Using Ruta Oil to Produce Biofuel and Its Effect on Engine Performance and Emissions

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Using Ruta Oil to Produce Biofuel and Its Effect on Engine Performance and Emissions

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Abstract .

This study experimentally investigates the effects of using biodiesel made from Ruta oil in combination with diesel fuel, on diesel engine performance. The blending ratio of the prepared Ruta methyl ester (RME) biodiesel with nominal diesel fuel might range from 10% to 30% by volume. The experimental study focuses on diesel engines operating at a steady speed and exposed to varying loads. The results show that adding RME biodiesel slightly lowers the BTE and enhances the BSFC and BSEC. Using data gathered from tests. Experimental results showed that a 20% RME biodiesel blend produced the best results, with HC and CO emissions dropping dramatically as the blend percentage increased. The results show that adding nanoparticles somewhat increased the BTE while decreasing the BSFC. The results acquired are confirmed by comparing them to those reported by other researchers operating under the same conditions

.

Keywords: Ruta, Castor methyl ester, biodiesel, Ruta, Engine Performance

1. Introduction

The Energy usage is ever rising. Owing to alterations in lifestyle and the proliferation of the global population. The rise in energy demand has been met by fossil resources, leading to significant depletion of fossil fuels and a subsequent increase in their prices. The utilization of fossil resources results in significant environmental consequences, including global warming, ozone depletion, deforestation, acidification, photochemical smog, and eutrophication. Consequently, there is an urgent necessity to seek alternative energy sources that are economically viable, environmentally sustainable, and socially acceptable.

For several years, internal combustion engines have been predominant as key drivers in multiple sectors, particularly in transportation and industry. This is due to its higher performance and extended durability properties. The swift expansion of urbanization has led to a significant rise in the quantity of cars on urban thoroughfares, with an escalation in the number of industrial plants and facilities globally.

The transportation and industrial sectors are the primary energy consumers, deemed significant contributors to the increase in energy demand. The transportation industry is recognized as the primary consumer of petroleum fuels, including gasoline, diesel, Compressed Natural Gas (CNG), and Liquefied Petroleum Gas (LPG) [1][2]. Vehicular emissions contribute significantly to air pollution, posing a substantial health risk due to the extensive exposure of persons. Vehicular emissions are responsible for a significant quantity of air pollutants, including NOx, CO, UHC, as well as organic and inorganic contaminants, which encompass trace metals and their detrimental effects on the environment and human health [3][4][5][6][7][8].

Furthermore, science and technology face challenges due to the depletion of petroleum supplies as fuel, rising fuel demand, and the implementation of stricter pollution standards. Consequently, numerous researchers have focused on investigating alternate fuels. The utilization of biodiesel sourced from vegetable oils and animal fats serves as a viable alternative to petroleum-based diesel fuels. The

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utilization of both edible and non-edible vegetable oil-based biodiesel is promising in this context. This is due to their capacity for local production and cultivation on arid terrain. Numerous writers have reported on the efficacy of various vegetable oils, including coconut, soybean, castor, and sunflower oils [9][10].

Global focus is being devoted towards the examination of biodiesel fuel owing to its compatibility and fuel characteristics [11][12]. Biodiesel has demonstrated superior qualities compared to petroleum diesel, including enhanced biodegradability, sustainability, great lubricity, non-toxicity, and a near absence of aromatics and sulfur. Biodiesel has the ability to reduce possible carcinogens and pollution levels. Furthermore, it is an environmentally sustainable energy source that may be utilized in a diesel engine without necessitating a change of the existing technology.

Renewable energy sources are the optimal alternative to fulfill the earth's energy requirement, owing to their vast availability and significant potential. Biodiesel is the most recognized alternative fuel source to diesel[13][14]. Moreover, it has gained importance recently due to its potential to replace fossil fuels, which are expected to deplete within a century. The utilization of biodiesel as an alternative to fossil fuels has been promoted due to environmental concerns associated with exhaust gas emissions, as it is demonstrated to be environmentally sustainable. Biodiesel is defined as a mixture of mono-alkyl esters derived from vegetable oils, and it is considered a carbon-neutral fuel since the carbon emitted in the exhaust was originally absorbed from the environment.

Furthermore, the utilization of biodiesel mitigates the greenhouse effect by preventing an increase in atmospheric carbon dioxide (CO2) levels [15][16]. The reduction of HC, CO, and smoke emissions is corroborated in [17][18], noting that emissions from the majority of biodiesel combustors exhibited elevated levels of NOx.

Vegetable oils are extensively utilized as feedstock’s for biodiesel manufacturing. Castor oil, a type of vegetable oil, possesses two notable characteristics as a biodiesel feedstock: its cultivation necessitates minimal resources and it does not compete with food oils. Under humid and hot tropical circumstances, castor plants can thrive satisfactorily without any fertilizer [19][20]

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Biodiesel is an oxygenated diesel fuel derived from the transesterification of triglycerides into esters. Transesterification is a process that employs alcohol, specifically ethanol, butanol, or methanol, in the presence of a catalyst such as potassium hydroxide (KOH) or sodium hydroxide (NaOH). These substances chemically decompose raw oil molecules into ethyl or methyl esters, producing glycerol as a by-product. This technique reduces the viscosity of the oil, as its qualities closely resemble those of diesel [21][22]

The utilization of biodiesel in compression ignition engines reduces carbon monoxide (CO) emissions, hydrocarbons (HC), and smoke. The oxygen concentration in biodiesel and the elevated temperature during complete combustion lead to increased NOx production. Nevertheless, the utilization of biodiesel presents certain disadvantages, including elevated molecular weight, increased viscosity, greater pour point, and reduced volatility in comparison to diesel [23][24].

In recent years, numerous researchers have focused on fuel formulation methods to enhance performance and emission characteristics through the use of fuel additives in biodiesel. Nanoparticles utilized with biodiesel represent a novel and promising fuel additive capable of optimizing performance and minimizing exhaust emissions [25][26]. The incorporation of nanoparticles into the fuel enhances its thermo-physical qualities, such as heat conductivity and the high surface area-to-volume ratio. Reports indicate that nano-additives, in conjunction with biodiesel, diesel, and their blends, enhance the fire point, flash point, and kinematic viscosity [27][28] .

In this research, Ruta oil was used to produce biodiesel fuel. This is considered the first research to use this type of oil. There is no source that used this oil. Here, in this research, previous research on castor oil was studied due to the similarity of the physical properties of Ruta oil. The current study is based on an experimental analysis of the characteristics of the combustion, performance and emissions for an engine running in two cases of biodiesel and diesel fuel. A comparison in terms of performance and emissions of the engine is studied for the two types of fuels. In addition, choosing the best blend between biodiesel (RME) and diesel fuel is investigated through performance comparison and emissions with

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diesel fuel. This includes examining the effect of blending on cylinder pressure, temperature, heat release, brake thermal efficiency (BTE), brake fuel consumption (BSFC), CO, UHC, smoke and NOx emissions.

The main aims of this experimental work are:

1. Prepare biodiesel from Ruta oil by esterification process and blend with pure diesel in different proportions.

2. Examine the performance and emission characteristics of a diesel engine running on biodiesel at different fuel ratios (10%, 20%, and 30%) compared to pure diesel fuel.

2-METHODOLGY

2-1 Biodiesel Preparation

The Ruta plant was obtained from the agricultural areas in Diwaniyah, specifically Al-Sudair and Al-Mahnawiyah regions. The Ruta plant seeds were traditionally extracted and then transferred to Al-Rafidain Oil Mill in Baghdad to extract the oil and convert it into biodiesel. All the necessary chemicals, including potassium hydroxide, were obtained from local markets based on known chemical sources and used without further purification. The components used in making biodiesel are shown in Figure (2.1). Pure diesel fuel for testing was obtained from Al-Diwaniyah Government Fuel Station. The experiments (preparation of biodiesel) were conducted in the laboratory of Al-Qadisiyah University. Figure (2.2) shows the esterification methods used in making biodiesel. This study uses a basic catalyst to investigate biodiesel production from Ruta oil through the esterification process. After completing the preparation of the biodiesel, samples are taken according to the selected proportions and mixed with pure diesel to examine the physical properties in the Dora refinery laboratory in Baghdad. After that, the diesel engine is operated on biodiesel fuel to study the effect of engine performance and combustion emissions.

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Fig (2.1) Materials used in the experiment

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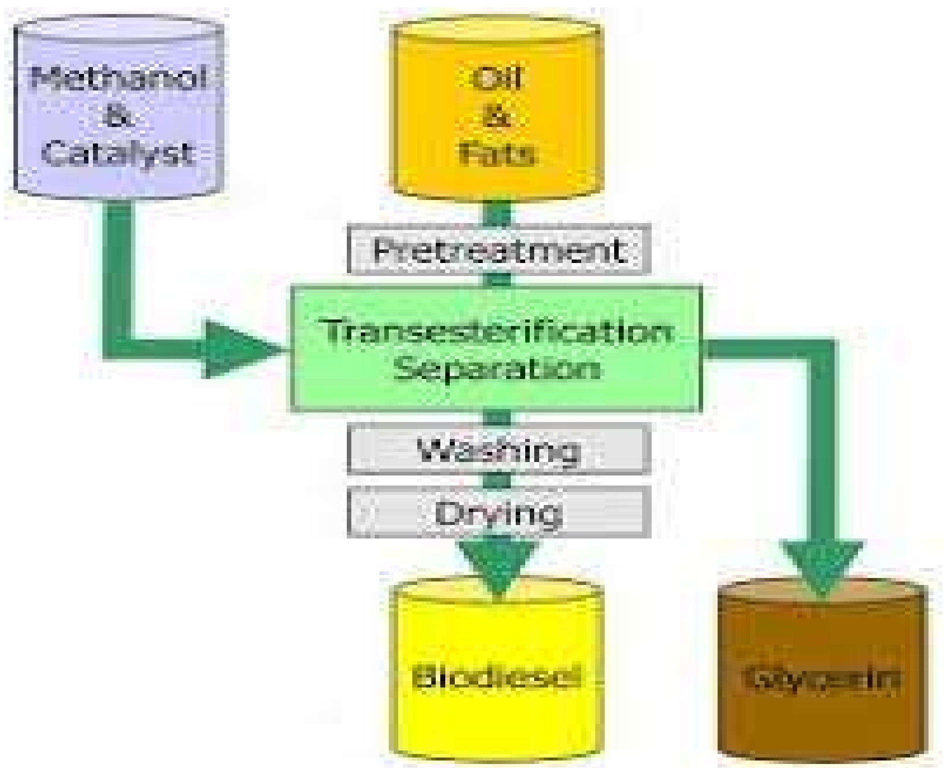

Fig (2-2): Flow chart of biodiesel preparation

First, a 500 ml beaker is brought and filled with Ruta oil. Then the second step begins, which is mixing the sodium methoxygen solution (consisting of 3 grams of NaOH granules dissolved in 200 ml of CH_3OH, with thorough stirring). This mixed solution is then placed inside the beaker and the temperature is fixed at 65°C using a magnetic stirrer for one hour. Then the mixture is placed inside the separating funnel shown in Figure (2-3) and left to rest overnight. The glycerin is then separated from

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the biodiesel through the valve located at the bottom of the funnel hen the biodiesel is prepared, samples are taken for the purpose of examining the physical properties.

Fig (2- 3) Glycerol Appearance

2.2Biodiesel Specifications

The physical properties of biodiesel prepared from Ruta oil and pure diesel were studied in the laboratories of Dora Refinery in Baghdad Governorate, Iraq. Table (2-1) shows the physical properties of pure diesel and the properties of biodiesel according to ASTM standards

Table (2-1) The characteristics of RME and DF

Property	Diesel	10% RME	20% RME	30% RME	100% RME	Oil Ruta	Test method
Density at 15 ºC (kg/m^3)	824.9	829.3	834.7	835	867.3	904.6	ASTMD 4052

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Viscosity at 40 ºC (pa.s)	0.00228	0.00256	0.00297	0.00333	0.00914	0.0038	ASTMD 455
Calorific value (MJ/kg)	45.85	45.78	45.7	45.71	45.21	45.89	Calculated
Cetane number	53.4	53.1	54.1	55.2	---	---	ASTMD 976

2-3 Experimental setup

The experiment includes a diesel engine that works with different types of fuel and consists of a single cylinder, four-stroke, water-cooled, with a constant speed of 1500 rpm and a constant compression ratio of 16.5bar. It is connected directly to an electric generator connected to an eddy current meter for the load, as well as a set of sensors that are connected to the computer, through which we know the results such as exhaust temperature, speed, emissions and other parameters. Figure (2-4) shows a real shot of the engine and its accessories, while Figure (2-5) shows a schematic image of the experiment.

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Fig (2-4) Engine components

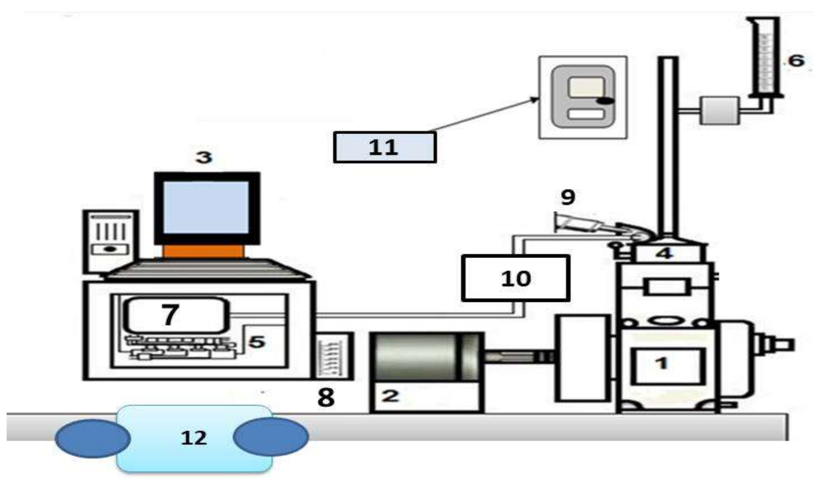

Fig (2-5) Test engine diagram

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Table (2-2) Test engine components

1	Engine block	5	Data Logge	9	Fuel injector
2	Eddy current dynamometer.	6	Fuel tank	10	Intake air
3	PC	7	Air surge tank	11	Voltage regulator
4	Cylinder head	8	Water manometer	12	Gas analyzer

2.4 Experimental procedure

The experimental procedures focus on investigating the impact of biodiesel on engine performance and emission characteristics. Initially biodiesel is prepared by mixing it with pure diesel in specific proportions: B10% (10% RME, 90% diesel), B20% (20% RME, 80% diesel), and B30% (30% RME, 70% diesel). This mixture is thoroughly blended to achieve homogeneity, after which samples are analyzed in the laboratory to assess their physical properties. A single-cylinder, four-stroke diesel engine is run at a constant speed of 1,500 rpm, with a water-cooled system and a constant compression ratio (16.5 bar) on pure diesel for 30 minutes. This creates a baseline by holding the exhaust gas temperature constant. Engine performance parameters, including temperature, load and fuel consumption, are recorded at different loads (0%, 25%, 50%, 75% and 100%). The engine is then tested with B10% biodiesel at the same load levels, followed by B20% biodiesel and then B30% biodiesel, with readings taken at each stage. After data on engine performance and exhaust emissions parameters – such as carbon monoxide, carbon dioxide, oxygen and nitrogen oxides – are collected, these results are compared with those of pure diesel. Based on the results between pure diesel and biodiesel, the optimal biodiesel blend is determined and the engine performance and emissions results are discussed in Chapter 3

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3. RESULTS AND DISCUSSION

3.1 Exhaust Gas Temperature (EGT)

Through experimental testing, the effect of load on exhaust gas temperature (EGT) was analyzed in a diesel engine operating on two types of fuel: conventional diesel and a diesel blend with different proportions of biodiesel.

3.1.1 The reproducibility of exhaust gas temperatures

Figure 3.1 shows the reproducibility of exhaust gas temperatures of a diesel engine across multiple tests (Test 1, Test 2, Test 3, and Test 4) with increasing load from 0% to 100%. There is a steady increase in exhaust gas temperature with increasing load. This behavior is expected in internal combustion engines, where increasing load leads to burning more fuel, resulting in higher exhaust gas temperatures. The variation between the four tests is small, indicating that the engine performance is stable and reproducible when operating on diesel, enhancing the results' accuracy and reliability.

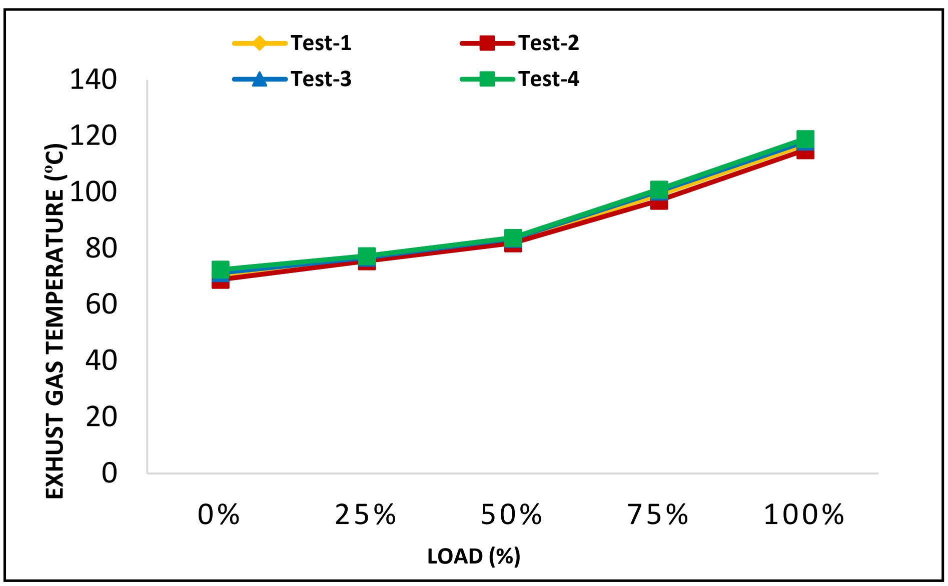

Figure:3.1 Repeatability of exhaust gas temperature variation with load for diesel fuel

3.1.2 Change in EGT vs. load

Figure 3.2 shows the change in exhaust gas temperature when using a diesel blend with biodiesel at 10%, 20%, and 30% compared to pure diesel (100% diesel). The graph reveals that all lines show a similar trend to Figure 3.1, with EGT increasing with increasing load. However, there is a noticeable

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difference between pure diesel and biodiesel blends. As the proportion of biodiesel in the blend increases, there is a slight increase in EGT, especially at higher loads.

This can be explained by the fact that biodiesel has different combustion characteristics than conventional diesel. Biodiesel typically contains more oxygen, which promotes complete combustion. This can slightly increase exhaust gas temperatures when blending biodiesel with diesel, especially at higher load levels.

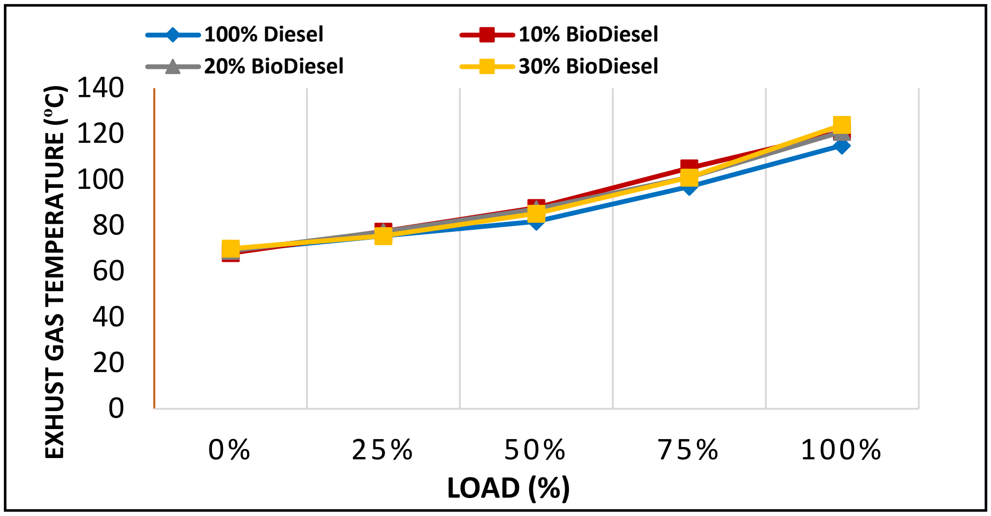

Figure:3.2 Change in EGT with load

In general, both Figures (3.1, 3.2) show that exhaust gas temperature increases with load, regardless of fuel type. However, biofuels have a noticeable effect on EGT, with temperatures rising slightly as the proportion of biofuels in the blend increases. These results are important when studying the impact of biofuels on engine efficiency and exhaust emissions, as higher EGTs can impact NOx emissions, which may require modifications to engine control systems to improve environmental performance.

3.1.3 Input Power vs. Load

Figure 3.3 shows the relationship between input power (kW) and load percentage for different fuel types, including 100% diesel and various biodiesel blends (10%, 20%, 30%). As the load increases, the input power required rises for all fuel types, with pure diesel consistently needing slightly less input power. The 10% and 30% biodiesel blends perform similarly to diesel, while the 20% blend requires slightly more power, especially at higher loads. Overall, biodiesel blends, particularly up to 30%, are viable alternatives to diesel with minimal impact on engine efficiency under varying loads.

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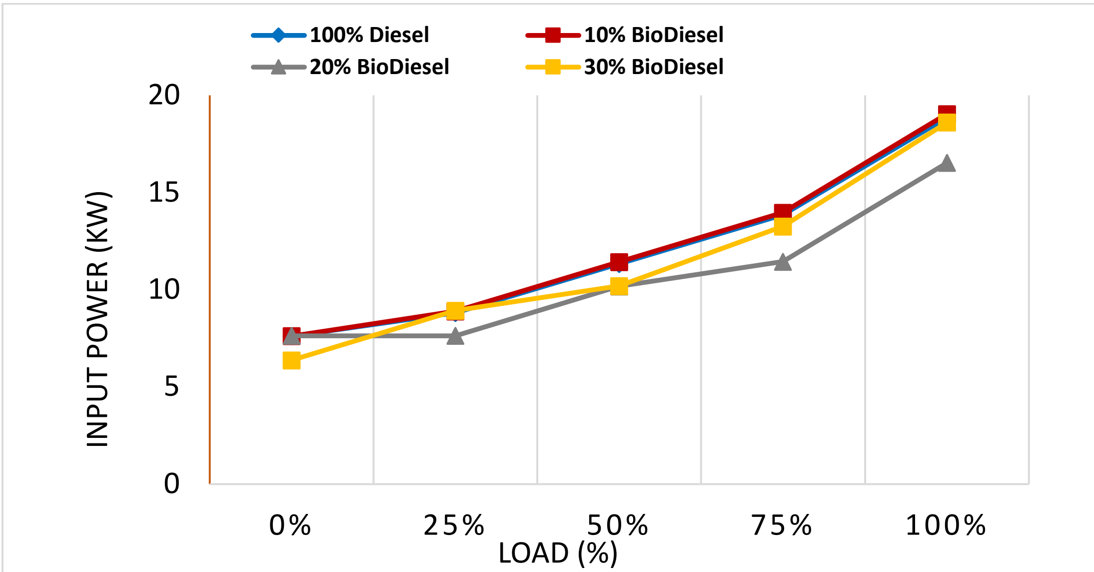

Figure:3.3 Change in input power with load

3.1.4 Brake Mean Effective Pressure (BMEP)

Figure 3.4 shows that the brake means effective pressure, a measure of engine efficiency, increases with biodiesel blends, with B20 achieving the highest values at medium to high loads. A higher BMEP means that the engine is producing more work per cycle, indicating better mechanical performance. The B20 blend provides the best pressure, indicating superior engine output. This makes B20 the ideal choice for improving engine performance when combined with nanomaterials, as it will maximize the engine's power output.

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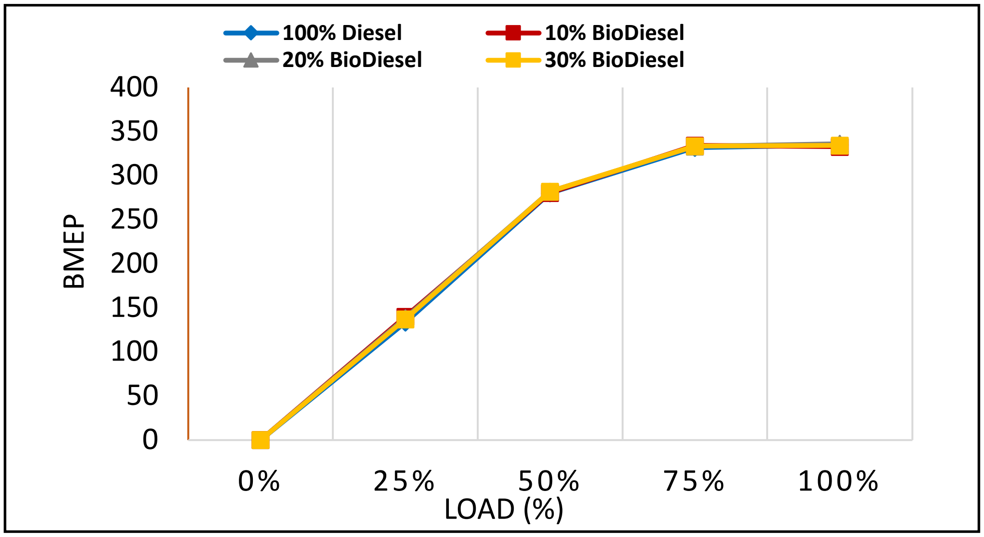

Figure:3.4 Change in BMEP with load

3.2 Emissions Analysis

In terms of emissions, the use of biodiesel significantly reduces carbon dioxide (CO_2) emissions compared to pure diesel. This represents a significant environmental benefit, as biodiesel helps reduce the carbon footprint of the engine. However, nitrogen oxide emissions tend to increase with higher biodiesel percentages due to higher combustion temperatures. For carbon monoxide (CO) and hydrocarbons (HC), emission levels are relatively similar between biodiesel and diesel, with biodiesel showing a slight advantage in reducing these emissions.

3.2.1 CO_2 Emissions

CO_2 emissions decrease with increasing biodiesel blend ratios, with B30 showing the lowest emissions across all loads, as shown in Figure 3.5. Biodiesel blends, especially B30, contribute significantly to CO_2 emissions reductions due to the renewable nature of biodiesel. For environmentally-conscious applications, reducing CO_2 emissions is critical, and B30 would be the most sustainable choice. However, in terms of overall engine performance and balance with other emission factors, B20 may be more practical.

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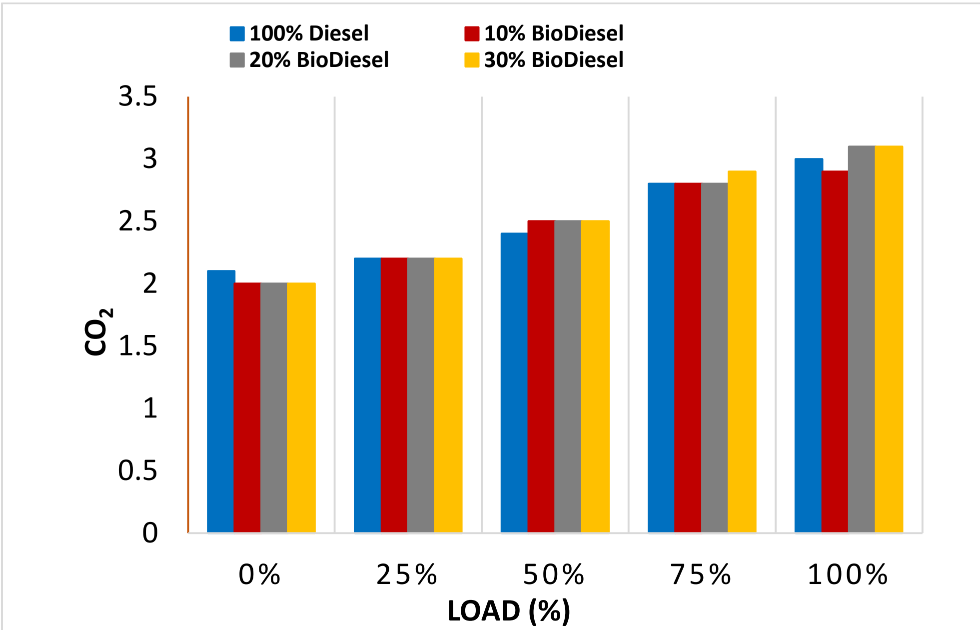

Figure:3.5 CO_2 emission variation depending on engine loads

3.2.2 Oxygen Emissions

In Figure 3.6, oxygen emissions decrease slightly with increasing biodiesel content, with B30 showing the lowest levels. The lower oxygen emissions in biodiesel blends indicate that the fuel is burning more efficiently. For systems using nanomaterials, this may indicate better oxidation processes and improved reaction kinetics due to the cleaner combustion environment provided by biodiesel blends.

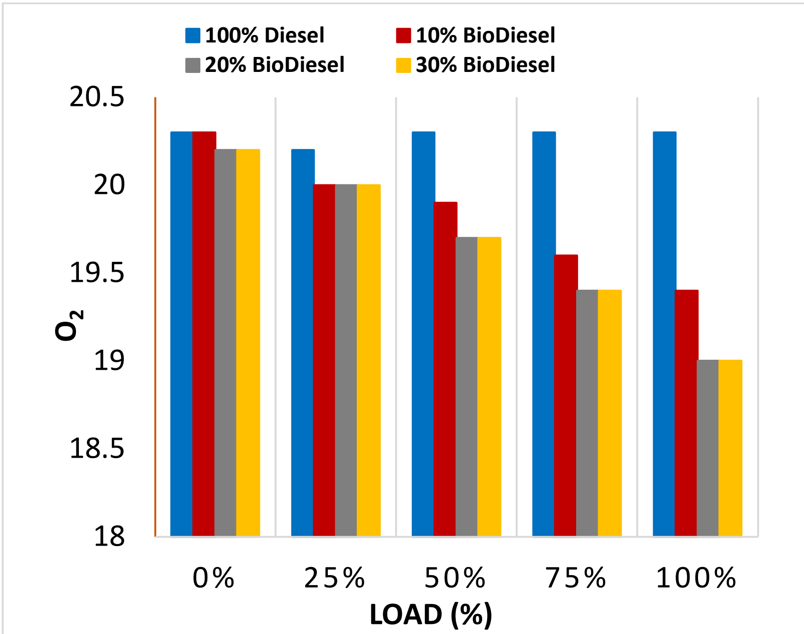

Figure: 3.6 O_2 emission variation depending on engine loads

3.2.3 NOx Emissions

As biodiesel percentages increase, NOx emissions also increase, especially with 30% biodiesel blends, as shown in Figure 3.7 This increase is a result of the higher combustion temperatures associated with biodiesel use. Since NOx emissions are generally associated with higher temperatures, higher biodiesel blends tend to produce more NOx. Although the 20% blend performs well in other respects, managing NOx emissions may require additional strategies, such as implementing exhaust after-treatment technologies.

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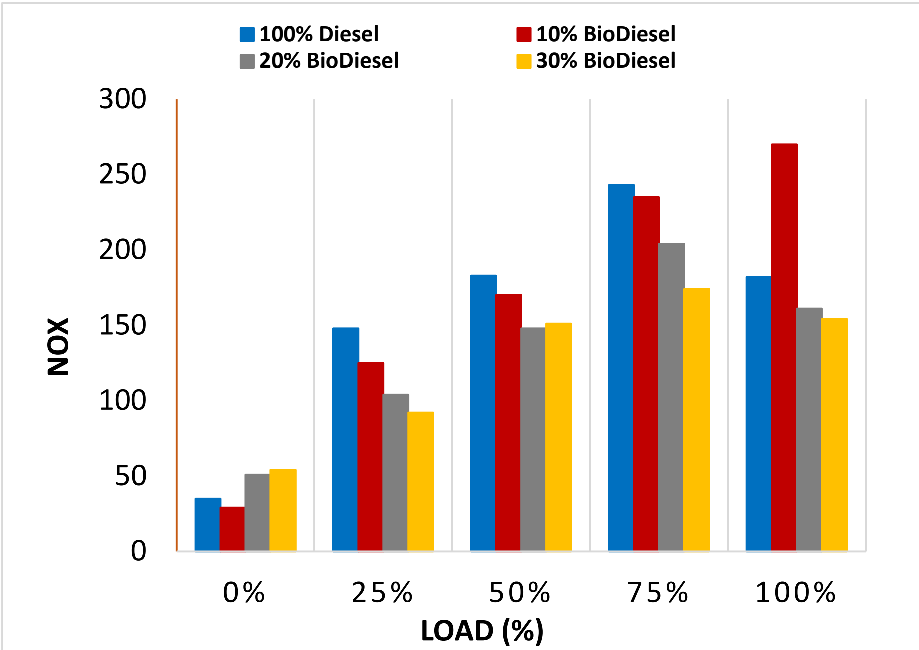

Figure:3.7 NOx emission variation depending on engine loads

3.2.4 Hydrocarbon Emissions

Hydrocarbon emissions are lower for biodiesel blends than for pure diesel, with B20 showing the lowest levels at medium to high loads, as in Figure 3.8. Lower hydrocarbon emissions indicate that biodiesel burns more completely than diesel, reducing the amount of unburned fuel in the exhaust. For nanomaterial-enhanced systems, lower hydrocarbon emissions can reduce fouling and improve the life and efficiency of catalytic surfaces.

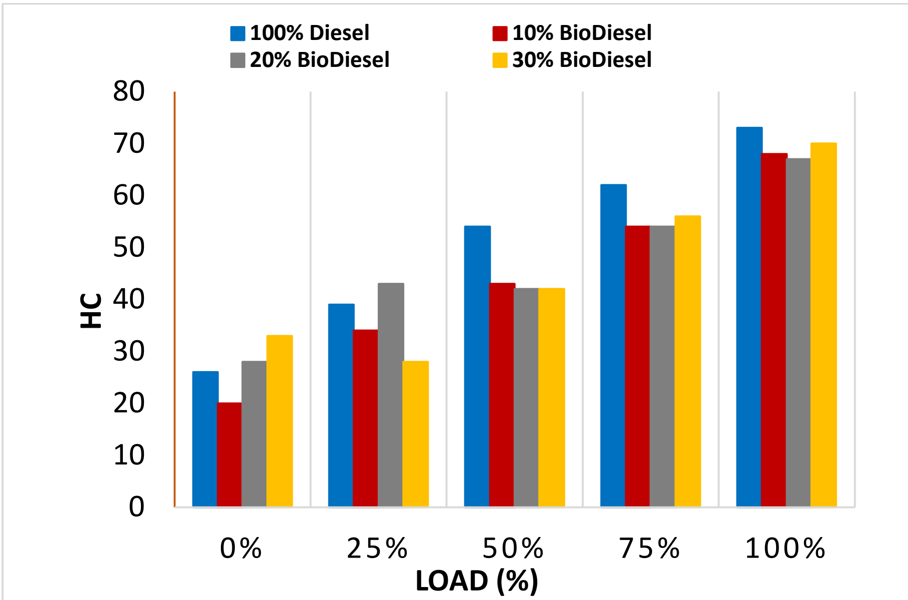

Figure:3.8 HC emission variation depending on engine loads

3.2.5 CO emissions

Figure 3.9 shows the variation in CO emissions for different fuels, including 100% diesel and biodiesel blends (10%, 20%, and 30%), as engine load increases. CO emissions are generally the result of incomplete combustion. The combustion process becomes less efficient at higher engine loads, resulting in more incomplete combustion, especially for biodiesel blends. At low engine loads (0% to 25%), CO emissions remain negligible across all fuels, indicating efficient combustion at these levels. However, as engine load increases to 75% and 100%, a significant increase in CO emissions is observed, especially with higher biodiesel blends. Although B20 has advantages in efficiency and combustion at low and medium loads, at full load, combustion becomes less efficient, resulting in higher CO emissions, followed by 30% and 10% blends, while 100% diesel produces lower emissions. This indicates that biodiesel produces higher CO_2 emissions at higher engine loads, likely due to less efficient combustion processes under these operating conditions.

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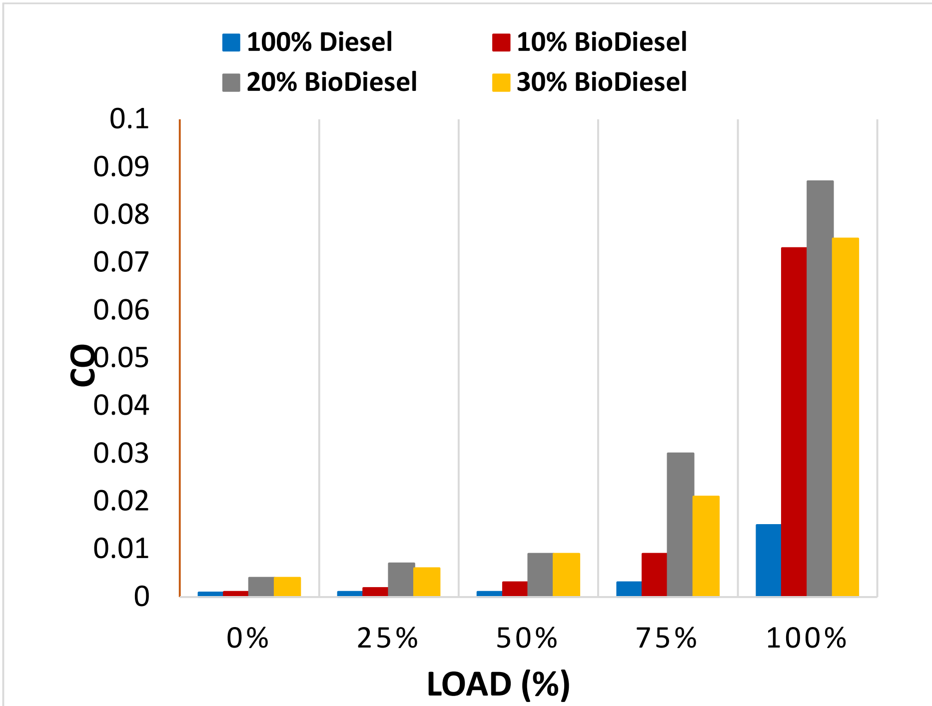

Figure:3.9 CO emission variation depending on engine loads

Based on the analysis of performance and emissions data, the 20% biodiesel blend (B20) appears to offer the best balance between performance and emissions. It improves braking efficiency and reduces the fuel-to-air ratio, key indicators of enhanced combustion. Although it exhibits higher CO emissions at full load, its overall fuel efficiency and combustion performance make it the optimal choice for use with nanomaterials in diesel engines. Therefore, the B20 blend is the most suitable for improving engine performance and reducing fuel consumption while providing reasonable emission control. It is a suitable choice for both performance and environmental considerations.

4. Conclusions

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This study thoroughly examines a diesel engine's performance and emission attributes utilizing biodiesel mixes containing nanoparticles. The principal conclusions derived from the research are as follows:

1. Enhancement of Engine Performance: Using biodiesel, namely the 20% blend (B20), improved the engine's mechanical efficacy. Critical parameters have significantly improved, including brake mean effective pressure (BMEP), brake power efficiency, and input power.

2. Decrease in Fuel Consumption: The B20 blend exhibited the most favourable fuel efficiency among all evaluated biodiesel blends. Fuel usage was markedly decreased, especially with the integration of nanoparticles. This drop happened because the catalytic properties of nanoparticles made combustion more efficient. This meant more energy could be extracted from the fuel, meaning less fuel was needed to keep the engine running.

3. Emission Control: Biodiesel blends decreased deleterious emissions, particularly when enhanced with nanoparticles. The 35% Al_2O_3 mix, specifically, attained minimal CO_2, CO, and hydrocarbon emissions compared to pure diesel and reduced biodiesel percentages. Although NO_x emissions rose somewhat with greater biodiesel percentages due to higher combustion temperatures, the overall environmental advantages were significant.

4. Improved Combustion Efficiency: The reduced fuel-to-air ratios associated with biodiesel blends, especially B20, demonstrated a more effective combustion process. Nanoparticles enhanced this efficiency, reducing fuel consumption and greater engine performance. The nanoparticles enhanced fuel combustion, minimizing unburned hydrocarbons and improving thermal efficiency.

5. Sustainability Advantages: The renewable characteristics of biodiesel and its diminished carbon impact establish biodiesel as a feasible substitute for traditional diesel. Nanoparticle-enhanced biodiesel blends boost engine efficiency while promoting environmental sustainability by decreasing greenhouse gas emissions and diminishing dependence on fossil fuels.

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NOMENCLATURE

SYMBOL	DESCRIPTION	UNITS
BSEC	Brake Specific Energy Consumption	kg/kW.hr
BSFC	Brake Specific Fuel Consumption	kJ/kW.hr
BP	Brake Power	kW
BTH	Brake Thermal Efficiency	
RPM	Revolution Per Minute	
UHC	Unburnt Hydrocarbons	
Cr	Compression Ratio	
DI	Direct Injection	Volt
10% RME	90 % DF and 10 % RME	
20% RME	80 % DF and 20 % RME	
30% RME	70 % DF and 30 % RME	
100% RME	100 % RME	
SFC	Specific Fuel Consumption	(kg/sec)
ASTM	American Standards for Testing and Materials	
O2	Oxygen	
CO2	Carbon dioxide	
CO	Carbon monoxide	
NOx	Nitrogen Oxide	
EGT	Exhaust Gas Temperature	

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