Experimental Investigation of Methanol Premixing with Nano Additives for Better Performance and Emission of SI Engines

Latera Samuel Kenea

Thesis Submitted to the Department of Mechanical Engineering
School of Mechanical, Chemical and Materials Engineering

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

Office of Graduate Studies

Adama Science and Technology University

May, 2024

Adama, Ethiopia

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DECLEREATION

I affirm that the thesis which is entitled **"Experimental Investigation on Methanol Premixing with Nano Additives for Better Performance and Emission of Petrol Engines"** is my personal work and hasn't been submitted for similar aim. The references incorporated for this thesis work were properly recognized by citing appropriately.

Latera Samuel	________________	________________
Student's Name.	Signature.	Date.

RECOMMENDATIONS

I, the supervisor of this thesis work, herewith confirm that I have thoroughly advised the student during the development of this thesis and also read this thesis with the title of **"Experimental Investigation of Methanol Premixing with Nano Additives for Better Performance and Emission of Petrol Engines"** prepared under my guidance by **Latera Samuel Kenea.** submitted for the partial fulfillment of the requirements for the degree of Master of Science in Automotive Engineering. Therefore, I recommend the submission of revised version of this thesis to the department following the appropriate procedures.

____________________	____________________	________________
Major Advisor	Signature	Date

APPROVAL

I, the thesis advisor entitled **"Experimental Investigation of Methanol Premixing with Nano Additives for Better Performance and Emission of Petrol Engines"** and developed by Latera Samuel Kenea; herewith verify that the commendation and suggestions forwarded by the board of examiners are properly incorporated into the final version of this thesis.

Dr. Getachow Alemayehu	______________________	_____________
Major adviser	Signature	Date

We, the undersigned, members of Board of Examiners of the thesis done by Latera Samuel Kenea. have read and evaluated the thesis entitled **"Experimental Investigation of Methanol Premixing with Nano Additives for Better Performance and Emission of Petrol Engines"** by examining the candidate through open defense. Therefore, this is to confirm that this thesis is accepted for partial fulfillment of the requirement of Master of Science in Automotive Engineering.

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ACRONYMS

ASTU	Adama Sci. and Tech. University
AASTU	Addis Ababa Sci. and Tech. University
BDC	Botom Dead Center
BSFC	Brake Speacific Fuel Consumption
CI	Compresion Ignittion
CeO_2	Cerium Oxide
CO_2	Carbon Dioxide
CO	Carbon Monoxide
CR	Compresion Ratio
HC	Hydrocarbons
LTC	Low Temperature Combustion
NEDC	New European Drive Cycle
NOx	Nitrogen Oxide
PM	Particulate Matter
RSM	Response Surface Methodology
SI	Spark Ignition
SOHC	Single Overhead Camshaft
TDC	Top Dead Center
WOT	Wide Open Throttle

ABSTRACT

Fuels derived from fossil fuels are essential for the rapidly growing industrial, agricultural, and transportation sectors. These fuels are growing scarcer by the day due to the rapidly increasing demand for them. Furthermore, burning fossil fuels releases a number of hazardous gases that are harmful to the environment. Petrol engine is mostly used in the transportation industry due to its lighter weight which affects fuel efficiency and overall performance and provide better acceleration. However, this engine frequently produces high exhaust emissions. To meet the strict emission standards using alternative fuels with cerium oxide nanoparticles are effective solutions in improving petrol engine's operation and their nature of exhaust. Methanol is an alternative fuel and has the ability to decreases emission and increases performance simultaneously due its property like presence of oxygen, higher vaporization of latent heat, and having high flame speed. Combining nanoparticles with its fuel increases thermophysical and physicochemical properties. The study investigated the impact of premixing Methanol and cerium oxide (CeO2) nanoparticle in petrol engines performance and emission targeting optimized performance and emission. The optimization was done by applying RSM method through analysis of different ratio or percentage of premixed methanol, Gasoline and Cerium oxide. From the experiment and RSM analysis optimized percentages or amounts of the control factors were obtained. The blend of methanol and gasoline with nanoparticles were developed. Optimization results from RSM indicated that optimized values of power, torque, SFC, HC, CO and NOx were obtained with values of 0.9457 kw, 2.3076 N, 0.1948 %, 0.1077 %, 0.0347 and 7.9311 ppm with load of 100.4538 %, methanol blend percentage of 10 % and a Gasoline mix of 90.1469 %. respectively. Similarly optimized values of Power and Torque were investigated with values of 0.9457 kw and 2.3076 N respectively with a load condition of 20 %, Speed of 3999.101 Rpm, methanol blend percentage of 14.997 % and a Gasoline mix of 89.3939 % for better performance including emission conditions in the chosen engine.

Keywords: *Emission, nanoparticles, optimization, Petrol Engine, Performance, RSM*

CHAPTER ONE

INTRODUCTION

1.1 Background

The transportation, agricultural, and industrial sectors of this time all depend on non-renewable fuels. Fossil fuels provide more than 80% of the energy used globally (Akhilendra et al., 2018). The transportation sector uses 30% of the energy delivered globally, 80% of which is used for road transport, making it the second-highest energy consumer globally after industry. The transportation sector currently supplies more than 60% of the global oil demand, and it is expected to grow at the fastest rate going forward (Kalghatgi, 2018). Researchers are now forced to search for low-cost, environmentally friendly alternative fuels from natural resources due to the issue of energy security brought on by growing environmental concerns, the depletion of petroleum resources, and a number of other socioeconomic factors. (Patel et., 2015).

An excellent alternative fuel for use in SI engines is alcohol. It works well with gasoline-fueled vehicles. They also have an octane rating higher than 100. There is no need to modify the engine if alcohols are added to gasoline in small amounts in SI engines. As is common knowledge, there are two ways to increase engine performance and lower environmental pollution: changing the fuel's composition and altering the engine itself. In this experiment, we attempted to alter the fuel's composition by blending gasoline and methanol in an appropriate ratio to enhance engine performance. (Gaurav, 2014).

In recent years several researches have been carried out to the influence of methanol on the performance of spark ignition engines. Among the alcohols, methanol has the lowest combustion energy. However, it also has the lowest stoichiometric or chemically correct air-fuel ratio. Therefore, an engine burning methanol would produce the maximum power. A lot of research has been done on the prospect of methanol as an alternative fuel. Methanol, CH3OH, is the simplest of alcohol and originally produced by the destructive distillation of wood. However, methanol can be produced from many fossil and renewable sources which include coal, petroleum, natural gas, biomass, wood landfills and even the ocean (Sayed, 2018). Methanol shares many of the same physicochemical properties as gasoline and is a safe, abundant, and environmentally benign fuel. Because it can be used directly in both spark and compression-ignition internal combustion engines, it is a promising alternative fuel in China. The goal of current spark-ignition engine development is to lower the engine's thermal efficiency by increasing the compression ratio (CR) and decreasing the fuel volume. However, because of the high temperature, raising the CR could worsen particulate matter (PM) (Jibai Wang, 2020).

Increased use of metal oxide nanoparticles (NPs) as fuel additives has the potential to improve fuel quality by increasing the rate of warm exchange, stabilizing and enhancing the thermophysical properties of fuel blends, increasing motor performance parameters, and reducing debilitate emissions. In general, a fuel additive increases combustion productivity while lowering contamination. These additional ingredients raise the fuel's cetane number, which raises the fuel's starting characteristics and lowers its oxidation temperature. Subsequent developments in nanotechnology enable the creation, manipulation, and characterization of nanoscale active materials. Because of their larger surface area, nanoparticles are more interesting than bulk materials. Generally speaking, including of metal oxide

Generally, as a result of the intriguing characteristics of nanoparticles, such as their unique surface range, greater warm conductivity, and chemical characteristics when compared to their bulk form (Mishra K., 2018). Consequently, when employed in base fuels for gasoline engines, nanoparticles can serve as both a catalyst and an energy carrier. Furthermore, when used with base fuels, small-scale nanoparticles help stabilize fuel suspensions (Aydin Huseyin et al., 2013). Nanoscale energetic materials can now be produced, controlled, and characterized thanks to recent developments in nanotechnology. Because of their larger surface area, nanoparticles outperform bulk materials in terms of effectiveness. In general, the properties of biodiesel fuel are improved by the addition of metal oxide nanoparticles. This is because of the intriguing characteristics of nanoparticles, such as increased thermal conductivity, particular (K. Mishra et., 2018).

1.2 Problem Statement

Today, one of the most important problems of the developed countries is the increase of the air pollution. The main role of this pollution is the emission of exhaust gases from motor vehicles. Replacing or modifying of fossil fuels with renewable clean fuel is a very sensible way to prevent fuel shortages for the automotive industry. Alcohol has been used as alternative fuel for engines since the 19th century. Among all types of alcohol, Methanol is known as an appropriate additive or alternative fuel for spark ignition (SI) engines. The creation of alternative techniques to satisfy the stringent emission regulations for exhaust gases released by gasoline-powered engines was spurred by these problems. To meet the strict emissionstandards using alternative fuels with metal oxide nanoparticles are effective solutions to improve petrol engine performance and exhaust emissions. Methanol raises the fuel's octane number, enabling the engine to run at a higher compression ratio. Consequently, there is a lot of promise for methanol fuel to increase engine performance and decrease emissions of air pollutants. Furthermore, Combining nanoparticles with fuel increases thermophysical and physicochemical properties. Therefore, to overcome these problems methanol premixing with metal oxide nanoparticles was used as alternative fuel for enhancing the efficiency of gasoline engines and lowering emissions of air pollutants. Solving the aforementioned problems is the aim of this thesis work.

1.3 Objectives

1.3.1. General objective

General objective of this investigation targets obtaining the optimized mixing ratios in methanol and nano additives with gasoline for better performance and emissions characteristics in engine.

1.3.2 Specific objectives

Specific objectives in this study are:

- Testing performance of methanol to gasoline blended with addition of nanoparticles
- Testing emission of methanol to gasoline blended with addition of nanoparticles
- Assessing impacts of premixing ratio on methanol to gasoline on petrol engine.
- To know the optimum premixing ratio of MTG for better performance using optimization and emissions.
- To analyze and compare the results with commercial gasoline fuel

1.4 Significance

The study's final finding suggests using alternative fuel in place of regular gasoline. Following the completion and application of the research, the following fundamental significance is anticipated:

- ✓ It increases the quality of environment by reducing emissions of greenhouse gases
- ✓ increasing power of engine
- ✓ decreasing SFC
- ✓ Obtaining optimized chosen control parameters: engine load, ratios of methanol and ratios of gasoline for best response outputs which makes vehicle engine operation environmentally friendly and efficient.

1.5 Scope

This investigation delimited only examining emission and performance features in methanol premixing and gasoline fuel with addition of nanoparticles. and optimization with RSM. Also, analyses and compare the results with conventional gasoline and their additives exhaustive.

1.6 Limitations

The limitations during this research work includes; well-equipped laboratory facilities or experimental set up, advanced measuring instruments for ratio measurements, limitations to obtain combustion analysis results including several thermal behaviors inside the combustion chamber. The limitation also includes financial constraints to fully conduct all expected tests

1.7 Organization of the thesis

Five chapters were developed in this study. Introduction being covered in the first chapter. It comprises the following: the study's background, the problem statement, its objectives, its significance, its scope, and its organization. The second chapter focuses on the review of the literature based on earlier works in the field. The third chapter outlines the supplies and procedures used to complete the suggested task. Discussion and results make up Chapter 4. In chapter five, conclusions are drawn along with suggestions for additional research areas.

CHAPTER TWO

REVIEW OF LITERATURES

2.1 Introduction

The chapter primarily consists of a review of the body of research on the subject. Clean and renewable alternative vehicle fuels are required to address the issues of environmental pollution and the scarcity of fossil fuels.

2.2 Methanol Synthesis and its application

The most basic alcohol, methanol is used to make a variety of chemicals and has great potential to be used as a renewable energy source and alternative fuel (Kesharavarz et al., 2020). A methyl group (CH3) and an hydroxyl group (OH) are the building blocks of methanol, also known as wood alcohol. Methanol is a poisonous, colorless, and tasteless alcohol that burns cleanly and biodegrades with a very slight odor. The production of methanol provides a "future-proof" switch to sustainable chemicals and fuels (Methanol Production, 2020). As was previously mentioned, natural gas, fossil fuels, or coal-based synthesis gas are the primary sources of methanol production (syngas).

One benefit of methanol is that it can be produced from any feedstock, which is a source of synthesis gas. Examples of feedstocks include biomass, CO2, agricultural waste, and municipal solid waste. This process is known as "poly-generation." Additionally, a variety of materials, including wood, CO2, sewage, and municipal solid wastes, can be used to make methanol (Pirol et al., 2017). For many researchers, the main goal is to find a suitable catalyst for the commercial production of methanol. There is a lot of consideration going on these days regarding the practical production of methanol from various feedstocks using creative and effective catalytic processes. Because it contributes to the reduction of greenhouse gases, the synthesis of methanol from CO2 using catalysts is given top priority (Kesharavarz et al., 2020).

These days, everyone is interested in carbon capture and storage, or CCS. In CCS technology, converting the captured CO2 to methanol will help prevent issues with carbon storage. Another way to produce methanal is to use renewable energy to reduce water and CO2 emissions. Reactor effluent distillation, syngas production, and syngas to methanol conversion are the three main methods used in the synthesis of methanol. (Pirol & colleagues, 2017). Syngas is produced by the process known as gasification. Approximately 138 billion liters, or 36.6 billion gallons, of total methanol production capacity are available from 90 methanol plants spread across several nations, according to data available on the methanol institute website. According to data from HIS, the global methanol demand reached 75 million metric tons in 2015, with evolving energy applications accounting for 40% of methanol consumption. Every day, about 200,000 tons of methanol are used as a chemical feedstock or as a transportation fuel worldwide (Yadav et al., 2017).

2.3 Methanol Applications and Its Importance

The following is a description of the significant uses for methanol (Shamsu et al., 2014). The primary regions for its use as an energy source are depicted in Figure 2.1.

- Methanol is a clean-burning fuel that can be added to improve engine performance and lower emissions, or it can be used in pure or blended form in internal combustion engines. It is a crucial part of the process used to produce renewable biodiesel fuel.
- Dimethyl ether (DME), a crucial methanol derivative, can successfully replace liquefied petroleum gas (LPG) as a fuel for home heating.
- Methanol is essential for cleaning wastewater in public and private waste treatment facilities and for removing hazardous nitrate-induced "dead zones" from streams.
- Methanol is a useful carrier storage compound for organic liquid hydrogen.
- Because it can be broken down into hydrogen and CO2, methanol is highly suited for fuel cell-powered vehicles.

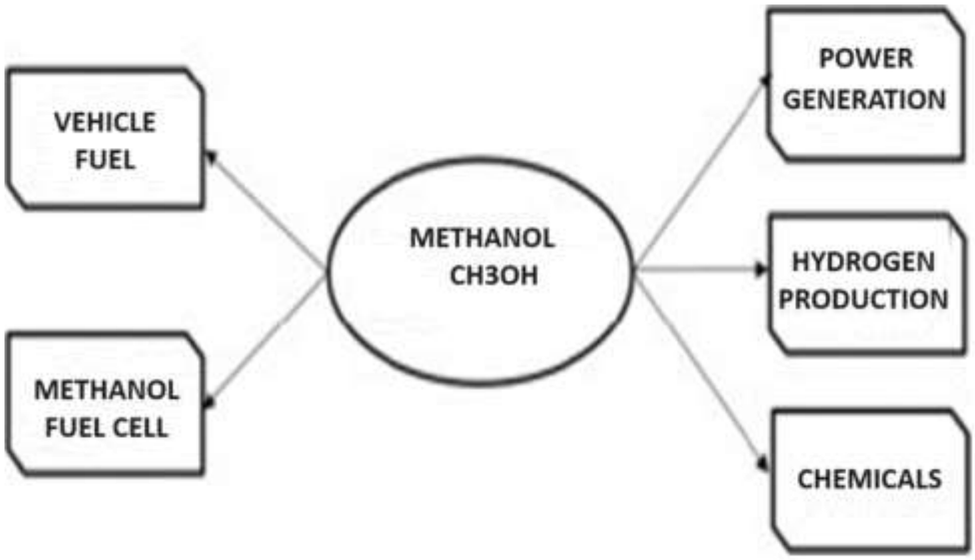

Figure 2.1. The main uses of methanol as an energy source (Zhang et al., 2020)

2.4 Methanol Being Alternative and Renewable Fuel

Methanol has been used as fuel for automobile engines all over the world in a mixture with motor spirit. Because of its superior combustion qualities, methanol is regarded as the best alcohol to use as a blending agent with gasoline and as a possible substitute fuel for vehicles (Danaih et al., 2014). Methanol has a higher oxygen content than gasoline, which helps automobile SI engines burn fuel more efficiently. When comparing methanol fuel to gasoline, some benefits include higher performance, lower regulated emissions, a lower risk of flammability,advantages for the environmental economy (Methanol Institute, 2016).

After researching the impact of oxygenated additives in a gasolineengine, (Soheil et al., 2012) came to the conclusion that the Reid vapor pressure (RVP) of gasoline

- ❖ The current electrical generation capacity in India may not support the widespread adoption of electric vehicles (EVs) in the transportation sector.
- ❖ lack of resources required to produce EVs.
- ❖ Methanol can be produced profitably in India, which lowers the cost of petroleum imports.
- ❖ Blends of methanol can be utilized as a substitute fuel without requiring substantial modifications to the current engines.

(According to Liu et al.'s(2007)research, methanol can be mixed with gasoline at lower concentrations to be used as an alternative fuel for SI engines without requiring any changes to the engine. They discovered that adding methanol to gasoline significantly reduces CO and HC emissions, which improves cold start emissions. Due to its high power delivery and low fuel consumption, gasoline direct-injection (GDI) engines are now commonly found in passenger cars. Nonhomogeneous air/fuel mixing may result in increased soot emission.

(According to Liu et al.'s2017study, methanol considerably decreased the amount of soot formed in the fuel blend of gasoline and methanol. (Danaih et al., 2014) found that adding methanol to gasoline up to a M15 concentration reduced the emissions of CO, CO2, HC, and NOx.

(Turner et al., 2013) looked at the impact of gasoline, ethanol, and methanol (GEM) blended in a flex-fuel vehicle and came to the conclusion that utilizing methanol as a ternary blend and taking into account its low cost could result in an approach to fuel that is both profitable and economical.

Methanol Advantages

- ❖ Because methanol can be made from any carbon-based feedstock, including biomass, coal, and natural gas, it can lessen reliance on imported petroleum.
- ❖ The primary characteristics of methanol fuel are its increased combustion efficiency, reduced sulfur and aromatic content, renewability, and biodegradability.
- ❖ When combined with a low stoichiometric air to fuel ratio, methanol's high latent heat of vaporization (LHOV) results in significant intake charge cooling.
- ❖ One explanation for methanol's high knock-resistant capacity may be its significant cooling effect. Because of its higher LHOV, knock is suppressed near TDC by lowering the mixture and compression temperatures.
- ❖ Using methanol fuel results in increased power and efficiency because it uses higher compression ratios and ideal spark timing.
- ❖ Methanol exhibits lower flammability and is therefore safer to transport and store than gasoline.
- ❖ Because methanol fuel has advanced linear fame propagation, which aids in early combustion, it can increase engine thermal efficiency.

- Because of its high octane value, methanol provides any vehicle engine with better power and decent acceleration.
- It is thought to be economical in that it can be obtained at lower prices than petroleum because of its higher octane number, which improves anti-knock performance for internal combustion engines (Bhavin et al., 2021).

Methanol's Physico-chemical Properties

Because of its high oxygen mass percentage, higher octane value, high latent heat of vaporization, and enhanced antiknock characteristics, among other benefits, methanol is used in SI engines. According to Masum et al. (2014), these characteristics result in higher charge density, volumetric efficiency, and occasionally better torque and performance. Because hydrogen bonds form between molecules, methanol has a higher boiling point and greater storage stability than gasoline. Methanol fuel can be used in engines with higher compression ratios due to its relatively higher octane number (Peng D., 2018). The physicochemical characteristics of methanol and gasoline are displayed in Table 2.1.

The octane number describes the fuel's ignition quality and indicates how well it can withstand knocking. According to Babazadeh et al. (2012), there are two categories for the specification of octane number: MON and RON. Because methanol has a higher octane number than conventional gasoline fuel, it is regarded as a functional alcohol additive. It was discovered that when the amount of methanol in the fuel blend increased, so did the motor octane numbers and research for methanol-gasoline blends. Thus, a higher methanol content in the blended fuel also improves engine performance. By increasing the octane distribution in the base gasoline fuel, methanol is a great blending agent that helps the engine run better during cold starts. Mixing.

Table 2.1 physicochemical properties Comparison; gasoline and methanol (Avad et al.2018).

Properties	Unit	Gasoline	Methanol
Chemical formula	-	Various	CH_3OH
Molecular weight	g/mol	95–120	32.04
Oxygen	mass%	0	49.93
Hydrogen	mass%	14	12.5
Carbon	mass%	87.5	37.5
Density	g/mL	0.737	0.792
Autoignition temperature	°C	257	423
Boiling point	°C	27-225	78
Freezing point	°C	-40	-97.5
Flashpoint	°C	-45 to -13	11
Reid vapor pressure	kPa	53-60	32.4
Motor octane no	-	82-92	88.6
Research octane no	-	92-100	108.7
Latent heat of vaporization	kJ/kg	349	920-1109
Low heating value	MJ/kg	44	20.1
Viscosity	mm^2/s	0.29	0.596
Stoichiometric AFR	kg/kg	14.7	6.5
Solubility in water at 25 °C	ml/100 ml H_2O	<0.1	Fully miscible

2.5 Methanol–Gasoline Blended Fuel

As previously mentioned, nearly every vehicle made today is incompatible with 100% pure methanol fuel. Thus, blended alcohol-based biofuels are used with gasoline. Since 1980, methanol and gasoline blends have been used with success. The greatest ways to combat the rising demand for gasoline and increase supply while still adhering to environmental regulations are through methanol blends. Methanol's high blending octane value offers an economical way to raise the low octane number of gasoline. Methanol is a highly effective blend stock suitable for all gasoline grades. One of the elements that negatively impacts the fuel blend's performance is the blending vapor pressure. Gasoline and methanol can combine to create nonideal (azeotropic effect) blends, and there's a chance that the blends with gasoline, and there's a chance that the 200–800 kPa range of Reid vapor pressure will rise. Reid vapor pressure increases can be mitigated by adding more alcohol to the meth-anol-gasoline blends. In contemporary engines with fuel injectors and a feed-back control system, methanol blends at a volume percentage of 15% are successfully utilized, and the engine performs satisfactorily when using the blend fuels. (Bhavin et al., 2021).

2.6 Additives of Fuel

The primary function of additives, which can be either organic or metal-based and easily soluble in fuel, is to preserve, enhance, and give the fuel positive properties without changing its performance or combustion parameters. The amounts of fuel additives added vary, varying from 100 parts per million to several thousand parts per million. Currently, a variety of chemical additives are burned in vehicle fuels to enhance the quality of gasoline, diesel, and biodiesel fuel and achieve the desired performance level. Additives assist petroleum in regaining engine performance, combustion, and environmental emission standards. Fuel additives, therefore, enhance the fuel properties of diesel, biodiesel, and their blends. The selection of additives is based on the disadvantages of biodiesel fuel, such as density, (K. Mishra et al.,2018).

a) Additives of Metal-Based

When added to fuel in the range of micro- or nano sizes through ppm (percentage by weight ratios), metals and metal oxides improve the fuel's burning properties. To improve the physiochemical properties of fuel, metals such as aluminum (Al), magnesium (Mg), iron (Fe), manganese (Mn), boron (B), silver (Ag), silica (Si), gold (Au), copper (Cu), graphene, etc., and metal oxides such as aluminum oxide (Al_2O_3), cerium oxide (CeO_2), zinc oxide (ZnO), cobalt oxide (Co_3O_4), titanium oxide (TiO_2), copper oxide (CuO), etc., are used as additives. Metal-based additives such as carbon nanotubes (CNT) and magnalium (Mg-Al) are utilized to improve fuel performance by altering their physiochemical properties (K. Mishra et al., 2018).

b) Additives of Oxygenated type

To enhance the burning characteristics of fuel with more ignition delay, oxygenated components such as biodiesel, ethanol, methanol, dimethyl ether, dimethyl carbonate, diethylene glycol diethyl ether, etc., are added at a negligible amount along with chemical compounds that have a higher oxygen content. It blends and mixes effortlessly with regular diesel fuel (K. Mishra et al., 2018).al., 2018).

c) Additives to Improve Cold Flow Behavior

The amount of wax in the biodiesel begins to freeze in cold weather, forming a crystal-like structure that lowers the cold filter plug point (CFPP). Using additives that increase the fuel's cloud point property, such as phthalimide, ethylene vinyl acetate copolymer, glycerol ketals, and succinimide copolymers, can help prevent this condition (K. Mishra et al., 2018).

d) Additives to improve Cetane Number

Cetane number is one of the main characteristics of the fuel, which determines the quality of the fuel or the flammability of the fuel. A diesel engine offers better efficiency with high cetane fuels. additives that improve the cetane number of fuel are nitrocarbonates, nitrates, nitroalkanes, peroxides, etc. (K. Mishra et al., 2018)

e) Anti-oxiidants

Transesterified biodiesels that are ready to react with oxygen in a process called autoxidation. To prevent auto-oxidation of biodiesel when mixed with petrodiesel, additives such as TBHQ (tert-butylhydroquinone), BHT (butylhydroxytoluene), BHA (butylated hydroxyanisole), PA (pyrogallol) and PG (propyl gallate) are mixed with petrodiesel. biodiesel blends (K. Mishra et al., 2018)..

Additives of fuel were taken as a simple method and cost-effective way to have better combustion and minimize harmful exhausts of IC engines. In addition to using usual additives of fuel, some new additives of fuel have capacity to enhance fuel characteristics. Studying the impacts of different additives with new perspective can pro- vide a appreciable situation to increase vehicle operatio/n through optimization of fuel. In their study, five unusual additives of gasoline including; isopropyl, aniline, ether, dimethyl malonate diethyl amine, and p-tert-butylphenol were mixed with gasoline baseline G92. These five fuel blends are coded as G92-5, G92-4, G92-3, G92-2, and G92-1 respec- tively. dissimilar additives of Fuels were examined on vehicle of compact type passenger having 1.4-L of gasoline with direct injection to analyze impacts of additives of these type on operational and exhaust characterstics, by comparing gasoline of G92 as a referencee.

Representative of passenger car in new European drive cycle (NEDC), on chosen light duty vehicles were used for tests. results from the experiment indicated that small changes SFC for fuels mixed with additives. All samples of five additives could increase the acceleration performance in small amount. diethyl amine showed a likely additive for gasoline to minimize emissions of carbon, improve SFC, and upgrade performances (Mingsheng Wen, 2022).

Fueling an engine in gasoline methanol blend, performance parameters such as BT, BP, volumetric efficiency and efficiency of brake thermal increases byincreasing methanol ratio in the mixed fuel whereas BSFC and equivalence fuel -air ratio reduced (S. Babazadeh Shayan, 2011).

(Ghazaly, 2022), briefly described on their introduction part, fuels of a biodiesel needs small injection time since low compressibility, so it is very vital to investigate the impact of bulk modulus on time of injection. It was concluded that the rise of pressure in biodiesel is very fast after injection, because biodiesel's bulk modulus of is greater. Immediate passing through injector nozzles was also observed as it has high velocity of sound. Since there is high viscosity, in the reduction of leakage of pump. These properties from the previous caused fast injection of needle to be designed for biodiesel. NOX emissions are highly impacted through Injection technology.

Experimental investigation was held on gasoline/methanol combinations in SI engine. The test observed the operational characteristics with formaldehyde exhaust characteristics of gasoline/methanol–mix by applying three different fractions of volumes; M0, M15, and M100 including impacts of CR on PM emissions was studied. On their result, the preceding coherence was investigated:

I. During blending methanol with gasoline there is an increased emission of formaldehyde. emissions of formaldehyde of methanol 100% were greater than that of methanol–gasoline blend for a fraction of 15% of methanol by volume; both emissions were greater than that of neat gasoline.
II. increased PM emissions where seen during increasing CR
III. Emissions of PM were linked positively with CR For a given blending ratio.
IV. Emissions of PM were linked negatively with volume fraction of methanol.

Finally, they concluded that, Methanol decreases heat loss around the surface of the wall. As methanol percentage increases in gasoline, emissions of PM minimize. In parallel, emissions of PM are linked positively with CR. The mixing of alcohols in lower amount dilutes the degree of soot, thus minimizing the soot (Jibai Wang, 2020).

(Henein, 2006), had examined the impact of pressure of injection including swirl motion in CI engine -out exhaust in advanced combustion and conventional regimes. Results indicated reduction of NOx but increase of soot through EGR increment in com- bustion regime of conventional types. However, soot emissions reductions were detected for increased amount of EGR in LTC ranges. In addition, it indicated that showed that soot emissions were reduced by applying higher injection pressures (1200 bar) and a moderate increase in the swirl ratio.Penalty in fuel economy and higher CO emissions were observed with the higher EGR rates. In addition to this, increase in energy requirement for injection pressure of higher values together with cooling lose increments were also seen by researchers.

Good characteristics of ethanol on petrol engine are that the possibility of producing from renew able sources of energy including cassava, sugar cane, waste materials biomass, barley and corn. In addition, higher evaporation heat is the property of ethanol, including flammability temperature and octane number. So its positive impact on operational characteristics including exhaust gas property is very well known. This investigation also dealt with effects of gasoline E0 of the unleaded type with E50 and E85 blends. The test was held experimentally on one cylinder 4-stroke SI engine during two CR positions10:1 and 11:1.

It was conducted by varying speed from 1500 to 5000 rpm in widely opened throttle. Results confirmed that unleaded gasoline with ethanol mix increased torque, SFC and power which reduced CO, NOx and HC characteristics. Also it was found out that blends of ethanol/gasoline permit increment of CR in the absence of knock incidence (Mustafa Koc, 2009).

Aiming to analyze operational features of petrol engines with experiment for E25, E30 and E35 of gasoline with ethanol mixture were used. The engine is single-cylinder, computer controlled, fitted dynamometer of eddy current type. exhaust gas tester is part of the set up.

Varying load, speed and CR the test were done and outputs recorded resulting better performance for all. Less SFC was registered in E25 compared to others on various loads. 0.32 kg/kW-hr BSFC was shown on this ratio also. The efficiency of thermal break of gasoline ethanol mix was found increasing compared to gasoline. BTE was Increased which is 27.87% in E35 mixture (Hamza Afser Delvi, 2019).

octane number of fuels in gasoline mixture will be increased when methanol is added affecting the setting of petrol engines. This investigation deals with the contribution of time and duration of injection applying M5 and M10 percentages on petrol engines having control module in it. The influential parameters including power, SFC, torque, CO, HC, CO2 were investigated. From the investigation optimum settings were obtained, which are time of ignition 24 ^{o}btdc, and additional 10% duration of injection showing an improvement on M5 and M10 samples with increase of torque 2.94% similarly 1.72% of power but reduction of 7.29% SFC applying similar fuel mixture samples (Ravi Farkhan Pratama)**.**

2.7 Additives of Alcohol having greater Methanol/Gasoline ratio

Basically, reduction of adversative impacts or disadvantages in using additives in blended fuels helps to achieve reduction of emission and enhancing of performance. This includes; corrosion inhibitors, oxygenates, compounds of antiknock, octane enhancers, dyes and deter- gents. by mixing alcohol most problems could be minimized in lowering the quantities of alcohol or by applying other cosolvent (Amine et al., 2019).

Greater alcohol ratios with physical and specific chemical properties if mixed with gasoline/methanol–blend reduce the contrary properties. ternary blend fuels the so called three-component are; higher alcohol+ alcohol+ gas oline). a higher carbon number in Alcohols contains greater energy content and can replace additional petroleum gasoline than methanol/gasoline mixed fuel (Sharudin et al., 2017). Influences like content of oxygen, heating value, octane number and fame speed affect efficiency of combustion and increase these factors, that could in boosting combustion and engine exhaust minimizations. (Pang et al., 2019).

Experimental study was also conducted by (Elfasakhany, 2016) and point out that both isobutanol/biomethanol–petrol blend and methanol-*n*-butanol—gasoline fuels has shown better performance and emissions in gasoline engine.

Another researcher (Geo et al., 2019) found out the impacts in adding alcohol on petrol engine with a volume of 10% n-pentanol, isobutanol and *n*-butanol in gasoline. Results confirmed that They found that all the oxygenate blends resulted better performance excluding the *n*-butanol mix. Exhaust also minimized in comparison with gasoline apart from NO*x*, which changed latant heat of vapor-ization.

(Edwin et al., 2019) have detected that lowering effects of emission parameters due to the greater alcohol/gasoline mixes were minimized particularly during greater load settings including pressure inside the cylinder. But comparatively there was an increase in heat re lease rates in comparison with gasoline.

(Yilmaz et al., 2018) examined the impacts in adding hydrogen in gasoline/methanol mixes operated on spark ignition engines operational characteristics. From the investigation adding H2 enhances the process of combustion reaction but resulted increased NO*x* and CO2. However, HC and CO were minimized since lean consequence due to methanol.

(Gong et al., 2019) investigated the impacts due to the addition of hydrogen in engines working with methanol. The investigation resulted that CO and HC outputs decrease in applying H2 particularly at minimum speeds and for different ignition timings however it rises soot and NO*x* productions. Although adding hydrogen on blends of methanol/gasoline has some benefits, storing it in a safe way including economy is still challenging. It requires such substantial changes in connection with design of engine to apply hydrogen directly on the conventional petrol drive engine (Hosseini et al., 2019), conventional IC engines achieve only with efficiency of 20 up to 25% and lower output of power when hydrogen is used comparing with conventional fuel. Running costs of vehicles working with hydrogen might be 1/3rd greater than current petrol operated vehicles since greater hydrogen cost. In addition greater NO*x* could be resulted. For this reason using greater alcohol in gasoline/methanol mixed fuel is a good option.

2.8 Response surface methodology

In doing optimization tasks, application of RSM is becoming common including in Automotive applications. Particularly many scholars are recommending RSM for its special benefits since it permits to study on multiple variables and their interrelations having also many responses or outputs. Considering many other recommendations on RSM this work applied technique by utilizing the MINITAB application.

Feature of RSM includes using DoE of a multivariate following the optimization over models of mathematics (Carabajal, M., 2020). Several approaches of statics in modeling and analyzing problems impacted by many factors for many responses also can be dealt with this RSM. This helps to trace the exact relationships and impacts existing between the variable and the response by aiming optimum factors for the optimum responses (Singh, etal, 2018).

In this study for the RSM analysis MINITAB software is applied or used that many researchers are using and recommending for Automotive applications

2.9 Research gap

Several investigators worked on impact of fuel additives targeting better outputs, efficiencies, SFC and exhaust gas nature. Most of them have concluded and suggested (recommended) that, additives (nanoparticles) may reveal a significant contribution for further enhancing combustion, SFC including exhaust associated with spark-ignition (gasoline or petrol) engines. Previous investigations in these related issues are relatively insignificant particularly considering methanol and CeO2 on petrol driven types specifically running by premixing of methanol and gasoline with nanoparticles. In the majority of research, scholars solely pay attention to the impact of premixing methanol on petrol engines. On these premises, the major focus of this research paper is in getting the most suitable additive (nanoparticle) that closely matches with the setup. Researches done by applying RSM for the mentioned setup and purpose are very inadequate. The chosen parameters and factor on petrol driven engines needs more optimization works for the development of efficient gasoline type engine. In general, the performance including exhaust issues of petrol engines are still unsolved challenges or gaps that we need to do more research experimentally or simulation including the RSM techniques.

CHAPTER THREE

MATERIALS AND METHODOLOGY

3.1 Introduction

The very significant part of conducting experiment starts from appropriate selection, utilization and sticking to manufacturers working manual including following recommended work procedures. Choosing appropriate and influential parameters or factors is very important that would strengthen the strength of the results including conclusions. How to conduct the experiment as per the sated objective is significant. The engine used for the experiment is indicated in Table 3.1 below.

Table 3.1. Specifications of TM3-01 petrol engine

Type	4-stroke, single-cylinder
Combustion system	OHV
Displacement	127 cc
Bore x stroke	62 × 42 mm
Max. horsepower	4.2HP/3600 rpm
Max. torque	7.7N.m(6.8)/2800 rpm
Compression ratio	8.5:1
Fuel consumption	230g/ps.h
Cooling system	Air-cooled
Ignition system	TCL
Ignition timing	BTDC250
Carburetor	Horizontal type butterfly valve
Air cleaner	Dual element type
Lubrication system	Splash
Oil Capacity	0.6 L
Starting system	Recoil or electric starter
Stopping system	Ignition primary circuit ground
Fuel	Unleaded petrol preferred
Fuel Capacity	2.5 L
PTO shaft rotation	Counterclockwise (from PTO side)
Carton dimension (L × W × H)	390 × 340 × 350 mm
Net Gross weight (approx.)	13.3 kg/14.4 kg

3.2. Facilities and Test Materials

Even though there is no well-equipped test arrangement facilities locally, rearranging and organizing the available test conditions is mandatory and very important. Since the extracted data reliability is based on proper lab item arrangement. Knowing the test equipment's well as per their lab manuals and guide is essential. The investigator checked these and followed as per the product manuals and guides. The existing lab equipment's were studied thoroughly for proper operation and safety. Table 3.2 indicates partial items used for the experiment. For numerical analysis, Minitab soft- ware was used.

Table 3.2 Items and equipment's for the test

SN	Equipment
1	Methanol
2	Gasoline fuel
3	Petrol engine
4	Exhaust gas analyzer
5	Dynamometer
6	Ultrasonicator cleaner
7	Test rig
8	Gas analyzer

3.3. Method

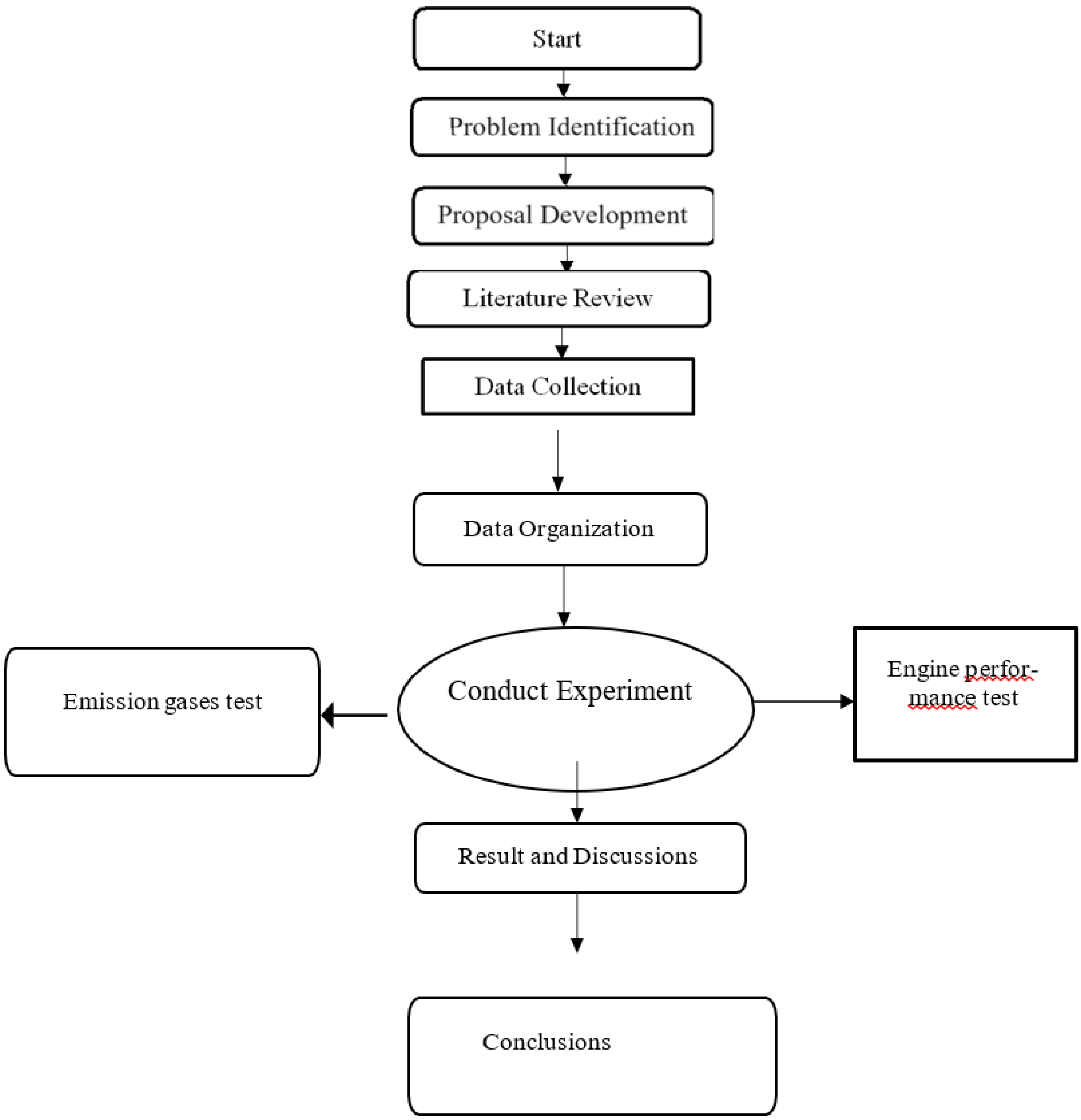

Figure 3.1: Flowchart of the methodology

3.3.1 Setup of Experiment

Experimental work was done at AASTU, engine lab. one-cylinder petrol driven engine is used as shown in Figure 3.1 and Figure 3.2, for this experiment its detail specifications is discussed above in Table 3.1. The maximum power is 4.2 HP/3600 rpm. Experiment was started by running the engine applying neat gasoline for a reference data. Data from computer were extracted for analysis as indicated in Figure 3.3 and Figure 3.4. In analyzing the performance, the output parameters torque, power and specific fuel consumption (SFC) were considered. Similar experiments were conducted using the chosen fuel blends. Gasoline and methanol fuels including cerium oxide nano material and the procurement was without compromising standards in the surrounding shops. NOx, HC and CO possibly measured using exhaust gas analyzer. Data to be studied were extracted in changing loads primarily; 20%, 20%, 30%, 40%, 50%, 60%, 70%, 80% load settings assuming earlier promising research efforts and also possible conduction of the experiments. For the test dynamometer of eddy current type with engine for unloading and loading, stirrer, Reaction flask, exhaust gas measuring device were arranged for the test.

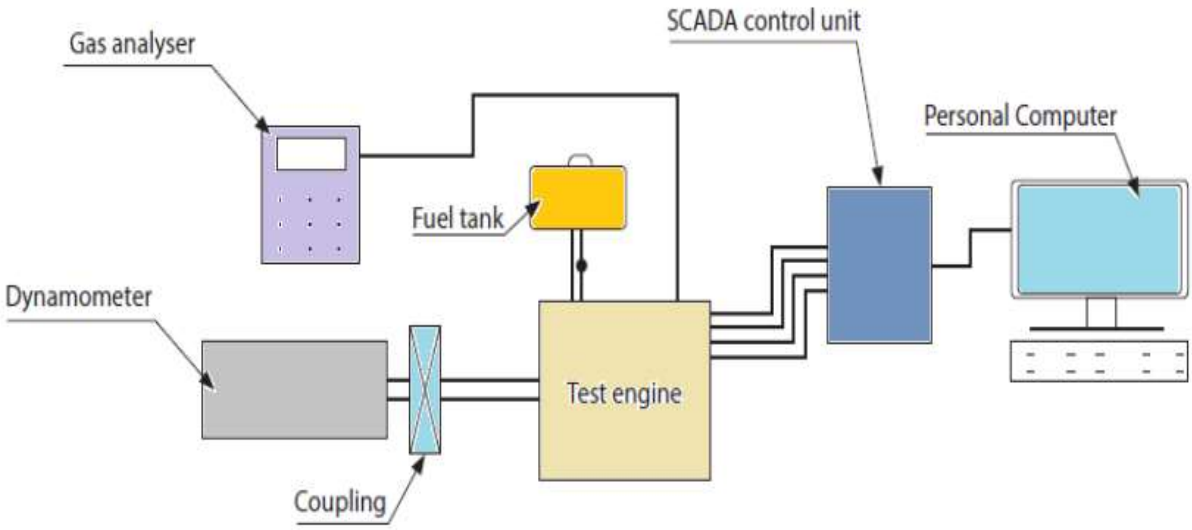

Figure 3.2 The schematic experimental setup of the test engine

Figure: 3.3 TBMC3-01 Engine used for the test

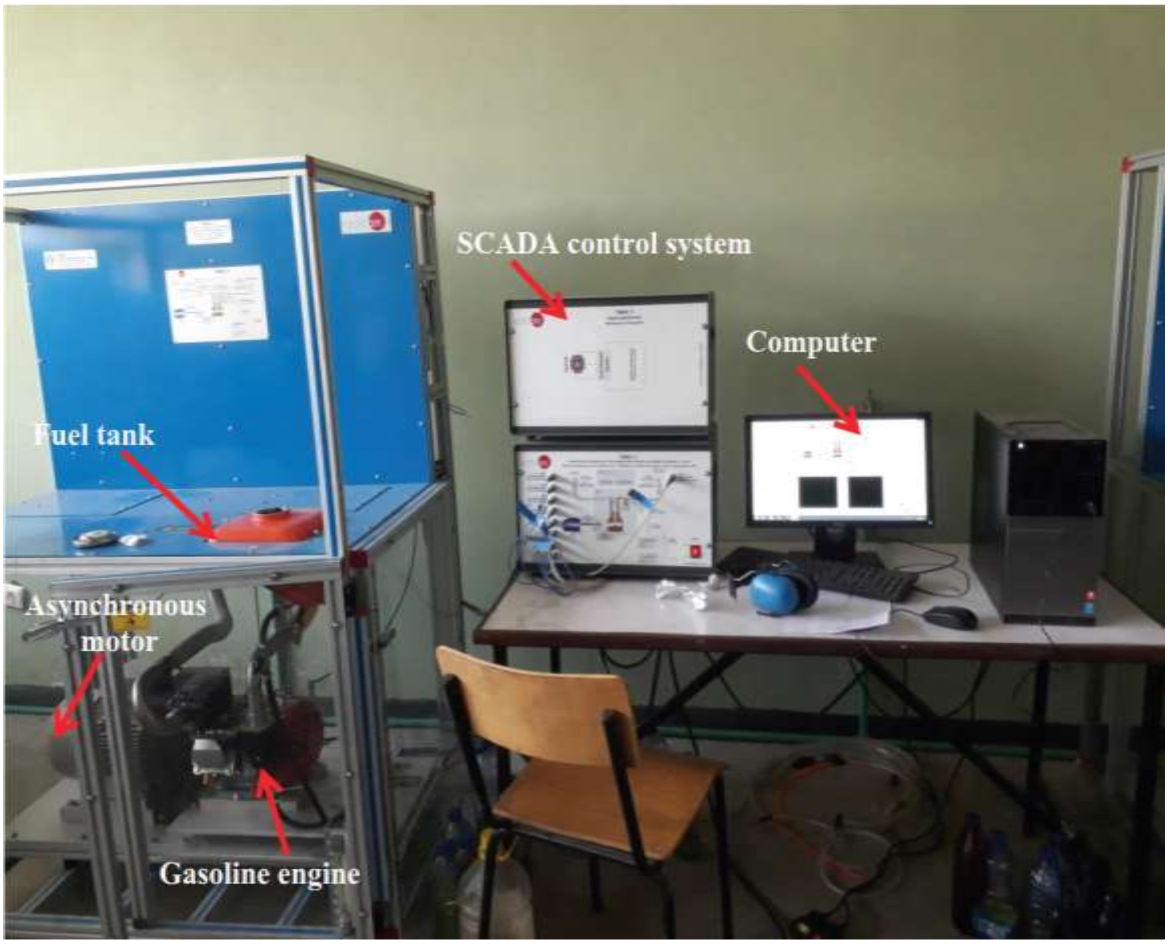

Figure 3.4 TBM3-01 engine experimental setup for SI

Data Acquisition Hardware and Control Software

Using the characteristic curves results of the experimental findings from the experimental test set up which includes; power, torque, SFC, HC, CO and NOx were computed with the chosen control factors. This was accomplished through data extracting Software and Hardware's in the test arrangement setting. Unit for this setup comprises; Controller program of the type LabVIEW, NI data retrievals panel, utiliz-ing four protection schemes of sorts; electric, mechanical & software package types.

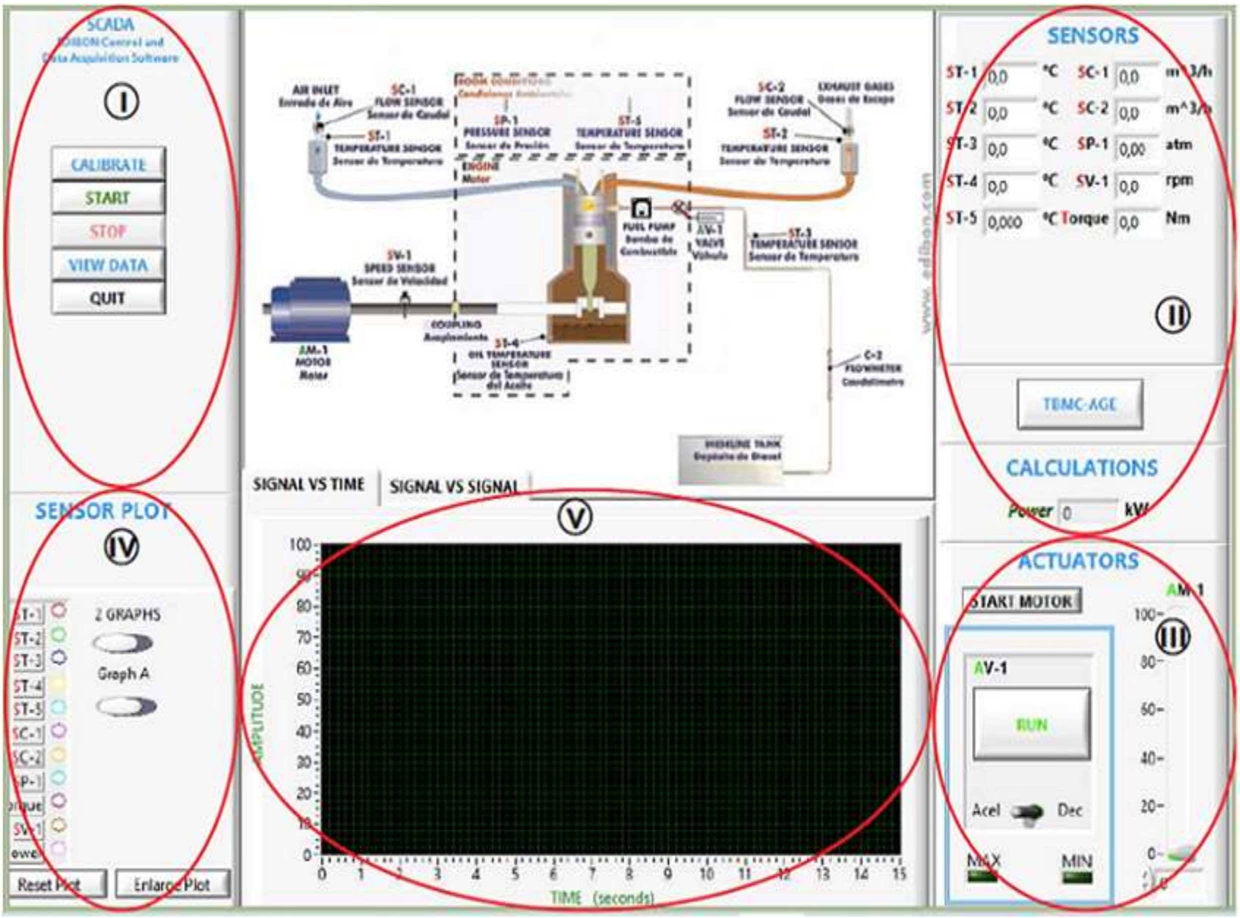

Fig 3.5 Display unit

These display unit gets order from the user and display data for registering and also to be stored in the PC that can be extracted with USB.

The study was conducted through the following methods and procedures in making the study to provide genuine data.

Assessing the previous and current researches

Hence for every scientific research, there should be a broad review of previous works, therefore this study was concentrated on working on literature reviews of the basic concept of petrol engines, the properties and performance of methanol, and the effects of nanoparticle additives were considered during the experiment including how the experimental setup is developed.

3.3.2 Setups for Measuring

By positioning different probes on the various engine systems the following parameters were measured and detected; Torque, power, pressure, fluid flow, temperature, exhausts etc that will be analyzed during the investigation. For these purpose different sensors are used for the detection which some of the following are discussed below.

A sensor which detects speeds in the ranges of 0 – 6000 rpm was installed and used for the test which is particularly the J type sensor which is installed in various systems of the test setup. Their pupose of sensing or detection includes measuring or sensing incoming temperature of air, temperature of exhaust, temperatures of fuel and oil. consumption of fuel was detected through a flow meter that can trace amount level differences between fuel reservoir and injection quantities. Detecting sensors designed in measuring incoming air entering into the cylinderr and also expelling gases of the cylinder were implemented .

3.3.3 Preparing blend of fuel samples

The mixture gasoline/methanol was prepared including cerium oxide additions or blends. The fuel samples prepared were M5G95 (5% methanol and 95% gasoline), M15G85(15% methanol and 85% gasoline) and M25G75 (25% methanol and 75% gasoline). Mixing nano-particles with fuel were accomplished through the help of ultrasonicaetor cleaner. This stage is the appropriate approach in scattering nanoparticles through main fuel, which enables likely piled nanoparticles to be reversed in nanometer (nm) values.

Methanol was mixed with gasoline fuel at various volumetric percentages to produce the fuel samples. The amounts of gasoline and methanol needed were measured using a graduated cylinder. next to preparation, the methanol and gasoline blend samples were put through several tests in the lab to conduct performance and emission tests.

Figure 3.6 Fuel samples/types used for the experiment

Name of the Product	Cerium Oxide Nanoparticle
CAS	1306-38-3
Molecular formula	CeO2
Average Particles Size	20-30nm
Purity	>99.9%
Color	light yellow
Morphology	Spherical.
Crystallographic Structure	Spherical
Specific surface	40-45 m2/g
Bulk Density	1.3 g/cm3
True Density	6.5 g/cm3
Atomic Weight	172.1148 g/mol
Melting Point	2,400 °C

Figure 3.7 specification of CeO2 and Methanol (99%) used for the experimental test

Figure. 3.8 Engine connected with dynamometer for the test set up

3.3.4 Testing emission and performance

Before beginning the test, it is mandatory to operate 15 minutes for proper engine warm-up. Then, the emission and performance characteristic for the chosen setup in the presence of methanol-gasoline mix including addition of metal oxide nanoparticles was carried out.

The main activities done during the test includes: Measuring and recording engine performance and emission results, continuous check up of the engine for proper operation and reliable data productions, varying the input parameters on the fuel blends and others.

Data Collection and Analysis

After effective collection or registering of data, the collected data were analyzed and optimized through RSM for optimum results of performance and emission for all samples of fuels and engine operational set ups. Following these the factors and responses were studied and analyzed for their patterns and relationships between them to obtain optimum engine performance and emissions.

Figure: 3.9 Registering data from the operational set up.

Error analysis

tracing the possible means of error and proper calibration of the measuring device has been checked. lessening errors throughout data registering three results were considered by averaging them were taken for minimizing error for the analysis. Gas analyzer implemented for the experiment was adjusted for its standards by means of clean air to meet product specification.

3.3.5 Exhaust Emission Measurements

elements of test bench comprises the components used for the test such as; computerized gas calorimeter, exhaust gas tester, fluid stream sensor which is to know the quantity of flow of exhaust.

computer-controlled of element type gas tester was implemented in testing expelling gases from the experimental engine in order to examine the behavior of the usual expected gases which includes: CO, HC and oxides of nitrogen (NOx).

Figure. 3.10 Automotive exhaust gas analyzer

Table: 3.3 Used exhaust gas analyzer specifications

Parameter	Resolution	Accuracy	Range
Carbon Monoxide	0.01 %	+/- 5 % of reading *1	0-10 %
(Infrared)		+/- 0.06 % volume *1	Over-range 20 %
Oxygen	0.01 %	+/- 5 % of reading*1	0-21 %
(fuel cell)		+/- 0.1 % volume *1	Over-range 25 %
Hydrocarbon	1 ppm	+/- 5 % of reading *1	0-5000 ppm
(Infrared)		+/- 12 ppm volume *1	Over-range: 10,000 ppm
Carbon Dioxide	0.1 %	+/- 5 % of reading *1	0-16 %
(Infrared))		+/- 0.5 % volume *1	Over-range: 25%
Nitric Oxide*2	1 ppm	0-1500ppm +/-5% or	0-1500ppm
(fuel cell)		25ppm;	Over-range: 5000 ppm
Carbon Monoxide	0.01%	Calculated	0-15%
Corrected COK			
Sensor response T_{95}	Nominal 20 seconds		
Warm up	Less than 2 minutes		
PC connection	Via RS 232 port		
Data-Logging	500 Tests		
Dimensions			
Weight	1kg		
Handset	220mm x 55mm x 120mm		
Probe	Insertion depth 350mm x Diameter 15mm		
	Clip handle to secure to exhaust, 4m long hose		
	Various probes available including high temperature		
Ambient Operating Range	+5°C to +45°C/10% to 90% RH non condensing		
Storage temperature	Minimum: 0°C		
	Maximum: +50°C		
Battery Charger	Input: 100-240 V ~ 47-63 Hz		
	Output: 12 V DC		
Analyzer battery run time	>4 hours from full charge with the pump running		

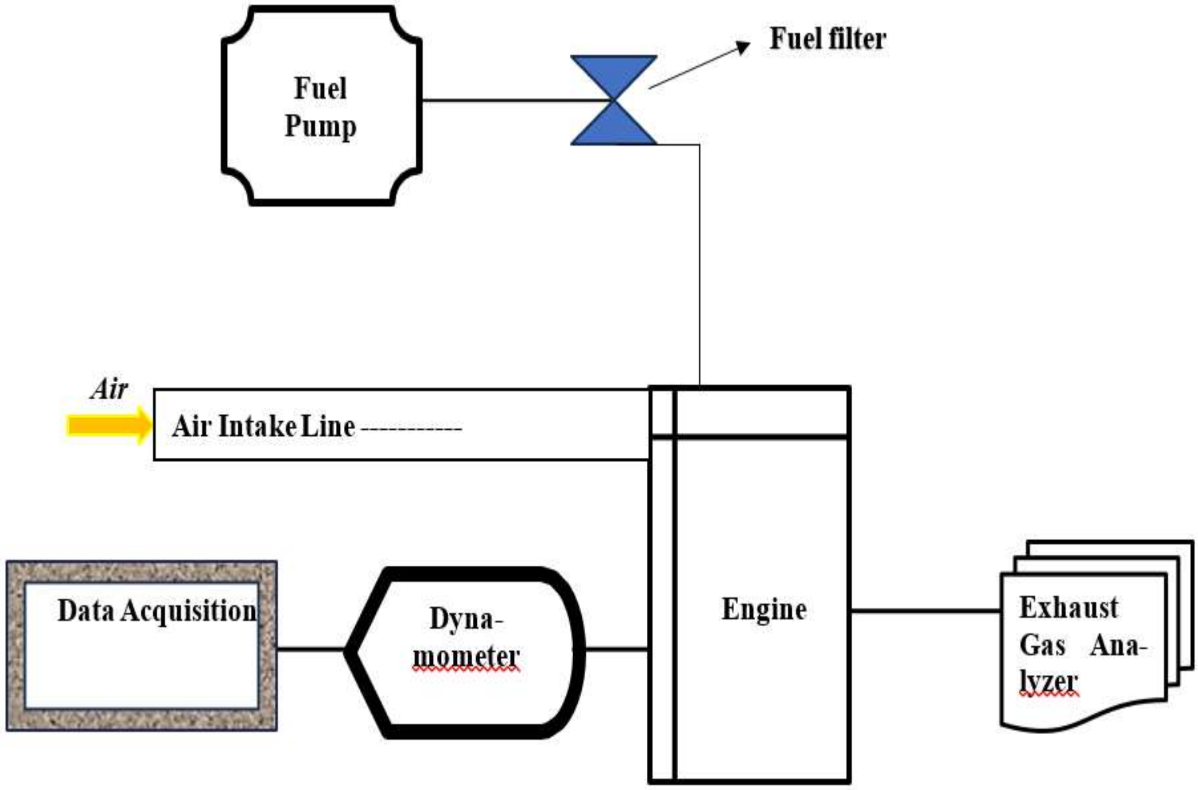

Figure 3.11: Schematic layout of experimental setup

3.3.6 Optimization Method

Response surface methodology

Combining input variables which are in optimum helped for better output responses. For this investigation RSM technique was used in exploring the impacts of the factors on the selected responses by using software MINITAB which is a recommended data analysing tool. RSM optimized for the combinations which are influential factors. RSM's targets were fullfiled by considering possible affiliations among basic influential factors or variables with the chosen outputs.

3.3.7 Test Matrix for the Experiment

The experiment was carried out considering the basic control factors with gasoline %, and the premix ed methanol % and nanoparticles (Cerium oxide) blending were conducted by following the basic inputs or factors and output responses as shown in Table 3.4 experimental test matrix and also the chart of the methodology shown in Figure 3.11

Table 3.4 Test Matrix from RSM for optimization

load	Speed (RPM)	Methanol	Gasoline	Power(kW)	Toque (Nm)
20	3999.101	15	85	0.844	2.032
25	3164.641	15	85	0.54	1.549
40	3018.431	5	95	0.443	1.42
50	2387.903	5	95	0.273	1.12
60	2008.727	5	95	0.223	1.058
75	1638.464	15	85	0.13	1.21
80	1011.294	15	95	0.12	1.247
90	869.78	5	100	0.11	1.16

load	Methanol	Gasoline	CO	HC	Nox
20	15	85	0.019	0.163	6.9
25	15	85	0.02	0.141	7.2
40	5	95	0.028	0.111	7.3
50	5	95	0.035	0.107	7.96
60	5	95	0.043	0.117	8.9
75	15	85	0.053	0.109	10
80	15	95	0.058	0.106	10.3

Table 3.5 Operating conditions and parameters

Engine operating test condition	Fuel samples for the test	Parameters evaluation
➢ Fixed load ➢ Varying speed ➢ Constant compression ratio	1. G100 2. M5G95+ $CeO_2$100 ppm 3. M15G85+ $CeO_2$100 ppm 4. M25G75+ $CeO_2$100 ppm	1. Engine performance ➢ Torque ➢ Power ➢ Specific fuel consumption (sfc) 2. Exhaust emissions ➢ CO_2 ➢ CO ➢ HC ➢ NO_X

CHAPTER FOUR

RESULT AND DISSCUSSION

4.1 Introduction

Doing an experiment using various volumes of gasoline, methanol and a constant volume or amount of $CeO2$ additive in a single cylinder gasoline engine was the aim of the investigation. The effects on these sample combinations on the operational and exhaust gas features were experimentally investigated and analyzed including response surface methodology applications. The parameters chosen for the analysis of performance and emission includes; SFC, CO, HC power, torque & NOx. Various graphs and analysis results were developed from the study. For the mentioned fuel types different engine load percentages (20%, 30%, 40%, 50%, 60%, 70%, 80%) were used. The results and discussion from the investigation with the mentioned performance on the chosen one cylinder naturally aspirated petrol operated engine were discussed below.

4.2 Engine performance Investigations

Methanol/Gasoline and cerium oxide mixed fuels combinations displayed hopeful ignition features and fuel types that might be appropriate in spark ignition engine which is intended to reduce harmful exhaust with no substantial impact on operational features.

4.2.1 Engine power

Results from the experiment showed that in blending the gasoline with methanol together with the addition of cerium oxide nonadditive indicated that there was an increase in engine power. As indicated in Figure 4.1 better power performance were obtained from higher percentages of gasoline and higher load conditions in relation to better thermal efficiency of the combustion. From the study, increaseing methanol ratio in the mix; brake thermal efficiency improved and, torque and power decreased. Development of power is lesser in methanol fueled compared to the ethanol one since heating value differences in mixture under the considered operating conditions which makes methanol less fortunate than petrol mode.

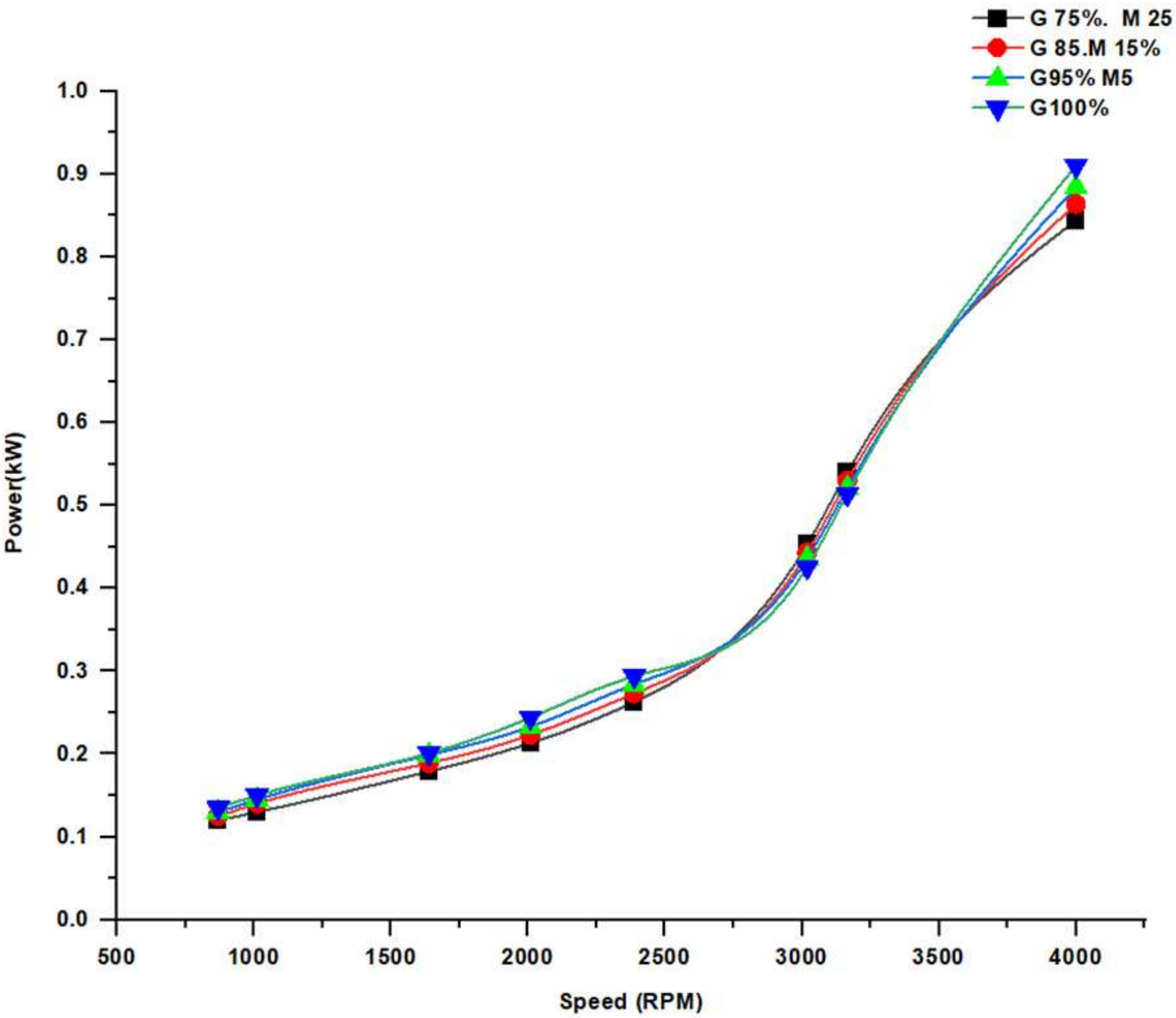

Figure:4.1 Power vs speed

As indicated in the Figure 4.1 and Figure 4.2; results of power from the engine rises as the speed rises for the entire sample types. Fuel samples G100, G95%with M5, and G85% with M15 showed an improved power in comparison with G75%with M25. RSM optimization results showed that an optimized result of 0.9457 kw power was obtained with a load condition of 20 %, Speed of 3999.101 Rpm, methanol blend percentage of 14.997 % and a Gasoline mix of 89.3939 %.

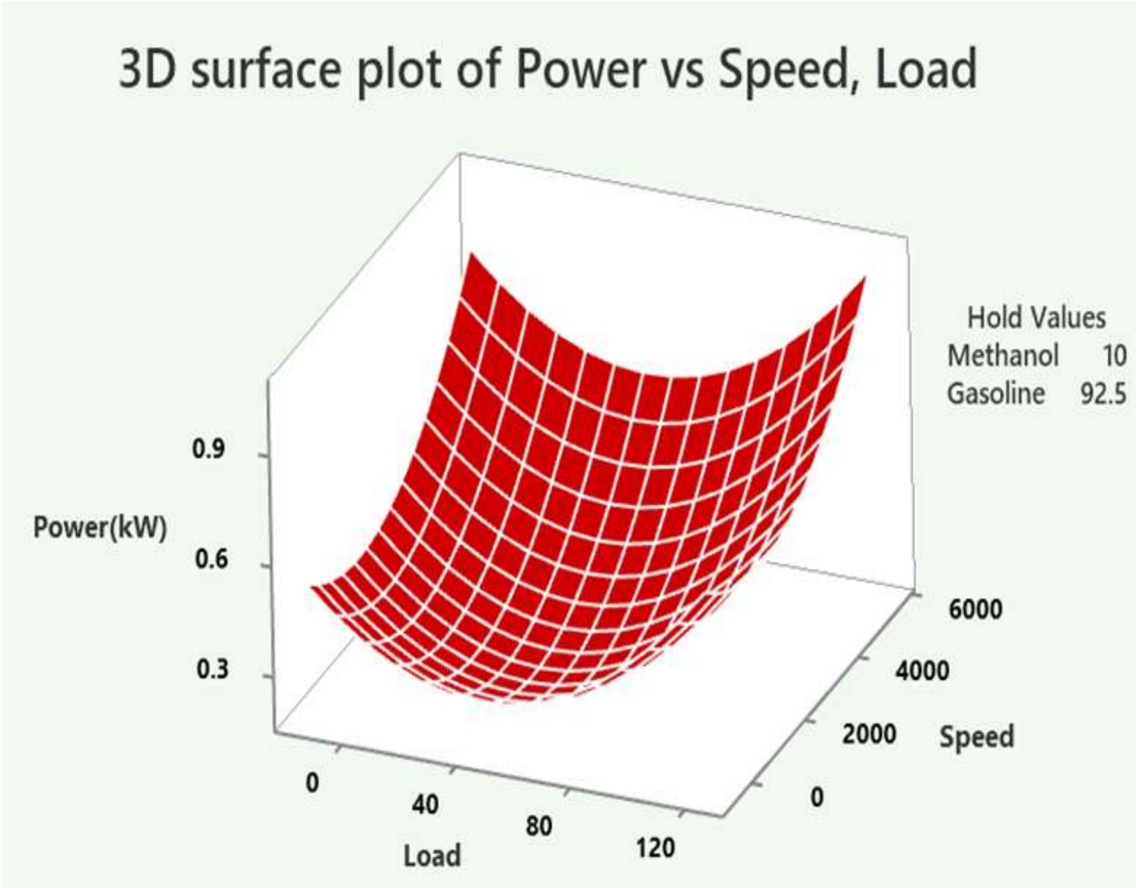

Figure:4.2 3D surface plot of Power vs Speed, Load

4.2.2 Engine torque

The torque developed by the chosen engine when fueled with methanol is almost equivalent to the torque developed in the gasoline fueled case including the power development. Other experimental findings confirmed that methanol used in spark ignition engines with greater percentage of methanol mixture or pure methanol, rises torque of the engine, efficiency including power in contrast to the baseline petrol tests for reason of more fuel octane ratings. As indicated in Figure 4.3 and Figure 4.4 also Figure 4.5; the engine torque is decreasing up to 2000rpm for both fuels and has increased for the increment of the speed due to the overall combustion features of the engine are the best at the indicated speeds in the figure.

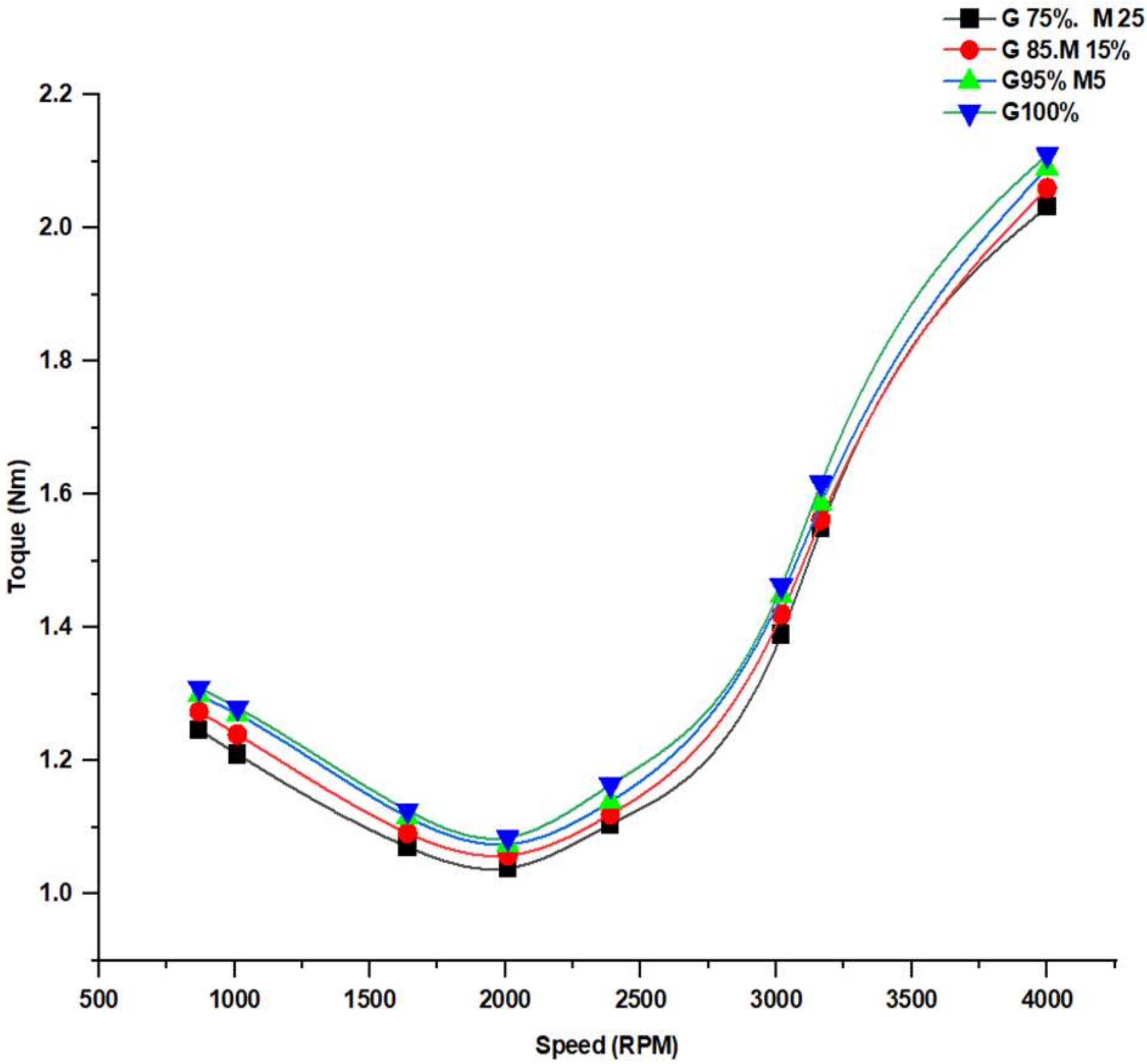

Figure: 4.3 Torque vs speed

From the experiment, changing the speed from lower to higher, blends of G95%with M5, and G100 resulted better torque output than G85% with M15 and G75% with M25.

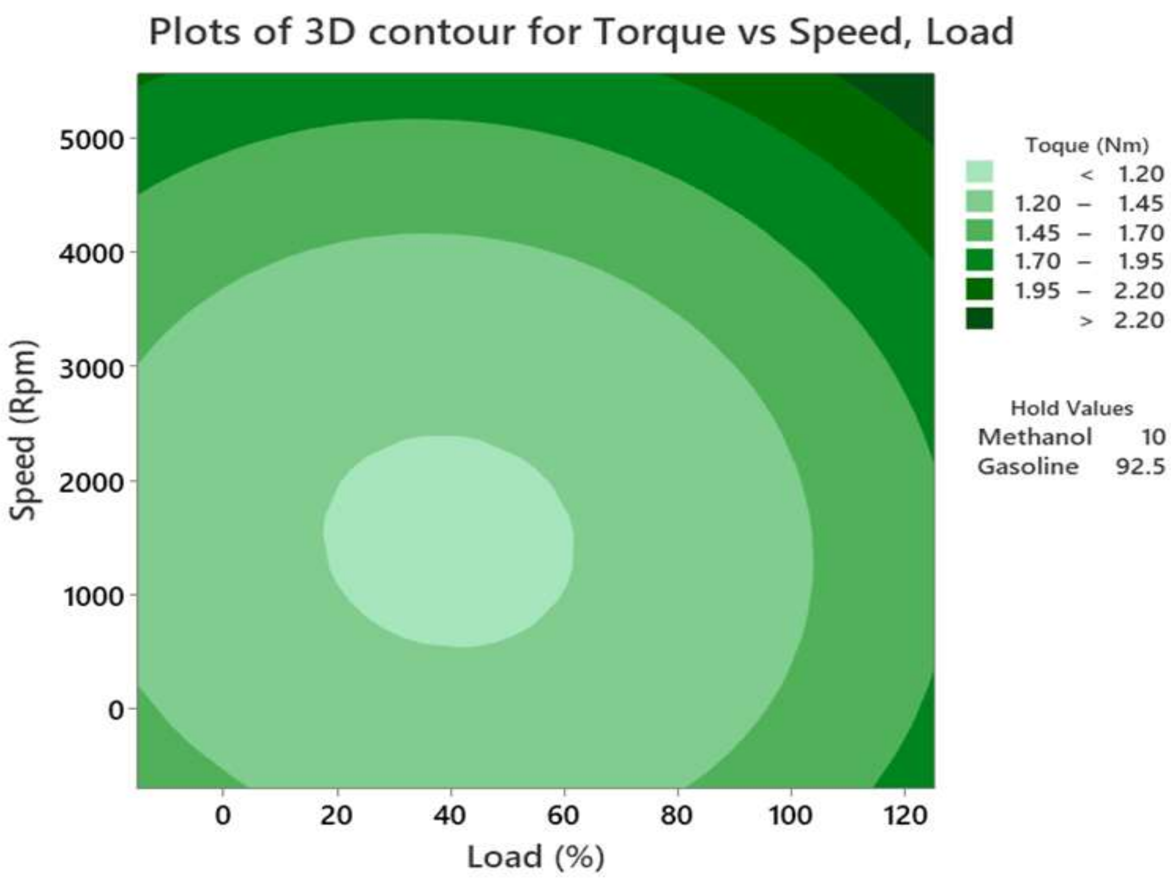

Fig 4.4: Torque vs Speed, Load; 3D contour Plot

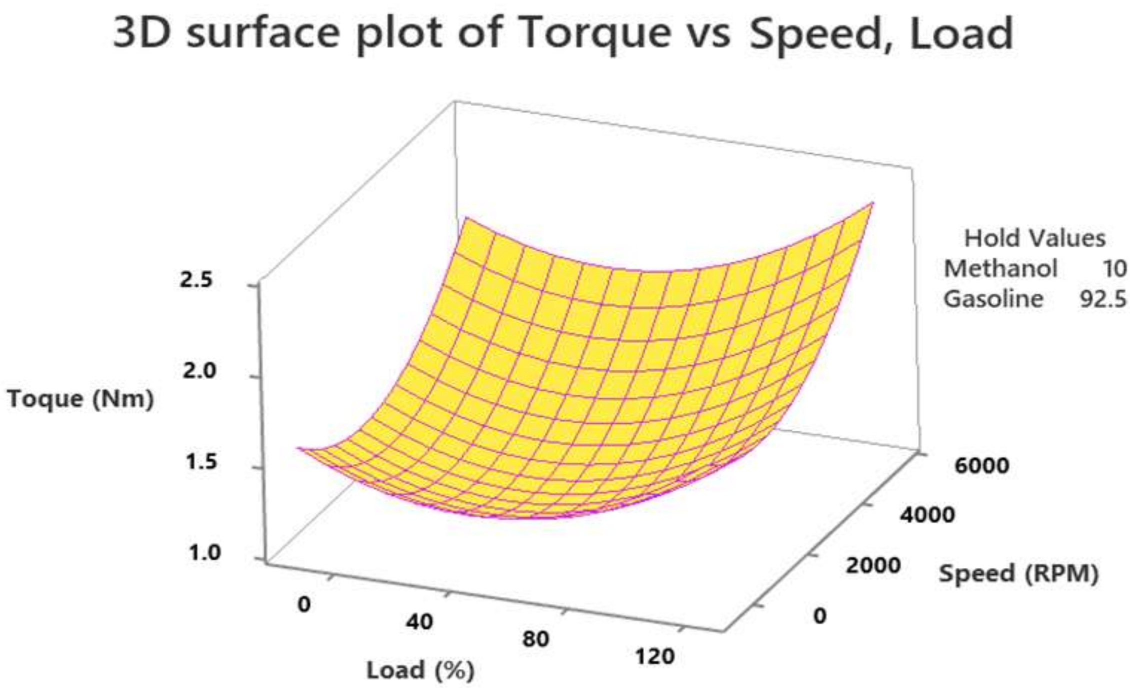

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Fig: 4.5 3D surface plot Torque versus Speed and Load

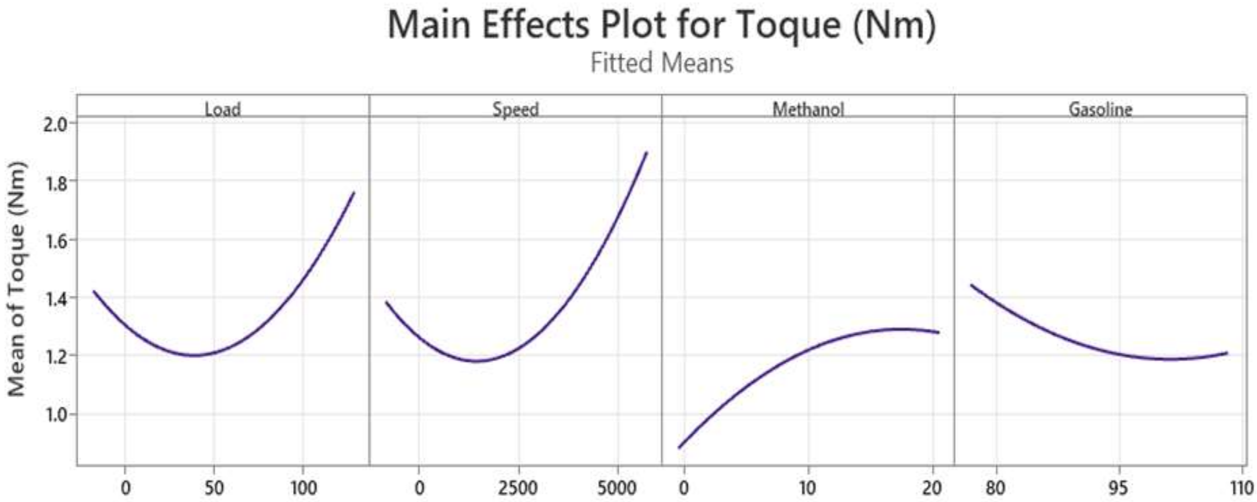

Fig 4.6 main effects plot

From the above main effects plot Figure 4.6 generated from the RSM analysis that we can identify which factors or parameters of load, speed, methanol percentages and gasoline blend percentages have the most significant influence on the response which is Torque which is also demonstrated in Figure 4.7 and Figure 4.8.

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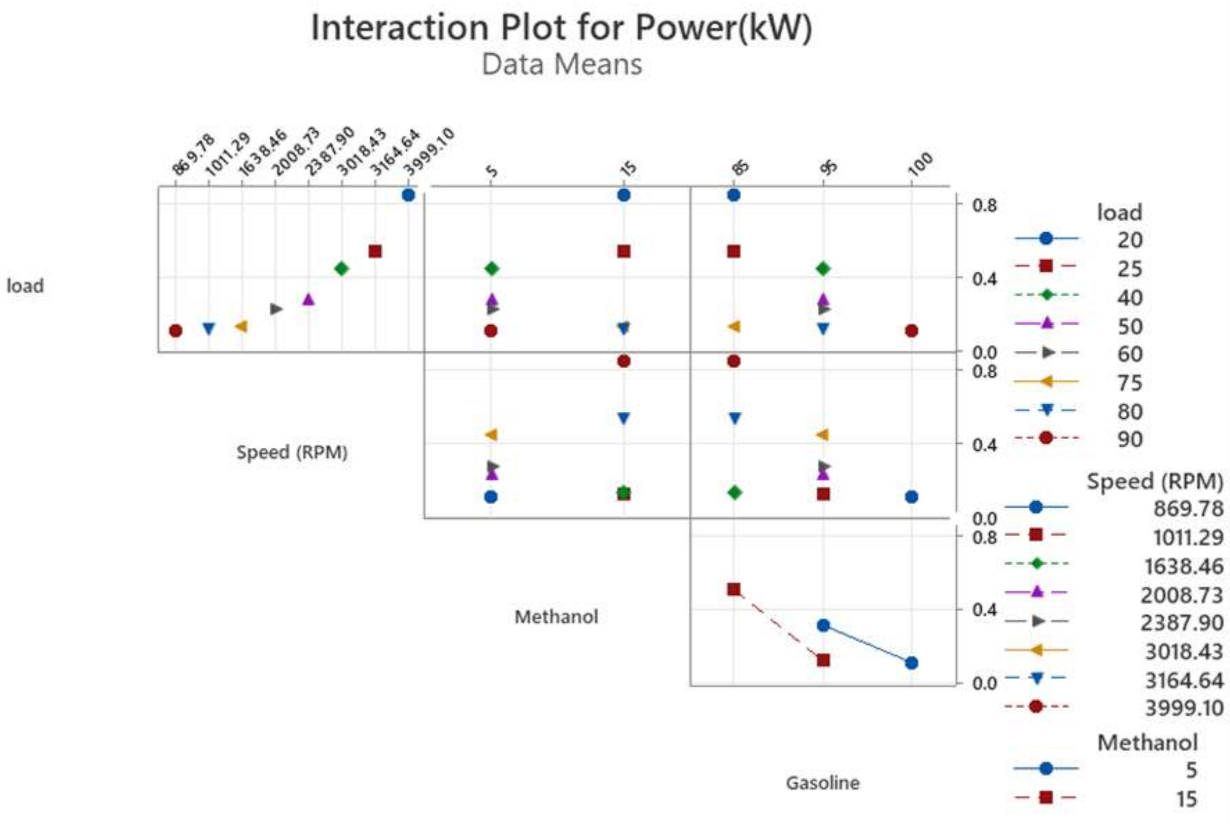

Fig: 4.7 power Interaction plot

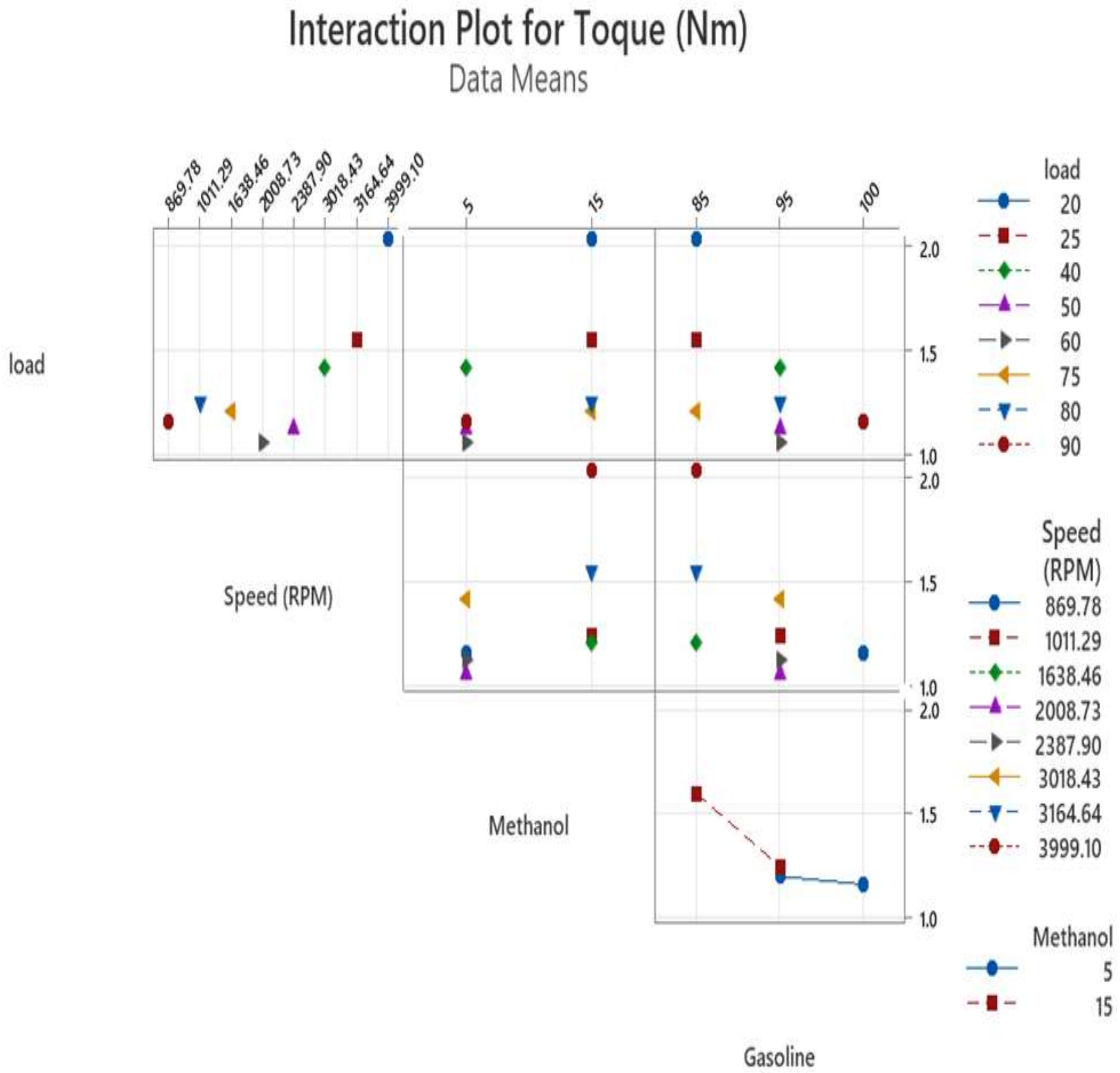

Fig 4.8 Torque Interaction plot

Interaction Plot for CO, HC, NOx, SFC

The following plots Figure 4.9 - Figure 4.11 indicates the interactions that exists among each control factors for optimum response results.

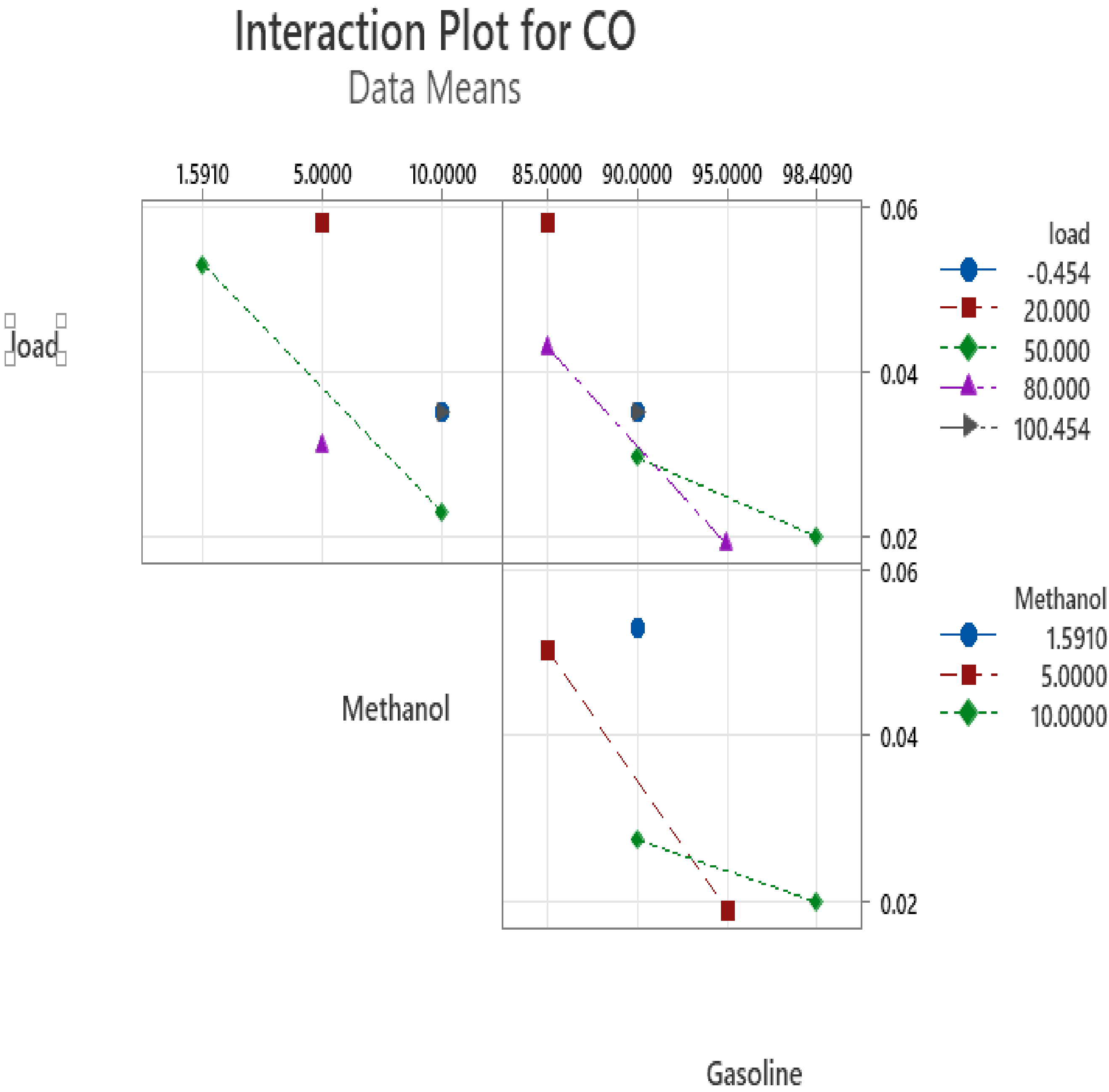

Fig 4.9 CO Interaction plot

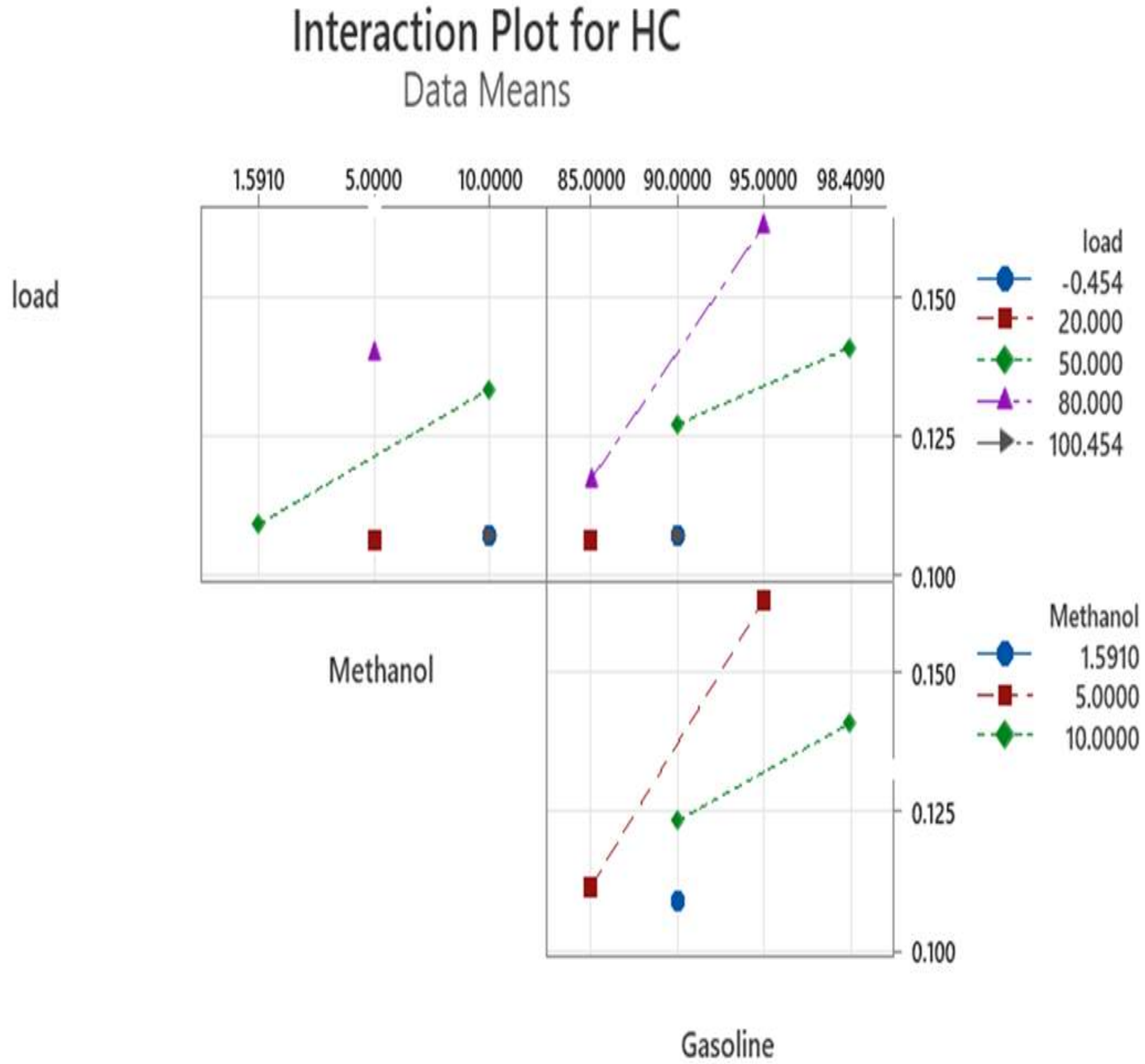

Fig 4.10 HC Interaction plot

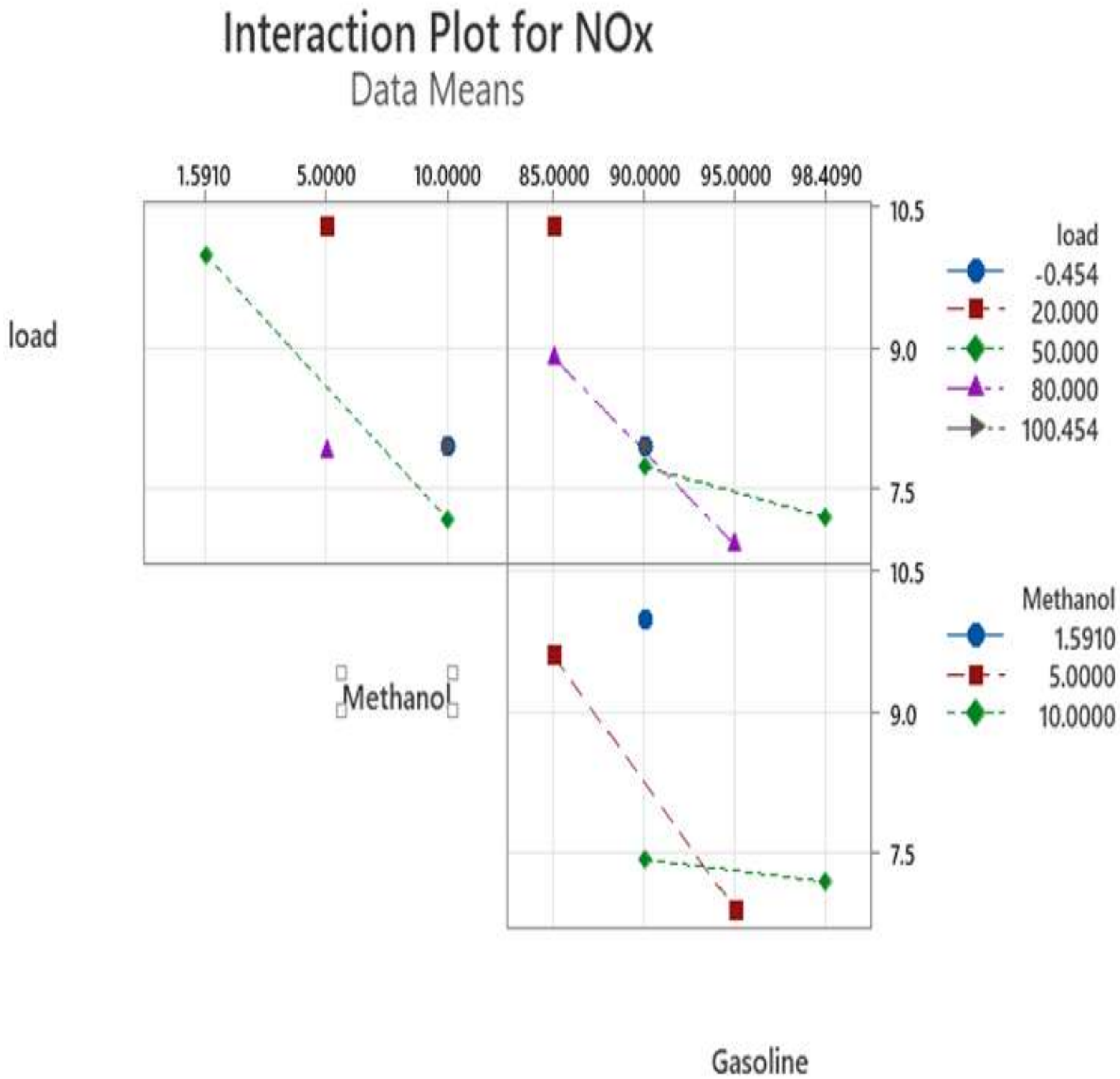

Fig 4.11 NOx Interaction plot

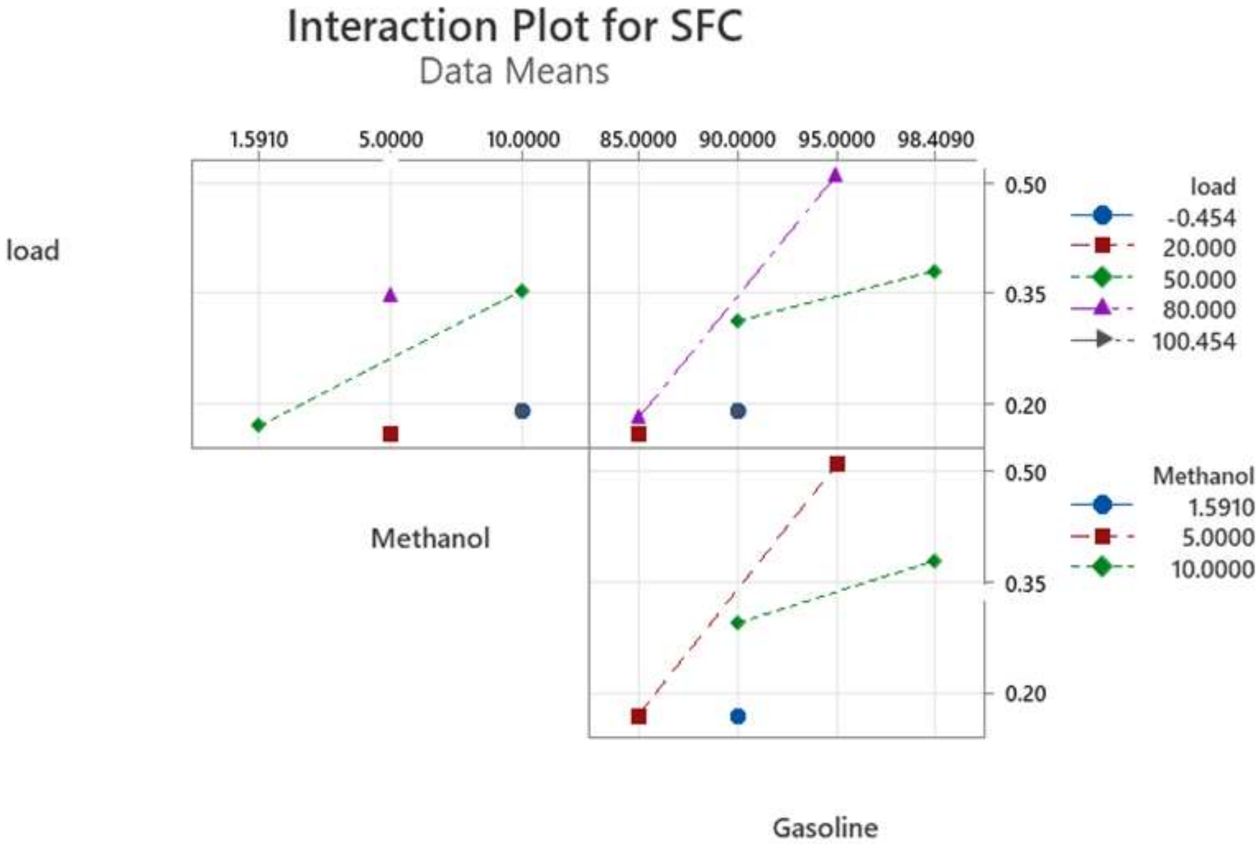

Fig 4.12 Plots of CO, HC, NOx, SFC calculated through the DOE of RSM.

From the above RSM optimization results of the interaction plots, Figure 4.12, they indicated that the interaction between the control factors; load, Methanol, Gasoline were taken as a determinant factor. The optimum configuration depends on the optimum ratio values. The control factors interaction was shown in this plot clearly

The above plot helps to trace the interactions of the control factors how much considerable interaction between the control factors in that how much the interaction is moderate or not with the other control factors which affect the response results. From Figures there is less interactions between load, A considerable interaction exists between methanol ratio and load for the responses.

The above interaction plot diagrams helps to analyze the comparative degree of impacts among the control factors. From the above plots it is indicated that a considerable interaction between methanol and gasoline in which they affected HC and CO productions.

these interaction results were highly impacted or achieved through the influence of the mixed cerium oxide CeO2 which is not even clearly shown in the plot and the Methanol blending.

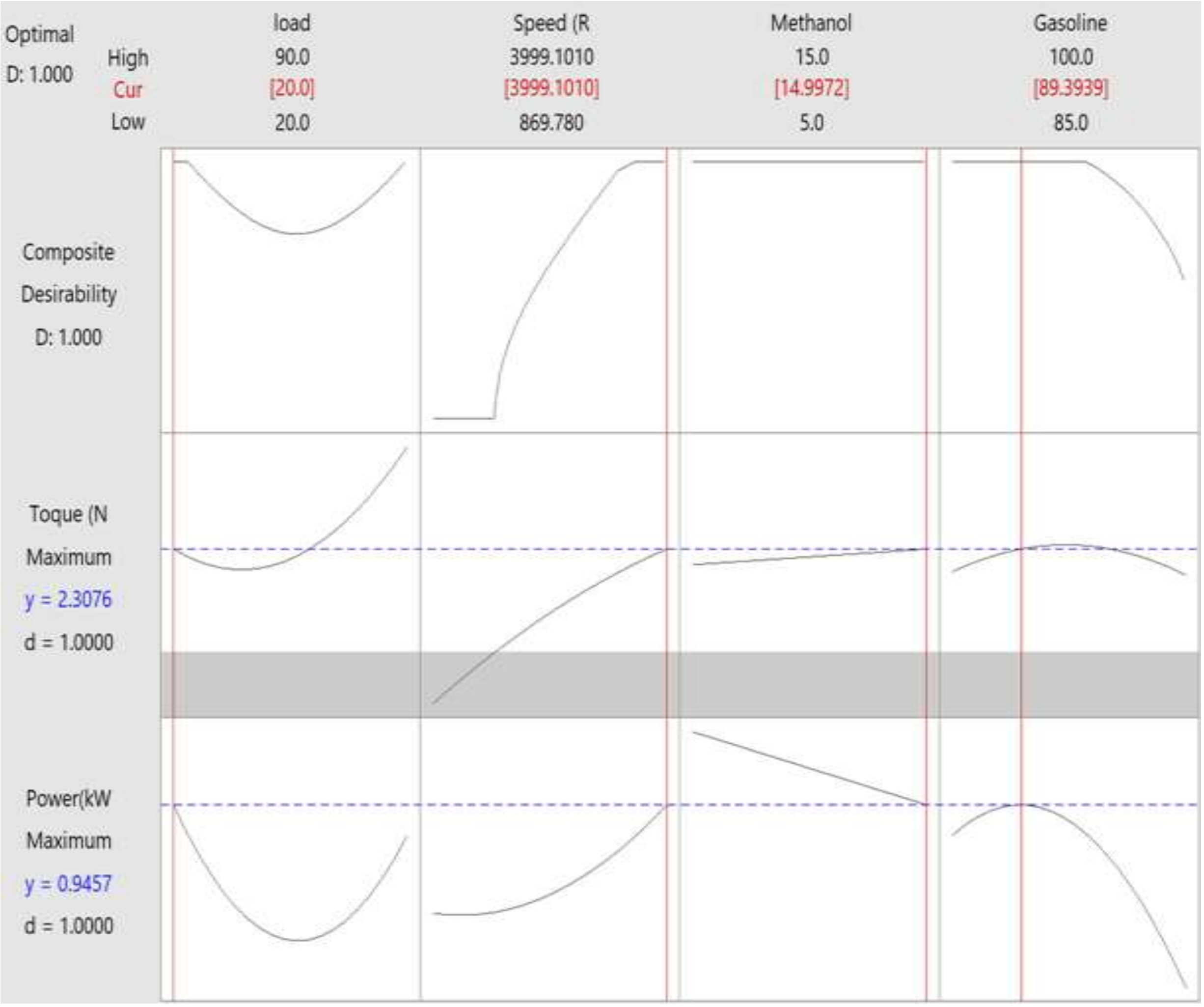

Figure: 4.13 Response Optimization: Toque (Nm) and Power(kW)

Similarly, optimization results from RSM as shown in Figure 4.13 indicated that better optimized result of 2.3076 N torque was obtained under a load of 20 %, methanol blend percentage of 14.9972 % and a Gasoline mix of 89.3939% %.

4.2.3 SFC (Specific fuel consumptions)

increasing methanol percentage along with cerium oxide nano additives resulted decrease of SFC comparing with other samples. Also, specific fuel consumption for all fuel samples decreases in the same fashion as load increases, Figure 4.16 and Figure 4.17.

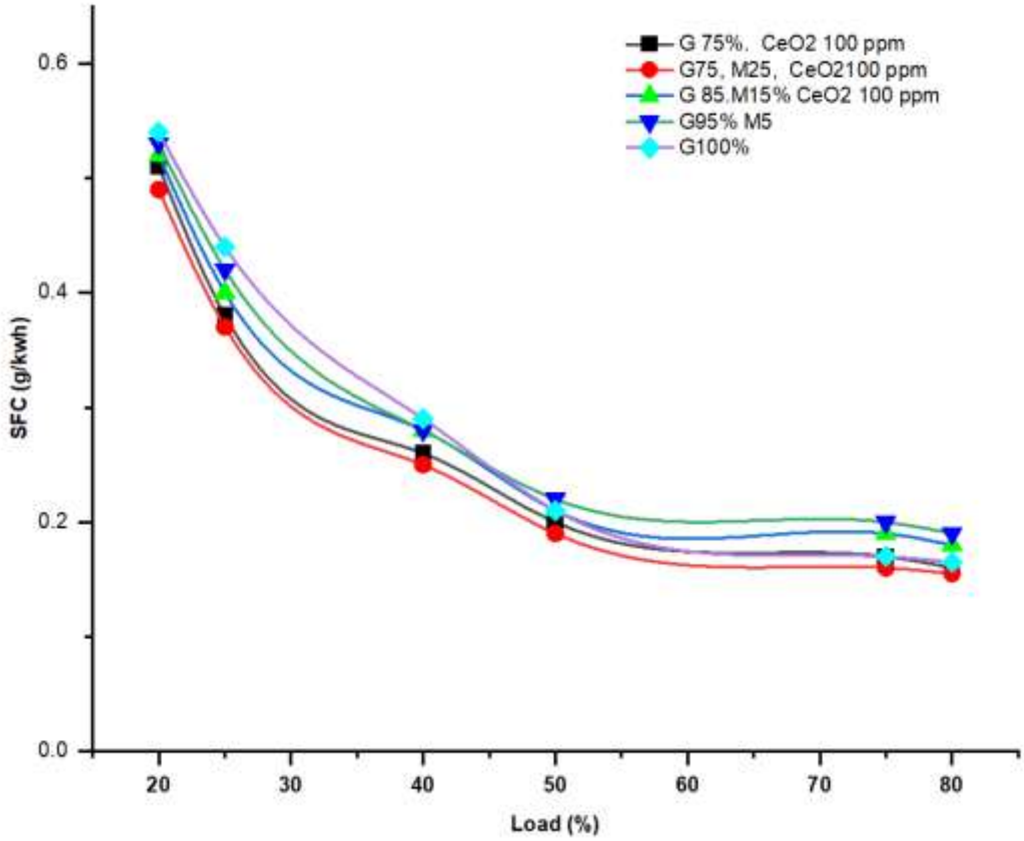

Figure: 4.14 SFC vs Load (%)

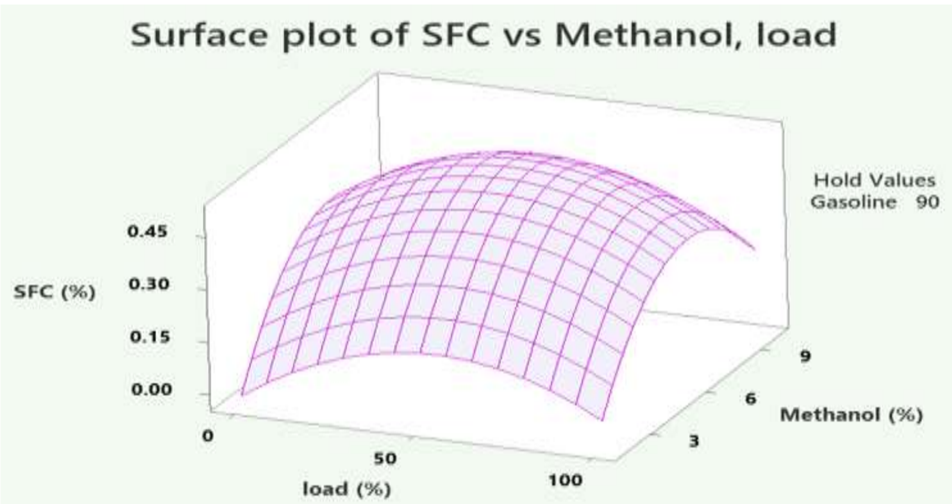

Figure 4.15: 3D surface plot of SFC vs Methanol, Load

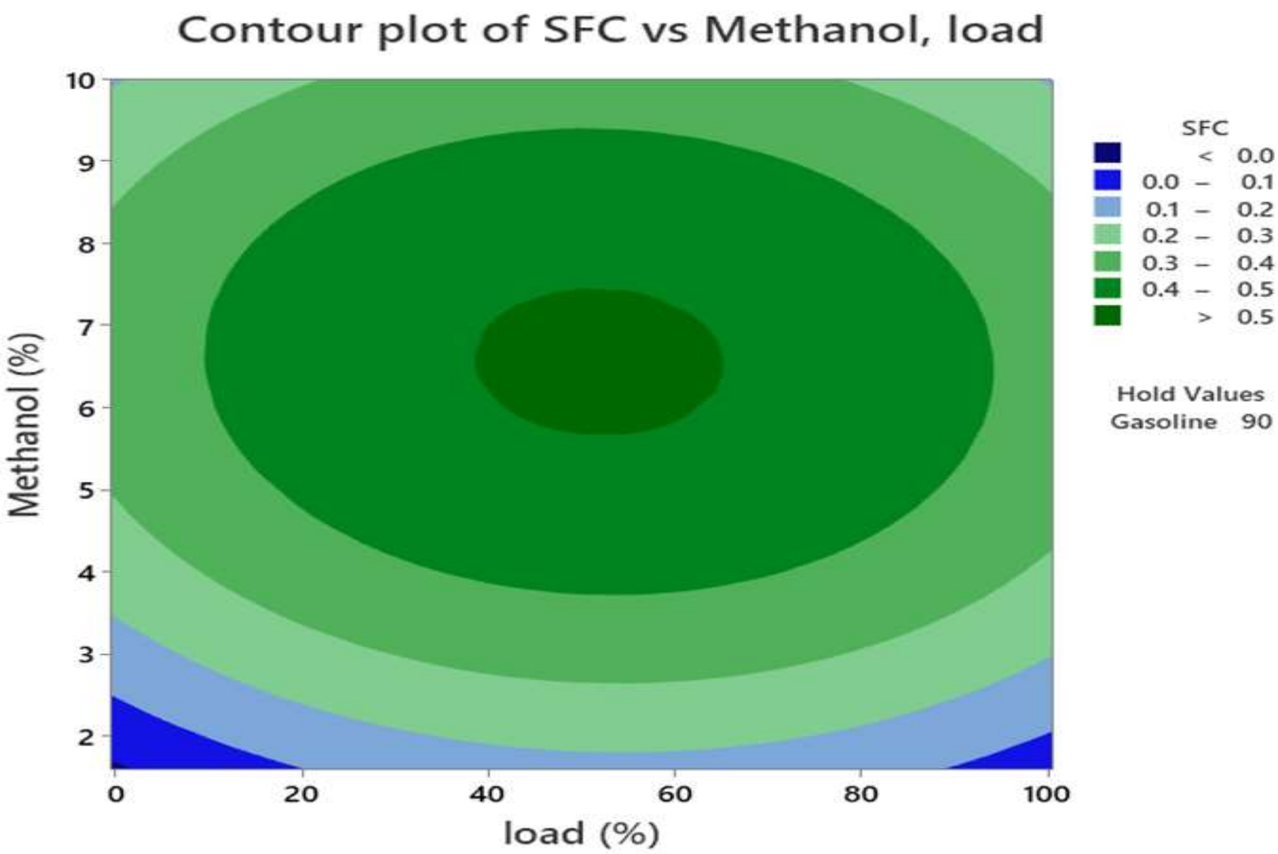

Figure: 4.16 Plots of 3D contour for SFC vs Methanol, Load

The SFC decreased by a maximum of 7% for the fuel sample G75% with M25 having cerium oxide nano additive comparing with G100.

The SFC shows how much the gasoline engine convert the available energy of thermal of the gasoline into the form of mechanical motions. As indicated on the experimental result graph in Figure: 4.14 the specific fuel consumption has decreased as load increases. It is indicated also that the SFC is minimum at condition of max. load due to better thermal efficiency conditions.

Increase in thermal efficiency were observed as the % of methanol increases considering constant load including enhancement in combustion features. The thermal efficiency relies on outputs power and calorific value. As it is shown in the Figure based on experimental findings the specific fuel consumption declines as the blending proportion rises and demonstrates greater value for neat gasoline considering similar loads. Mixing methanol indicates lower specific fuel consumption in comparison to conventional since greater oxygen percentage within methanol. In increasing load the SFC decrease as shown in the experimental results in the graph.

So the finding from this experiment shows that applying a blend (G75% with M25 having cerium oxide 100 nano additive) in spark ignition engine improves the operational features by decreasing hazardous exhaust gases since the higher percentage of oxygen in methanol. G100 and gasoline with less methanol content (G95 with M5) demonstrated maximum value on the graph results.

RSM optimization results indicated that a better optimized result of 0.1948 % of SFC was obtained with a load a load condition of 100.4538 %, methanol blend percentage of 10 % and a Gasoline mix of 90.1469 %.

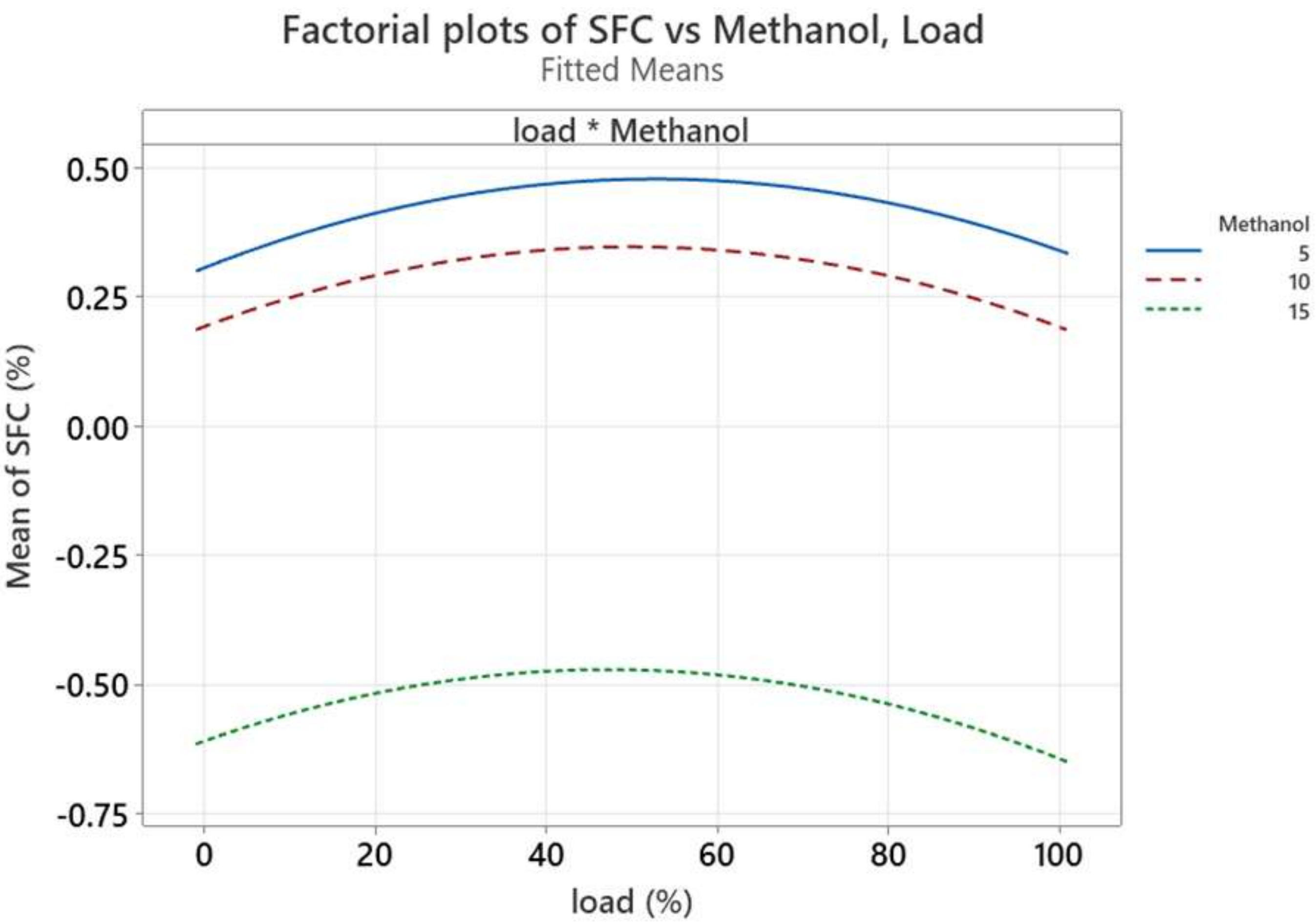

Figure: 4.17 factorial plot for SFC vs methanol, load

The above factorial plot indicates the relationship between methanol percentages and their impacts on SFC as per load conditions. From the plot M15 has lower SFC than M10 and M5.

4.2.4 Impacts from methanol and cerium oxide nano additive with gasoline on emissions

Calibration of gas tester using clean air was the first task that was done during the experiment since to obtain manufacturers recommended values. Results of Emissions from exhaust ejected from test engine was detected using a computer governed TBMC3 gas tester. Knowing the unburned hydrocarbon (HC), CO and NOx was fresh accomplished through this gas tester. The tester requires making periodically zero of sensors. After completing the calibration time to next zero is shown after minutes confirming that sufficient time before starting the experiment. clean ambient air is mandatory for the analyzer for the calibration to obtain the expected standards. Amount of stream of gases of the exhaust were measured by an installed flow sensor. Exhaust gas analyzer has the capacity to detect gases such as O2, HC, NOx, CO and CO2.

4.2.5 Unburned hydrocarbon (HC) emission

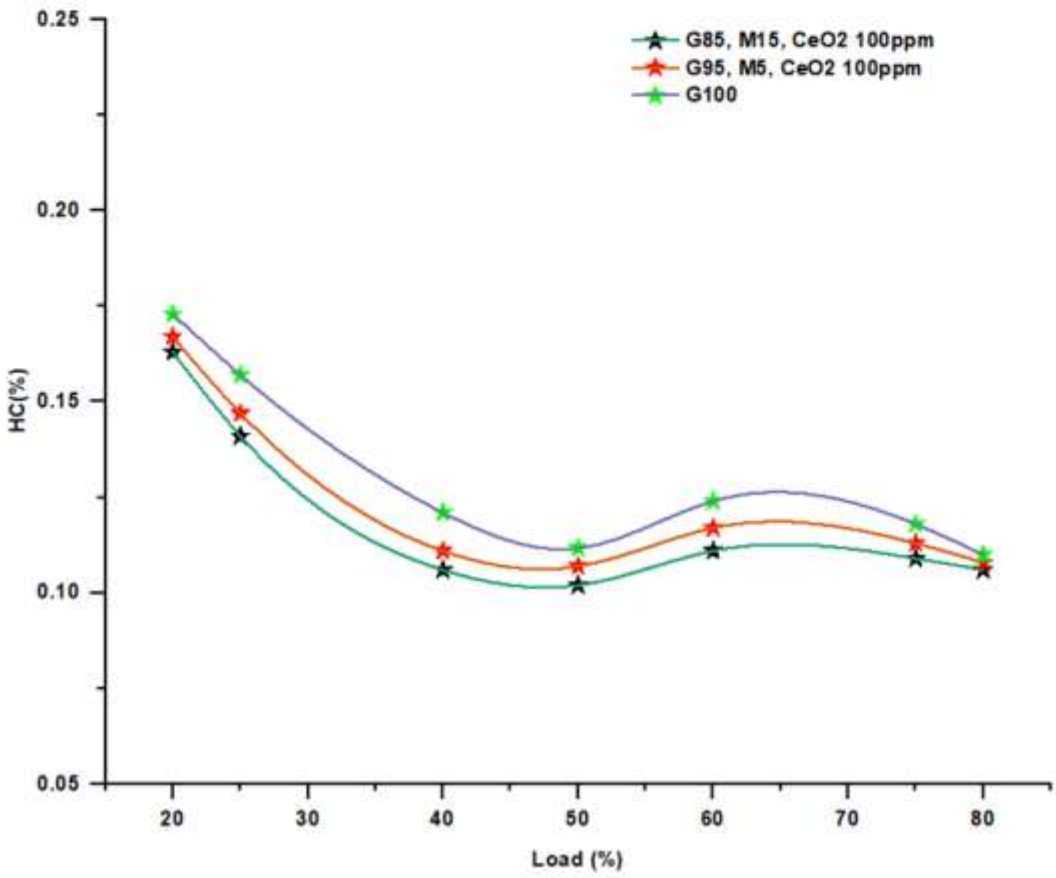

Figure: 4.18 HC vs Load (%)

In this experiment applying G85% with M15 including blends of cerium oxide 100 nano additive resulted a decrease in HC emission by 5.7%.

Based on this emission analysis of the chosen engine using different methanol-gasoline blends and cerium 100 nano additive, the better blend for lower HC emission results was found which is G85, M15, and cerium oxide CeO_2 100ppm.

From Figure 4.18 of the experimental finding the higher methanol ratio or percentage mixing together with cerium oxide additive has shown a promising reduction of HC emission than the pure gasoline fuel. The study also revealed that a decrease in hydrocarbon emission was observed in increasing the load of the engine in contrast with the carbon monoxide results. Optimization results from RSM indicated that better optimized result of 0.1077 % HC was obtained with load of 100.4538 %, methanol blend percentage of 10 % and a Gasoline mix of 90.1469 % which this ranges are also shown from Figure 4.19- Figure 4.21.

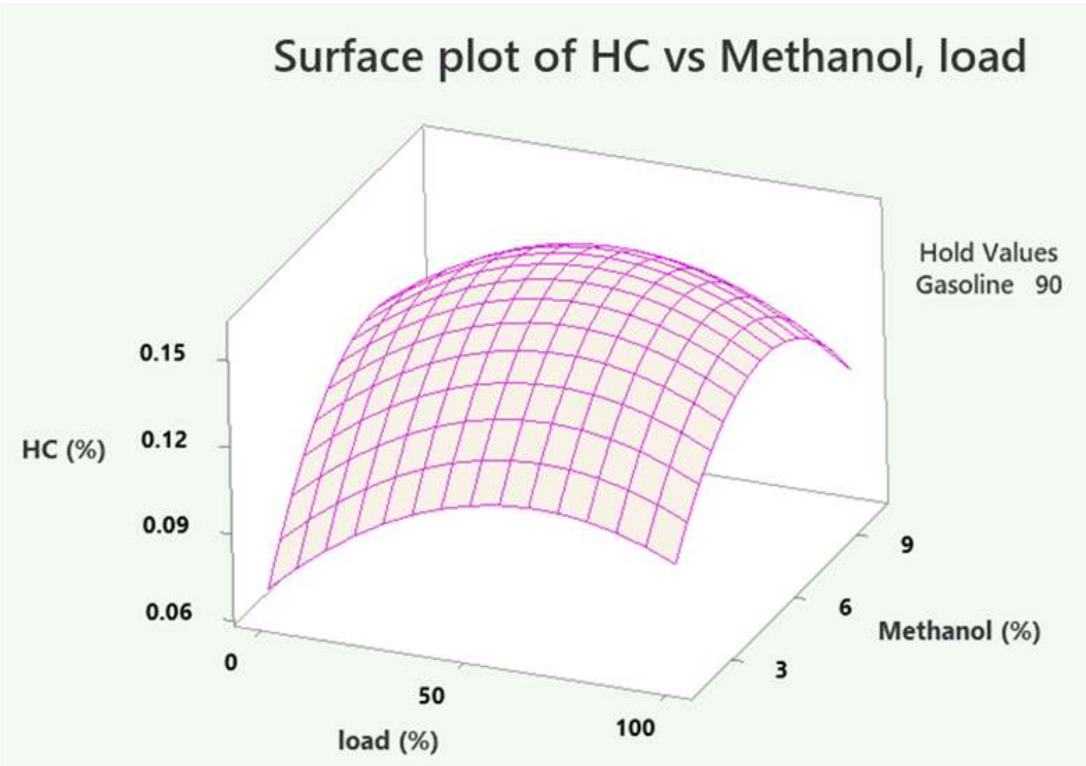

Figure: 4.19 3D surface plot for HC versus Methanol and Load

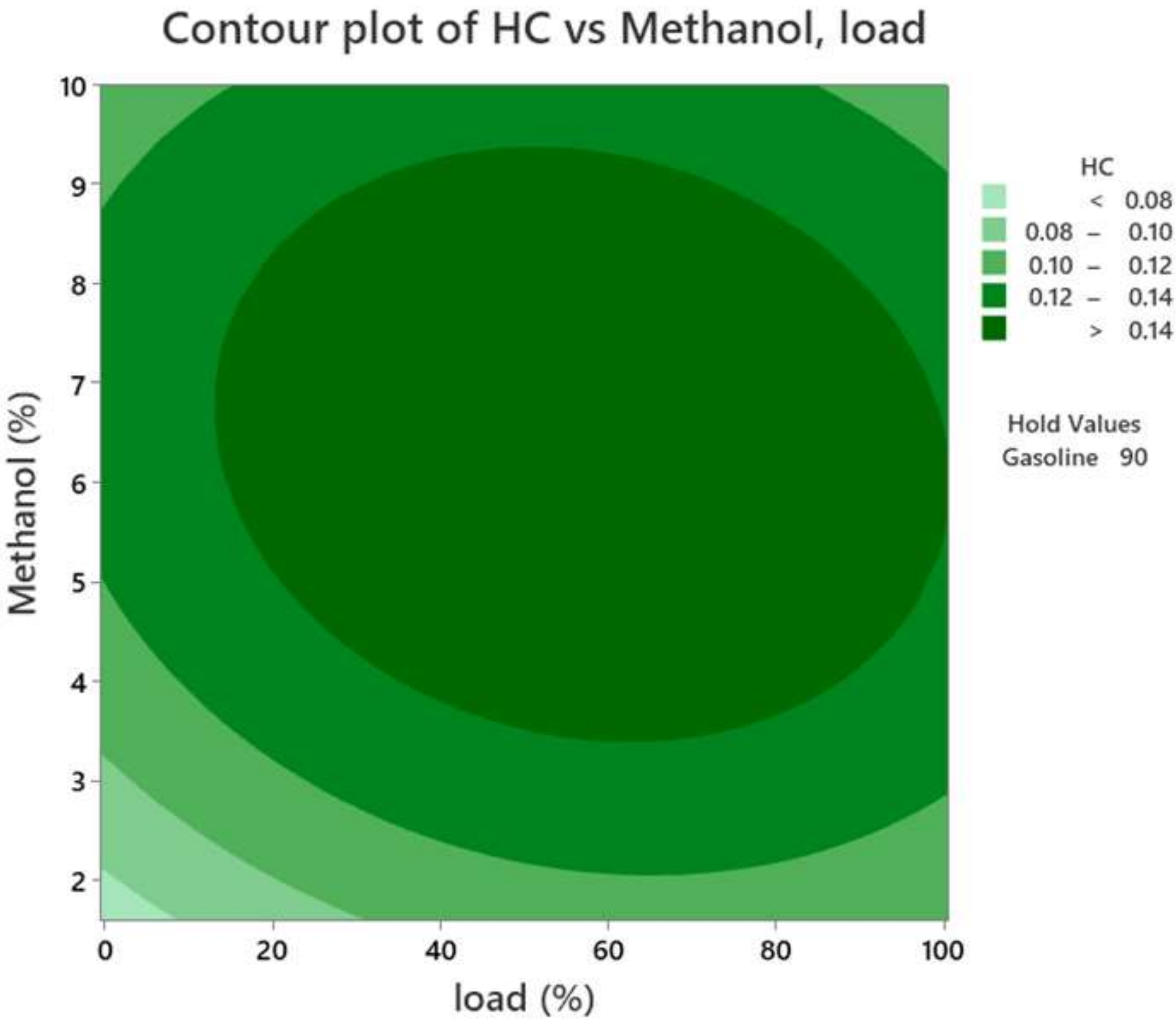

Figure: 4.20 Plots of 3D contour of HC versus Methanol, Load

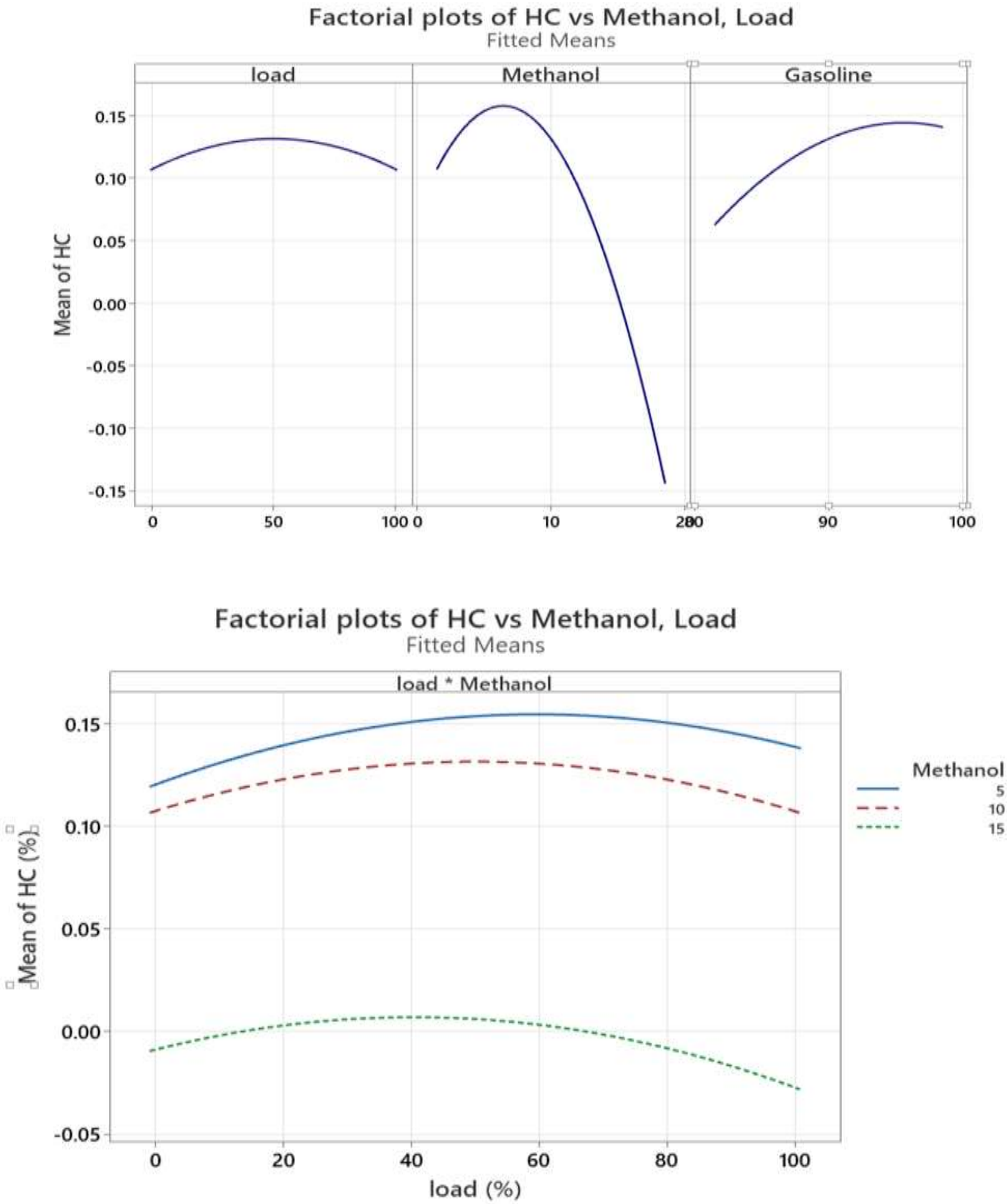

Figure. 4.21 Factorial plots of HC vs Methanol, Load

4.2.6 CO emissions

Similar to the HC emission above, it is observed that the engine produces less CO emissions by applying higher methanol ratio or percentage together with cerium oxide additive compared to the neat gasoline operated engine.

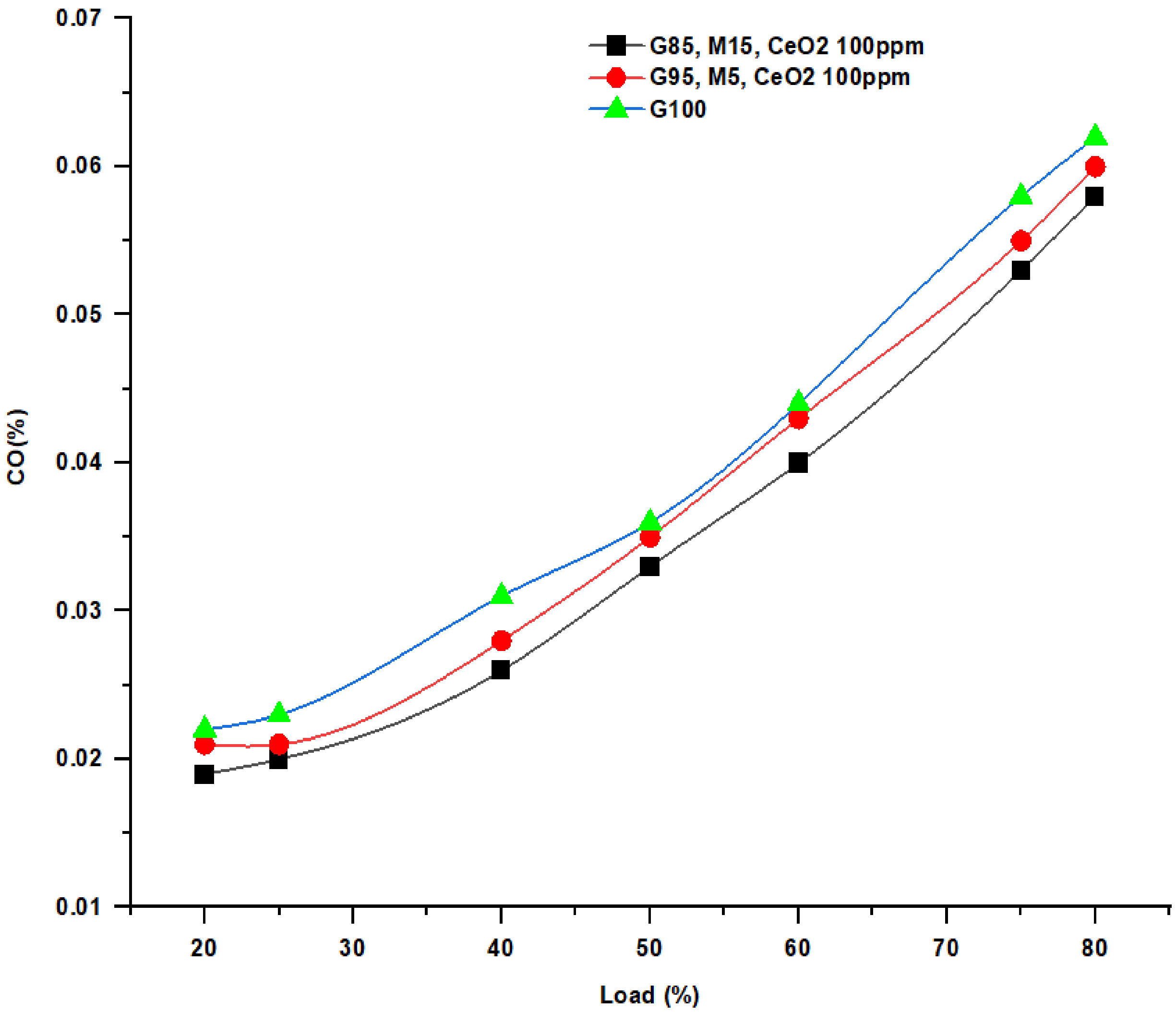

Figure: 4.22 CO vs Load (%)

Studies confirmed that generally methanol addition on gasoline engines makes the to produce more HC emissions than gasoline operated engines since there is more consumption of gasoline almost double as compared to gasoline consumption per cycle. This feature was minimized in this experiment due to CeO2 addition. In this investigation emission amount of CO is appreciably minimized with the blending or mixing of cerium oxide Nanoparticles together with methanol blending which is M5 and M15 particularly the M15 blend.

Optimization results from RSM indicated that better optimized result of CO with 0.0347 % was obtained with load of 100.4538 %, methanol blend percentage of 10 % and a Gasoline mix of 90.1469 % also similarly the value ranges are shown in Figure 4.23 - Figure 4.24.

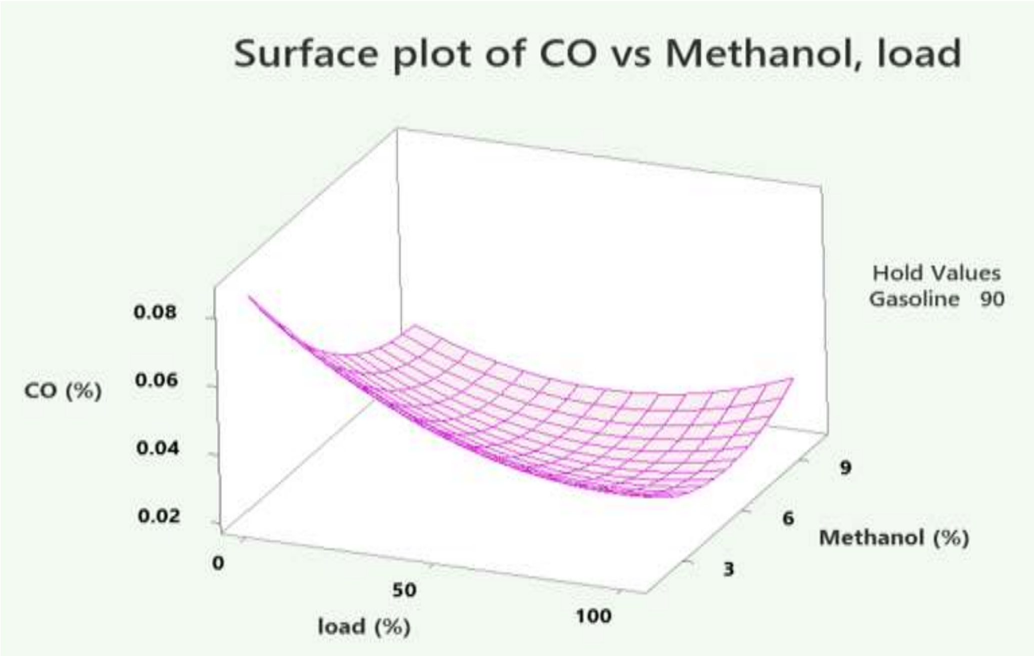

Figure 4.23: 3D surface plot for CO vs Methanol, Load

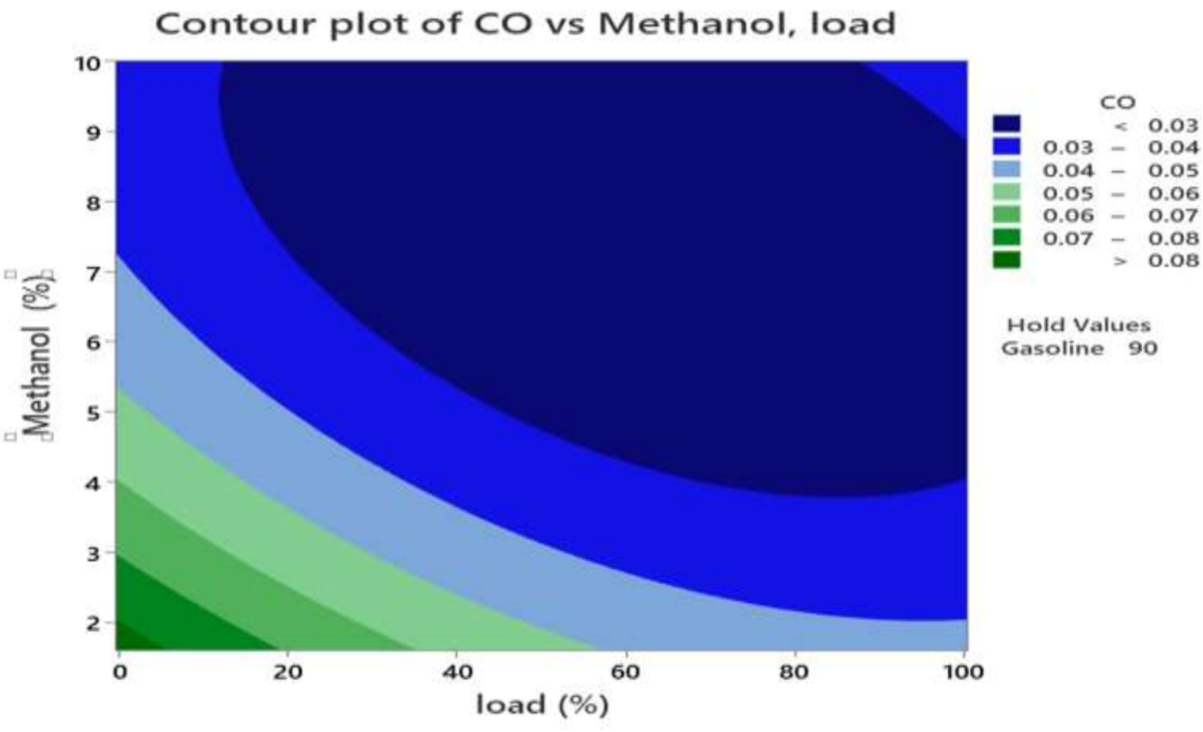

Figure 4.24 Plots of 3D contour for Methanol vs Methanol, Load

4.2.7 Oxides of Nitrogen (NOx) Emission

Impacts from methanol blending together with cerium oxide nano particle is disccused and shown in graphs below

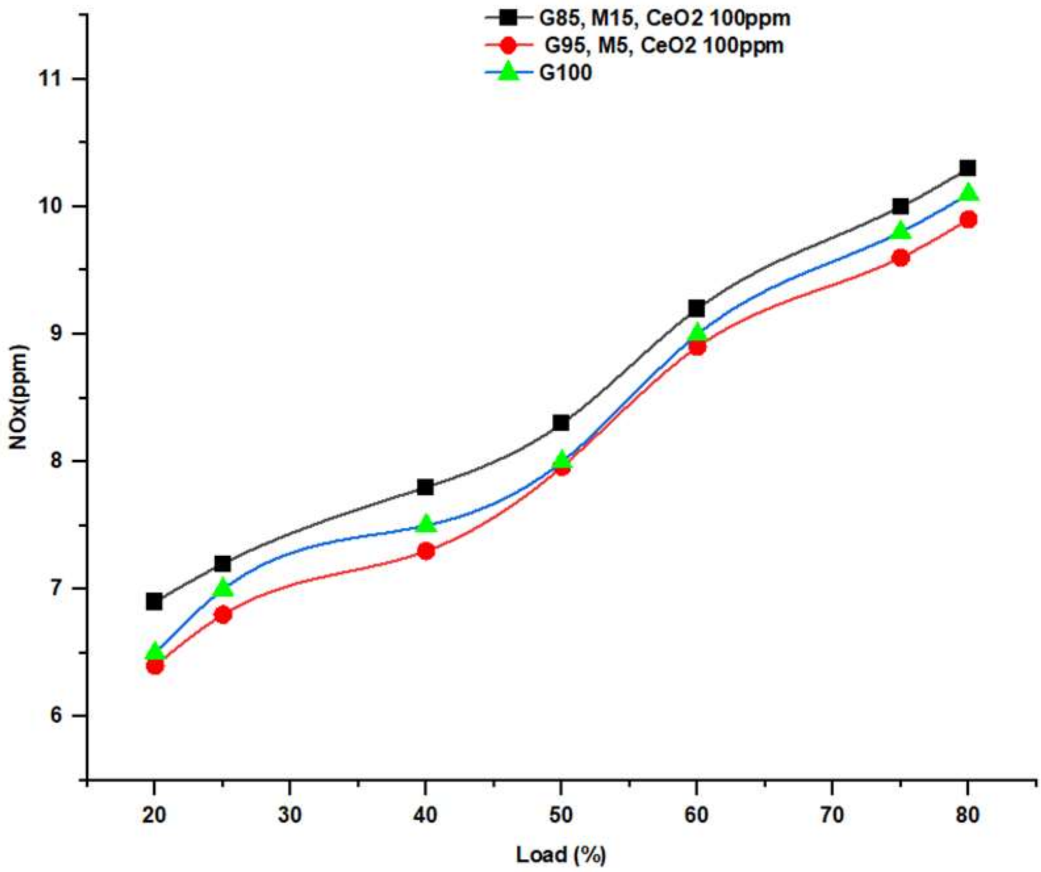

Figure: 4.25 NOx (ppm) vs Load (%)

Optimization results from RSM indicated that better optimized result of 7.9311 ppm was obtained with load of 100.4538 %, methanol blend percentage of 10 % and a Gasoline mix of 90.1469 %. From the study NOx results is noticeably minimized by mixing CeO2 100 nanoparticle together with minimum percentage of methanol blending which is M5 than M15.

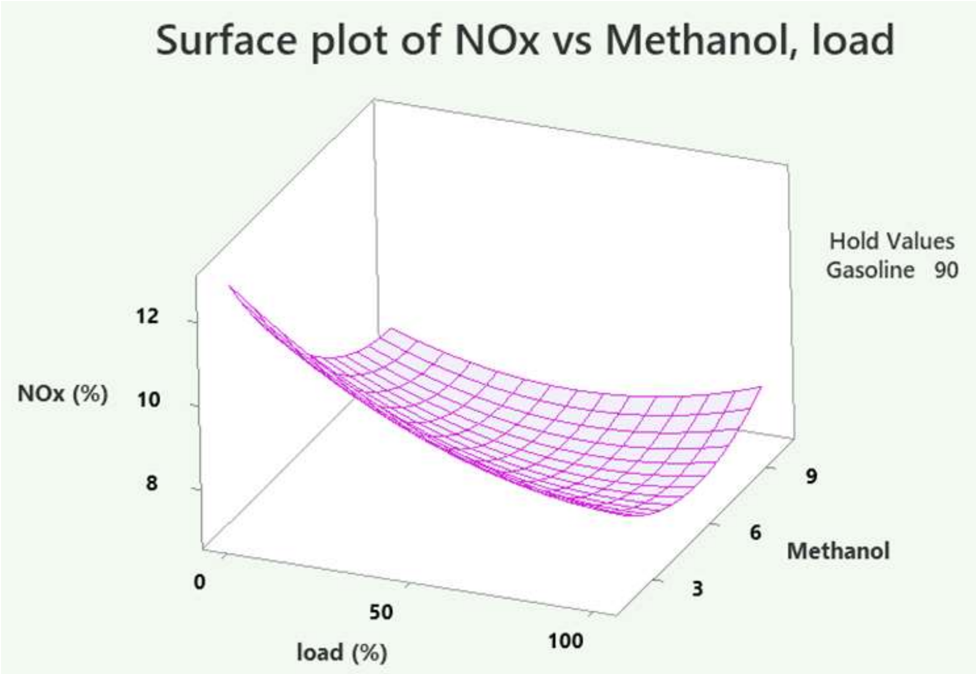

Figure 4.26 3D surface plot for NOx vs Methanol, Load

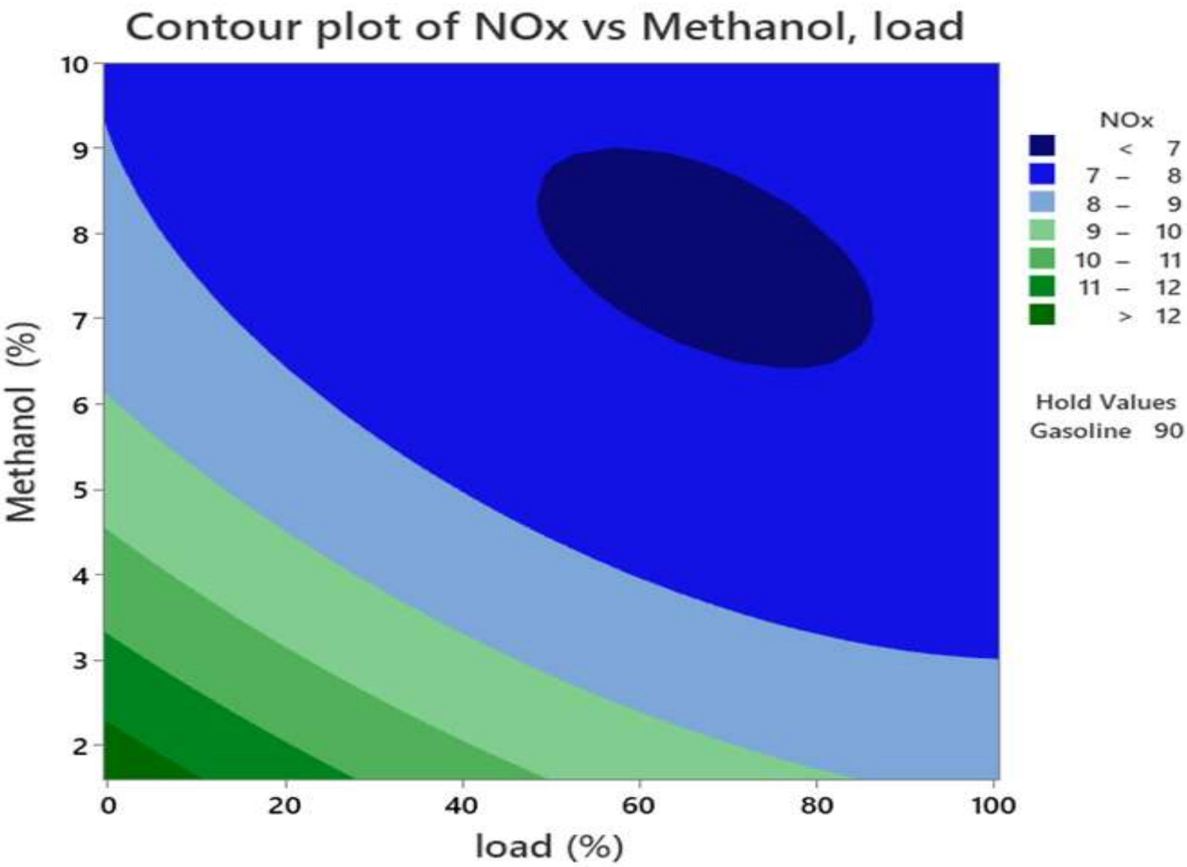

Figure 4.27: Plots of 3D contour for NOx vs Methanol, Load

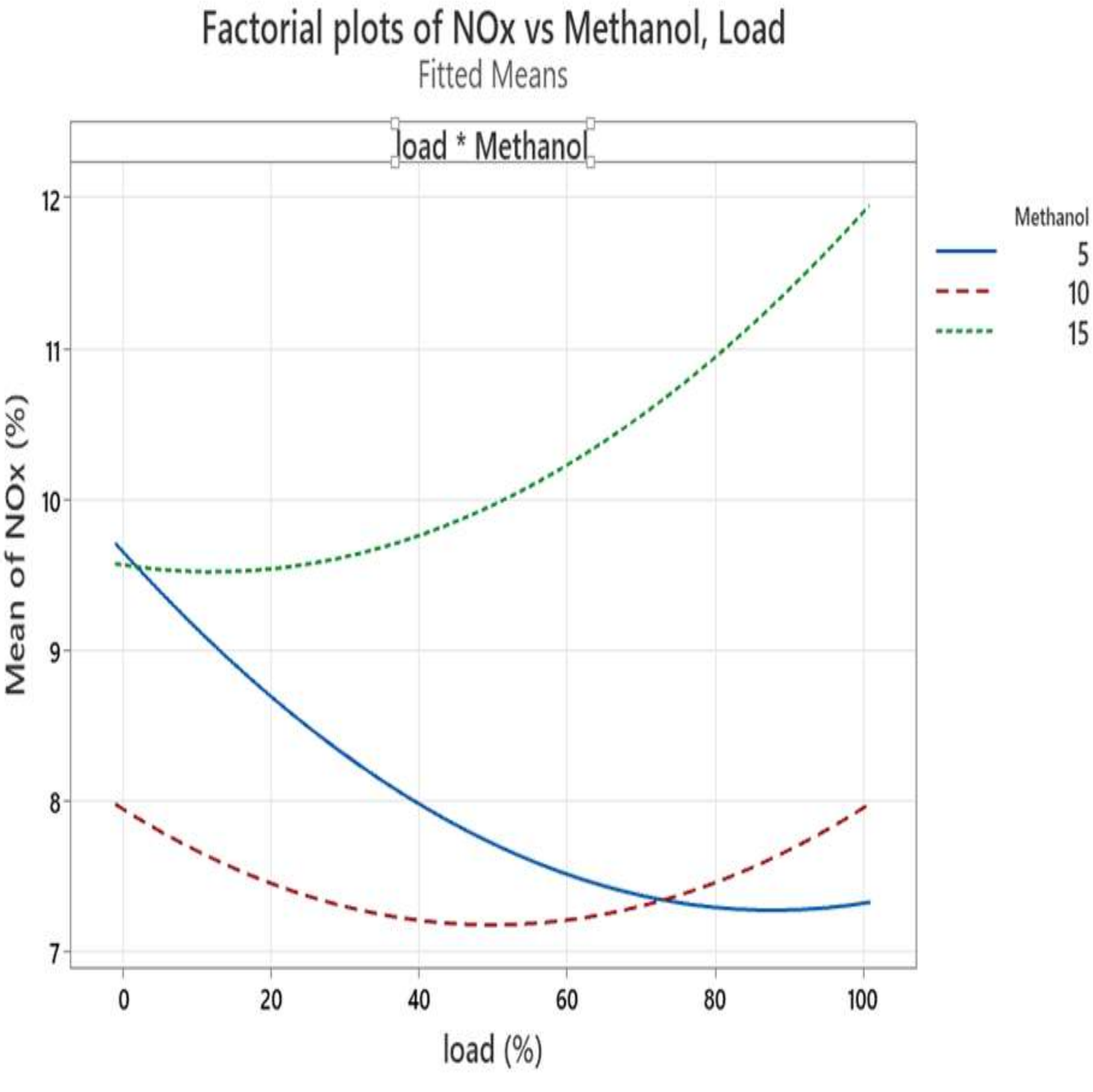

Figure 4.28: Factorial Plots of NOx vs Methanol, Load

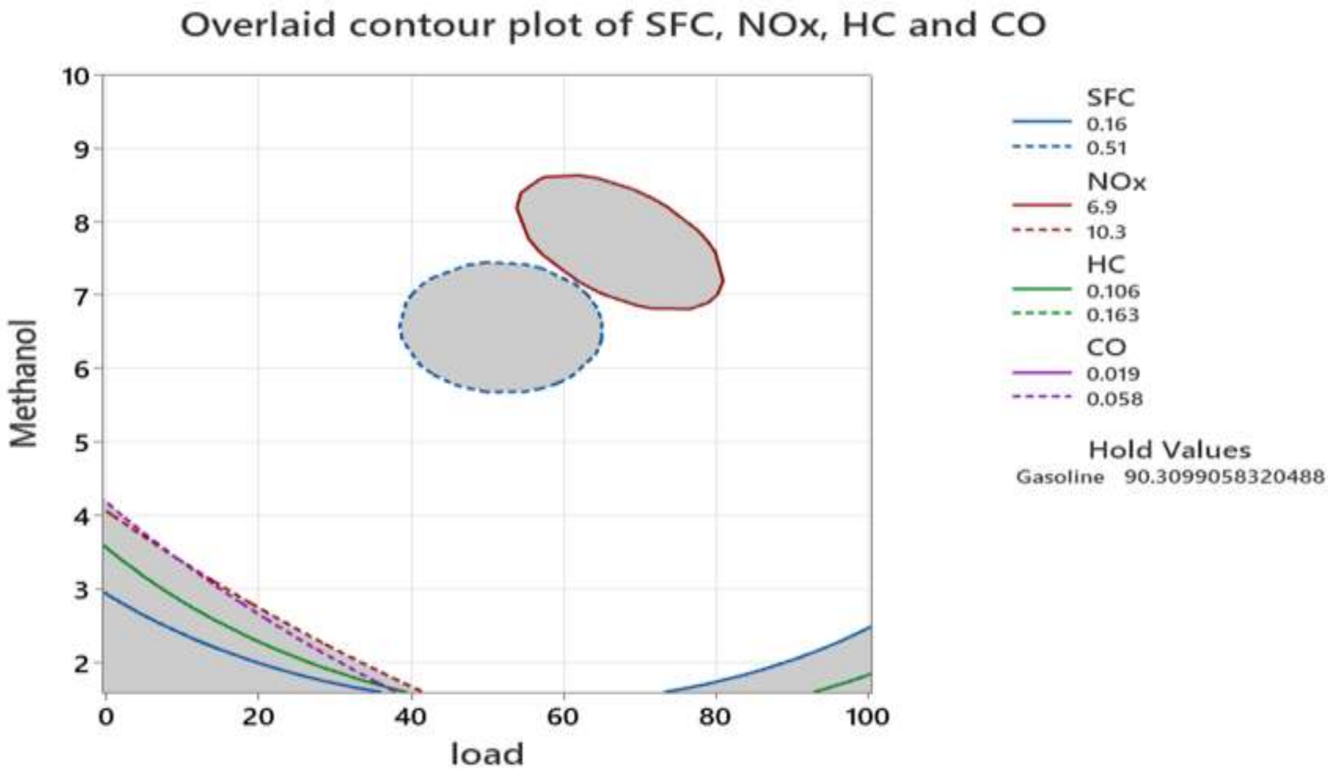

Figure 4.29: Overlaid contour plot of SFC, NOx, HC and CO

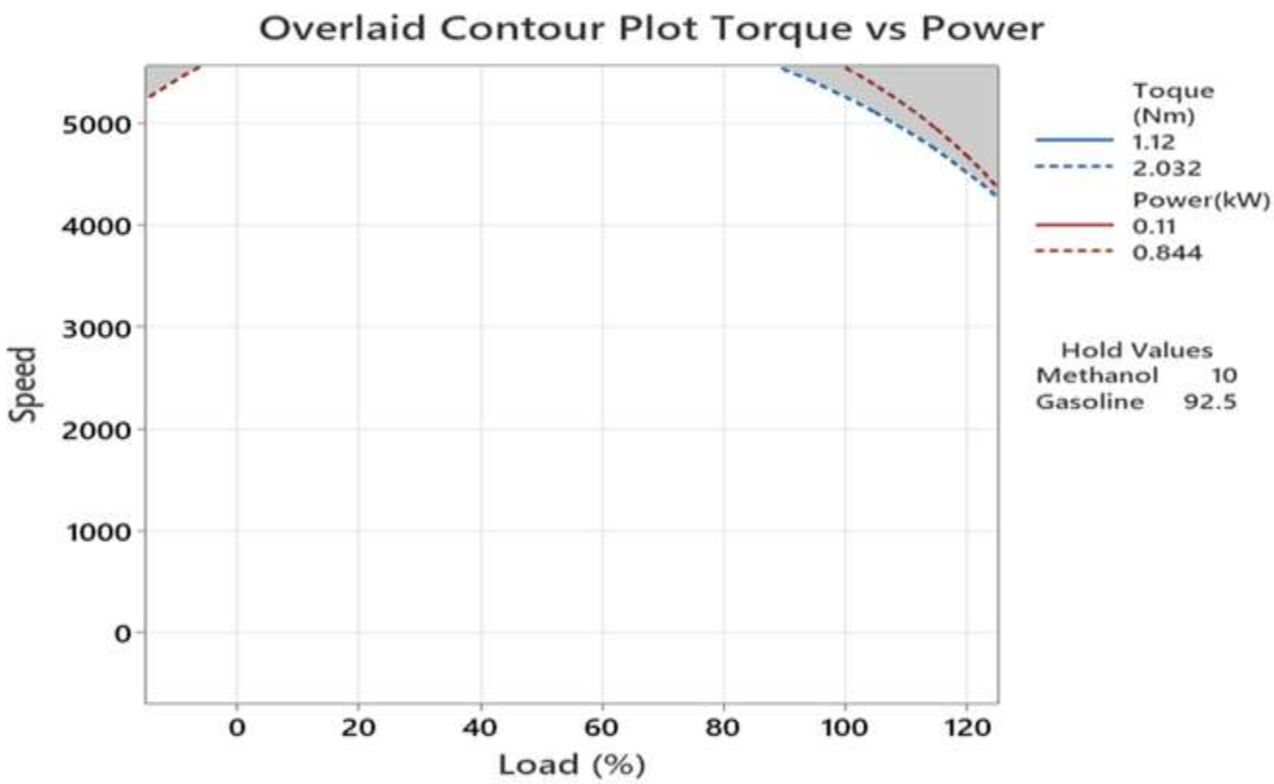

Figure 4.30: Overlaid contour plot for Torque vs Power

The above overlaid contour plots helps to visually identify an area where the predicted means of the responses variables are in the acceptable range. Since multi response variables are challenging than a single response parameter or variable. The plot helps to see the impacts of methanol, and load on the shown emission features including SFC in one graph or plot. From the plot that is generated from the RSM analysis, we can see clearly the promising ranges of methanol and load combinations for lower SFC, NOx, HC and CO in Figure4.29 and also for optimized results of power and torque from speed and load combinations as indicated in Figure 4.28 - 4.30.

4.2.8 Optimization results for SFC, HC, CO and NOx

Figure 4.31 below shows the optimized results of SFC, HC, CO and NOx done through RSM technique by better combination of the control factors Load, Methanol, gasoline and the impacts from the already premixed Cerium Oxide nano addetive which is not shwn here in the RSM applications.

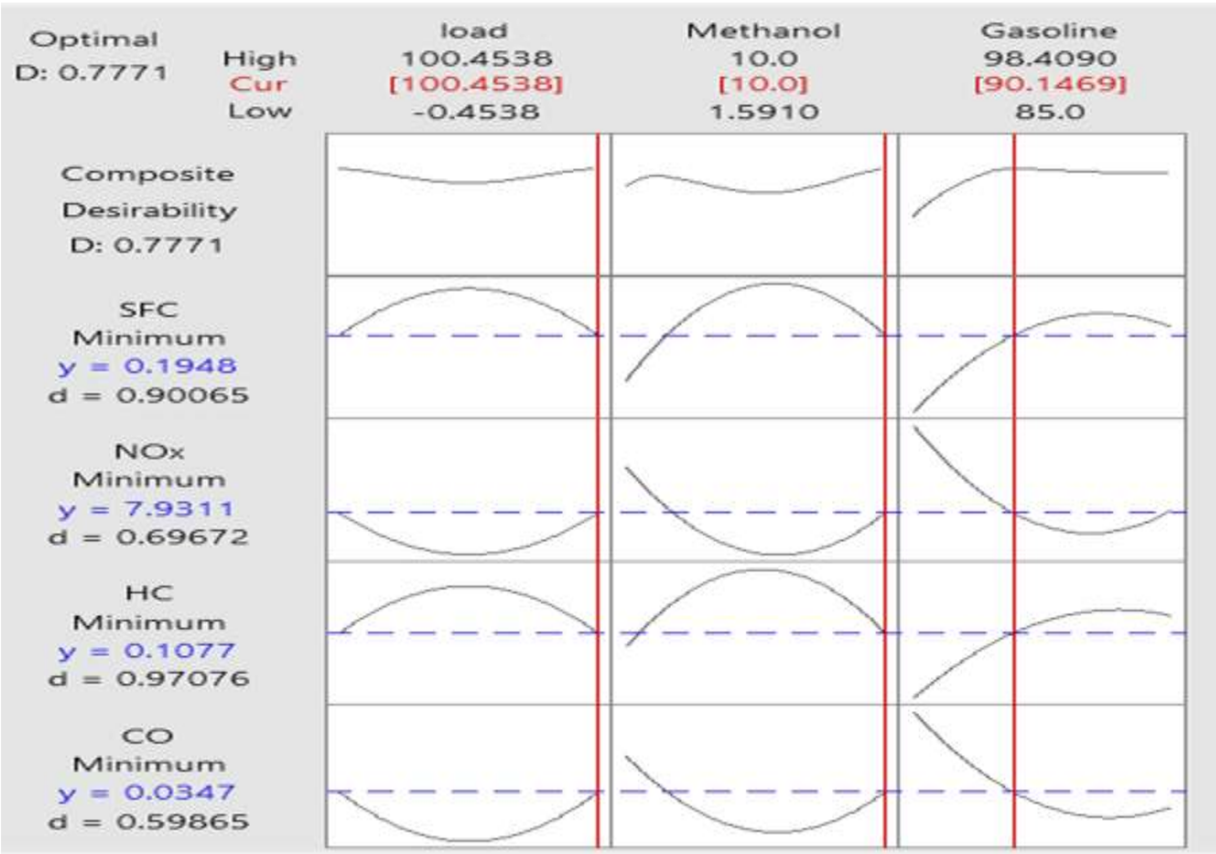

Figure 4.31 Optimized results of SFC, HC, CO and NOx from RSM

Validation Test

In confirming results obtained applying the RSM method of experimental Validation was held applying the important factors set at optimal settings. Obtained optimized results mentioned above were used for the confirmation test under optimum settings. Experimental outputs aligned with the obtained results from RSM optimizations. Validation experimental test value showed optimizing many response challenges, RSM is a suitable optimization means.

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

From the optimized results, it is possible to deduce that methanol blending with gasoline together with the mixing cerium oxide nanoparticle improved the operational characteristics related to performance and nature of exhaust. Methanol with gasoline mixture together with cerium oxide nano particle were investigated in this study. The test compared these sample fuels with the conventional gasoline fuel. results indicated that by applying these fuels the engine performance particularly power and torque are comparable with the conventional gasoline fuel and the BSFC increases when methanol ratio increases in the mixed fuel. The study demonstrates the contribution of CeO2 having the ability to act as oxygen barrier and has an impact on other exhaust gas and operational features including NOx, CO, HC and SFC, power and torque features. In this experiment a substantial effect on the performance and emission characteristics of gasoline engine is also shown by the Methanol blending. The methanol blending has confirmed its contribution in increasing temperature related and increased output of power since its greater octane value and increased vaporization of heat characteristics.

This investigation indicated that better operational circumstances, in relation with optimum results of SFC, NOx, HC and CO is operating the engine at higher loads almost full load condition, greater ratio of gasoline ratios with 90% and methanol blending of 10%. Optimum results of power and torque for better trade-off relationships of performance and emission characteristics is obtained that as the engine is working at load of 20% and at rpm of 3999 and methanol blend ratio 14.9972% which is almost M15.

Optimized results of SFC, HC, CO and NOx done through RSM technique by better combination of the control factors Load, Methanol, gasoline and the impacts from the already premixed Cerium Oxide nano additive.

By increasing the methanol percentage particularly for M75 with together with the presence of cerium oxide (CeO2 100 ppm) nano additives resulted a decrease in specific fuel consumption comparing with the other sample fuels of G100, G95% M5. In this investigation emission amount of CO is appreciably minimized with the blending or mixing of cerium oxide Nanoparticles together with methanol blending which is M5 and M15 particularly the M15 blend.

From this experimental finding the higher methanol ratio or percentage mixing together with cerium oxide additive has shown a promising reduction of HC emission than the pure gasoline fuel. From the experiment, changing the speed from lower to higher, blends of G95%with M5, and G100 resulted better torque output than G85% with M15 and G75% with M25.

In general, this study showed that by using the application of RSM optimization technique and through the purposely chosen input parameters optimized values of power, torque, SFC, HC, CO and NOx were obtained with values of 0.9457 kw, 2.3076 N, 0.1948 %, 0.1077 %, 0.0347 and 7.9311 ppm with load of 100.4538 %, methanol blend percentage of 10 % and a Gasoline mix of 90.1469 %. respectively. Similarly optimized values of Power and Torque were investigated with values of 0.9457 kw and 2.3076 N respectively with a load condition of 20 %, Speed of 3999.101 Rpm, methanol blend percentage of 14.997 % and a Gasoline mix of 89.3939 % for better exhaust and performance conditions for the engine chosen. Additional optimizations and fuel blending techniques could improve the overall operation of the petrol engines in making the engine environmentally safe and efficient.

5.2 Recommendations

- Additional optimization studies should be conducted on various approaches of nano particle mixing on gasoline engines through methanol premixing approaches. In addition to premixing the methanol other alternative way effective mixing technologies of methanol should be studied together with the previous attempts.

- Similar experiments should be conducted considering these promising fuel samples by hybrid this approach with the compression ignition concepts that could enhance the performance and emission behaviours in parallel.

- Many researches confirmed the important features of methanol in improving the performance of IC engines including spark ignition engines but actual implementation on engines for commercialization is very limited and more has to be done for such experimental attempts for its commercialization including the nano additives.

- There is no advanced laboratory setups nationally for conducting engine research that concerned bodies should give due attention for the field considering the current expansion of the automotive manufacturing sector in Ethiopia.
- Research on IC engine should continue till a competent and smart IC engine is produced which should function equally with that of EV vehicles interns of environment and economical aspects.

REFERENCES

Amine M., Barakat Y. (2019). Properties of gasoline-ethanol-methanol ternary fuel blend compared with ethanol-gasoline and methanol gasoline fuel blends. *Egypt. J. Pet. 28, 371–376*. https://doi.org/10.1016/j.ejpe.2019.08.006.

Awad O.I. Mamat, R.Ali, O.M. Sidik, N.A.C. Yusaf, T.Kadirgama, K.Kettner (2018). Alcohol and ether as alternative fuels in spark ignition engine. *Renew. Sustain. Energy Rev.82, 2586–2605*. https://doi.org/10.1016/j.rser.2017.09.074.

Babazadeh Shayan, Seyedpour, S.M.Ommi, F. (2012). Effect of oxygenates blending with gasoline to improve fuel properties. *Chin. J. Mech. Eng. 25, 792–797.*

Balki M.K. Sayin, C (2014). The effect of compression ratio on the performance, emissions and combustion of an SI (spark ignition) engine fuelled with pure ethanol, methanol and unleaded gasoline. *Energy 71, 194–201*. https://doi.org/10.1016/j. energy.2014.04.074.

Danaiah, P. Ravi Kumar, P. Vinay Kumar, D (2014). The effect of ignition timing and methanol gasoline blends on the performance and emissions of the spark ignition engine. *Int. J. Ambient Energy 35, 132–138.* https://doi.org/10.1080/01430750.2013.789983.

Elfasakhany (2016). A Performance and emissions of spark-ignition engine using ethanol–methanol–gasoline, n-butanol–isobutanol–gasoline and iso-butanol–ethanol–gasoline blends: a comparative study. *Eng. Sci. Technol. Int. J. 19, 2053–2059* https://doi.org/10.1016/j.jestch.2016.09.009.

Ghazaly, M. S. (2022). Injection and Combustion of biodiesel at different blends: A review, *SVU-International Journal of Engineering Sciences and Applications, 39-40.*

Gong, C. Li, Z. Chen, Y.Liu, J.Liu, F. Han, Y. Influence of ignition timing on combustion and emissions of a spark ignition methanol engine with added hydrogen under lean-burn conditions. https://doi.org/10.1016/j.fuel.2018.07.097.

Singh, Y., Sharma, A., Singh, G. K., Singla, A., & Singh, N. K. (2018). Optimization of performance and emission parameters of direct injection diesel engine fuelled with pongamia methyl esters-response surface methodology approach. Industrial crops and products, 126, 218-226.

Hamza Afser Delvi, M. F. (2019). Effect of Ethanol-Gasoline Blends on Performance Combustion and Emission Characteristics of Spark Ignition Engine. *Journal of Advanced Re-*

search in Fluid Mechanics and Thermal Sciences.

Henein, N. A. (2006). Effect of injection pressure and swirl motion on diesel engine-out emissions in conventional and advanced combustion regimes. *SAE Paper No. 2006-01-0076*.

Hosseini, S.E. Butler, B. (2020). An overview of development and challenges in hydrogen powered vehicles. *Int. J. Green Energy 17, 13–37* https://doi.org/10.1080/15435075.2019.1685999.

Samie Adel, M. S.; Ameri, E.; Beni, A. A. Production of modified fuels based on Isfahan diesel by adding CeO2 nanoparticles, surfactant and 2-ethylhexyl nitrate. Chem. Eng. Res. Des. 2022, 187, 196−205.

Tang, M.; Liu, S.; Fu, W.; Wang, J.; Yin, K.; Zhu, M.; Tian, J.; Sun, Y.; Dai, Y. Surface Oxygen Vacancies Promoted Pt Nanoparticles on Celery-like CeO2 Nanofibers for Enhanced Sinter-Resistance and Catalytic Performance. Mater. Today Nano 2022, 20, No. 100249.

Jesu Godwin, D.Edwin Geo, V.Thiyagarajan, S. Leenus Jesu Martin, M.Maiyalagan, TSaravanan, C.G. Aloui, F. (2019). Effect of higher and lower order alcohol blending with gasoline on performance, emission and combustion characteristics of SI engine. https://doi.org/10.1016/j.fuel.2019.115806.

Jibai Wang, P. Z. (2020). Performance and Emissions of a Premixed Combustion Engine Fueled by Methanol–Gasoline Blends. *Research Squere*.

Keshavarz, A. Mirvakili, A. Chahibakhsh, S. Shariati, A.Rahimpour, M.R. (2020). Simultaneous methanol production and separation in the methanol synthesis reactor to increase methanol production. *Chem. Eng. Process. Process Intensif. 158, 108176* https://doi.org/10.1016/j.cep.2020.108176.

Shenghua L, Clemente ERC, Tiegang H, Yanjv W. Study of spark ignition engine fueled with methanol/gasoline fuel blends. Applied Thermal Engineering. 2007;27:1904-1910

Bilgin A, Sezer I. Effects of methanol addition to gasoline on the performance and fuel cost of a spark ignition engine. Energy & Fuels. 2008; 22:2782-2788

Carabajal, M., Teglia, C. M., Cerutti, S., Culzoni, M. J., & Goicoechea, H. C. (2020). Applications of liquid-phase microextraction procedures to complex samples assisted by response surface methodology for optimization. Microchemical Journal, 152, 104436.

Li, X.; Ren, S.; Liu, L.; Xing, X.; Chen, L.; Li, J.; Yang, J.; Liu, Q. Superior PbO-Resistance of CeO2/ZrO2 Catalyst Promoted by Solid Superacid SO42−/ZrO2 for Selective Catalytic Reduction of NO with NH3. Fuel 2023, 332, No. 126103.

Li, Y. Gong, J.Deng, Y.Yuan, W. Fu, J.Zhang, B. (2017). Experimental comparative study on combustion, performance and emissions characteristics of methanol, ethanol and butanol in a spark ignition engine. *Appl. Therm. Eng. 115, 53–63* https://doi.org/10.1016/j.applthermaleng.2016.12.037.

Liu, S. Cuty Clemente, E.R. Hu, T. Wei, Y. (2007). Study of spark ignition engine fuelled with methanol/gasoline fuel blends. *Appl.Therm. Eng. 27, 1904–1910.* https://doi.org/10.1016/j.applthermaleng.2006.12.024

Pourkhesalian AM, Shamekhi AH Salimi F. Alternative fuel and gasoline in an SI engine A comparative study of performance and emissions characteristics. Fuel. 2010;89:1056-1063

Varol Y, Oner C, Oztop HF, Altun S. Comparison of methanol, ethanol, or nbutanol blending with unleaded gasoline on exhaust emissions of an SI engine. Energy Source, Part A. 2014;36:938-948

Liu, F.Hua, YWu, HFon Lee, C.Shi, Z. (2017). Experimental and kinetic studies of soot formation in methanol-gasoline cof1ow diffusion fames. *J. Energy Inst.* https://doi.org/10.1016/j.joei.2017.12.002.

Masum, B.M.Kalam, M.A. Masjuki, H.H. Palash, S.M.Fattah, I.M.R. (2014). Performance and emission analysis of a multicylinder gasoline engine operating at different alcohol-gasoline blends. *RSC Adv. 4, 27898–27904.* https://doi.org/10.1039/c4ra04580g.

Methanol Institute, Methanol Production (2020). https://www.methanol.org/methanol-production/. Accessed 10 Dec 2020.

Methanol Institute, Methanol Use in Gasoline—Blending, Storage and Handling of Gasoline Containing Methanol (2016). *Singapore,Washington DC.methanol.org.*

Ming sheng Wen, Z. Y. (2022). Effects of Different Gasoline Additives on Fuel Consumption and Emissions in a Vehicle Equipped with the GDI Engine. *Frontiers in Mechanical Engineering*.

Mishra K., N. S. (2018). Green Nanotechnology for Biofuel Production. *Biofuel and Biorefinery Technologies*.

Muhammad Ali Ijaz Malik, M. U. (2021). Experimental evaluation of methanol gasolinefuel blend on performance, emissions and lubricant oil deterioration in SI engine. *journals. sagepub.com/home/ad Vol. 13(6)*, 1-17.

Mustafa Koc, Y. S. (2009). The effects of ethanol–unleaded gasoline blends on engine performance and exhaust emissions in a spark-ignition engine. *ELSEVIER*.

Pang, X. Zhang, X Wu, S.Ma, M. Xiang, Y.; Ma, J.; Ji, J.;Wang, G.; Liu, H. (2019). Effects of C3–C5 alcohols on solubility of alcohols/diesel blends. *Fuel 236, 65–74* https://doi.org/10.1016/j.fuel.2018.08.129.

Peng, D.-X. (2018). Effects of biofuels (methanol, ethanol, and butanol) on internal combustion engine performance and exhaust emissions. *Chem. Technol. Fuels Oils 54, 29–36.* https://doi.org/10.1007/s10553-018-0894-y.

Pirola, C. Bozzano, G. Manenti, F. (.2017) Fossil or Renewable Sources for Methanol Production?*Elsevier, Amsterdam* https://doi.org/10.1016/B978-0-444-63903-5.00003-0.

Ravi Farkhan Pratama, C. S. n.d. (2021). An experimental investigation of gasoline-methanol (M5-M10) blends on performance in SI engine.

S. Babazadeh Shayan, M. S. (2011). Impact of Methanol–Gasoline Fuel Blends on the Performance and Exhaust Emissions of a SI Engine. *International Journal of Automotive Engineering.*

Shamsul, N.S.; Kamarudin, S.K.; Rahman, N.A.; Kofi, N.T.: An overview on the production of bio-methanol as potential renewable energy. *Renew. Sustain. Energy Rev. 33, 578–588 (2014).* https://doi.org/10.1016/j.rser.2014.02.024.

Sharudin, H.; Abdullah, N.R. Najaf, G.; Mamat, R. Masjuki, H.H. (2017). Investigation of the effects of iso-butanol additives on spark ignition engine fuelled with methanol-gasoline blends. *Appl. Therm. Eng. 114, 593–600.* https://doi.org/10.1016/j.applthermaleng.2016.12.017.

Shirazi, S.A. Abdollahipoor, B. Windom, B.Reardon, K.F.Foust, T.D. (2020). Effects of blending C3–C4 alcohols on motor gasoline properties and performance of spark ignition engines: a review. *Fuel Process. Technol. 197, 106194.* https://doi.org/10.1016/j.fuproc.2019.106194.

Turner, J.W.G.;Pearson, R.J.Dekker, E Iosefa, B. Johansson, K. Bergström, K. (2013). Extending the role of alcohols as transport fuels using iso-stoichiometric ternary blends of gasoline, ethanol and methanol. *Appl. Energy. 102, 72–86.* https://doi.org/10.1016/j.apenergy.2012.07.044.

Yadav, P.Athanassiadis, D.Yacout, D.M.M. Tysklind, M. Upadhyayula, V.K.K. (2020). Environmental impact and environmental cost assessment of methanol production from wood biomass. *Environ. Pollut. 265, 114990.* https://doi.org/10.1016/j. envpol.2020.114990.

Yilmaz, I Taştan, M. (2018). Investigation of hydrogen addition to methanol-gasoline blends in an SI engine. Int. J. Hydrog. Energy1, 10. https://doi.org/10.1016/j.ijhydene.2018.07.088.

Zhang, H.Wang, LPérez-Fortes, M. Van Herle, J.Maréchal, F.Desideri,(2020).U. Techno-economic optimization of biomass to-methanol with solid-oxide electrolyzer. *Appl. Energy 258,114071.* https://doi.org/10.1016/j.apenergy.2019.114071.