DAYANANDA SAGAR COLLEGE OF ENGINEERING
DEPARTMENT OF MECHANICAL ENGINEERING
(Accredited by NBA)
Accredited by National Assessment & Accreditation Council (NAAC) with 'A' Grade
(AICTE Approved, an Autonomous Institute Affiliated to VTU, Belagavi)
Shavige Malleshwara Hills, Kumaraswamy Layout, Bengaluru-560078

A Project Report on

"Impact of Nanoparticles as an Additive in Biodiesel Under Varying Loads and Compression Ratios on The Working Characteristics of a CI Engine"

Submitted in partial fulfilment for the award of degree of

BACHELOR OF ENGINEERING
IN
MECHANICAL ENGINEERING

Submitted by

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Certificate

Certified that the project report entitled **'Impact of Nanoparticles as an Additive in Biodiesel Under Varying Loads and Compression Ratios on The Working Characteristics of a CI Engine'** is a bonafide work carried out by **Mr. Aditya Kamath** bearing USN: **1DS17ME008**, **Mr. Jatin S** bearing USN: **1DS17ME047**, **Mr. Shreyas Nagaraj** bearing USN: **1DS17ME120** under the guidance of **Dr. Mohan Das A.N** Assistant Professor, Department of Mechanical, Dayananda Sagar College of Engineering, Bengaluru in partial fulfilment for the award of Bachelor of Engineering in Mechanical Engineering of the Visvesvaraya Technological University, Belagavi.

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DECLARATION

We the below mentioned students hereby declare that the entire work embodied in the project report entitled '**Impact of Nanoparticles as an Additive in Biodiesel Under Varying Loads and Compression Ratios on The Working Characteristics of a CI Engine'** has been independently carried out by us under the guidance of Dr. Mohan Das A.N, Assistant Professor Department of Mechanical Engineering, Dayananda Sagar College of Engineering, Bengaluru, in partial fulfilment of the requirements for the award of Bachelor Degree in Mechanical Engineering of Visvesvaraya Technological University, Belagavi.

We further declare that we have not submitted this report either in part or in full to any other university for the award of any degree.

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ABSTRACT

The charts of the modern-day usage of petroleum products have proliferated to exhausting extents. The search for an alternative resource has become more than just a challenge, somewhat inevitable. As growth has marched into sectors like transportation, modern-day industries, incessant power generation sector, agricultural sectors, etc., the craving for more inputs has led biodiesel to be experimental as a substitute for diesel. Biodiesel is a renewable and environment-friendly fuel benignant to petro-diesel, with benefits of the lower level of smoke, unburned hydrocarbons, and carbon monoxide than petro-diesel. Although biodiesel is on course to be proven clean, economical, etc., attention on fuel formulation technique to achieve better performance and emission characteristics with additives has been predictable propitiously.

In this work the performance of fuel MME20 (MoringaMethyEster) and its blends were analysed on a four stroke, single cylinder, water cooled, variable compression ratio diesel engine. In this study synthesis of Graphene nanoparticles and steady blending with MME20 to improve the fuel properties of the biodiesel and enhance the overall characteristics of a variable compression ratio diesel engine for attaining the utmost improvement in the performance and level best reduction of exhaust emission. The synthesized Graphene nanoparticles were dispersed in MME20 at three dosage levels (30, 60, & 90 ppm) using ultrasonication process and were used as fuel in the variable compression ratio single cylinder four stroke multi fuel engine at 1500rpm, variable load conditions and different compression ratios i.e., 16, 17.5 & 19 The results obtained are compared with standard diesel fuel. The combustion pressure of fuel MME20 GNA30 at Compression Ratio 19(CR) reveals percentage increase by 14% when compared to Standard Diesel. The Ignition Delay of the fuel when compared to Standard Diesel decreases by 20% at CR19. An increase in the Combustion Duration for the blend MME20 GNA30 by 23.5% when compared to diesel at CR19. BTHE for fuel MME20 GNA30 at CR19 shows an increase by 2.64% when compared to all the other blends and Compression ratios. The value of BSFC and EGT for fuel MME20 GNA30 when compared to all the other blends decreases by 3.6% and 3.9% at Compression ratio 19.

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We would like to express our heartfelt gratitude to **Dr. C. P. S. PRAKASH**, Principal, DSCE, who has given us an opportunity to successfully complete our project.

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We are highly obliged in taking the opportunity to sincerely thank our project guide **Dr. Mohan Das A N** Professor, Department of Mechanical Engineering, DSCE. It was their guidance and moral support that never let us down at times of encountered difficulty. Their immense knowledge and dedication towards this subject have not only helped us in completion of this wonderful project, but also has augmented our knowledge and develop greater interest towards vastness of this particular subject. They have invested a huge amount of their precious time and effort towards the betterment of the project and enhancement of learning abilities towards the subject. We are honoured to follow your instructions and work under your guidance.

We would like to express our special gratitude and thanks to all the teachers and non-teaching staff who have indirectly helped us complete the project successfully. And last but not the least, gratitude to our parents, their blessings and concern without which we couldn't have completed this project. We would like to thank all our friends who have helped and supported in successfully completing the project.

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Nomenclature

BSFC	Brake Specific Fuel Consumption
BTHE	Brake Thermal Efficiency
^{o}CA	Crank Angle degree
CD	Combustion Duration
CHRR	Cumulative Heat Release Rate
CI	Compression Ignition
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CP	Combustion Pressure
CR	Compression Ratio
EGT	Exhaust Gas Temperature
FFA	Free Fatty Acid
HC	Hydrocarbons
ID	Ignition Delay
IP	Indicated Power
ITHE	Indicated Thermal Efficiency
ME	Mechanical Efficiency
MFB	Mass Fraction Burnt
MME20	20% Moringa Methyl Ester + 80 % Diesel
MME20 GNA30	20% Moringa Methyl Ester + Diesel + 30ppm Graphene Nano additive
MME20 GNA60	20% Moringa Methyl Ester + Diesel + 60ppm Graphene Nano additive
MME20 GNA90	20% Moringa Methyl Ester + Diesel + 90ppm Graphene Nano additive
NHRR	Net Heat Release Rate
NO_x	Nitrogen Oxides
O_2	Oxygen
PPM	Parts per Million

Chapter 1

INTRODUCTION

The constant need for petroleum products is increasing at a drastic rate in today's world and the constant depletion of resources is a major concern. The usage of energy resources in the form of fossil fuels is abundant as it is used in most of the industries to operate heavy machinery and is the important form of resource for sustainable development of mankind. Fossil fuels adds up to 80% of the worlds energy and diesel is utilized in most of the major industries for production of goods and also in the transportation sector where a lot of energy is consumed in the form of diesel and gasoline. All these factors will lead to rise in fuel prices which in turn increases transportation costs and lead to economic recession and global conflicts.[3]. The surging increase in the economy of developing countries will lead to consumption of fossil fuel resources by 40-50 years. The emission rate and properties of the gases produced by fossil fuels contributes to the majority of the air pollution and global warming. For this reason, the countries have to resort to search of a renewable and a cleaner alternative fuel which can help increase the economy of the country as well as help reduce the environmental consequences by reducing the harmful emissions to the environment which in turn helps to reduce global warming [2]. All the major industry sectors can adopt the same in order to run their heavy machinery and for transportation purposes.

Biodiesel is one of the most capable and feasible fossil-fuel substitutes for running a diesel engine and its importance has rapidly increased as it practically reads several benefits. Biodiesel can be produced by combining the crude oil extracted from vegetable seeds or animal fat with alcohol such as methanol, ethanol, etc., chemically by transesterification process. Various studies and researches have proven that biodiesel made of vegetable oil can be used as a fuel to run a diesel engine [3]. Since most of the economy in India is dependent on agriculture and a lot of vacant land is available, it can be used to grow the plants that can provide crude oil for production of biodiesel.

Biodiesel-fuel can be stored, utilised as fuel and impelled the same way the diesel fuels are used. It can also be used in blended or pure forms securely [2]. The fuel-economy will profit from using biofuel as it is nearly identical to petroleum fuel and can be utilised all year round. We can even manufacture biofuels using the waste as raw materials and this proves to be an excellent example of answering to the crisis of our economy, by reducing and reusing the waste.

Since biodiesel fuel is manufactured from plant/vegetable seeds which can be grown on self-owned agricultural land, it provides job opportunities to the ever-growing population. Emerging countries will benefit from the economic growth in the demand for world energy. Its properties are such that it is a reliable, non-depleting fuel with a lower percentage of pollutant emission as the presence of sulphur is very less. Biodiesel is also claimed to be the most successful alternative fuel to complete the rigorous emissions and health study under EPA's Clean Air Act. Biodiesel-fuel will reduce emissions of carcinogenic compounds as high as 85%. Compared to the regular petroleum diesel fuel, biodiesel has much better properties in terms of octane and cetane number. The engine life has improved because of the lubrication property of biodiesel.

Graphene has attracted much attention from researchers due to its interesting mechanical, electrochemical and electronic properties. As a novel nanomaterial, graphene possesses unique electronic, optical, thermal, and mechanical properties. Critically reviewing the reports on metal nanoparticle combustion revealed that the nano-size metallic powders possess high specific surface area and potential to store energy, which leads to high reactivity. It has been proven that nanoparticles can be used as a catalyst and an energy carrier. A single atomic layer of graphene is the thinnest sp2 allotrope of carbon. It, therefore, has various unique electrical and optical properties of interest to scientists and technologist and it is due to this an enhancement in the reaction rates can be done through several mechanisms including enhanced heat transfer (radiation and conduction) and chemical reactivity (catalysis and carbon oxidation) [1].

Thus, in this work, different nanoparticle percentages will be used with diesel and biodiesel alongside viands for attaining the utmost improvement in the performance and level best reduction of exhaust emission. The effect of the blending ratio and compression ratio on a diesel engine performance has to be studied in order to arrive at the best fuel blend and compression ratio (CR) to be selected. Thus, the diesel engine is operated under varying load, compression ratios, and nano additive blends, to characterize the impact of biodiesel on Combustion, Performance, and Exhaust Emissions of diesel engines. The properties of pure diesel were first studied so as to determine the standard comparison barrier and later compare it with different MME biofuel blends. Further, tests were conducted for various compression ratios (16, 17.5, 19) by using different piston head of various diameters which in turn changes the compression ratio. The experiment was performed for various loads, blends and compression ratios and the results were tabulated.

Chapter 2

LITERATURE SURVEY

This chapter presents a survey of the past research studies involving the issues of interest. It presents research works on biodiesel and the effects of various parameters on the performance, combustion and emission attributes of the CI engine.

In today's world, the incessant requirement for petroleum and petroleum products have led to severe depletion of fossil fuel which has led to an extreme drop in the carbon resources causing major global crisis of fossil fuel depletion and degradation of the environment. It has been predicted that within the next 50-60 years these fossil fuels would deplete and become exhausted. This has led to the dire search in need of an alternative fuel which could provide and assure a sustainable future development. The current usage of petroleum diesel fuel is proving to be efficient to operate the major industry's heavy machinery and locomotives, but it comes at a cost of environmental pollution which has led to global warming. So, the dire need of an alternative is not only due to the fossil fuel depletion but also to assure a clean environment. Its main purposes are to help stop excess consumption of fossil fuels, protect environment as well as provide better performance, combustion and emission characteristics for the Compression Ignition engine. An alternative fuel which is the future, is the Biodiesel. The production of biodiesel can be done using several processes, but the more widely process is the Transesterification process and is because of its economically friendly extraction procedures by using vegetable seeds (palatable and Non-palatable) or animal fat. The extracted fuel by nature has lesser smoke emissions (CO, HC, CO2, etc.,) when used in the compression ignition engine. The results obtained were of improved performance when compared to regular petroleum diesel fuel with a few negative impacts which could be altered by varying the blend composition.

In all countries, Energy is the most valuable resource which decide the financial growth and also the sustainable development of the current and future generations of life. The energy policy of India is largely well-defined by the country's expanding energy deficit and increased focus on developing alternative sources of energy.

The Primary consumption of fuel in India grew by 2.3% in the recently calculated statistical data in 2019, and is proven to be the 3rd largest energy consumer and purchaser in the world behind USA, China. The consumption of fossil fuel in India is such that 80% of electricity and power is generated using fossil fuels. India ranks 2nd in production of renewable resources and its carbon intensity is around 0.29 Kg CO_2 per kWh, which is the highest (Energy Policy of India-2019). Rapid economic expansion in India has led to India becoming the world's fastest growing energy stations and is expected to be the second-largest contributor to the increase in global energy demand by 2035, accounting for 18% of the spike in global energy consumption. In 2019, India imported about 229.1 million tons of crude oil, 45 million tons of refined petroleum and exported about 64 million tons of refined petroleum products, which led to India becoming the 2nd biggest importer of crude oil (Energy Policy of India-2019). The development of India's economy may compel the demand for rich energy resources across all major Industrial Sectors. The alarming need for a alternative source of energy has been rapidly increasing in the recent past.

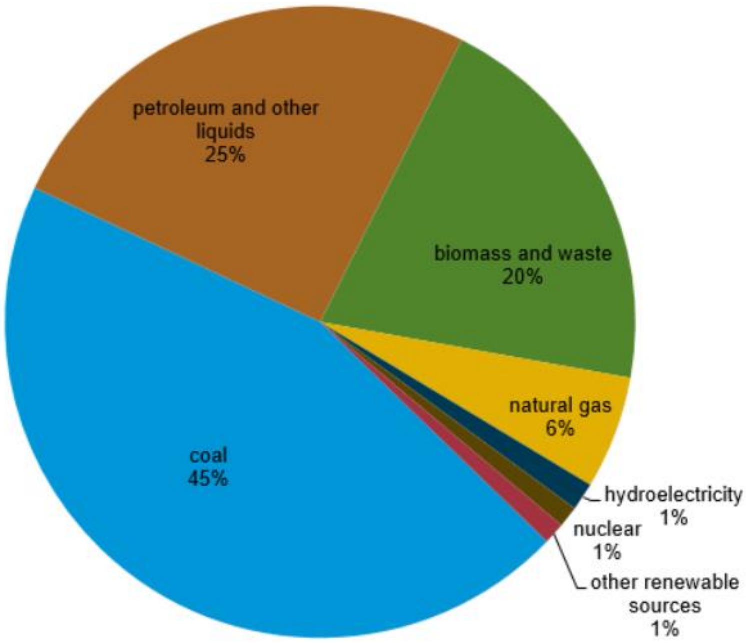

Fig. 2.1 Percentages of Energy Consumption in different forms

The figure 3.1 shows the power energy consumption in India in 2019 (International Energy Agency, World Energy Outlook 2019). India consumes 45% of energy from coal and 25% through petroleum. A total of 70% of the country's energy is dependent on these fossil fuels. With hydroelectricity, nuclear and other renewable resources at a mere 1% each along with natural gas at 6% and biomass and waste at 20% add up to the overall energy consumption chart. This graph not only illustrates the countries dependency on fossil fuels but clearly shows how less of a proportion renewable resources take up.

2.1 Alternative Fuels

Alternative fuels are called as non-conventional fuels. Any material or substance that can be used as a fuel, other than conventional fuels, nuclear materials, and artificial radioisotope fuels that are made in nuclear reactors, are termed non-conventional fuels.

2.1.1 Liquid fuel

Compression ignition engine utilizes mostly liquid fuel. Liquid fuels are combustible energy generating molecules that can be extracted to produce energy (mechanical), usually kinetic energy. These fuels are used in CI engines due to its desired properties such as low viscosity, density and its very ease of transportation and storage, etc. Residual oil, asphalt oil are some of the examples of liquid fuel.

2.1.2 Alcohol

In many countries Methanol and ethanol fuel are primary sources of energy. They are convenient fuels for storing and transporting energy and these can be used in internal combustion engines as alternative fuels in their blended form. Butane has another advantage i.e. it can be readily transported through the current petroleum-pipeline networks (The only alcohol based fuel which can), instead of only by tanker trucks and railroad-cars. Ethanol can be processed from any feedstock like corn and other grams. Gram is first crushed and cooked with water to convert to sugar. This is then fermented to produce raw ethanol.

2.1.3 Vegetable Oil

Vegetable oils are the major contributors in the production of Biodiesel. The fuel produced are used in vehicles (unmodified), generators, etc., but usage of straight vegetable oil needs a special set of vehicle which have to process heating of the oil in order to reduce its viscosity and surface tension. This concept has been in research and development from the early 1900’s. The benefits of using vegetable oils as bases for biodiesel showed tremendous benefits in performance, combustion and emission properties of a CI. Early researches noted that this might be the future of alternative fuels once the petroleum diesel fuels prices start increasing rapidly due to its depletion. Vegetable oil fuels, works as the best alternative due to their very similar properties as conventional fuel. In the current situation, due to the prediction that, in the coming 40 years fossil fuels might be exhausted, thus more and more research is been done, but it has been difficult due to the increasing cost of vegetable oils which could be eased out by improved environmentally friendly extraction procedures and cultivation. Many oils have been tested, i.e., from soybean oil to esters, etc., and around 70% of those are available in India. Since agriculture sector is a majority in India it is easier to improve cultivation with less cost.

2.2 Biodiesel Production

2.2.1 Lipase catalyzed Method:

Lipased catalyzed method is nothing but transesterification process, but using enzymes as catalysts. Researchers have found out that a better yield is produced by using lipase as a catalyst (Triglycerol Acylhydrolaces). This helps accelerate the transesterification process. Enzyme reaction is much more acceptable compared to chemical reaction, as it has the ability to make a high quality product and does the separation process in the mildest of conditions. Lipase is an important catalyst that helps in the transesterification reaction to produce methyl esters (biodiesel). Lipase due to its greater biochemical and physiological properties is less sensitive to FFA (Free fatty acid) with the only drawback of the reaction rate being slower as it can only occur in groups as it needs an activated-catalyst.

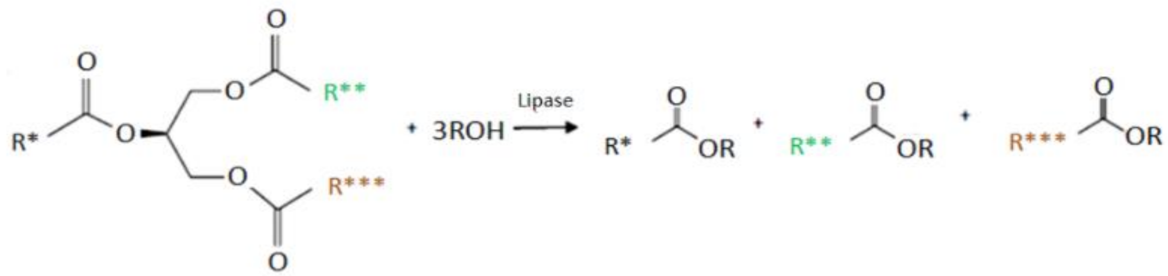

Fig 2.2 Lipase Reaction

2.2.2 Ultrasonic Reactor Method

In Ultrasonic Reactor method, ultrasonic mixing reactors are used for the production of biodiesel at any scale. The ultrasonic mixing improves mass transfer and reaction kinetics leading to faster transesterification and higher yield. It saves excess methanol and catalyst. This helps it gain a uniform mixing and also lesser reaction time and energy input.

2.2.3 Supercritical Process

The mining of biodiesel-fuel from vegetable oils and fats obtained from animals has become more important as a possible source of alternative energy source to help reduce our dependence on petroleum diesel fuels. The catalytic processes commonly used for the production of biodiesel fuel present a few drawbacks, one of them being the high energy consumption required for complex purification operations and undesirable side reactions. Supercritical fluid (SCF) process of transesterification performed under supercritical conditions. It is a catalyst-free chemical reaction between triglycerides and Free fatty acids where it is transesterified simultaneously in the supercritical method and helps reduce the pre-treatment as well as operating costs. Supercritical transesterification results in ester yield higher than 95% with non-ester composition and glycerol collectively less than 5%.

2.2.4 Transesterification:

The transesterification of vegetable oils, animal fats or waste cooking oils is the process behind conventional biodiesel. In the process, glyceride reacts with an alcohol (typically methanol or ethanol) in the presence of a catalyst forming fatty acid alkyl esters and an alcohol.

The General transesterification has the following steps:

1. In this process, the crude oil is extracted from the seeds and titration process is done adding alcohol, indicator and a catalyst. The proportion of FFA is determined for the transesterified crude oil.
2. Free Fatty Acids are produced by hydrolysis of fats and oils. Since they are less stable than regular neutral oil, they are more prone to oxidation and thereby turning rancid.
3. If the FFA produced is less than 4% then a single-phase transesterification process is performed. If greater than 4% double-phase transesterification process is performed
4. In Single-phase transesterification certain amount of alcohol and catalyst has to be mixed thoroughly with a measured amount of vegetable oil.
5. The mixture is heated and maintained at 60°C for 2 hr, and then it undergoes natural cooling. Glycerol will deposit at the bottom of the flask, and it is separated out using a separating funnel.
6. The remnants in the flask are the esterified vegetable oil (Biodiesel) which is nothing but biodiesel.

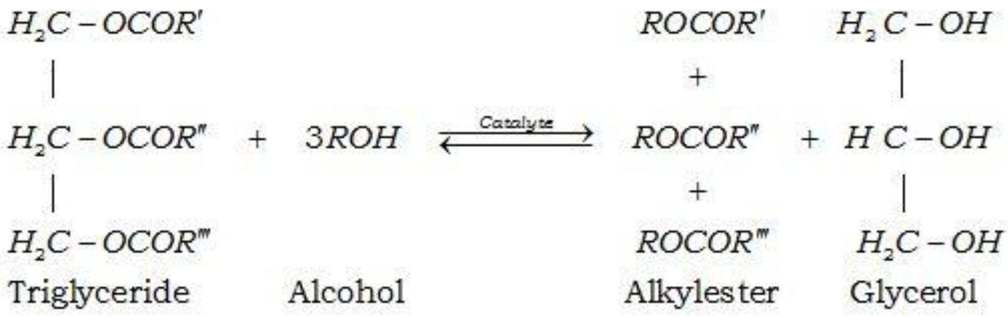

Fig 2.3 Transesterification Reaction of Biodiesel

2.3 Biodiesel Properties

Some of the main properties of biodiesel are:

1. Density: It is the degree of compactness of a substance and is one of the most important parameters of a biodiesel. It is slightly miscible with water and has a density value of 0.885 and that of diesel 0.8.
2. Kinematic viscosity: In terms of oil, Kinematic viscosity is defined as its resistance to flow and shear due to gravity or external force. The kinematic viscosity of biodiesel is significantly lesser than diesel.
3. Flash Point: The lowest temperature at which a chemical can vaporize to form an ignitable mixture. It can also be defined as the minimum temperature at which a liquid form a vapor above its surface in sufficient concentration that it can be ignited. Lower the flash point higher is the flammability. Flash point of biodiesel is 160 °C which is greater than that of diesel which is 96 °C
4. Fire Point: The minimum temperature at which the liquid continues to burn after ignition under an open flame standard dimension is called fire point. The fire point is the temperature at which lubricant combustion will be sustained. The fire point of biodiesel is 168°C which is greater than that of diesel is 126°C.
5. Gross Calorific Value (GCV): The calorific value of a fuel is the quantity of heat produced by its combustion – at constant pressure and under standard conditions (0^oC and under a pressure of 1.013 mbar). Gross calorific value (GCV) assumes all vapour produced during the combustion process is fully condensed. The GCV of biodiesel is 39852.6 Kj/g which is lesser than diesel which is 44800 Kj/g.
6. Cloud point: The temperature at which components within the fluid under test precipitate on cooling. i.e. temperature at which paraffin starts separating when oil is

reduced to a lower temperature and is used to check performance under lower conditions. Cloud point of biodiesel is biodiesel is 4°C and diesel is -40°C.

7. Pour point: The lowest temperature at which the oil continues to flow when it is cooling, without stirring is called pour point. i.e. the lowest temperature at which oil flows under gravity. The pour point of biodiesel is -6°C which is greater than diesel -40°C
8. Total Acid Number: The measurement of acidity that is determined by the amount of potassium hydroxide (KOH) in milligrams (mg) that is needed to neutralize the free fatty acids in one gram of oil. It is an important quality measurement of crude oil.
9. Octane Number: Octane number is the number that shows the ability of the fuel to resist pre-ignition of fuel (knocking) in the engine.
10. Cetane Number: Cetane number is the number used to measure ignition delay. The ignition delay is shorter i.e. fuel takes lesser time to burn if the cetane number is higher. Cetane number of biodiesels is in the range of 55-60 and regular petroleum diesel is about 45-48.

2.4 Compression Ratio

Compression ratio in an IC engine is the degree to which the fuel is compressed before ignition i.e. The compression ratio is defined as the ratio between the total cylinder volume (Swept Volume + Clearance volume) to the clearance volume. Few factors that affect compression ratio are fuel octane, cylinder volume, combustion chamber volume, piston-to-head clearance and ignition timing. The compression ratio can be altered by replacing the piston in the cylinder and various CRs can obtained by machining the piston head. It can be increased by changing the flat-top pistons to high compression ones that curve upward to result in a higher compression ratio but this also results in knocking and Supercharging. This gives an increased charge proportional to rpm, but loads the engine straightaway like an aircon pulley and Turbocharging. The selection of the three compression ratios (16, 17.5, 19) was done based on various research papers studied in the past, it was suggested that for conducting various performance, combustion and emission tests on a compression ignition engine the ideal Compression ratio would be 17.5. A comparison research was done between standard diesel and biofuel with CR's of 16-21 in intervals of 0.5 in many papers and majority of the papers proved the ideal compression ratio to be selected should be between 16-21 but since the compression ratios above 19 proved to have shown lesser and mixed results in the improvement and enhancement of the properties with respect to combustion performance and emission due to the fact that engine overheats when a higher compression ratio is selected and researches have also proved that selecting a lower compression ratio can lead to an increase in the emission of carbon monoxide due to more dilution of fresh air and also poor mixing of fuels occur in the engine. Keeping these factors in mind and also for the purpose of having uniform difference space of 1.5 between the CR's the selection of 16, 17.5 and 19 was done. [41][42][43].

The following are the discussions of literature reviews related to Biodiesel and different Nano Additives

4. Soudagar, Manzoore et al [4]. performed a study to assess characteristics of modified CI Engine using Mahua Bio-Diesel and its blends with Zinc Oxide as Nano Additive. The results obtained was that Zinc Oxide blend Mahua Bio-Diesel resulted in the overall enhancement in the CI Engine Characteristics.
5. Prabu, A et al., [5]. investigates the performance, combustion and emission characteristics of a single cylinder direct injection diesel engine with three blends of the fuel biodiesel–diesel (B20), biodiesel–diesel–nanoparticles (B20A30C30) and biodiesel–nanoparticles (B100A30C30). The results drawn were that there was significant improvement in brake thermal efficiency is observed for nanoparticles dispersed test fuels and that addition of nanoparticles in biodiesel decreases the ignition delay and there was a significant decrease in emission of harmful gases like NO, CO, CO2.
6. Anderson, Larry et al., [6]. studied the effect of using biodiesel blends on vehicles pollutant-emissions. In this, the effects of substituting from petroleum-diesel fuel to biodiesel blended fuels on relative vehicle emissions for heavy, light-duty vehicles by using only vehicle emissions data and no engine data are determined separately. The emission test results varied for each class and hence the results were combined to assess the effect of biodiesel use on the broader class of vehicles.
7. Yunus, Mohammed et al., [7]. Performed a judgement study where the characteristics of Bio-Diesel blend and pure diesel were compared and it was observed that 10% of honge and Mustard oil mixture mixed with 90% of diesel was the best suited blend for Diesel engine. It was concluded that Honge and Mustard oil can be used as an alternate to diesel.
8. O. Awogbemi et al., [8]. conducted a research-study which deals with the effect of using biodiesel blends on vehicles pollutant emissions, where the effects of switching from petroleum diesel fuel to biodiesel blended fuels on relative vehicle emissions for heavy and

light duty vehicles by using only vehicle emissions data and no engine data are determined separately.

9. P. Kanthasamy et al., [9]. conducted a review-study that covers the characteristics of Bio-Diesel from edible, non-edible oils and its blend with Diesel. Three fuels – Pure Bio-Diesel, Blended form and Diesel were tested and nearly identical thermal efficiency were obtained. Along with these results, the study showed that there needs to be an appropriate blend of the Nano-Additives with Bio-Diesel to ensure the best performance. Based on the outputs obtained suitable measures such as Pre-heating the Bio-Diesel and use of a Turbocharger were suggested.
10. Gavhane, Rakhamaji et al., [10]. Performed the synthesisation of zinc oxide nanoparticles and its steady blending with soybean biodiesel (SBME25) at different loads and varying CRs on a VCR, single cylinder engine with IT of 23◦BTDC and at a constant speed 1500 rpm to improve the fuel properties of SBME25 and enhance the overall characteristics of a VCR diesel engine. The conclusions drawn validate the nanoparticles ZnO in soybean biodiesel at a CR of 21.5 to enhance performance and combustion, and reduce the emissions of a common rail direct injection engine.
11. Solomon, Giwa et al., [11]. Produced evidence that the use of Egusi Melon for biodiesel production is very beneficial and has food uses as well. Research proved that Egusi melon seed kernels are a good source of edible oil (31–59%), protein (19–37%), fibre (3–4%), and carbohydrate (8–20%). Studies show that egusi kernel oil competes well with other established oil-based crops such as safflower and sunflower for food and fuel uses. The flow behaviours of egusi kernel oil biodiesel and its blends (B2, B5, B10, B15, B20, and B25) depicted its benefits on the different performance and emission characteristics of a diesel engine.
12. Praveena, V et al., [12]. conducted a research to reveal the engine's performance and its emissions (CI engines) with the effects of addition of nano additives in biodiesels. the main disadvantages we are facing from diesel engines are emission (CO, NOx, HC) and to reduce the fuel consumption. Al2O3 under the measure of ppm will added with biodiesel MME20D80 resulted in reduction of 7.66% of BSFC at maximum load, increases BTE by 1.58% . 35% of NOx emissions will be reduced with the addition of CNT with biodiesels. The cost of these have forced into more researches in the future.
13. Hotti, Siddalingappa et al., [13]. researched to evaluate the sugar apple seed oil as a potential raw material for the production of biodiesel and to check its feasibility for the replacement of current petroleum-diesel fuels. The sugar apple oil was converted to

biodiesel by transesterification with a catalyst. The physical and chemical properties of biodiesel produced were found to be close to those of diesel fuel and also satisfy ASTME standard.

14. Guirong wu et al., [14]. summarized the influence of biodiesel applications on diesel engines, its impact on engine performance, combustion and emission characteristics, noise characteristics and check compatibility. The unregulated emissions such as volatile organic compounds (VOCs) and polycyclic aromatic hydrocarbons (PAHs)
15. Manzoor Elahi M Soudagar et al., [15]. Studied to comprehend the effect of biodiesel blend (MOEE) which was prepared by transesterification process, on the performance of engine parameters like, BTE, BP and other fuel properties like flash point, cloud point, kinematic viscosity, calorific value, cetane number and density were studied.
16. S. Imran et al., [16]. was a study to analyze the potential of hydrogen being used in combination with natural gas with diesel and rapeseed methyl ester as primary fuels. It has the potential to achieve a better trade-off between the higher NOX related with H and higher hydrocarbon emissions linked with natural gas-based dual fueling of compression ignition engines.
17. M.A. Mujtaba et al., [17]. Performed an analyses the properties of sesame seeds, summarizes sesame cultivation, SSO production, the physicochemical properties of SSO and its potential as an alternative renewable fuel source. Results show that blending SSO with palm oil before transesterification will successfully improve the cold flow properties and oxidation stability of palm methyl ester (biodiesel).
18. Awogbemi, O et al., [18]. Performed a research to understand the effect of biodiesel blend magnitude on the performance of engine parameters such as brake power (BP), brake thermal efficiency (BTE) and fuel properties like cloud point, flash point, calorific value, and cetane number as well as the economic feasibility, emission characteristics and finally Greenhouse gas emissions.
19. Manzoore Elahi et al., [19]. Conducted a study in which Graphene oxide nanoparticles were merged with dairy scum oil biodiesel at proportions of 20, 40 and 60 ppm using ultrasonication technique. Experiments were performed at a constant speed and varying load conditions. The results were notable improvements in the performance and emissions characteristics.
20. Asif Afzal et al., [20]. Prepared different blends of the biodiesel (B20,B40,B60,B80,B100) along with different proportions of 1-propanol and isobutanol and to test the performance and emission characteristics of the results were that the engine performance of diesel is

seen to be better than any other combination of biofuels at both the pressures. Among blends without additive, B20 performed better than other blends.

21. Suresh Vellaiyan et al., [21]. Presented the results of investigations carried out to evaluate the improvement in combustion, performance, and emission characteristics of a diesel engine fueled with neat petro-diesel, soybean biodiesel, and 50% SB blended by using carbon nanotube (CNT) as an additive.
22. Shiva Kumar et al., [22]. Studied the pongamia biodiesel blends of B20 with ferrofluid as the additive with various volumetric proportions were used as fuel. The investigation was done on diesel engine at different loads. The results indicated that adding of ferrofluid had a positive effect on fuel, decreasing BSFC by 8% as compared to non-additive fuel. CO and HC emission were found to be lower for nano additive biodiesel blend compared to biodiesel blend. The blend B20 with 1% ferrofluid resulted maximum efficiency with reduced emission compared to all the fuel blends.
23. Balasubramanian Prabakaran et al., [23]. Investigated the effect of zinc oxide nano particle on addition with biodiesel blends. Solubility tests were done for the fuels at three different temperatures. blends were stable at 5°C, 15°C and above 25°C as per ASTM standards. In the same blend, zinc oxide was added in the amount of 250ppm. For this blend, there was an increase in BSFC and cylinder pressure. Also, there was a decrease in BTE, NOx and smoke, as compared to diesel.
24. Tayfun Özgür et al., [24]. Bought to light the effects of addition of oxygen containing nanoparticle additives to biodiesel on fuel properties and effects on diesel engine performance and exhaust emissions were investigated. Two different nanoparticle additives, namely MgO and SiO_2, were added to biodiesel at the addition dosage of 25 and 50 ppm. As a result of this study, engine emission values NO_x and CO were decreased and engine performance values slightly increased with the addition of nanoparticle additives.
25. Dr. S. Karthikeyan et al., [25]. Investigated the performance, combustion and exhaust emission characteristics of compression ignition engine have been found out at the constant engine speed under the full load when it is loaded with various blends. Results were shown that, with the addition of zinc oxide nanoparticles it accelerates early ignition of combustion and shortens ignition delay and increases NOx emissions.
26. HarishVenu et al., [26]. Performed a Comparative analysis was done for addition of Diethyl ether (DEE) and alumina nanoparticle (Al_2O_3) at various proportions. Experimental results indicate that, DEE addition in BE results in increased emissions and BSFC but it lowered the NOx and smoke emission. This is a result obtained due to higher value of latent heat

evaporation and low temperature combustion. Al_2O_3 addition in BE resulted in increase in NOx and smoke with lowered HC, CO, CO2 and BSFC.

27. Umer Rashid et al., [27]. evaluated *Moringa oleifera* oil as potential source for biodiesel. The biodiesel was obtained by a standard transesterification procedure with methanol and an alkali catalyst at 60 °C. *The* oil has a high content of oleic acid content with saturated fatty acids comprising most of the remaining fatty acid profile. Results showed that, the biodiesel obtained from this oil shows a higher cetane number and other fuel properties of such as cloud point, kinematic viscosity and oxidative stability were also determined and compared with biodiesel standards.
28. M. A. Wakil1 et al., [28]. showed the effect of the biodiesel blends of rice bran and moringa on the CI engine. The physiochemical properties were measured and then the engine test was performed which resulted in an improvement when comparing to regular diesel in aspects of BSFC, emission properties and temperature of exhaust which proved that rice bran and moringa oil would be the feasible option for biodiesel as they satisfy ASTM standard limit.
29. X.J. Man wt al., [29]. Focussed on the emissions (both regulated and unregulated) of a diesel engine fueled with different proportion of blends and even in its pure form. Tests were conducted on the engine so that the influence of engine load and speed on the emissions could be found. Results dictated that increase of biodiesel in the blended fuel causes reductions of HC, CO but an increase in NO_x. For the unregulated emissions, emissions increase with increasing biodiesel content.
30. Ekrem Buyukkaya et al., [30]. Checked the combustion, performance and emission characteristics of regular diesel fuel and biodiesel produced from soybean oil and its blends were compared. Tests were performed at ideal conditions in a single-cylinder diesel engine. The results, indicated that, comparing to diesel, biodiesel had a decrease in the torque and an increase in the BSFC due to the LHV of the biodiesel, lesser emissions of harmful gases but the carbon dioxide (CO_2) emissions increase.
31. Huaxin Chen et al., [31]. Experiment-studied where the biodiesel was prepared using transesterification with NaOH being used as a catalyst this work uses the fundamental information from the porous sphere experiments to explain the combustion characteristics in the engine cylinder. Studies in the engine show that the starting rate of combustion is earlier with the biodiesel blends and there is a rapid increase rate of pressure during continuous combustion phase is also faster.

32. I.M. Rizwanul et al., [32]. reviewed the facts and feasibility of biofuel utilization mainly the edible biodiesels namely soybean, rapeseed, palm and two non-edible jatropha and cottonseed to reduce exhaust gas and noise emission from engine. Results showed that there are many benefits of biodiesel including sustainability, reduction of greenhouse gas emissions along with noise emission.
33. Knothe. G et al., [33]. researched about Biodiesel. The source of biodiesel varies with the location it is crucial to have the data on how the different fatty acids concentration can influence biodiesel fuel properties. The properties of the various individual fatty esters that are included in biodiesel determine the overall fuel properties of the fuel. The crucial fuel properties that are affected are cetane number, emissions, heat of combustion, oxidative stability, viscosity, and lubricity.
34. M. Norhafana et al., [34]. performed a strict review so as to find the various vegetable feedstock available that can be used as a base and as a metal based nonadditive keeping in mind its effect on the combustion characteristics and performance of engine. Nanometal additives with feasible physiochemical properties were tested and resulted that non-edible oil-based biodiesel are one of the best source of energy and leads to reduced harmful emissions.
35. A.S Ramadhas et al., [35]. was a study done as a result of degradation of petroleum fuels and the search for an alternative is was a must and one which had to be produced from available materials in the country. Thorough research was done in production and characterization of vegetable oil and practical work carried out as well to find out the compartibility to use vegetable oils as a biodiesel and its pros and cons noted along with future challenges.
36. Raheman et al., [36]. presented the results of different blends of karanja biodiesel from 20%-80% in a diesel engine and engine tests were conducted which led to the results of reduction in exhaust emissions together with increase in torque, brake power, brake thermal efficiency and reduction in brake-specific fuel consumption
37. Ayhan Demirbas et al., [37]. studied the problems that biodiesel from edible oils not being feasible as well as extreme use of edible ones can lead to food crisis which can be solved by low feedstock non-edible oils. This paper reviews numerous options of non-edible oils as the substantial feedstocks, biodiesel processing, and effect of different parameters on production of biodiesel.
38. Ali M.A et al., [38]. found the effect of COME blending ratio on viscosity of the biodiesel blend fuel mixture. The engine performance has been calculated and found out in terms of

the in-cylinder pressure data as well measured at constant engine rated speed and different engine loads. The main results indicated, the value of the in-cylinder peak pressure depends mainly on the engine load and the biodiesel blending ratio. The best value of Brake Specific Energy Consumption (BSEC) is attained at blended fuel containing 20% blend of fuel (B20)

39. LeiZhu et al., [39]. Conducted a study of mustard biodiesel that was produced from crude mustard oil and experimented on a four-cylinder, diesel engine to investigate the combustion, performance and emission characteristics of the engine at different engine speeds and full load conditions. Results indicated that the Biodiesel and its blends have reduced ignition delay when compared to diesel fuel. The pre-mixed combustion phase and the start of injection timing for B100 and its blends took place earlier than B0. Performance tests showed biodiesel blends having higher brake specific fuel consumption and lower brake power compared to diesel fuel.
40. Jagannath hirkude et al., [40] discussed the results of investigations carried out on a diesel engine operated on methyl esters of waste fried oil blended with refined diesel. The performance of the engine with diesel was considered as the standard data. The performance characteristics was very similar to diesel engine but emission characteristics differ.
41. Rahul Kumar Mishra et al., [41]. found an alternative fuel which would act as a supplement petroleum fuels. Karanja oil performance was analyzed on a four stroke, variable compression ratio diesel engine. The results obtained was compared to the standard values and it displayed that the properties were dependent on the variable compression ratios and biodiesel blends and gave optimistic results.
42. M. Santhosh et al., [42]. Explored the effects of variable compression ratio. The cottonseed oil methyl ester is combined with standard diesel and used as fuel in the variable compression ratio four stroke multi fuel engine. The investigation revealed that, heat release rate, combustion pressure and brake thermal efficiency is higher, brake power and mechanical efficiency increases at higher CR. It is also found that there is a reduction the emission of HC and CO2 but increase the emission of NOX.
43. R. D. Eknath et al., [43]. analyzed the effect of compression ratio on the performance and emission of dual blends of biodiesel. Jatropha and Karanja with Diesel fuel was tested on single cylinder VCR DI diesel engine for compression ratio 16 and 18. High density of biodiesel fuel causes longer delay period for Jatropha fuel was observed compare with Karanja fuel.

44. A. Santoshkumar et al., [44]. focused on the production of the biodiesel-fuel and the ideal conditions to do so and is also optimized by response surface method(RSM) and the tests were carried out on a 4-stroke-single-cylinder DI. The optimal conditions were to be found as 45°C, 120min, 6:1 alcohol ratio as well as BTE being lesser and NOx emissions and brake specific energy is higher.
45. Amar Pandhare et al., [45]. researched about the performance of the jatropha blend in a Diesel engine (1-cylinder) at a rate of 1500rpm, Results showed that for VCR equipped engine B100 blend the fuel consumption was the peak point compared to diesel as well as the BTE, temperature of exhaust gas and CO2 emission were higher whilst the harmful emissions were lower.
46. Supriya Chauvan et al., [46]. was a study that was done to figure out the different emissions that are caused by using the variant blends in the VCR diesel engine. A blend made from Jatropha was used to perform this investigation where all blends were made at 40°C and tested on an engine with VCR. Emission results showed that the blended-biodiesel produced much lesser emissions of CO and HC with an increase in amounts of NOx.

Chapter 3

LITERATURE GAP

1. Limited research work has been done on Nanoparticles as additives with Biodiesel.
2. It has been noticed that no work has been done using Moringa Oil.
3. Engine experiments using Graphene as a Nano additive is limited.
4. Research based on varying compression ratio along with Nano additive fuel is limited.

3.1 Motivation and Problem Statement

Rapid exploration and lavish consumption of underground non-renewable petroleum resources have led to the scarcity of underground fossil fuels. Toxic emissions from such fuels are pernicious but have increased the health hazards around the world. Demand have surged up for diesel incessantly for purposes of transportation, captive power generation and agricultural sector. The aim was to find an alternative fuel which would meet the requirements of petroleum or fossil fuels. Biodiesel is a clean, renewable and bio-degradable fuel having several advantages, one of the most important of which is being its eco-friendly and better knocking characteristics than diesel fuel. Considering these conditions, a change in the energy production industry with biodiesel as an alternative or a replacement for the tenacious fossil fuel-based energy production industry has motivated us to produce and test the feasibility of biofuels extracted from vegetable seeds, in our case Moringa seeds. Fuel produced from theses seeds are trans esterified and blended along with a nano additive to obtain a uniform blend. Nanoparticle dispersion in optimum quantity can bring about improvement in the performance of the engine and properties of the fuel and also would help in reduction of exhaust emission. The experimental outputs on usage of biodiesel extracted from Moringa seeds with nanoparticle Graphene forming a blend can bring about an actual development by implementing on real world basis. When introduced about biodiesel, a lot of properties and characteristics are to be considered, questions on efficiencies, Heat Release Rate, Break Specific Fuel Consumption, percentage of emission gases such as CO, CO2, HC, NOx etc., are beneficiary when compared with the standard diesel. As biodiesel is a renewable source and are eco-friendly considering the smoke emission percentage, they are considered more advantageous compared to standard diesel. As the performance and combustion characteristics of the engine improve with usage of the biofuel, the engine life expectancy and maintenance will have considerable advantages when compared with that of standard diesel characteristics.

Chapter 4

OBJECTIVES

The objectives of current study have been enumerated below:

1. To investigate the novel biodiesel and nano additive emulsified fuel to the existing diesel engine.
2. To create the demand for selected crude oil, which will help to grow the economic condition of the farmer
3. To enhance the properties of biodiesel by dispersion of nanoparticles.
4. To optimize the compression ratio and nanoparticle proportion for the existing diesel engine concerning performance, emissions, and combustion attributes.
5. To improve fuel quality and enhance the thermal brake efficiency by reducing emissions.

Chapter 5

METHOD AND METHODOLOGY

The three main processes involved in preparing the Biodiesel are:

1. Production of the fuel - The crude oil has to be extracted from the Moringa seeds and the fuel is further processed.
2. Blending - The Oil has to be blended with Nanoparticle additives, and four batches of fuel are acquired for the testing of the most efficient one.
3. Test analysis - Run the biodiesel in a diesel engine lab and get the results and check for the efficiency and check whether Engine characteristics has been enhanced.

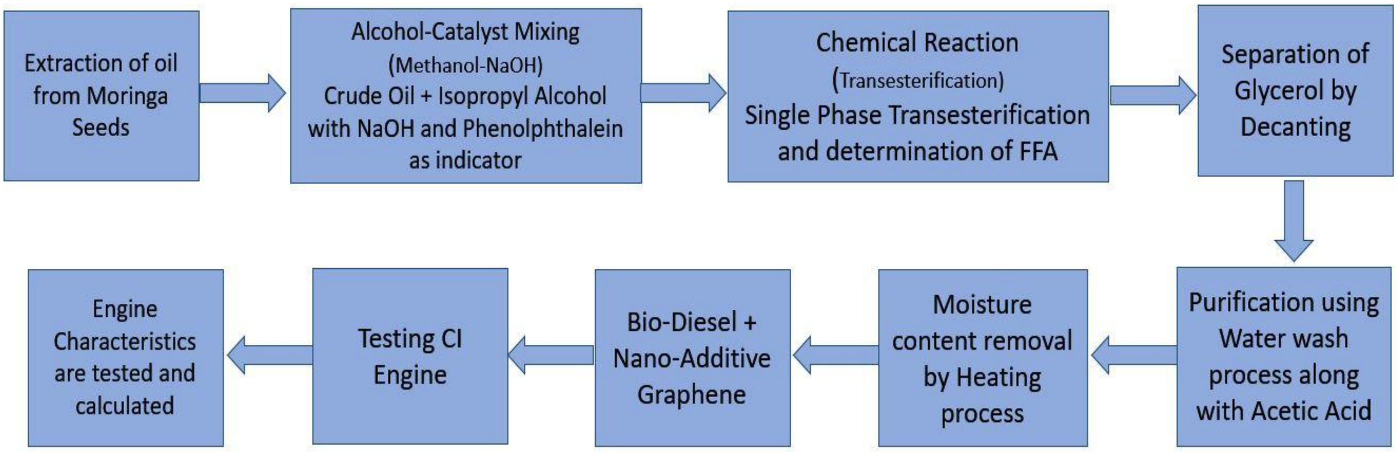

Fig 5.1 Flowchart of the Methodology

Methodology Process

1. Selection of suitable biodegradable fuel as a substitute for diesel fuel.
2. Generation of Bio Diesel from selected crude oil by Transesterification process.
3. The oil has to be blended with different proportions of Nanoparticle additives, and four batches of fuel are acquired to test the most efficient one.
4. Characterization of the biodiesel and its blend
5. Engine Test analysis Run the engine with fuel samples prepared in the previous stage by varying the load and compression ratio.
6. Study of performance, combustion, and emissions characteristics of a C.I. engine with selected fuel samples to optimize the better fuel proportions and Compression ratio for the conventional diesel engine.

Design of Experiments

A series of steps performed with changes made in the input in order to observe and identify changes in the output. In this particular experiment the input fuel was varied with different proportions of Nano Additive along with loads varying from 0% to 100% & at Compression Ratios 16, 17.5 and 19.

Table 5.1 Design of Experiments

Operating Condition: Varying Compression Ratio			
Ex. No	**Fuel Used**	**Load %**	**REMARKS**
CR 16			
1.	**B20**	**ALL LOADS**	
2.	**B20+GNA30ppm**	**ALL LOADS**	
3.	**B20+GNA60ppm**	**ALL LOADS**	
4.	**B20+GNA90ppm**	**ALL LOADS**	
CR 17.5			
5.	**B20**	**ALL LOADS**	
6.	**B20+GNA30ppm**	**ALL LOADS**	
7.	**B20+GNA60ppm**	**ALL LOADS**	
8.	**B20+GNA90ppm**	**ALL LOADS**	
CR 19			
9.	**B20**	**ALL LOADS**	
10.	**B20+GNA30ppm**	**ALL LOADS**	
11.	**B20+GNA60ppm**	**ALL LOADS**	
12.	**B20+GNA90ppm**	**ALL LOADS**	

Chapter 6

Experimental setup and Testing Procedures

6.1 Extraction of Biodiesel

6.1.1 Determination of Free Fatty Acid (FFA):

Procedure: 1ml of oil is taken in the conical flask and 10 ml of isopropyl alcohol is added to it with 2-3 drops of phenolphthalein indicator and NaOH (0.01%) is taken in the burette. Titration is conducted, during which the crude oil colour turns to pale pink colour. Note down the reading of burette at that time.

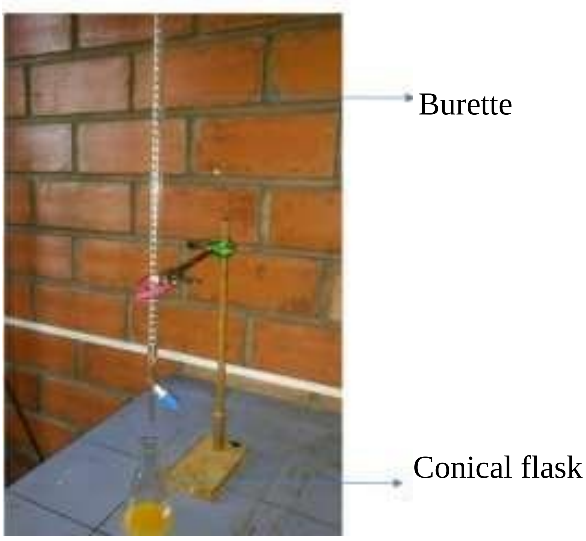

Fig 6.1 Photographic view of Titration test

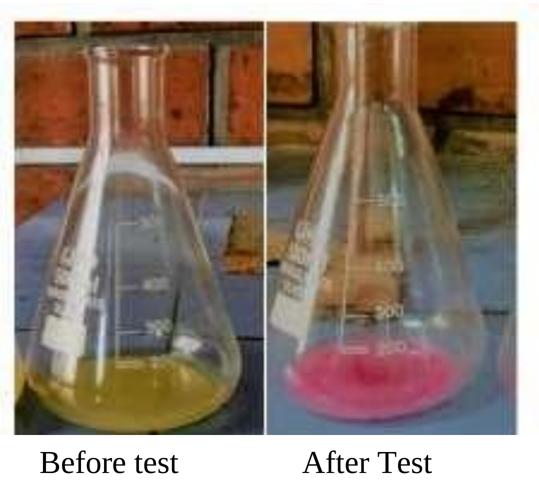

Fig 6.2 Change in colour

Yellow solution turns pale pink, indicated end point is 2ml. This shows the FFA.

FFA VALUE OF MORINGA OIL	2%

From the above FFA test it was found that, the acid value of oil is less than 4% and hence we have to carry out the transesterification by single-phase method.

And also found, amount of NaOH to be added with 200ml Methanol for 1 liter of crude oil by using following relation:

$$3.5 + X = L$$

Where,

L= Total amount NaOH required transesterify triglycerides in the oil. 3.5gm/3.5ml=Amount of NaOH required to transesterify triglycerides in the oil (standard).

X=2gm /2ml (Amount of NaOH required to neutralise the FFA).

$$3.5+2=5.5$$

5.5 gm /5.5ml of NaoH required to transesterify triglycerides in the oil.

Add 200ml of methanol +5.5gm/5.5ml of NaOH +crude oil to produce biodiesel during transesterification process.

6.1.2 Transesterification Process:

6.1.2.1 Single-phase Transesterification method:

If the percentage of FFA present in the raw vegetable oil is less than 4%, the transesterification process by single-phase method has to be chosen. In this method, a measured amount of methanol (CH_3OH) and sodium hydroxide (NaOH) has to be mixed thoroughly with a measured amount of vegetable oil. The mixture is heated and maintained at 60°C for 2 hr, and then it undergoes natural cooling. Glycerol will deposit at the bottom of the flask, and it is separated out using a separating funnel. The remnants in the flask are the esterified vegetable oil. Another commercial name for esterified vegetable oil is biodiesel.

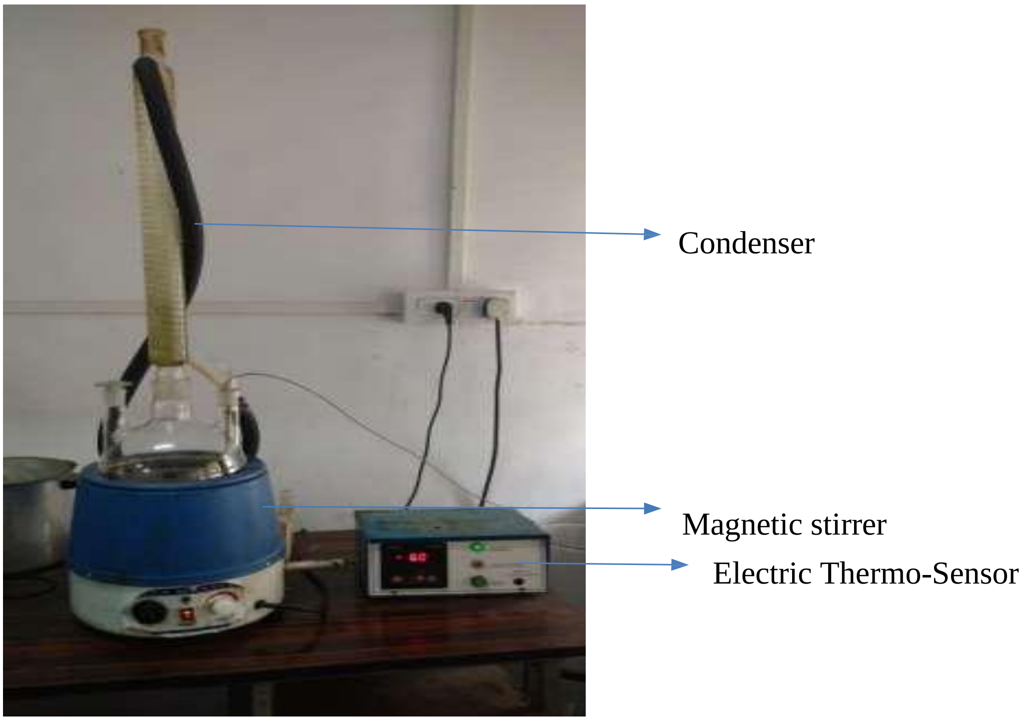

Fig 6.3 Photographic View of Transesterification setup

6.1.3 Settling of Glycerol

Settling process ***After settling***

Fig 6.4 Settling process of glycerol

Fig 6.5 Separation of glycerol (Photographic View)

After transesterification process, the oil is subjected to gravity separation method in a settling flask to remove unwanted glycerol for few hour

6.1.4 Water Washing Process:

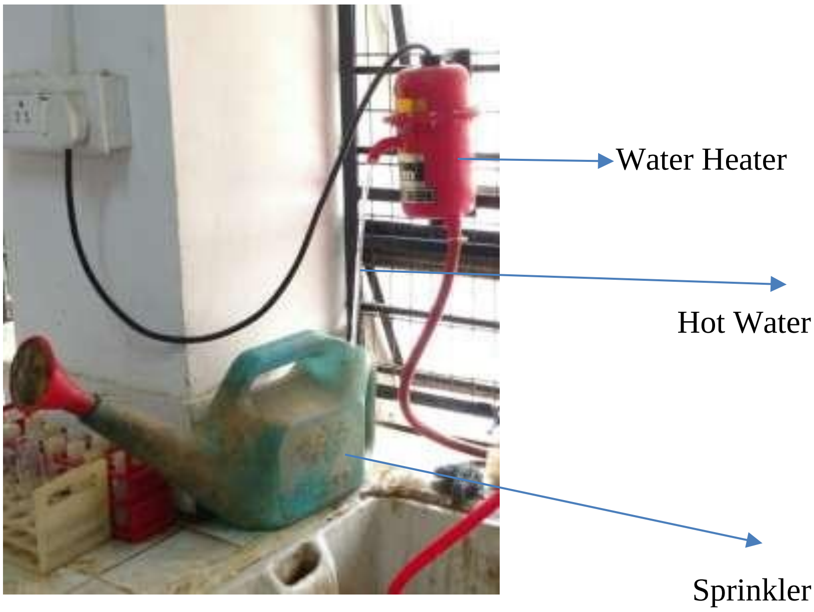

Fig 6.6 Water washing equipment (Photographic View)

Fig 6.7 Water washing (Photographic View)

6.1.5 Stages of Washing:

STEP 1: First Wash

Fig 6.8 First Wash (Photographic View)

- In the 1st wash along with warm water, 25-30 ml of acetic acid is added to avoid emulsification and sprinkled evenly. Then allow 30 to 45 minutes to settle and separate the contaminated water which contains some amount of glycerol. Again repeat with water washing process until all glycerol content in MME is removed.

STEP 2: Second Wash

Fig 6.9 Second Wash (Photographic View)

- Wash until clear water is obtained and separate the water, here clear water indicates that there is no glycerol content in MME.

6.1.6 Heating:

Fig 6.10 Heating process (Photographic View)

- Once completing the water washing process, collect the MME. There is a chances of moisture content present in the MME.
- MME should not contain any moisture therefore it has to be removed by heating process.
- The oil is heated up to 110^{o}C, which removes all moisture content in MME.

After all the above steps we get the pure biodiesel. The photographic view of pure MME is as shown in fig

Fig 6.11 Biodiesel (B100) (Photographic View)

6.2 Graphene and its property Analysis

The principal aim of Raman analysis is to produce high magnification images of the internal structure of any given sample. Fig illustrates Raman Analysis image of the Graphene sample at 200nm and magnification levels of 50,000X. The analysis also helps to determine the values on the crystalline structure, contamination, Intrinsic stress/strain and fractures present inside the Graphene structures. Initially, Graphene is dispersed on a Si/SiO_2 substrate as both of these materials exhibit fluorescence properties at visible spectrums of light i.e. around the range 530-630nm. Different bands such as G, D and 2d bands are formed by which the structure of Graphene can be precisely viewed. B20 Fuel- 20% Bio Diesel 80% Diesel (1.5L)

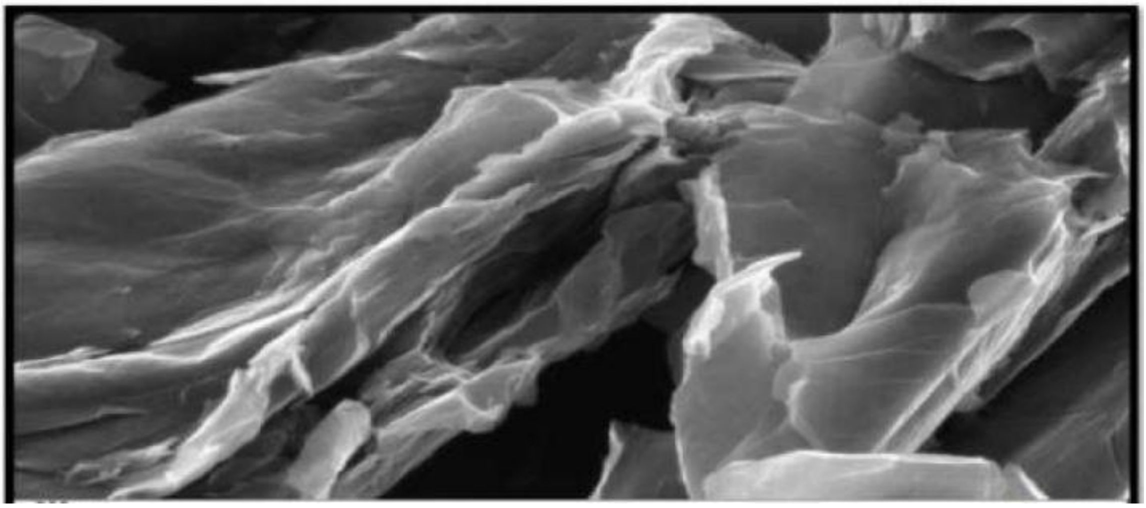

Fig 6.12 View of Graphene Nano Particle under Raman Spectrum Analysis instrument

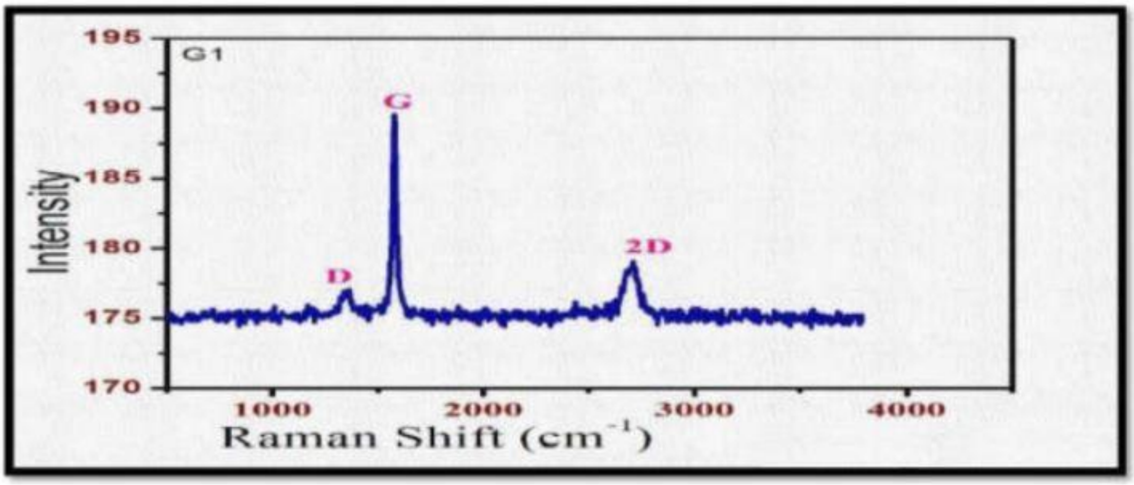

Fig 6.13 Graphical view of Graphene bands

6.3 Testing in CI Engine

A single cylinder, four stroke, variable compression ratio (VCR) Diesel engine is connected to eddy current type dynamometer whose purpose is engine loading. The compression ratio of the engine can be changed by changing the piston heads and without altering the geometry of the combustion chamber. During the experiment the pressure was kept constant at 200bar and fuel injection timing was maintained at a constant 23^{O}bTDC. It is provided with necessary instruments for combustion pressure and crank-angle measurements. These signals are interfaced to computer through engine indicator for Pθ−PV diagrams. Provision is also made for interfacing airflow, fuel flow, temperatures and load measurement. The set-up has stand-alone panel box consisting of air box, fuel tank, 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 engine performance 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 “Engine soft” is provided for online performance evaluation.

During experimentation the load on the engine was varied to measure the performance at three different compression ratio 16, 17.5 and 19. Initially test was conducted for Diesel engine fuel then for MME20 and its nano additive blends. Every time fuel tank and fuel line was completely drain out and to ensure new fuel supply to the engine was initially run for five to ten minutes. To ensure the steady state readings were taken only when the oil temperature was observed to be constant for a period of at least five minutes.

- **General procedure for testing multiple fuels in a varying compression ratio compression ignition engine**.
    1. Biodiesel blend (B20) is obtained using transesterification process, and various nano fuel blends of graphene are prepared by adding quantities of graphene at 30ppm, 60ppm, 90ppm and a uniform mixture of each blend was obtained using an ultrasonicator.
    2. The required amount of biodiesel (MoringaMethylEster) (B20 i.e. MME-20) is to be filled in the fuel tank located at the back of the Electronic Unit.
    3. The Electronic Unit was switched ON after connecting all the main plug-ins and the indicators and temperature sensors were set to the default readings.

4. The piston head is fixed to the cylinder head in order to set the compression ratio to 16.
5. Switch ON Compression ignition engine for preheating.
6. The fuel is filled into a burette located at the back of the Electronic Unit (converts electronic to mechanical energy) and is fed into the engine once the preheat temperature is reached during the intake stroke.
7. The load is gradually increased, starting from 0 -100%.
8. The load is then increased to 25% and the time taken for 10mL of fuel to be consumed is determined using a stopwatch.
9. The percentage emissions of CO, HC, CO_2, O_2 and NOx were found with the help of Emission Analyzer and hence tabulated.
10. A software named EngineSoft LV is used for performance monitoring. This software can be used for monitoring, data entry, data logging and reporting purposes. The software evaluates power, efficiencies, fuel consumption and heat release. It is configurable as per engine set up. The data obtained is stored graphically and in tabular formats.
11. Thus performance attributes namely, BTHE, ITHE, IP, BSFC, EGT, etc., and combustion attributes namely, combustion pressure, pressure rise, NHRR, MFB, CHRR, etc., are obtained and tabulated.
12. The engine is put to rest and the same procedure is repeated for blends MME-20 with 30ppm, 60ppm and 90ppm graphene addition at CR16.
13. Once all the fuels are tested, the piston head of CR 16 is removed from the cylinder head and is fitted with another piston head of CR 17.5 and the procedure is repeated. The same is done for CR 19 and the results are tabulated and the inferences are drawn.

Fig 6.14 Ultrasonicator

Table 6.1 Ultrasonicator Specifications

Parameters	Specifications
Model	MX50SH 0.7LQ
Volume Size (L)	0.7
Tank Internal Dimension L x W x D (mm)	152 x 87 x 65
Operation Frequency (kHz)	40
Ultrasonic Power (Watt)	50
Heating	✓
Drainage Valve	NaN
Carrying Handle	NaN
Unit Weight(kg)	1.8
Carton Size (cm)	48 x 47 x 43

Fig 6.15 Blends of Moringa Methyl Ester

Table 6.2 Fuel Properties

Parameters	Diesel	B20	30ppm	60ppm	90ppm	B100
Density (kg/m3)	830	835	836.95	838.9	840.85	855
Kinematic Viscosity	6	3.24	3.18	3.16	3.1536	4.2
Flash Point	52	74.8	71.3	67.8	64.3	164
Fire Point	58	81.7	78.2	74.7	71.2	168
Gross Calorific Valued	44000	44402.12	44602.12	45192.12	45212.12	39852.6
Cloud point	14	3.29	3.16	3.02	2.89	4
Pour point	-9	-19	-17.09	-15.2	-13.3	-6
Total acid number	0.38	Nil	Nil	Nil	Nil	Nil

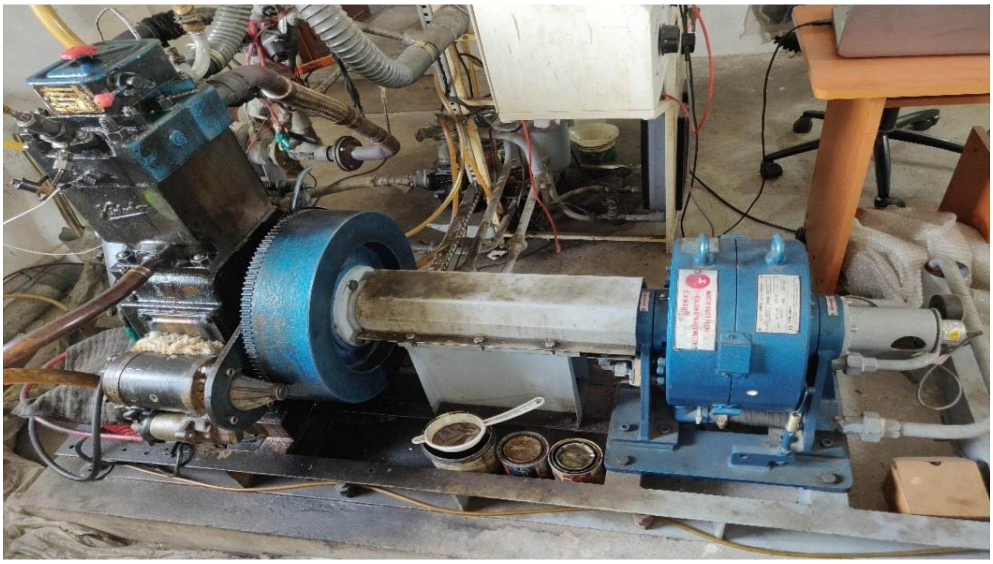

Fig. 6.16 Compression Ignition Engine Setup

Fig 6.17 Electrical Setup

Fig 6.18 Piston with Compression ratios 16, 17.5 and 19

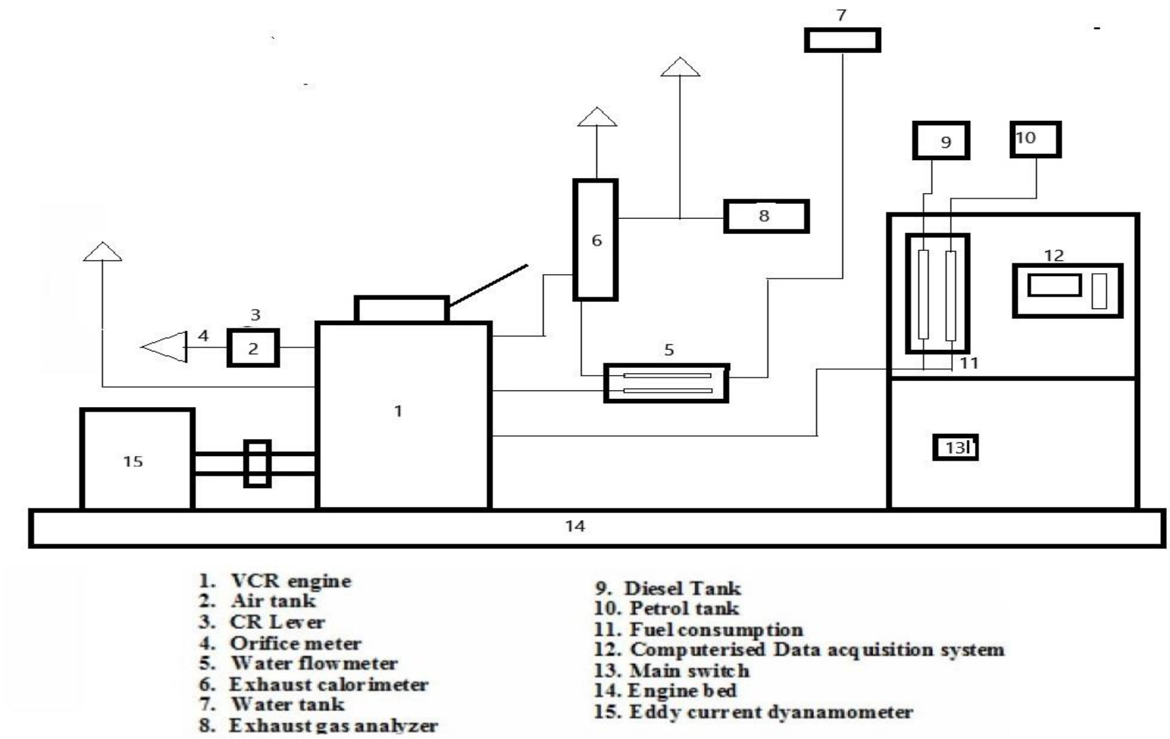

Fig 6.19 Schematic Representation of the Compression Ignition Engine

Kirloskar Engine TV 1 Specifications.

Type: Four Stroke, Single Cylinder Vertical Water-Cooled Diesel Engine.

Table 6.3 Kirloskar Engine TV 1 Specifications

Rated power	5.2kW
Rated speed	1500rpm
Bore diameter (D)	87.5mm
Stroke (L)	110mm
Compression ratio	17.5:1
C.V. of Fuel for diesel	42,0000kJ/kg
Density of diesel	830kg/m^3

Table 6.4 Eddy Current Dynamometer Specifications

Parameters	Dimensions
Make	Techno Mech
Model	TMEC - 10
KW	Nm * RPM/ 9549305
Max KW	7.5
Dynamometer Arm Length	185mm
RPM	1500-6000

Table 6.5 Engine test setup and additional indicators

Product	Engine test setup 1 cylinder, 4 stroke, Diesel (Computerized)
Product code	224
Engine	Make Kirloskar, Model TV1, Type 1 cylinder, 4 stroke Diesel, water cooled, power 5.2 kW at 1500 rpm, stroke 110 mm, bore 87.5 mm. 661 cc, CR 17.5
Dynamometer	Type eddy current, water cooled
Propeller shaft	With universal joints
Air box	M S fabricated with orifice meter and manometer
Fuel tank	Capacity 15 lit with glass fuel metering column
Calorimeter	Type Pipe in pipe
Piezo sensor	Range 5000 PSI, with low noise cable
Crank angle sensor	Resolution 1 Deg, Speed 5500 RPM with TDC pulse.
Data acquisition device	NI USB-6210, 16-bit, 250kS/s.
Piezo powering unit	Model AX-409.
Temperature sensor	Type RTD, PT100 and Thermocouple, Type K
Temperature transmitter	Type two wire, Input RTD PT100, Range 0–100 DegC, I/P Thermocouple, Range 0–1200 DegC, O/P 4–20mA
Load indicator	Digital, Range 0-50 Kg, Supply 230VAC
Load sensor	Load cell, type strain gauge, range 0-50 Kg
Fuel flow transmitter	DP transmitter, Range 0-500 mm WC
Air flow transmitter	Pressure transmitter, Range (-) 250 mm WC
Software	"Enginesoft" Engine performance analysis software
Rotameter	Engine cooling 40-400 LPH; Calorimeter 25-250 LPH
Pump	Type Monoblock
Overall dimensions	W 2000 x D 2500 x H 1500 mm
Optional	Computerized Diesel injection pressure measurement

Table 6.6 Gas Analyzer Specifications

Model - AVL DI GAS 444N (5 Gas Analyzer)	
Measurement Data	Resolution
CO – 0-15% Vol	0.0001% Vol
HC – 0 – 20000 ppm Vol	1ppm / 10ppm
CO_2 – 0-20%	0.1% Vol
O_2 – 0 – 25% Vol	0.01% Vol
NO_x 0 – 6000 ppm Vol	1 ppm Vol

Fig 6.20 Gas Analyzer and Smoke Meter

Table 6.7 Smoke Meter Specifications

Model – AVL 437C Smoke Meter	
Measurement Data	Resolution
Opacity – 0-100%	0.1%
Absorbtion (K Value)	0-99-99 m^{-1} 0.01m^{-1}

Chapter 7

RESULTS AND DISCUSSION

This chapter deals with the results and discussions on Performance, Combustion and Emission characteristics of Morniga Methyl Ester fueled variable compression ignition engine. Various tests were experimented after ensuring the full warm-up of the engine. The tests conducted were for different blends of the fuel and repeated five times for each of a kind in order to enhance the reliability of the experimental results. These tests experimented were on the basic of varying loads and varying compression ratios. The varying compression ratios included 16, 17.5 and 19, and the loads varied were as follows 0kg, 4.5kg, 9kg, 13.5kg and 18kg.

7.1 Performance, Combustion and Emission characteristics of CIDI engine for diesel and blends of biodiesel

7.1.1 The effect of Graphene as a nano additive and blends of Moringa biofuel on Performance attributes.

1. **The effect of MME20-Graphene blends on Break Thermal Efficiency (BTHE) at different compression ratios and varying loads.**

The variation in BTHE and the loads for fuel blends at different compression ratio is presented in Figure. All fuel blends showed lower BTHE values compared to diesel at all loads and compression ratios due to lower calorific value, lower brake power, and higher viscosity. The lower calorific value & higher viscosity leads to a poor atomization inside the combustion chamber causing reduction in the efficiency of the fuel. At maximum load the BTHE increased by 3.34% (MME20+GNA30ppm), 3.04% (MME20+GNA60ppm), 2.54% (MME20+GNA90ppm), when compared with the (MME20) at CR 17.5. The values that were obtained experimentally at full load conditions showed that the BTE decreased by 4.16% (MME20), 0.7% (MME20+GNA30ppm), 0.75% (MME20+GNA90ppm), by comparing CR 16 with CR 17.5 and decreased by 0.66% (MME20), 3.27% (MME20+GNA60ppm), 3.45% (MME20+GNA90ppm), by comparing CR 17.5 with CR 19 and is due to lower compression temperature, which resulted in poor combustion of fuel. The BTHE for blend (MME20+GNA30ppm), was almost similar when compared with diesel at CR 19 at 75% load. The BTHE for blend (MME20+GNA30ppm) increased by 3.87% when compared with blend (MME20) at CR 19. Blend MME20 at CR 16 shows the highest BTHE compared to all the other blends. An enhancement in BTHE was seen with increase in loads and lower heat losses at higher engine load. Graphene nanoparticles act as a catalyst due to their high reactive surface area during the combustion process leading to a micro explosion of fuel droplets resulting in improved combustion characteristics, such as combustion pressure and high HHR, therefore increasing the BTHE.

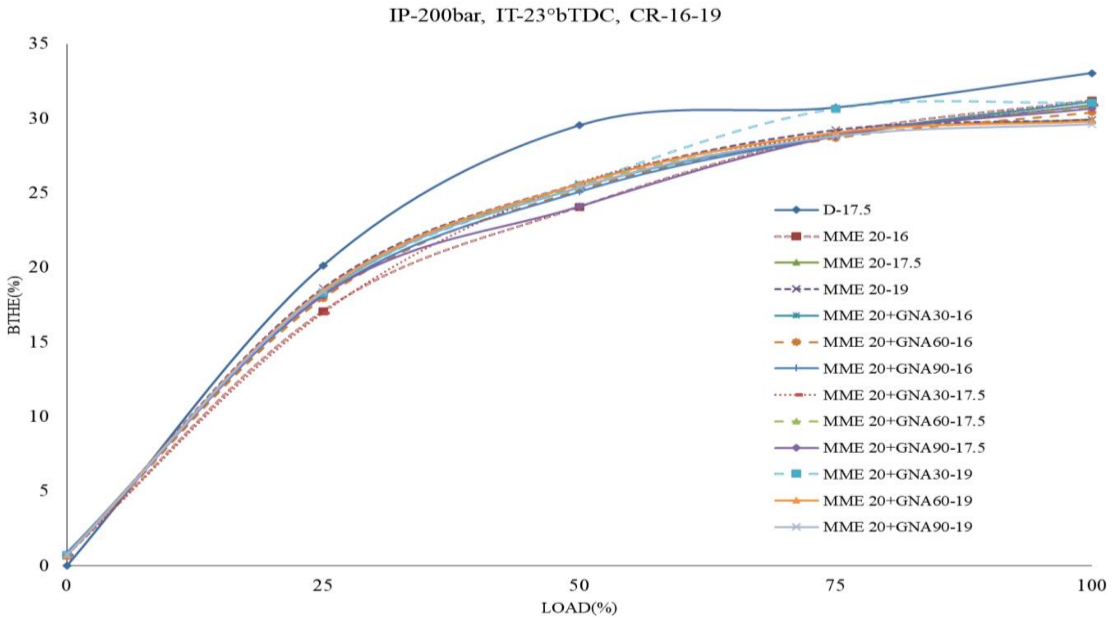

Fig 7.1 Variation of BTHE with respect to load for compression ratios 16, 17.5 and 19.

2. **The effect of MME20-Graphene blends on Indicated Thermal Efficiency (ITHE) at different compression ratios and varying loads.**

The variation in ITHE and the loads for fuel blends at different compression ratio is presented in Figure. It is seen that the ITHE is lower for all the blends when compared with diesel at varying loads and compression ratios. As seen from the experimental results the ITHE of one particular blend (MME20+GNA30ppm) at CR 19 was similar to the ITHE of diesel at 75% load. At full load, CR17.5 the ITHE increased by 7.3% (MME20+GNA30ppm), 5.70% (MME20+GNA60ppm) and 5.57% (MME20+GNA90ppm), when compared with (MME20). An increase of 3.68% can be seen at CR 19 for blend (MME20+GNA30ppm) when compared with (MME20) at full load. Blend (MME20+GNA30ppm) at CR 19 shows the highest ITHE compared to all the other blends.

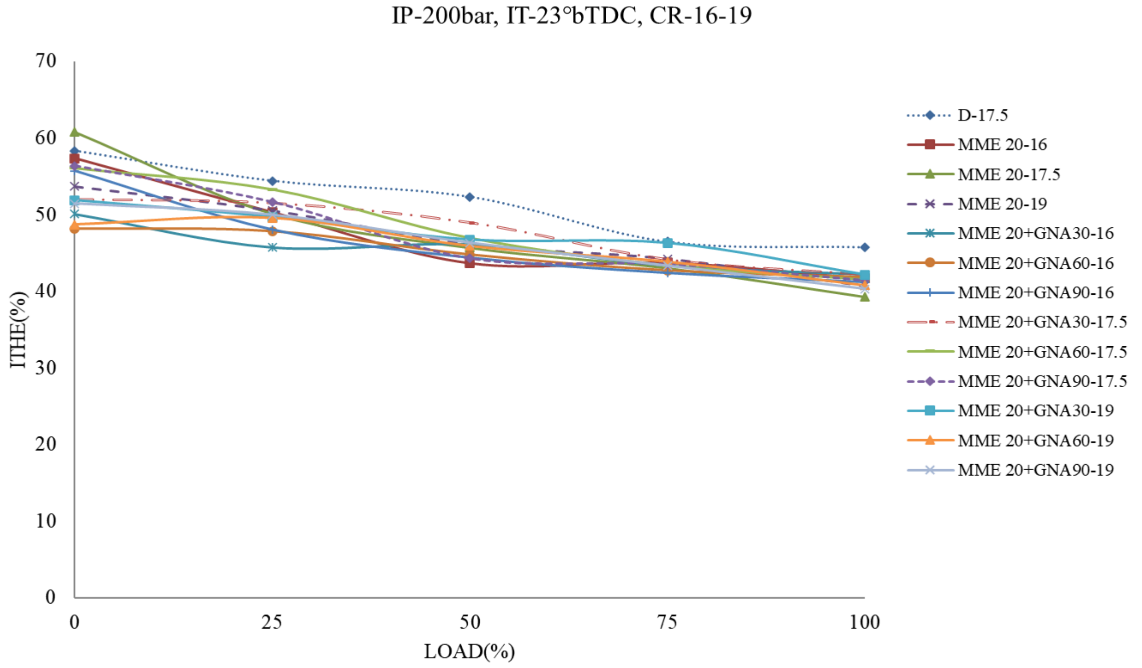

Fig 7.2 Variation of ITHE with respect to load for compression ratios 16, 17.5 and 19.

3. The effect of MME20-Graphene blends on Mechanical Efficiency (ME) at different compression ratios and varying loads.

The Mechanical Efficiency for different CRs, different proportions of blends and diesel are shown in the Figure. It is evident that mechanical efficiency increases with increasing blend proportions at all Compression ratios. The ME of different blends of MME20 at different loads increased by 3.74% (MME20) CR16, 5.472% (MME20)CR17.5, 1.8% (MME20) CR19, 2.32%(MME20+GNA30ppm), 0.64%(MME20+GNA60ppm), 3.93%(MME20+GNA90ppm) for CR 16, 1.59%(MME20+GNA30ppm), 2.84%(MME20+GNA60ppm), 2.46% MME20+GNA90ppm), for CR 17.5,1.98% (MME20+GNA30ppm), 1.26%(MME20+GNA60ppm), 1.82%(MME20+GNA90ppm), for CR19, when compared with Diesel. The highest ME when compared amongst the lot was for blend MME20 for compression ratio 17.5.[42]

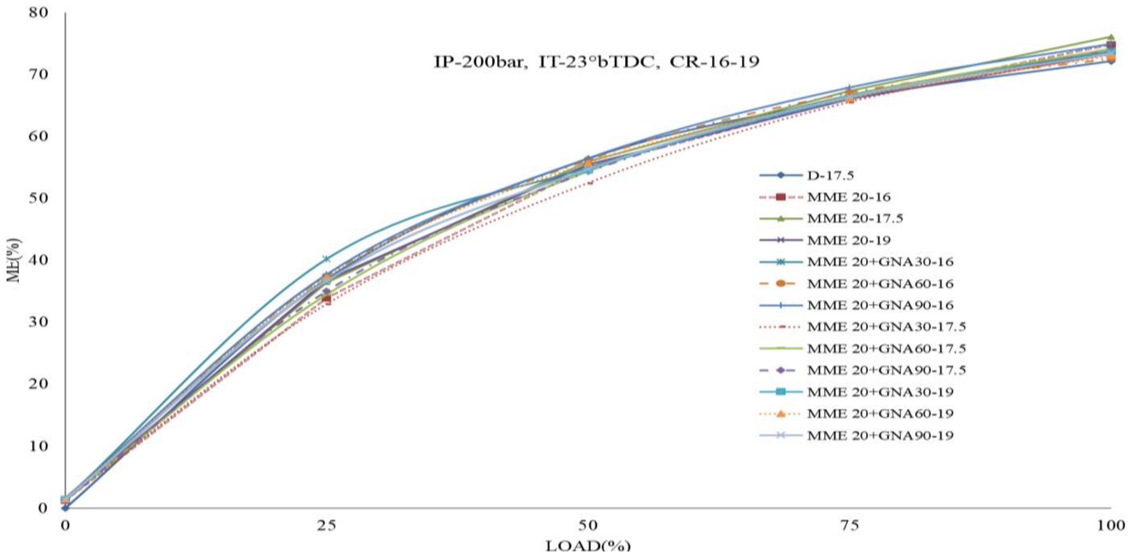

Fig 7.3 Variation of ME with respect to load for compression ratios 16, 17.5 and 19.

4. The effect of MME20-Graphene blends on Indicated Power (IP) at different compression ratios and varying loads.

The Indicated Power for different CRs, different proportions of blends and diesel are shown in the Figure. We know that Indicated power is the total power available from the expanding of gases in the cylinders nullifying the presence of any friction, heat loss or entropy within the boundaries of the system. It is seen that the IP is lower for all the blends when compared with diesel at varying loads and compression ratios. This is due to lower charge energy of various blend that reduces the volumetric efficiency of engine during induction stroke. When compared with the IP of diesel i.e 7KW the IP of the blend (MME 20+GNA60) at CR 19 we can see a similarity for 95.72% of the values at full operating load and has the highest IP compared to the remaining lot. It has been seen that for CR 16 and 19, the fuel blend (MME 20) when compared with graphene nano additive blends (MME 20+GNA30) and (MME 20+GNA60), the IP has increases by 1.52% & 1.21% for CR16 and 0.30% & 0.75% for CR19, whereas for blend (MME20+GNA90) the value decreases by a certain percentage.

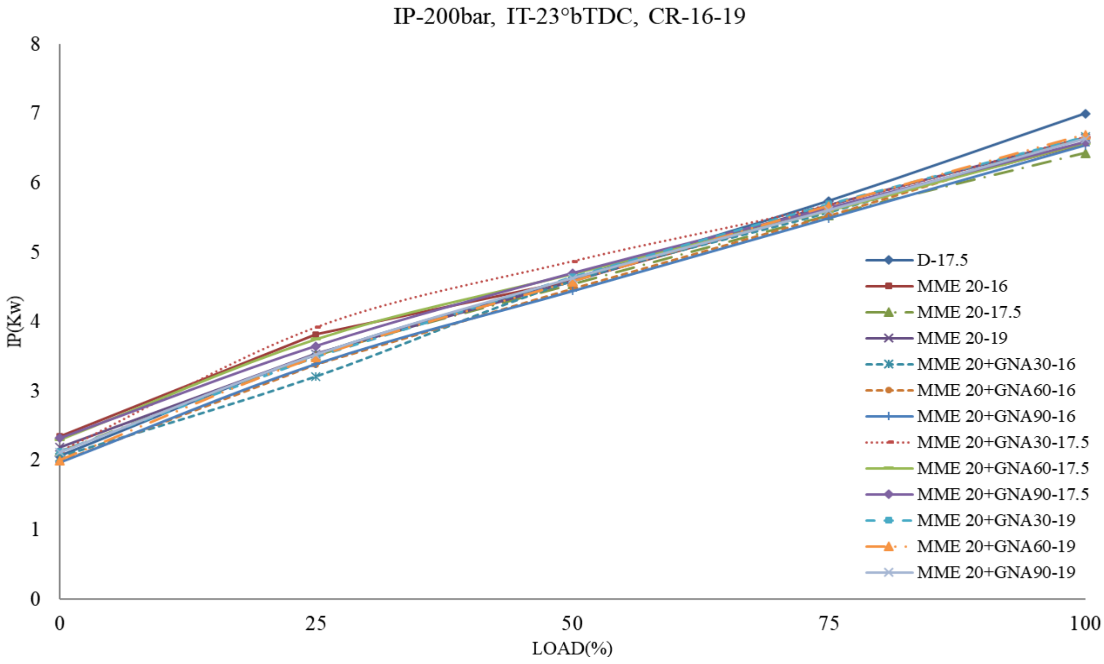

Fig 7.4 Variation of IP with respect to load for compression ratios 16, 17.5 and 19.

5. The effect of MME20-Graphene blends on Break Specific Fuel Consumption (BSFC) at different compression ratios and varying loads.

Figure shows the variation of BSFC with respect to load for compression ratios 16, 17.5 and 19 for different proportions of blends and for standard diesel. BSFC is defined as the mass of fuel consumed per hour for per kg of brake power produced. At low load conditions the BSFC is higher for all the fuel blends but as the load increases, BSFC starts decreasing and this is because at higher loads there is an increase in temperature inside the engine cylinder and at such a high temperature the viscosity of the fuel decreases which causes proper atomization of fuel and also along with this, at higher load the brake power produced by engine increases and hence BSFC decreases.[10] It can be seen that the BSFC of pure blends increases by a percentage of 3.84%, 11.53% and 11.53% when compared with that of diesel at CR 16, 17.5 and 19. At CR 17.5 the BSFC of the nano additive blends when compared with pure blend decreased by 3.44%, this is because nanoparticle enhances the air–fuel mixing, micro explosion of fuel droplets, and secondary atomization which results in lower BSFC Blends. Blends (MME20-GNA30 GNA60 &GNA90) for CR 16 and 17.5 along with blends MME 20 GNA30 at CR19 show a constant and lower BSFC when compared to other blends amongst the lot. A similar reduction in BSFC has been reported in various nano additive varied biodiesel were tested [41,42].

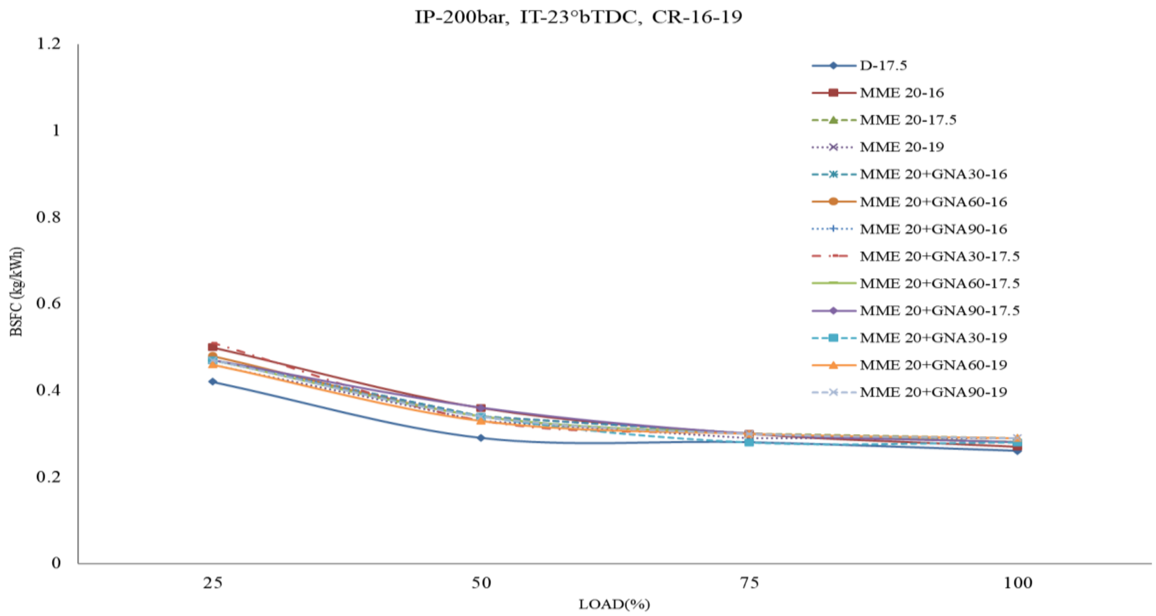

Fig 7.5 Variation of BSFC with respect to load for compression ratios 16, 17.5 and 19.

6. The effect of MME20-Graphene blends on Volumetric Efficiency (VE) at different compression ratios and varying loads.

Figure shows the variation of VE4 with respect to load for compression ratios 16, 17.5 and 19 for different proportions of blends and for standard diesel. The volumetric efficiency represents the efficiency of a compressor cylinder to compress gas. It can be seen that the values of VE of blends at CR 17.5 and 19 have lower values compared to that of the Std diesel by percentage of 0.98% and 2.122% for pure blends. There can be seen a 0.55% and 0.52% increase in the efficiency values for blends MME20 AND MME20-GNA30 for CR 16 when compared with diesel at fully operating load.

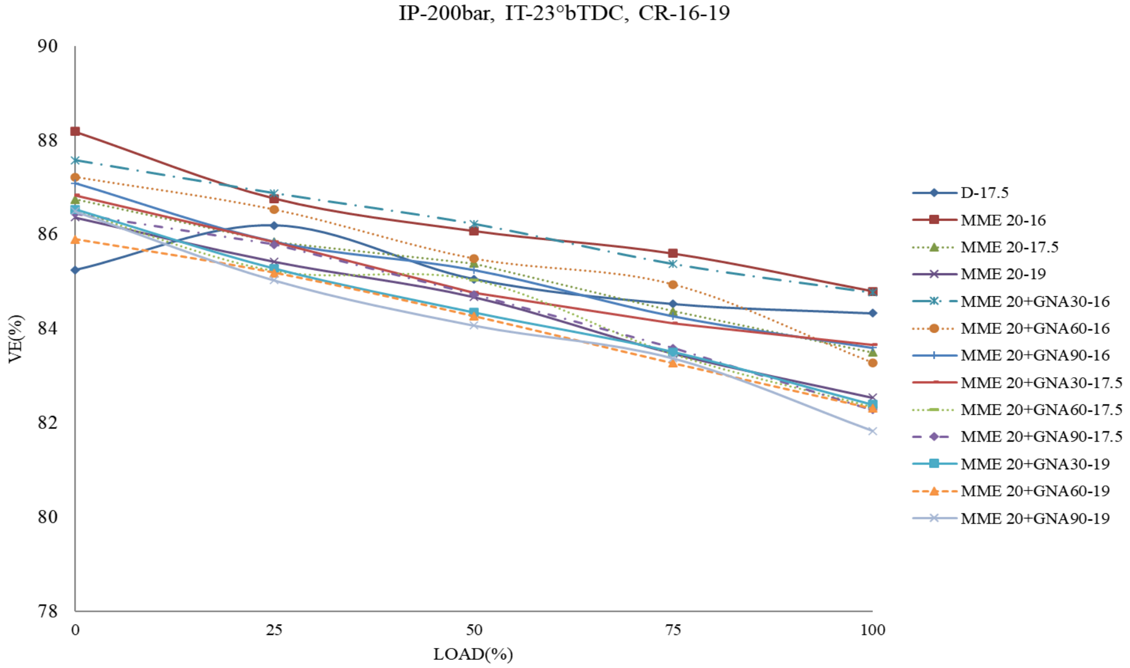

Fig 7.6 Variation of VE with respect to load for compression ratios 16, 17.5 and 19.

7. The effect of MME20-Graphene blends on Estimated Gas Temperature (EGT) at different compression ratios and varying loads.

The Estimated Gas Temperature for different CRs, different proportions of blends and diesel are shown in the Figure. During combustion the temperature of exhaust gases from the engine cylinder, shows the extent of temperature reached inside the cylinder, with increase in load on engine the cylinder pressure increases and more of the fuel is burnt leading to an increase in temperature. It can be seen that the values of EGT for the fuel blends when compared with diesel have increased when operating at full load and it is due to its lower cetane number which leads to longer ignition delay of biodiesel which contributes as slower burn rate and higher exhaust gas temperature. Amongst those blends, the values of MME 20-17.5 and MME 20+GNA30-17.5, have the least exhaust gas temperature of about 413^{O}C and 414^{O}C that are very close to that of the EGT of the diesel. The temperature for all the remaining blends with higher values of EGT is because of its high calorific value and hence more amount of heat is released in the combustion chamber leading to higher temperature released in the combustion. chamber leading to higher temperature [42]

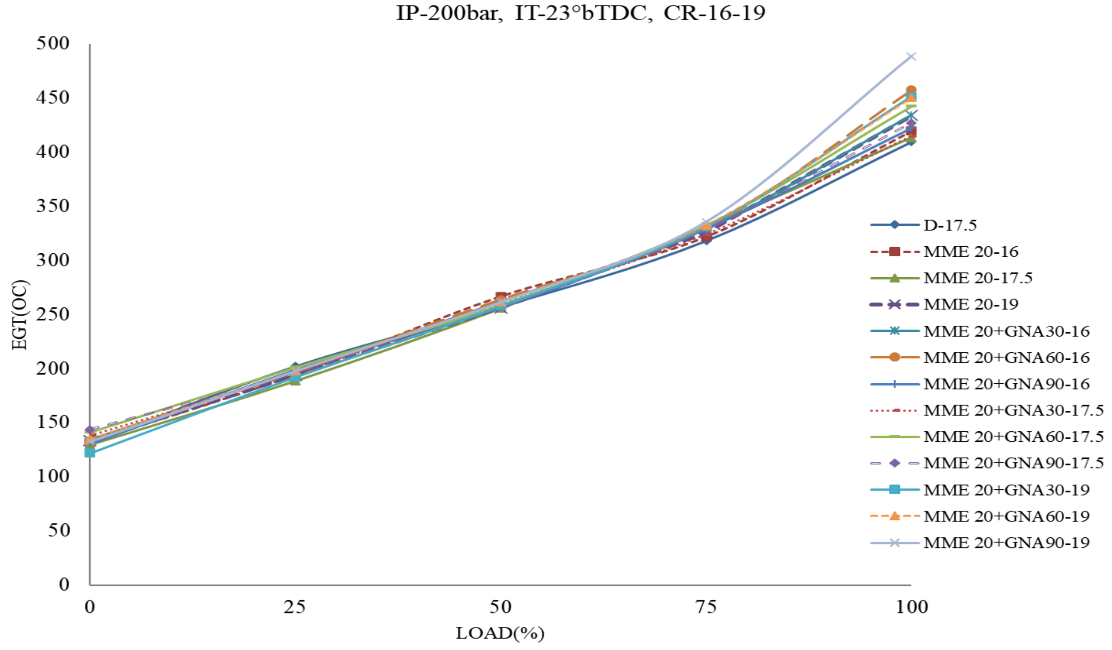

Fig 7.7 Variation of EGT with respect to load for compression ratios 16, 17.5 and 19

7.1.2 The effect of Graphene as a nano additive and blends of Moringa biofuel on combustion attributes.

1. **The effect of MME20-Graphene blends on combustion pressure at different compression ratios and varying loads.**

Figure shows the variation of combustion pressure with respect to crank angle for compression ratios 16, 17.5 and 19, for different proportions of blends and for standard diesel. As we can see the values vary slightly and are almost similar for each compression ratio. At compression ratio 16 the maximum combustion pressure is seen to be 63.36 bar for fuel MME 20+GNA30 and this is due to longer ignition delay which leads to more amount of fuel admitted in cylinder. The same trend follows with CR 17.5 and 19, the combustion pressures are maximum for the blend MME20+GNA30. When compared with Std diesel the combustion pressures are lower for the blends at CR 16 and 17.5, this is due to the intense pre combustion phase of diesel which has resulted in high pressure rise, as more fuel is accumulated during the delay period. The decrease in combustion pressure for blend MME 20+GNA30 at CR 16 and 17.5 are 13.99% and 5.30% when compared with diesel. The highest combustion pressure is obtained for the same blend at CR 19 is 75.69 bar, i.e. 2.741% more when compared with diesel. Due to the increase in flash and fire point of this particular blend may have led to a shorter ignition span that proposed an increase in the combustion pressure [42]

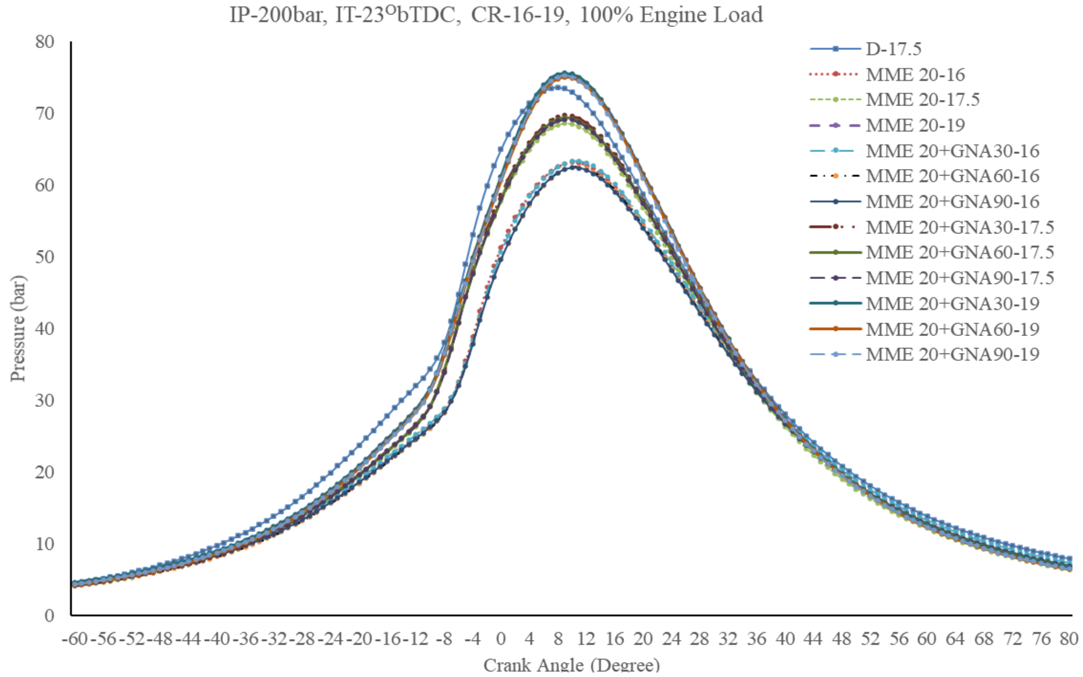

Fig 7.8 Variation of combustion pressure with respect to crank angle for compression ratios 16, 17.5 and 19.

Table 7.1 Maximum Combustion Pressure Values

Parameters	D-17.5	MME 20-16	MME 20 -17.5	MME 20-19	MME 20 +GNA30-16	MME 20 +GNA60-16	MME 20 +GNA90-16	MME 20 +GNA30-17.5	MME 20 +GNA60-17.5	MME 20 +GNA90-17.5	MME 20+GNA 30-19	MME 20 +GNA60-19	MME 20 +GNA90-19
Start of injection	-23	-23	-23	-23	-23	-23	-23	-23	-23	-23	-23	-23	-23
Start of Combustion	-8	-6	-10	-10	-6	-6	-6	-10	-10	-10	-11	-10	-10
Maximum Combustion Pressure/ Crank Angle	73.67/8°	63.21/10°	68.61/9°	75.47/9°	63.36/11°	62.54/11°	62.46/10°	69.76/9°	69.42/9°	69.2/9°	75.69/9°	75.08/9°	75.26/9°

2. The effect of MME20-Graphene blends on pressure rise at different compression ratios and varying loads.

Figure shows the variation of pressure rise with respect to crank angle for compression ratios 16, 17.5 and 19 for different proportions of blends and for standard diesel. The results obtained were thus of a higher percentage value when compared with pure diesel. At CR16 the maximum pressure rise was seen for blend MME20+GNA30 i.e. 14.67% higher when compared with diesel. A similar pattern of increase in the pressure rise was seen with increase in compression ratio. As the percentage of nano additive increased the pressure rise increased compared to diesel. The pressure rise seen for diesel, MME20, MME20+GNA30ppm, 60ppm and 90ppm for CR17.5 were 2.18, 2.14, 2.19, 2.24, 2.20. There was a 2.75% increase in pressure rise for the blend MME20+GNA60 at CR 17.5 compared to diesel and was due to higher cetane number of biodiesel which tend to lower ignition delay period of biodiesel blends than base diesel. The maximum pressure rise amongst all blends of biodiesel was seen for blend MME20+GNA90 i.e. 2.73 bar which is 25.22% more compared to the Std diesel value and 21.88% more when compared with pure biodiesel at CR 17.5.

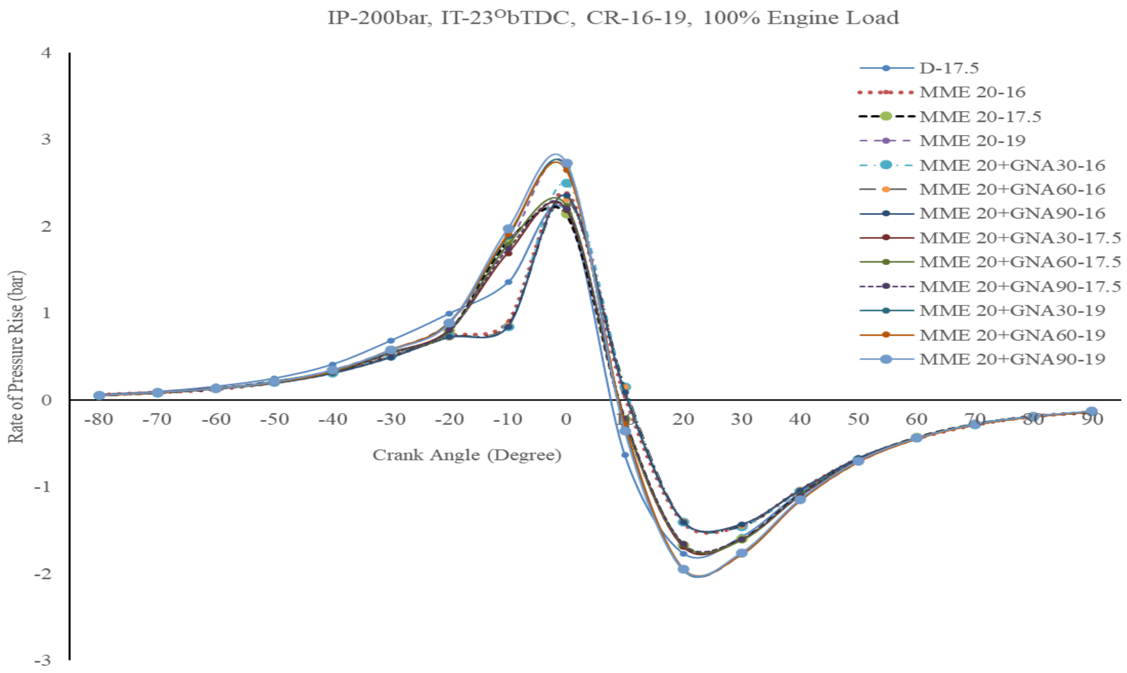

Fig 7.9 Variation of pressure rise with respect to crank angle for compression ratios 16, 17.5 and 19.

3. **The effect of MME20-Graphene blends on Net Heat Release Rate (NHRR) at different compression ratios and varying loads**

The HRR with respect to CA for different CRs and for different proportions of blends and standard diesel is shown in Figure. The first law of thermodynamics is used to evaluate the heat release rate (HRR). The experimental results showed that NHRR was the highest for diesel i.e., 36.66 J/deg. This recorded result was due to accumulation of fuel in the cylinder due to long delay. At CR 17.5 the NHRR observed for the following blends MME20, MME20+GNA30ppm, 60ppm and 90ppm were 29.5, 31.47, 29.62, 30.28 J/deg and a decrease of 14.15% can be seen when compared with diesel. The NHRR of all the blends have values below the reference line and this is because of the heat generated in the previous cycle during the compression stroke There can be seen a slight decrease in the NHRR when the CR is increased and is due to the air entrainment and lesser air-fuel mixing in combustion chamber. The maximum heat release rate for biodiesel blends were less compared with pure biodiesel. It is also observed that the HRR obtained for MME20 is lower than that of standard diesel due to shorter ignition delay. [42,43]

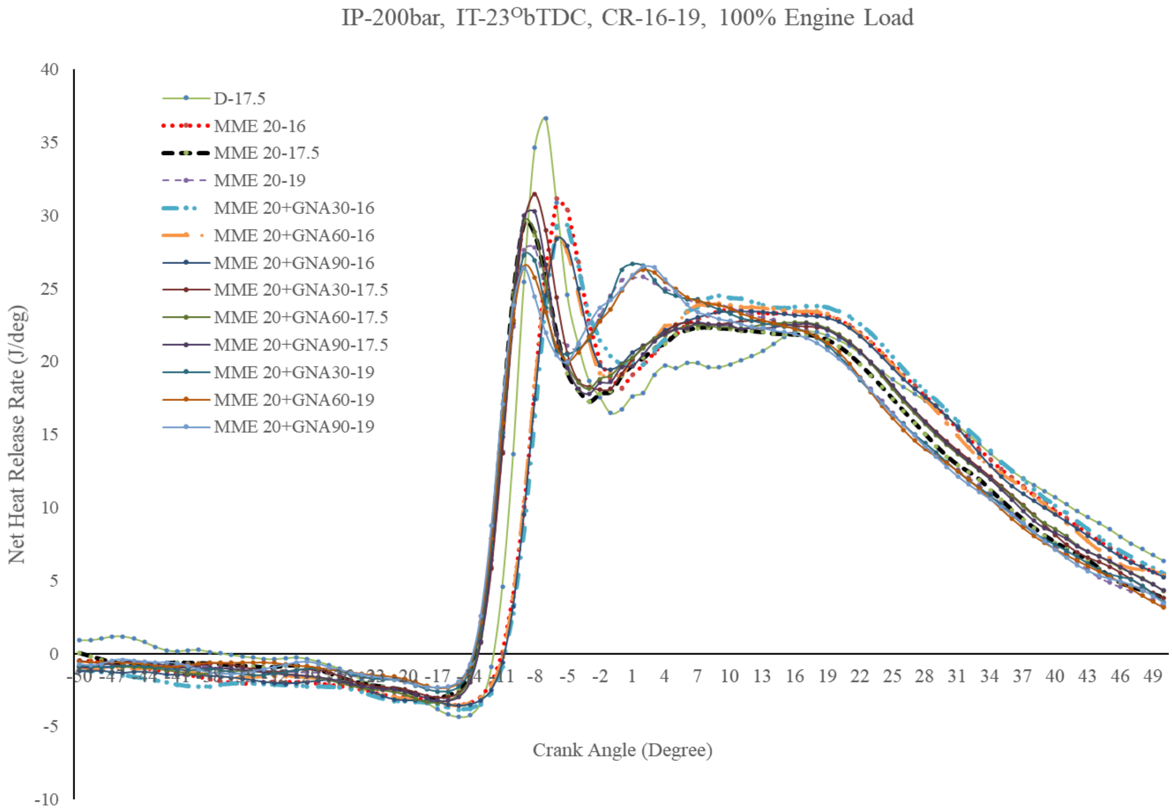

Fig. 7.10 Variation of Net Heat Release Rate (NHRR) wrt crank angle for compression ratios 16, 17.5 and 19.

4. The effect of MME20-Graphene blends on Mass Fraction Burn (MFB) at different compression ratios and varying loads.

The mass fraction burned with respect to crank angle for different CRs, different proportions of blends and diesel are shown in the Figure. It can be seen that the MFB for blends all the blends at CR16 occurs at 2^{O}CA, 3^{O}CA, 3^{O}CA & 2^{O}CA later than MFB of the diesel, and at approximately 2^{O}CA, 2^{O}CA, 2^{O}CA & 1^{O}CA later than standard condition (Blends of biodiesel at CR 17.5) at 50% load. 75% of MFB occurs at 2^{O}CA, 0^{O}CA, 2^{O}CA & 2^{O}CA earlier than Std diesel conditions and at approximately 2^{O}CA earlier than standard condition for CR 19. And 90% of MFB is seen to occur at more or less the same CA for all blends and CR's. From the results inferenced it can be noted that, early MFB occurred at high CR, and this might be due to shorter ignition delay and high flame temperature in the combustion chamber at high CR's and therefore causing early burning of charge. The highest mass fraction burned is found at CR

16 due to supplementary oxygen content of blends and thereby sustaining the combustion.[42,43]

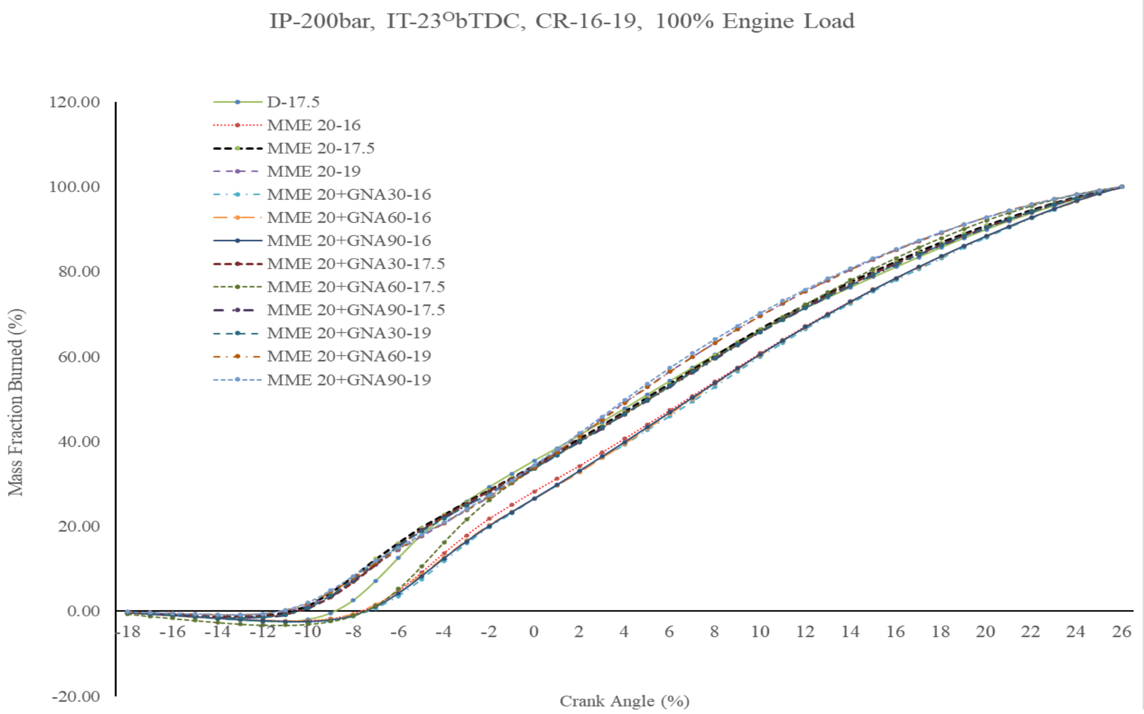

Fig 7.11 Variation of Mass Fraction Burn (MFB) wrt crank angle for compression ratios 16, 17.5 & 19

5. The effect of MME20-Graphene blends on Cumulative Heat Release Rate (CHRR) at different compression ratios and varying loads.

The Cumulative Heat Release Rate with respect to crank angle for different CRs, different proportions of blends and diesel are shown in the Figure. An increase in CHRR can be seen as the CR increases at 100% engine load. The CHRR of blends MME20, MME 20+GNA30, MME 20+GNA60, MME 20+GNA90, are found to be 1.20, 1.22, 1.19, 1.18 for CR16 & 1.18, 1.22, 1.21, 1.21, for CR17.5 & 1.24, 1.24, 1.23, 1.23 for CR19, at 100% loading conditions. From the experimental results obtained it can be inferred that a 5.08% increase in CHRR is obtained for blends MME20 and MME 20+GNA30 at CR19, when compared with Std diesel condition and a 5.08% and 1.64% increase when compared to blends at Std 17.5CR at fully operating load conditions. This increase in trend might be due to complete combustion because of improved mixing of charge and less ignition delay for varied CR.

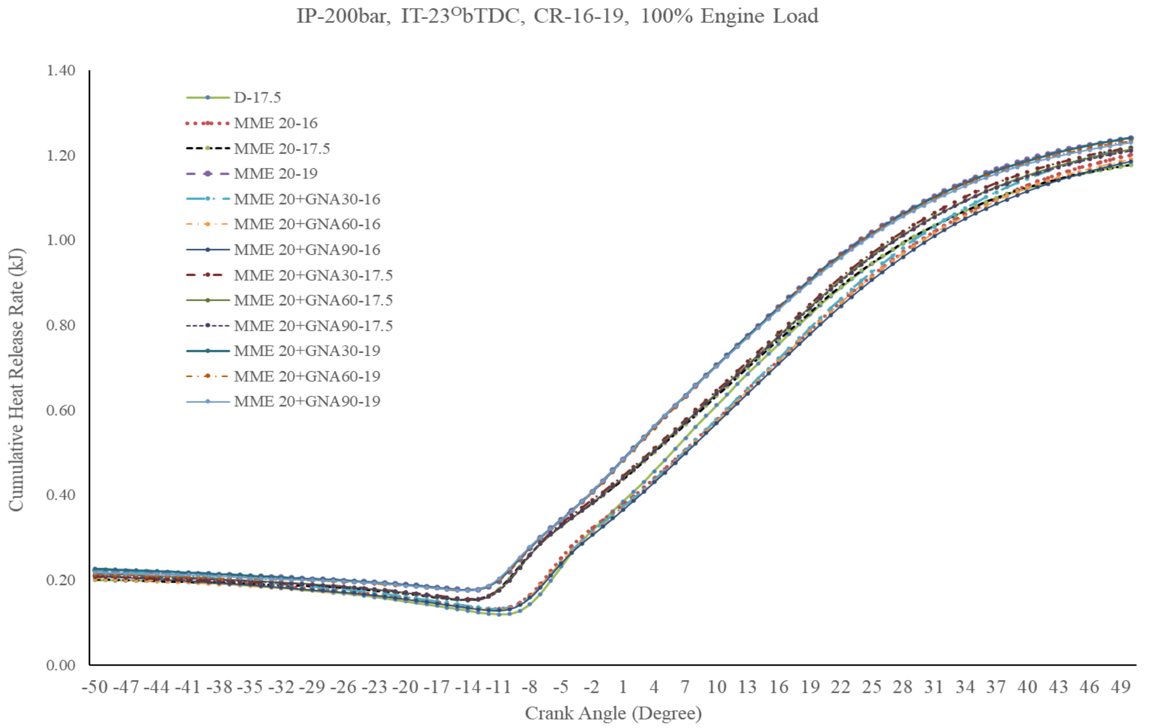

Fig 7.12 Variation of Cumulative Heat Release Rate wrt crank angle for compression ratios 16, 17.5 & 19.

6. The effect of MME20-Graphene blends on Ignition Delay at different compression ratios and varying loads.

Ignition delay period of a diesel engine is the time period between the start of injection and start of combustion. The ignition delay period when taken into account that of diesel engines, it is the period from the first charge of fuel entering the combustion chamber to the period when the first flame propagates (). Figure shows that the ignition delay period reduces with an increase in the load and CR due to a rise in the pressure and temperature for all the fuel blends. A shorter ignition delay period is obtained because of the rise in pressure which results in the mixture of molecules coming closely together, enhancing the chemical reactions due to the active collisions of molecules. For the experimental results it can be seen that the ID period for blends (MME20-GNA30), (MME20-GNA60), (MME20-GNA90) for both CR 17.5 and 19 have drastically reduced by 13.33% and by 20% for (MME 20+GNA30-19) in particular, at 100% load. Graphene nanoparticles in the fuel blend results in a reduction in the ignition delay period due to enhancement of combustion rate and better premixed combustion phase.[10]

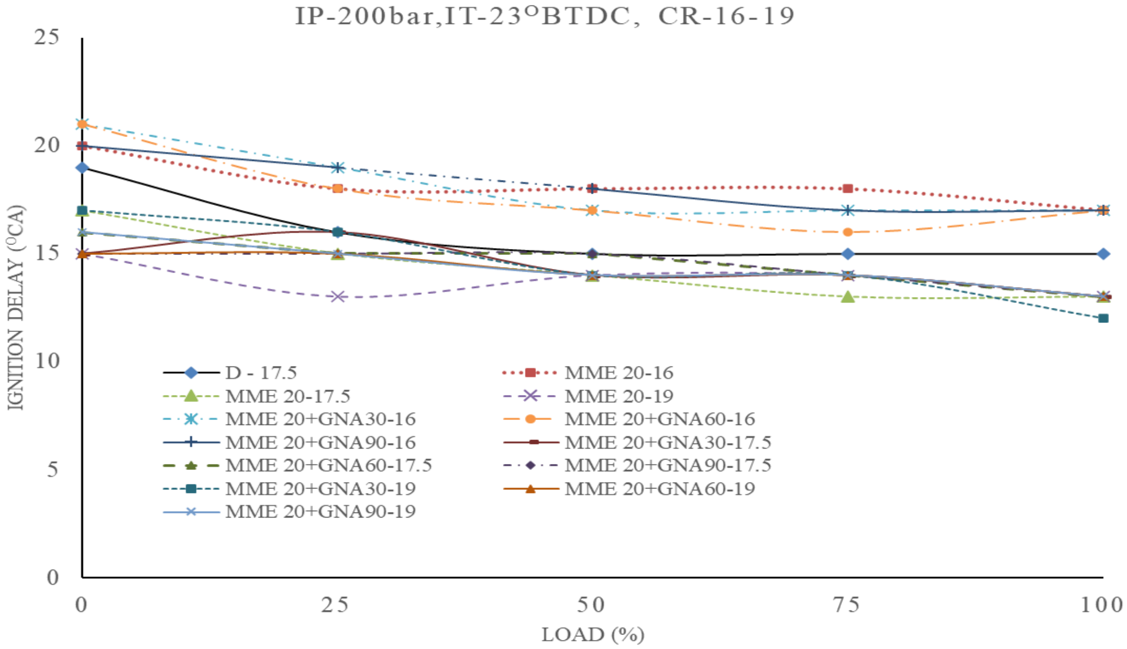

Fig 7.13 Variation of Ignition Delay (ID) with respect to crank angle for compression ratios 16, 17.5 & 19

Table 7.2 Ignition Delay Values

Load	Parameters	D-17.5	MME 20-16	MME 20 - 17.5	MME 20-19	MME 20 +GNA30-16	MME 20 +GNA60-16	MME 20 +GNA90-16	MME 20 +GNA30-17.5	MME 20 +GNA60-17.5	MME 20 +GNA90-17.5	MME 20+GNA30-19	MME 20 +GNA60-19	MME 20 +GNA90-19
25	Start	-23	-23	-23	-23	-23	-23	-23	-23	-23	-23	-23	-23	-23
	End	-8	-6	-9	-11	-6	-6	-5	-8	-9	-9	-8	-9	-9
	Ignition Delay	16	18	15	13	18	18	19	16	15	15	16	15	15
50	Start	-23	-23	-23	-23	-23	-23	-23	-23	-23	-23	-23	-23	-23
	End	-9	-6	10	10	-7	-7	-6	10	-9	-9	10	10	10
	Ignition Delay	15	18	14	14	17	17	18	14	15	15	14	14	14
75	Start	-23	-23	-23	-23	-23	-23	-23	-23	-23	-23	-23	-23	-23
	End	-9	-6	-11	10	-7	-8	-7	10	10	10	10	10	10
	Ignition Delay	15	18	13	14	17	16	17	14	14	14	14	14	14
100	Start	-23	-23	-23	-23	-23	-23	-23	-23	-23	-23	-23	-23	-23
	End	-9	-7	-11	-11	-7	-7	-7	-11	-11	-11	-12	-11	-11
	Ignition Delay	15	17	13	13	17	17	17	13	13	13	12	13	13

7. The effect of MME20-Graphene blends on Combustion Duration (CD) at different compression ratios and varying loads.

The Combustion Duration with respect to load for different CRs, different proportions of blends and diesel are shown in the Figure. Combustion duration is the one which gives the value of how much duration it took for the complete combustion of fuel. Combustion duration gives the value of time period it took for compete combustion, and it also is defined as the crank angle rotation period between start and end of combustion. From the results obtained it can be clearly observed that the CD increases with both increase in load and compression ratio. Std diesel has the least value for combustion duration and this is because of more ignition delay period of the diesel which in turn leads to more fuel accumulating into the cylinder, and hence the total fuel is ready for atomization along with proper mixing. A 17.65% increase in CD has been obtained for blends (MME20), (MME20-GNA60), & (MME20-GNA90), for compression ratios 17.5 and 19, when compared with diesel at fully operating load. This bares a reason i.e. the latent heat of vaporization is more for biodiesel compared to diesel, hence biodiesel takes more time to get vaporized which leads to longer combustion duration compared to diesel. A percentage increase of 23.53% is seen for blend (MME 20+GNA30) at compression ratio 19 when compared with diesel at 100% load.[44]

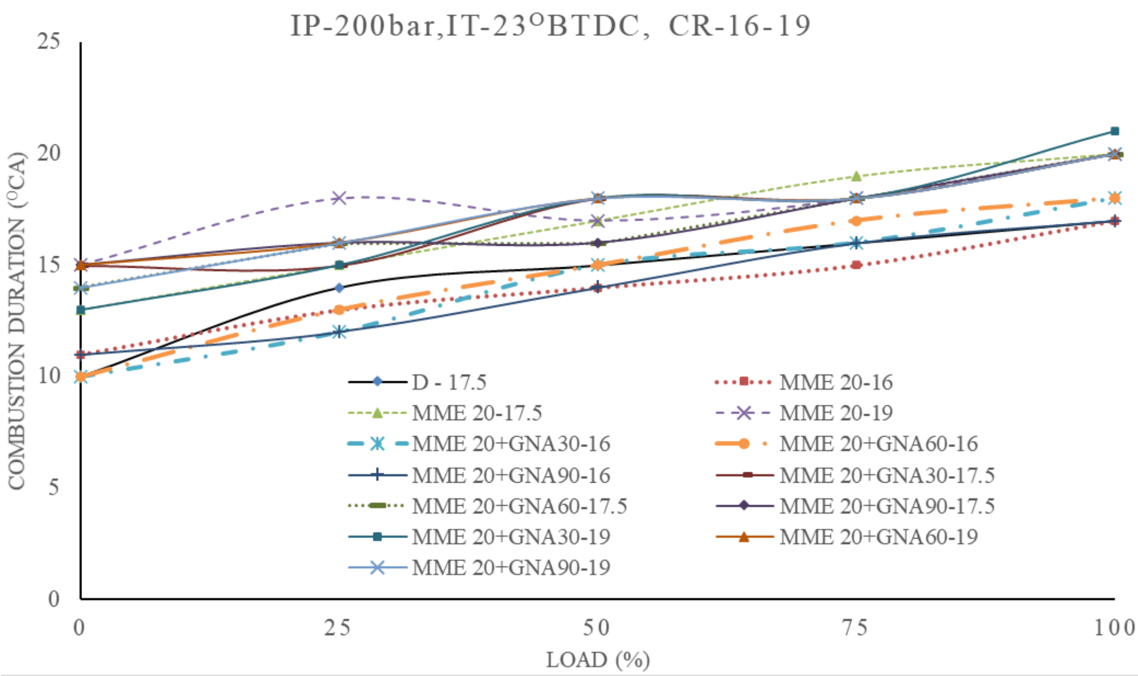

Fig 7.14 Variation of Combustion Duration (CD) wrt crank angle for compression ratios 16, 17.5 & 19

Table 7.3 Combustion Duration Values

Load	Parameters	D-17.5	MME 20-16	MME 20 -17.5	MME 20-19	MME 20 +GNA30-16	MME 20 +GNA60-16	MME 20 +GNA90-16	MME 20 +GNA30-17.5	MME 20 +GNA60-17.5	MME 20 +GNA90-17.5	MME 20+GNA 30-19	MME 20 +GNA60-19	MME 20 +GNA90-19
25	Start	-7	-5	-8	-10	-5	-5	-4	-7	-8	-8	-7	-8	-8
	End	6	7	6	7	7	7	7	7	7	7	7	7	7
	Combustion Duration	14	13	15	18	12	13	12	15	16	16	15	16	16
50	Start	-8	-5	-9	-9	-6	-6	-5	-9	-8	-8	-9	-9	-9
	End	6	8	7	7	8	8	8	8	7	7	8	8	8
	Combustion Duration	15	14	17	17	15	15	14	18	16	16	18	18	18
75	Start	-8	-5	-10	-9	-6	-7	-6	-9	-9	-9	-9	-9	-9
	End	7	9	8	8	9	9	9	8	8	8	8	8	8
	Combustion Duration	16	15	19	18	16	17	16	18	18	18	18	18	18
100	Start	-8	-6	-10	-10	-6	-6	-6	-10	-10	-10	-11	-10	-10
	End	8	10	9	9	11	11	10	9	9	9	9	9	9
	Combustion Duration	17	17	20	20	18	18	17	20	20	20	21	20	20

7.1.3 The effect of Graphene as a nano additive and blends of Moringa biofuel on Emission attributes.

1. **The effect of MME20-Graphene blends on Carbon Monoxide (CO) Emission at different compression ratios and varying loads.**

The variation in carbon monoxide emissions and the loads for fuel blends at different compression ratio is presented in Figure. Carbon monoxide emissions are produced due to incomplete combustion during the combustion phase. It can be seen from the experimental results that the blends (MME20), (MME20-GNA30), (MME20-GNA60), and (MME20-GNA90), at compression ratio 16 have a lesser rate of CO emission when compared with that of diesel by 10.50%, 18.29%, 2.72% and 18.29%, at fully operating load. This was due to higher temperature in combustion chamber thereby reducing ignition lag and complete combustion is achieved in cylinder. The blends among the various blends with the lowest CO emissions are (MME20-GNA30) and (MME20-GNA90) at CR 16 when compared with that of the Std diesel. The reduction in the CO emission was also due to the higher oxygen content and lower carbon to hydrogen ratio of the biodiesel which promotes the combustion process. [42,43]

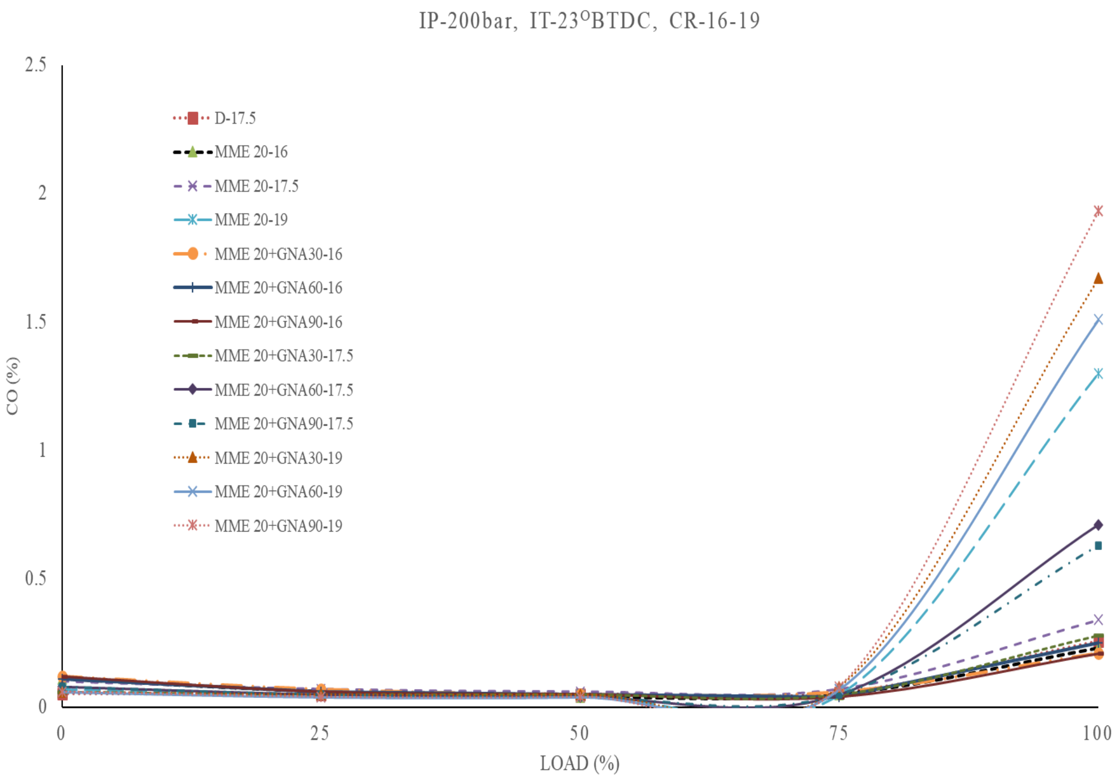

Fig 7.15 Variation of CO emission with respect to load for compression ratios 16, 17.5 and 19.

2. **The effect of MME20-Graphene blends on Hydrocarbons (HC) Emission at different compression ratios and varying loads.**

The emission of HC for different CRs and different proportions of fuel blends and for the standard diesel is found and shown in Figure. It is found from the experimental results that the emission of HC decreases with an increase in blend proportions and CRs. Fuel characteristics, fuel spray properties, and different engine operating conditions are those which mainly affected the HC emissions. As it was seen, the HC emissions reduced with increase in CR's for pure blend (MME20) by 18.37%, 20.40%, & 23.57%, when compared with diesel. A significant decrease in HC emissions were seen for blends (MME20-GNA30), (MME20-GNA60), & (MME20-GNA90) when compared to both pure blend and Std diesel. When compared to pure blend (MME20) the percentage decrease in HC emissions at CR16 was 20%, 15% & 20%, for all three nano additive blends. The higher emission of HC at lower CR is due to ignition delay and flame quenching in cylinder wall causing incomplete combustion of the fuel. A similar increase in HC emissions due to a lower compression ratio was reported. [43,45]

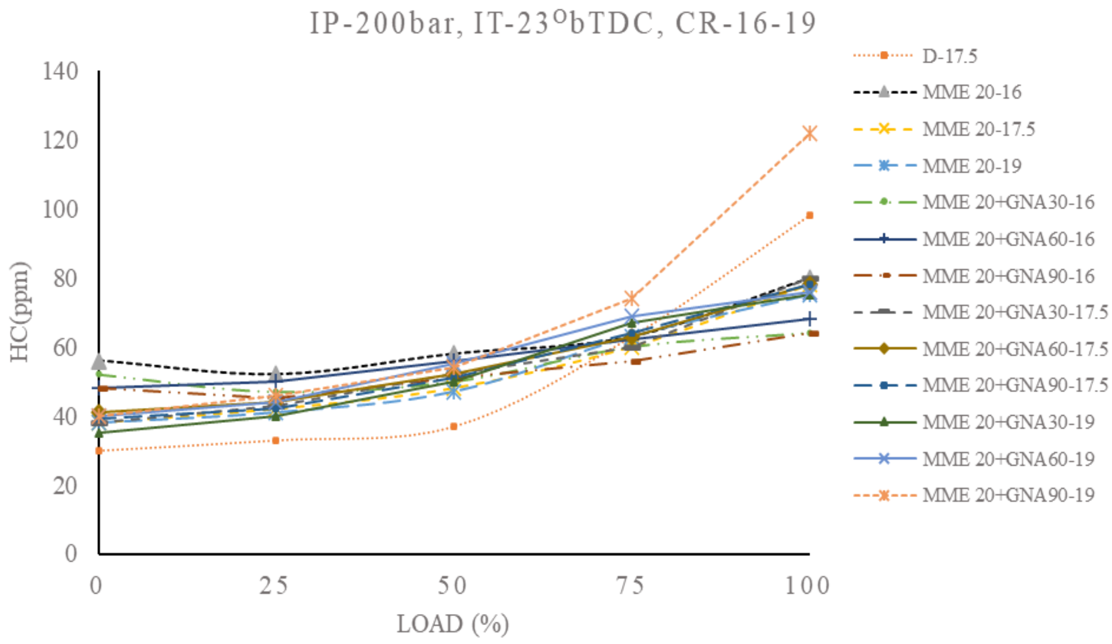

Fig 7.16 Variation of HC emission with respect to load for compression ratios 16, 17.5 and 19.

3. The effect of MME20-Graphene blends on Carbon Dioxide (CO2) Emission at different compression ratios and varying loads.

Figure show an increasing trend in CO2 emissions with increasing loading conditions and compression ratios. The carbon molecules from the fuel combustion combines with the oxygen to produce carbon dioxide emissions. For the compression ratio of 17.5, the nanofuel blend (MME 20+GNA30) has a lower value of carbon dioxide emissions due to complete fuel combustion and lower generation of carbon molecules post combustion process compared to that of diesel by 7.76% at fully operating load. When compared with diesel, the CO2 emission are at a slightly higher percentage for the blends of MME20, i.e. by 9.7%, 7.76%, & 13.5%, at CR 16, 17.5 & 19. The emissions that were produced by the blend (MME20-GNA30) at 17.5 CR has a lower emission rate because of the large surface area of Graphene nanoparticles enabling complete combustion of hydrocarbon molecule.

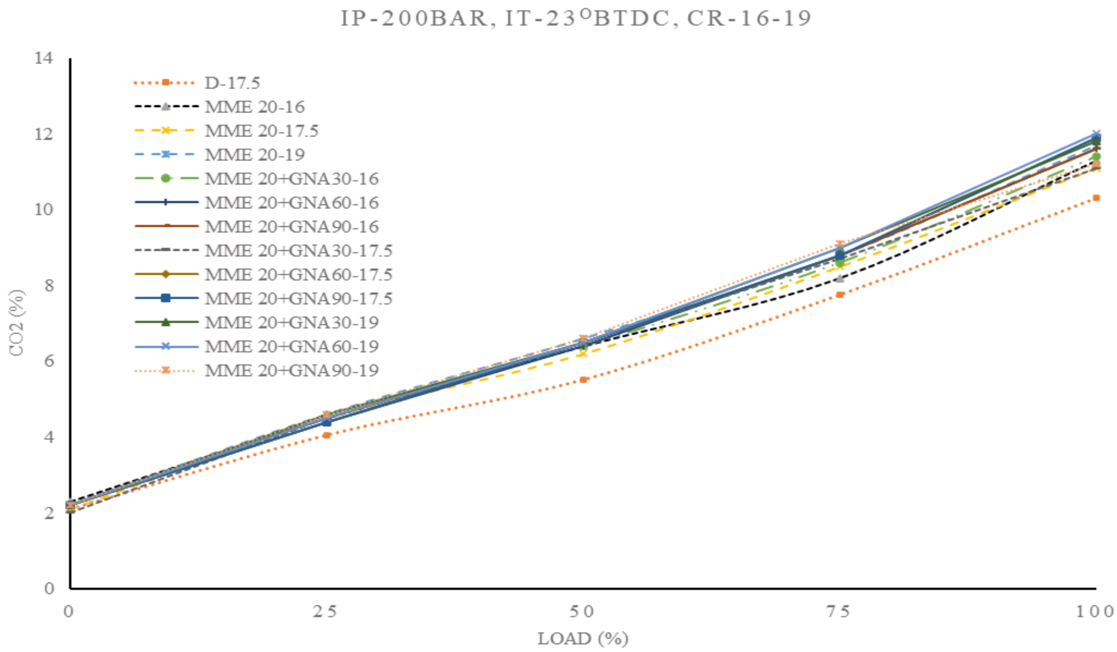

Fig 7.17 Variation of CO2 emission with respect to load for compression ratios 16, 17.5 and 19.

4. **The effect of MME20-Graphene blends on Oxygen (O2) Emission at different compression ratios and varying loads.**

Figure show a decreasing trend in O2 emissions with increasing loading conditions and compression ratios. As seen from the experimental results, the O2 emissions decrease as the compression ratio increases from 16 to 19. At CR 19, decrease in O2 emissions by 23.2% for pure blend when compared with that of diesel and a decreasing trend for nano blends at 30ppm, 60ppm, & 90ppm can be seen at percentages, 10.98%, 10.06%, & 42.1%, when compared with its pure blend, at fully operating load. MME20 and its nano additive blends at 30ppm, 60ppm, & 90ppm at CR19 when compared with CR 17.5, a percentage decrease of 25.3%, 36.33%, 17.6% & 47.75% in O2 emissions are obtained at fully operating engine load.

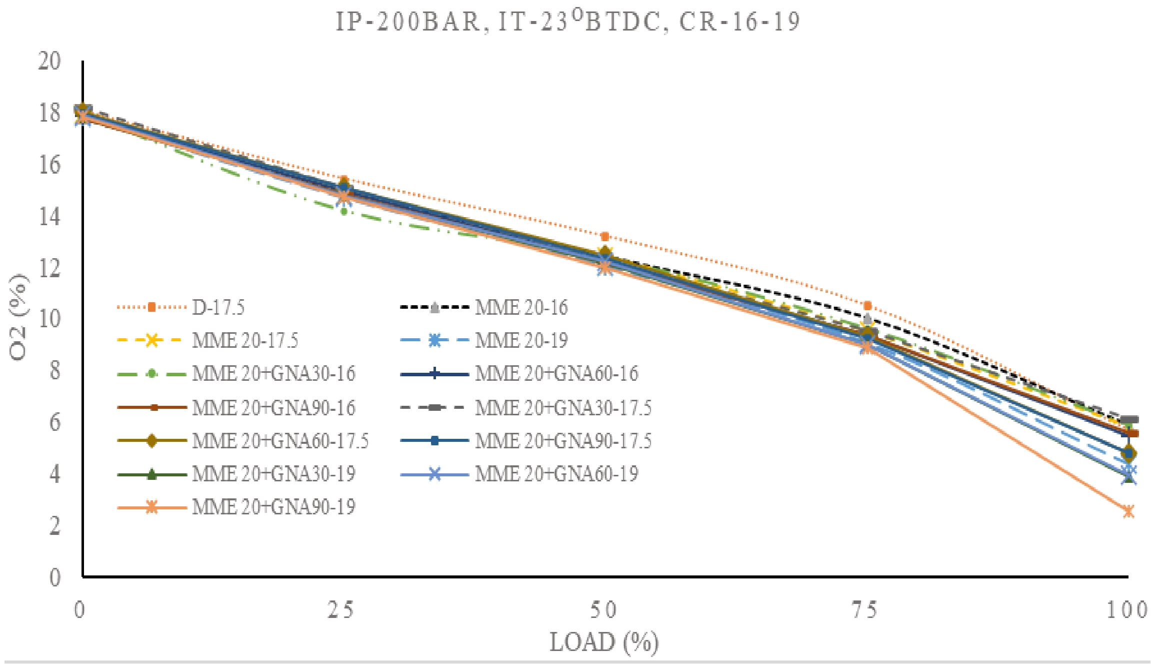

Fig 7.18 Variation of O2 emission with respect to load for compression ratios 16, 17.5 and 19.

5. **The effect of MME20-Graphene blends on Nitrogen Oxides (NOx) Emission at different compression ratios and varying loads.**

The emission of NOx for different CRs, different proportions of blends and for diesel are measured and shown in Figure. A decrease in the Emission of NOx can be seen from the experimental results. The fuel blends, (MME20-CR16), (MME20-CR19), (MME20-GNA30-CR16), (MME20-GNA60-CR16), (MME20-GNA90-CR16), (MME20-GNA30-CR19), (MME20-GNA60-CR19), (MME20-GNA90-CR19), & (MME20-GNA30-CR17.5), (MME20-GNA60-CR17.5), show a significant decrement in the NOx emissions by 8.51%, 16.55%, 8.88%,7.31%, 5.74%, 23.2%, 19.34%, 37.34%, 3.44%, & 2.47%, when compared with diesel at fully operating load. And this is because of the reduction of ignition lag which leads to better and complete combustion. This higher temperature is the cause for increase in the emission of NOX. There can be seen a increase in NOx emissions for pure blend at CR 17.5 by 0.36% when compared with diesel and it was because of increase in combustion temperature which results in better combustion of fuel. The increase in combustion temperature is due to the oxygen content of the biodiesel. [42,43]

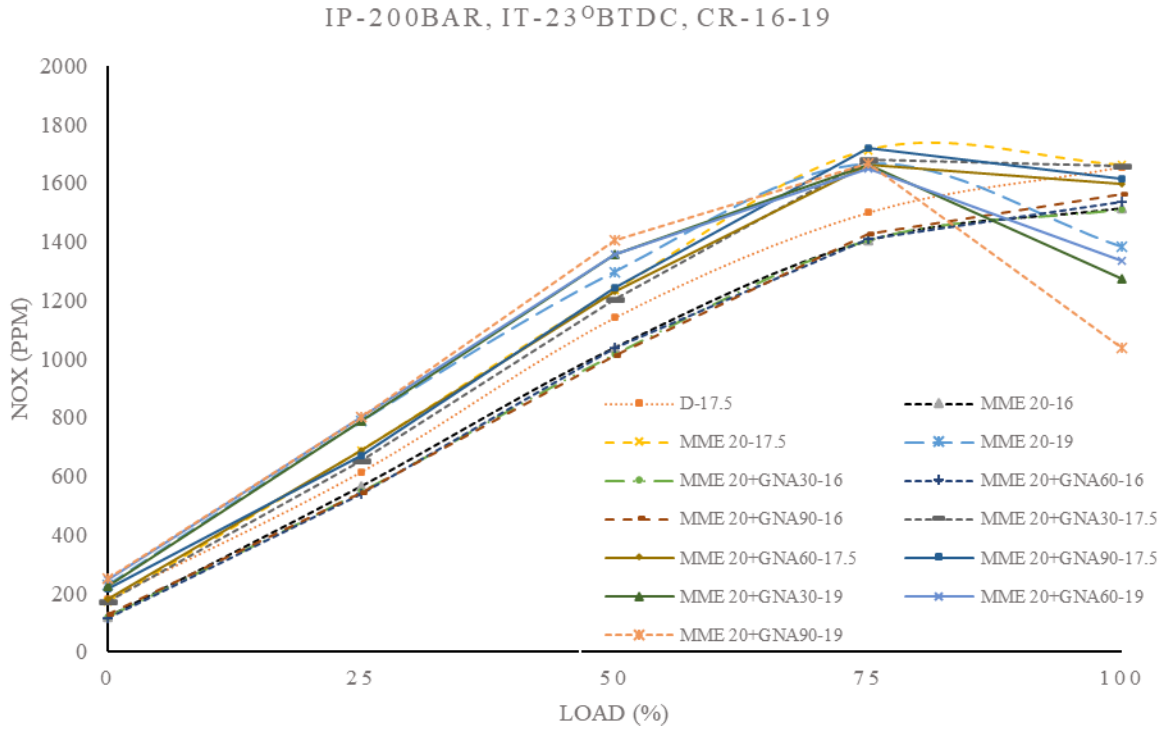

Fig 7.19 Variation of NOX emission with respect to load for compression ratios 16, 17.5 and 19.

6. **The effect of MME20-Graphene blends on Opacity at different compression ratios and varying loads.**

The smoke emissions i.e. the test for opacity for all tested fuels with variable loads and different compression ratios are illustrated in Figure. Incomplete combustion of hydrocarbon particles in the combustion chamber, a rich air-to-fuel mixture, and poor fuel vaporization are the basis of smoke emissions. From the experimental results it can be seen that the smoke emissions (Opacity test), have lowered by a significant percentage when compared with diesel at fully operating load. The pure blend at CR 16, 17.5 & 19 have lower smoke emission values i.e. by 3.46%, 3.33%, & 5% when compared with Std diesel. The biodiesel blends with Graphene nanoparticles improved the micro-explosion phenomenon and air-to-fuel mixing, leading to lower smoke emissions, i.e. the blends (MME20-GNA30-CR17.5), (MME20-GNA60-CR17.5), (MME20-GNA90-CR17.5), decreased by 1.46%, 2.38%, & 1.19%, when compared with (MME20-CR17.5). Graphene nanoparticles enhances the combustion process because of its large surface area resulting in complete fuel combustion. An increase in the compression ratio leads to better air-to-fuel mixing and increases the temperature during the compression stroke. In addition, an increase in the compression ratio reduces the dilution of the fuel charge by residual gases.[10]

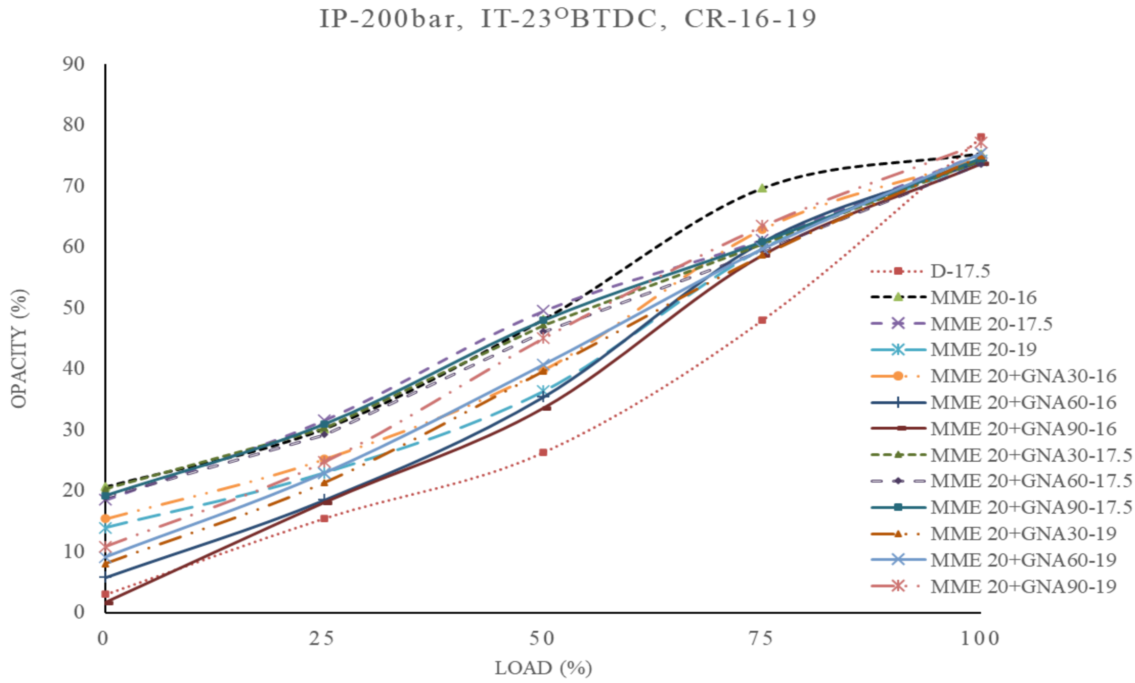

Fig 7.20. Variation of Opacity with respect to load for compression ratios 16, 17.5 and 19

Chapter 8

CONCLUSION

The present study focusses on the effects of Graphene Nanoparticles and Moringa Methyl Ester blends fueled at different loads and by varying the CRs on a Compression Ignition Engine. In the investigation, the engine was operated on different blends of fuel i.e. MME20, MME20 GNA30, MME20 GNA60 and MME20 GNA 90 at three compression ratios of 16, 17.5 and 19. The inferences drawn after the experimentation and comprehensive study of the fuel blends are

1) Influences on Combustion characteristics
   - The Combustion Pressure for the blend MME 20+GNA30 at CR 19 is 75.69 bar which is the highest for the fuels tested when compared with Diesel.
   - The Pressure rise for the blend MME20+GNA90 at CR 17.5 is 2.73 bar and is 25.22% higher than the Std Diesel value. Hence it is inferred that this has the highest pressure rise among all blends.
   - The Net heat release rate is found to be lower in all blends when compared to diesel. MME20+GNA30ppm at CR 17.5 has the highest NHRR i.e. 31.47J/deg among the blends and a decrease of 14.15% is seen when compared to Diesel which has 36.66 J/deg.
   - The Mass Fraction burnt is found to be the higher for all blends at CR16 when compared with MFB of Diesel i.e. 2^{o}CA, 3^{o}CA, 3^{o}CA & 2^{o}CA greater than the ^{o}CA of Diesel, which is due to the supplementary oxygen content of the blends which help in prolonged combustion.
   - The Cumulative Heat Release Rate of MME20 and MME 20+GNA30 at CR19 shows an increase of 5.08% when put into comparison with the Std Diesel which is the highest percentage increase among all other blends.
   - The Ignition Delay for the blend is found to be the lowest for MME 20+GNA30 at CR 19 in comparison to Diesel as the ID has decreased by 20%.
   - The Combustion Duration is the longest for the blend MME 20+GNA30 at CR 19 and 100% load. A 23.53% increase in CD was recorded for this blend when compared with Diesel.

2) Influences on Performance characteristics
   - The BTHE of all fuel blends were lower in comparison with Diesel at different CRs and Loads. The BTHE value MME20 at CR 16 has the highest efficiency among all the blends.
   - The ITHE of all fuel blends were lower in comparison with Diesel at different CRs and Loads. The ITHE value MME20 GNA30 at CR 19 is the highest among all the blends as it showed an increase by 3.68%.
   - The ME of MME20 showed the highest increase in comparison to Diesel by 5.472% which was greater than all the other fuel blends.
   - The IP was evidently highest for the blend MME 20+GNA60 at CR 19 and at full load in comparison with Diesel. There is similarity observed for around 95.72% of the values which is greater than the rest of the blends.
   - The BSFC of blends MME20-GNA60 &GNA90 at CR 19 showed a constant BSFC compared to other pure blends.
   - The VE of the blends MME20 and MME20-GNA30 at CR16 saw an increase by values 0.55% and 0.52% in comparison to diesel at full loads.
   - The EGT values of MME 20 at CR17.5 and MME 20+GNA30 at CR17.5 showed the least temperatures of 413^{O}C and 414^{O}C respectively which is found to be very close to the EGT values of Diesel.
3) Emission characteristics
   - The CO emissions for MME20-GNA30 and MME20-GNA90 at CR 16 was lesser by 18.29% for both the blends when compared with the values of Diesel, as higher Oxygen content in the blends aided in complete combustion process.
   - The HC emissions decreased for all blends when compared with values of diesels at both 16 & 17.5 CRs. For blends MME20 GNA 30 and 90 for CR 16 has reduced by 34.70% for both and thereby can be regarded as the best fuel blend amongst the lot for reduced HC emissions.
   - The CO2 emissions for MME 20+GNA30 at CR 17.5 was lesser than 7.76% of that of Diesel is the least of the lot when operating at full load as the large surface area of GNA enabled complete combustion
   - The O2 emissions was the least in MME20 GNA90 at CR19 as it showed a decrease of 47.75% when compared to nano blend at CR17.5 and 42.1% decrease when compared to pure blend at CR19.

- The NOx emissions of the blend MME20-GNA90-CR19 decreased by a significant percentage of 37.34 which was the highest decrement in emissions of all the blends
- The opacity values for most of the blends showed a decrease in emission values when compared to diesel. The pure blends at CRs 16, 17.5 and 19 showed a decrease in values of emissions by 3.46%, 3.33% and 5% respectively. Also taking into account the blends MME20-GNA30-CR17.5, MME20-GNA60-CR17.5 and MME20-GNA90-CR17.5 when compared to the Pure blend at CR 17.5 exhibits a decrease in harmful emission by 1.46%, 2.38% and 1.19%.

From the above observations, we can substantiate that the performance of the Moringa Methyl Ester Graphene Nano Additive 30ppm at Compression Ratio 19 (MME20-GNA30-CR19) blend is better when compared with the conventional standard diesel. The results and conclusion validate that Graphene nanoparticles in Moringa Methyl Ester biodiesel at CR enhance performance and combustion, and reduce the emissions of Compression Ignition engine. The experimental result reveals that MME20-GNA30-CR19 can be used as a substitute for the conventionally used Diesel fuel.

FUTURE WORK

1. Present work can be further extended to use biodiesel in various types of engines such as V6, V8 and V12 used in Sport vehicle for in-depth analysis of the fuel blends.
2. To further enhance the engine characteristics the Nano Additive blends can be varied proportionally in order to obtain fuel blend

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This is to certify that Mr./Ms. SHREYAS. NAGARAJ

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