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Evaluation of CI Engine Performance, Emissions, and Combustion Characteristics Using Corn Biofuel Blend with Divergent Cr's and Exhaust Gas Recirculation

ADITYA JHA

Guide: Dr Basanta Kumar Palai
Associate Professor

DEPARTMENT OF MECHANICAL ENGINEERING

GIET UNIVERSITY, GUNUPUR-765022

ABSTRACT

This thesis investigates the potential of corn oil biodiesel as a renewable alternative fuel for diesel engines. An experimental study is conducted to enhance the engine characteristics of corn oil blended diesel through various approaches, including adjusting the compression ratio, employing different exhaust gas recirculation (EGR) rates, and incorporating Nano additives into the fuel.

Preliminary examinations of corn oil methyl ester (COME) blends at 10%, 20%, and 30% reveal that the COME20 blend outperforms the others, establishing it as the preferred blend for further investigation. Subsequently, the investigation proceeds with COME20 at different load and speed conditions.

The experimental results demonstrate notable improvements in engine performance. Specifically, at a compression ratio of 20:1 (CR20:1) compared to 18:1 (CR18:1), brake thermal efficiency increases by 2.72%, and brake-specific fuel consumption (BSFC) decreases by 7.8%. Furthermore, significant reductions in exhaust emissions, including carbon monoxide (17.64%), unburnt hydrocarbons (13.8%), and smoke opacity (3.5%), are observed. However, there is an increase in nitrogen oxides (NOx) emissions.

In terms of exhaust gas recirculation (EGR), the addition of 6% and 12% EGR to COME20-CR20 results in reduced NOx emissions compared to diesel. Notably, the 12% EGR exhibits a greater reduction in NOx emissions but compromises engine performance to a greater extent than the 6% EGR.

In conclusion, this study highlights the potential of optimizing engine design (compression ratio), control (EGR rate), and fuel reformulation (COME biodiesel blending) to facilitate the efficient utilization of COME biodiesel blended diesel fuel in compression ignition (CI) engines. The findings contribute to the advancement of renewable fuel technologies and offer insights for future developments in the field of sustainable transportation.

KEYWORDS: *Corn oil biodiesel, Renewable alternative fuel, BSFC (Brake-specific fuel consumption), Compression ratio, Exhaust gas recirculation (EGR), Nano additives, COME20 blend*

CHAPTER – 1
INTRODUCTION

1.1 What is Biodiesel?

Biodiesel is a renewable, biodegradable fuel derived from organic sources, typically vegetable oils or animal fats. It is considered an alternative to conventional diesel fuel, as it can be used in diesel engines without requiring significant engine modifications. Biodiesel is produced through a chemical process called transesterification, which involves reacting vegetable oils or animal fats with an alcohol (such as methanol) in the presence of a catalyst.

The transesterification process breaks down the oils or fats into fatty acid methyl esters (FAME), which are the main components of biodiesel. Biodiesel can be used as a pure fuel (B100) or blended with petroleum diesel in various proportions. Common biodiesel blends include B20 (20% biodiesel, 80% petroleum diesel) and B5 (5% biodiesel, 95% petroleum diesel).

Biodiesel offers several advantages over petroleum diesel. It is a renewable fuel source that can be produced from agricultural crops, waste oils, and animal fats, reducing dependence on fossil fuels. It has lower emissions of pollutants such as sulphur, particulate matter, and carbon monoxide, resulting in improved air quality. Biodiesel also has better lubricating properties than petroleum diesel, which can enhance engine performance and reduce wear.

One of the key advantages of biodiesel is its reduced environmental impact. Compared to petroleum diesel, biodiesel significantly reduces emissions of harmful pollutants such as sulfur, particulate matter, and carbon monoxide. It also has lower levels of toxic air pollutants and aromatics, which contribute to air pollution and health problems. As a result, biodiesel can help improve air quality and reduce the environmental burden of transportation.

Biodiesel is also known for its biodegradability, meaning it can naturally break down into harmless substances, reducing its impact on soil and water systems. This property makes biodiesel a more environmentally sustainable fuel option compared to petroleum diesel, which can persist in the environment for long periods.

In addition to its environmental benefits, biodiesel offers other advantages. It has excellent lubricating properties, which can help reduce engine wear and extend engine life. Biodiesel's high cetane number, a measure of its combustion quality, can result in smoother engine operation, quieter combustion, and improved cold-start performance.

Moreover, biodiesel contributes to energy security by diversifying fuel sources. Since it can be produced from a variety of feedstocks, including crops and waste materials, biodiesel reduces reliance on imported petroleum and enhances domestic energy production. It also promotes rural economic development by creating opportunities for farmers and local communities involved in the production and supply chain of feedstocks.

As with any fuel, biodiesel does have some considerations. It has a slightly higher viscosity than petroleum diesel, which may require engine modifications or the use of additives in colder climates. Biodiesel also has slightly lower energy content per volume compared to petroleum diesel, resulting in slightly reduced fuel economy.

In conclusion, biodiesel is a renewable and environmentally friendly fuel option that offers numerous benefits. It reduces emissions, improves air quality, promotes energy security, and supports rural economies. Continued research and development in biodiesel production, feedstock diversity, and engine compatibility will further enhance its viability as a sustainable fuel for the future.

1.2 Types of Biodiesels

There are several types of biodiesel, which are classified based on the feedstock or raw material used in their production. The most common types of biodiesel include:

Vegetable Oil Biodiesel

Vegetable oil biodiesel is a type of biodiesel fuel derived from vegetable oils. It is considered a renewable and sustainable alternative to conventional diesel fuel, as it can be produced from a variety of vegetable oil feedstocks, such as soybean oil, rapeseed oil, palm oil, sunflower oil, and more.

The production of vegetable oil biodiesel involves a process called transesterification. In this process, the vegetable oil is chemically reacted with an alcohol, usually methanol or ethanol, in the presence of a catalyst, typically sodium hydroxide or potassium hydroxide. This reaction converts the vegetable oil into fatty acid methyl esters (FAME), which make up the biodiesel fuel.

Vegetable oil biodiesel shares similar properties to conventional diesel fuel, making it compatible with existing diesel engines and infrastructure. It can be used as a direct replacement or blended with diesel fuel in various proportions, depending on the desired fuel properties and regulatory requirements.

One of the key advantages of vegetable oil biodiesel is its potential to reduce greenhouse gas emissions. Biodiesel is derived from renewable plant sources, which absorb carbon dioxide during growth, offsetting the carbon emissions produced during combustion. As a result, vegetable oil biodiesel has a lower carbon footprint compared to fossil diesel, contributing to efforts in mitigating climate change.

Furthermore, vegetable oil biodiesel offers other environmental benefits, including lower emissions of particulate matter, sulphur, and aromatic compounds, which are associated with air pollution and adverse health effects. It also exhibits lubricity properties, which can help reduce engine wear and extend the life of fuel system components.

However, there are some considerations with vegetable oil biodiesel. The availability and cost of vegetable oil feedstocks can vary regionally, affecting its commercial viability. Additionally, concerns have been raised about the potential impact of large-scale vegetable oil production on deforestation, biodiversity, and land-use change.

To address these challenges, ongoing research focuses on developing sustainable and low-cost feedstock options, improving production processes, and exploring advanced technologies such as algae-based biodiesel.

Overall, vegetable oil biodiesel represents a promising renewable fuel option that can contribute to reducing greenhouse gas emissions, promoting energy security, and diversifying the fuel supply in a more sustainable manner. Its use in transportation and other sectors can help pave the way towards a cleaner and more environmentally friendly future.

Waste Cooking Oil Biodiesel

Waste cooking oil biodiesel, also known as recycled cooking oil biodiesel or waste vegetable oil biodiesel, is a type of biodiesel fuel produced from used cooking oil. It is considered a sustainable and environmentally friendly alternative to conventional diesel fuel.

Waste cooking oil biodiesel is derived from cooking oils that have been used in various food preparation processes, such as frying or deep-frying. Instead of disposing of the used cooking oil, which can have detrimental effects on the environment if not properly handled, it can be collected and processed into biodiesel.

The production process of waste cooking oil biodiesel is similar to that of other biodiesel fuels. The used cooking oil undergoes a refining and transesterification process to convert it into fatty acid methyl esters (FAME), which form the basis of the biodiesel. Typically, a catalyst, such as sodium hydroxide or potassium hydroxide, is used to facilitate the reaction.

There are several benefits associated with the use of waste cooking oil biodiesel. Firstly, it offers a sustainable solution for the management of used cooking oil, reducing waste and minimizing environmental pollution. By repurposing waste cooking oil as biodiesel, it avoids the need for disposal methods that can harm the ecosystem, such as improper disposal in drains or landfills.

Secondly, waste cooking oil biodiesel contributes to reducing greenhouse gas emissions. Biodiesel, in general, has a lower carbon footprint compared to fossil diesel because it is derived from renewable sources. The combustion of waste cooking oil biodiesel releases fewer carbon dioxide emissions, helping to mitigate climate change and improve air quality.

Furthermore, waste cooking oil biodiesel can be used as a direct substitute or blended with conventional diesel fuel in various proportions, depending on the desired fuel properties and local regulations. It is compatible with existing diesel engines and infrastructure, requiring no significant modifications for its use.

However, it is essential to ensure the quality and proper treatment of waste cooking oil before its conversion into biodiesel. Adequate collection, filtration, and purification processes are necessary to remove impurities, contaminants, and water content that can affect the biodiesel's performance and cause engine issues.

In conclusion, waste cooking oil biodiesel provides an eco-friendly solution for the management of used cooking oil while offering environmental benefits such as reduced greenhouse gas emissions. Its use in transportation and other sectors can contribute to a more sustainable and cleaner energy future. Algae Biodiesel: Algae-based biodiesel is an emerging type of biodiesel that is produced from algae biomass. Algae have the potential to yield high amounts of oil, and their cultivation does not compete with food crops for land use. Algae biodiesel offers the advantage of higher yields and can be grown in various environments, including wastewater or non-arable land.

Jatropha Biodiesel

Jatropha biodiesel refers to a type of biodiesel fuel derived from the oil extracted from the seeds of the Jatropha curcas plant. Jatropha curcas is a perennial shrub or small tree native to tropical and subtropical regions.

Jatropha biodiesel gained attention as a potential alternative to conventional diesel fuel due to several characteristics of the Jatropha curcas plant. The plant is known for its ability to grow in arid and marginal lands, requiring less water and fertile soil compared to many other crops. It is also considered non-edible, meaning it does not compete with food crops for resources.

The production of jatropha biodiesel involves a multi-step process. The first step is the cultivation of Jatropha cruces plants and the extraction of oil from the seeds. The extracted oil is then processed through transesterification, a chemical reaction that converts the oil into biodiesel. This process typically involves the use of an alcohol (such as methanol) and a catalyst (such as sodium hydroxide) to produce fatty acid methyl esters (FAME), the main component of biodiesel.

Jatropha biodiesel possesses several benefits and challenges. One advantage is its potential as a renewable and sustainable energy source. Jatropha curcas plants can grow in various climates and soil conditions, including marginal lands that are not suitable for food crops, thereby avoiding competition with food production. Additionally, jatropha plants have the potential to enhance land restoration and provide economic opportunities for rural communities in developing regions.

From an environmental perspective, jatropha biodiesel has the potential to reduce greenhouse gas emissions compared to fossil diesel. Biodiesel, in general, has a lower carbon footprint since it is derived from renewable plant sources. However, it is worth noting that the overall environmental impact of jatropha biodiesel depends on various factors, including cultivation practices and land use change considerations.

On the other hand, there are challenges associated with jatropha biodiesel production. The plant has a long gestation period, typically requiring several years before it reaches full productivity. This can pose challenges in achieving economic viability and scalability of jatropha cultivation. Additionally, the quality and yield of jatropha oil can vary depending on factors such as plant genetics, growing conditions, and oil extraction methods.

In recent years, the interest in jatropha biodiesel has somewhat diminished due to challenges in commercial-scale cultivation, low oil yields, and competition with other biofuel feedstocks. However, research and development efforts continue to explore ways to optimize jatropha cultivation techniques, improve oil extraction processes, and enhance the overall sustainability of jatropha biodiesel production.

In summary, jatropha biodiesel is a biodiesel fuel derived from the oil of the Jatropha curcas plant. While it holds promise as a renewable and sustainable energy source, there are challenges to overcome in terms of cultivation, oil extraction, and commercial viability. Ongoing research and advancements in jatropha biodiesel production may contribute to its future potential as an alternative to conventional diesel fuel.

Waste Oil Biodiesel

Waste oil biodiesel, also known as recycled or used oil biodiesel, is a type of biodiesel fuel produced from waste or discarded oils. It involves converting waste oils, such as used cooking oil, motor oil, or industrial oils, into a usable and renewable fuel source. This process helps to reduce waste and recycle materials that would otherwise be disposed of or cause environmental harm.

The production of waste oil biodiesel follows similar principles to traditional biodiesel production. The waste oil undergoes a process called transesterification, which involves reacting the oil with an alcohol (commonly methanol) and a catalyst (such as sodium hydroxide or potassium hydroxide). This chemical reaction breaks down the triglycerides in the oil, converting them into fatty acid methyl esters (FAME), the main component of biodiesel. The resulting biodiesel can be used as a substitute for petroleum-based diesel fuel.

Waste oil biodiesel offers several advantages. Firstly, it reduces the dependence on fossil fuels and contributes to the use of renewable energy sources. By utilizing waste oils that would otherwise be discarded or contribute to pollution, waste oil biodiesel helps to minimize environmental impact and promote sustainability. Additionally, waste oil biodiesel has a lower carbon footprint compared to fossil diesel, as it emits fewer greenhouse gases during combustion.

Furthermore, waste oil biodiesel can help address waste management issues. Instead of disposing of used cooking oil or other waste oils, they can be collected and processed into biodiesel. This reduces the potential for environmental contamination and eliminates the need for costly waste disposal methods.

However, there are certain considerations and challenges associated with waste oil biodiesel production. The quality and composition of waste oils can vary significantly, which may require additional pre-treatment steps or adjustments in the biodiesel production process. Waste oils may contain impurities or contaminants that need to be removed to ensure the quality and performance of the biodiesel fuel.

Moreover, proper collection and handling of waste oils are essential to prevent cross-contamination and ensure the feedstock's integrity. It is important to follow regulations and guidelines for the collection, storage, and transportation of waste oils to maintain their suitability for biodiesel production.

Overall, waste oil biodiesel is a valuable solution for repurposing and recycling waste oils, reducing environmental impact, and promoting renewable energy sources. With proper processing and quality control measures, waste oil biodiesel can be a viable alternative to conventional diesel fuel, contributing to a more sustainable and circular economy.

It is worth noting that the specific properties of biodiesel, such as viscosity, oxidation stability, and cold flow characteristics, may vary depending on the feedstock used. These variations can influence the suitability of biodiesel for different engine types and climate conditions. Additionally, biodiesel can be blended with petroleum diesel in different proportions to create biodiesel blends, such as B20 (20% biodiesel, 80% petroleum diesel) or B5 (5% biodiesel, 95% petroleum diesel), to meet specific requirements or regulations.

1.3 Exploration of Oil-Bearing Crops

The search for sustainable alternatives to conventional fossil fuels has led to the investigation of numerous oil-bearing crops and low viscous biofuels as potential sources for biodiesel production. This subsection explores the diverse range of oil-bearing crops and the utilization of certain low viscous biofuels with properties similar to diesel. Additionally, the cost considerations and the imperative of addressing global warming are discussed.

Oil-Bearing Crops

More than 350 oil-bearing crops have been recognized globally, offering a rich diversity of potential feedstocks for biodiesel production. Researchers have extensively studied crops such as Palm, Nigella sativa, Jatropha, Sunflower, Soybean, and Karanja due to their oil-rich nature and compatibility with biodiesel synthesis processes. These crops have shown promising characteristics in terms of oil yield, fatty acid composition, and overall suitability for biodiesel production.

Low Viscous Biofuels

In addition to traditional oil-bearing crops, certain low viscous biofuels have gained attention in biodiesel research. Lemon peel oil and orange peel oil, for example, have been explored by various investigators and have been used up to 100% in biodiesel blends due to their similar properties to diesel. These biofuels exhibit low viscosity, which is advantageous for fuel atomization and combustion efficiency in engines. However, widespread usage of these low viscous biofuels has been limited by cost considerations.

Cost Considerations

The cost of production and availability of feedstocks play a significant role in the commercial viability and widespread usage of biodiesel. While various oil-bearing crops and low viscous biofuels have demonstrated potential as biodiesel feedstocks, the cost of cultivation, oil extraction, and processing must be carefully evaluated to ensure economic feasibility. Strategies such as optimizing cultivation techniques, improving oil extraction methods, and developing efficient processing technologies are being explored to mitigate the cost barriers associated with these feedstocks.

Addressing Global Warming

Global warming, resulting from the emission of greenhouse gases, poses a significant threat to the environment. Biodiesel, as a renewable and lower carbon-emitting fuel, offers a viable solution to mitigate greenhouse gas emissions and combat climate change. By utilizing oil-bearing crops and low viscous biofuels in biodiesel production, we can contribute to reducing the carbon footprint of transportation and promote sustainable energy practices.

The exploration of oil-bearing crops and low viscous biofuels as potential feedstocks for biodiesel production provides a wide range of options to diversify feedstock sources and enhance sustainability. Through comprehensive research and cost optimization, these feedstocks can contribute to the development of a more environmentally friendly and economically viable biodiesel industry. Furthermore, their utilization can support efforts in mitigating global warming and transitioning towards a greener and more sustainable future.

1.4 Assessing the Impact of Corn Oil Blends on Emissions in Diesel Combustion

The extensive use of fossil fuels in various applications has led to environmental concerns and the need for alternative energy sources. Renewable energy derived from feedstocks has emerged as a promising solution to reduce dependence on fossil fuels and mitigate their impact on the environment. In this context, the utilization of biodiesel has gained significant attention, and this section provides an overview of the literature on the use of different biodiesel blends, focusing on corn oil blends.

Corn Oil Blends and their Impact on Emissions

A study was conducted to investigate the effects of blending different percentages of corn oil (10%, 20%, and 30%) with diesel fuel. The results indicated that hydrocarbon (HC) emissions increased with the increase in the blending percentage. Among the blends, the maximum HC emissions were observed for the B30 blend.

The higher HC emissions in the B30 blend can be attributed to the high latent heat of vaporization of corn oil, which reduces the combustion temperature and causes incomplete fuel-air mixing. This incomplete mixing leads to inefficient combustion, resulting in higher HC emissions. It is important to note that higher blending percentages of corn oil in diesel fuel may contribute to increased HC emissions, highlighting the need for careful optimization of biodiesel blends to achieve desired emission levels.

Reduction in NOx Emissions

Additionally, the study reported a reduction in nitrogen oxide (NOx) emissions when comparing the corn oil blends to pure diesel fuel. NOx emissions play a significant role in air pollution and contribute to the formation of smog and acid rain. The lower NOx emissions observed with the corn oil blends indicate their potential as a cleaner fuel alternative.

Conclusion

The analysis of various corn oil blends in diesel combustion revealed an increase in HC emissions with higher blending percentages, primarily due to incomplete fuel-air mixing caused by the high latent heat of vaporization. However, the blends showed a reduction in NOx emissions compared to pure diesel fuel, emphasizing their potential as a cleaner and more sustainable fuel option. Further research and optimization of biodiesel blends, including corn oil blends, are necessary to achieve optimal combustion performance and minimize emissions.

Overall, the findings highlight the importance of carefully considering the blending percentages and characteristics of biodiesel fuels to ensure efficient combustion and reduced emissions, thus contributing to a more sustainable energy future.

CHAPTER – 2
LITERATURE REVIEW

2.1 Mahua Biodiesel Blends

Mahua biodiesel blends refer to the mixture of biodiesel derived from the Mahua tree (Madhuca indica) seeds with conventional diesel fuel. Mahua biodiesel is produced through the transesterification process, where the oil extracted from Mahua seeds is chemically reacted with an alcohol (usually methanol) to convert it into biodiesel.

Mahua trees are native to India and are widely grown for their edible flowers and oil-rich seeds. The seeds of the Mahua tree contain a significant amount of oil, which can be used as a feedstock for biodiesel production. Mahua biodiesel is considered a renewable and environmentally friendly alternative to fossil diesel, as it reduces dependence on fossil fuels and helps in reducing greenhouse gas emissions.

When Mahua biodiesel is blended with conventional diesel fuel in various proportions, such as B20 (20% biodiesel, 80% diesel) or B40 (40% biodiesel, 60% diesel), it creates Mahua biodiesel blends. These blends can be used as a drop-in replacement for diesel fuel in diesel engines without requiring any modifications to the engine.

The use of Mahua biodiesel blends offers several benefits. Firstly, it helps in reducing the consumption of fossil diesel and thus contributes to energy sustainability. Secondly, Mahua biodiesel has a higher cetane number than conventional diesel, which improves the combustion efficiency and leads to better engine performance. It can also result in reduced engine wear and maintenance costs.

Additionally, Mahua biodiesel blends have the potential to lower emissions of pollutants such as carbon monoxide, particulate matter, and unburnt hydrocarbons, compared to pure diesel fuel. The exact impact on emissions may vary depending on the blend ratio and engine specifications.

However, it is important to note that the production and use of Mahua biodiesel blends should be carried out following proper quality control measures to ensure that the biodiesel meets the required standards and does not negatively impact engine performance or durability.

In reference [1], the researchers conducted experiments to evaluate the performance of mahua biodiesel blends B20 (20% biodiesel, 80% diesel) and B40 (40% biodiesel, 60% diesel) in comparison to conventional diesel fuel. The study aimed to assess the potential of these biodiesel blends to improve engine efficiency and reduce emissions without requiring any modifications to the existing diesel engine.

The results of the investigation indicated a slight improvement in Brake Thermal Efficiency (BTE) and Brake Specific Fuel Consumption (BSFC) for the mahua biodiesel blends when compared to pure diesel fuel. This suggests that the addition of biodiesel to the fuel mixture led to a more efficient combustion process, resulting in better utilization of the energy content of the fuel.

Furthermore, the researchers observed a reduction in emissions when using the mahua biodiesel blends. This reduction is particularly significant when considering the emission of pollutants such as particulate matter, carbon monoxide, and hydrocarbons. The lower emission levels suggest that the use of mahua biodiesel blends can contribute to improved air quality and a reduction in the environmental impact associated with combustion engines.

Importantly, the study found that these improvements in engine performance and emissions were achieved without requiring any modifications to the existing diesel engine. This is a significant finding as it indicates the potential for a seamless transition from conventional diesel to biodiesel blends, without the need for costly engine modifications or changes in infrastructure.

Overall, the research presented in reference [1] highlights the promising potential of mahua biodiesel blends B20 and B40 as a viable alternative to conventional diesel fuel. The observed slight improvement in engine efficiency, reduced fuel consumption, and decreased emissions make these biodiesel blends an attractive option for a more sustainable and environmentally friendly transportation sector.

2.2 Improved Biodiesel Performance

In reference [2], the researchers conducted a study to evaluate the performance and emissions characteristics of lower percentage biodiesel blends in comparison to conventional diesel fuel. The objective was to investigate whether the use of biodiesel blends could lead to improvements in engine performance and reductions in exhaust emissions without any modifications made to the engine.

The results of the study revealed that the usage of lower percentage biodiesel blends resulted in enhanced performance compared to pure diesel fuel. Performance parameters such as fuel efficiency, power output, and torque were found to be improved when using biodiesel blends. This suggests that the inclusion of biodiesel in the fuel mixture contributed to a more efficient combustion process, leading to better utilization of the energy content of the fuel and improved engine performance.

Additionally, the researchers found that the utilization of biodiesel blends led to diminished exhaust emissions compared to conventional diesel fuel. Pollutants such as particulate matter, carbon monoxide, and nitrogen oxides were observed to be reduced when using biodiesel blends. This reduction in emissions is significant as it indicates a potential reduction in the environmental impact associated with combustion engines and contributes to improved air quality.

An important aspect highlighted in the study is that these performance enhancements and emissions reductions were achieved without any modifications made to the engine. This finding is particularly noteworthy as it suggests that the transition from conventional diesel fuel to lower percentage biodiesel blends can be implemented seamlessly, without the need for costly engine modifications or infrastructure changes.

In summary, the research presented in reference [2] concludes that the usage of lower percentage biodiesel blends offers enhanced engine performance and diminished exhaust emissions compared to conventional diesel fuel, all without requiring any modifications to the engine. These findings support the potential of biodiesel blends as a viable and sustainable alternative to conventional diesel, contributing to a greener and more environmentally friendly transportation sector.

2.3 Combustion Analysis of Cottonseed Biodiesel Blends in Diesel Engines

Cottonseed biodiesel blends are mixtures of biodiesel derived from cottonseed oil with conventional diesel fuel. Cottonseed oil is extracted from the seeds of the cotton plant (Gossypium spp.), which is primarily cultivated for its fibers used in the textile industry. Cottonseed oil can also be used as a feedstock for biodiesel production.

To create cottonseed biodiesel, the oil extracted from cottonseeds undergoes a chemical process called transesterification, where it is reacted with an alcohol (typically methanol) in the presence of a catalyst. This process converts the oil into biodiesel, which can then be blended with diesel fuel in different ratios.

Cottonseed biodiesel blends are typically identified by the percentage of biodiesel in the mixture. For example, B5 refers to a blend containing 5% biodiesel and 95% diesel fuel, while B20 represents a blend with 20% biodiesel and 80% diesel fuel. The blend ratios can vary based on the desired properties and applications.

The use of cottonseed biodiesel blends offers several advantages. Firstly, it helps reduce the reliance on fossil fuels and promotes the use of renewable energy sources. Cottonseed biodiesel is considered a cleaner-burning fuel compared to conventional diesel, resulting in reduced emissions of pollutants such as carbon monoxide, particulate matter, and certain hydrocarbons.

Cottonseed biodiesel blends can be used as a drop-in replacement for diesel fuel in existing diesel engines without requiring significant modifications. The blends have similar properties to diesel fuel and can be used in transportation, agriculture, and other sectors that rely on diesel-powered equipment.

It is important to ensure that cottonseed biodiesel blends meet the necessary quality standards to ensure proper engine performance and minimize potential issues such as fuel system clogging or engine deposits. Quality control measures should be followed during production to ensure consistent and reliable biodiesel blends.

In [3], a comprehensive study was conducted to investigate the combustion characteristics of diesel engines using cottonseed biodiesel blends, specifically B5 to B20. The research aimed to examine the impact of biodiesel content on ignition delay and maximum rate of pressure rise in comparison to traditional diesel fuel.

The findings of the study demonstrated that the use of cottonseed biodiesel blends resulted in a decrease in ignition delay and maximum rate of pressure rise when compared to pure diesel fuel. This improvement in combustion attributes can be attributed to the superior cetane number of the B20 biodiesel blend.

The lower ignition delay observed with cottonseed biodiesel blends indicates a more efficient and timely ignition process, contributing to better overall engine performance. The reduction in maximum rate of pressure rise suggests smoother and more controlled combustion, which can enhance engine durability and reduce the likelihood of knocking or detonation.

The higher cetane number of the B20 biodiesel blend, a measure of its ignition quality, plays a significant role in the observed combustion characteristics. A higher cetane number promotes quicker and more complete fuel combustion, leading to improved engine efficiency and reduced emissions.

This study highlights the potential of cottonseed biodiesel blends as a viable alternative to traditional diesel fuel. The findings support the use of these blends in diesel engines without the need for significant modifications, providing an environmentally friendly option with improved combustion attributes.

Overall, the investigation presented in [3] offers valuable insights into the combustion behaviour of cottonseed biodiesel blends, shedding light on their potential for optimizing engine performance and reducing environmental impact.

2.4 Performance Analysis of Papaya Seed Oil Methyl Ester (PSME) Blends

In [4], a series of experiments were conducted to investigate the effects of papaya seed oil methyl ester (PSME) blended with 10% n-butanol as an alternative fuel in diesel engines. The study aimed to examine the performance characteristics of the PSME-n-butanol blends under different load conditions and analyze their impact on brake thermal efficiency (BTE), exhaust gas temperature (EGT), and oxides of nitrogen (NO_x) emissions.

The results of the experiments revealed that the effects of the PSME-n-butanol blend were more pronounced under medium load conditions compared to low load and peak load conditions. This suggests that the blend's performance enhancements are most significant in moderate operating conditions.

One of the key findings of the study was the observed increase in brake thermal efficiency when using PSME-n-butanol blends. This improvement indicates a more efficient conversion of fuel energy into useful work, resulting in enhanced engine performance. The higher BTE is advantageous as it leads to better fuel economy and reduced fuel consumption.

Furthermore, the usage of PSME-n-butanol as an alternate fuel showed an increase in exhaust gas temperature (EGT). The elevated EGT can be attributed to the altered combustion characteristics of the blend, such as improved combustion efficiency and altered heat release patterns. Monitoring EGT is crucial as it helps assess the engine's operating conditions and provides insights into combustion efficiency.

Regarding emissions, the study found that the PSME-n-butanol blends had an impact on oxides of nitrogen (NOx) emissions. While the specific results were not provided, the mention of increased NOx emissions suggests that further investigation is required to evaluate the blend's environmental impact and the potential need for emission control measures.

Overall, the investigation presented in [4] demonstrates the potential of PSME-n-butanol blends as a promising alternative fuel option in diesel engines. The study highlights the blend's positive influence on brake thermal efficiency, exhaust gas temperature, and its potential impact on NOx emissions. Further research is recommended to optimize the blend composition and assess its long-term effects on engine performance and emissions.

2.5 Performance Analysis of Waste Fry Oil Biodiesel Blends

In [6], an experimental study was conducted to evaluate the impact of waste fry oil biodiesel blends on the performance of diesel engines. The investigation focused on three different compression ratios, namely 14:1, 16:1, and 18:1, to assess the influence of compression ratio on the performance characteristics of the biodiesel blends.

The results of the experiments indicated that the performance of the biodiesel blends varied with the compression ratio used. Higher compression ratios were found to yield improved performance in terms of power output and efficiency. This improvement can be attributed to the increased air-fuel mixture density and improved combustion characteristics associated with higher compression ratios.

However, along with the performance enhancement, the study also revealed that higher compression ratios led to increased emissions of nitrogen oxides (NOx). NOx emissions are a concern as they contribute to air pollution and have adverse effects on human health and the environment. The higher NOx emissions observed with the higher compression ratios may be attributed to the increased combustion temperatures and pressures, which promote the formation of NOx compounds during the combustion process.

The findings of this study emphasize the trade-off between performance and emissions when utilizing waste fry oil biodiesel blends in diesel engines. While higher compression ratios can enhance engine performance, the associated increase in NOx emissions highlights the need for emission control strategies and technologies.

Further research is warranted to explore techniques for reducing NOx emissions while maintaining the performance advantages of the biodiesel blends. This could include investigating advanced combustion strategies, exhaust gas recirculation, selective catalytic reduction, or other emission control technologies.

Overall, the study presented in [6] provides valuable insights into the performance characteristics of waste fry oil biodiesel blends at different compression ratios. The results highlight the need for optimizing the compression ratio to achieve a balance between performance and emissions in diesel engines running on biodiesel blends derived from waste fry oil.

2.6 Performance and Emission Analysis of Waste Cooking Oil

In [7], a comprehensive investigation was conducted to assess the impact of waste cooking oil, ethanol, and diesel blends on the performance and emissions characteristics of diesel engines. The study focused on varying the compression ratios from 18:1 to 22:1 to examine the influence of compression ratio on the engine's behaviour when running on the blended fuels.

The experimental results revealed that the blend consisting of 20% waste cooking oil, 5% ethanol, and 75% pure diesel exhibited the most favourable engine performance and emissions attributes at a compression ratio of 21:1. This specific blend and compression ratio combination resulted in significant improvements in various performance parameters.

In terms of engine performance, the blend demonstrated enhanced combustion efficiency, leading to improved power output and increased brake thermal efficiency. These improvements can be attributed to the synergistic effects of waste cooking oil and ethanol, which contribute to better combustion characteristics, such as improved atomization, vaporization, and more complete combustion.

Moreover, the chosen blend at the optimum compression ratio showed promising emission reduction potential. The emissions of pollutants like nitrogen oxides (NOx), carbon monoxide (CO), and hydrocarbons (HC) were significantly reduced compared to pure diesel fuel. The reduction in emissions can be attributed to the oxygen-rich nature of ethanol and the chemical properties of waste cooking oil, which have a lower carbon-to-hydrogen ratio, leading to reduced carbon emissions.

The findings of this study highlight the potential of waste cooking oil, ethanol, and diesel blends as a viable alternative fuel option for diesel engines. By optimizing the blend composition and selecting an appropriate compression ratio, it is possible to achieve improved engine performance while simultaneously reducing emissions.

Further research is recommended to delve deeper into the combustion characteristics, exhaust gas composition, and long-term effects of using waste cooking oil, ethanol, and diesel blends. Additionally, the study could be expanded to investigate the influence of different compression ratios and blend compositions on the engine's thermal efficiency, combustion stability, and exhaust emissions under various operating conditions.

In conclusion, the study presented in [7] provides valuable insights into the performance and emissions characteristics of waste cooking oil, ethanol, and diesel blends at varying compression ratios. The identified optimal blend composition and compression ratio combination can serve as a basis for further development and implementation of these blends in diesel engines, promoting sustainable and environmentally friendly transportation solutions.

Most of the literature reveals that the increase in compression ratio shows the enhanced performance, combustion attributes, but, with the drastic rise in NOx emissions [8].

2.7 Impact of Exhaust Gas Recirculation on Engine Performance and Emissions

The implementation of an Exhaust Gas Recirculation (EGR) system has emerged as one of the most effective techniques for reducing emissions in internal combustion engines, as highlighted in [9]. The EGR system works by recirculating a portion of the engine's exhaust gases back into the intake manifold, resulting in lower combustion temperatures and reduced formation of nitrogen oxides (NOx).

However, it is important to note that while the EGR system offers significant benefits in terms of emission reduction, it can also have certain drawbacks on engine performance. One of the main concerns is the decrease in thermal efficiency associated with the implementation of EGR. By introducing inert exhaust gases into the combustion chamber, the oxygen concentration is reduced, leading to incomplete combustion and a decrease in overall engine efficiency.

Furthermore, the usage of the EGR system can result in increased emissions of carbon monoxide (CO) and unburnt hydrocarbons (HC). The reduced oxygen concentration within the combustion chamber can lead to incomplete combustion, causing higher levels of these pollutants in the exhaust gases. These emissions need to be carefully managed and controlled to ensure compliance with environmental regulations.

The conclusions drawn from previous studies, as mentioned in [9], highlight that the implementation of EGR can significantly affect the combustion process. The presence of recirculated exhaust gases alters the combustion characteristics, leading to changes in peak pressure timing and magnitude. Specifically, the peak pressure point is shifted away from the top dead center (TDC) and the peak pressure itself is reduced, indicating a change in the combustion dynamics.

To mitigate the potential negative effects on performance and emissions, proper calibration and optimization of the EGR system are crucial. Engine control strategies, such as adjusting the EGR flow rate, timing, and mixture composition, can help strike a balance between emission reduction and maintaining acceptable engine performance.

Future research should focus on further understanding the complex interactions between the EGR system, combustion process, and engine performance. Advanced control algorithms, sensor technologies, and modelling techniques can be utilized to develop optimized EGR strategies that minimize the impact on thermal efficiency while effectively reducing emissions.

In summary, the utilization of an Exhaust Gas Recirculation (EGR) system is a promising technique for reducing emissions in internal combustion engines. While it may have some impact on engine performance, proper calibration and optimization can help achieve a balance between emission reduction and acceptable engine operation. Further research and development are necessary to enhance the effectiveness and efficiency of EGR systems in order to meet the challenges of achieving cleaner and more sustainable transportation.

2.8 Performance Analysis of Jatropha Oil Blends

In [10], the impact of exhaust gas recirculation (EGR) on a diesel engine fuelled with 20% blends of jatropha and fish oil methyl esters was investigated. The study aimed to assess the performance and emission characteristics of these biodiesel blends when compared to standard diesel fuel, particularly under different EGR conditions.

The study found that when compared to diesel fuel, the brake thermal efficiency (BTE) values for the 20% blend of jatropha oil at a 20% EGR condition slightly decreased from 28.43% to 27.12%. This reduction in BTE can be attributed to the dilution effect caused by recirculating a portion of the exhaust gases into the intake manifold. The presence of inert gases lowers the oxygen concentration, affecting the combustion process and resulting in a slight decrease in efficiency.

However, it is important to note that the overall results of the study indicated that the usage of the 20% blend of jatropha and fish oils, combined with a 20% EGR rate, yielded performance and emissions characteristics similar to those of standard diesel fuel. This finding suggests that the biodiesel blends, when combined with EGR, can achieve comparable engine performance and emissions levels, offering a promising alternative to conventional diesel fuel.

The close performance and emissions observed with the 20% blend of jatropha and fish oils, along with the 20% EGR rate, demonstrate the potential for utilizing biodiesel blends in conjunction with EGR as a sustainable and environmentally friendly solution. This combination allows for a reduction in exhaust emissions, particularly nitrogen oxides (NOx), which are a major contributor to air pollution.

Further research in this area could explore the optimization of EGR parameters, such as EGR rate and timing, to maximize the benefits of using biodiesel blends while minimizing any potential drawbacks on engine performance. Additionally, investigations into the combustion characteristics, emissions formation, and long-term effects of EGR on engine components would contribute to a better understanding of the overall system performance.

In conclusion, the study presented in [10] highlights the potential of using 20% blends of jatropha and fish oil methyl esters in diesel engines with the implementation of exhaust gas recirculation. The findings indicate that this combination can achieve performance and emissions characteristics comparable to standard diesel fuel. The results contribute to the growing body of knowledge on the use of biodiesel blends and EGR as sustainable solutions for reducing emissions in internal combustion engines.

CHAPTER – 3
PROBLEM IDENTIFICATION

Through an extensive survey of existing literature, it becomes evident that optimizing the trade-off effect between engine performance and emissions requires a comprehensive approach. This involves investigating and understanding the various design parameters of the engine, controlling the operating parameters effectively, and exploring fuel reformulation strategies.

However, despite the abundance of research on biodiesel and its impact on engine performance and emissions, there appears to be a limited analysis focusing on the combined effect of compression ratio and exhaust gas recirculation specifically for the selected biodiesel. This research gap presents an opportunity to delve deeper into understanding the intricate relationship between these variables and their potential to mitigate the trade-off effect.

COME20 blend refers to a specific biodiesel blend consisting of 20% Camelina oil methyl ester (COME) and 80% petroleum diesel fuel. Biodiesel blends, such as COME20, are created by combining a renewable fuel source, in this case, Camelina oil methyl ester, with conventional petroleum diesel.

By specifically examining the effects of compression ratio and exhaust gas recirculation on the COME20 blend, this study aims to contribute to the existing body of knowledge in the field. The COME20 blend, which has been identified as a preferable blend in previous investigations, provides a suitable platform for exploring the combined influence of these parameters.

Biodiesel blends like COME20 are compatible with existing diesel engines and require no major modifications to the engine or fueling infrastructure. They can be used in various applications, including transportation, agriculture, and stationary power generation.

The significance of this research lies in its potential to provide valuable insights into optimizing the performance and emissions characteristics of biodiesel blends. By filling this research gap, the study aims to enhance our understanding of how engine design parameters, control parameters, and fuel reformulation approaches can be effectively integrated to achieve a balance between improved performance and reduced emissions.

Overall, this investigation represents a crucial step towards advancing the understanding of biodiesel utilization in diesel engines. The findings of this study have the potential to inform future engine design and optimization strategies, enabling the development of more efficient and environmentally friendly alternative fuel solutions.

3.1 Objective and Novelty

The main objective of the present study is to investigate the engine performance and emission characteristics by combining the effects of compression ratio (CR) and exhaust gas recirculation (EGR) for the proposed biofuel. This research aims to provide valuable insights into optimizing the performance of the engine while simultaneously reducing emissions.

In order to ensure sustainable and cost-effective fuel options, it is crucial to explore alternatives that do not negatively impact food production. In this context, corn oil emerges as a reliable and promising option. However, it is worth noting that there has been limited research conducted on different blends of corn oil methyl ester (COME). Therefore, there is a significant research gap that needs to be addressed in terms of evaluating the performance and emissions characteristics of COME blends.

The novelty of the present research lies in its approach of combining the effects of compression ratio and exhaust gas recirculation for the selected biodiesel. By integrating these two parameters, the study aims to develop an efficient approach that mitigates the trade-off effect between engine performance and emissions. This novel approach holds promise for optimizing the utilization of biodiesel blends, particularly COME, in diesel engines.

The significance of this research work is rooted in the need for sustainable and environmentally friendly solutions in the transportation sector. By exploring the combined effect of compression ratio and exhaust gas recirculation, the study aims to provide a comprehensive understanding of how these parameters influence the performance and emissions characteristics of the proposed biofuel. The findings of this research will not only contribute to the existing knowledge base but also have practical implications for engine design and optimization.

Overall, the present study represents an important step towards advancing the understanding of biodiesel utilization and its impact on engine performance and emissions. By addressing the research gap and incorporating the effects of compression ratio and exhaust gas recirculation, this research contributes to the development of more efficient and sustainable solutions for the transportation sector.

3.2 Methodology

The methodology for making corn oil biodiesel involves several steps, including oil extraction, purification, and transesterification. Here is an overview of the process:

Oil Extraction: The first step is to obtain corn oil, which can be extracted from corn kernels through mechanical pressing or solvent extraction. Mechanical pressing involves crushing the corn kernels to release the oil, while solvent extraction uses a chemical solvent to dissolve the oil from the kernels. The extracted oil is typically a crude form and may require further purification.

Purification: The crude corn oil needs to be purified to remove impurities such as moisture, solids, and free fatty acids. This can be achieved through processes like degumming, neutralization, and bleaching. Degumming involves removing the gums and phospholipids from the oil, while neutralization helps to eliminate free fatty acids by reacting them with an alkaline solution. Bleaching involves the removal of colour pigments and other impurities through adsorption onto activated carbon or clay.

Transesterification: Once the purified corn oil is obtained, it is ready for transesterification, which is the key process for converting the oil into biodiesel. Transesterification involves reacting the oil with an alcohol, usually methanol, in the presence of a catalyst, typically sodium or potassium hydroxide. The reaction results in the formation of fatty acid methyl esters (FAMEs), which are the main components of biodiesel, along with glycerol as a by-product.

The transesterification reaction is typically carried out in a controlled environment, such as a reactor, with constant stirring and at an appropriate temperature. The reaction time may vary depending on the specific conditions and the desired degree of conversion. After completion, the mixture is allowed to settle, and the glycerol layer is separated from the biodiesel.

Washing and Drying: The biodiesel obtained from transesterification may still contain some impurities and traces of catalyst and alcohol. To remove these impurities, the biodiesel is washed with water or a water-methanol mixture. The mixture is then allowed to settle, and the water phase is drained off. This washing process is repeated several times until the desired purity is achieved. After washing, the biodiesel is dried to remove any remaining water, usually through the use of a drying agent such as anhydrous sodium sulphate.

Quality Control: To ensure the quality and compliance of the corn oil biodiesel, it is important to conduct various tests and analyses. These tests may include measuring parameters such as density, viscosity, flash point, sulphur content, and acid value. The biodiesel should meet the relevant quality standards and regulations for commercial use.

It is worth noting that the specific details of the corn oil biodiesel production process may vary depending on factors such as the scale of production, equipment used, and desired quality standards. Additionally, safety precautions should be followed throughout the process to handle chemicals properly and minimize any potential hazards.

The blending process plays a crucial role in achieving the desired biodiesel blend, such as a 20% blend of biodiesel from corn oil. Here are some detailed steps involved in the blending process:

Preparing the biodiesel: Before blending, the biodiesel obtained from the transesterification process needs to be properly prepared. This includes removing any impurities or contaminants that may affect the quality and stability of the blend. Common purification methods include filtration, settling, and washing.

Determining blend ratios: The next step is to determine the desired blend ratio. In the case of a 20% blend, the biodiesel will be mixed with 80% conventional diesel fuel. It's important to carefully measure the quantities of biodiesel and diesel fuel to achieve the desired blend accurately.

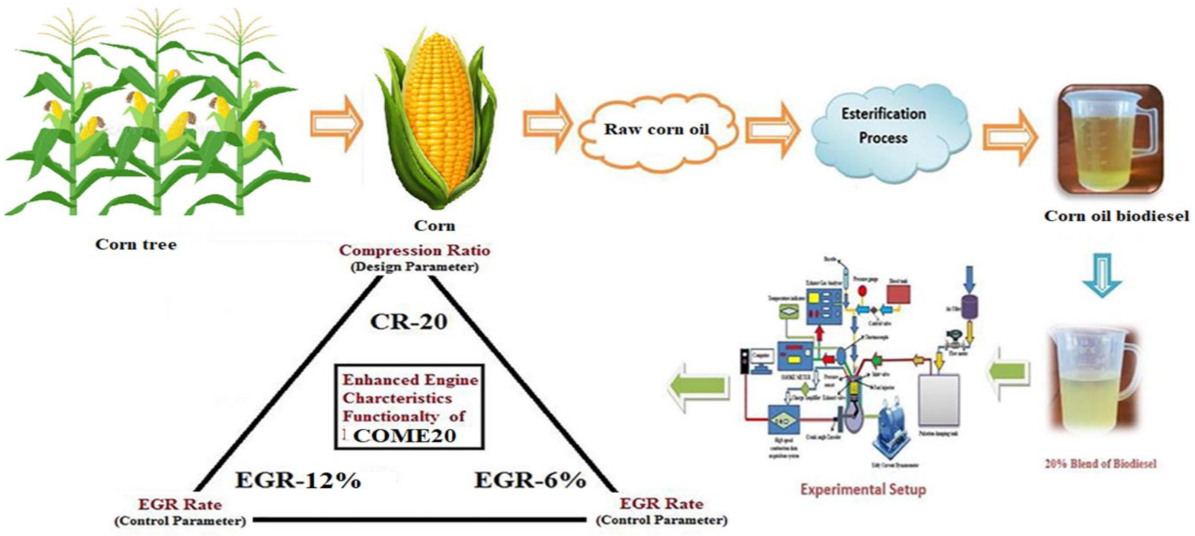

Fig 3.2 Methodology for the preparation and testing of corn oil biodiesel

Compatibility testing: Prior to blending, compatibility testing may be performed to ensure that the biodiesel and diesel fuel are compatible and will not cause any adverse effects on engine performance or fuel system components. This testing evaluates parameters such as stability, solubility, viscosity, and potential chemical reactions between the biodiesel and diesel fuel.

Homogeneous mixing: To achieve a consistent blend, the biodiesel and diesel fuel need to be mixed thoroughly. This can be done through mechanical agitation or blending equipment designed specifically for fuel mixing. The mixing process should ensure complete integration of the biodiesel and diesel fuel, creating a homogeneous blend.

Filtration and quality control: After blending, the biodiesel blend may undergo additional filtration to remove any remaining impurities or particles. This helps to ensure the fuel's cleanliness and prevent potential clogging of fuel filters or engine components. Quality control testing may also be performed to verify that the blended fuel meets the required specifications and standards.

Storage and handling: The blended biodiesel fuel should be stored and handled appropriately to maintain its quality and prevent degradation. It is recommended to store the blend in a clean, dry, and well-ventilated area, away from direct sunlight and extreme temperatures. Proper labelling and documentation of the blend ratio are essential for identification and tracking.

By following these detailed steps, the blending process ensures that the biodiesel and conventional diesel fuel are mixed thoroughly, resulting in a consistent and reliable blend, such as a 20% blend of biodiesel from corn oil.

3.3 Experimental Setup

The experimental setup for evaluating the performance, emissions, and combustion characteristics of a CI (Compression Ignition) engine using a corn biofuel blend with divergent Compression Ratios (CRs) and Exhaust Gas Recirculation (EGR) typically involves the following components:

CI Engine: A suitable CI engine is selected for the experiments. The engine should be compatible with the biofuel blend and capable of accommodating variations in CR and EGR. The engine's specifications, such as displacement, bore, stroke, and compression ratio, need to be documented.

Fuel System: The fuel system is modified or adjusted to handle the corn biofuel blend and enable the variation of CR and EGR. This includes the fuel tank, fuel lines, fuel filters, and fuel injectors. Any necessary modifications or adaptations are made to ensure proper fuel delivery and injection.

Data Acquisition System: A data acquisition system is set up to measure and record various engine parameters during the experiments. This includes sensors for measuring engine speed, torque, temperature, pressure, exhaust emissions, and other relevant parameters. The data acquisition system ensures accurate and reliable data collection for analysis.

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EGR System: The experimental setup incorporates an Exhaust Gas Recirculation (EGR) system. The EGR system recirculates a portion of the engine's exhaust gases back into the intake manifold, reducing oxygen concentration and lowering combustion temperatures. The EGR rate can be adjusted using EGR valves or other control mechanisms.

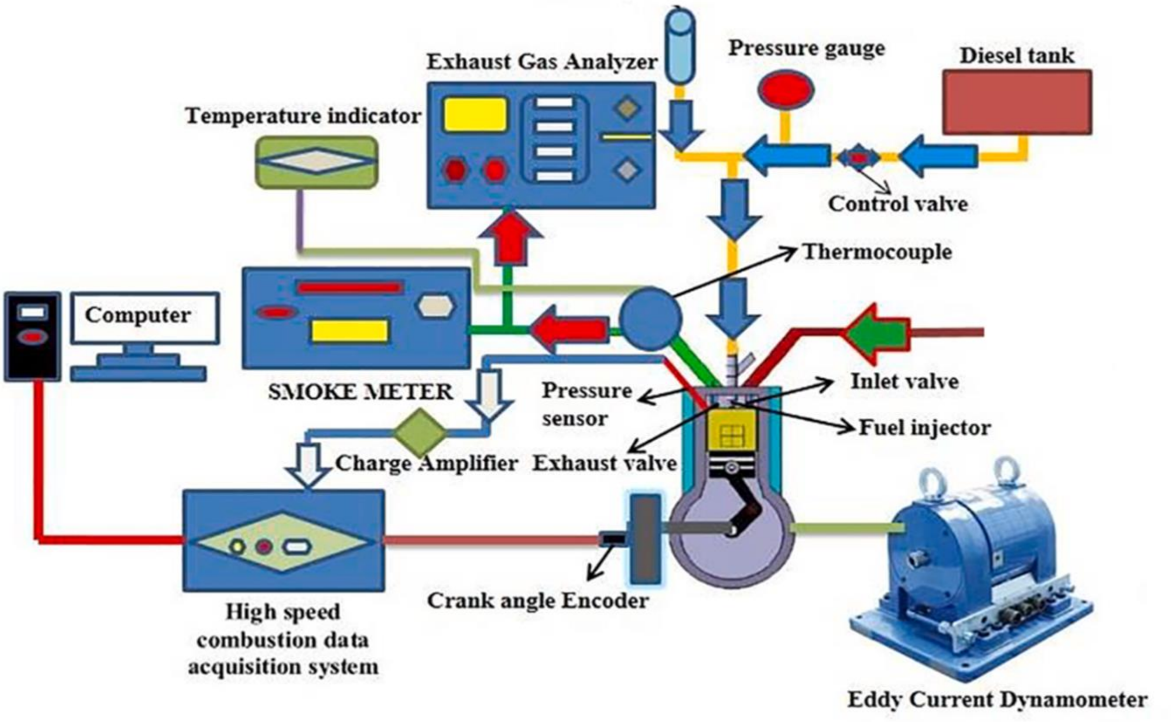


Fig 3.3 Experimental setup for evaluating the performance, emissions, and combustion characteristics of a CI (Compression Ignition) engine using a corn biofuel blend

CR Variation: In a diesel engine, the compression ratio refers to the ratio of the cylinder's total volume when the piston is at the bottom dead center (BDC) to the volume when the piston is at the top dead center (TDC) during the compression stroke. The compression ratio plays a critical role in the performance and efficiency of a diesel engine. The experimental setup includes provisions for varying the Compression Ratio (CR) of the engine. This can be achieved by modifying the engine design or using adjustable components such as cylinder heads, pistons, or engine blocks. The CR is adjusted to different predetermined values to study its impact on engine performance and emissions.

Instrumentation: Various instruments and sensors are installed to measure engine parameters and emissions. This may include thermocouples for measuring temperatures, pressure transducers for combustion pressure analysis, exhaust gas analyzers for measuring emissions, and flow meters for quantifying fuel consumption.

Test Conditions: The experimental setup allows for conducting tests under different operating conditions. This includes variations in engine speed, load, CR, and EGR rate. Test conditions are carefully controlled and documented to ensure repeatability and accuracy of the experimental results.

Experimental Procedure: A systematic experimental procedure is followed to conduct the tests. This includes setting the desired operating conditions, starting the engine, allowing it to stabilize, and collecting data at specific intervals or under steady-state conditions. Multiple runs are performed to ensure statistical significance and validate the results.

Analysis and Interpretation: The collected data is analyzed to evaluate the engine performance, emissions, and combustion characteristics. Statistical analysis techniques may be applied to identify significant trends or differences between different CRs, EGR rates, and fuel blends. The results are interpreted to draw conclusions and make recommendations.

Fig 3.4 Engine

Engine type	Four stroke, Kirloskar CI engine
Number of cylinders	One
Method of cooling	Water cooled engine
Type of Ignition	Compression-ignition
category of Injection	Direct Injection
Compression Ratio	17.5:1
Maximum speed and power	1500 rpm and 4.4 kW
Stroke and Bore	110 mm and 87.5 mm
Rated Torque	28.2 Nm
Injection pressure	220 bar
Static Injection timing	23° CA before top dead center
Displacement Volume	661 cm^3
Type of aspiration	Naturally aspirated CI engine
Clearance Volume	36.87 cm^3
Nozzle holes	3
Capacity of the fuel tank	6.5 Liters

Specifications of Four Stroke Kirloskar CI Engine

CHAPTER – 4
PERFORMANCE RESULTS AND DISCUSSIONS

4.1 Brake Thermal Efficiency (%) Plot

Brake Thermal Efficiency (BTE) is a measure of how effectively an engine converts the energy from fuel into useful work. It is typically expressed as a percentage. The evaluation of engine performance in terms of Brake Thermal Efficiency (BTE) reveals interesting findings. Data was gathered by collecting the necessary information on fuel consumption and power output at various operating points or load conditions of the engine. The collected data was then used to calculate the BTE values for each operating point. BTE was calculated as the ratio of useful work (power output) to the energy input (fuel consumption). Next, the data was organized in a table format, with the load conditions or operating points in one column and the corresponding BTE values in another column. A line graph or scatter plot was created to visualize the data. The load conditions were represented on the x-axis, while the BTE values were displayed on the y-axis. Each data point represented a specific operating point of the engine. Clear labels were provided for the x-axis and y-axis, indicating the load conditions and the BTE values respectively. The appropriate units of measurement were included. A descriptive title was assigned to the plot, reflecting the purpose of the analysis. If there were multiple series or different engine configurations, a legend was added to distinguish between them. The plot was customized by adjusting the colour, line style, marker style, and other visual elements according to the preferences or requirements of the thesis. The BTE plot was then analyzed by interpreting the trends and patterns. Attention was given to any significant variations in BTE across different load conditions or operating points.

It is observed that as the load on the engine increases, there is an improvement in BTE. This can be attributed to the fact that at higher loads, a larger quantity of fuel is burnt, resulting in more energy being converted into useful work. Under standard conditions, the BTE for the diesel fuel is recorded as 25.28%, whereas for the COME20 blend, it is slightly lower at 22.89%.

The reduction of BTE by 1.9% for the COME20 blend can be attributed to the lower heating value of biodiesel compared to diesel. Biodiesel typically has a slightly lower energy content, which affects the overall efficiency of the engine. However, it is important to note that even with the reduction in BTE, the COME20 blend still demonstrates a considerable level of efficiency.

Furthermore, the experimental results indicate that varying the Compression Ratios (CRs) has an impact on BTE for the COME20 blend. As the CR increases from 16:1 to 20:1, there is a

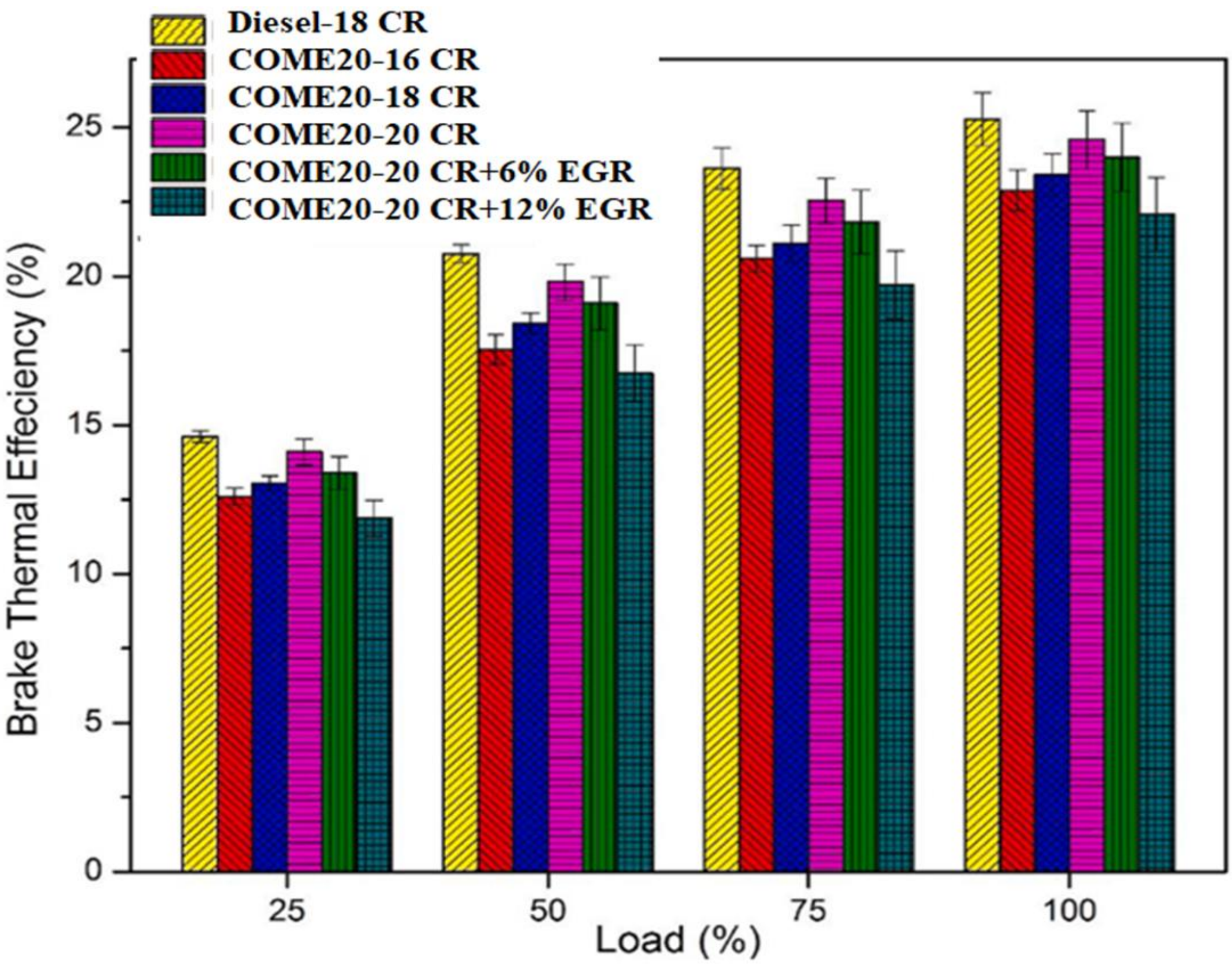


Fig 4.1 Brake Thermal Efficiency (%) Plot

noticeable improvement in BTE, with values of 22.89%, 23.41%, and 24.59% recorded for CRs of 16:1, 18:1, and 20:1, respectively.

This improvement in BTE can be attributed to the increase in pressure and temperature at the end of the compression stroke with higher CRs. The higher compression ratios create a more favourable environment for combustion by increasing the temperature and pressure during the compression stroke. Efficient air-fuel mixing is crucial for achieving optimal combustion and, subsequently, higher brake thermal efficiency.

In summary, the evaluation of BTE for the COME20 blend indicates a reduction compared to diesel due to the lower heating value of biodiesel. However, by increasing the compression ratio, there is a noticeable improvement in BTE, primarily attributed to the enhanced air-fuel mixing and combustion efficiency. These findings emphasize the importance of optimizing engine design parameters, such as compression ratio, to achieve improved performance and efficiency when utilizing biodiesel blends like COME20.

4.2 Brake Specific Fuel Consumption (Kg/Kw-hr) Plot

To create a Brake Specific Fuel Consumption (BSFC) plot, the following steps were taken:

1. Gathered Data: The necessary data on fuel consumption and power output was collected at various operating points or load conditions of the engine.

2. Calculated BSFC: The collected data was used to calculate the BSFC values for each operating point. BSFC was calculated as the ratio of fuel consumption to the power output.

3. Organized the Data: The data was arranged in a table format, with the load conditions or operating points in one column and the corresponding BSFC values in another column.

4. Plotted the Data: A line graph or scatter plot was created with the load conditions on the x-axis and the BSFC values on the y-axis. Each data point represented a specific operating point of the engine.

5. Labelled the Axes: Clear labels were provided for the x-axis and y-axis, indicating the load conditions and the BSFC values respectively. Appropriate units of measurement were included.

6. Added Title and Legend: A descriptive title was given to the plot that reflected the purpose of the analysis. If there were multiple series or different engine configurations, a legend was added to distinguish between them.

7. Customized the Plot: The plot was enhanced by adjusting the color, line style, marker style, and other visual elements according to the preference or requirements of the thesis.

8. Analyzed the Plot: The BSFC plot was interpreted by analyzing the trends and patterns. Significant variations in BSFC across different load conditions or operating points were examined.

By following these steps, a meaningful BSFC plot was created that provided insights into the fuel consumption efficiency of the engine at different operating points.

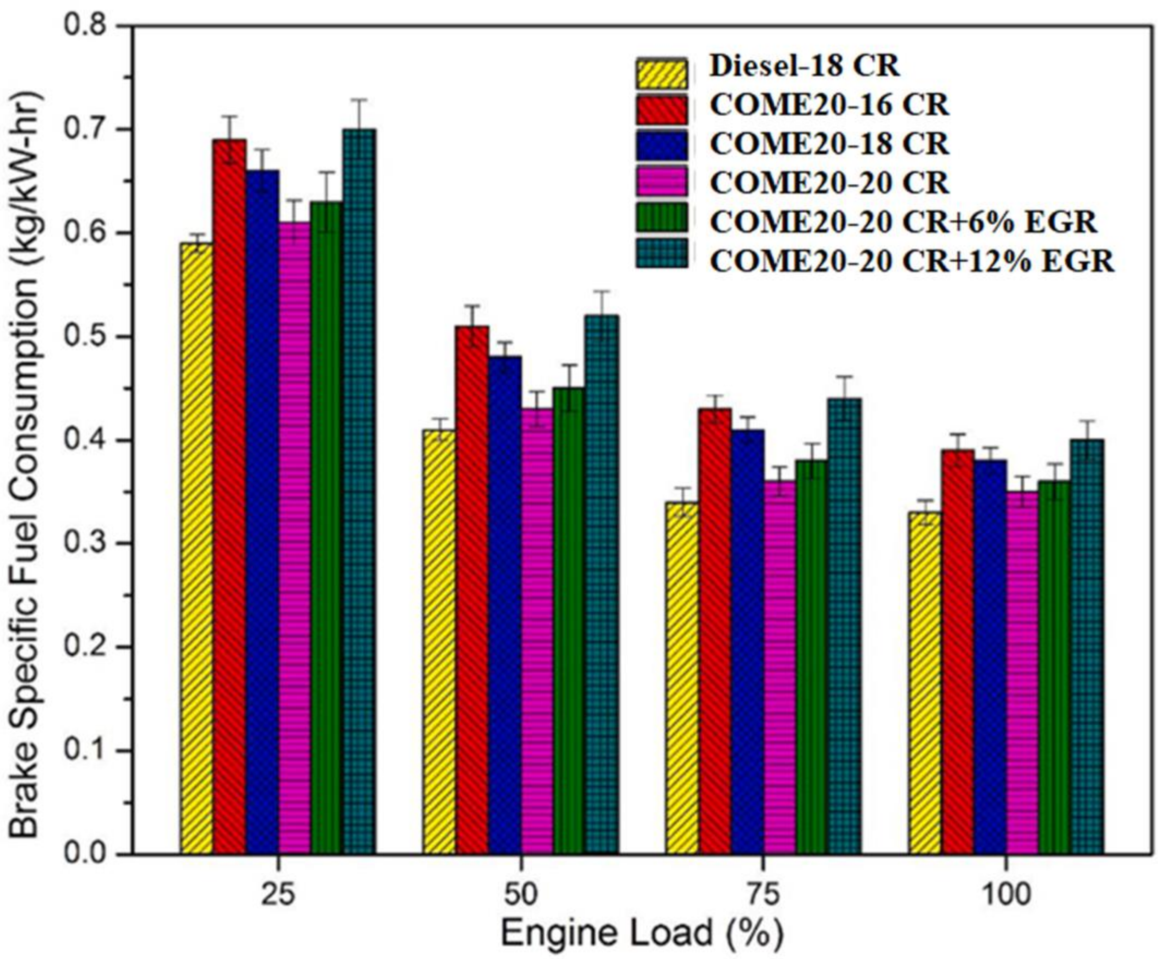
When comparing the Brake Specific Fuel Consumption (BSFC) between the COME20 blend and diesel fuel, it is observed that the BSFC tends to increase for the COME20 blend. This can be attributed to the higher viscosity of COME20 in contrast to diesel fuel. The higher viscosity of the biodiesel blend affects the proper mixing of air and fuel, leading to an incomplete combustion process. Improper air-fuel mixing degrades the overall combustion efficiency, causing the peak pressure and peak Heat Release Rate (HRR) to move away from the Top Dead Center (TDC) position.

However, the experimental results indicate that as the compression ratio increases, the BSFC tends to decrease. The increase in compression ratio plays a crucial role in improving the combustion process. It creates higher temperatures and pressures during the compression stroke, promoting better atomization and vaporization of the fuel. As a result, the air-fuel mixing becomes more efficient, leading to enhanced combustion and a reduction in BSFC.

At full load conditions, the brake specific fuel consumption for diesel fuel at a compression ratio of 18:1 is recorded as 0.33 kg/kW-hr. For the COME20 blend, the BSFC values at compression ratios of 16:1, 18:1, and 20:1 are obtained as 0.39 kg/kW-hr, 0.38 kg/kW-hr, and 0.35 kg/kW-hr, respectively.

Based on the experimental findings, it can be concluded that the COME20 blend with a compression ratio of 20:1 shows the most favorable results compared to other compression ratios. It exhibits a BSFC value that is closer to diesel fuel, indicating a more efficient fuel consumption rate. This suggests that the combination of a higher compression ratio and the use of a 20% blend of corn oil biodiesel leads to improved engine performance in terms of fuel efficiency.

Fig 4.2 Brake Specific Fuel



Consumption (Kg/Kw-hr) Plot

In summary, the increase in BSFC for the COME20 blend can be attributed to its higher viscosity, affecting the air-fuel mixing process. However, the use of higher compression ratios contributes to a reduction in BSFC by promoting better combustion characteristics. The optimal combination is achieved with a compression ratio of 20:1 for the COME20 blend, where the BSFC values are closer to those of diesel fuel, indicating improved fuel consumption efficiency.

CHAPTER – 5
EMISSION RESULTS AND DISCUSSIONS

5.1 Hydrocarbon Emissions (ppm) Plot

A Hydrocarbon Emissions (ppm) plot is a graphical representation of the levels of hydrocarbon emissions from an engine at different operating points or load conditions. Hydrocarbon emissions refer to the release of unburned or partially burned fuel molecules into the atmosphere. These emissions are measured in parts per million (ppm), which indicates the concentration of hydrocarbons in the exhaust gases. To create a Hydrocarbon Emissions (ppm) plot, the following steps were followed:

1. Gathered Data: The necessary data on hydrocarbon emissions at various operating points or load conditions of the engine was collected.

2. Organized the Data: The data was arranged in a table format, with the load conditions or operating points in one column and the corresponding hydrocarbon emissions values in another column.

3. Plotted the Data: A line graph or scatter plot was created with the load conditions on the x-axis and the hydrocarbon emissions values on the y-axis. Each data point represented a specific operating point of the engine.

4. Labelled the Axes: Clear labels were provided for the x-axis and y-axis, indicating the load conditions and the hydrocarbon emissions values respectively. Appropriate units of measurement, such as parts per million (ppm) for hydrocarbon emissions, were included.

5. Added Title and Legend: A descriptive title was given to the plot, reflecting the purpose of the analysis. If there were multiple series or different engine configurations, a legend was added to distinguish between them.

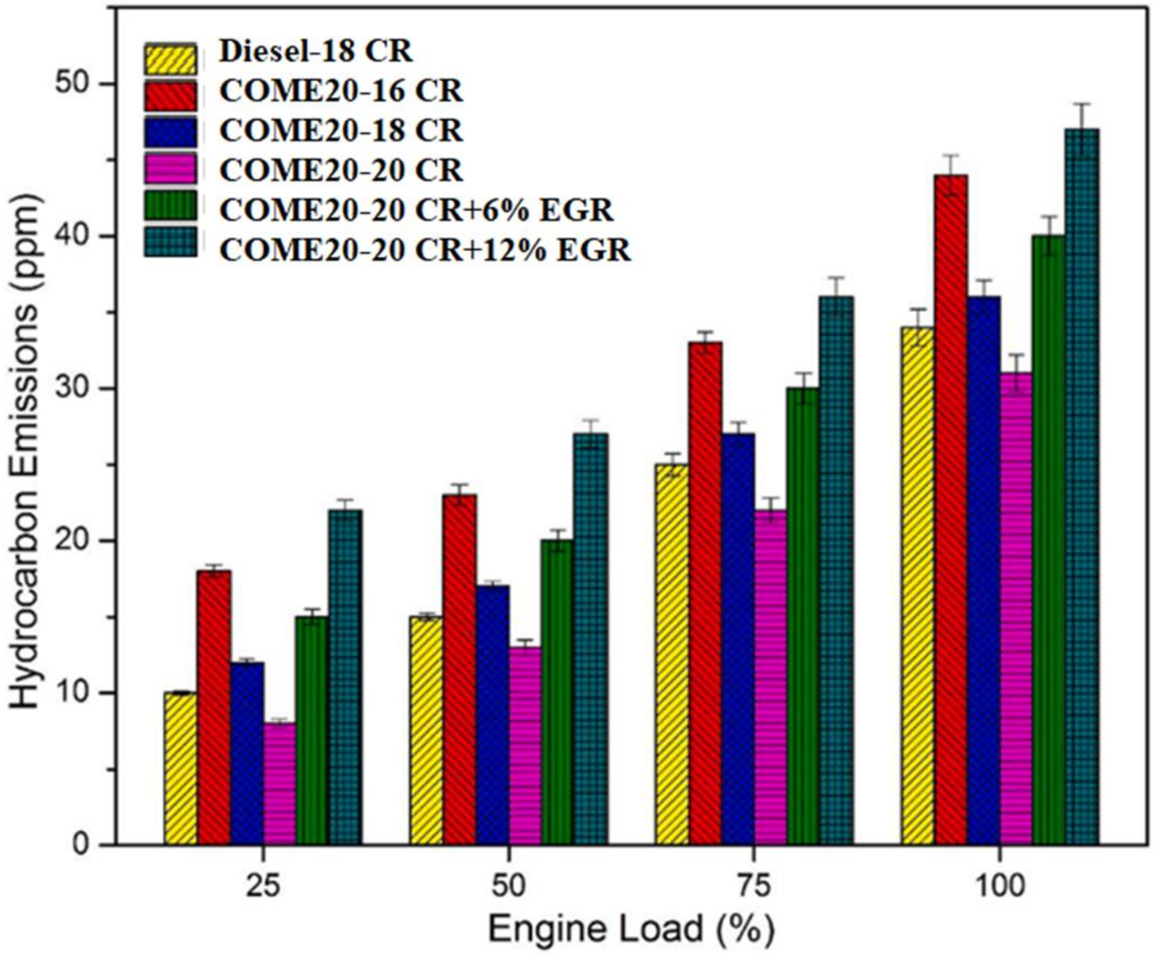
6. Customized the Plot: The plot was enhanced by adjusting the colour, line style, marker style, and other visual elements according to the preference or the requirements of the thesis.

7. Analyzed the Plot: The hydrocarbon emissions plot was interpreted by analyzing the trends and patterns. Any significant variations in hydrocarbon emissions across different load conditions or operating points were identified and analyzed.

By following these steps, a meaningful Hydrocarbon Emissions (ppm) plot was created, providing insights into the levels of hydrocarbon emissions from the engine at different operating points.

Hydrocarbon (HC) emissions in internal combustion engines are primarily formed due to incomplete combustion and poor mixing of air and fuel. When more fuel is burnt at higher loads, the quantity of unburned hydrocarbons increases, leading to elevated HC emissions. In the case of the COME20 blend, an increase in HC emissions was observed compared to diesel fuel, particularly at full load conditions and a compression ratio of 18:1. The higher viscosity and surface tension of the COME20 blend can contribute to an inferior spray behaviour, resulting in incomplete combustion and higher HC emissions.

Fig 5.1 Hydrocarbon Emissions (ppm) Plot



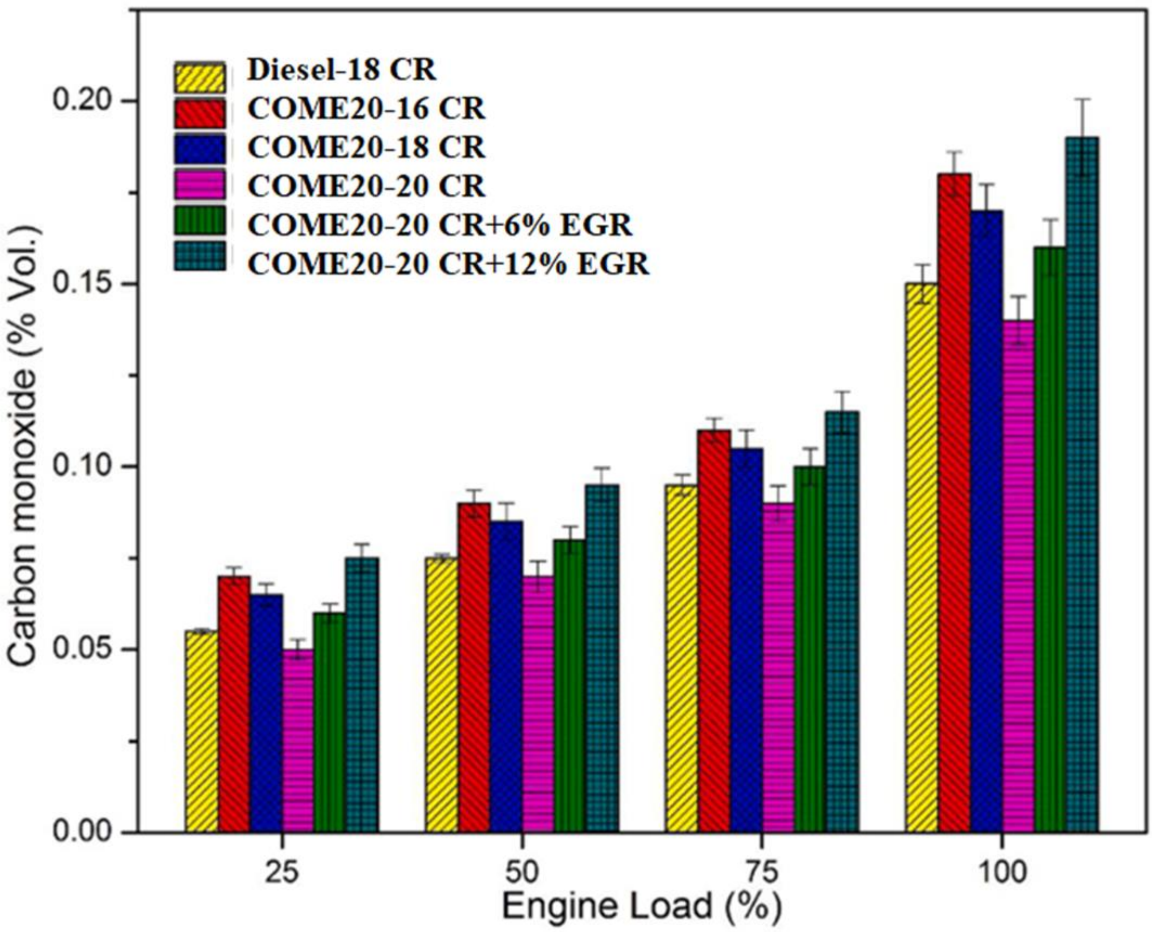
However, the experimental results demonstrate that HC emissions decrease as the compression ratio increases. The hydrocarbon emissions for the COME20 blend at compression ratios of 16:1, 18:1, and 20:1 were recorded as 44 ppm, 36 ppm, and 31 ppm, respectively. Compared to diesel fuel, the HC emissions for COME20 at a compression ratio of 20:1 were found to be 8.82% lower

The decrease in HC emissions with an increase in compression ratio can be attributed to the improved mixing of air and fuel. Higher compression ratios promote better swirl motion in the engine's combustion chamber, resulting in enhanced air-fuel mixing. This leads to more efficient combustion, minimizing the presence of unburned hydrocarbons and reducing HC emissions.

In summary, the rise in HC emissions observed with the COME20 blend can be attributed to its higher viscosity and surface tension, affecting the spray behaviour and resulting in incomplete combustion. However, increasing the compression ratio helps mitigate this issue by promoting better air-fuel mixing and more efficient combustion, leading to reduced HC emissions. The experimental data indicate that at a compression ratio of 20:1, the COME20 blend exhibits a notable decrease in HC emissions compared to diesel fuel.

5.2 Carbon Monoxide Emissions (% Vol.) Plot

Fig 5.2 Carbon Monoxide Emissions (% Vol.) Plot



A Carbon Monoxide (CO) Emissions (% Vol.) plot is a graphical representation of the levels of carbon monoxide emissions from an engine at different operating points or load conditions. Carbon monoxide is a colourless and odourless gas that is produced as a by-product of incomplete combustion of fossil fuels.

The plot typically displays the load conditions on the x-axis, representing different engine operating points such as varying power outputs or throttle positions. The y-axis represents the carbon monoxide emissions levels as a percentage of volume (% Vol.). Each data point on the plot corresponds to a specific operating point, and the plotted line or scatter points connect these data points.

By analyzing the Carbon Monoxide Emissions (% Vol.) plot, researchers and engineers can gain insights into the levels of carbon monoxide emissions under different engine conditions. They can observe the trends and patterns in emissions, identify any significant variations across load conditions, and evaluate the effectiveness of emission control strategies or modifications.

The Carbon Monoxide Emissions (% Vol.) plot is a valuable tool in assessing the environmental impact of engines and evaluating the efficiency of emission reduction technologies. It helps in understanding the performance of engines in terms of carbon monoxide emissions and guides efforts to minimize the release of this harmful pollutant into the atmosphere.

Carbon monoxide (CO) emissions in internal combustion engines are influenced by factors such as oxygen content, heat content, viscosity, temperature, and pressure. When comparing the CO emissions of diesel fuel and the POME20 blend at a compression ratio of 18:1, it was observed that the CO emissions for POME20 were slightly higher at 0.17% compared to diesel at 0.15%. Despite having lower heat content and higher viscosity than diesel, the presence of more oxygen content in POME20 did not lead to a drastic increase in CO emissions. This can be attributed to the combustion characteristics of biodiesel, which tend to promote more complete oxidation of carbon monoxide.

Interestingly, at a compression ratio of 20:1, the CO emissions for POME20 decreased by 17.64% compared to the compression ratio of 18:1 for the same fuel sample. The higher temperatures and pressures developed at higher compression ratios create favorable conditions for the oxidation of CO into CO2. As a result, less carbon monoxide is emitted into the exhaust gases.

The specific CO emissions for diesel at a compression ratio of 18:1 and POME20 at compression ratios of 16:1, 18:1, and 20:1 were recorded as 0.15%, 0.18%, 0.17%, and 0.14% respectively. Additionally, the effect of exhaust gas recirculation (EGR) was examined by adding 6% and 12% concentrations of EGR to POME20 at a compression ratio of 20:1. The carbon monoxide readings were observed as 0.16% and 0.19% for POME20-CR20 with 6% and 12% EGR, respectively.

The experimental results indicate that the CO emissions for the POME20 blend are slightly higher than diesel fuel at a compression ratio of 18:1 but decrease at a higher compression ratio of 20:1. The presence of more oxygen content in POME20 and the favorable conditions created by higher compression ratios contribute to the oxidation of CO into CO2, resulting in reduced CO emissions.

5.3 Carbon Dioxide and Nitrogen Oxide Emissions Plot

A Carbon Dioxide (CO2) Emissions (% Vol.) plot is a graphical representation of the levels of carbon dioxide emissions from an engine at different operating points or load conditions. Carbon dioxide is a greenhouse gas that is primarily produced through the combustion of fossil fuels.

The plot typically presents the load conditions on the x-axis, representing different engine operating points such as varying power outputs or throttle positions. The y-axis represents the carbon dioxide emissions levels as a percentage of volume (% Vol.). Each data point on the plot corresponds to a specific operating point, and the plotted line or scatter points connect these data points.

By analyzing the Carbon Dioxide Emissions (% Vol.) plot, researchers and engineers can gain insights into the levels of carbon dioxide emissions under different engine conditions. They can observe the trends and patterns in emissions, identify any significant variations across load conditions, and evaluate the environmental impact of engine operation.

The Carbon Dioxide Emissions (% Vol.) plot is an important tool in assessing the contribution of engines to greenhouse gas emissions and climate change. It helps in understanding the relationship between engine load conditions and the corresponding carbon dioxide emissions levels. This information is crucial for developing strategies to reduce carbon dioxide emissions, improve fuel efficiency, and mitigate the environmental impact of engine operation.

Furthermore, the Carbon Dioxide Emissions (% Vol.) plot provides a visual representation of the efficiency of an engine in converting fuel into useful work. By analyzing the plot, researchers can assess the performance of different engine configurations, fuels, or emission control technologies in terms of carbon dioxide emissions. This can guide efforts to optimize engine designs and develop cleaner and more sustainable transportation systems.

In summary, the Carbon Dioxide Emissions (% Vol.) plot serves as a valuable tool for understanding and quantifying the carbon dioxide emissions from engines at different operating points. It aids in evaluating the environmental impact of engine operation and supports the development of strategies to reduce greenhouse gas emissions and promote sustainable energy systems.

Carbon dioxide (CO_2) is a greenhouse gas that contributes to global warming and climate change. It is mainly formed due to the complete combustion of the air-fuel mixture in the combustion chamber. In the present study, the CO_2 emissions were measured for both diesel and COME20 blends at different compression ratios. The results showed that the CO_2 readings for diesel at CR18 and COME20 at CR16:1, CR18:1 and CR20:1 were 5.1%, 5.6%, 6.5% and 7.2%, respectively. As the compression ratio increased, the CO_2 emissions also increased for both diesel and COME20 blends.

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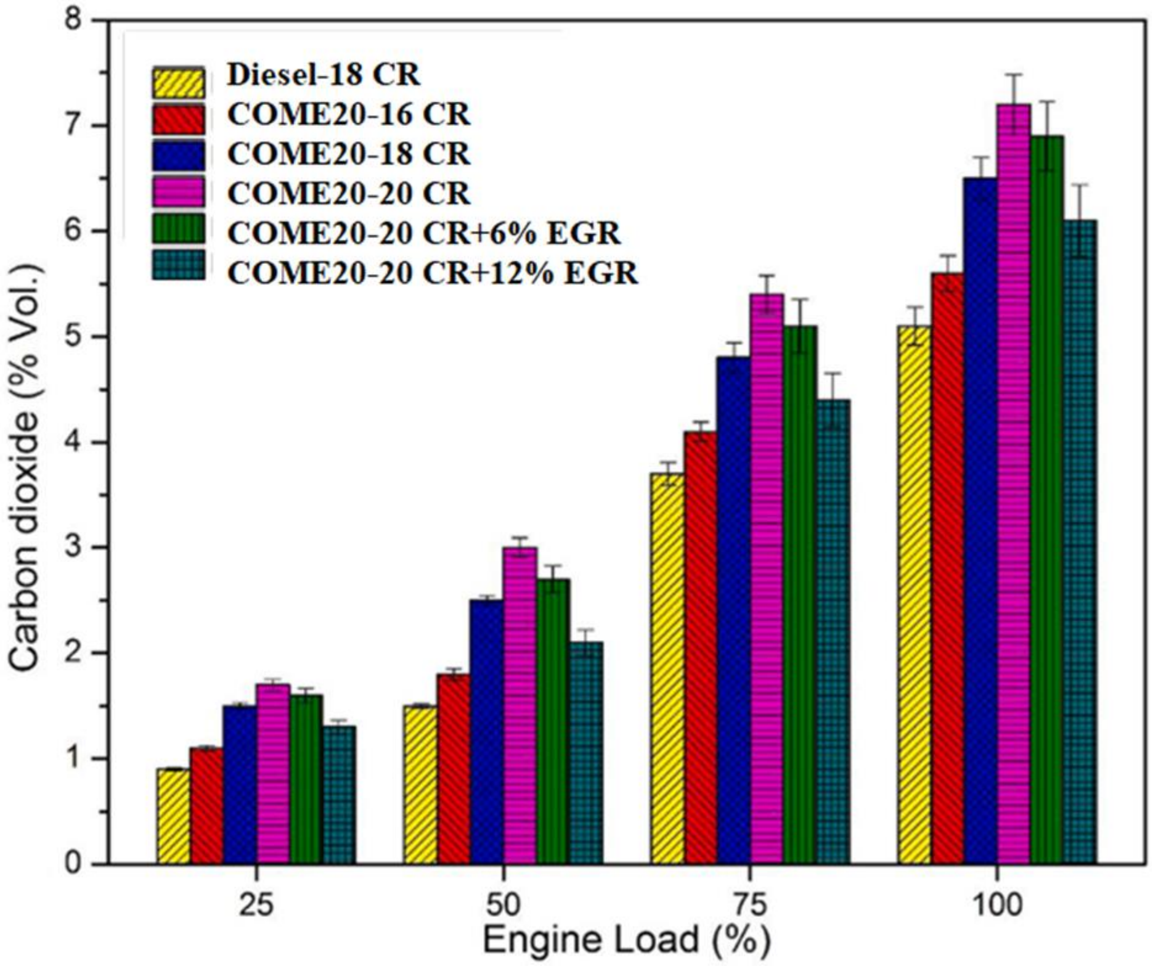
Fig 5.3 Carbon Dioxide Emissions (% Vol.) Plot



Nitrogen oxides (NOx) are harmful pollutants that are formed during combustion due to high temperatures and oxygen content. To create a Nitrogen Oxide (NOx) Emissions (ppm) plot, the following steps were followed:

1. Gathered Data: The necessary data on nitrogen oxide emissions was collected at various operating points or load conditions of the engine. This data was obtained through emissions testing or measurement devices.

2. Organized the Data: The data was arranged in a table format, with the load conditions or operating points in one column and the corresponding NOx emissions values in another column. The NOx values were ensured to be measured in parts per million (ppm).

3. Plotted the Data: A line graph or scatter plot was created with the load conditions on the x-axis and the NOx emissions values on the y-axis. Each data point represented a specific operating point of the engine.

4. Labelled the Axes: Clear labels were provided for the x-axis and y-axis, indicating the load conditions and the NOx emissions values respectively. The appropriate units of measurement, which is parts per million (ppm), were included for NOx emissions.

5. Added Title and Legend: The plot was given a descriptive title that reflected the purpose of the analysis, such as "NOx Emissions at Different Load Conditions." If there were multiple series or different engine configurations, a legend was added to distinguish between them.

6. Customized the Plot: The plot was enhanced by adjusting the color, line style, marker style, and other visual elements according to the preference or the requirements of the thesis.

7. Analyzed the Plot: The NOx Emissions (ppm) plot was interpreted by analyzing the trends and patterns. Significant variations in NOx emissions across different load conditions or operating points were looked for. The impact of factors such as engine tuning, fuel composition, and emission control technologies on NOx emissions was considered.

By following these steps, a meaningful Nitrogen Oxide (NOx) Emissions (ppm) plot was created, providing insights into the levels of NOx emissions from the engine at different operating points. This plot helped in assessing the environmental impact of engine operation and in evaluating the effectiveness of emission control strategies or technologies.

In this study, the NOx emissions were measured for both diesel and COME20 blends at a compression ratio of 18:1. It was observed that the NOx emissions for COME20 were 12.78% more than diesel. The reason for the increase in NOx emissions for COME20 was due to the complete combustion generated by sufficient oxygen content present in the biodiesel blend. The higher flame temperatures and superior oxygen content in the biodiesel blend are the fundamental reasons for the formation of NOx.

Overall, the results of the study suggest that the use of biodiesel blends in diesel engines can lead to changes in engine performance, emissions, and combustion characteristics. The study shows that the use of a 20% blend of corn oil methyl ester (COME20) with diesel resulted in a reduction in brake thermal efficiency, an increase in BSFC, HC and CO emissions, and an increase in CO2 and NOx emissions. However, it was observed that increasing the compression ratio of the engine resulted in an improvement in engine performance and a reduction in emissions. The use of exhaust gas recirculation (EGR) was also found to be effective in reducing NOx emissions for the COME20 blend.

The emissions of nitrogen oxides (NOx) for COME20 blends operated with compression ratios (CR) of 16:1, 18:1, and 20:1 were measured and found to be 450 ppm, 540 ppm, and 588 ppm, respectively. It is well-known that the quality of combustion and in-cylinder temperature increases at higher compression ratios. Since both NOx and carbon dioxide (CO2) emissions are temperature-dependent, a significant increase in their values was observed at higher compression ratios.

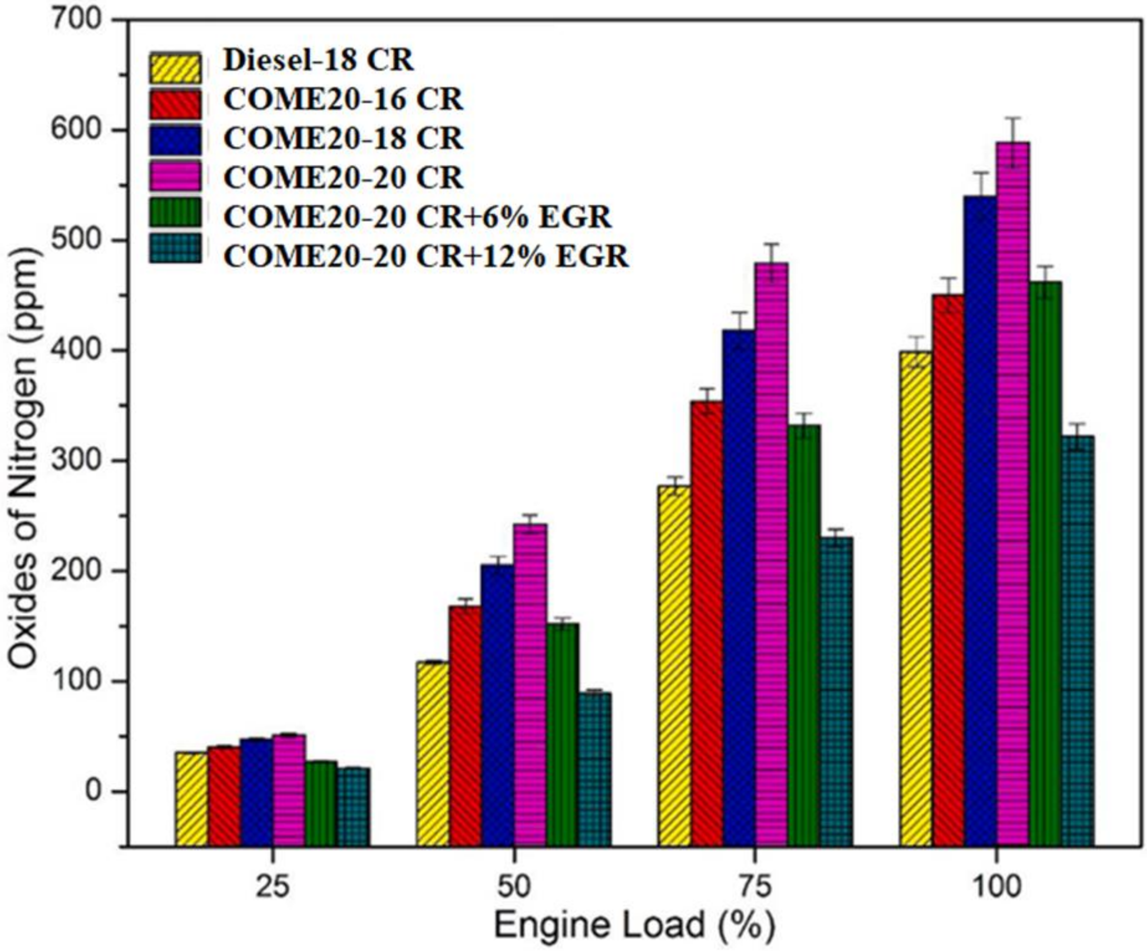


Fig 5.4 Nitrogen Oxide Emissions (ppm) Plot

The addition of an exhaust gas recirculation (EGR) system in the engine can have a significant impact on combustion characteristics. In the case of EGR, the recirculated exhaust gases contain inert components such as carbon dioxide, water vapor, and nitrogen, which act as diluents in the combustion process. As a result, the flame propagation speed is reduced, and the combustion duration is increased.

By extending the combustion duration, a portion of the combustion process is shifted to the expansion stroke of the engine, where temperatures start decreasing due to the expansion of gases. This phenomenon has several effects on emissions. Firstly, the reduction in temperature during the expansion stroke hinders the oxidation of carbon and nitrogen, leading to a decrease in both NOx and CO2 emissions. Secondly, the prolonged combustion duration allows for more thorough mixing of fuel and air, resulting in improved combustion efficiency.

The application of the EGR technique, therefore, plays a crucial role in reducing NOx and CO2 emissions. It effectively modifies the combustion process by altering the temperature profile and combustion duration, leading to a decrease in the formation of nitrogen oxides and carbon dioxide. This technique offers a promising approach to mitigate the environmental impact of combustion engines while maintaining acceptable levels of engine performance.

In summary, the implementation of an EGR system in the combustion process has demonstrated its ability to reduce both NOx and CO2 emissions. The reduction in flame propagation speed, increased combustion

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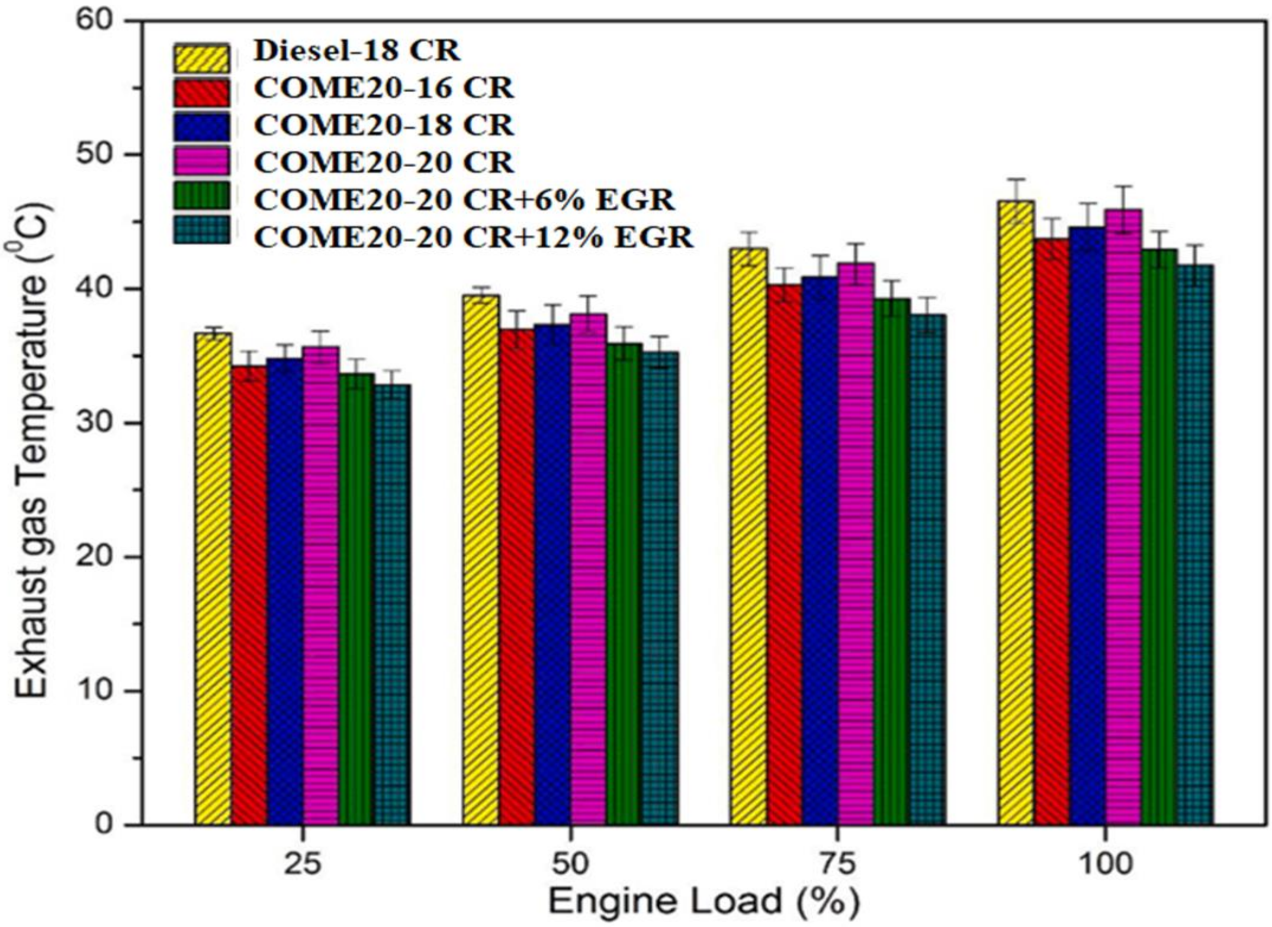
duration, and altered temperature profile contribute to the suppression of nitrogen oxide formation and the optimization of combustion efficiency. The findings of this study highlight the importance of EGR as a technique for reducing emissions and improving the environmental performance of engines operating on COME20 blends.

5.4 Exhaust Gas Temperature Plot

Fig 5.5 Exhaust Gas Temperature Plot



An Exhaust Gas Temperature (EGT) plot is a graphical representation that illustrates the changes in temperature of the exhaust gases at different operating points or load conditions of an engine. It provides valuable information about the thermal characteristics of the engine's exhaust system and can be used to analyze engine performance and diagnose potential issues.

To create an EGT plot, data on exhaust gas temperature is collected at various points along the exhaust system. This data can be obtained using temperature sensors or thermocouples placed strategically in the exhaust manifold or downstream components.

The collected data is then organized in a tabular format, with the load conditions or operating points in one column and the corresponding exhaust gas temperature values in another column. The load conditions can be represented by factors such as engine speed, load torque, or power output.

Using the organized data, a line graph or scatter plot is created, with the load conditions on the x-axis and the exhaust gas temperature values on the y-axis. Each data point on the plot represents a specific operating point of the engine.

The axes of the plot are labelled clearly, indicating the load conditions and the exhaust gas temperature values. The units of measurement, typically degrees Celsius or Fahrenheit, are included alongside the axis labels.

A descriptive title is given to the plot to reflect the purpose of the analysis, such as "Exhaust Gas Temperature Variation at Different Load Conditions." If there are multiple series or different engine configurations, a legend is added to differentiate between them.

The plot can be customized by adjusting the colour, line style, marker style, and other visual elements to enhance clarity and readability.

Analyzing the EGT plot involves interpreting the trends and patterns observed. Significant variations in exhaust gas temperature across different load conditions can indicate engine performance characteristics, combustion efficiency, or the effectiveness of cooling and exhaust systems. Deviations from expected temperature ranges may suggest issues such as fuel-air mixture imbalances, exhaust system restrictions, or engine cooling problems.

In total, an Exhaust Gas Temperature plot provides valuable insights into the thermal behavior of the engine's exhaust gases and assists in monitoring and optimizing engine performance and emissions control.

With an increase in compression ratio, there was a noticeable rise in the exhaust gas temperature. At the top load condition, the exhaust gas temperatures for Diesel at CR18, POME20 at CR16:1, CR18:1, and CR20:1 were recorded as 46.55°C, 43.72°C, 44.61°C, and 45.88°C, respectively.

The increase in exhaust gas temperature can be attributed to the improved combustion process resulting from higher compression ratios. As the compression ratio increases, the air-fuel mixture is subjected to higher pressures and temperatures during the compression stroke. This elevated pressure and temperature lead to better combustion characteristics, including improved air-fuel mixing, enhanced vaporization, and increased flame propagation speed. Consequently, the combustion process becomes more efficient, generating higher levels of thermal energy, which manifests as increased exhaust gas temperatures.

Furthermore, in the case of POME20 at CR20, the effects of exhaust gas recirculation (EGR) were investigated. EGR involves introducing a portion of exhaust gases back into the combustion chamber, which affects the combustion process. In this study, EGR rates of 6% and 12% were applied to POME20 at CR20, resulting in exhaust gas temperature readings of 42.93°C and 41.76°C, respectively.

The introduction of EGR has a cooling effect on the combustion process. By recirculating exhaust gases, the oxygen concentration in the combustion chamber is reduced, which leads to a decrease in the peak combustion temperature. This reduction in temperature is mainly attributed to the dilution effect caused by the presence of inert gases, such as carbon dioxide and water vapor, in the recirculated exhaust gases. The dilution effect lowers the peak flame temperature, resulting in reduced thermal energy being transferred to the exhaust gases.

Additionally, the incomplete combustion of the air-fuel mixture caused by the inclusion of exhaust gases in the inlet air can contribute to a decrease in exhaust gas temperature. The presence of exhaust gases in the inlet air reduces the available oxygen for combustion, leading to incomplete burning of the fuel. This incomplete combustion results in a reduced release of thermal energy, leading to a lower exhaust gas temperature.

In summary, the increase in compression ratio generally leads to higher exhaust gas temperatures due to improved combustion characteristics. However, the introduction of exhaust gas recirculation can have a cooling effect on the combustion process, resulting in lower exhaust gas temperatures. The combination of increased compression ratio and the application of EGR can significantly influence the exhaust gas temperature, and understanding these effects is crucial for optimizing engine performance and emissions.

CHAPTER – 6
COMBUSTION RESULTS AND DISCUSSIONS

6.1 Cylinder Pressure Plot

A Cylinder Pressure Plot, also known as an Indicated Pressure Plot or Pressure vs. Crank Angle Plot, is a graphical representation of the pressure inside the combustion chamber of an engine cylinder throughout the engine's operating cycle.

The plot is typically obtained by using pressure sensors installed in the cylinder to measure the pressure at different crank angles during the engine cycle. The crank angle represents the position of the piston within the cylinder as it moves through the four strokes: intake, compression, power, and exhaust.

The Cylinder Pressure Plot provides valuable information about the combustion process and the engine's performance. It helps in understanding the pressure variations within the cylinder, which are influenced by factors such as fuel-air mixture composition, ignition timing, compression ratio, and engine load.

The x-axis of the plot represents the crank angle, usually expressed in degrees, while the y-axis represents the pressure inside the cylinder, typically measured in units such as bar or psi. The plot displays the pressure values at different crank angles, creating a waveform that shows the pressure changes over time.

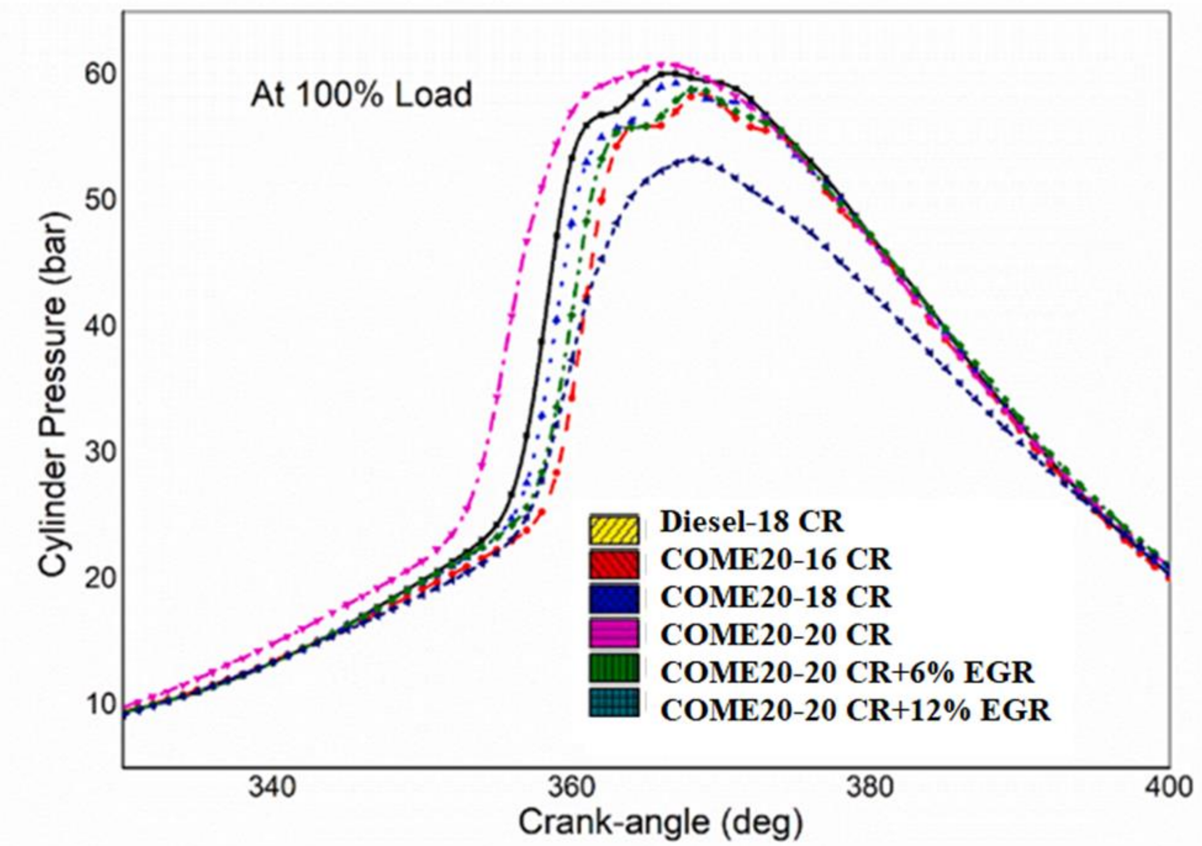
By analyzing the Cylinder Pressure Plot, engineers can assess the efficiency of the combustion process, detect abnormalities or irregularities in the cylinder pressure, and optimize engine performance. It provides insights into the combustion quality, timing, and efficiency, allowing for adjustments and improvements to be made in engine design, fuel injection, ignition timing, and other engine parameters.

The Cylinder Pressure Plot is an essential tool in engine development, tuning, and diagnostics, providing valuable information for optimizing fuel economy, power output, and emissions control.

The rate at which the air-fuel mixture burns within the combustion chamber is a critical factor influencing the increase in cylinder pressure. During the combustion process, the mixture of air and fuel ignites and generates a rapid release of energy, resulting in a significant rise in cylinder pressure.

The maximum rise in cylinder pressure typically occurs within a specific crank angle range after the piston reaches its highest position, known as top dead center (TDC). In this particular study, the maximum rise in cylinder pressure was observed between the crank angles of 362 and 368 degrees after TDC.

Fig 6.1 Cylinder Pressure Plot



During this phase, the combustion reaction reaches its peak intensity, with a substantial amount of fuel being burned and converted into high-pressure gases. The rapid expansion of these gases exerts a force on the piston, driving it downward and generating the power necessary to propel the engine.

The exact timing and magnitude of the maximum cylinder pressure depend on various factors, including the air-fuel mixture composition, ignition timing, compression ratio, and overall engine design. These factors influence the combustion process and determine how quickly and efficiently the air-fuel mixture burns.

Achieving an optimal rate of burning is essential for maximizing engine performance and efficiency. It ensures that the energy released from the combustion process is effectively harnessed to generate power, while minimizing losses and inefficiencies. By carefully controlling the combustion process, engineers can optimize the timing and duration of the maximum cylinder pressure, thus improving the overall performance of the engine.

The maximum cylinder pressure is a critical parameter that reflects the combustion efficiency and power output of an internal combustion engine. In the case of this study, the maximum cylinder pressure values were measured for both diesel fuel and POME20 (20% blend of corn oil methyl ester) at different compression ratios: 16:1, 18:1, and 20:1.

For diesel fuel operated at a compression ratio of 18:1, the maximum cylinder pressure was recorded as 60.08 bar. When POME20 was used as the fuel, the maximum cylinder pressures at CR16:1, CR18:1, and CR20:1 were 58.4 bar, 59.31 bar, and 60.8 bar, respectively.

The variation in maximum cylinder pressure can be attributed to several factors. Firstly, the compression ratio plays a significant role. As the compression ratio increases, the air-fuel mixture is compressed to a higher pressure before ignition, leading to a more intense combustion process. This results in higher peak cylinder pressures.

Additionally, the properties of the fuel can influence the combustion characteristics and, consequently, the maximum cylinder pressure. In this study, the use of POME20, which is a blend of biodiesel derived from corn oil, introduced differences in fuel properties compared to diesel fuel. The presence of biodiesel components in the fuel mixture can affect the combustion process and alter the peak cylinder pressure.

Other factors that can influence the maximum cylinder pressure include the engine's design parameters, fuel injection timing, and combustion chamber geometry. These factors can impact the air-fuel mixing, combustion efficiency, and combustion duration, ultimately affecting the peak pressure attained during the power stroke.

Monitoring and understanding the variations in maximum cylinder pressure provide valuable insights into the combustion characteristics and performance of the engine. It enables researchers and engineers to optimize engine design, fuel formulation, and operating conditions to achieve higher efficiency, reduced emissions, and improved overall engine performance.

The rise in cylinder pressure with an increase in the compression ratio is a well-known phenomenon in internal combustion engines. It occurs due to the fundamental relationship between compression ratio, air temperature, air movement, and the combustion process.

When the compression ratio is increased, the air-fuel mixture inside the engine cylinder is compressed to a higher pressure before the onset of combustion. This higher compression ratio leads to an increase in the air temperature within the cylinder. As the air is compressed, its temperature rises due to the adiabatic compression process.

The higher air temperature resulting from the increased compression ratio has several effects on the combustion process. Firstly, it promotes better air combustion by ensuring that the air molecules possess sufficient energy for an efficient chemical reaction with the fuel. The increased air temperature facilitates the activation of the fuel molecules and enhances the likelihood of a complete and rapid combustion process.

Furthermore, a higher compression ratio also leads to quicker air movement within the engine chamber. The increased compression forces the air to move at a higher velocity during the intake and compression strokes, resulting in improved air-fuel mixing. This enhanced mixing ensures a more homogeneous distribution of the fuel particles throughout the air, allowing for better combustion.

The combination of higher air temperature and quicker air movement achieved through a higher compression ratio contributes to a more favorable combustion environment. The increased air temperature provides the necessary energy for ignition and sustains the combustion process, while the improved air-fuel mixing enhances the combustion efficiency.

Ultimately, the rise in cylinder pressure observed with an increase in the compression ratio is a result of these favorable conditions for combustion. The higher pressure indicates a more effective utilization of the air-fuel mixture and a stronger force acting on the piston, which translates into increased power output and improved engine performance.

Understanding the relationship between compression ratio, air temperature, air movement, and cylinder pressure is crucial for optimizing engine design and operation. By carefully selecting the appropriate compression ratio, engineers can achieve a balance between efficient combustion, power output, and emission control in internal combustion engines.

6.2 Net Heat Release Rate (NRR) Plot

A Net Heat Release Rate (NRR) Plot, also known as Heat Release Rate vs. Crank Angle Plot, is a graphical representation of the rate at which heat is released during the combustion process inside an engine cylinder throughout the engine's operating cycle.

The plot is typically obtained by analyzing the pressure data obtained from pressure sensors installed in the cylinder and using thermodynamic analysis techniques. By integrating the pressure data over the engine cycle, the net heat release rate can be calculated and plotted against the crank angle.

The NRR Plot provides valuable insights into the combustion characteristics and efficiency of the engine. It shows how the heat release rate varies with crank angle, representing the combustion process's timing and intensity. The shape and magnitude of the NRR Plot can provide information about the combustion stability, combustion duration, and heat transfer within the cylinder.

The x-axis of the plot represents the crank angle, usually expressed in degrees, while the y-axis represents the net heat release rate, typically measured in units such as J/deg or kW/deg. The plot displays the rate at which heat is released at different crank angles, creating a waveform that shows the variation in heat release over time.

By analyzing the NRR Plot, engineers can gain insights into the combustion process and make adjustments to optimize engine performance, fuel efficiency, and emissions control. It helps in understanding the combustion timing, combustion phasing, and the effects of various factors such as ignition timing, air-fuel ratio, and engine load on the heat release rate.

The NRR Plot is widely used in engine research, development, and optimization. It provides crucial information for understanding the combustion characteristics of different fuels, evaluating combustion chamber designs, and improving engine efficiency and emissions performance.

The variation of heat release rate with respect to different crank angles is a crucial parameter in evaluating the combustion characteristics of an internal combustion engine. The heat release rate represents the rate at which thermal energy is released during the combustion process inside the engine's combustion chamber.

During the combustion process, fuel is injected into the compressed air within the cylinder, and it undergoes a series of chemical reactions, releasing heat energy. The heat release rate describes how this energy release changes over time, providing insights into the combustion efficiency and the timing of the combustion process.

At different crank angles, the heat release rate can vary significantly, reflecting the dynamic nature of the combustion process. Typically, the heat release rate experiences a gradual increase from the start of combustion until it reaches a peak value. This peak corresponds to the period when the combustion process is most intense, with the highest rate of heat energy release.

The location of the peak heat release rate within the crank angle cycle can vary depending on factors such as the fuel properties, air-fuel mixture, and engine operating conditions. The timing of the peak heat release rate is important for optimizing engine performance, as it determines the efficiency of power generation and the combustion stability.

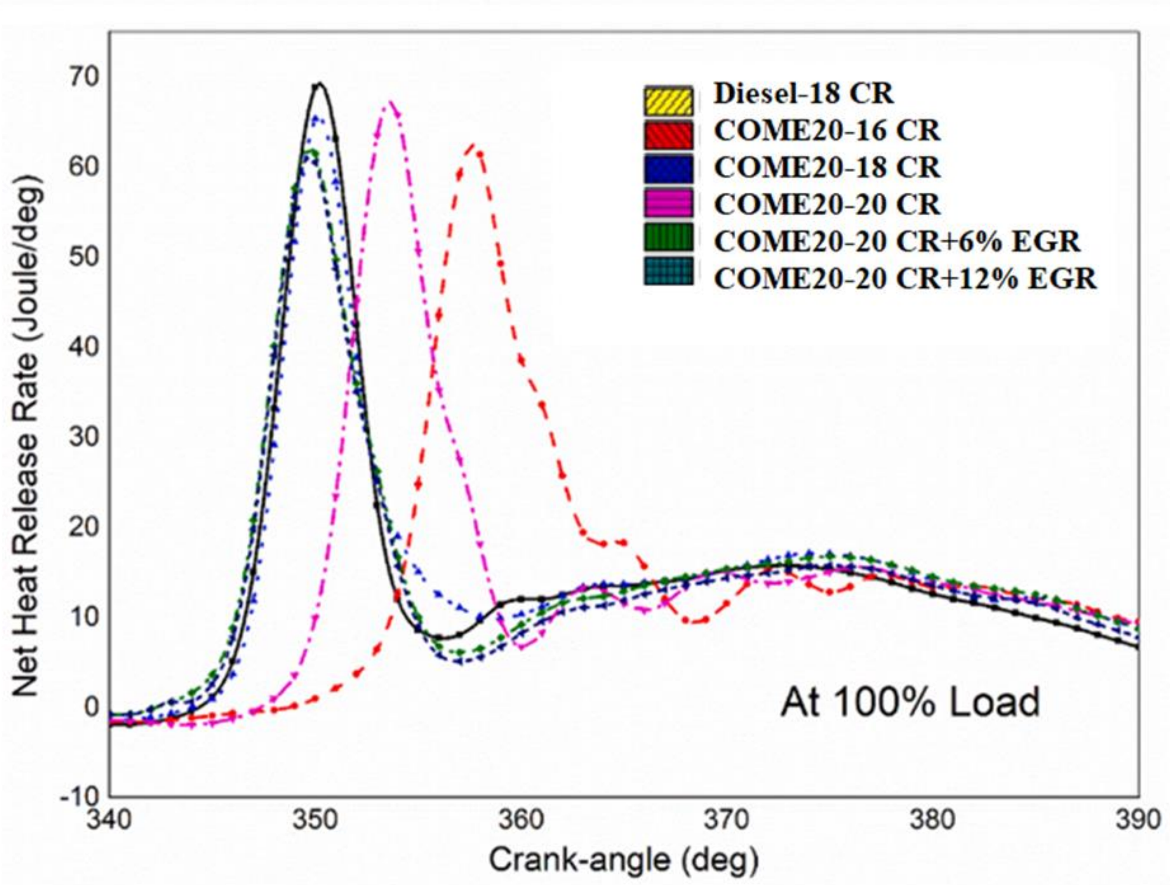


Fig 6.2 Net Heat Release Rate (NRR) Plot

The shape and magnitude of the heat release rate curve provide valuable information about the combustion characteristics. A well-designed combustion process aims for a controlled and efficient release of heat energy, resulting in a smooth and consistent heat release rate curve. Deviations from the desired shape or irregularities in the curve can indicate issues such as incomplete combustion, abnormal combustion, or inefficient energy conversion.

The variation of the heat release rate with different crank angles can also be influenced by the compression ratio. Higher compression ratios tend to result in more rapid and intense combustion due to increased air temperature, air-fuel mixing, and pressure. This can lead to a higher peak heat release rate and potentially improved combustion efficiency.

Studying the heat release rate at different crank angles and relating it to the compression ratio provides valuable insights into the combustion process's dynamics and efficiency. It helps researchers and engineers understand how changes in engine design parameters, fuel properties, and operating conditions impact the combustion characteristics and overall engine performance.

By analyzing the heat release rate curve, engineers can optimize combustion strategies, improve fuel efficiency, reduce emissions, and enhance the overall performance and reliability of internal combustion engines.

The heat release rate (HRR) is a crucial parameter that characterizes the rate at which thermal energy is released during the combustion process inside the engine's combustion chamber. It provides insights into the combustion efficiency, timing, and intensity of the combustion process.

In the context of the comparison between diesel and COME20 (20% blend of corn oil biodiesel) operated at different compression ratios (CR16:1, CR18:1, and CR20:1), the HRR values obtained were 68.87 J/°CA, 61.36 J/°CA, and 65.34 J/°CA for diesel@CR18, and 65.81 J/°CA for COME20 at CR20:1.

When the compression ratio is increased, it results in a higher charge density within the combustion chamber. This means that a larger amount of air-fuel mixture is present, allowing for more efficient combustion. The increased charge density leads to improved air-fuel mixing, which enhances the combustion process.

However, as the compression ratio increases, the spray penetration of the fuel spray decreases. Spray penetration refers to the distance travelled by the fuel spray as it is injected into the combustion chamber. The reduced spray penetration is due to the higher pressure and temperature conditions created by the increased compression ratio.

The relationship between compression ratio, charge density, and spray penetration has a significant impact on the heat release rate. The higher charge density achieved with increased compression ratio results in a more rapid and intense combustion process, leading to a higher heat release rate. This is reflected in the higher HRR values observed for COME20 at higher compression ratios compared to diesel@CR18.

It is important to note that the specific HRR values obtained for each condition are influenced by various factors such as fuel properties, air-fuel mixing, combustion chamber design, and injection characteristics. These factors can contribute to variations in the combustion process and subsequently affect the heat release rate.

By analyzing the HRR values and understanding the relationship between compression ratio, charge density, and spray penetration, researchers and engineers can optimize the combustion process to achieve higher efficiency, lower emissions, and improved overall engine performance. The knowledge gained from these analyses can guide the development of advanced combustion strategies and engine designs that enhance the thermal efficiency and environmental sustainability of internal combustion engines.

Increasing the charge density within the combustion chamber, which is achieved through a higher compression ratio, has a significant impact on the flow dynamics inside the chamber. As the charge density increases, it creates a greater mass of air-fuel mixture, leading to increased swirl and turbulence during the intake and compression strokes.

Swirl refers to the rotational motion of the air-fuel mixture within the combustion chamber, while turbulence refers to the chaotic flow patterns created by the interaction of different flow streams. Both swirl and turbulence play a crucial role in enhancing the air-fuel mixing process.

The intensified swirl and turbulence result in better intermixing of the air and fuel, creating a more homogeneous mixture throughout the combustion chamber. This improved mixing is essential for achieving efficient and complete combustion. When the air and fuel are thoroughly mixed, the combustion process becomes more uniform, with a better distribution of fuel droplets and oxygen.

The enhanced air-fuel mixing facilitates faster and more consistent flame propagation, allowing for a more controlled and efficient combustion process. It promotes the simultaneous ignition and combustion of a larger portion of the air-fuel mixture, leading to a higher combustion efficiency and improved combustion stability.

Furthermore, the increased swirl and turbulence help to break down larger fuel droplets into smaller ones, increasing the surface area available for combustion. This increased surface area enhances the interaction between the fuel and oxygen, facilitating a more thorough and rapid combustion process.

The overall effect of increased charge density, swirl, and turbulence is a more favorable combustion environment with improved air-fuel mixing and combustion quality. This leads to benefits such as reduced emissions, improved fuel efficiency, and enhanced engine performance.

Understanding the relationship between charge density, swirl, turbulence, and combustion quality is crucial for optimizing engine design and combustion strategies. By manipulating these factors, researchers and engineers can further improve the combustion process, leading to more efficient and environmentally friendly engines.

CONCLUSION

The utilization of corn oil as a feedstock for biodiesel production holds significant promise as a reliable and cost-effective alternative fuel option. However, to ensure its widespread adoption and address the trade-off effect between engine performance and emissions, an efficient approach is necessary.

A thorough analysis of the existing literature highlights the need for a comprehensive strategy to optimize the performance and emissions characteristics when using corn oil methyl ester blended fuel in compression ignition (CI) engines. While corn oil biodiesel offers several advantages such as renewable sourcing and reduced greenhouse gas emissions, it is crucial to overcome any potential drawbacks that might impact engine performance.

To achieve this, researchers and engineers are exploring various avenues to mitigate the trade-off effect and enhance the compatibility of corn oil methyl ester blended fuel with CI engines. This includes investigating engine design parameters, control strategies, and fuel reformulation techniques.

By examining engine design parameters, such as compression ratio, combustion chamber geometry, and injection timing, researchers aim to optimize the combustion process and ensure efficient utilization of the blended fuel. Additionally, control parameters such as exhaust gas recirculation (EGR) rate and fuel injection strategies can be fine-tuned to balance performance and emissions trade-offs.

Furthermore, the fuel reformulation approach involves exploring the possibility of blending corn oil methyl ester with other compatible fuels or additives to improve its properties and address any issues related to viscosity, cetane number, and lubricity. This approach aims to find an optimal blend ratio that maximizes engine performance while minimizing emissions.

The research gap identified in the literature emphasizes the need for a comprehensive investigation into the combined effects of compression ratio and exhaust gas recirculation on the performance and emissions of corn oil biodiesel blends. This approach holds promise for achieving an efficient balance between engine performance and emissions, ensuring the viability of corn oil methyl ester blended fuel as a practical and sustainable alternative in CI engines.

By addressing the trade-off effect and optimizing the utilization of corn oil biodiesel blends, researchers and engineers can pave the way for the widespread adoption of this renewable fuel source, contributing to a greener and more sustainable future for the transportation sector.

Therefore, in light of the research gap and the need for a comprehensive understanding of the combined effects of compression ratio and exhaust gas recirculation (EGR) on the performance and emissions of corn oil biodiesel blends, the present investigation aims to bridge this gap and contribute to the existing knowledge in the field.

The combined effect of compression ratio and EGR has not been extensively explored or proposed specifically for the selected biodiesel, which highlights the novelty and significance of this research endeavor. By investigating this combined approach, the study aims to uncover valuable insights into the optimal operating conditions and parameters that can effectively mitigate the trade-off effect between engine performance and emissions for the selected biodiesel.

The inclusion of compression ratio as a variable in the investigation is crucial because it plays a fundamental role in determining the air-fuel mixture's compression and subsequent combustion process. By exploring different compression ratios, ranging from low to high values, the study seeks to understand their impact on combustion efficiency, power output, and emissions characteristics of the corn oil biodiesel blend.

Additionally, incorporating exhaust gas recirculation into the investigation further enhances the scope and relevance of the study. EGR involves reintroducing a portion of the engine's exhaust gases into the combustion chamber, which can have significant effects on combustion temperature, emissions formation, and overall engine performance. By systematically varying the EGR rate in combination with different compression ratios, the research aims to optimize the trade-off between engine performance and emissions for the selected biodiesel.

The outcomes of this investigation are expected to provide valuable insights into the combined effect of compression ratio and exhaust gas recirculation on the engine performance, emissions, and combustion characteristics of the corn oil biodiesel blend. The findings will not only fill the existing research gap but also contribute to the development of effective strategies for mitigating the trade-off effect in the utilization of this biodiesel in compression ignition engines.

Ultimately, the goal of this research is to enhance our understanding of the optimal operating conditions and parameters for achieving improved engine performance and reduced emissions when using corn oil biodiesel blends. The knowledge gained from this investigation can guide future advancements in engine design, fuel formulation, and control strategies, facilitating the wider adoption of sustainable and environmentally friendly alternative fuels in the transportation sector.

A series of carefully designed experiments were conducted to evaluate the performance and emissions characteristics of a corn biodiesel blend, COME20, in comparison to diesel fuel. The experiments involved varying the compression ratios (CR16:1, CR18:1, and CR20:1) and introducing different concentrations of exhaust gas recirculation (EGR) (6% and 12%).

The investigation yielded significant findings regarding the brake thermal efficiency (BTE) of COME20 under different operating conditions. The results indicated that the BTE of COME20 improved with increasing compression ratios. Specifically, at CR16:1, CR18:1, and CR20:1, the BTE values were observed as 22.89%, 23.41%, and 24.59%, respectively. Additionally, when considering COME20 at a compression ratio of 20:1, the application of 6% and 12% EGR resulted in BTE values of 24.01% and 22.09%, respectively.

Moreover, the study highlighted the influence of compression ratio and EGR on emissions, particularly nitrogen oxides (NOx). It was observed that COME20 with a compression ratio of 20:1 and 6% EGR concentration exhibited a notable reduction in NOx emissions compared to diesel at CR18. Specifically, NOx emissions were lowered by 6.76% and 2.75% for COME20-CR20@6% EGR in comparison to diesel-CR18 at peak load conditions.

Based on the comprehensive analysis of the experimental results, it can be inferred that COME20 blended fuel, operating at a compression ratio of 20:1 with 6% EGR concentration, shows promising potential as a viable alternative to diesel fuel. This combination demonstrated enhanced engine performance in terms of improved brake thermal efficiency while also achieving a reduction in NOx emissions.

The findings of this study provide valuable insights into the optimization of engine performance and emissions characteristics for corn biodiesel blends. The identified operating condition of COME20 at CR20:1 with 6% EGR concentration presents a practical and environmentally friendly alternative to conventional diesel fuel, showcasing the potential of sustainable and renewable biofuels in the transportation sector.

Further research and development in this area are warranted to validate and refine these findings, as well as to explore the long-term durability and compatibility of the proposed engine configuration. With continued efforts, the utilization of corn biodiesel blends may contribute significantly to achieving a greener and more sustainable future in the field of transportation.

FUTURE SCOPE

The analysis suggests that conducting further investigation into the utilization of mango seed oil as a blended fuel in compression ignition engines is warranted. Specifically, the study recommends exploring the use of mango seed oil at a concentration of 20% in combination with two different compression ratios: 18:1 and 20:1. Additionally, the investigation should include varying exhaust gas recirculation (EGR) rates of 6% and 12%. Furthermore, the study proposes incorporating nanoparticles into the blended fuel to assess their potential impact.

The detailed exploration of these parameters aims to shed light on the performance and emissions characteristics of the mango seed oil blended fuel. By varying the compression ratios, the investigation seeks to determine the optimal ratio that achieves improved engine performance, combustion efficiency, and reduced emissions. Higher compression ratios can result in increased air temperature, enhanced air-fuel mixing, and improved combustion, leading to higher brake thermal efficiency and torque output.

The inclusion of EGR in the experimental setup is essential to examine its influence on engine performance and emissions. EGR involves recirculating a portion of the engine's exhaust gases back into the combustion chamber. This process helps lower combustion temperatures, reducing the formation of nitrogen oxides (NOx) and improving fuel efficiency. The investigation aims to identify the most effective EGR rate that maximizes the benefits of reduced emissions without compromising engine performance.

Moreover, the addition of nanoparticles to the mango seed oil blended fuel introduces another dimension to the study. Nanoparticles can enhance fuel combustion by promoting better fuel atomization, increasing the surface area for combustion, and facilitating faster and more complete combustion. By evaluating the effects of nanoparticle type, concentration, and size, the investigation seeks to determine their impact on engine performance, combustion characteristics, and emissions reduction.

To conduct the investigation, a comprehensive experimental methodology is proposed. This includes using a single-cylinder compression ignition engine equipped with suitable instrumentation to measure performance parameters, combustion characteristics, and emissions. Various operating conditions, such as different compression ratios, EGR rates, and nanoparticle concentrations, will be tested to gather comprehensive data.

The expected outcomes of this investigation are significant. It is anticipated that utilizing mango seed oil as a blended fuel, particularly at a concentration of 20% and with specific compression ratios and EGR rates, will lead to improved engine performance, including increased brake thermal efficiency and higher torque output. Additionally, the study aims to achieve a notable reduction in emissions, particularly NOx, CO, and PM. The optimal operating conditions identified through this research can contribute to both environmental and economic benefits by providing a greener and more sustainable fuel option for transportation.

In conclusion, the detailed investigation proposed in the analysis holds the potential to contribute valuable insights into the utilization of mango seed oil as a blended fuel in compression ignition engines. By examining the effects of compression ratios, EGR rates, and the incorporation of nanoparticles, this research aims to optimize engine performance, enhance combustion efficiency, and reduce emissions, thus paving the way for a more sustainable future in transportation.

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