of Hydrocarbon Emission

An SI engine's exhaust gases contain partially reacted and unburned fuel components as they exit the combustion chamber. Small molecules that are created when big fuel molecules fracture (thermally crack) during the combustion reaction make up these partially reacted particles. Treating these molecules as though they only had one carbon atom—that is, as HC—is frequently convenient (Sarkar, 2013)

The result of incomplete fuel combustion is hydrocarbons. High amounts of HC are produced in the exhaust products when a rich fuel mixture is used because there is insufficient oxygen to react with all the carbon. Because of wear, an engine's clearance between the cylinder walls and pistons frequently increases with age.

4.3.1 Hydrocarbon emission test for E0 fuel type.

The engine running on pure gasoline fuel has the maximum hydrocarbon emission at 10 kg of engine load, which is 61 ppm, and the lowest hydrocarbon emission at 75 kg of engine load. The test engine produces the least amount of hydrocarbon emissions when it is operating at a low load, and the amount increases as engine load increases. Figure. 4.8 illustrates the hydrocarbon emissions from an engine running solely on gasoline fuel.

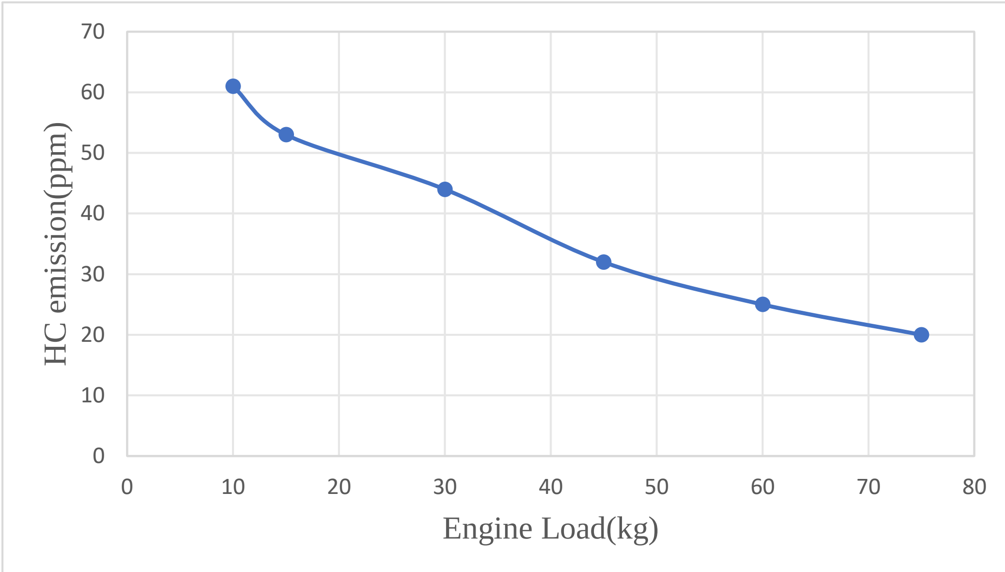


Figure 4.8 HC emission for E0 fuel type.

4.3.2 Hydrocarbon emission test for E5 fuel type.

The hydrocarbon emission for an engine running on fuel type E5 is highest at an engine load of 10 kg, or 53 ppm, and lowest at an engine load condition of 75 kg, or 18 ppm. The amount of hydrocarbon emissions decreases as engine load increases. All load conditions for E5 test fuel's hydrocarbon emissions are displayed in Figure 4.9.

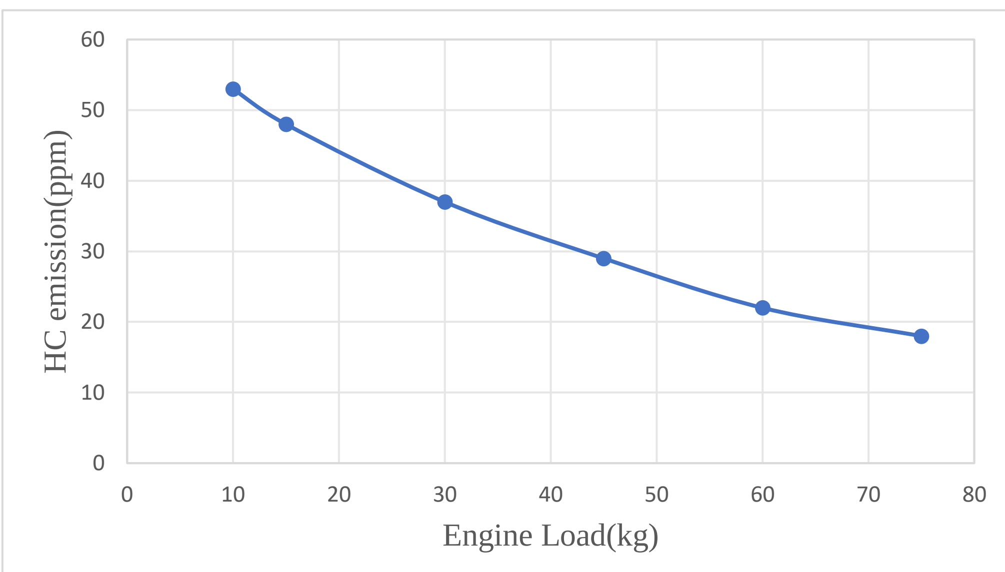


Figure 4.9 HC emission for fuel E5.

4.3.3 Hydrocarbon emission test for E10 fuel type.

The maximum hydrocarbon content in an engine running on E5 test fuel is 49 ppm when the engine load is 10 kg, and it falls to 14 ppm when the engine load is 75 kg. As the engine load increases, the hydrocarbon emission decreases. The E10 test fuel's hydrocarbon emissions are displayed in Figure 4.10

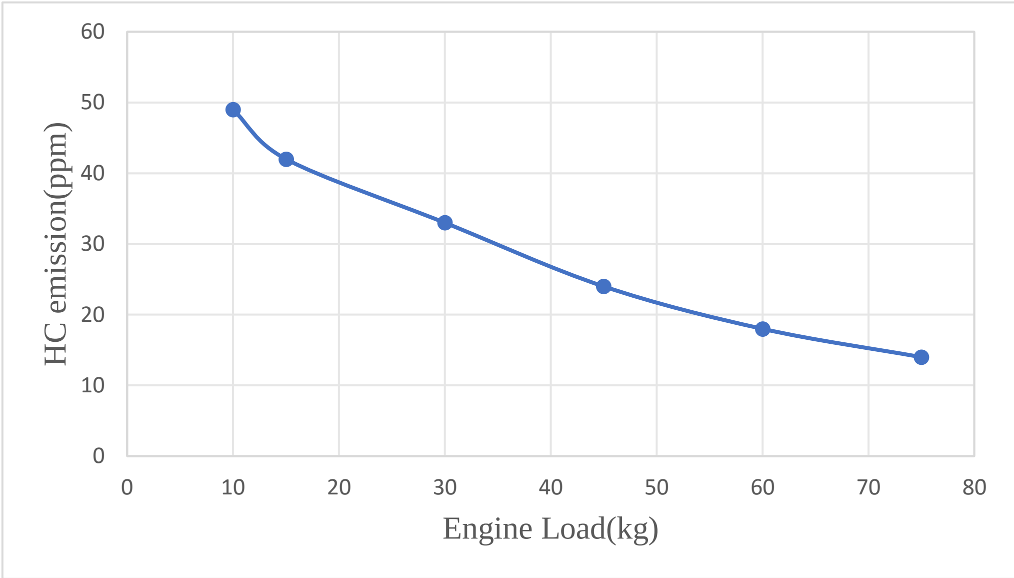


Figure 4.10 HC emission for E10 fuel type.

4.3.4 Hydrocarbon emission test for E15 fuel type.

At an engine load condition of 10 kg, the maximum hydrocarbon emission peaks at 43 ppm, while the lowest emission of 14 ppm is observed at an engine load condition of 75 kg. Figure 4.11 illustrates the trend of decreasing hydrocarbon emissions as the engine load condition increases.

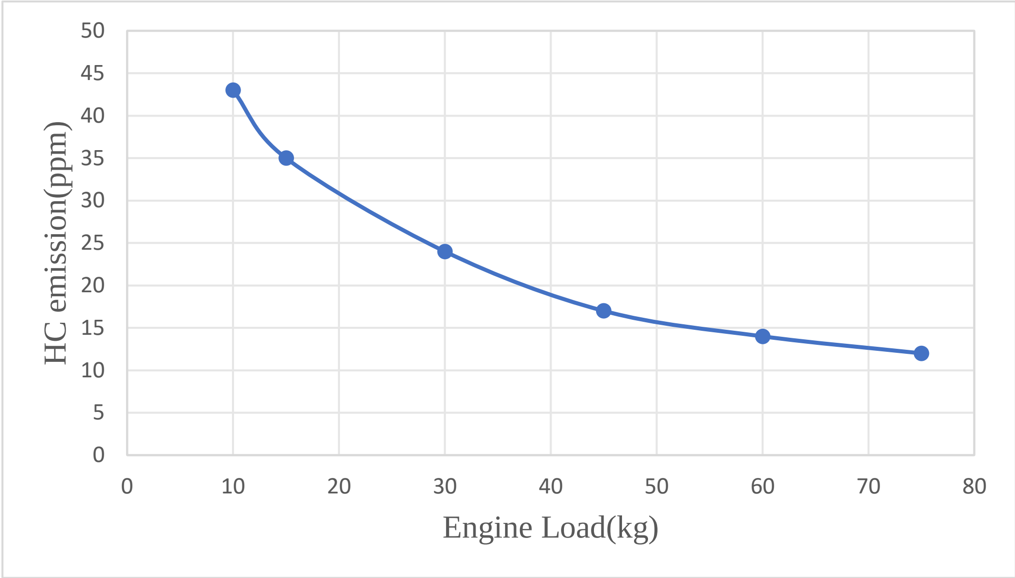


Figure 4.11 HC emission for E15 fuel type.

4.3.5 Hydrocarbon emission test for E20 fuel type.

When the engine load is 10 kg, the maximum hydrocarbon content in an engine running on E5 test fuel is 49 ppm; at 75 kg, the maximum hydrocarbon content drops to 14 ppm. Hydrocarbon emissions decrease with increasing engine load. Figure 4.12 shows the hydrocarbon emissions from the E20 test fuel.

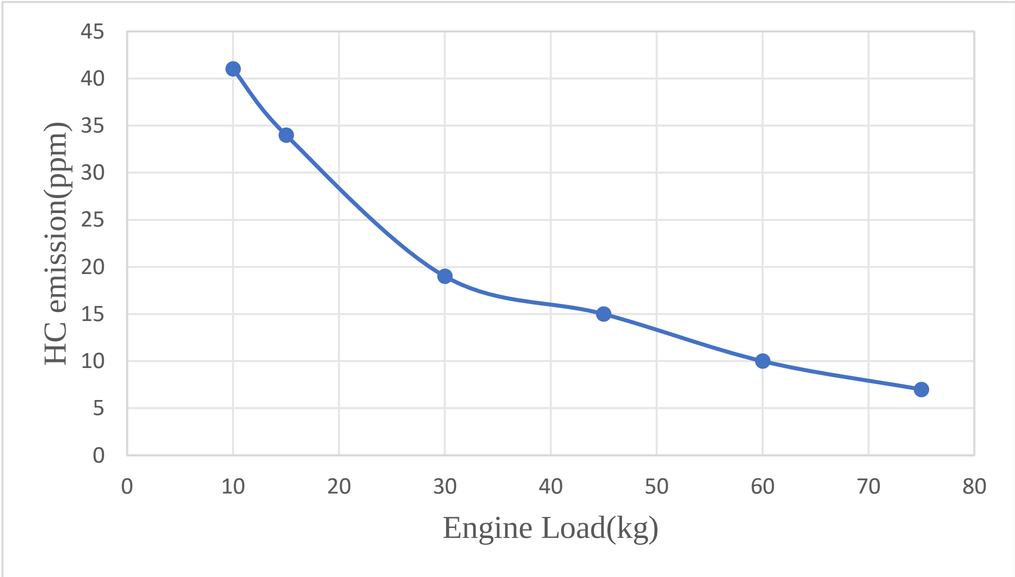


Figure 4.12 HC Emission for E20 Fuel.

4.3.6 Hydrocarbon emission test for E25 fuel type.

In the case of E25 test fuel, the maximum hydrocarbon emission is recorded at 37 ppm under the lowest engine load condition, while the lowest emission of 7 ppm is observed at an engine load condition of 75 kg. As the engine load increases, hydrocarbon emissions show a decreasing trend. The hydrocarbon emissions for all test fuels at the selected engine load conditions are presented in Figure 4.13.

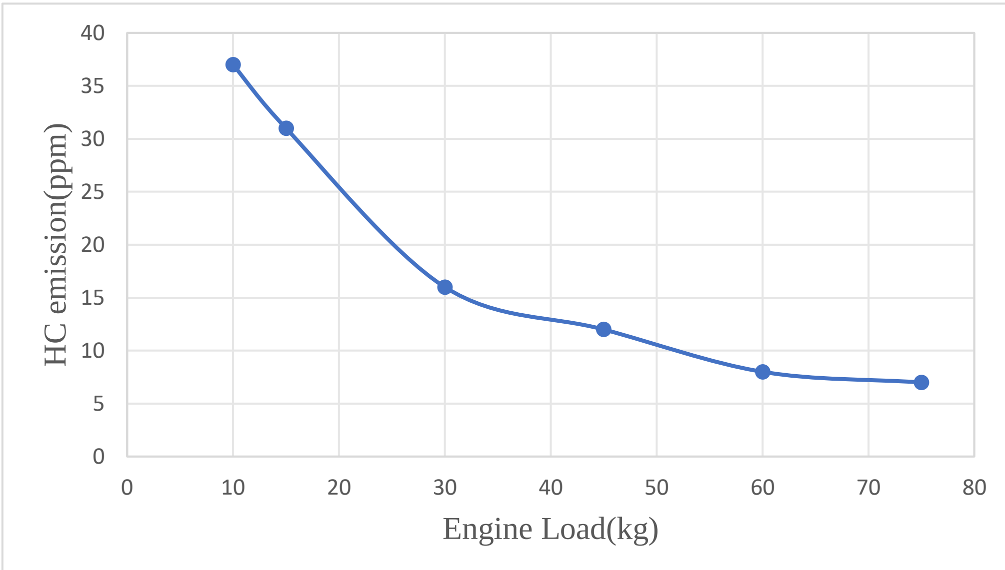


Figure 4.13 HC emission for E25 fuel type.

4.3.7 Summary of HC emission for E0, E5, E10, E15, E20 and E25

For the E0, E5, E10, E15, E20, and E25, the average HC emissions are 39.2 ppm, 34.5 ppm, 30 ppm, 24.2 ppm, 21 ppm, and 18.5 ppm, respectively. In comparison to pure gasoline fuel, the average HC emissions of the E5, E10, E15, E20, and E25 show reductions of 11.99%, 23.47%, 38.26%, 46%, and 53.57%, respectively. The amount of HC emissions reduced by E25 fuel is higher. Figure. 4.14 below compares the emissions of hydrocarbons for each test fuel.

Because of its improved combustion efficiency(oxygen content and higher octane rating), the cooling effect, HC emission decreases as the volume of ethanol in gasoline fuel increases (Mourad & Noureldenn, 2019).

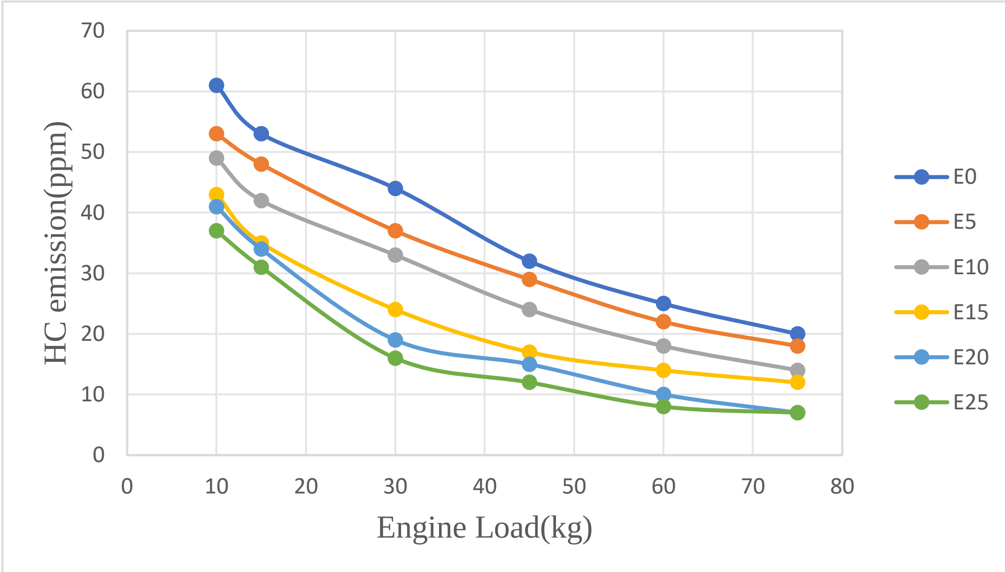


Figure 4.14 Comparison of HC emission for E0, E10, E15, E20 and E25 fuels.

4.4 Evolution of NO_x emission.

E0, E5, E10, E15, E20, and E25 have average NOx emissions of 337.5 ppm, 392 ppm, 447.8 ppm, 484.3 ppm, 489.33 ppm, and 502 ppm respectively. In comparison to pure gasoline fuel, the average NOx emissions of E5, E10, E15, E20, and E25 increase by 16.23%, 32.68%, 43.5%, 44.99%, and 48.74%, respectively. NOx emissions rise more when using E25 fuel. Table 15 below displays the NOx emission results for fuel types E0, E5, E10, E15, E20, and E25 during engine operation.

Ethanol has a higher heat of vaporization compared to gasoline, which can lead to cooler intake air temperatures and more dense air-fuel mixture. However, ethanol also has a higher octane rating, allowing for more advanced ignition timing and higher compression ratios. These conditions can result in higher peak combustion temperatures, which promote the formation of NOx (Dinh et al., 2020).

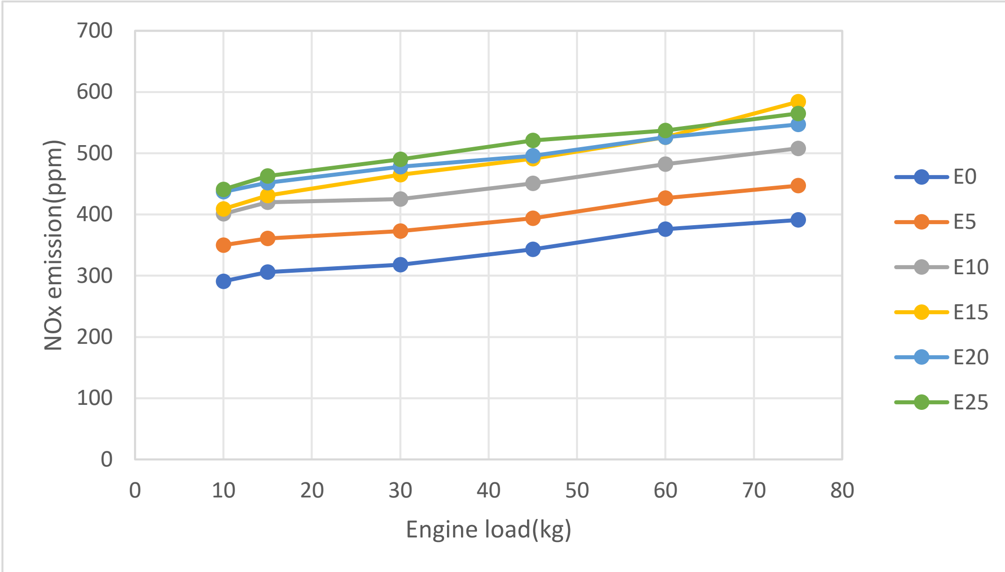


Figure. 4.15 Comparison of NO_x emission for all test fuel.

4.5 Performance test for E0 fuel

The current research has been conducted using a engine dynamo meter. Pure gasoline fuel has an engine power maximum of 439.6 W at a 10 kg engine load and a minimum engine power of 157 W at a 75 kg engine load. When the engine reaches its maximum power, it begins to gradually decrease from its initial starting point. At 30 kg of engine load, or 4.4 Nm, the maximum engine torque is also reached, and at 75 kg of engine load, or 1.5 Nm, the minimum engine torque is reached. When the test engine is run on pure gasoline fuel, the engine power and torque are displayed In figure 4.16.

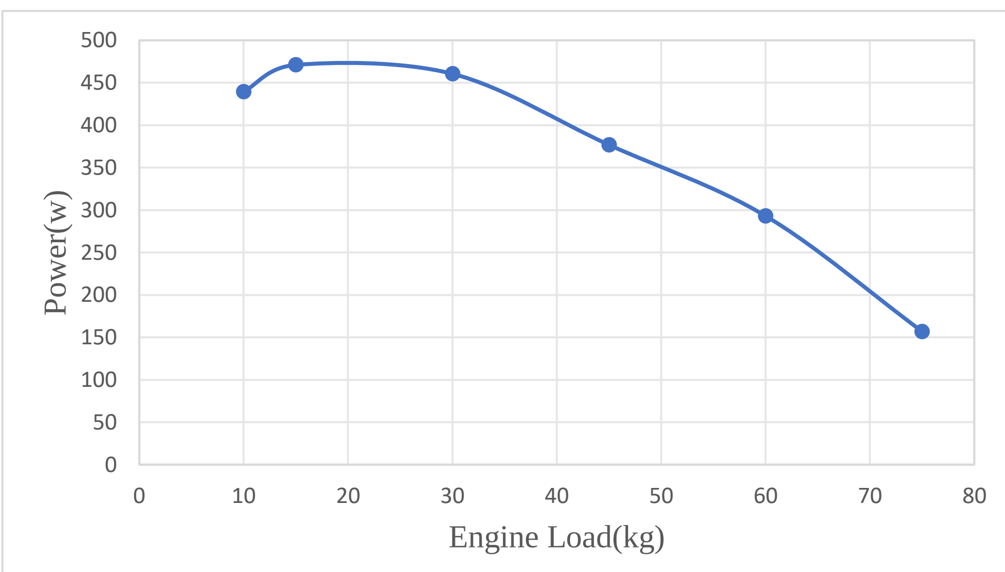


Figure 4.15 Engine power for E0 fuel

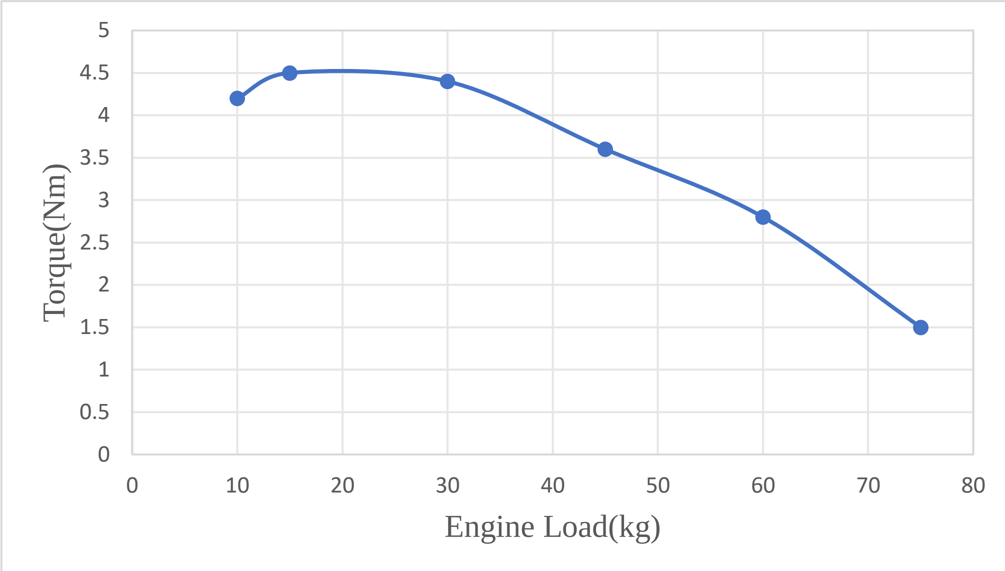


Figure 4.16 Engine torque for E0 fuel

4.6 Performance test for E5 fuel type.

With fuel type E5, engine power ranges from 489.84W to 177.93W. When the engine load is 30 kg, engine power is at its highest, and when it is 75 kg, it is at its lowest. The engine has a torque range of 4.68 Nm to 1.7 Nm. Additionally, engine load conditions of 30 kg and 75 kg, respectively, reach the maximum and minimum engine torques. Figure 4.17 shows engine torque and power for E5 fuel.

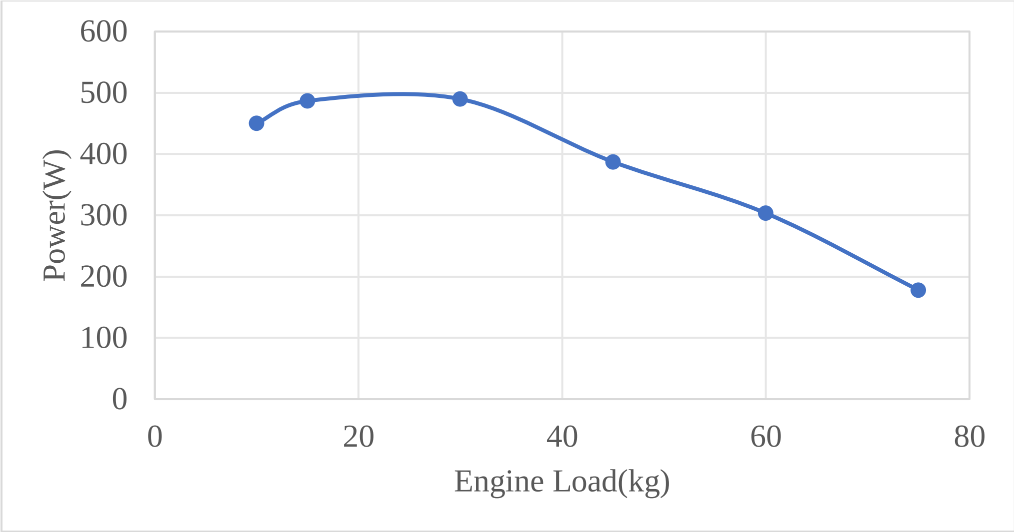


Figure 4.17 Engine power for E5 fuel

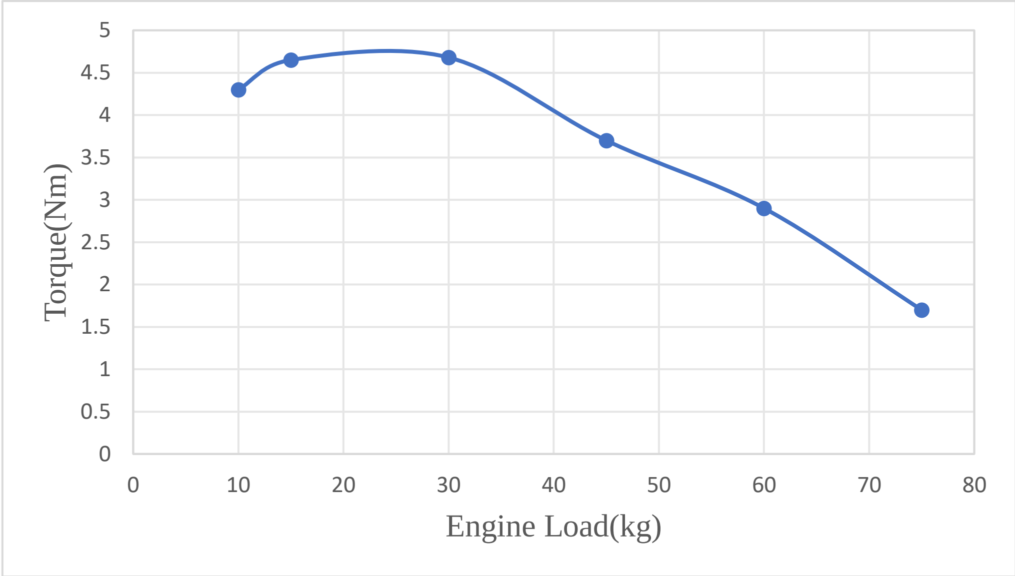


Figure 4.18 Engine torque for E5 fuel.

4.7 Performance test for E10 fuel

The engine's maximum power of 518.1 W at a 30 kg engine load condition and its minimum power of 198.86 W at a 75 kg engine load condition are achieved when it is powered by fuel type E10. When using E5 fuel, the engine produces 4.95 Nm of torque at 30 kg of engine load, and at the highest engine load condition, the engine produces 1.9 Nm of minimum torque. Figure 4.19 display the test results for the E10 fuel type.

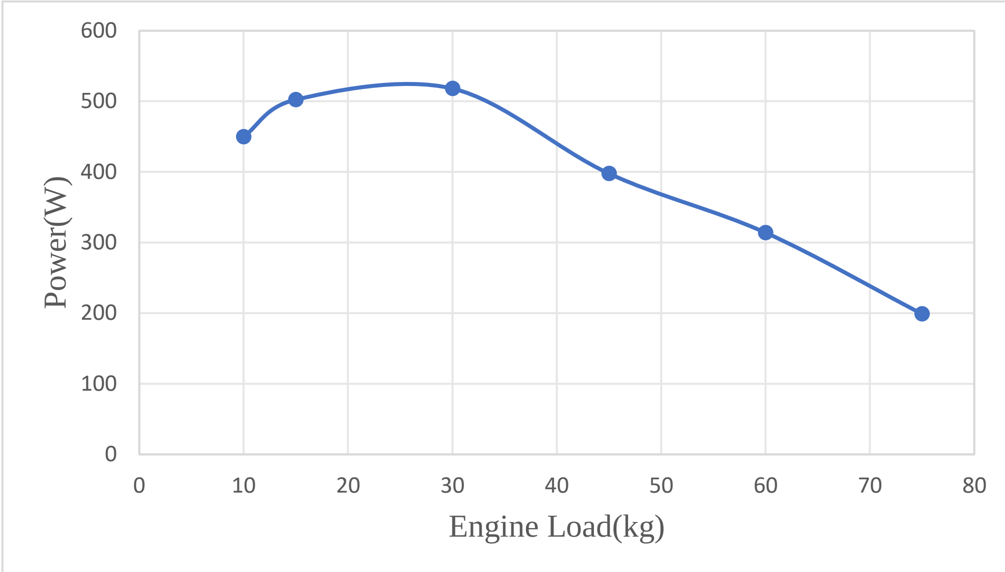


Figure 4.19 Engine power for E10 fuel.

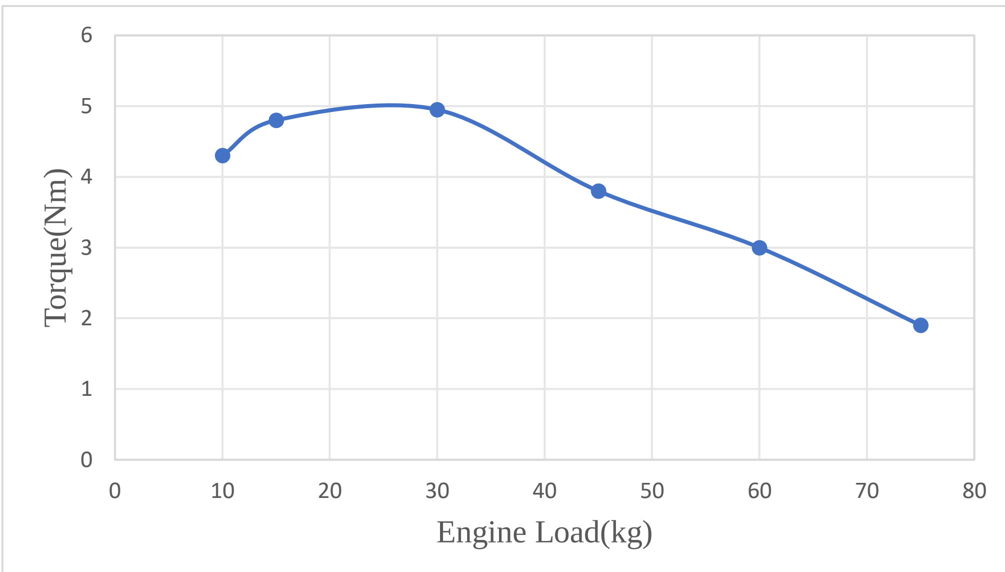


Figure 4.20 Performance test for E15

At 30 kg and 75 kg of engine load, respectively, the engine's maximum power output is 565.2 W when running on fuel type E15, and its minimum power output is 240.3 W. The power curve's characteristic appears to increase at first and then decrease as engine power reaches its maximum. When the engine load was 30 kg, the engine torque reached its maximum of 5.4 Nm, and when the engine load was 75 kg, the engine torque was at its lowest of 2.3 Nm. Engine power and torque for the E15 fuel type are displayed in Figure 20.

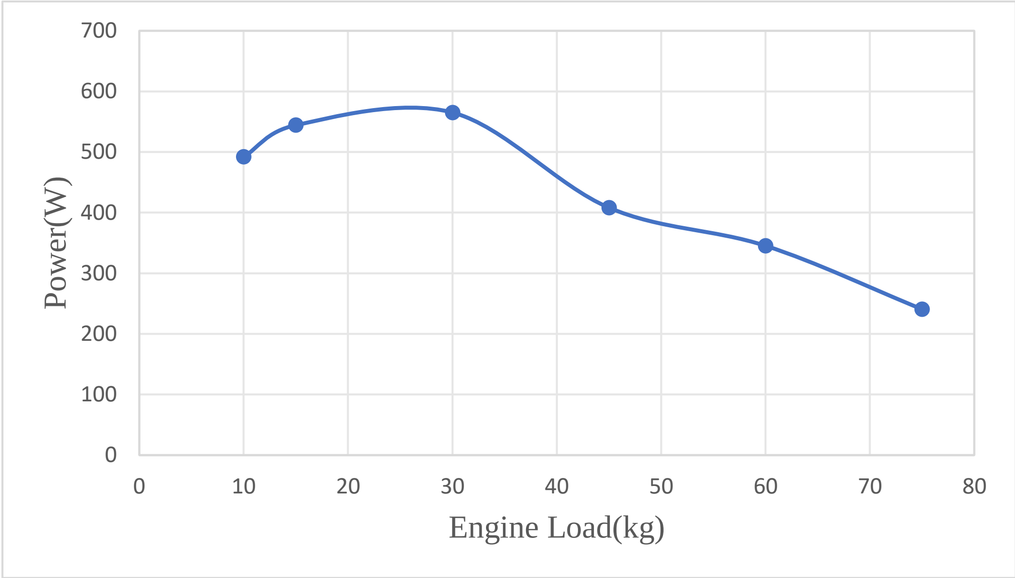


Figure 4.21 Engine power for E15 fuel.

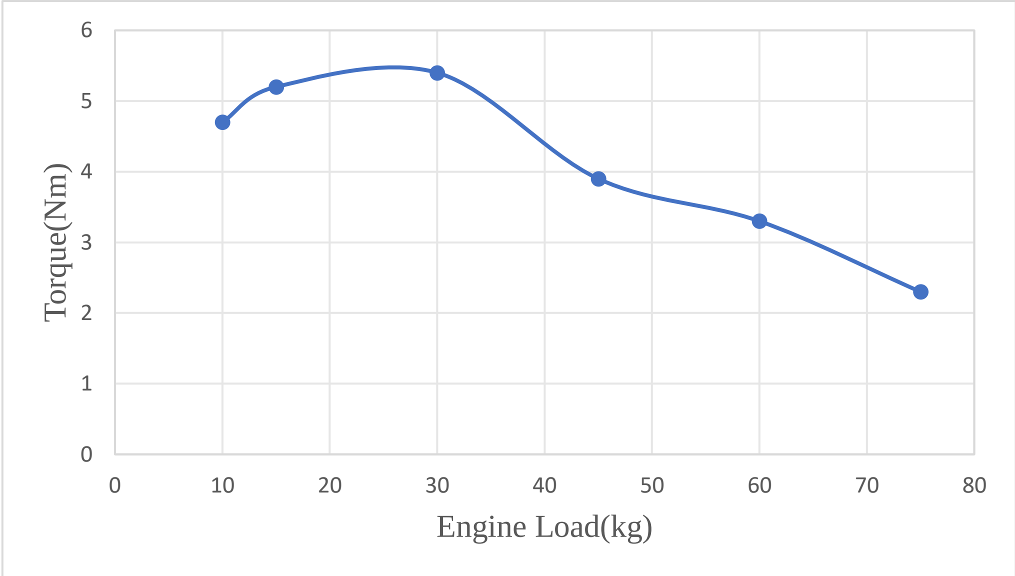


Figure 4.22 Engine power for E20 fuel.

4.8 Performance test for E20 fuel

Fuel type E20 powers the engine to its maximum power of 638.47W and minimum power of 293.07W at engine load conditions of 30kg and 75kg respectively. The maximum engine torque is 6.1 Nm and then drops to 2.8 Nm when the engine load is 30 kg or 75 kg, respectively. Engine power and torque are displayed in Figure. 4.23 and Figure 4.24 respectively when fuel type E20 is used.

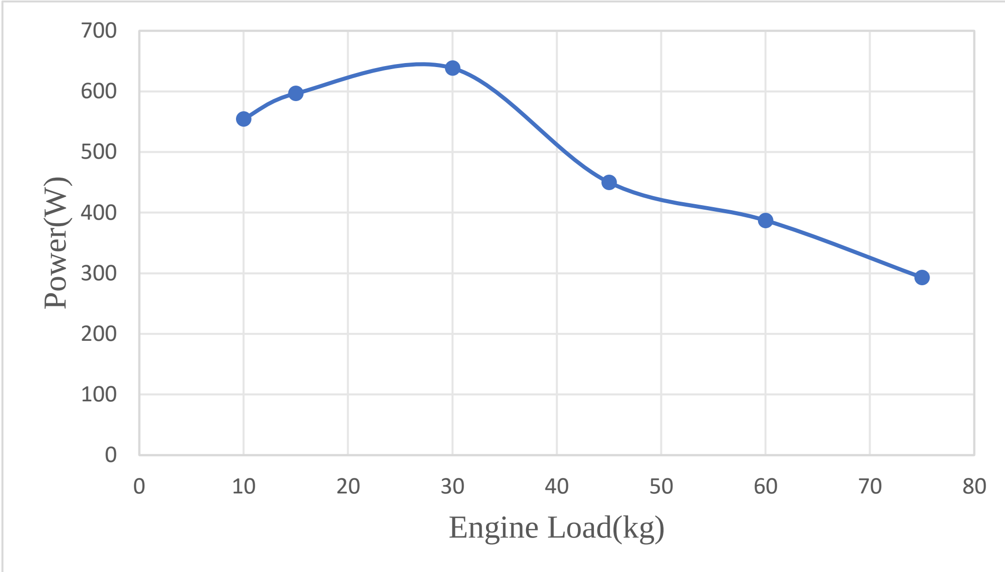


Figure 4.23 Engine power for E20 fuel.

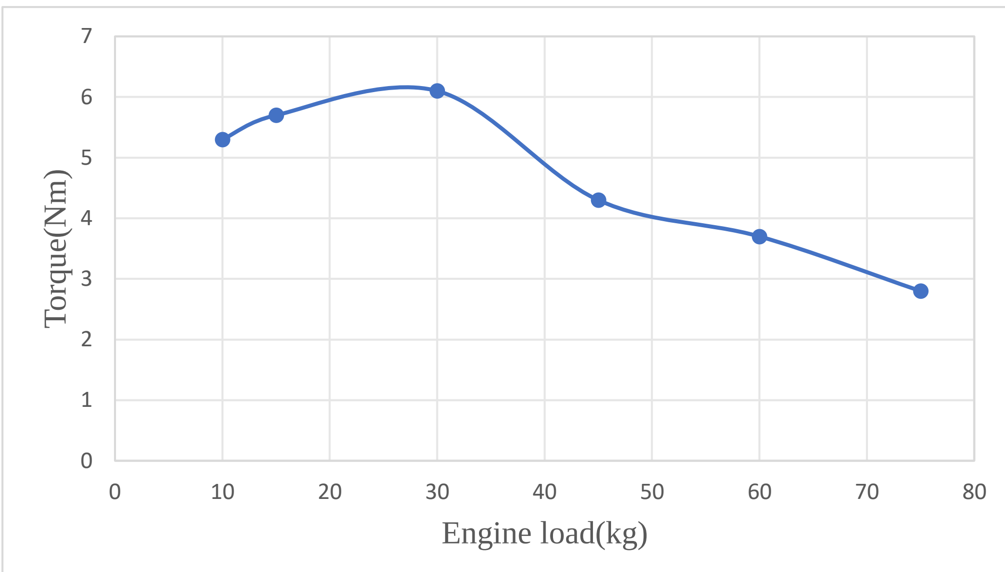


Figure 4.24 engine torque for E20 fuel.

4.9 Performance test for E25 fuel

Engine power on test fuel E20 reaches a maximum of 669.87 W and decreases to 324.47 W at 30 kg and 75 kg engine load conditions, respectively. At engine load conditions of 30 kg and 75 kg, the engine torque decreases to 3.1 Nm from its maximum torque of 6.4 Nm. Figure 4.25 illustrates engine power and torque when using fuel type E25 in engines.

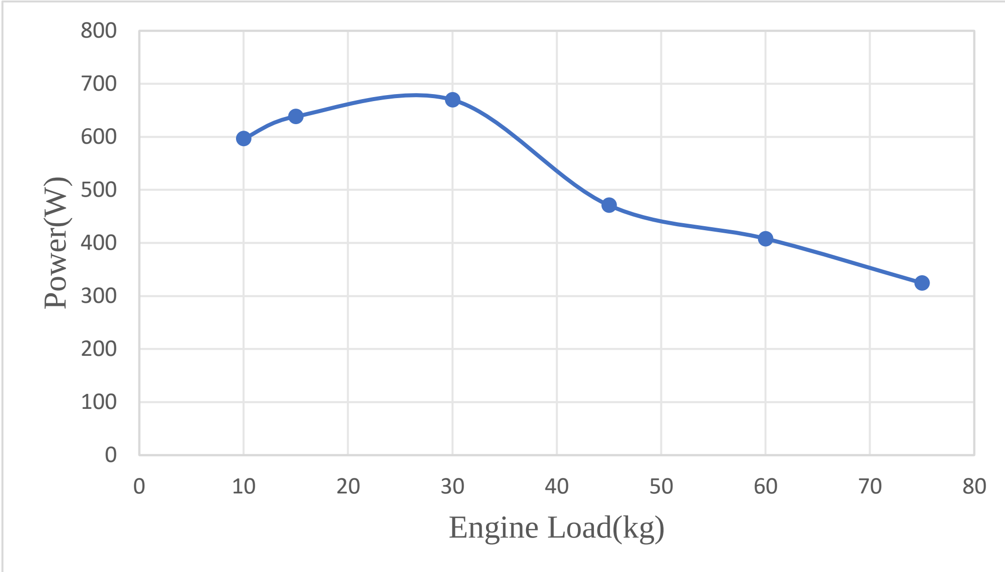


Figure 4.25 Engine power for E25

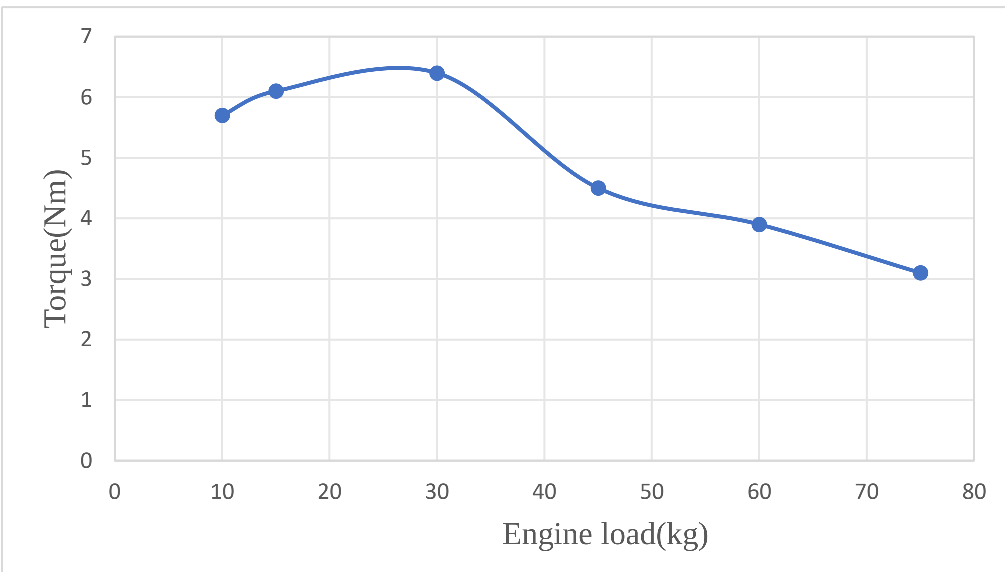


Figure 4.26 Engine torque for E25

4.10 Summary of Engine Performance

4.10.1 Analysis of engine torque

For the E0, E5, E10, E15, E20, and E25, the average engine torque is 3.5 Nm, 3.6 Nm, 3.8 Nm, 4.1 Nm, 4.65 Nm, and 4.95 Nm, in that order. The engine torque experiences a rise when contrasted with using pure gasoline as fuel. for the E5, E10, E15, E20, and E25 is 3%, 8.6%, 17%, 32.9%, and 41%, respectively. The test fuel with the highest engine torque was E25. Engines for test fuels are shown in Figure 4.27.

Engine torque increases as the concentration of ethanol in gasoline increases in a spark-ignition (SI) engine due to characteristics of ethanol such as higher octane rating, higher heat of vaporization, and low energy density(Wallner et al., 2009).

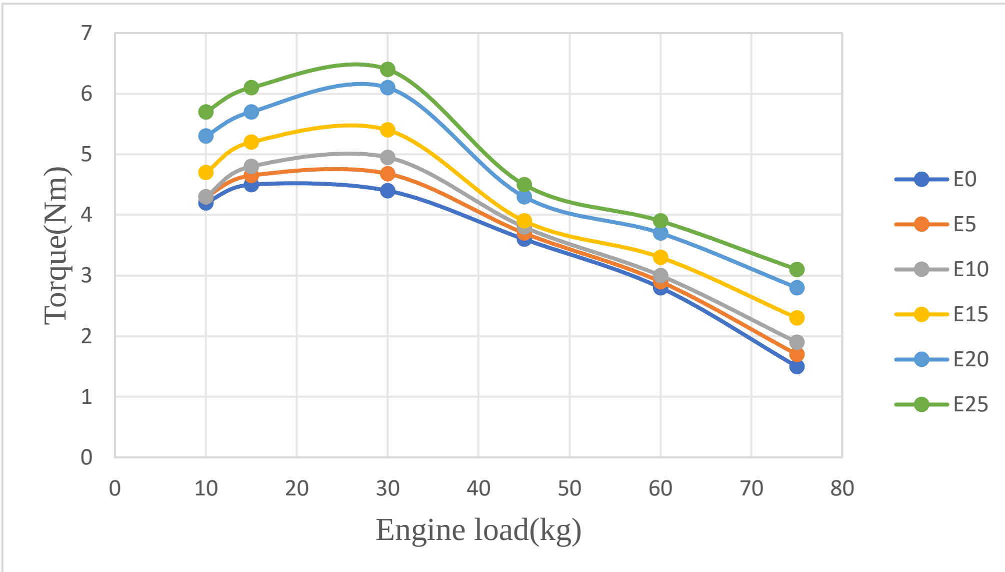


Figure 4.27 Engine torque for all test fuels.

4.10.2 Analysis of Engine Power

E0, E5, E10, E15, E20, and E25 engine power test fuels have average values of 366W, 382.6W, 396.9W, 432.6W, 486.7W, and 518W, respectively. Comparing test fuel E10, E5, E15, E20, and E25 to pure gasoline fuel, the increases in engine power are 4.5%, 8.44%, 18.2%, 32.9%, and 45%, respectively. The engine power compared with the test fuels is shown in Figure 4.28.

Engine power increases as the concentration of ethanol in gasoline increases in a spark-ignition (SI) engine due to characteristics of ethanol such as higher octane rating, higher heat of vaporization, and low energy density (Tornatore et al., 2019).

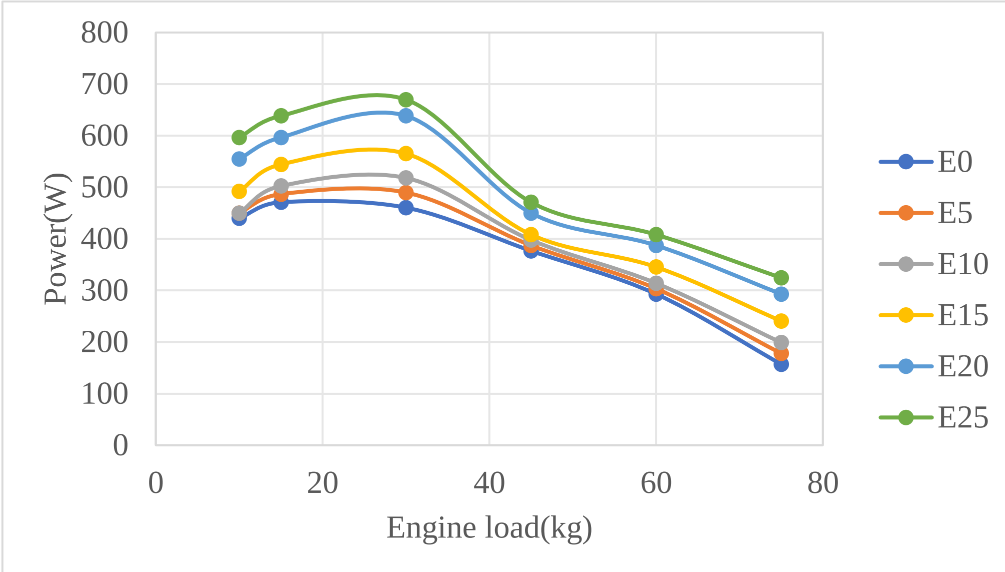


Figure 4.28 Comparison of engine power for all fuels.

4.10.3 Evaluation of Brake-Specific Fuel Consumption

In engine tests, fuel consumption is quantified as a flow rate, represented by mass flow per unit time (mf). Specific fuel consumption (sfc), which denotes fuel flow rate per unit power output, serves as a more significant measure. It assesses the efficiency with which an engine utilizes the fuel provided to produce work.

$$BSFC = \frac{mass\ flow\ rate\ (\dot{m}f)}{power\ (P)} \quad \text{..Equation. (1)}$$

where $\dot{m}f$ and P_b is measured as fuel consumption (kg/hr) and brake power (kW) respectively.

Mass flow rate = density of fuel x injection rate

Density of blend fuel

Density of gasoline is 0.720g/ml

Density of ethanol is 0.789g/ml

The density of blend fuel is calculated as follows.

$$\text{Density blend fuel} = \frac{\text{VG x 0.720g/ml + VE x 0.789}}{\text{VG + VE}} \quad \text{..............................(Equation 2)}$$

Where VG -volume of Gasoline

VE -Volume of Ethanol

Table 4.1 Density of blend fuel

Fuel Type	Density(g/ml)
E0	0.72
E5	0.7235
E10	0.7269
E15	0.7303
E20	0.7338
E25	0.7718

E0, E5, E10, E15, E20, and E25 average BSFC values of 992.2g/kwh, 923.2g/kwh, 843.5g/kwh, 798g/kwh, 709.9g/kwh, and 626g/kwh, respectively. Comparing test fuel E10, E5, E15, E20, and E25 to pure gasoline fuel, BSFC is reduced by 6.95%, 14.9%, 19.5%, 23.2%, and 26.9%, respectively.The test fuel with the lowest BSFC was E25(25% Ethanol + 75% gasoline).

Ethanol-gasoline blends can lead to higher volumetric fuel consumption due to ethanol's lower energy density, they can also improve combustion efficiency and thermal efficiency, which can help reduce BSFC. The overall effect on BSFC depends on the blend ratio of ethanol and gasoline (Manikandan et al., 2013).

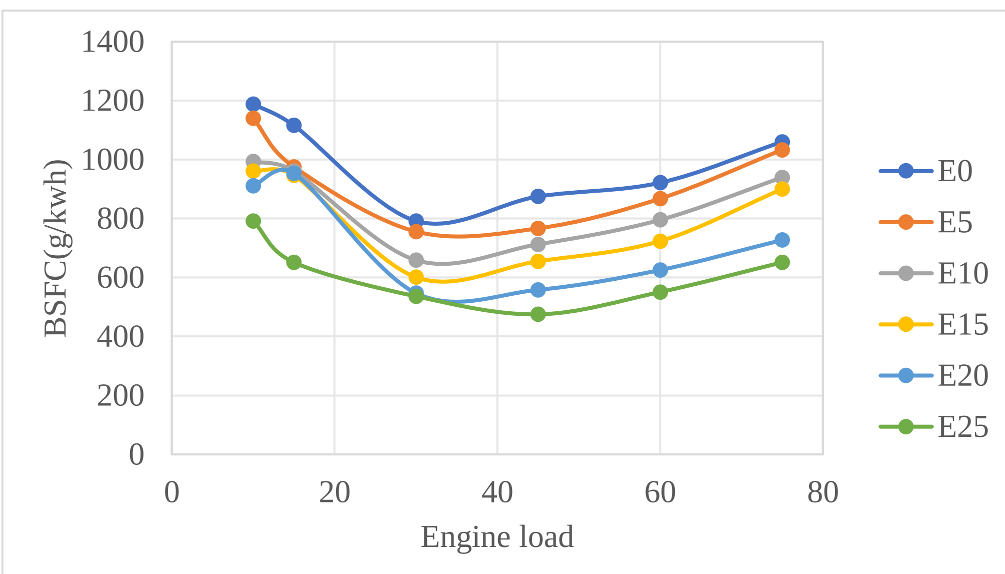


Figure 4.29 BSFC for all test fuel

4.11 Engine vibration analysis

Engine vibrations in the X-axis, Y-axis, and Z-axis were recorded for a range of test fuels at varying engine speeds in this experimental investigation. The overall engine vibration for all test fuel is calculated by the below equation.

V= $\sqrt{x^2 + y^2 + z^2}$

4.11.1 Engine vibration analysis for E0 fuel.

The engine vibrates as much as 6.054 m/s^2 when running on pure gasoline fuel, and as little as 4.69 m/s^2 when the engine is loaded with 75kg and 10kg, respectively. Engine power grows as engine load rises. Maximum engine vibration was attained in the vertical direction of the engine. Engine vibrations are displayed for pure gasoline fuel for selected engine load conditions in Figure 4.3.

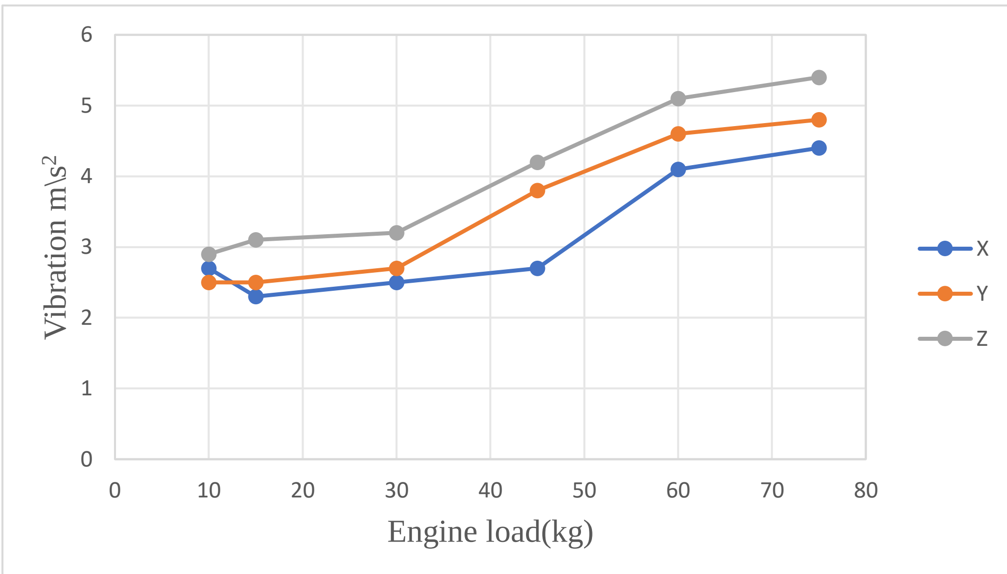


Figure 4.30 Engine vibration E0 fuel in X, Y and Z directions.

4.11.2 Engine vibration analysis for E5 fuel.

Engine vibration can reach 6.39 m/s^2 when running on E5 fuel, and it can be as low as 4.75 m/s^2. Engine vibration rises with increasing engine load conditions. The engine vibrates strongly in a vertical direction when running the E5 fuel type. Figure 4.31 shows engine vibration for engines operated by E5 fuel type.

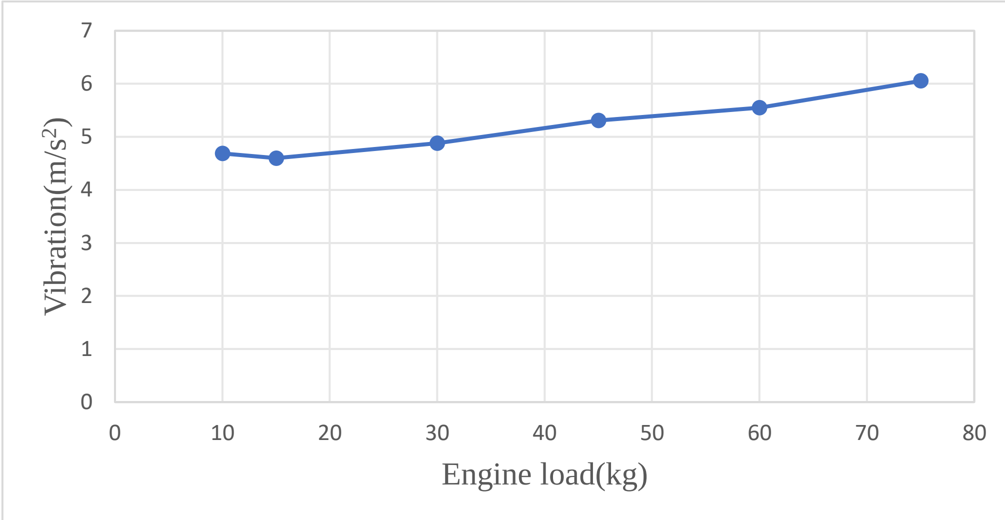


Figure 4.31 Engine vibration for E5 fuel

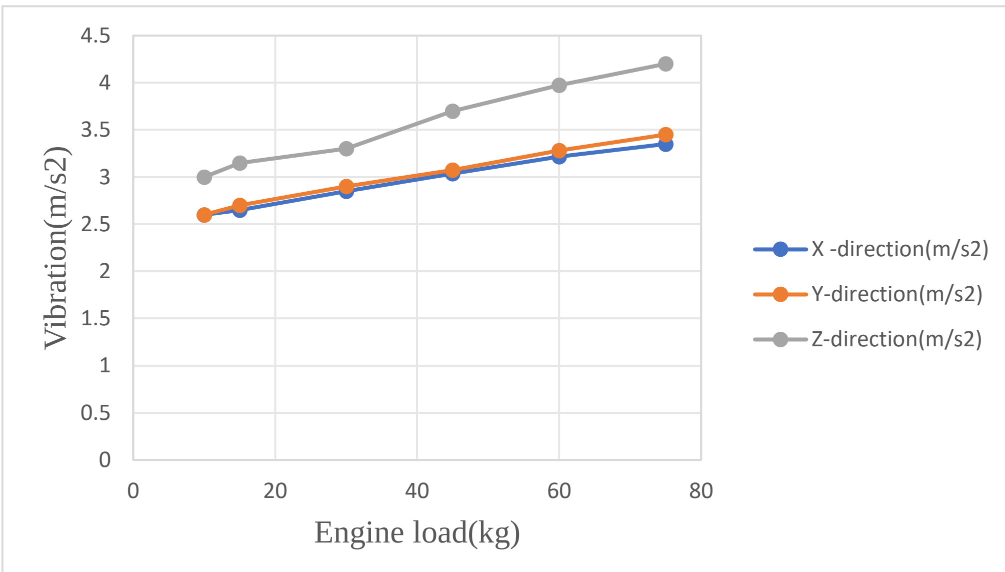


Figure 4.32 Engine vibration for E5 fuel.

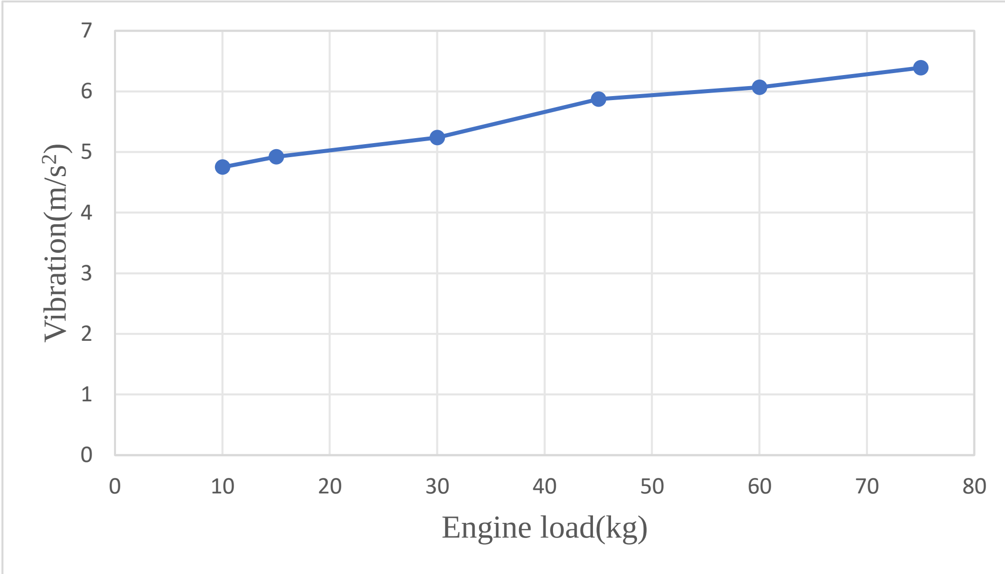


Figure 4.33 Engine vibration for E5 fuel.

4.11.3 Engine vibration analysis for E10 fuel.

Under engine load conditions, the overall engine vibration can reach a maximum of 6.72m/s^2 and a minimum of 4.8m/s^2 for the E10 fuel type. Engine vibration increases with increasing engine load, with maximum vibrations occurring in the vertical direction of the engine. Engine vibration is displayed in Figure 4.34 when the engine is running on fuel type E10

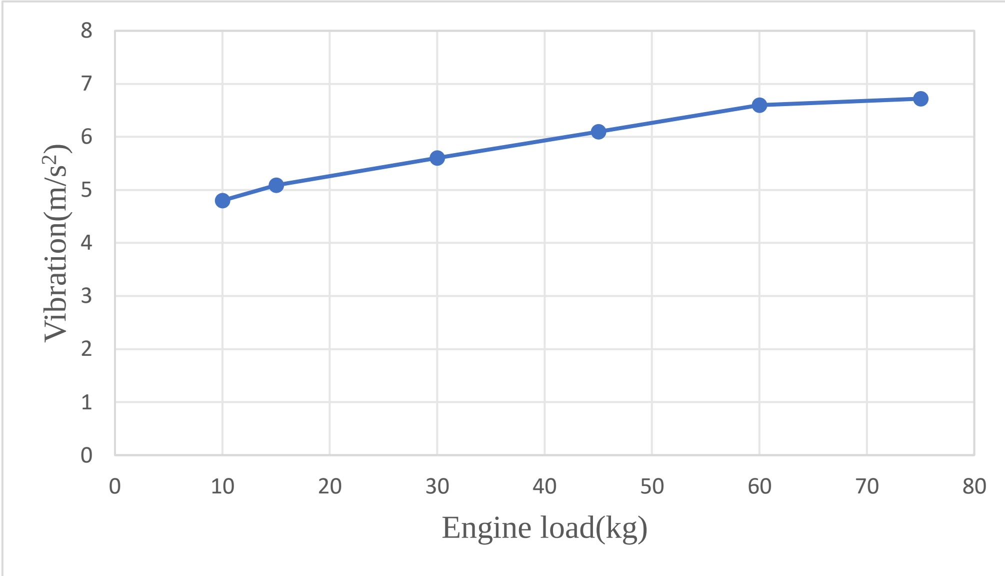


Figure 4.34 Overall engine vibration for E10 fuel.

4.11.4 Engine vibration analysis for E15 fuel.

When the engine is operating at 75 kg of engine load, the maximum overall engine vibration for an E15 fuel is 6.8m/s^2. The previous test found that when the engine load increased, engine vibration increased, with the maximum engine vibration occurring in the vertical direction test engine. The minimum overall engine vibration was achieved at an engine load of 10 kg, or 4.92m/s^2. Engine vibration is displayed in figure 4.36 when using E15 fuel.

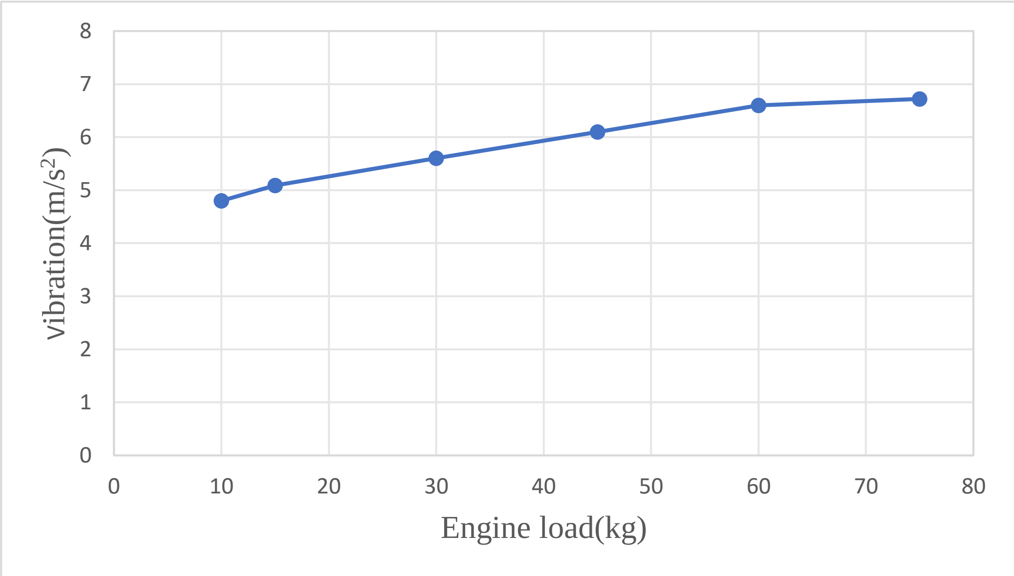


Figure 4.35 Overall engine vibration for E15 fuel.

4.11.5 Engine vibration analysis for E20 fuel.

When using E20 fuel, the engine's maximum vibration is 7.06m/s^2 and its minimum vibration is 5.32 when the engine is loaded with 75 kg and 10 kg, respectively. As engine load increases, engine vibration increases as well. The vertical direction test engine exhibits the highest level of engine vibration. Engine vibration is shown in Figure 4.39 when the engine is operating by test fuel E20.

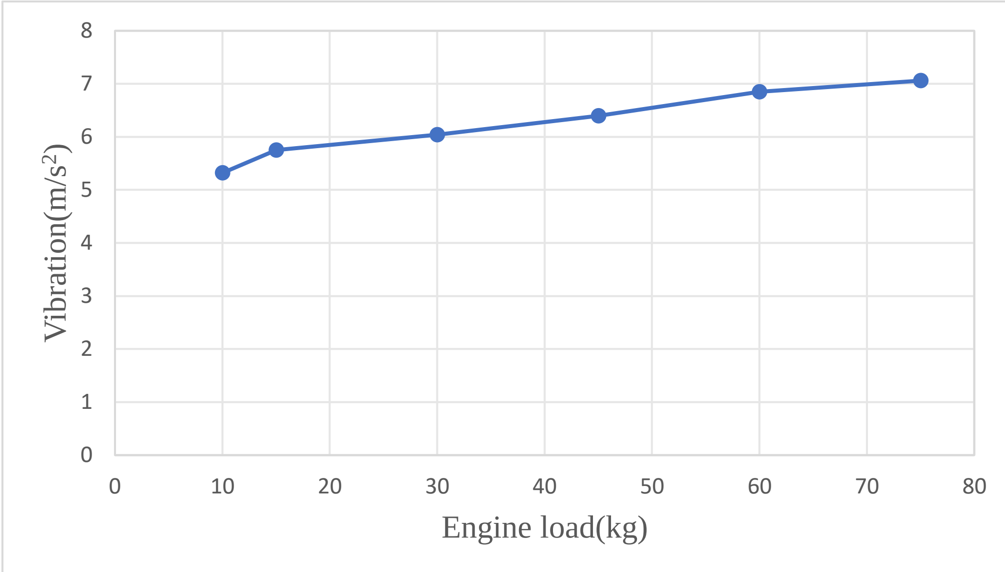


Figure 4.36 Overall engine vibration for fuel E20.

4.11.6 Engine vibration analysis for E25 fuel.

The engine vibrates at a maximum of 7.55 m/s^2 and a minimum of 5.59 m/s^2 when test fuel E25 is used, with an engine load condition of 75 kg and 10 kg, respectively. According to certain tests, engine vibration rises with increasing engine loads. Additionally, the vertical axis is the direction in which the engine vibrates the most.

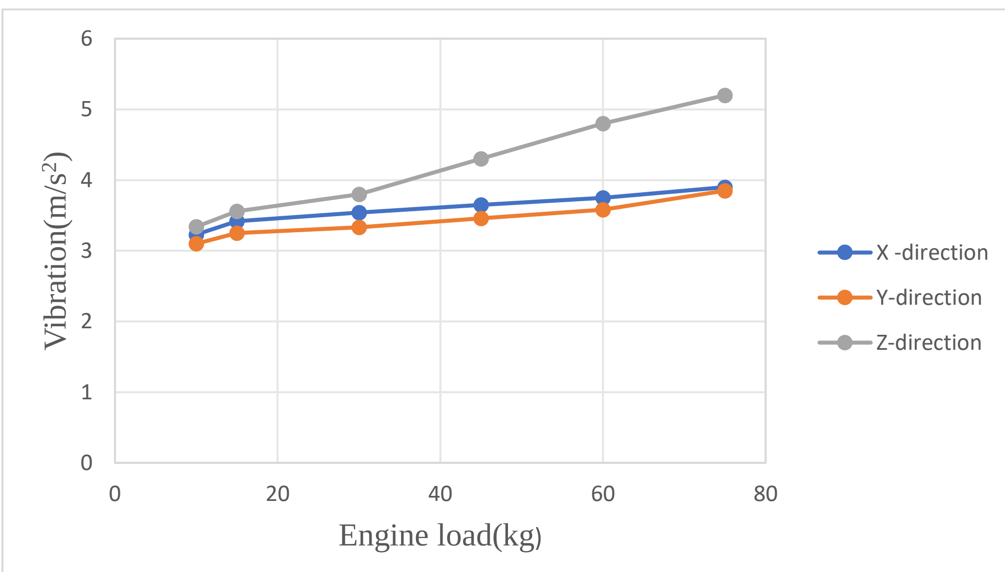


Figure 4.37 Engine vibration for E25 fuel type.

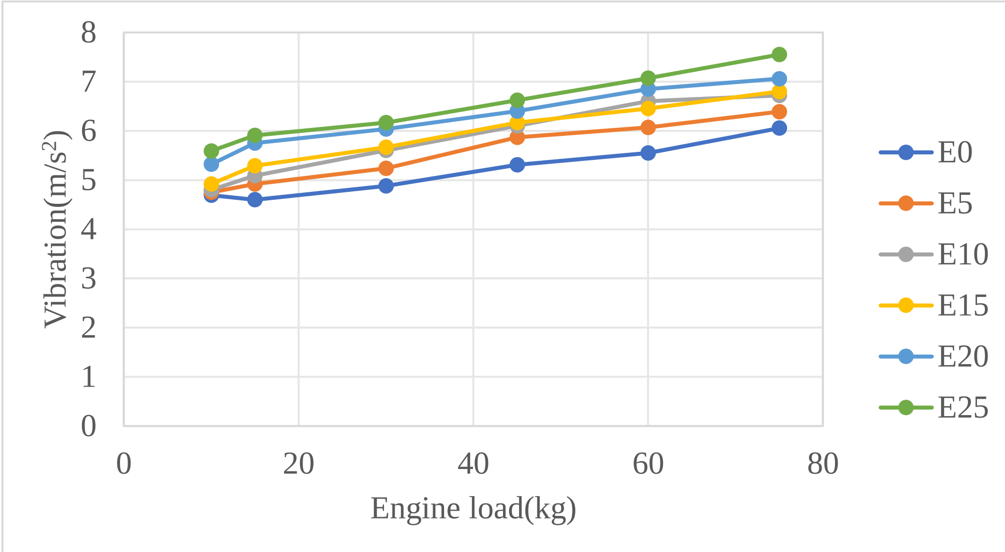


Figure 4.38 Comparison of overall engine vibration for all fuels.

4.11.7 Summary of Engine Vibration

The average test engine vibration when engine used fuel E0, E5, E10, E15, E20 and E25 are,5.18m/s^2, 5.54m/s^2, 5.82m/s^2, 5.88m/s^2, 6.24m/s^2 and 6.49m/s^2 respectively.The increase in engine vibration for test fuel E5, E10, E15, E20, and E25 is, 6.5%, 12.4%, 13.5%, 20.46%, and 25.3% compared to pure gasoline fuel. Regarding direction, the Z-axis direction exhibits the highest vibration about the X-axis and Y-axis directions.

Engine vibrations can increase with higher concentrations of ethanol in ethanol-gasoline blends. Ethanol has a different combustion profile compared to gasoline. It has a higher flame speed and a more complete combustion process, which can change the dynamics of the combustion event. This can result in more abrupt pressure changes within the cylinders, leading to increased vibrations (Sharma et al., 2019).

To determine the impact of the engine vibration caused by different fuel blend International Standard Organization (ISO) is used. To identify the impact first the class of engine must be known based on the criteria standard.

4.12 International standard organization ISO 10816

Ensuring the health and continuous operation of the engine is the primary goal of condition monitoring and machinery protection systems. To continuously measure and analyze machine vibrations, vibration measurement systems, and vibration transducers are installed. To assess each machine's condition, users need a reference to compare the vibration of the machine. Based on a statistical analysis of historical data collected by ISO TC 108, ISO 10816 offers a reference such as allowable vibrations and alarm or trip conditions for different types of machinery.

One of the earliest and most widely used standards for evaluating the vibration of various types of machinery, such as wind turbines, hydro turbines, gas and steam turbines, reciprocating machinery, etc., is ISO 10816.

4.12.1 Class of test Engine identification

Table 4.3 is used to identify the engine class according to ISO 10816. Given that the test engine's maximum power of 3 kW is less than 15 kW, class I status has been given to it.

Table 4.2 ISO 10816-1

Engine class	Engine power
Class I	15KW
Class II	15KW-75KW

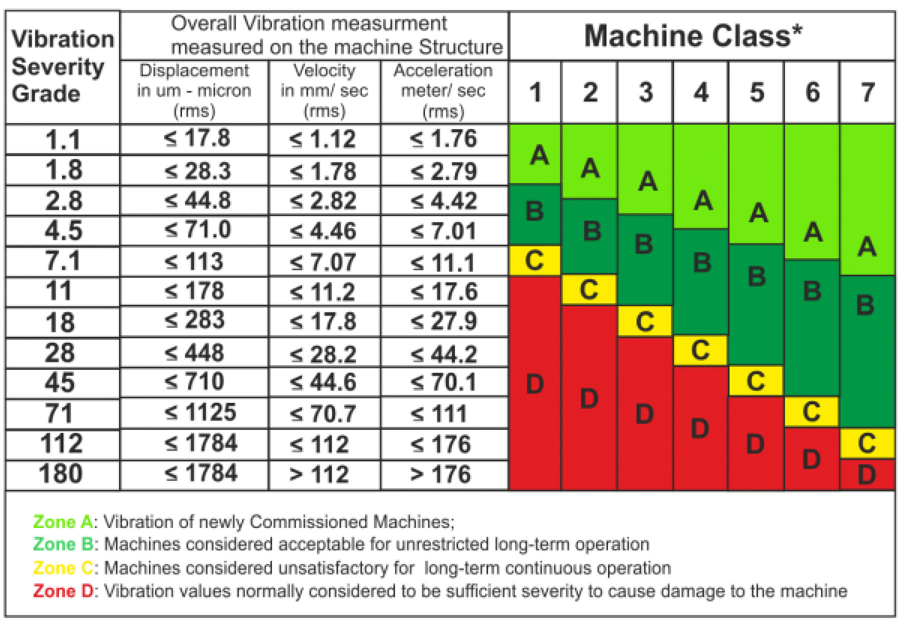


Figure 4.39 ISO 10816-6

4.12.2 Evaluation of engine vibration impact based on ISO 10816-6

According to Figure 46 above, an engine classified as class I is considered to be within the acceptable value range if its engine vibration is less than 2.79 m/s^2. When engine vibration is less than 7.01 m/s^2, it is considered suitable for unrestricted long-term operation; when it is less than 11.1 m/s^2, it is considered unsatisfactory for long-term continuous operation; and when it is greater than 11.1 m/s^2, it is considered severe enough to cause damage to the machine.

The overall engine vibration for fuel types E0, E5, E10,E15, E20, and E25 is 6.054 m/s2, 6.39 m/s2, 6.72 m/s2, 6.8 m/s2, 7.08 m/s2, and 7.55 m/s2, according to the data above. This indicates that only when the engine uses fuel E20 and E25, engines have vibrations greater than 7.01 m/s2, which is an unrestricted state for long-term operation. For this fuel type, this level of vibration affects the test engine under higher engine load conditions, but it is tolerable under lower and medium engine load conditions.

Table 4.3 Impact of vibration on engine.

Fuel type	Max.vibration(m/s^2)	State of the engine
E0	6.054	Acceptable value
E5	6.39	Acceptable value
E10	6.72	Acceptable value
E15	6.8	Acceptable value
E20	7.06	Unsatisfactory for long operation
E25	7.55	Unsatisfactory for long operation

The table 4.3 illustrates that when ethanol is used in gasoline at percentages of 5%,10%, and 15% for spark ignition engines, the vibration that results from this fuel type does not impact engine performance. Nevertheless, the long-term operation of the engine at full load condition is negatively impacted by the use of 20% and 25% ethanol in gasoline fuel in SI engines.

5. SUMMARY CONCLUSION AND RECOMMENDATION

5.1 Summary

After it was completed, the thesis attempted to demonstrate that using gasoline-ethanol blend fuel to power gasoline engines is one solution to the world's ever-increasing greenhouse gas emissions. For the study, a single-cylinder, four-stroke gasoline engine was chosen. After installing the experimental setup system, the engine's performance for each test fuel was obtained, the exhaust gas analyzer measured the amount of emissions and Vibxpert II measured the engine vibrations.

Emission testing of the SI engine running on a gasoline-ethanol blend was the focus of the research's initial phase. Engine performance and vibration are the topics of the second and third sections.After installing the required experimental setup,the engine's performance, emissions and vibration were examined using test fuel. The comparison of the acquired test results leads to a conclusion.

5.2 Conclusion

Testing the performance of SI engines running on gasoline-ethanol blend fuel was the primary goal of the study. The following conclusions and recommendations are made in light of the research findings.

5.2.1 Emission characteristics

The E25 fuel blend, consisting of 25% ethanol and 75% gasoline, demonstrates decreased emissions of hydrocarbon and carbon monoxide compared to the E0, E5, E10, E15, and E20 test fuel variants based on emission characteristics. As the ethanol content rises, the levels of carbon monoxide and hydrocarbon emissions from gasoline fuel decrease. This reduction in harmful emissions translates to reduced exposure to detrimental gases for individuals. However, with increased ethanol content in gasoline fuel, there is a concurrent increase in NOx emissions. Specifically, the NOx emissions from the E5 test fuel are lower than those from the E25 test fuel.

5.2.2 Brake Torque

E25(ethanol 25% and 75%) has superior torque performance compared to E0(pure gasoline), E5, E10, E15 and E20, according to torque performance characteristics. The torque of the engine will increase as the volume concentration of ethanol in gasoline fuel increases.

5.2.3 Brake power

It is evident from the brake power performance characteristics that the E25 test fuel-a mixture of 25% ethanol and 75% gasoline- is a good option for spark-ignition engines. Compared to other test fuel types, such as E0, E5, E10, E15 and E20, this test fuel exhibits higher braking power. Brake power increases in proportion to the concentration of ethanol in gasoline fuel.

5.2.4 Brake Specific Fuel Consumption

According to the brake-specific fuel consumption (bsfc) data, E25, which is composed of 25% ethanol and 75% gasoline perform greater than E0, E5, E15 and E20 test fuel type. According to the experiment's best alternative solution for spark ignition in terms of brake-specific fuel consumption, E25 is the best option.

5.2.5 Engine vibration

Experimental results indicate that pure gasoline causes less engine vibration compared to fuels like E5, E10, E15, E20, and E25. Notably, engine vibration is more pronounced with E20 (20% ethanol, 80% gasoline) and E25 (25% ethanol, 75% gasoline). Higher engine loads exacerbate the vibration with these ethanol blends, although at lower loads, the vibration remains within acceptable limits. Consequently, ethanol-gasoline blends with less than 15% ethanol do not negatively impact engine performance. However, long-term use of blends with 20% or 25% ethanol poses operational issues at higher loads. Therefore, for sustained operation and higher loads, E15 is the optimal blend. Generally, engine vibration increases with higher ethanol concentrations in the fuel.

5.3 Recommendation

Additional research work is needed on methods for mitigating NOx emissions and enhancing the performance of spark ignition vehicles using ethanol/gasoline blends. It is recommended that the government spearhead the establishment of ethanol production facilities, given the current steep price of ethanol at 900 birr per liter. This initiative is crucial for reducing the expenditure on imported fuel, as ethanol-gasoline blends exhibit superior brake-specific fuel consumption (BSFC) compared to pure gasoline.

REFERENCE

AAIT. (2012). africa_final-report-ethiopia. *Final Report on Pilot Global Fuel Economy Initiative Study in Ethiopia*, 53.

Abdeta, A., Densa, D., Deresso, H., & Bedada, T. (2015). *Performance Evaluation of Gasoline Vehicle with Gasoline-Ethanol-Methanol Emulsion as a fuel Department of Mechanical and Vehicle Engineering*.

Ağbulut, Ü., Sarıdemir, S., & Durucan, G. (2018). The Impacts of Ethanol - Gasoline Blended Fuels on the Pollutant Emissions and Performance of a Spark - Ignition Engine : An Empirical Study. *International Journal of Analytical, Experimental and Finite Element Analysis (IJAEFEA)*, *5*(4). https://doi.org/10.26706/ijaefea.4.5.20181201

Ansari, F. T., Prakash Verma, A., & Chaube, A. (n.d.). *Effect on Performance and Emissions of SI Engine Using Ethanol as Blend Fuel Under Varying Compression Ratio*. www.ijert.org

Biswal, A., Gedam, S., Balusamy, S., & Kolhe, P. (2020). Effects of using ternary gasoline-ethanol-LPO blend on PFI engine performance and emissions. *Fuel*, *281*. https://doi.org/10.1016/j.fuel.2020.118664

Ceviz, M. A., & Yüksel, F. (2005). Effects of ethanol-unleaded gasoline blends on cyclic variability and emissions in an SI engine. *Applied Thermal Engineering*, *25*(5–6), 917–925. https://doi.org/10.1016/j.applthermaleng.2004.07.019

Chen, R. H., Chiang, L. Bin, Chen, C. N., & Lin, T. H. (2011). Cold-start emissions of an SI engine using ethanol-gasoline blended fuel. *Applied Thermal Engineering*, *31*(8–9), 1463–1467. https://doi.org/10.1016/j.applthermaleng.2011.01.021

Chen, Y. L., Chen, S., Tsai, J. M., Tsai, C. Y., Fang, H. H., Yang, I. C., & Liu, S. Y. (2012). Optimization of suitable ethanol blend ratio for motorcycle engine using response surface method. *Journal of Environmental Science and Health - Part A Toxic/Hazardous Substances and Environmental Engineering*, *47*(1), 101–108. https://doi.org/10.1080/10934529.2012.629949

Costa, R. C., & Sodré, J. R. (2010). Hydrous ethanol vs. gasoline-ethanol blend: Engine performance and emissions. *Fuel*, *89*(2), 287–293. https://doi.org/10.1016/j.fuel.2009.06.017

Costa, R. C., & Sodré, J. R. (2011). Compression ratio effects on an ethanol/gasoline fuelled engine performance. *Applied Thermal Engineering*, *31*(2–3), 278–283. https://doi.org/10.1016/j.applthermaleng.2010.09.007

Dalla Nora, M., Lanzanova, T. D. M., & Zhao, H. (2018). Investigation of performance and combustion characteristics of a four-valve supercharged two-stroke DI engine fuelled with gasoline and ethanol. *Fuel*, *227*, 401–411. https://doi.org/10.1016/j.fuel.2018.04.078

Deresse Firew, N. Ramesh Babu, & Mukesh Didwania. (2016). The performance evaluation of diethyl-ether (DEE) additive with Diesel blends using Diesel Engine test rig. *International Journal of Scientific & Engineering Research*, *7*(6), 23–29.

Ding, Y., Li, Y. (Computer scientist), Li, S., Fan, Z., & Wang, L. (2011). *Proceedings, 2011 Eighth International Conference on Fuzzy Systems and Knowledge Discovery : FSKD 2011 : 26-28 July 2011, Shanghai, China*.

Dinh, T., K. Nguyen, T. Pham and V. Nguyen (2020). "Study on performance enhancement and emission reduction of used carburetor motorcycles fueled by flex-fuel gasoline-ethanol blends." Journal of the Chinese Institute of Engineers 43(5): 477-488.

Durucan, G., S. Sarıdemir and Ü. Ağbulut (2018). "The Impacts of Ethanol - Gasoline Blended Fuels on the Pollutant Emissions and Performance of a Spark - Ignition Engine: An Empirical Study." International Journal of Analytical, Experimental and Finite Element Analysis (IJAEFEA) 5(4).

Dinh, T., Nguyen, K., Pham, T., & Nguyen, V. (2020). Study on performance enhancement and emission reduction of used carburetor motorcycles fueled by flex-fuel gasoline-ethanol blends. *Journal of the Chinese Institute of Engineers, Transactions of the Chinese Institute of Engineers,Series A*, *43*(5), 477–488. https://doi.org/10.1080/02533839.2020.1751719

Elfasakhany, A. (2017). Investigations on performance and pollutant emissions of spark-ignition engines fueled with n-butanol–, isobutanol–, ethanol–, methanol–, and acetone–gasoline blends: A comparative study. In *Renewable and Sustainable Energy Reviews* (Vol. 71, pp. 404–413). Elsevier Ltd. https://doi.org/10.1016/j.rser.2016.12.070

Elnajjar, E., Selim, M. Y. E., & Omar, F. (2010). Effect of dual fuel engine parameters and fuel type on engine noise emissions. *ASME 2010 10th Biennial Conference on Engineering Systems Design and Analysis, ESDA2010*, *3*(10), 45–57. https://doi.org/10.1115/ESDA2010-24253

Farzam, R., B. Jafari and F. Kalaki (2020). "Turbocharged spark-ignition engine performance prediction in various inlet charged air temperatures fueled with gasoline-ethanol blends." International Journal of Engine Research 22(7): 2233-2243.

Gravalos, I., Loutridis, S., Moshou, D., Gialamas, T., Kateris, D., Tsiropoulos, Z., & Xyradakis, P. (2013). Detection of fuel type on a spark ignition engine from engine vibration behaviour. *Applied Thermal Engineering*, *54*(1), 171–175. https://doi.org/10.1016/j.applthermaleng.2013.02.003

Gravalos, I., Moshou, D., Gialamas, T., Kateris, D., Xyradakis, P., & Tsiropoulos, Z. (2011). Vibration Effects on Spark Ignition Engine Fuelled with Methanol and Ethanol Gasoline Blends. In *Journal of Agricultural Machinery Science* (Vol. 7, Issue 4).

Guo, T., X. Duan, Y. Liu, J. Liu, X. Zhou, Y. Li, M.-c. Lai and G. Guo (2020). "A comparative experimental study on emission characteristics of a turbocharged gasoline direct-injection (TGDI) engine fuelled with gasoline/ethanol blends under transient cold-start and steady-state conditions." Fuel 277.

H J Kurji, M. S. I. a. A. S. B. (2021). "The impact of using pure ethanol additives on gasoline fuel concerning SI engine emissions." IOP Conference Series: Materials Science and Engineering.

Hu, Y., Huang, Z., Wang, L., Sun, X., & Chen, W. (2022). Experimental study on combustion and emissions of a compression ignition engine fueled with gasoline. *Advances in Mechanical Engineering*, *14*(7), 1–8. https://doi.org/10.1177/16878132221109983

Kalwar, A., A. P. Singh and A. K. Agarwal (2020). "Utilization of primary alcohols in dual-fuel injection mode in a gasoline direct injection engine." Fuel **276**.

KESKIN1, A. (2010). "Noise Reduction in Gasoline DI Engines by isolating the fuel system." Hitachi Automotive Systems, Ltd: 1-2.

Keskin, A. (2011). The influence of ethanol-gasoline blends on spark ignition engine vibration characteristics and noise emissions. *Energy Sources, Part A: Recovery,* *Utilization and Environmental Effects*, *32*(20), 1851–1860. https://doi.org/10.1080/15567030902804749

Laganá, A. A. M., Lima, L. L., Justo, J. F., Arruda, B. A., & Santos, M. M. D. (2018). Identification of combustion and detonation in spark ignition engines using ion current signal. *Fuel*, *227*, 469–477. https://doi.org/10.1016/j.fuel.2018.04.080

Li, Z., Zhang, S., & Cao, F. (2020). Analysis of Performance and Stability Factors of Vehicle Ethanol Gasoline for Motor Vehicle. *IOP Conference Series: Earth and Environmental Science*, *514*(4). https://doi.org/10.1088/1755-1315/514/4/042025

Manikandan, K., Walle, M., & Professor, A. (2013). *The Effect of Gasoline-Ethanol Blends and Compression Ratio on SI Engine Performance and Exhaust Emissions*. www.ijert.org

Masum, B. M., Masjuki, H. H., Kalam, M. A., Rizwanul Fattah, I. M., M Palash, S., & Abedin, M. J. (2013). Effect of ethanol-gasoline blend on NOx emission in SI engine. In *Renewable and Sustainable Energy Reviews* (Vol. 24, pp. 209–222). https://doi.org/10.1016/j.rser.2013.03.046

Mehra, R. K., Duan, H., Juknelevičius, R., Ma, F., & Li, J. (2017). Progress in hydrogen enriched compressed natural gas (HCNG) internal combustion engines - A comprehensive review. *Renewable and Sustainable Energy Reviews*, *80*(May), 1458–1498. https://doi.org/10.1016/j.rser.2017.05.061

Mohammed, M. K., Balla, H. H., Al-Dulaimi, Z. M. H., Kareem, Z. S., & Al-Zuhairy, M. S. (2021). Effect of ethanol-gasoline blends on SI engine performance and emissions. *Case Studies in Thermal Engineering*, *25*(May 2020), 100891. https://doi.org/10.1016/j.csite.2021.100891

Mourad, M., & Noureldenn, E. H. (2019). Benefits of exhaust gas energy for preheating biodiesel fuel to enhance engine emissions and performance. *Journal of Mechanical and Energy Engineering*, *3*(2), 157–168. https://doi.org/10.30464/jmee.2019.3.2.157

Najafi, G., Ghobadian, B., Yusaf, T., Ardebili, S. M. S., & Mamat, R. (2015). Optimization of performance and exhaust emission parameters of a SI (spark ignition) engine with gasolineeethanol blended fuels using response surface methodology. *Energy*, *90*, 1815–1829. https://doi.org/10.1016/j.energy.2015.07.004

Pan, J., Cheng, B., Tao, J., Fan, B., Liu, Y., & Otchere, P. (2021). Experimental

Investigation on the Effect of Blending Ethanol on Combustion Characteristic and Idle Performance in a Gasoline Rotary Engine. *Journal of Thermal Science*, *30*(4), 1187–1198. https://doi.org/10.1007/s11630-021-1487-3

Sharma, N., Patel, C., Tiwari, N., & Agarwal, A. K. (2019). Experimental investigations of noise and vibration characteristics of gasoline-methanol blend fuelled gasoline direct injection engine and their relationship with combustion characteristics. *Applied Thermal Engineering*, *158*. https://doi.org/10.1016/j.applthermaleng.2019.113754

Srinivasan, C. A., & Saravanan, C. G. (2010). Emission reduction on ethanol - Gasoline blends using 1, 4 Dioxan. *WCE 2010 - World Congress on Engineering 2010*, *2*(June 2010), 1501–1504.

Taneja, S., Singh, P., & Singh, G. (2018). Comparative analysis of the Performance and Emission Characteristics of ethanol-butanol-gasoline blends. *IOP Conference Series: Materials Science and Engineering*, *310*(1). https://doi.org/10.1088/1757-899X/310/1/012136

Tang, Q., P. Jiang, C. Peng, H. Chang and Z. Zhao (2021). "Comparison and analysis of the effects of spark timing and lambda on a high-speed spark ignition engine fuelled with n-butanol/gasoline blends." Fuel **287**.

Thakur, A. K., Mer, K. K. S., & Kaviti, A. (2018). An artificial neural network approach to predict the performance and exhaust emissions of a gasoline engine using ethanol–gasoline blended fuels. *Biofuels*, *9*(3), 379–393. https://doi.org/10.1080/17597269.2016.1271630

Tornatore, C., Marchitto, L., Costagliola, M. A., & Valentino, G. (2019). Experimental comparative study on performance and emissions of e85 adopting different injection approaches in a turbocharged PFI SI engine. *Energies*, *12*(8). https://doi.org/10.3390/en12081555

Wallner, T., Miers, S. A., & McConnell, S. (2009). A comparison of ethanol and butanol as oxygenates using a direct-injection, spark-ignition engine. *Journal of Engineering for Gas Turbines and Power*, *131*(3). https://doi.org/10.1115/1.3043810

Yaman, H. and M. K. Yesilyurt (2021). "The influence of n-pentanol blending with gasoline on performance, combustion, and emission behaviors of an SI engine." Engineering Science and Technology, an International Journal 24(6): 1329-1346.

Ye, Y., Hu, J., Zhang, Z., Zhong, W., Zhao, Z., & Zhang, J. (2023). Effect of Different Ratios of Gasoline-Ethanol Blend Fuels on Combustion Enhancement and Emission Reduction in Electronic Fuel Injection Engine. *Polymers*, *15*(19). https://doi.org/10.3390/polym15193932

Yücesu, H. S., Topgül, T., Çinar, C., & Okur, M. (2006). Effect of ethanol-gasoline blends on engine performance and exhaust emissions in different compression ratios. *Applied Thermal Engineering*, *26*(17–18), 2272–2278. https://doi.org/10.1016/j.applthermaleng.2006.03.006

APPENDIX-A

The final report on Ethiopia's pilot study for the global fuel economy initiative states that, excluding two and three-wheeler, 152,909 vehicles used gasoline fuel overall in 2011. Further, the number of vehicles in the regions of Gambela and Affar is not included in this total. Given the large number of gasoline-powered vehicles in our country, modifications are required because these vehicles emit certain emissions. The table. A1 below shows that the detail of the number of vehicles used for gasoline fuel in each region (AAIT, 2012).

Table-A1 Number of vehicles which use gasoline fuel.

No	Location	Number of vehicles
1	Addis Ababa	12,3645
2	Amhara	6,023
3	Benshangul Gumuz	469
4	Oromia	11,140
5	SNNPR-Debub	2,888
6	Tigray	1,763
7	ET	5,631
8	Diredawa	2,389
9	Somali	648

Appendix 4.1 CO Emission test for E0 fuel.

Load(kg)	CO%
10	4.13
15	4.52
30	4.9
45	4.5
60	4
75	3.52

Appendix 4.2 CO emission for E5 fuel.

Load(kg)	CO%
10	3.6
15	3.91
30	4.24
45	4
60	3.25
75	2.76

Appendix 4.3 CO% Emission test for fuel E10.

Engine Load(kg)	CO% Emission
10	3.1
15	3.3
30	3.57
45	3.5
60	2.5
75	2

Appendix 4.4 CO% emissions for E15 fuel.

Engine load(kg)	CO% Emission
10	3.25
15	3.18
30	3.1
45	2.8
60	2.02
75	1.68

Appendix 4.5 E20 fueled engine CO% emission.

Engine load(kg)	CO% Emission
10	3.2
15	3
30	2.32
45	2.4
60	1.7
75	1.4

Appendix 4.6 HC Emission for E0 Fuel

Engine load(kg)	HC (ppm)
10	61
15	53
30	44
45	32
60	25
75	20

Appendix 4.7 CO% emissions for E25 fuel.

Engine load(kg)	CO% Emission
10	3.1
15	2.8
30	2.32
45	2.1
60	1.4
75	1.3

Appendix 4.8 HC emission for E5 fuel.

Engine load(kg)	HC (ppm)
10	53
15	48
30	37
45	29
60	22
75	18

Appendix 4.9 HC Emission for E10 Fuel

Engine load(kg)	HC(ppm)
10	49
15	42
30	33
45	24
60	18
75	14

Appendix 4.10 HC Emission for E15 Fuel type.

Engine load(kg)	HC (ppm)
10	43
15	35
30	24
45	17
60	14
75	12

Appendix 4.11 HC Emission for E20 Fuel

Engine load(kg)	HC (ppm)
10	41
15	34
30	19
45	15
60	10
75	7

Appendix 4.12 HC emission for E25 fuel type.

Engine load(kg)	HC (ppm)
10	37
15	31
30	16
45	12
60	8
75	7

Appendix 4.13 NO_x emission test for all test fuel in ppm

Engine load(kg)	E0	E5	E10	E15	E20	E25
10	291	350	401	409	437	441
15	306	361	420	431	452	463
30	318	373	425	465	478	490
45	343	394	451	491	496	521
60	376	427	482	526	526	537
75	391	447	508	584	547	565

Appendix 4.14 Performance test for E0 fuel.

Engine load(kg)	Power (W)	Torque (Nm)
10	439.6	4.2
15	471	4.5
30	460.53	4.4
45	376.8	3.6
60	293.07	2.8
75	157	1.5

Appendix 4.15 Engine torque and power for E5 fuel.

Engine load(kg)	Power (W)	Torque (N.m)
10	450.07	4.3
15	486.7	4.65
30	489.84	4.68
45	387.27	3.7
60	303.53	2.9
75	177.93	1.7

Appendix 4.16 power and Engine torque by E10

Engine load(kg)	Power (W)	Torque (N.m)
10	450.067	4.3
15	502.4	4.8
30	518.1	4.95
45	397.73	3.8
60	314	3
75	198.86	1.9

Appendix 4.17 Power and torque of engine for E15 fuel

Engine load(kg)	Power (W)	Torque (N.m)
10	491.93	4.7
15	544.27	5.2
30	565.2	5.4
45	408.2	3.9
60	345.4	3.3
75	240.73	2.3

Appendix 4.18 Power and torque of engine for E20 fuel

Engine load(kg)	Power (W)	Torque (N.m)
10	554.733	5.3
15	596.6	5.7
30	638.47	6.1
45	450.07	4.3
60	387.27	3.7
75	293.07	2.8

Appendix 4.19 Engine torque and power for E25

Engine load(kg)	Power (W)	Torque (N.m)
10	596.6	5.7
15	638.47	6.1
30	669.87	6.4
45	471	4.5
60	408.2	3.9
75	324.47	3.1

Appendix 4.20 Flow rate (ml/min)

Engine load(kg)	E0	E5	E10	E15	E20	E25
10	10	8	5	12.8	18	15
15	8	7.3	5.3	13	13	14
30	7.2	6.4	4	12	12	16
45	3.8	4.2	4.2	11	10	11
60	5	4.7	3.1	12.7	7	8.2
75	5.4	4.9	3	12.5	6	8

Appendix 4.21 Mass flow rate(g/s)

Engine load(kg)	E0	E5	E10	E15	E20	E25
10	0.12	0.096	0.06	0.155	0.218	0.185
15	0.096	0.088	0.064	0.157	0.158	0.173
30	0.087	0.077	0.048	0.145	0.145	0.197
45	0.046	0.051	0.051	0.133	0.122	0.136
60	0.06	0.057	0.037	0.154	0.086	0.101
75	0.074	0.059	0.036	0.152	0.073	0.099

Appendix 4.22 Engine BSFC(g/KWh) for all fuel types

Engine load(kg)	E0	E5	E10	E15	E20	E25
10	982.8	766.8	479.88	1134	1090.8	1116
15	734.4	651.6	457.2	1036.8	954	975.6
30	680.4	565.2	459.0	925.2	817.2	1060.4
45	439.2	475.2	460.8	1173.6	975.6	1040.4
60	738	676.8	424.8	1605.6	799.2	889.2
75	1692	1188	651.6	2267.6	896.4	1098

Appendix 4.23 Engine vibration for E0 test fuel in x, y and z direction

Engine load(kg)	X -direction	Y-direction	Z-direction
10	3.23	3.1	3.34
15	3.42	3.25	3.56
30	3.54	3.33	3.8
45	3.65	3.46	4.3
60	3.75	3.58	4.8
75	3.9	3.85	5.2

Appendix 4.24 Engine vibration for E5 test fuel in x, y and z directions

Engine load(kg)	X -direction(m/s2)	Y-direction(m/s2)	Z-direction(m/s2)
10	2.7	2.5	2.9
15	2.6	2.5	3.1
30	2.5	2.7	3.2
45	2.67	2.85	3.6
60	2.73	2.96	3.75
75	3.1	3.2	4.1

Appendix 4.25 Engine vibration for E10 test fuel in x,y and z directions

Engine load(kg)	X -direction	Y-direction	Z-direction
10	2.5	2.7	3.1
15	2.7	2.9	3.2
30	3.2	3.1	3.4
45	3.4	3.3	3.8
60	3.7	3.6	4.2
75	3.6	3.7	4.3

Appendix 4.26 Engine vibration for E15 test fuel in x,y and z directions

Engine load(kg)	X -direction	Y-direction	Z-direction
10	2.6	2.6	3
15	2.65	2.7	3.15
30	2.85	2.9	3.3
45	3.035	3.075	3.7
60	3.215	3.28	3.975
75	3.35	3.45	4.2

Appendix 4.27 Engine vibration for E20 test fuel in x,y and z directions

Engine load(kg)	X -direction(m/s2)	Y-direction(m/s2)	Z-direction
10	2.6	2.6	3
15	2.65	2.7	3.15
30	2.85	2.9	3.3
45	3.035	3.075	3.7
60	3.215	3.28	3.975
75	3.35	3.45	4.2

Appendix 4.28 The overall engine vibration for E0 fuel.

Engine load(kg)	Overall engine vibration(m/s^2
10	4.69
15	4.599
30	4.88
45	5.31
60	5.55
75	6.054

Appendix 4.29 Overall engine vibration for E5 fuel.

Engine load(kg)	Overall engine vibration(m/s^2)
10	4.75
15	4.92
30	5.24
45	5.87
60	6.07
75	6.39

Appendix 4.30 Overall engine vibration for E10 fuel.

Engine load(kg)	Overall engine vibration(m/s^2)
10	4.8
15	5.09
30	5.6
45	6.1
60	6.6
75	6.72

Appendix 4.31 Overall engine vibration for E15 fuel

Engine load(kg)	Overall engine vibration(m/s^2)
10	4.92
15	5.29
30	5.67
45	6.17
60	6.45
75	6.8

Appendix 4.32 Overall engine vibration for E20

Engine load	Overall engine vibration(m/s^2)
10	5.32
15	5.75
30	6.04
45	6.40
60	6.85
75	7.06

Appendix 4.33 Overall engine vibration for E25 fuel.

Engine load(kg)	Vibration(m/s^2)
10	5.59
15	5.91
30	6.17
45	6.62
60	7.07
75	7.55

Appendix 4.34 Comparison of the overall engine vibration for all test fuels.

Engine load(kg)	E0	E5	E10	E15	E20	E25
10	4.69	4.75	4.8	4.92	5.32	5.59
15	4.599	4.92	5.09	5.29	5.75	5.91
30	4.88	5.24	5.6	5.67	6.04	6.17
45	5.31	5.87	6.1	6.17	6.40	6.62
60	5.55	6.07	6.6	6.45	6.85	7.07
75	6.054	6.39	6.72	6.8	7.06	7.55

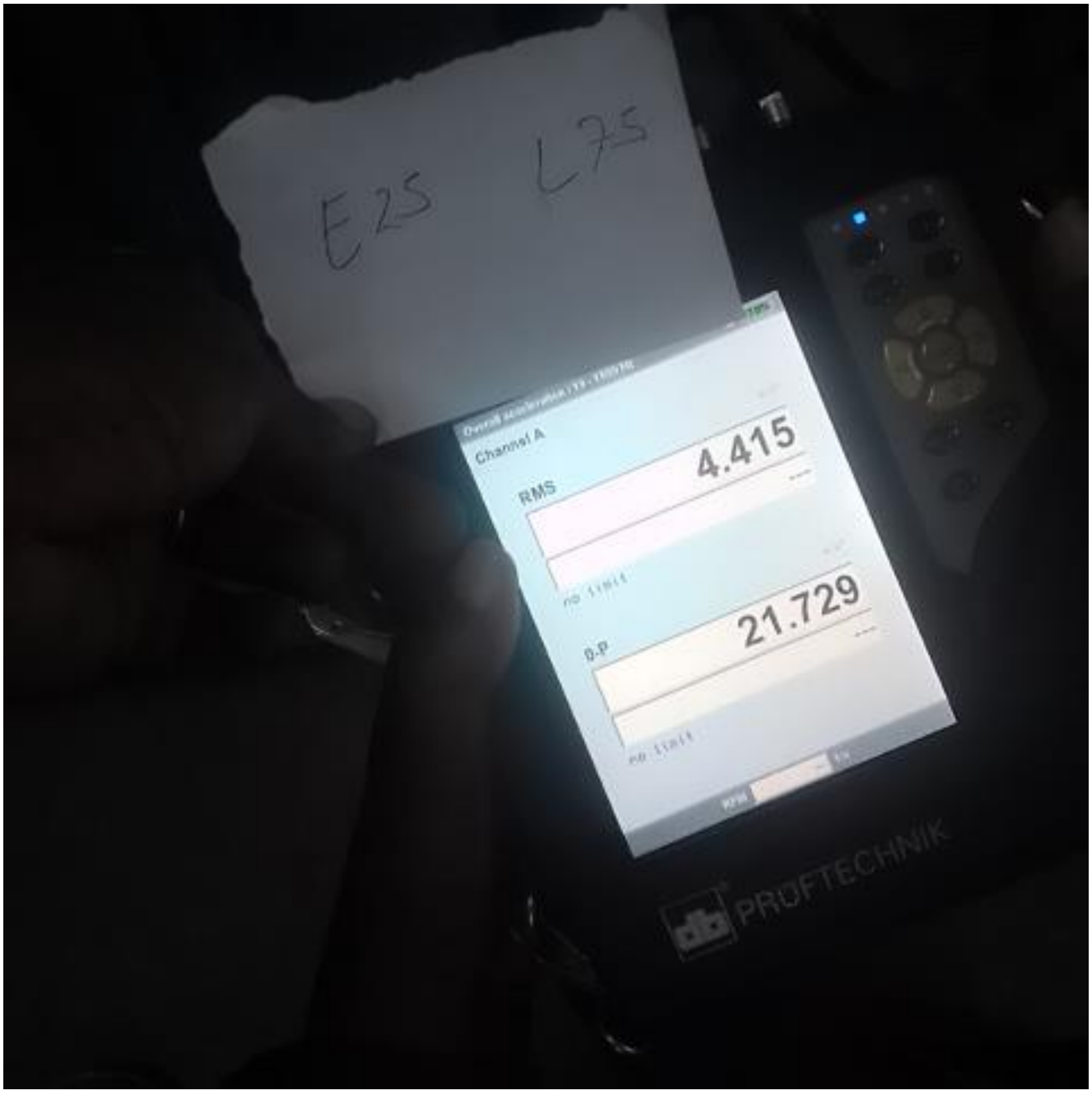
Blend fuel preparation

Appendix 4.35 Test fuel blend preparation

Engine Vibration Test

Appendix 4.36 Engine vibration test

Measurent of Engine vibration



Appendix 4.37 Measurement of