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Comparative Analysis and Ranking of Selected Bio-Fuels

Manjeet Kharub
Assoc. Prof., CVR College of Engineering/Mechanical Engg. Department, Hyderabad, India
Email: manjeetkharub@gmail.com

Abstract: **As public awareness of environmental issues increases, the need to investigate alternative energy sources becomes crucial. Numerous alternative energy sources, such as nuclear, solar, wind, and biofuels, are well-known worldwide. Biofuel is a process that generates energy from organic materials that can replace fossil fuels. Transesterification, the process of animal and vegetable oils into usable fuels, causes a substantial amount of energy. This paper analyses the mechanical properties of an internal combustion (IC) engine operating on conventional diesel and biofuels, including power, torque, and efficiency. Biodiesel, among others, is a formidable competitor to traditional diesel. It was discovered that biodiesel produces a significant amount of energy. In addition, research articles have demonstrated that the torque produced by biofuels will be distributed as follows: Diesel fuel vs biodiesel vs methanol vs pine oil. Biofuel, fossil fuels, trans-esterification, and animal and vegetable oils are included in the index.**

Index Terms: **first term, second term, third term, fourth term, fifth term, sixth term**

I. INTRODUCTION

Biofuels are considered the best alternative fuel and are produced via transesterification [1]. Among others, vegetable oils, ethanol, or animal fat are used to make biofuel fuels, which are then combined with alcohol to form ethyl esters and glycerol [2]. The use of biofuels has resulted in a decrease in the consumption of gasoline and diesel. These oils have found their applications in the transportation system after being blended with diesel or in their pure form as crude oil. Numerous studies have demonstrated that using biofuels reduces harmful gas emissions such as carbon monoxide (CO), unsaturated hydrocarbons (UHC), sulphur dioxide (SO2), nitric polycyclic aromatic hydrocarbons (NPAHC), and particulate matter (PM) [3]. But even though these studies showed that biofuels cut down on harmful gas emissions, they have one problem in the same area: Nitrogen Oxides (NOx) are observed to be increased in the case of biofuels when compared to diesel fuel [4]. Table 1 summarises the available biofuels.

The table depicts that biofuels such as pine oil, methanol, and biodiesel have very similar properties to diesel in terms of kinematic viscosity (mm^2/s), calorific value (KJ/kg), density (Kg/m^3), flash point (^0C), and boiling point (^0C) [5]. Also, it is observed that biodiesel is superior to diesel in every way that makes the diesel engine run smoothly [6].

However, when it comes to pine oil, a few areas must be improved, such as viscosity. As per the findings [7], if viscosity needs to be increased, the temperature properties of the fluid may decrease. When the temperature of a diesel engine falls below the required temperature, mechanical properties reduce. While methanol is deficient in every way, it is a renewable resource. Through research and increased use of methanol as a fuel, it is possible to improve its properties [8]. Because biofuels are renewable, they help to reduce our reliance on fossil fuels [9]. This also contributes to reducing emissions, making it more environmentally friendly [10].

TABLE I.
VARIOUS PROPERTIES OF BIO-FUELS AND DIES

Property/Fuel Names	Pine oil	Methanol	Bio-Diesel	Diesel
Kinematic viscosity (mm^2/s)	1.3	0.4	5.6	3.5
Calorific Value (KJ/Kg)	41500	22700	37270	43500
Density (Kg/m^3)	875	760	875	850
Flash Point (°C)	55	9	150	62-65
Boiling Point (°C)	160	65	340-375	160

In contrast, they have some disadvantages, such as biofuels do not produce as much power as diesel or petrol [11], and they are not as efficient as diesel and gasoline in terms of thermal efficiency. There are, however, numerous other alternatives, such as retrofitting vehicles with hybrid technology. These alternative modes of transportation are efficient but not renewable, whereas biofuels are renewable but less efficient than conventional fuels [12]. Although the researches on biofuels are still in progress, they are considered potential alternative in the face of critical environmental condition and to meet future demands of sustainable development.

II. DESIRABLE MECHANICAL PROPERTIES

The following section discusses the desirable mechanical properties of a typical diesel engine:

A. Torque
B. Speed
C. Dimensions (length, diameter)
D. Power
E. Efficiency

A. Torque

Torque is a twisting force that refers to the engine's rotational power and indicates how much of that rotational force is available when the engine is exerted. While horsepower is expressed as a single number, torque is typically expressed in pounds-feet. Calculating the magnitude of the torque is practical by first determining the lever arm and then multiplying it by the applied force. The lever arm is the perpendicular distance between the rotational axis and the force's line of action.

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B. Speed

The term "speed" refers to spinning the crankshaft in piston engines and rotating compressors, turbines, and electric motor rotors, and it is quantified in terms of revolutions per minute (RPM).

C. Power

A four-stroke engine is an internal combustion (IC) engine in which the piston travels through four distinct strokes as the crankshaft is turned. A stroke is a total distance travelled by the piston in either direction along the cylinder.

D Efficiency

Mechanical efficiency is a metric that indicates how effectively an automated system works. It is often defined as the ratio of the power produced by an automatic system to the power given to it, and this efficiency is always less than one due to friction.

E Brake Power

An IC engine's braking power equals the power available at the crankshaft. This power is typically determined using a brake mechanism, the force produced by a machine at the output shaft.

F. Indicated Power

It is generated by the gases expanding in the cylinders, ignoring any friction, heat losses, or entropy inside the system. The force produced by an engine cylinder is calculated using an indication diagram and some primary engine data.

G. Actual Mean Effective Pressure

The mean adequate pressure is a parameter associated with the functioning of a reciprocating engine. It is a valuable indicator of an engine's ability to do work independently of its displacement.

H. Brake Mean Effective Pressure

The brake means adequate pressure (BMEP) is derived from the dynamometer power (Torque). This is the engine's actual output at the crankshaft.

I. Engine Dimensions (Bore & Stroke)

The bore of the cylinder is the diameter, while the stroke is the distance travelled by the piston from the top dead centre (TDC) to the bottom dead centre (BDC). The stroke used to be larger than the bore in older engines, but the trend in recent years has been toward a shorter piston stroke. The faster the piston stroke, the less power is lost through friction. Additionally, the bearings' inertia and centrifugal load are decreased. The square engine, the most advanced technology available, has an equal bore and stroke.

III. EXPERIMENTATION

Transesterification is used in the experiment. Any vegetable oil and alcohols are used in the transesterification process, transforming mixed reactions into ethyl esters and glycerol. Transesterification is described scientifically as a chemical reaction in which one-mole triglycerides (the scientific term for vegetable oils or animal fats) interact with three moles of alcohol to form three moles of alkyl esters or ethyl esters and one-mole glycerol. Glycerol is a by-product or a co-product of a chemical reaction. In this instance, the reactants react in the presence of a catalyst, primarily potassium hydroxide and sodium hydroxide. Triglyceride is a term that refers to a molecule composed of three fatty acids linked to a glycerol backbone. Each molecule's three fatty acids functioning as triglycerides may be identical or distinct. The fatty acid compositions of the oil or fat contribute to many of the resulting biofuels' characteristics. Transesterification begins rapidly and gradually slows down until it approaches equilibrium. At this stage, some unreacted glycerides remain unchanged in the biofuel. It is possible to enhance the quality by removing the settled glycerides and running another reaction, thus shifting the equilibrium point closer to the products. This is the scientific process by which the reactants create the intended outcome, which in this case, is biofuel.

The apparatus required for the experiment are:

i. *Pine oil, methanol, and Bio-diesel act as the triglycerides in this process. The mentioned bio-fuel individually consists of 3 fatty acids*
ii. *Ethanol acts as the alcohol,*
iii. *Two flasks containing 125 ml and 250 ml, all with stoppers, (iv) A 250 ml separatory funnel,*
iv. *A stirring hot plate,*
v. *Magnetic Stir bar*
vi. *Thermometer,*
vii. *Aluminium foil,*
viii. *A weighing scale,*
ix. *Potassium Hydroxide,*
x. *A 4-stroke single-cylinder diesel engine.*

3.1. Pine Oil

The process of making biofuels from pine oil is as follows:

a) Firstly, weigh 1 gram of potassium hydroxide into a 125 ml flask. Into the same flask, add 20 ml of ethanol.
b) Add a stir bar and cover the flask with aluminium foil. Place the flask on a stirring hot plate.
c) Continue the process until potassium hydroxide is completely dissolved.
d) Now, add 80 ml of pine oil to a 250 ml flask. Add a magnetic stir bar and put the flask on a stirring hot plate.
e) Start heating the oil to around 600 C, which the thermometer can measure.
f) Once the temperature reaches 600C, add the alcoholic-catalyst mixture to the oil in the flask. Cover the flask with aluminium foil to keep the alcohol vapours from escaping.
g) Stir the mixture at a moderate speed for up to 60 minutes while maintaining the temperature at 600C.
h) After 60 minutes, stop heating and stir the mixture in the flask. Now, transfer the mixture into a 250 ml separatory funnel and allow it to cool for about 20-30 minutes.

i) After the cooling process, the glycerol and biofuel will be separated. The top end of the flask will be bio-fuel, and the bottom end will be glycerol. Due to their weight, they are separated at their respective places.
j) Finally, take the glycerol present in the funnel, and thus 100% of bio-fuel is obtained.

3.2. Methanol

The process of making biofuels from methanol is as follows:

a) Firstly, weigh 1 gram of potassium hydroxide into a 125 ml flask. Into the same flask, add 20 ml of ethanol.
b) Add a stir bar and cover the flask with aluminium foil. Place the flask on a stirring hot plate.
c) Continue the process until potassium hydroxide is completely dissolved.
d) Now, add 80 ml of methanol to a 250 ml flask. Add a magnetic stir bar and put the flask on a stirring hot plate.
e) Start heating the oil to around 600 C, which the thermometer can measure.
f) Once the temperature reaches 600C, add the alcoholic-catalyst mixture to the oil in the flask. Cover the flask with aluminium foil to keep the alcohol vapours from escaping.
g) Stir the mixture at a moderate speed for up to 60 minutes while maintaining the temperature at 600C.
h) After 60 minutes, stop heating and stir the mixture in the flask. Now, transfer the mixture into a 250 ml separatory funnel and allow it to cool for about 20-30 minutes.
i) After the cooling process, the glycerol and biofuel will be separated. The top end of the flask will be bio-fuel, and the bottom end will be glycerol. Due to their weight, they are separated at their respective places.
j) Finally, take the glycerol present in the funnel, and thus 100% of bio-fuel is obtained.

3.3. Vegetable Oil (Bio-Diesel)

The process of making biofuels from Vegetable oil is as follows:

a) Firstly, weigh 1 gram of potassium hydroxide into a 125 ml flask. Into the same flask, add 20 ml of ethanol.
b) Add a stir bar and cover the flask with aluminium foil. Place the flask on a stirring hot plate.
c) Continue the process until potassium hydroxide is completely dissolved.
d) Now, add 80 ml of Vegetable oil to a 250 ml flask. Add a magnetic stir bar and put the flask on a stirring hot plate.
e) Start heating the oil to around 600 C, which the thermometer can measure.
f) Once the temperature reaches 600C, add the alcoholic-catalyst mixture to the oil in the flask. Cover the flask with aluminium foil to keep the alcohol vapours from escaping.
g) Stir the mixture at a moderate speed for up to 60 minutes while maintaining the temperature at 600C.
h) After 60 minutes, stop heating and stir the mixture in the flask. Now, transfer the mixture into a 250 ml separatory funnel and allow it to cool for about 20-30 minutes.
i) After the cooling process, the glycerol and biofuel will be separated. The top end of the flask will be bio-fuel, and the bottom end will be glycerol. Due to their weight, they are separated at their respective places.
j) Finally, take the glycerol present in the funnel, and thus 100% of bio-fuel is obtained.

3.4. Engine Performance

Purified biofuel is then utilised to evaluate the engine's performance characteristics in a four-stroke single-cylinder diesel engine [13]. As we all know, a four-stroke engine is a kind of internal combustion engine in which the piston completes four distinct strokes as the crankshaft is turned. Suction, Compression, Expansion, and Exhaust are the four different strokes. The piston's stroke changes from TDC to BDC during the suction stroke. The cylinder's valve opens to allow the air-fuel combination to enter the engine.

Usually, the piston travels from BDC to TDC during a compression stroke, compressing the air-fuel mixture and initiating the ignition. Diesel has a higher flash point than biodiesel, which results in a shorter ignition delay during the compression stroke [14]. The crankshaft has now completed a complete 360-degree rotation. While the piston is at TDC, a spark plug or the heat produced by high compression ignites the compressed air-fuel combination, forcing the piston back to BDC [15]. This stroke causes the engine to generate mechanical work to spin the crankshaft. The piston travels from BDC to TDC during the exhaust stroke [16]. While the exhaust valve is open, the piston returns from BDC to TDC. During this stroke, the exhaust valve discharges the lean air-fuel mixture [17]. We get the necessary data throughout this period, such as engine speed, engine torque, and actual, and brake mean effective pressures.

IV. RESULTS AND DISCUSSION

A. Diesel

Figure 1 illustrates the performance characteristics of an IC engine in terms of Power, Torque, and Efficiency [18, 19, 20,23].

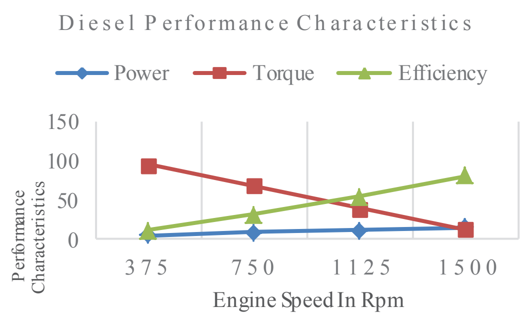

Figure 1. Performance characteristics of an IC engine like Power, Torque & Efficiency using diesel

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As many academics have studied and shown that diesel provides superior performance to all other fuels, we obtained the same level of performance via testing. While the mechanical characteristics of diesel in a diesel engine are a benefit, there are a few drawbacks. The emission characteristics of diesel in a diesel engine continue to be a source of contention. There are two reasons to be looking for biofuels [21]. They are renewable energy sources and greenhouse gas emissions. Though diesel produces 33% fewer pollutants than gasoline, it is a factor to consider when attempting to reduce emissions. Carbon Monoxide (CO), Unsaturated Hydrocarbons (UHC), Sulphur Dioxide (SO2), Nitric Polycyclic Aromatic Hydrocarbons (NPAHC), and Particulate matter (PM) are some of the pollutants released.

B. Pine Oil

The chart below, i.e., figure 2, illustrates the performance characteristics of an internal combustion engine (IC) in terms of Power, Torque, and Efficiency [20, 22, 23] while utilising Pine oil.

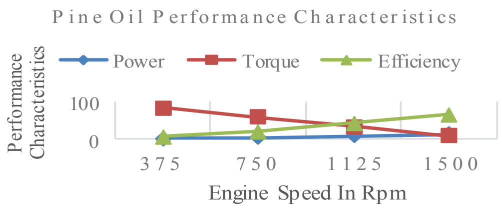

Figure 2. Performance characteristics of an IC engine like Power, Torque & Efficiency using Pine Oil

Through extensive study and testing, it has been determined that pine oil performs somewhat less well than diesel but produces fewer pollutants. B5 is utilised in these biofuels (5 percent pine oil and 95 percent Diesel). Initially, the emission rate for pine oil is likewise very high, although less so than diesel, but the emission rate progressively lowers. Carbon Monoxide (CO), Unsaturated Hydrocarbons (UHC), Sulphur Dioxide (SO2), Nitric Polycyclic Aromatic Hydrocarbons (NPAHC), and Particulate matter (PM) were all released in much lower amounts.

Further study and testing on different compositions such as B10-B100 (10% pine oil & 90% diesel – 100% pine oil) may enhance the performance characteristics and get them closer to those of diesel. When compared to diesel, pine oil consumes more fuel. Because pine oil is renewable, this is not an issue in these instances.

C. Methanol

Figure 3 illustrates the performance characteristics of an internal combustion engine (IC) in terms of Power, Torque, and Efficiency [23, 24]. It was determined through extensive study and testing that methanol's mechanical performance characteristics are nowhere near those of diesel or the next biofuel. Carbon Monoxide (CO), unsaturated hydrocarbons (UHC), sulphur dioxide (SO2), nitric polycyclic aromatic hydrocarbons (NPAHC), nitrogen oxides (NOx), and particulate matter (PM) emissions are very low in comparison to other biofuels or diesel.

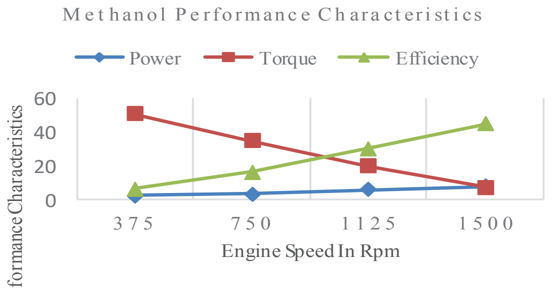

Figure 3. Performance characteristics of an IC engine like Power, Torque & Efficiency using methanol

The emissions are much lower than with biodiesel. Methanol has an extremely high fuel consumption due to its low viscosity, calorific value, flash point, boiling temperature, and density. Essentially, all characteristics necessary for a vehicle to operate normally are fuel economy and mechanical performance. Methanol has the same chemical makeup as pine oil B5 (5 percent methanol & 95 percent Diesel).

D. Bio-Diesel

The chart below, i.e., figure 4, demonstrates the performance characteristics of an internal combustion engine (IC) utilising biodiesel in terms of Power, Torque, and Efficiency [5, 6, 11, 20, 23].

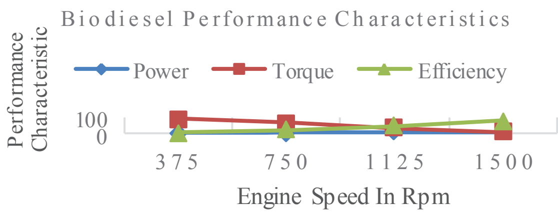

Figure 4. Performance characteristics of an IC engine like Power, Torque & Efficiency using Bio-Diesel

Following extensive study and testing, it was determined that the mechanical performance characteristics of bio-diesel are equivalent to those of conventional diesel. Additionally, the emission characteristics of biodiesel are improved. Carbon Monoxide (CO), unsaturated hydrocarbons (UHC), sulphur dioxide (SO2), nitric polycyclic aromatic hydrocarbons (NPAHC), and particulate matter (PM) emissions are very low in comparison to other biofuels or diesel. Except for Nitrogen Oxides (NOx), which are somewhat increased due to their more unique flash point, which results in a much quicker combustion process. The higher the rate of combustion, the greater the NOx emissions since there is no additional combustion within. When compared to conventional diesel, biodiesel consumes more fuel.

E. Power

Figure 5 illustrates the performance characteristics of an internal combustion engine (IC engine), such as power [25], while utilising Pine oil, methanol, and Bio-Diesel.

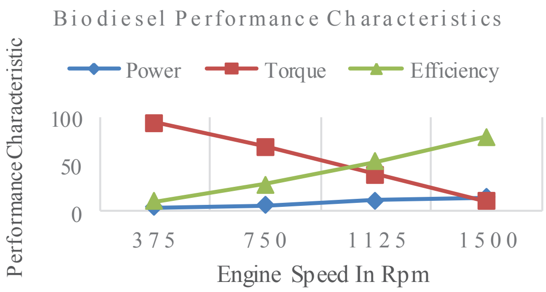

Figure 5. Analysis of Performance characteristics of an IC engine like power using Pine oil, Bio-Diesel & Methanol

The study of these three fuels is based on the measurements taken during the testing and the conversion of the measured values to their corresponding formulas. The engine's torque and speed determine the performance of power. Pine oil, methanol, and biodiesel have performed better in testing than in the study. According to a few study articles, fuel produced from pine oil cannot surpass 8KW, methanol cannot exceed 5KW, biodiesel cannot exceed 10KW, and all other biofuels exceed theoretical limits. As a result, the following sequence applies to biofuels: Biodiesel>Pine oil>Methanol. When the composition is just B5, this power value is obtained. By increasing the design, the performance is improved further, and it may be used as a substitute fuel.

F. Torque

The chart below, i.e., figure 6, illustrates the performance parameters of an internal combustion engine (IC), such as torque [25], while utilising Pine oil, methanol, and Bio-Diesel. The study of these three fuels is based on data taken during testing with a dynamometer to determine the torque at the specified speed [26].

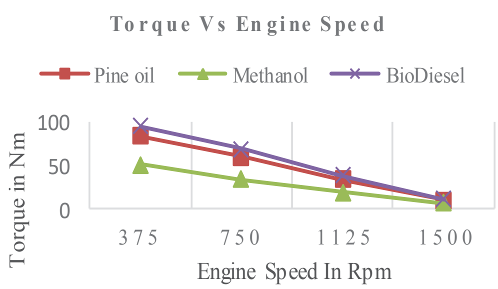

Figure 6. Analysis of Performance characteristics of an IC engine like torque using Pine oil, Bio-Diesel & Methanol

Pine oil, methanol, and bio-diesel perform better in testing. According to a few study articles, the fuel produced from pine oil cannot exceed 70Nm, methanol cannot exceed 50Nm, biodiesel cannot exceed 80Nm, and all of the bio-fuels surpassed the theoretical limits. As a result, the following sequence applies to biofuels: Biodiesel>Pine oil>Methanol. When the composition is just B5, this power value is obtained. By increasing the design, the performance is improved further, and it may be used as a substitute fuel.

G. Efficiency

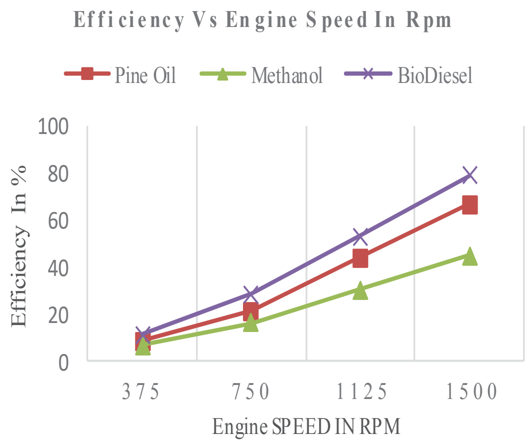

Figure 7. Analysis of Performance characteristics of an IC engine like efficiency using Pine oil, Methanol & Bio-Diesel

The above chart, i.e., figure 7, illustrates the performance characteristics of an internal combustion engine, such as its efficiency while running on pine oil, methanol, or biodiesel. The study of these three fuels is based on the measurements taken during the testing and the conversion of the measured values to their corresponding formulas. Efficiency performance depends on the engine's brake and indicated power [27]. Brake and implied control are proportional to break and mean adequate pressure. Pine oil, methanol, and biodiesel have performed better in testing than in the study. According to a few study articles, the fuel produced from pine oil cannot surpass 50%, methanol cannot exceed 30%, bio-diesel cannot exceed 70%, and all other bio-fuels exceed the theoretical limits. As a result, the following sequence applies to biofuels: Biodiesel>Pine oil>Methanol. When the composition is just B5, this power value is obtained. By increasing the document, the performance is improved further, and it may be used as a substitute fuel.

V. Conclusions

All fuels are compared to conventional diesel, and biodiesel, among others, is found to be a close rival. The amount of power produced by biodiesel is highly significant. Torque comparisons revealed similar findings, with biodiesel providing the highest torque, followed by pine oil and methanol. Initially, in literature was seen that the power produced by all biofuels would be much less than diesel. Additionally, it has been shown in study articles that the torque produced by biofuels will be in the following sequence: Diesel fuel vs biodiesel vs methanol vs pine oil.

However, it was discovered via testing and research that the sequence is conventional diesel > biodiesel > pine oil > methanol. We obtained the power value by noting the gained torque value and putting it into the appropriate power equations. As a result, the Power order is identical to that of Torque: Diesel fuel > Biodiesel fuel > Pine oil > Methanol. We get the efficiency value by determining the IMEP and BMEP values of the fuel in the engine and inserting them into their corresponding formulas, i.e., indicated power and brake power. Efficiency is prioritised: Diesel fuel > Biodiesel fuel > Pine oil > Methanol. The primary drawback of utilising biodiesel is its slow start-up time. The following is a ranking of biofuels: Power, Torque, and Efficiency: Methanol > Biodiesel > Pine oil**.**

The primary goal of this project was to highlight the need for alternative fuel(s) as demand continues to grow. The primary issue with alternative fuels is their performance compared to conventional fuels such as diesel, gasoline, and so on. The performance and emissions of alternative biofuels in internal combustion engines are measured and analysed in this research. Another issue with biofuel(s) is carbon monoxide, carbon dioxide, hydrocarbon, and nitrogen oxide emissions. Despite their relatively high performance, biofuels are assessed for their environmental effect. Carbon monoxide and carbon dioxide emissions are low in biofuels; however, NOx emissions vary depending on the alternative.

In comparison to traditional fuels, biofuels and mixes produce less smoke. The study identified key variables affecting the future of combustion engine fuels. Natural availability, environmental effect, economic feasibility, and mass manufacturing are all variables to consider. Biofuels are both economically effective and environmentally beneficial. It is strongly suggested that pentanol be utilised directly in the CI engine without modification. Pentanol, methanol, neem-oil biofuel, 15% di-ethyl ester mix, jatropha biofuel blend, and vegetable oils are all recommended biofuels for optimal performance and decreased emissions. Numerous studies have shown that increasing the bio-diesel percentage in blends improves performance while lowering emissions. Certain compounds have been shown to reduce hazardous emissions substantially. Metal-based additives such as copper (II) oxide result in a modest performance boost.

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