

**NON-PREMIXED HIGH-PRESSURE DIRECT INJECTION
OF METHANOL AND PILOT INJECTION OF DIESEL:
DUAL-FUEL ENGINE CONCEPT**

Submitted in partial fulfillment of the requirements for the award of
**Bachelor of Engineering / Technology Degree in
Mechanical Engineering**

BY

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SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **P.L. LEONARD IGNATIUS (38150060)** and **R. NAVEEN (38150069)** who carried out the project entitled **"NON-PREMIXED HIGH-PRESSURE DIRECT INJECTION OF METHANOL AND PILOT INJECTION OF DIESEL: DUAL-FUEL ENGINE CONCEPT"** under our supervision from **November, 2021** to **May, 2022**.

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We **P.L. LEONARD IGNATIUS (38150060)** and **R. NAVEEN (38150069)** hereby declare that the Project Report entitled **NON-PREMIXED HIGH-PRESSURE DIRECT INJECTION OF METHANOL AND PILOT INJECTION OF DIESEL: DUAL-FUEL ENGINE CONCEPT** done by us under the guidance of **Dr. S.P. VENKATESAN, M.E., Ph.D.**, is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in **Mechanical Engineering**.

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ABSTRACT

The current fossil fuel problem, along with an increase in the number of vehicles on the road, has prompted us to consider alternate fuels. The price of fossil fuels is rising every day, and the emissions from these sources are increasing air pollution. The present study investigates the direct injection (DI) of non-premixed methanol with diesel as pilot injection. This experiment is carried out by single-cylinder, four stroke research engine at constant engine speed of 1500 rpm with compression ratio of 17.5. The diesel which is used as pilot injection in this study, we use three Methanol substitution such as M90D10, M80D20, M70D30, where M90D10 means 90% Methanol is used as main fuel and 10% Diesel is used for Pilot injection. Similarly, M80D20 means 80% of Methanol is used as main fuel and 20% Diesel is used for Pilot injection. Same for M70D30 where, 70% of Methanol is used as main fuel and 30% Diesel is used for Pilot injection. Methanol combustion produces low soot and low emissions. This study evaluates the Break thermal efficiency (BTE), Specific fuel consumption (SFC) and Emission characteristics, and the results are compared with regular diesel. The results indicates that the methanol combustion increases Break thermal Efficiency and Specific fuel consumption with decreased NO_x, CO and HC emissions.

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LIST OF ABBREVIATIONS

BSFC	-	Brake Specific Fuel Consumption
BTE	-	Brake Thermal Efficiency
CI	-	Compression Ignition
CO	-	Carbon Monoxide
DI	-	Direct Injection
DLF	-	Diesel Like Fuel
DMFC	-	Direct Methanol Fuel Cells
EGT	-	Exhaust Gas Temperatures
GHG	-	Greenhouse Gas
HC	-	Hydrocarbon
ICE	-	Internal Combustion Engines
MgO	-	Magnesium Oxide
NO _x	-	Nitrogen Oxide
PI	-	Pilot Injection
PM	-	Particulate Matter
SFC	-	Specific Fuel Consumption
SOI	-	Start of Injection
TDC	-	Top Dead Center
UHC	-	Unburned Hydrocarbons
VCR	-	Variable Compression Ratio

CHAPTER 1

INTRODUCTION

Oil products accounted for more than 90% of the transportation sector fuel consumption in 2016, while internal combustion engines were the dominating power source in this sector. Due to their excellent fuel conversion efficiency, power capabilities, and operating range, diesel engines are ideal in the heavy-load agriculture and maritime sectors. Diesel engines, on the other hand, have issues with NO_x, particulate matter, and, to a smaller extent to greenhouse gas (GHG) emissions. Advanced engine technology and alternative fuels are needed to limit the usage of fossil fuels and reduce carbon emissions as concerns about the growth of climate change.

1.1 CI ENGINE

Compression Ignition (CI) or Diesel engines are widely used in transportation, automotive, agricultural, and industrial applications because of their high fuel conversion efficiency and simple operation. Conventional diesel fuel generated from crude oil is used in existing CI engines. It is common knowledge that the world's petroleum sources are finite, and that crude oil production is growing increasingly difficult and costly. Pollutants such as unburned hydrocarbons (UHCs), carbon monoxide (CO), nitrogen oxides (NO_x), and smoke opacity emissions, have been regulated by legislation in several nations.

Many studies on IC engines have recently been carried out with the goal of reducing emissions by modifying engine operating characteristics such as valve timing, injection timing, and atomization ratio. Simultaneously, the depletion of fossil fuels and environmental concerns have prompted research into renewable fuels including methanol, ethanol, hydrogen, and biodiesel [2].

Increased interest in alternate non-petroleum fuels for engines has been triggered by rising petroleum fuel prices, geographically limited availability, and more rigorous government rules on exhaust pollutants. Even in oil-producing Third World countries like India and Nigeria, energy depletion is a barrier to economic development.

This is especially true in rural places. Diesel, which is used to run industrial and agricultural machines, is often low in supply. The use of ethanol as a supplementary fuel in diesel engines will not only cut down the time and money, it also takes to purchase commercial fuels, but it will also help rural industrialization and reduce pollution significantly [2].

Diesel fuel, which has a high cetane number i.e., low octane rating, is commonly used in CI engines. Diesel fuel has the disadvantages of being a fossil fuel and being made up of relatively long hydrocarbon chains, which have a greater tendency to create particulate matter (PM), primarily in the form of soot. Alcohols, for example, can be used as an alternative to diesel. Without injecting a tiny amount of diesel, a compression ignition or diesel engine cannot run totally on producing gas. This is due to the fact that the producing gas cannot ignite on its own under the current pressure. The compression ignition engine, is the most prevalent type of power generator, especially in off-grid conditions. To heat the air in the engine cylinder, the engine utilizes a higher compression ratio than a spark ignition engine. The fuel, usually diesel, which is denser than gasoline, is then introduced and spontaneously ignites.

Researchers are more interested in compression-ignition (CI) engines than spark-ignition engines because they have a higher compression ratio and no throttling loss. The typical CI engine, on the other hand, continues to emit high levels of nitrogen oxides (NO_x) and particulate matter (PM). Furthermore, because of the direct link between carbon dioxide (CO₂) emissions and crude oil usage, increasing fuel economy is always a goal. As a result, for the past two decades, the heavy-duty CI diesel engine has been a study focus [2].

However, fossil fuel reserves are depleting as time passes, causing the price of petroleum oil to rise on a regular basis. All of this puts a strain on the availability of fossil fuels. In these circumstances, demand for alternative fuels as a substitute for conventional fossil fuels in the transportation sector is growing in order to solve energy security concerns. Methanol and ethanol, among the alternative fuels, have gotten a lot of interest as possible diesel fuel substitutes.

Methanol, in particular, is readily available from biomass, coal, and natural gas conversion. Methanol is similar to standard gasoline and diesel fuels in terms of storage, transportation, distribution, and application as a liquid. [5] Transportation of people and products is heavily reliant on fossil fuels, which contributes to global warming and local air quality issues. There are a variety of alternatives to fossil fuels that can reduce pollution emissions while avoiding net carbon emissions. However, many are finding it challenging to compete with fossil fuels because to limited supply, low energy density, or high cost. [4].

1.2 ALTERNATIVE FUELS FOR CI ENGINE

Due to the fast depletion of traditional fuels, global climate change concerns, rising energy consumption, and economic pressure, alternative fuels have become crucial in diesel engines. So, researches about alternative fuels have been carried out.

1.3 BIODIESEL

Biodiesel is a biodegradable, renewable fuel made from vegetable oils, animal fats, or restaurant grease. Biodiesel is not the same as renewable diesel, sometimes known as "green diesel. Biodiesel is a liquid fuel that is sometimes referred to as B100 or "neat" biodiesel. Biodiesel, like petroleum diesel, is used to power compression-ignition engines. By allowing diesel engines to run without modification, biodiesel as a vehicle fuel enhances energy security, the environment, and the economy. Our country has the world's largest per capita usage of fossil fuels. Biodiesel, which is made up of fatty acid alkyl esters, has gotten a lot of attention as an environmentally friendly alternative fuel for diesel engines.

1.3.1 *Waste Lubrication Oil*

Waste lubricant oil is the key alternative fuel sources that have proven to be the greatest replacements for conventional petroleum fuels, as waste produced oils account for more than 60% of all used lubricant oils. As a result, waste oils are one of the most common pollution leftovers produced today, amounting to 24 million metric tonnes per year.

Researchers have become increasingly interested in recycling waste lubricant oils and using the products as fuels in recent years. The majority of lubricating oils are derived from petroleum resources. Currently, petroleum-derived base oils account for over 97 percent of global lubricant production. However, after a certain amount of time, these oils degrade into waste oils that are hazardous to the environment.

Refined and treated waste oils can be utilized to produce fuels or lubricating oil base stock. Waste oils, on the other hand, are hazardous to the environment because of their metal content and other pollutants. Refining and treatment technologies can turn high-volume waste oils into marketable fuel products. It is critical to convert waste oils into diesel and gasoline-like fuels that may be used in engines without being disposed away. It was concluded that by using the pyrolysis technique, waste lubrication oil can be converted into a Diesel Like Fuel (DLF) [8].

1.3.2 *Waste Vegetable Oil*

Biodiesel, a promising alternative fuel that does not produce sulphur oxides and produces fewer soot particles than petroleum diesel, has gained significant attention due to the finite nature of fossil energy resources. It does not produce sulphur oxides and produces fewer soot particles than petroleum diesel. One of the most promising alternatives to conventional fossil fuels is the use of liquid fuels such as biodiesel made from vegetable oil via the trans-esterification process.

In the first step of this experiment, waste soybean vegetable oil was used as a test material, and it was converted into soybean oil ethyl ester, also known as biodiesel, in the presence of a homogeneous acid catalyst, with operating parameters such as reaction temperature, amount of alcohol and catalyst required, stirring rate, and esterification time optimised. The physical parameters of the mentioned biodiesel, such as density, flash point, kinematic viscosity, cloud point, and pour point, were determined in the second stage. For the purpose of gathering the baseline data for analysis, the identical characteristics study was conducted for diesel fuel. The values obtained from biodiesel made from waste vegetable oil are quite similar to those obtained from pure diesel, and it may be utilised in existing diesel engines without any mechanical changes [10].

1.3.3 *Oil Extracted from Algae*

The current technical viability of developing microalgae-derived biofuels as a renewable energy source and mitigating the GHG-related consequences of petroleum-derived fuels Algae's economic viability as a source of biofuels could be enhanced by high yields of both lipids and biomass, as well as some beneficial co-products if purposefully exploited. In terms of net energy balance, Phototrophic production is the most efficient. When compared to heterotrophic production, however, productivity figures differ greatly and are much lower. Overall, the inherent qualities of the chosen algal strain determine the technical viability of a production system, indicating a need for more species screening as well as study on culture conditions and production systems.

Microalgae-based bio-mitigation of CO₂ emissions provide an additional function that can be used to lower the cost of biofuel production. The utilisation of leftover CO₂ from power plants to boost output has been demonstrated to be technically viable, and hence might be used to cut production costs and reduce GHG emissions. The biggest share of energy input during production is spent harvesting algal biomass, yet there are currently no reliable harvesting techniques. Adapting existing technologies from the food, pharmaceuticals, and wastewater treatment industries could provide solutions.

Lipids are the most easily extracted biofuel feedstock from algae, however the presence of polyunsaturated fatty acids (PUFAs), which cause oxidation processes, and the high moisture content of the algal feedstock limit possible storage. Following the extraction of oils from algae, this review concludes that thermochemical liquefaction and pyrolysis appear to be the most technically feasible ways for converting algal biomass to biofuels. For long-term sustainability and environmental benefits, manufacturing steps of microalgae biofuels must be simplified with no need for considerable energy use, particularly drying [7].

1.4 ADDITIVES

Fuel additives are chemicals that are added to gasoline to improve its quality and efficiency. They raise the octane rating of a gasoline or act as corrosion inhibitors or lubricants, allowing higher compression ratios to be used for increased efficiency and power. Rough idling, slow acceleration, stumbling, and stalling can all be avoided with the use of fuel additives.

Fuel additives improve engine performance, allowing for longer travel on additive-infused gas than would otherwise be possible. Another major benefit of fuel additives is engine maintenance. They efficiently prolong the life of the vehicle by preventing the formation of sludge and other deposits in various sections of the engine. Fuel additives are also said to improve the lubrication of moving parts. This gain translates to less wear and tear on the moving parts.

1.4.1 *Metal Additives*

Metal-based fuel additives have proven to be a viable alternative for improving diesel engine performance and emissions. Many research has been conducted on the usage of metal-based fuel additives in diesel engines, such as magnesium, platinum, titanium, and cerium.

Additives will help the gasoline meet its engine's environmental standards for combustion, performance, and emissions. The oxygenated additions in biodiesel will improve the fuel's ignition quality while reducing pollution in the environment.

1.4.1.1 *Cerium oxide*

Metal-based additives, as well as Cerium-based additives in blend fuels, improves overall combustion quality and reduce emissions. Because of the increased combustion induced by the catalytic activity during the combustion process.

Cerium-based additives are advantageous in enhancing braking power and brake thermal efficiency (BTE), as well as lowering brake specific fuel consumption (BSFC) and pollutants.

To promote combustion and reduce fuel consumption and emissions for hydrocarbon fuels, metal-based additives have been used as combustion catalysts. Cerium (Ce), cerium–iron (Ce–Fe), platinum (Pt), platinum–cerium (Pt–Ce), are some of the metal-based additives. The reduction in emission when adding metal-based additives could be due to the metals reacting with water vapour to form hydroxyl radicals or acting as an oxidation catalyst, lowering the oxidation temperature and hence increasing particle burnout.

Cerium oxide functions as an oxygen donor catalyst, supplying oxygen to the combustion process. Because cerium oxide's activation energy serves to burn off carbon deposits within the engine cylinder at wall temperature and prevents the formation of non-polar chemicals on the cylinder wall, HC emissions are reduced.

The research demonstrated that cerium oxide nanoparticles can be added to diesel and diesel-biodiesel blends to considerably improve complete combustion. The use of cerium oxide nanoparticles in diesel-biodiesel blends and neat diesel reduces carbon monoxide emissions. When compared to neat diesel and biodiesel mixes, the addition of cerium oxide reduces HC emissions. The NO emission of neat diesel is lower than that of oxygenated mixes. The amount of smoke produced by fuel blends containing an oxygenated ingredient is reduced. Adding cerium oxide nanoparticles to straight diesel and biodiesel- mixtures reduces smoke even further [5].

1.4.1.2 *Aluminium oxide*

The research for alternative fuels and fuel additives has been motivated by the continued expansion of global energy consumption, harmful engine emissions, and fossil fuel depletion. Nano-fuel additives are one of the several solutions that are thought to be effective in reducing the energy and environmental crises. Nano-oxide additions such as Al_2O_3 , TiO_2 , CeO_2 , Co_3O_4 and Fe_2O_3 are utilised to reduce fuel consumption and emissions.

Nano-metal oxide additions improve the entire combustion process by promoting combustion activation. The amount of study into improving heat transfer in thermal systems is increasing these days. Surface tension and the form of liquid droplets have an impact on this. Nanoparticles such as alumina, TiO_2 , and carbon nanotubes are added to cooling water and lubricant oil in automobiles to increase heat transmission properties. The addition of nanoparticles to base fuel improves the fuel's chemical characteristics.

Nanoparticles offer unique properties such as increased activity, increased surface area, and enhanced combustion. With the accumulated internal energy, aluminium particles provide improved thermal activity. Because of its higher heat of reaction, aluminium particles boost combustion properties. Aluminium nanoparticles increase the rate of combustion of a fuel-air mixture. It also shows that the oxidizer has a higher surface area to volume ratio than the fuel. With the use of alumina nanoparticles, the heat transmission characteristics and droplet ignition of pure diesel were improved. The addition of alumina nanoparticles to gasoline resulted in quicker oxidation, a shorter ignition delay, and complete combustion [6].

1.4.1.3 *Magnesium oxide*

Magnesium Oxide (MgO) is made by combining EDTA as a fuel and magnesium nitrate as a precursor in a combustion technique. For characterisation, the produced MgO nanoparticles were submitted to a variety of analytical methods. The XRD pattern reveals that MgO has a cubic phase of periclase in its crystal structure. Magnesium Oxide is a semiconductor/insulator that crystallises in a cubic structure similar to rock salt.

Using an ultrasonication process, MgO nanoparticles are combined with diesel fuel as a base fuel. The fuel parameters of flash point, fire point, and viscosity were studied using a blended diesel fuel. When compared to the base diesel fuel, the fuel qualities have greatly enhanced.

When MgO nanoparticles are added to fuels like diesel, their viscosity, flash point, and fire point are reduced, allowing the fuel to burn at a lower temperature and flow more smoothly. No evident solid-state interaction between MgO and LSCF was found under the experimental conditions, indicating that the two phases are chemically compatible.

By incorporating MgO nanoparticles into basic fuels, fuels can be made more effective in a variety of applications, including lubrication and combustion [3].

1.4.2 *Alcohol Additives*

Alcohol additives is one of the most important sources of energy, because of its renewable nature and plenty of feedstock on the planet. Even though numerous promising prospects for alcohol fuels shine a light on alternative options for an environmentally conscious society. The future energy path is simple and obvious. It is a low-carbon economy that makes use of renewable energy sources at a reasonable cost. In order to achieve this far-reaching goal, alcohol fuels can serve as connecting threads between the current conventional oil/gas society and the future hydrogen society. Alcohol additives must continue to be an important part of achieving a sustainable low-carbon society.

Alcohols can be created from biomass with a comparatively high energy conversion ratio, and PM generation is reduced to a minimum when combusted. Due to the non-existence of a NOX-soot trade-off, this considerably decreases the limits when seeking to reduce NOX emissions.

As alcohols have a high-octane number, the combustion chamber must have a sufficiently high temperature at the start of injection (SOI). This can be accomplished by either raising the inlet air temperature or increasing the compression ratio (r_c) [4].

1.4.2.1 *Ethanol*

Ethanol is a poisonous, clear, colourless liquid with a distinct odour. Humans are not considered to be harmful to ethanol. Ethanol has a higher-octane number than gasoline, making it a better liquid fuel for blending. Ethanol has less energy per volume than gasoline, while denatured ethanol has about the same amount of energy per volume as gasoline. Because ethanol includes oxygen, using it as a gasoline addition reduces carbon monoxide emissions by up to 50% compared to regular gasoline. Ethanol is soluble in both polar and nonpolar solvents, has a significantly greater vapour pressure than gasoline, and has a 35 percent oxygen content. Ethanol is a good solvent by itself, and it can be mixed with water in endless amounts.

Ethanol–diesel blend qualities have a big impact on safety, engine performance and durability, and emissions. A set of criteria for ethanol–diesel mixes that determine important fuel properties. In partnership with the gasoline industry, additives should be developed. Before these blends can be commercialised, they must work with additive makers and engine manufacturers. When employing ethanol–diesel blends, expect an increase in fuel consumption roughly equal to the drop in energy content of the fuel. Operators have observed no apparent differences in performance while using ethanol levels of 10% or less compared to diesel fuel.

The addition of ethanol to diesel fuel is expected to have a major impact on PM emissions at the very least. The amount of improvement varies from engine to engine, as well as within the engine's operating range. While the ability to utilise the gasoline in an unaltered engine has a lot of value, modest changes to the fuel injection parameters could result in even more reductions in emissions.

The increased urgency to address the remaining challenges to the commercial adoption of ethanol–diesel blends as a commercial fuel should be fuelled by increasingly strict emissions rules and government proclamations to encourage biofuel usage [1].

1.4.2.2 *Butanol*

Butanol has a higher energy density than gasoline and can be distributed using existing network. The use of ethanol as an octane booster in gasoline has a variety of drawbacks, including metal component corrosion and vapour lock. Such problems can be solved by changing the engine and fuel system, but adding alcohols with a high carbon number, such as bio-butanol, allows them to be used in current systems without requiring any changes. Alcohols with a high carbon content, such as butanol, can be made from syngas via a catalytic procedure including modified Fischer-Tropsch or methanol catalysts.

Butanol is being considered as an alternative gasoline blend/replacement. It has a number of advantages to ethanol, which is more commonly utilised.

It does not absorb moisture from the air and, in all concentrations, creates a miscible and stable blend with gasoline. It is less corrosive, has more energy, is more viscous, and less volatile, and can be made from a variety of renewable and environmentally acceptable feedstocks. Microalgae has shown to have a lot of promise and can be a good source of butanol, according to recent studies. The goal is to manufacture fuels from low-cost, sustainable feedstocks using efficient conversion technology and genetically modified organisms. The chemical process for producing n-butanol from ethanol is relatively easy and cost-effective. Butanol has the potential to be a viable substitute to gasoline, and it would be good in reducing hazardous emissions from automobiles.

Butanol has the potential to improve diesel engine performance while also lowering emissions. Because it may be fermented from non-edible biomass feedstock and does not require a recovery process to achieve a pure chemical, BA could be a feasible alternative additive for diesel fuel. An increase in the n-butanol fraction can result in a more significant reduction in soot.

It can be discovered that by adding n-butanol to the injection strategy, it is possible to simplify the injection strategy. Although both post injection and n-butanol have the ability to minimise CO emissions [9].

1.4.2.3 *Pentanol*

Pentanol is the most important higher alcohols that fall within the second/third generation biofuels group, which are capable of tackling major challenges such as environmental degradation and energy insecurity. Pentanol usage in CI engines decreases reliance on food crops while boosting the renewable fuel component. Furthermore, according to the available literature, Pentanol is the best biodiesel/diesel blend for use in non-modified CI engines. It is vital to increase the percentage of biofuels used in CI engines in order to promote non-dependence on fossil fuels, sustainability, and environmentally friendly nature.

Pentanol, a higher alcohol, has shown promise as an alternative fuel in compression ignition engines, where it is employed as a fuel addition in diesel and/or biodiesel.

The addition of pentanol to diesel had a significant impact on the reduction of NO_x emissions. However, pentanol with waste oil methyl ester had an opposite effect on NO_x emissions. This is mainly because of the increasing oxygen content inside the cylinder which leads to high temperature regions to form NO_x. Various blends of diesel-pentanol and biodiesel-pentanol fuels in different engines over extended periods of time would be helpful for expanding alternative fuel use in engines and reducing emissions.

Pentanol has a lower viscosity and density, which improves the spray properties of the blends. Higher BTE of the engine against diesel operation is due to a higher percentage of premixed heat release rates and enhanced spray properties of the alcohol/ diesel blends. The oxygenated nature of pentanol and biodiesel enhances the local equivalency ratio of alcohol/diesel (or biodiesel/diesel) blends, resulting in better combustion characteristics and lower soot emissions. Pentanol can be blended up to 20% with biodiesel to completely replace diesel in CI engines with minimal engine modifications.

When compared to biodiesel and diesel operations, these blends had higher BTE and BSFC, as well as lower EC and PM emissions. In comparison to neat gasoline, the emission measurements for gasoline and other test fuel samples revealed that adding higher-order alcohol to the gasoline reduced the majority of the exhaust emissions. It should be highlighted that the existence of inherent oxygen molecules in the n-pentanol chemical structure allowed for lower emission ratios than gasoline [14].

1.5 METHANOL

Methanol is a clear liquid chemical that is water soluble and readily biodegradable. Methanol is comprised of four parts hydrogen, one-part oxygen and one-part carbon, and is the simplest member of a group of organic chemicals called alcohols. Today, methanol is predominantly produced on an industrial scale using natural gas as the principal feedstock [11].

One of these options is methanol (CH_3OH), which was validated in big fleet trials in the 1980s and 1990s and is now being reintroduced in a range of places and uses.

It can be made from fossil fuels, biomass, and renewable energy sources in carbon capture and utilisation schemes. It can be used in either pure form or as a blend component in internal combustion engines (ICEs) or direct methanol fuel cells (DMFCs). These qualities, combined with the fact that it is a liquid fuel, make it one of the most tempting scalable solutions for storing and delivering energy [12].

One of the key reasons for looking at methanol as a transportation fuel is its scalability. Because of its simplicity of synthesis and wide range of source feedstocks, it is a promising contender for a sustainable fuel that has the ability to drastically reduce transportation's fossil carbon footprint. The greater braking thermal efficiency it creates in combustion systems, together with the increased efficiency with which it can be manufactured in comparison to ethanol or synthetic hydrocarbons, means that it has a double, compounded effect on boosting primary energy usage [13].

Methanol is used to make a range of chemical derivatives, which are then used to make tens of thousands of products that we use every day, including construction materials, foams, resins, plastics, paints, polyester, and a variety of health and pharmaceutical products.

Methanol is also a biodegradable and clean-burning fuel. Methanol is becoming a more appealing alternative fuel for powering automobiles and ships, cooking food, and heating industry due to its environmental and economic benefits. Methanol is one of the most versatile chemical commodities and energy sources accessible today, as it can be manufactured from a variety of feedstocks. [15].

Methanol (CH_3OH) is a completely unadulterated chemical. Diesel fuel, on the other hand, is a complicated blend of several different hydrocarbons (such as C_3 – C_{25} hydrocarbons). As a result, depending on the quantity of hydrocarbon types employed in the fuel mixture, its fuel characteristics can fluctuate. Methanol is classified as a partially oxidised hydrocarbon since it contains one oxygen atom. The energy content of methanol is lower than that of diesel fuel. As a result, more gasoline is required to provide the same level of power as a diesel-fuelled engine. Its high stoichiometric fuel/air ratio, high oxygen content, and high H/C ratio will help to improve combustion and reduce soot and smoke production [17].

Methanol has a larger latent heat of vaporisation than diesel fuel, so when it vaporises, it removes more heat. As a result, the cylinder charge may experience a cooling impact. Nitrogen oxide emissions can be reduced as a result of the cooling effect. Methanol is easily injected, atomized, and mixed with the air delivered into the cylinder since it has a low viscosity compared to diesel fuel. Because of its low cetane number, high latent heat of vaporisation, and high ignition temperature, methanol has a poor ignition behaviour. As a result, the ignition delay may increase. Methanol's autoignition temperature is higher than that of diesel fuel, making it safer to transport and store. [16].

Methanol has two essential characteristics: first, it can burn exceedingly cleanly; as noted later, it has been employed as a fuel for air quality concerns.

It can't easily create the carbonaceous particulate matter found in long-chain hydrocarbons because it only has one carbon atom (a characteristic it shares with methane). Second, the simplest carbonaceous molecule that is liquid at STP is methanol. This makes it simple to store and transfer with minimum fuel infrastructure and vehicle losses.

Methanol is liquid at STP, because of the hydrogen bonding phenomenon caused by its OH characteristic group [16]. Methanol possesses a number of physical characteristics that make it an excellent transportation fuel.

Methanol helps refiners to expand gasoline supply to a larger number of vehicles while also upgrading normal gasoline to higher premium grades by improving octane. Methanol contains oxygen for cleaner fuel combustion, a lower boiling temperature for greater fuel vaporisation, and a higher blending octane for smoother burning with less knock, all of which benefit automakers. Methanol has a number of other characteristics that make it a great spark-ignition fuel [12].

CHAPTER 2

LITERATURE SURVEY

The effect of Methanol on engine performance and combustion parameters has been the subject of significant research. The current research examines the impact of Methanol in diesel engines. A thorough literature review was carried based on this work.

2.1 LITERATURE REVIEW RELATED TO BIODIESEL

K.A. Abed et al. (2018) said that, Transesterification was used to make biodiesel from residual cooking oil. B10, B20, and B30 blends of waste cooking oil biodiesel and diesel oil were made in volume percentages of 10, 20, and 30%, respectively. ASTM criteria for physical and chemical characterization of biodiesel blends are similar to those for diesel fuel. Experiments were conducted on diesel engine performance and exhaust pollutants when a waste cooking-oil blend was burned with diesel fuel. This experiment was carried out on a diesel engine at various engine loads ranging from zero to full.

Waste cooking-oil biodiesel blends have poorer thermal efficiency than diesel oil. Biodiesel mixes had higher specific fuel consumption than diesel fuel. When comparing biodiesel blends to diesel oil, higher exhaust gas temperatures were observed. CO₂ emissions were higher for waste cooking-oil biodiesel blends than for diesel oil. Biodiesel blends had lower CO, smoke opacity, and HC emissions than diesel fuel. Biodiesel mixes have higher NO_x emissions than diesel fuel.

Venkata Ramesh Mamilla et al. (2015), The goal of this work is to make diesel-like fuel (DLF) from waste lubrication oil and compare its performance and emission characteristics to petroleum diesel. The tests were conducted on a four-stroke, single-cylinder, direct-injection, air-cooled diesel engine with a power output of 3.7kW. Using the results, the fuel attributes of diesel like fuel from 20 to 100 percent by volume are investigated.

Engine tests were conducted with the goal of obtaining comparative measures of brake power, specific fuel consumption, and emissions such as CO₂, CO, HC, and NO_x in order to analyse and compute the diesel engine's behaviour. When compared to petroleum diesel, the 20 percent blend (DLF) has a little drop in thermal efficiency but a large improvement in carbon monoxide and hydrocarbon reduction. The results of the experiment suggest that using 20% of the mix improves performance while reducing emissions.

Mohankumar Subramaniam et al. (2020), Diesel Powered engines are commonly found in vehicles and power generators. Due to the fast depletion of fossil fuels such as diesel, alternative fuels for transportation and power generation are required. Third-generation fuels, such as algae, appear to be a promising alternative for meeting our future energy needs. Algae is employed as an alternative fuel in these studies, with various blend combinations with diesel, and the findings are summarised. Algae fuel, referred to as A10, A20, A30, A40, and A100, is a volume-based blend of algae and diesel that can be used in diesel engines. The fuels' characteristics were discovered using American Society for Testing and Materials standards. A single cylinder direct injection diesel engine was used to conduct the tests.

A20 showed the closer estimation with diesel resulted in improved thermal efficiency, reduced HC, CO, Smoke, and particle matter emissions among the various blends evaluated. Other emissions, such as nitrous oxide and carbon dioxide, were found to be slightly higher. In terms of cylinder pressure and heat release rate curves, when compared to diesel, the peak value obtained is significantly lower at greater load conditions.

2.2 LITERATURE REVIEW RELATED TO METAL ADDITIVES

S.P. Venkatesan et al. (2013), The test fuels were synthesized using a mechanical agitator and an ultrasonicator to distribute aqueous cerium oxide at a rate of 50cc per litre into diesel and diesel–biodiesel. Because of their huge contact surface area per unit volume, cerium oxide nanoparticles present in aqueous cerium oxide have increased catalytic activity and can react with water at high temperatures to create hydrogen and improve fuel combustion.

Cerium oxide nanoparticles also operate as oxygen buffers, causing simultaneous oxidation and reduction of hydrocarbons (HCs) and nitrogen oxides. The neat diesel and test fuels were tested in an engine without changing the engine system at 0 percent, 25 percent, 50 percent, 75 percent, and 100 percent load conditions, and the incorporation of aqueous cerium oxide in the test fuels resulted in a significant increase in brake thermal efficiency, improved brake-specific fuel consumption, and decreased concentrations of HC, NO_x, and smoke in the exhaust emitted from the diesel engine.

S. Ganesan et al. (2021), Magnesium oxide can be utilised to oxygenate diesel – watermelon seed oil biodiesel blends and boost the cetane number value for better combustion, according to collaborative research on the diesel – watermelon seed oil biodiesel and additives. The emission and performance characteristics can be improved by employing B20 blends. The results of the experiments demonstrate that a biodiesel blend including water melon seed oil is a good alternative fuel with good performance and emission characteristics. The sample S2 (20 percent biodiesel, 100 ppm magnesium oxide (MgO) additive, and 80 percent diesel) performs well in this analysis when compared to other blends. As a result of this research, a new environmentally friendly biodiesel replacement has been developed.

S.P. Venkatesan et al. (2015), The combustion, performance, and emissions characteristics of a diesel engine using nano-aluminium oxide (n-Al₂O₃) mixed diesel were investigated in an experimental study. For the formulation of alternative fuels, 40 nm n-Al₂O₃ was mixed into diesel fuel at a rate of 1g/l and 1.5g/l. An ultrasonic vibrator was used to disperse the n-Al₂O₃ in order to achieve homogeneous dispersion of n-Al₂O₃ in the diesel fuel. Nano-Al₂O₃ has improved combustion properties and a higher surface-area-to-volume ratio, allowing more diesel to react with the oxidizer and so improving the test fuels' burning efficiency. Because of nano Al₂O₃'s better combustion characteristics and improved degree of mixing with air, the diesel fuel with and without n-Al₂O₃ additive was tested in a direct injection diesel engine at different load conditions, and the results revealed a significant increase in brake thermal efficiency and a substantial reduction in NO_x and unburnt hydrocarbon (UBHC) content at all loads compared to neat diesel.

2.3 LITERATURE REVIEW RELATED TO ALCOHOL ADDITIVES

H J Kurji et al. (2021), The knocking phenomenon, noises created in the combustion chamber during the combustion procedure as a result of the pre-ignition process, is a severe difficulty in the gasoline engine operation process under heavy-duty situations. These arise as a result of the air's high temperature, which permits fuel to ignite without the need for additional activation energy (spark). The resistance of gasoline fuel to autoignition is measured by its octane number. The impact of adding pure ethanol to conventional gasoline fuel at percentages ranging from 10% to 90% in 10% increments by volume was investigated in this study, with various fuel properties such as density, octane number, viscosity, fuel vapour pressure, and flash point temperature measured and compared. Fuel additives including ethanol were discovered to boost fuel density, flash point temperature, viscosity, and octane number while lowering fuel vapour pressure. The trials used a single-cylinder gasoline engine that was naturally aspirated and air-cooled.

The testing results for specific fuel usage indicated reductions of up to 29% at a 90 percent volumetric percentage of ethanol in conventional gasoline fuel, while engine NO_x, CO, and HC emissions dropped by 67.7%, 69 percent, and 61 percent, respectively. CO₂ emissions, on the other hand, increased.

Mingfa Yao et al. (2010), The purpose of this experiment was to see how the amount of n-butanol in diesel fuel affected the performance and emissions of a heavy-duty direct-injection diesel engine with multi-injection capabilities. Exhaust gas recirculation rates were adjusted to keep NO_x emissions at 2.0 g/kW h at constant engine speed and load. Diesel fuels with various levels of n-butanol (0 percent, 5 percent, 10 percent, and 15 percent by volume) were employed. The results demonstrate that adding n-butanol improves soot and CO emissions while maintaining constant specific NO_x emissions without having a substantial influence on break specific fuel usage and NO_x. When employing blended fuels, the effects of pilot and post injection on engine parameters are comparable to those found when using pure diesel.

Although early pilot injection minimises soot emissions, it causes a significant increase in CO. Soot and CO emissions are effectively reduced after injection. The increase in fuel n-butanol content leads to a reduction in soot in each injection technique. The study found that a triple-injection technique with the highest n-butanol fraction produces the least soot.

Nadir Yilmaz et al. (2017), Biodiesel cannot be used directly in diesel engines, because of some of its fuel qualities that have little effect on engine operation, but it can be combined with diesel fuel or alcohols. It's critical to look at biodiesel-rich fuels that could be used as alternatives to diesel and B20. 1-Pentanol, a higher alcohol, has shown potential as an alternate fuel for compression ignition engines using diesel and/or biodiesel. The goal of this study is to see how using 1-pentanol in waste oil methyl ester (B) and diesel fuel (D) affects the exhaust emissions and performance of a diesel engine running at different loads (0, 3, 6, and 9 kW) while keeping the engine speed constant (1800 rpm).

D90P10, D80P20, B90P10, and B80P20 were created by adding 1-pentanol (10% and 20% by volume) to diesel fuel and waste oil methyl ester to form the following fuel blends: D90P10, D80P20, B90P10, and B80P20. The basic qualities of fuel were investigated and found to be within acceptable limits. The addition of 1-pentanol to diesel and biodiesel enhanced brake specific fuel consumption (BSFC) and exhaust gas temperatures (EGT), according to engine test data. The brake thermal efficiency (BTE) of the diesel fuel blends D90P10 and D80P20 was found to be lower during testing. Biodiesel blends B90P10 and B80P20, on the other hand, showed an increase in BTE. D90P10 and D80P20 diesel blends increased carbon monoxide (CO) and unburned hydrocarbon (HC) emissions while lowering nitrogen oxides production (NO_x). B80P20 reduced CO, HC, and NO_x emissions at 0 and 3-kW loads while increased emissions at 6 and 9-kW loads when compared to other biodiesel mixes.

2.4 LITERATURE REVIEW RELATED TO METHANOL

Cenk Sayin et al. (2009), Concerns about the environment and the finite supply of petroleum fuels have sparked interest in developing alternative fuels for internal combustion (IC) engines. Alcohols are gaining popularity in diesel engines since they are oxygenated and renewable fuels. As a result, the influence of injection timing on the exhaust emissions of a single cylinder, naturally aspirated, four-stroke, direct injection diesel engine was explored experimentally utilising methanol-blended diesel fuel from 0% to 15% with a 5% increment in this study. The experimental test results revealed that as the amount of methanol in the fuel mixture grew, BSFC, NO_x, and CO₂ emissions increased while BTE, smoke opacity, CO, and UHC emissions dropped. NO_x and CO₂ emissions dropped, however smoke opacity, UHC, and CO emissions rose with the delayed injection timing when compared to the original injection schedule (15 CA BTDC). At all test conditions, however, with the advanced injection timing (25 CA BTDC), decreasing smoke opacity, UHC and CO emissions decreased, and NO_x and CO₂ emissions increased. Retarded and advanced injection timings exhibited negative results for all fuel mixes in all engine loads in terms of BSFC and BTE.

Mu-Rong Chao et al. (2001), The impact of MCA on regulated and uncontrolled emissions from a heavy-duty engine was explored in this study. THC and CO emissions increased with the addition of MCA in both steady-state and transient cycle tests as compared to regular diesel fuel. The trend in NO_x emissions, on the other hand, was the contrary. These are mostly due to MCA blends' lower energy densities, which resulted in incomplete combustion. Because MCA has a higher oxygen content, lower sulphur and aromatic content, density, and 90 percent distillation temperature than pure diesel fuel, adding less than 10% in heavy load testing would result in a significant reduction in PM emissions. However, the benefits of these fuel qualities in terms of PM emissions are minor. In the low load and transient cycle tests, the heating value content of MCA blends had a greater impact on PM emissions, which rose as the amount of additional MCA increased.

In the case of unregulated emissions, the MCA did not show any substantial CO reduction benefits, but it did show a reduction in 2 PAH emissions. The vapor-phase PAHs make up the majority of the total PAHs quantified in both steady-state and transient cycle experiments. When either 5% or 8 % MCA was employed in high load and transient cycle testing, both vapor-phase and particle-associated PAHs emissions were quite low, likely because to the reduced PAHs concentration in MCA blends. Furthermore, in this investigation, particle-associated PAHs emissions were found to have a high association with PM emissions. In conclusion, adding a moderate amount of MCA to a diesel engine might help to lower air pollutants such as NO_x PM, and PAHs.

M. Abu-Zaid et al. (2004), This study is an experiment to see how adding methanol to gasoline affects the performance of spark ignition engines. Various mixtures of methanol gasoline fuel were used in the performance testing, which were conducted at wide open throttle and varying speeds between 1000 and 2500 rpm. Methanol was discovered to have a considerable impact on the performance of a gasoline engine.

When a 15% volume methanol and 85% gasoline blend is employed, the engine performs best (within the range investigated) in terms of greatest power output and minimum braking specific fuel consumption. Because methanol raises the octane number of gasoline, engines that run on a methanol-gasoline blend can run at greater compression ratios. Methanol has a substantial impact on gasoline engine performance. A 15% volume methanol 85% volume gasoline blend provides the highest engine performance, most power output, and lowest brake specific fuel consumption. Operating the engine at low and moderate speeds produces the best results in terms of brake specific fuel consumption. The octane number of gasoline is increased when methanol is added. As a result, the gasoline engine can run at higher compression ratios.

CHAPTER 3

AIM AND SCOPE OF PRESENT INVESTIGATION

3.1 AIM

The experiment's objective is to produce methanol as an alternative fuel for internal combustion engines in order to meet energy demand and also reducing hazardous gas emissions. Increase the energy systems function better in terms of Environmental performance and also to decrease the dependence on Gasoline fuels.

3.2 SCOPE OF THE STUDY

The current investigation shows promising results, with a methanol substitution ratio of more than 70%, reduced HC emissions, and steady combustion. Low load sites could be improved in terms of efficiency and emissions if the current investigation is continued. Future testing to improve these areas could be linked to the main fuel's injection pressure as well as the temperature of the intake air.

CHAPTER 4

EXPERIMENTAL AND METHODS

4.1 METHANOL



Fig. 4.1: Methanol

Methanol, or CH_3OH , is a simple oxygenated hydrocarbon that is among the world's top five most commonly traded chemicals. It is traditionally used to make adhesives, paints, LCD screens, silicones, pharmaceuticals, and is also widely utilized in the wood and automobile industries. It has been widely employed for energy purposes in recent years, with around 20 million tonnes of methanol generated annually as a fuel or fuel blend component, a figure that is growing every year. So, Methanol would be a perfect alternative for Diesel.

4.2 PROPERTIES OF METHANOL WITH NEAT DIESEL

4.2.1 Viscosity

Hydrodynamic flow of lubricating oil is called viscosity. The viscosity should remain constant at the temperatures. Viscosity Index is an indication of the change of viscosity of oil with temperature. A high viscosity index means less change of oil with temperature rise.

4.2.2 Flash Point

The temperature at which oil ignites is known as the flash point. The oil's flash point should be high enough to prevent oil vapours from flashing; otherwise, the oil will fire at any time.

4.2.3 Fire Point

When a mixture of vapour and air is ignited by a specific flame, the fire point is the temperature to which the product must be heated under the required parameters of the procedure to burn continually.

4.2.4 Calorific Value

The amount of energy produced by the complete combustion of a fuel. In other words, the total amount of heat liberated when a unit mass of fuel is burnt completely. Measured in units of energy per amount of material, e.g., kJ/kg.

4.2.5 Density

Density of fuel is the mass of fuel per unit volume. Density can also be stated as the ratio of its mass to its volume. The density is determined by the quality of the crude used to produce the fuel and the refining process.

Table 4.1: Properties of Diesel and Methanol

PROPERTY	DIESEL	METHANOL
Flash Point (°C)	50	53
Fire Point (°C)	65	60
Viscosity at 40 °C (cSt)	2.426	0.18
Calorific Value (kJ/kg)	42700	7906.18
Density (g/cc)	0.824	0.676

4.3 ENGINE

A single-cylinder, 4-stroke, Variable compression ratio diesel engine with a maximum brake power of 3.5 kW at 1500 rpm was used to collect the required experimental Analysis. The engine's compression ratio is 17.5 (Figure 4.2). The engine has 661.45 cubic centimeters (cc) swept capacity, an 87.50 mm bore diameter, and a stroke length of 110.00 mm.

The setup consists of single cylinder, four stroke, VCR (Variable Compression Ratio) Electric start Diesel engine connected to eddy current type dynamometer for loading. The compression ratio can be changed without stopping the engine and without altering the combustion chamber geometry by specially designed tilting cylinder block arrangement. Setup is provided with necessary instruments for combustion pressure and crank-angle measurements. These signals are interfaced to computer through engine indicator for PPV diagrams. Provision is also made for interfacing airflow, fuel flow, temperatures and load measurement. The setup has stand-alone panel box consisting of air box, two fuel tanks for blend test, manometer, fuel measuring unit, transmitters for air and fuel flow measurements, process indicator and engine indicator.

Rotameters are provided for cooling water and calorimeter water flow measurement. The setup enables study of VCR engine performance with EGR for brake power, indicated power, frictional power, BMEP, IMEP, brake thermal efficiency, indicated thermal efficiency, Mechanical efficiency, volumetric efficiency, specific fuel consumption, A/F ratio and heat balance. Labview based Engine Performance Analysis software package "Enginesoft" is provided for on line performance evaluation. A computerized Diesel injection pressure measurement is optionally provided.



Fig. 4.2: Test Engine

4.3.1 Engine Specifications

4.3.1.1 Engine details

IC Engine set up under test is Research Diesel having power 3.50 kW at 1500 rpm which is 1 Cylinder, four stroke, Constant Speed, Water Cooled, Diesel Engine, with Cylinder Bore 87.50(mm), Stroke Length 110.00(mm), Connecting Rod length 234.00(mm), Compression Ratio 17.50, Swept volume 661.45 (cc).

4.3.1.2 Combustion parameters

Specific Gas Const (kJ/kgK): 1.00, Air Density (kg/m³): 1.17, Adiabatic Index: 1.41, Polytrophic Index: 1.36, Number of Cycles: 10, Cylinder Pressure Reference: 6, Smoothing 2, TDC Reference: -11.

4.3.1.3 Performance parameters

Orifice Diameter (mm): 20.00, Orifice Coeff. Of Discharge: 0.60, Dynamometer Arm Length (mm): 185, Fuel Pipe dia (mm): 12.40, Ambient Temp. (Deg C): 27, Pulses Per revolution: 360, Fuel Type: Diesel, Fuel Density (Kg/m³): 830, Calorific Value of Fuel (kJ/kg): 42000.

4.3.1.4 Engine software

EngineSoft is Labview based software package developed by Apex Innovations Pvt. Ltd. for engine performance monitoring system. EngineSoft can serve most of the engine testing application needs including monitoring, reporting, data entry, data logging. The software evaluates power, efficiencies, fuel consumption and heat release. It is configurable as per engine set up. Various graphs are obtained at different operating condition. While on line testing of the engine in RUN mode necessary signals are scanned, stored and presented in graph. Stored data file is accessed to view the data graphical and tabular formats. The results and graphs can be printed. The data in excel format can be used for further analysis.

4.4 AVL SMOKE METER

The AVL Smoke Meter is a filter-type smoke metre that can be used to determine the optical properties of diesel exhaust. These instruments were created to measure visible black smoke emissions using physical processes such as light beam extinction by scattering and absorption.



Fig. 4.3: AVL Smoke Meter

4.5 EXPERIMENTAL PROCEDURE

Examine the engine's specifications before running it at a constant speed 1500 rpm with neat diesel and determining the total fuel consumption, specific fuel consumption and exhaust gas temperature.

With this information, we determined the engine's performance and combustion characteristics.

This experiment used a four-stroke, single-cylinder, constant-speed, direct-injection water-cooled diesel engine with a rated braking power output of 4.4 kW at 1500 rpm. The engine is connected to an eddy current dynamometer. The load applied to the engine is calculated using the load cell in the dynamometer. The flow rate of gasoline to the engine is measured using a burette with an infrared optical sensor. During the suction stroke, an air sensor detects the flow rate of air to the engine. The cylinder combustion status is received by the combustion analyser through a rotary encoder and a pressure transducer. It is transformed and transmitted to the computer in a methodical manner from the combustion analyser. The cylinder combustion pressure and heat release curves are plotted and displayed on the computer.

The injection pressure of Methanol is 240 bar and the injection pressure of Diesel is 180 bar. The AVL smoke metre and gas analyser are used to measure the engine's exhaust emissions. All engine load testing were conducted at a constant compression ratio of 17.5 and observed measurements were taken while the engine was in a steady state of operation.

Performance, emission and combustion test was conducted on the computerised single cylinder diesel engine coupled with eddy current dynamometer. At five intervals, the load is increased by 25% (0, 25 percent, 50 percent, 75 percent, 100 percent). At the start of the experiment, there is no evidence of lubricating oil or fuel leakage. The fuel usage was calculated by allowing the fuel to sit in the engine for 30 seconds. After finishing the engine run with diesel, the fuel was drained completely from the fuel line and the fuel tank, and 90%, 80%, 70% methanol was added to the fuel tank.

The engine was then run with increasing loads in 5-minute intervals, and readings were taken. The exhaust gases are routed through a pipe to the Gas Analyzer, where varying percentages of exhaust gases are calculated. We use three Methanol substitution such as M90D10, M80D20, M70D30, where M90D10 means 90% Methanol is used as main fuel and 10% Diesel is used for Pilot injection. Similarly, M80D20 means 80% of Methanol is used as main fuel and 20% Diesel is used for Pilot injection. Same for M70D30 where, 70% of Methanol is used as main fuel and 30% Diesel is used for Pilot injection.

Performance graphs like Brake thermal efficiency Vs Load, Specific fuel consumption Vs Load; and emission graph between exhaust gases like CO, HC, NOX are plotted for the different blends and are compared with each other.

CHAPTER 5

RESULTS AND DISCUSSION

5.1 ENGINE PERFORMANCE RESULTS

5.1.1 *BTE vs Load*

Figure 5.1, shows comparison between BTE and Load of various Methanol substitution with Diesel as pilot injection. The substituted compositions were M90D10, M80D20, M70D30 at 0% to 100% loads running at 1500 rpm. Finally, the observed performance value of Methanol substituted was related to pure Diesel. Among the results, the M70D30 gives better performance than other Methanol substitutions and Diesel. The reason for better performance is the oxygen in methanol improves the spray characteristics and makes the fuel combustion more efficient and thus improving the BTE of the engine.

M70D30 (33.78%) and Diesel (32.59%) are the BTE values at 100% load condition. BTE for M70D30 generates more than Diesel by 1.19%.

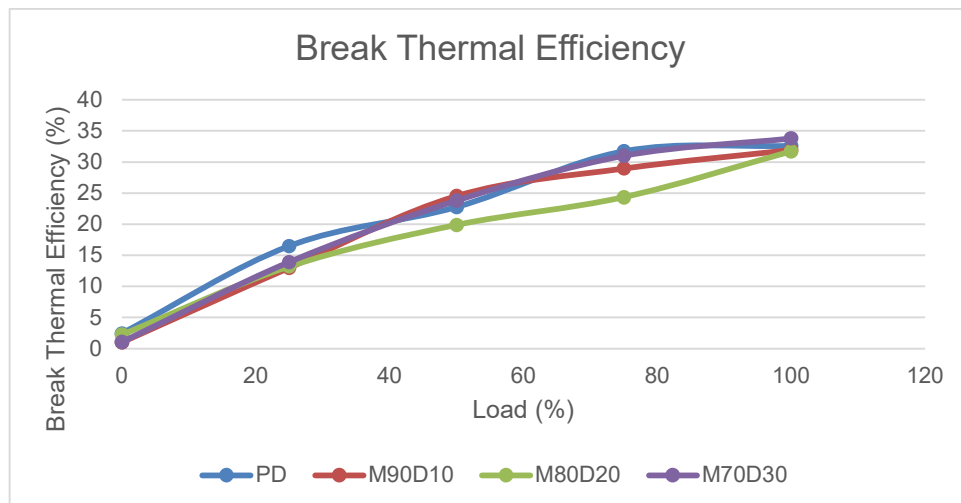


Fig. 5.1: BTE vs Load

5.1.2 SFC vs Load

Figure 5.2, shows the comparisons SFC vs Load of various methanol substitution and Pure Diesel. This has been analyzed with various load at constant engine speed of 1500 rpm.

The values of Methanol substitution (M90D10, M80D20, M70D30) are observed with Pure Diesel. M70D30 consumes high SFC than other Methanol substitution. The reason for high SFC is due to Methanol fuel viscosity and its lower calorific value.

Maximum Fuel consumption at 100% load of Methanol substitution was found out in M70D30 (0.31 kg/kWh), whereas, in Pure Diesel (0.20 kg/kWh).

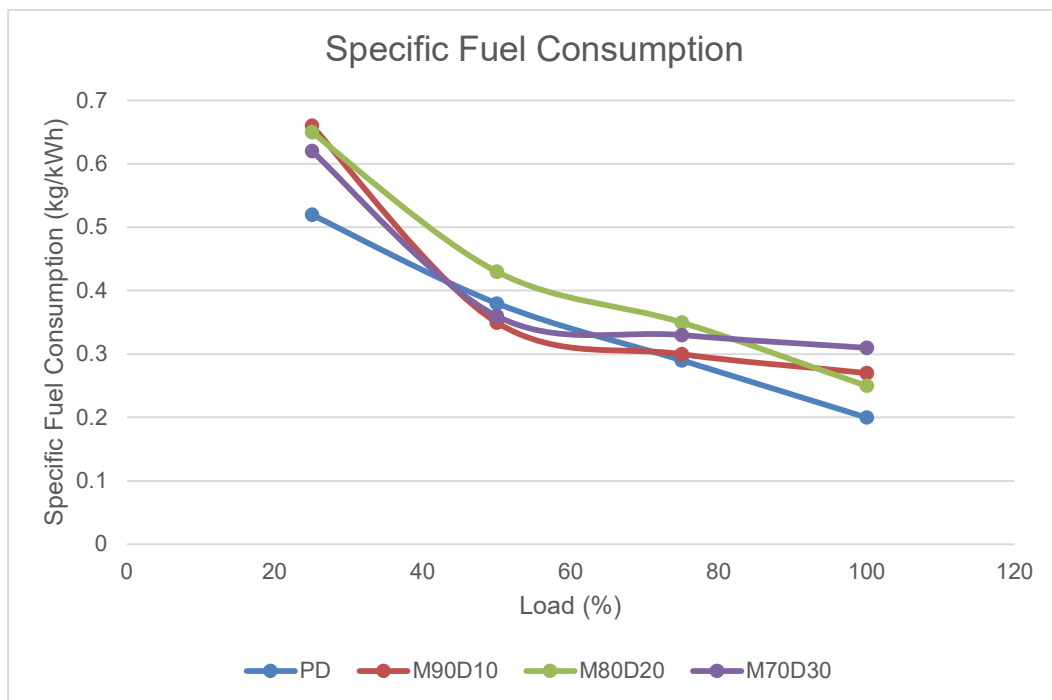


Fig. 5.2: SFC vs Load

5.2 ENGINE EMISSION RESULTS

5.2.1 NOx vs Load

Figure 5.3, shows the emissions of nitrogen oxides of Methanol substitution and Pure Diesel at different load conditions. Among the Methanol substitution, M70D30 (465PPM) shows the low percentage increase in NOx emission, but compared to Pure Diesel (457PPM), NOx emission increases slightly. Higher content of O₂ in the molecular structure of methanol has more of an effect on increasing the NOx emissions in the exhaust gas.

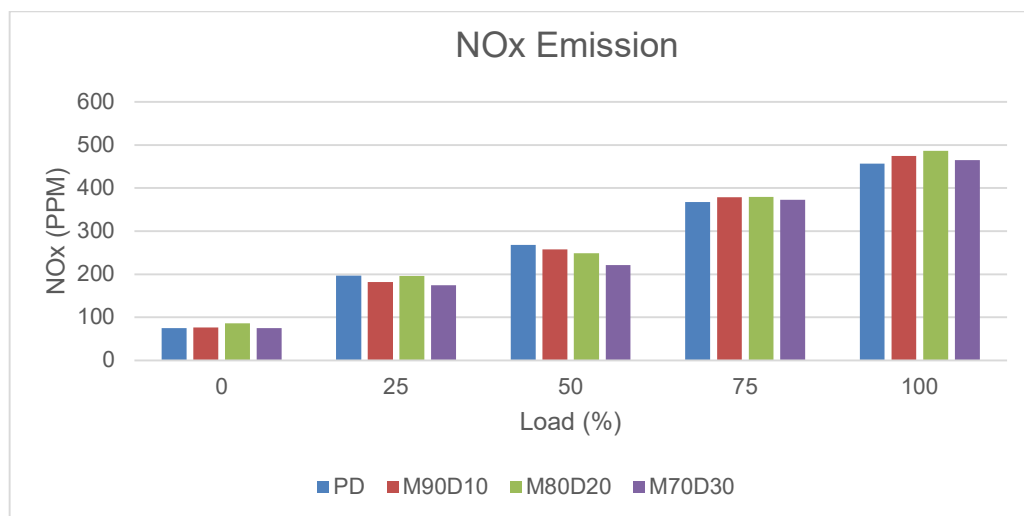


Fig. 5.3: NOx vs Load

5.2.2 CO vs Load

Figure 5.4, presents variations of carbon monoxide of Methanol substitution and Pure Diesel under different load conditions. CO emissions are reduced significantly because a higher engine load creates more desirable pressure and temperature conditions for methanol combustion. Among them M70D30 (0.042) shows decreased CO emission compared to Pure Diesel (0.059) under 100% load. The reason behind this is due to presence of Oxygen in the molecular structure of Methanol.

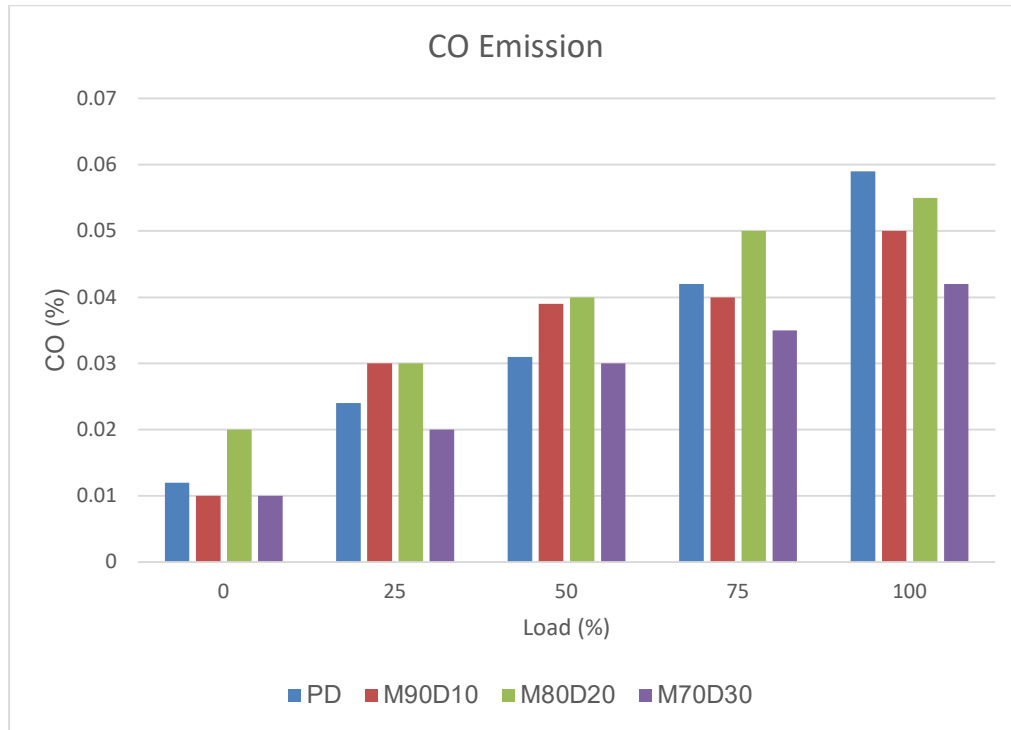


Fig. 5.4: CO vs Load

5.2.3 HC vs Load

Figure 5.5, shows the CO emissions of Methanol substitution and Pure Diesel with various load conditions. HC emission depends on the ignition quality fuel. Among the Methanol substitution, M70D30 (12PPM) shows decreased HC emissions when compared with Pure Diesel (19PPM) at 100% load condition. The reason for this is due to Methanol fuel viscosity and low volatility and also the presence of O₂ in Methanol makes it complete efficient combustion.

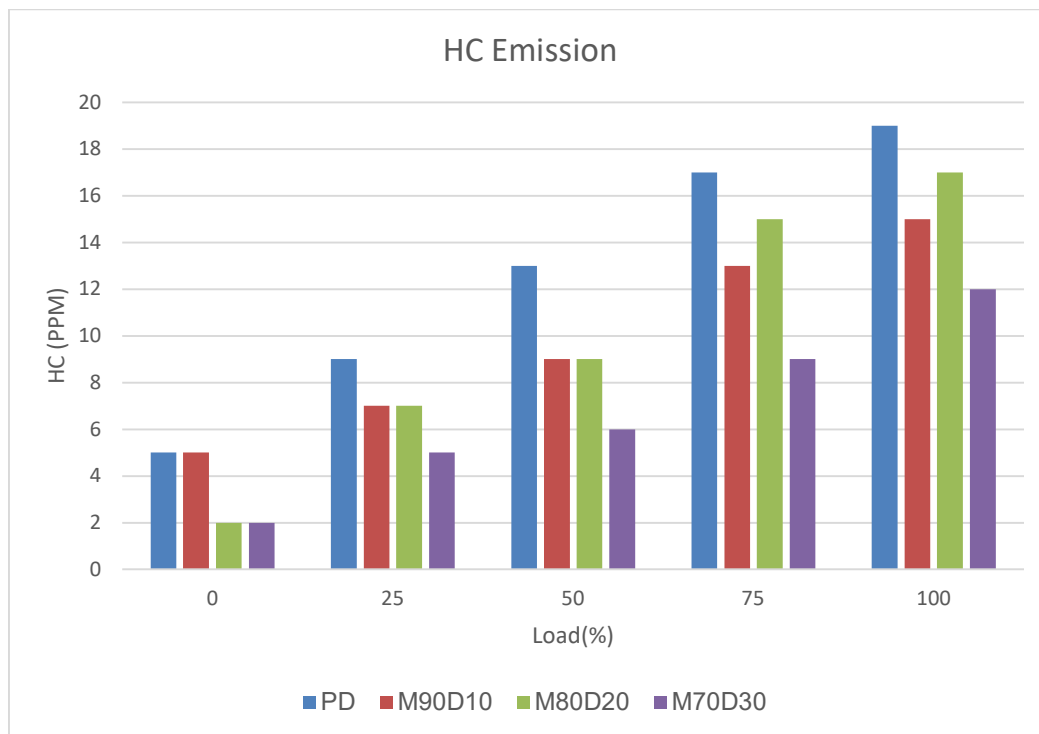


Fig. 5.5: HC vs Load

CHAPTER 6

SUMMARY AND CONCLUSIONS

The present experimental investigation has dealt with non-premixed high pressure direct injection of Methanol and pilot injection of Diesel and performance evaluation at various loads. From investigation, the following conclusions can be drawn. The performance characteristics of single cylinder compression ignition engine fuelled with Methanol have been studied and compared to the Standard Diesel fuel.

The experiment was carried out with different parameters vs various loading conditions. The investigation pointed out that, the Methanol can be directly used in a diesel engine as a result of its unique chemical possessions. Based on the experimental results the following conclusions were made.

M70D30 showed significantly comparable Thermal Efficiency and consumption of Specific fuel with Diesel, which is noteworthy as an Alcohol fuel.

According to the Emissions reports, the CO and HC emissions level have been considerably reduced for Methanol fuel compared with regular diesel at full loading conditions. On the other hand, Methanol fuel shows an advanced level of NOx emission compared with normal diesel.

The emissions of NOx increase with increasing load. At lower loads, NOx emissions for Methanol are close to Diesel. All the Methanol fuel shows lower HC and CO emissions compared to Diesel. This may be due to better combustion of Methanol due to presence of Oxygen. Increase in the emission of NOx was observed in comparison with diesel.

As a result, it was concluded that when Methanol is directly injected in high pressure of 240 bar with the pilot injection of diesel of 180 bar, there has been improved Break Thermal Efficiency and Specific fuel consumption, and significantly there has been reduced HC and CO emission with a slightly increased NO_x emission.

REFERENCES

- [1] Ajav, E.A., Bachchan Singh, and Bhattacharya, T.K., "Performance of a stationary diesel engine using vapourized ethanol as supplementary fuel", Vol. 15, No. 6, 1998, pp. 493–502.
- [2] Alan, C. Hansen, Qin Zhang, and Peter W.L. Lyne, "Ethanol–diesel fuel blends — a review", Vol. 96, No. 3, 2005, pp. 277–285.
- [3] Chandra Sekhara Reddy, K., Sathish Kumar, K.M., and Reddy Yadav, L.S., "Synthesis and characterization of magnesium oxide nanoparticles using combustion method to study the fuel properties", Materials Today.
- [4] Dong, Y., Kaario, O., Hassan, G., Ranta, O., Larmi, M., and Johansson, B., "High-pressure direct injection of methanol and pilot diesel: A non-premixed dual-fuel engine concept", Fuel, Vol. 277, 2020, p.117932.
- [5] Farfaletti, A., Astorga, C., Martini, G., Manfredi, U., Mueller, A., and Rey, M., et al. "Effect of water/fuel emulsions and a cerium-based combustion improver additive on HD and LD diesel exhaust emissions".
- [6] Gad, M. S. Abdel Razeq, S. M., Manu, P., and Jayaraj, S., "Experimental investigations on diesel engines using alumina nanoparticle fuel additive", Advances in Mechanical Engineering, Vol. 13, No. 2, 2021, p. 1687814020988402.
- [7] Idrees, M., "Making biofuels from microalgae-A review of technologies", Journal of Food Science and Technology, Vol. 1, No. 2, 2014, pp. 007-014.
- [8] Mamilla, D. V. R., and D. L. N. R. G, "A review: Waste lubricating oil as an alternative fuel blended with diesel," International Journal of Advanced Scientific Research, Vol. 1, No. 1, 2016, pp. 1-4.
- [9] Preeti Nair, and Meenakshi, H. N., "Review on the synthesis, performance and trends of butanol: a cleaner fuel additive for gasoline", International Journal of Ambient Energy, 2021.
- [10] Roshid, M.M., Ahamed, J.U., and Chowdhury, M.S.U., "Production of Biodiesel from Waste Vegetable Oil", 5th BSME Int. Conf. Therm. Eng. Gazipur, Bangladesh, Vol. 5 2015, 2012.

- [11] Sayin, Cenk, & Ilhan, Murat & Canakci, Mustafa and Gumus, Metin, "Effect of injection timing on the exhaust emissions of a diesel engine using diesel-methanol blends", *Renewable Energy*, Elsevier, Vol. 34, No. 5, 2009, pp. 1261-1269.
- [12] Shamun, Sam, Haşımoğlu, Can; Murcak, Ahmet; Andersson, Öivind; Tunér, Martin; Tunestål, Per, "Experimental investigation of methanol compression ignition in a high compression ratio HD engine using a Box-Behnken design", *Fuel*, Vol. 209, 2017, pp. 624–633.
- [13] Verhelst, Sebastian; Turner, James, W.G., Sileghem, Louis, Vancoillie, and Jeroen, "Methanol as a fuel for internal combustion engines", *Progress in Energy and Combustion Science*, Vol. 70, 2019, pp. 43–88.
- [14] Vinod Babu, M., Madhu Murthy, K., and Amba Prasad Rao, G., "Butanol and pentanol: The promising biofuels for CI engines – A review", *Renewable and Sustainable Energy Reviews*, Vol. 78, 2017, pp. 1068–1088.
- [15] Wang, Quangang; Wei, Lijiang; Pan, Wang; Yao, and Chunde, "Investigation of operating range in a methanol fumigated diesel engine", *Fuel*, Vol. 140, 2015, pp. 164–170.
- [16] Ward, P., and Teague, J., "Fifteen years of fuel methanol distribution", In: *11th Conference on Alcohol Fuels*; Sun City, SA; 1996, pp. 1–12.
- [17] Wei, Hongyuan, Yao, Chunde; Pan, Wang; Han, Guopeng; Dou, Zhancheng; Wu, Taoyang; Liu, Meijuan; Wang, Bin; Gao, Jian; Chen, Chao; Shi, and Junjie, "Experimental investigations of the effects of pilot injection on combustion and gaseous emission characteristics of diesel/methanol dual fuel engine", *Fuel*, Vol. 188, 2017, pp. 427–441.