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PERFORMANCE AND EMISSION STUDIES OF VARIABLE COMRESSION RATIO ENGINE USING NEEM OIL BASED BIO DIESEL

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Abstract: One of the most promising alternative fuels for diesel engines is biodiesel, which can be produced from vegetable oils and is potentially renewable, non-toxic, biodegradable, clean burning, high lubricity, and low impact on the environment. It can also be used directly in diesel engines without requiring significant engine modifications. Because of their fuel efficiency, dependability, and durability, diesel engines are being used in a wide range of industries and applications, including transportation, industry, agriculture, and power production. The demand for energy from fossil fuels is rising, which is resulting in higher usage and more emissions. Global warming and air pollution are both caused by these emissions. The need for alternate resources has consequently grown. Alternative energy sources like solar, wind, biomass, tidal wave energy, and biodiesel made from vegetable, seed, and animal fats are currently available for the creation of electricity. Among them, biodiesel might satisfy a portion of the world's demand. Without requiring any modifications, biodiesel and its mixes can be utilized in standard diesel engines to improve operating effectiveness and reduce pollution emissions. Many different plants, including palm, jatropha, cotton, sesame, linseed, honge, rubber seed, and others are used to extract biodiesel. Because of its higher density, surface tension, and viscosity than diesel, biodiesel influences the atomization of fuel by enlarging the size of the fuel droplet. One of the friendliest alternative fuels for diesel engines is biodiesel, which offers power comparable to that from regular diesel fuel. They can be found anywhere and are renewable. The biodiesel can be utilized in any ratio in a diesel engine with little to no engine modification required. One of its greatest benefits is supposed to be this. Evidently, there is no need to update the present internal combustion engine technology or any infrastructure. In the present study the review of performance and emissions studies of Variable compression ratio engines were used to test the performance and emissions of neem biodiesel blends. The everlasting neem, which is widely accessible and has a variety of uses, could be used as a feedstock for biodiesel.

1. Introduction

India is currently the world's third-largest consumer of mineral diesel and the second-most populous nation worldwide. The economy has grown remarkably during the past few decades, which has led to an increase in the number of transportation vehicles. Greater comfort and a higher standard of living have been made possible by urbanization, which is also one of the main reasons for an increase in the number of utility and transportation vehicles. Between 1980–1981 and 2003–2004, there was an increase in transport vehicles of more than 90% [1]. The sales of cars used for domestic transportation increase by 15% yearly [2]. Between 2001 and 2011, the number of automobiles registered nationwide increased at a compound annual growth rate (CAGR) of 9.9%. In India, the population of urban regions depends entirely on the road system. Due to its effectiveness, dependability, and high energy density, diesel-powered vehicles are most prevalent in the transportation sector. The use of diesel engines is expanding in a variety of other industries, including agriculture, industry, mining, aviation, and shipping. Key mineral diesel consumers are depicted in Figure 1. According to research, the transport sector consumes over 70% of all diesel [3]. However, India is completely reliant on the purchase of crude oil from other oil-producing nations due to its limited oil resources.

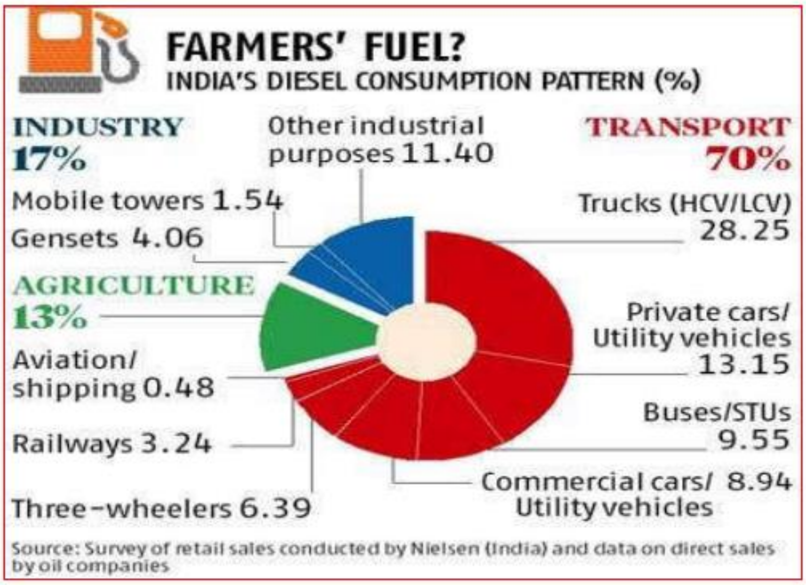

Figure 1: Sector wise diesel consumption (%) [3]

Only 20% of the petroleum products utilized in India are now produced there. As reported by Niti Ayog, India's government, the country's oil import bill for the same years was \$143 billion, \$113 billion, and \$70 billion for the aforementioned period, representing 78.5%, 80.9%, and 82% of total oil demand, respectively [4]. Due to falling crude oil prices in 2016–17, the import bill was reduced; however, because crude oil prices have now begun to climb, the import bill may eventually reach \$150 billion due to rising demand. According to a government assessment, the demand for diesel might increase from its current level of 90 billion liters to 150 billion liters by the year 2030. If demand increases at a rate of 3% per year, the total reserve of mineral diesel is expected to be depleted in 45 years [5]. In India, air pollution is one of the main factors contributing to early morality, along with cost concerns [6], and the transport industry is responsible for the majority of the pollution (about 72%). The National Ambient Air Quality (NAAQ) standard has been exceeded in the majority of Indian cities as a result of an expanding fleet of transportation vehicles.

1.1 World Energy Scenario

A third of the world's primary energy use up until 2016 came from oil, one of the most popular energy sources. According to the statistical Review of Energy (2017), 4382.4 and 4418.2 million tons of oil were produced and consumed globally in 2016 and 2017, respectively. In comparison to 2015, this is 0.3% and 1.5% higher. This demonstrates that there is a significant increase in the global rate of oil consumption. It is nearly impossible to comprehend how a country would run on a daily basis without it. Unfortunately, oil is a finite resource and has a finite shelf life. According to predictions, the ratio of oil reserves to output will be 50.6 by the end of this decade. This means that at the current rate of production, oil would only be available for around 50 years. The impending tragedy of oil scarcity will force the development of other energy sources. Unconventional oil and gas resources are becoming commercially viable alternatives because of this, which has a big impact on how the world's energy demands are met.

1.2 National Energy Scenario

According to data on fuel use in India, the transportation sector accounts for roughly 70% of the country's conservative diesel consumption, with busses, heavy commercial vehicles, and light commercial vehicles collectively using about 38%. About 22% of all diesel use is accounted for by UVs (Utility Vehicles) and cars, of which public-owned vehicles account for about 60%. The rising number of cars and UVs, especially public-owned vehicles, is to blame for the high levels of fuel consumption by private vehicles. The contribution from the agricultural sector is just under 13%. This term is usually used to describe tractors-based agricultural machinery like harvesters and threshers. Figure 2 below show fornon-transport and transport sections, both direct and retail.

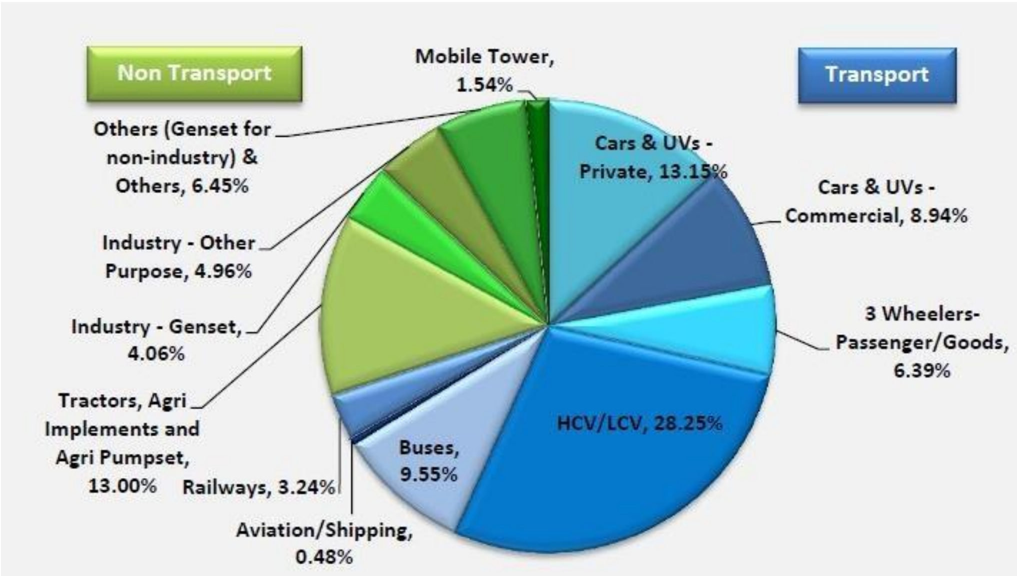

Figure 2: Fuel consumption of automobiles in India [SIAM Estimate, 2020].

2. Biodiesel

Vegetable oil is referred to as biodiesel because its properties resemble mineral diesel when the viscosity has been reduced. By trans-esterifying an oil or fat with an alcohol, biodiesel is described as a "mono-alkyl ester of vegetable oils or animal fats [7]. According to ASTM requirements for use in diesel engines, biodiesel is described as mono-alkyl esters of long chain fatty acids produced from vegetable oils or animal fats. Before being blended with diesel fuel, biodiesel was an entirely separate fuel. A clean-burning alternative fuel made from domestic, renewable resources is known by the moniker "biodiesel." Although biodiesel **does not** contain any petroleum, it may be mixed with diesel at any ratio to produce biodiesel blends. It needs minimal to no changes in order to be used in compression-ignition engines. Simple to use, biodegradable, nontoxic, and practically free of sulfur and aromatics are all attributes of biodiesel.

2.1 Biodiesel scenario of World

Many nations are switching to the green fuel "Biodiesel" as a result of various problems such the depletion of crude oil, environmental pollution, increased import costs, and health crises. The output of biodiesel in several countries for the year 2017 is shown in Table 1 [8].

Table 1: The production of biodiesel in various countries in 2017. (Source: https://www.statista.com)

Country	Production of Biodiesel(in billion litre)
USA	6.0
Brazil	4.3
Germany	3.5
Argentina	3.3
Indonesia	2.5
France	2.3
Thailand	1.4
Spain	1.3
China	1.0
Poland	1.0
Belgium	0.5
Columbia	0.5
Canada	0.5
Netherland	0.4
India	0.2

2.2 Biodiesel scenario of India

India's biodiesel production accounts for just 0.22% of the nation's current consumption. The Indian government approved the country's national biofuel strategy, with the goal of incorporating 20% biodiesel by the year 2017. The national biodiesel mission was launched by the Indian government, and jatropha seed was chosen as the biodiesel feedstock of choice. Lack of adequate biodiesel to meet demand is the main barrier to the biodiesel program's implementation in India. In order to blend at 5%, 4.5 billion litters of mineral diesel must be produced, but only 0.2 billion litters of biodiesel are currently produced. The introduction of large-scale biodiesel crop cultivation is hampered by a number of problems, including unclear biodiesel legislation, the longer gestation and payback periods of biodiesel crops, inadequate distribution channels, etc. Jatropha cultivation on 10 million hectares of land is intended to produce 7.5 million tons of fuel annually, however this goal may not be met due to high costs and excessive red tape. Due to its large population, India cannot compromise its food security policy, hence the arable agricultural area cannot be spared for the growth of biodiesel crops [9]. About 23% of India's territory is covered in forests, and there are many of diverse tree-borne non-edible oil seeds to choose from. In India, there is a potential for 3-3.5 million tonnes of tree-borne oil seed, but only 0.5-0.6 million tonnes can be harvested, and the remaining seeds end up as trash in the forest [10]. The average yearly production of several non-edible oil seeds in India is shown in Table 2.

Table 2: Annual production of some non-edible oil seeds

Oil Seed	Production(lakh T)	References
Castor	7.3	[10]
Karanja	0.55	[11]
Kusum	0.66	[10]
Mahua	600	[10]
Neem	5.4	[10]
Sal	15	[12]

Therefore, research should be focused on non-edible tree-borne oil seeds that can help to resolve the nation's energy and environmental crises.

2.3 Advantages of biodiesel

The points listed below provide an overview of various advantages of biodiesel [13], [14],

• The biodiesel is non-toxic, environmentally friendly, sustainable, and ecologically conscious. It also includes 10-12% more oxygen than regular diesel, which aids in proper combustion.

• The bio-degradation process is enhanced by the increasing oxygen content.

It is referred to as 'carbon neutral' fuel. When utilized as engine fuel, biodiesel plants emit less carbon dioxide than they absorb throughout the photosynthesis process.

• When compared to mineral diesel, biodiesel has a shorter delayed ignition period.

• Compared to a conventional diesel engine, a biodiesel-fueled engine produces fewer different pollution components.

• Because biodiesel does not include sulfate, there is no risk of acid rain.

Because biodiesel has a flash point that is greater than mineral diesel, there is far less risk of a fire danger as a result of its use.

It can also be blended easily with mineral diesel, which reduces the nation's reliance on fossil fuels and increases its energy security and independence.

2.4 Disadvantages of biodiesel

• Biodiesel has a higher viscosity, density, and copper strip corrosion.

• The characteristics of biodiesel's cold flow are undesirable.

• The majority of biodiesel has poor stability during oxidation.

• More NOx emissions in comparison to mineral diesel

Low calorific value results in higher BSFC and higher production costs.

2.5 Biodiesel and environment

The production of toxic exhaust gases including Carbon Monoxide (CO), Particulate Matter (PM), Hydrocarbon (HC), and Oxides of Nitrogen (NOx), among others, is one of the main problems with the operation of the diesel engine. These gases harm people's health and contaminate the environment. It has been demonstrated that using biodiesel greatly reduces emissions of CO, PM, and HC, but increases NOx emissions [15, 16]. The effect of utilizing biodiesel in exhaust emissions, with the exception of NOx, is beneficial, according to the draft study by the United States Environmental Protection Agency on heavy duty highway engines as shown in Figure 3 [17].

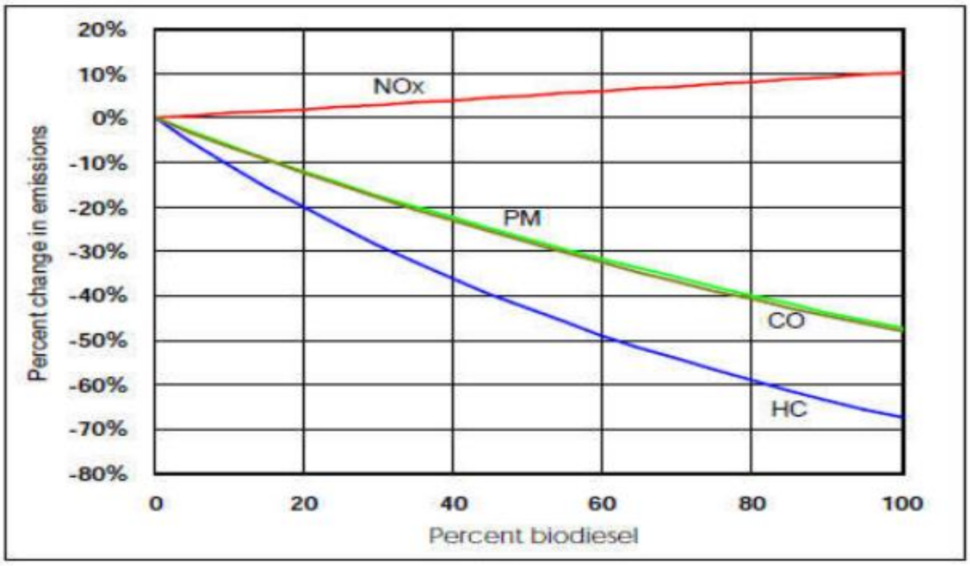

Figure 3: Reduction of exhaust emission by using biodiesel [17]

When the appropriate circumstances and microorganisms are present, the biodiesel decomposes more quickly. More than 98% of pure biodiesel reportedly degrades over the course of 28 days, compared to 50% of mineral diesel over the same time period [18].

2.6 BIO-DIESEL AND ITS BLENDS:

Fuel Modification by Esterification:

Bio-diesel is created by converting vegetable oils into their methyl and ethyl alcohol esters. Almost all the issues with vegetable oils may be resolved through ester formation. Vegetable oils high viscosity could be reduced to acceptable levels using the esterification process. There are three ways to make esters from oils and fats.

I) Oil trans-esterification with base catalyzed alcohol. ii) Oil and methanol are esterified directly under acid catalysis. iii) Oil is converted using acid catalysts first to fatty acids and then to alkyl esters.

Because it is more affordable, the first approach is favored. Transesterification is the process of converting vegetable oil (Triglyceride Esters) to methyl esters, which results in a molecular weight reduction to one-third, an 8-fold reduction in viscosity, and an increase in volatility. Alcohol and vegetable oil are combined with catalyst NaOH. For one hour, the mixture is heated to 65^0C and kept there while being continually agitated with a stirrer. Glycerin forms the lower layer, while ester forms the upper layer, forming two different layers. Calcium chloride is used to dissolve the ester and separate the upper layer. It has been noted that vegetable oil provides 90% of the ester. A.S. Ramadhas et. al [19] carried out a labor-intensive and time-consuming experimental investigation of the engine using several kinds of biodiesel and their mixes. In their study, rubber seed oil that has not been processed is used to make biodiesel. The C.I. engine used in the performance testing is powered by biodiesel and its blends with diesel (B20 and B100). Using this model, the effects of relative air-fuel ratio and compression ratio on engine performance for various fuels are also examined. The findings of theoretical and experimental comparisons are shown. The lower biodiesel blends improved the thermal efficiency of the brakes and decreased fuel usage. The concentration of biodiesel increased as the exhaust gas emissions decreased. The outcomes of the experiment demonstrated that biodiesel, which is made from raw rubber seed oil, is a competitive substitute for diesel in compression ignition engines.

3. Problems associated with Diesel Fuel

Although diesel fuel works quite well in CI engines, there are a few typical problems that are difficult to fix, and these are covered in more detail below.

3.1 Depletion of fossil fuel

Twenty years ago, it was noted that petroleum products are expensive and had a finite supply. The population is rising day by day, along with their needs, and as a result, amenities and the number of automobiles are also rising. In India, petroleum fuels were used a lot in transportation. Currently, to cover its overall consumption, India imports about 80% of its crude petroleum needs from other nations. Natural resources like petroleum cannot be replenished and require a very long time to do so. On the other hand, petroleum goods continue to see daily increases in both demand and price.

3.2 Emissions

The main contributors to atmospheric pollution are gasoline and diesel engine exhaust emissions, which led to the creation of alternative fuels. [20]. By discharging exhaust pollutants into the air, which contain dangerous substances that are an odorant, an irritant, and some are carcinogenic, automobile use contributes significantly to pollution.

3.3 Carbon Monoxide (CO) emission

Incomplete fuel combustion, heterogeneity in the air-fuel combination, and chamber temperature rise all contribute to CO emissions. Due to the richer fuel mixture used in heavy-duty vehicles, carbon monoxide (CO) is emitted upon startup or when accelerating while under load. [21]. The CO is regarded as a wasteful release that also results in a loss of chemical energy.

3.4 Oxides of nitrogen (NOx)

The production of nitrogen oxides is reliant on the presence of oxygen and a hot burning environment inside the ignition chamber. Ozone is created when NOx combines with natural gasses, and this is what causes photochemical smog. Nitrogen oxides' long-term effects include an increase in cyanosis, especially on the lips, body, and toes, as well as adverse modifications to the lung walls' cell structure.

4. Need for Alternative Technologies and Alternative Fuels

Petroleum products and crude oil are expected to become exceedingly expensive and scarce under the current conditions. Engine efficiency is increasing daily and will keep doing so. However, as the number of cars increased significantly, it started to become clear that fuel was necessary [22]. As a result, gasoline and regular diesel will become scarce and expensive in the near future.

4.1 Alternative Fuels for IC Engines

Solid, liquid, and gaseous are the three general phases into which fuels can be divided. Today's automotive engines frequently use petroleum-based fuels as their main fuel source. Some engines, though, use gaseous fuels like LPG and CNG. The numerous alternative fuels for IC engines are briefly covered in the section that follows. In recent years, biofuel resources have been seen as more hospitable and effective. The cost of the conventional fossil fuels is rising as they become more scarce day by day. During burning, these fossil fuels also create pollution. All of these reasons make looking for alternatives necessary. In some areas of the world, gasoline-based fuels are also practical, but these resources are also slowly running out. The exciting solution to the current energy dilemma is the pursuit of the possibility of producing biofuels from locally accessible sources and using them as an alternative to various petroleum products. Additionally, it has been discovered that biofuels are commercially enticing due to their numerous financial advantages and high market demand. The breakdown of agricultural or anaerobic products results in the production of biofuel through a natural process. Contrarily, traditional fuels like coal and petroleum are eventually created beneath the earth's layers by a biological process. Biomass can be converted into solid, liquid, and gaseous fuels, including bio-fuels. Among these, liquid biofuels are of utmost significance because transportation is essential to modern life [23]. These liquid fuels are growing in popularity since it is possible to extract them from seed oils. Primary and secondary generating fuels are two different categories for biofuels. Primary generation fuels are biofuels that are created primarily from food that humans consume, such as vegetable oils, bio-ethanol, biodiesel, and biogas, as well as from animals. Lignocellulose ethanol, fuels based on syngas, and fuels based on pyrolysis are examples of secondary generation biofuels without dietary variation. The fact that these biofuels have no negative environmental effects, such as pollution, global warming, or health problems, is one of their greatest advantages [24].

This advantageous nature is a result of its carbon acting impartially on the environment. It is common knowledge that CO_2 is produced when any type of biomass fuel is used. Through the process of photosynthesis, plants use this CO_2 to produce a variety of nutrients that are necessary for their growth. In this method, by promoting plantation activities and discouraging deforestation, the created CO_2 in the atmosphere can be easily balanced. The investigation looked into the relatively few things that have been found to be biofuel energy sources, including biomass, biogas, alcohols, vegetable oils, and biodiesel.

Biomass: Biomass is regarded as a sustainable source of energy because it is abundant in nature, can be utilized as a fuel in solid form, and is unbounded. It includes agricultural outputs and products, wood, forestry outputs, water plants, garbage, and leftover problems. The most common source of biomass energy is wood from trees, which is largely used for cooking and for producing the steam needed to create electricity. Charcoal has been produced for a long time by partially pyrolyzing biomass. By preserving the air quality, biomass is one of the reliable sustainable energy assets that offers the greatest consumer and environmental benefits.

Biogas: Because it is created from real gas that has been delivered from carbon by growing plants throughout flow-developing seasons, biogas is an endless and clean-burning fuel. Microorganisms and archaea organisms create it through the anaerobic breakdown of vulnerable, unreliable natural phenomena. Methane and CO_2 gases make up the majority of biogas, with little hydrogen or nitrogen gas content. The method used to create biogas is known as bio-methanation. A biogas engine with an alternator is attached to and sustained by methane gas, a source of useful energy, to generate electricity.

Vegetable oil: Vegetable oil has been used as a fuel for CI engines since 1893, when Dr. Rudolf Diesel created the first diesel engine that could run on a variety of fuels. He built an engine that was powered by shelled nut oil in the year 1900, and he predicted that formers would gain an advantage by using their own homemade vegetable oils to power the engine. Due to the availability of inexpensive oil energizes, the usage of vegetable oil was ignored. After a considerable amount of time due to unusually high unrefined petroleum prices, energy security, and strict emanation requirements, vegetable oils are again receiving attention as flighty energies due to their endless supply and low discharges. Similar benefits apply to vegetable oil, such as its production from environmentally friendly plant material, ease of accessibility, lower sulfur content, risk-free transportation, biodegradability, lower discharges, etc. [15]. Many countries are currently funding research on the proper use of vegetable oils as well as the discovery of new technologies that will make it possible for vegetable oils to be combined with normal fills. Due to their extreme gooeyness, vegetable oils present some challenges when used directly in diesel engines. They can be utilized in diesel engines, but only after changing the engine or adjusting the fuel's qualities. Thickness is one of these characteristics, and vegetable oils have unusually high levels of it because of their challenging composition and atomic weight.

Biodiesel: Few countries are gradually importing a huge amount of crude petroleum to meet the regular wants of their expanding populations. Many of the world's oil reserves are found in politically unbalanced countries. Supplies of unrefined petroleum are interrupted as a result of the unstable administration. This type of intermittent supply of crude oil has misrepresented several nations. Numerous nations looked for solutions to reduce this reliance; one such solution is biodiesel, another fuel. While it cannot be said that biodiesel completely solves the problem, it has shown to be a partial solution to this problem. Unsaturated fat methyl esters, such as those found in biodiesel, can be made from animal or vegetable fats as well as other unending sources of biomass. The expansion of biodiesel should adhere to the guaranteed quality standards specified by the American Society for Testing and Materials (ASTM). The sources of biodiesel are many in supply and available all over the world. These resources should be used by the many countries that are striving to achieve a balance between the financial and biological aspects of their societies and countries. Vegetable oil has been used as fuel for a long time, but due to their prohibitive costs and the availability of oil products at lower prices, their widespread use has been curtailed. Many nations are currently interested in using biodiesel due to the advantageous natural conditions that it is surrounded by. More far-flung than many attractions, to name just a few, are its availability, ease of production, and lower carbon content compared to petroleum goods. The use of biodiesel significantly reduces emissions of particulate matter, carbon monoxide, sulfates, and hydrocarbons. By reducing the amount of biodiesel in diesel fuel, emissions are reduced. The best dwindled discharges those produced by clean biodiesel. A few studies found that mixing 20–25% biodiesel with 70–75% diesel had the best results for engine performance and exhaust flow when compared to diesel-fueled engines. The level of atmospheric carbon is maintained by biodiesel. Light and carbon dioxide gas are essential components for the growth of any plant. The carbon released while burning is identical to the carbon stored by plants during their growth. Given that it is made from plant matter, biodiesel has a good vitality balance. Fuel vitality equalization is the ratio of the vitality expended during the burning season to that expended during its generation, refinement, and circulation.

5. Advantages of bio-fuels used as CI engine fuel

The benefits of using biofuels in CI engine fuel include:

• Simple access to biofuels.

• Offers more heat (approximately 88 percent of diesel fuel).

• Easy to transport due to its liquid nature.

• It ought to be regenerative.

• Safe because it degrades.

• Pleasant and low in aromatic content.

• The improved lubrication qualities of biofuel.

• Low sulfur content and environmentally friendly.

• Due to its greater Cetane number than Diesel, there is potential for improved engine performance and lower exhaust emissions.

• Reducing carbon monoxide emissions as much as possible.

• Storage safety because of their greater flashpoint

• Because of its higher oxygen concentration, it guarantees a better combustion process.

5.1 Disadvantage of Bio-fuels

The following are some drawbacks of biofuels:

- The limited supply of biodiesel on the market.
- Using biodiesel in a cold climate is challenging.
- When compared to regular Diesel, the volatility and calorific value of biodiesel are lower.
- In comparison to ordinary Diesel, it has a higher viscosity.
- The fuel consumption of an engine running on regular Diesel is greater than that of an engine running on biodiesel.

6. Methods of modification of vegetable oils

Operational issues and durability issues can be used to categorize the issues that arise during engine tests. The starting, ignition, combustion, and performance issues are operational. The issues with durability are related to deposit development, injector tip carbonization, ring sticking, and lubricant oil dilution or degradation. Direct injection engines are more prone to durability issues than indirect injection engines, which appears to be a fairly significant function of the engine type. Vegetable oil viscosities had a significant influence on how the fuel spray was shaped. Large droplets, poor atomization, and strong spray jet penetration are some effects of high viscosity. High viscosity causes the jet to behave more like a solid stream as opposed to a spray of tiny droplets.

6.1 Fuel modification by transesterification

Through a process called transesterification, rice bran oil's triglycerides are changed into the equivalent monoesters by reacting methanol with a catalyst made of potassium hydroxide. The viscosity of triglycerides has been reduced by using this method often. It is thought that the transesterification involves three sequential, reversible reactions: When methanol is used in the esterification, the first stage is the conversion of triglycerides to diglycerides, then diglycerides to monoglycerides, and ultimately monoglycerides to glycerol, giving one methyl ester molecule from each glyceride at each step. To speed up the reaction and move the equilibrium to the product side, respectively, a catalyst and too much alcohol are utilized.

6.1.1 Neem oil

Neem is known by the scientific name azadirachta indica. It is a member of the Meliaceae family. 40% to 50% of the kernels are made up of an oil that is bitter and greenish yellow to brown and strongly smells like garlic. Nimbin, Nimbidin, and Nimbosterol are sulfur-containing substances that contribute to the bitter flavor. Oleic acid is the most abundant component, followed by stearic, palmitic, and linolenic acids. The oil is utilized in Ayurvedic medicine, soap production, pharmaceutical, cosmetic, and lighting applications. The refined oil is used to create emulsifying and disinfectant sprays that are used to control insects. West Africa and India both sell neem oil. The Properties of Neem oil are shown in Table 3.

Table 3: Properties of Neem oil–diesel blends

Neem oil(%)	Diesel (%)	Density(gm/cc)at 40^0C	Viscosity(cst)at 30^0C	Viscosity reduction (%)
100	0	0.919	34	-
75	25	0.897	30	11.76
50	50	0.875	22	35.29
25	75	0.853	14	58.82
0	100	0.840	5	85.29

6.2 Characteristics of vegetable oils

The key physical and chemical characteristics of Linseed oil, Castor oil, Palm stearin oil, Mahua oil, and Neem oil are assessed using Indian Standard (IS:1448) instrumentation in the fuels and lubricants laboratory of the Mechanical engineering department. Diesel is denser than all other types of used oils. Compared to other forms of utilized oils, castor oil has a higher density of 0.956 gm/cc. Among the selected oils, 0.917 gm/cc has the lowest density. All commonly used oils have a higher viscosity than diesel. When compared to diesel, castor oil has the maximum viscosity (52 cst), followed by palm stearin, Mahua, Neem, and linseed oil. All commonly used oils have greater flash points and fire points than diesel. Comparing castor oil to other types of used oils, its flash and fire points are the highest at 320^0C and 345^0C, respectively.

All commonly used oils have a lower calorific value than diesel. The test vegetable oil has a calorific value that is between 85% and 95% that of diesel. All of the selected oils have lower cetane values than diesel oil.

6.3 Application of vegetable oil as fuel

Many investigators are looking for an eco-friendly liquid fuel that may be utilized in diesel engines because to the exhaustibility of fossil fuels, their increasing demand, and the negative effects of exhaust pollution. Vegetable oil appears to be an excellent choice to address both the energy and environmental crises because of its many advantageous qualities, including its renewability, non-toxicity, accessibility, and lack of sulphur [25]. It is not a novel idea to use vegetable oil as fuel in a diesel engine. Without making any modifications, he was successful in running a diesel engine on peanut oil. In some remote locations where shipping petroleum oil was exceedingly challenging during the Second World War, the use of vegetable oil has also been documented [26]. Brazil has prohibited the export of cotton seed oil at that time to replace diesel fuel. Tung oil was also utilized as a substitute for diesel fuel in China. Vegetable oil, however, cannot replace mineral diesel since it includes wax and has a high viscosity, which causes issues with engine operation such as poor the atomization process insufficient combustion, carbon deposit, injector coking, filter clogging, and engine fouling [27].

6.4 Biodiesel production

Biodiesel, a mono alkyl ester of fatty acid, is produced when biofuels like methanol, ethanol, alcohol, and edible or inedible vegetable seed oils or animal fat are combined. One of the friendliest alternative fuels for diesel engines is biodiesel, which offers power comparable to that from regular diesel fuel. They can be found anywhere and are renewable. The biodiesel can be utilized in any ratio in a diesel engine with little to no engine modification required. One of its greatest benefits is supposed to be this. Evidently, there is no need to update the present internal combustion engine technology or any infrastructure.

Transesterification is the method used to make biodiesel. When a vegetable oil reacts with methanol or ethanol in the presence of a catalyst like sodium hydroxide or potassium hydroxide, esters and glycerol are ultimately produced. This process is known as transesterification. An agent that increases the reaction's yield and rate is referred to as a catalyst. Catalysts are allegedly defined as alkali, acid, or enzymes. The process of transesterification that is acid catalyzed proceeds significantly more slowly than the process that is alkali catalyzed [28]. The biodiesel produced by this transesterification reaction, which is alkali catalyzed, is completely miscible with diesel in any ratio. The viscosity of biodiesel is roughly identical to that of regular diesel. After esterification, the biodiesel's flash point decreases and its cetane number rises. Process flow chart of biodiesel production is shown in Figure 4.

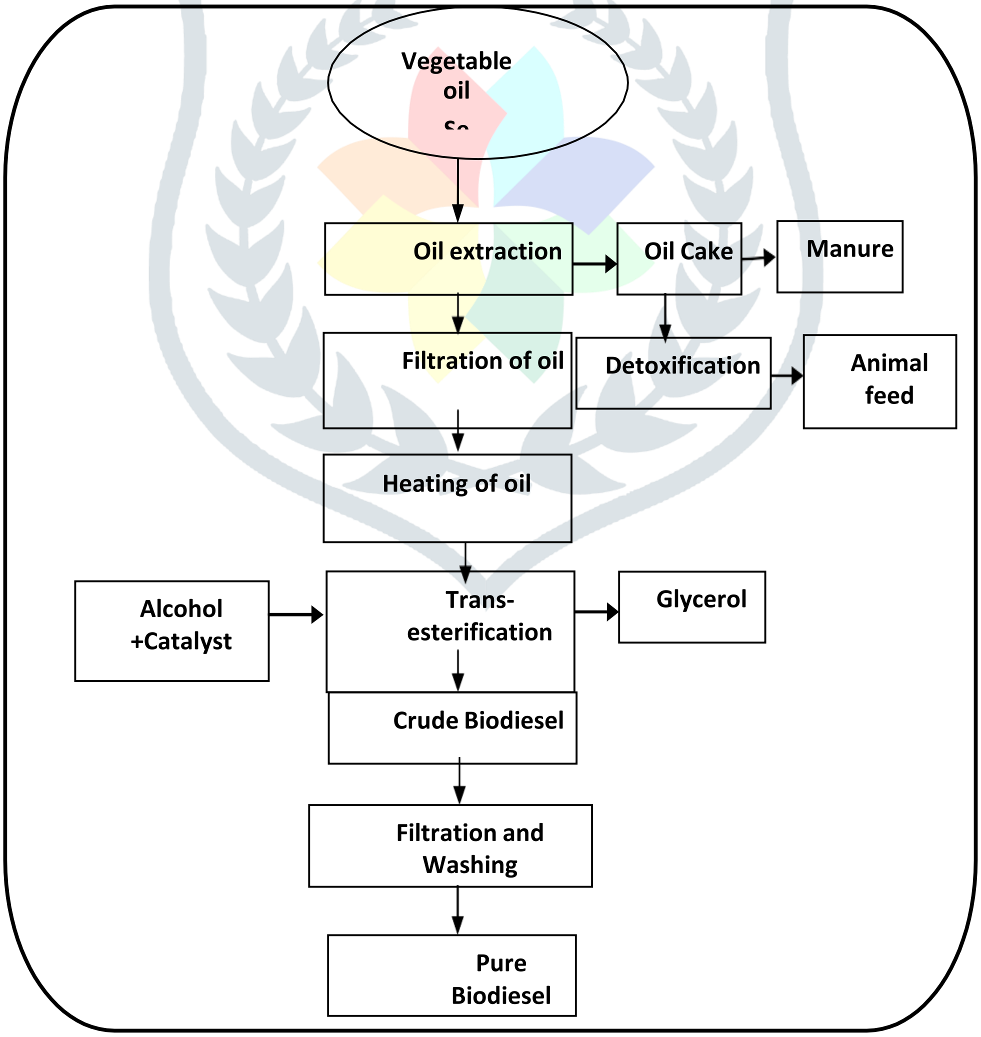

Figure 4: Process flow chart of biodiesel production

7. *The VCR Engine*

One kind of engine in which the CR can be altered is the VCR engine. Typically, this is accomplished by altering the clearing volume. The fundamental idea behind the VCR concept is to use high CR at low loads for high efficiency and lower CR at greater loads to account for banging and internal heat transfer. As a result, a compact supercharged engine can deliver the performance of a larger engine while using less fuel.

7.1 THE VCR ENGINE SETUP

Various author designed a VCR engine setup and the details as under A single-cylinder, four-stroke VCR diesel engine is used in the setup, which also includes a loading dynamometer with eddy current and hydraulic cooling. Using a tilting cylinder block design, the CR may be changed without shutting down the engine or changing the combustion chamber geometry. The set-up consists of tools for measuring crank-angle and combustion pressure. The engine indicator, which shows pressure-crank angle (P-) and pressure-volume (P-V) diagrams for each 360-degree rotation of the crank, transmits the signals to the computer. The quantification of measurements for airflow, fuel flow, temperature, and load are also covered. The system has a stand-alone panel box that houses an engine indication, a process indicator, an air box, a fuel tank, a manometer, a fuel measuring unit, transmitters for detecting air and fuel flow, and a fuel measuring unit. There are also calorimeter water flow meters and rotameters for cooling water measuring. Effect of changing the compression ratio on diesel engine performance andemission.

Higher compression ratios are advantageous, because to their improved thermal efficiency, they allow an engine to derive more mechanical energy from a given mass of air-fuel combination. This happens as a result of improved internal combustion engine efficiency, such as in heat engines, which makes it possible to achieve the same combustion temperature with less fuel and a longer expansion cycle, increasing mechanical power output and lowering exhaust temperature. Consider it more in terms of "expansion ratio," as higher expansion regulates the temperature of the exhaust gas and, consequently, the quantity of energy wasted into the atmosphere.

7.2 Injection timing and pressure and their impact on diesel engine’s performance and emission

In diesel engines, the high temperature produced by air compression is solely responsible for the igniting of the fuel. Because of their improved efficiency and fuel economy, diesel engines have become more popular recently. A number of factors, such as the compression ratio, the amount of fuel injected, the timing and pressure of the injection, the shape of the combustion chamber, the size and location of the injection nozzle hole, and the fuel spray pattern, affect a diesel engine's performance and emission characteristics. The diesel engine, compression ratio, and fuel injection systems are currently the main targets of optimization efforts. The sizes of the fuel particles grow larger and the ignition delay period during combustion lengthens as the fuel injection pressure is decreased. As the combustion process degrades, this circumstance causes a rapid rise in pressure, which lowers engine performance. Fuel-air mixing is improved during the same ignition phase when injection pressure is increased because fuel particle diameters are reduced. This improves engine efficiency. Excessive injection pressure diminishes combustion efficiency, reduces the probability of uniform mixing, and shortens the ignition delay period.

7.3 ENGINE PERFORMANCE AND EMISSION OF BIODIESEL

In this section, various performance and emission characteristics of a diesel engine operating at full load including brake specific fuel consumption (BSFC), brake thermal efficiency (BTE), and emission characteristics of carbon monoxide (CO), hydrocarbon (HC), nitrogen oxides (NOx), and smoke have been studied from various literatures and contrasted with the performance of mineral diesel as reported in the relevant literature.

7.3.1 Brake Specific Fuel Consumption

Regarding an engine's suitability in terms of fuel efficiency, the fuel consumption rate is a crucial factor to consider. The same is assessed using brake specific fuel consumption, or BSFC, which measures fuel consumption per unit of power output. There have been reports in the relevant literatures of a maximum increase of 55% in BSFC for jatropha biodiesel [29] and a minimum increase of 5% in BSFC for neem biodiesel [30] w.r.t mineral diesel. However, jojoba biodiesel has been reported to have a 7% drop in BSFC, and this is because it has a higher calorific value. The BSFC is lower for fuels with a higher calorific value and vice versa. BSFC is seen to vary inversely with engine load as well. The percentage increase in fuel needed to operate the engine is less than the percentage increase in brake power due to the relatively smaller fraction of heat losses at higher loads, which is one possible explanation for the fluctuation of BSFC with engine load [31]. The BSFC is impacted by engine speed as well. Researchers that looked at the relationship between BSFC and engine speed found that it initially reduces up to a particular engine speed before increasing [32]. Different biodiesel and engine operating conditions will result in a different number for the engine speed at which the BSFC is minimal.

7.3.2 BRAKE THERMAL EFFICIENCY

When comparing different fuels for a specific engine and similar operating conditions, the properties of the fuel are the primary considerations when determining the Brake Thermal Efficiency (BTE) of an engine. However, it is also stated that because jojoba biodiesel has a larger calorific value than mineral diesel, its BTE is higher [33]. Neem biodiesel exhibits a greater BTE as well because it has more oxygen, which promotes better burning [34]. The load and speed of an engine have an impact on its BTE. The majority of researchers have also noted that an engine's BTE fluctuates directly with engine load, which is likewise explained by the fact that heat loss decreases as load increases [35]. When engine speed is increased, the BTE of a biodiesel-fueled engine initially rises; it reaches a high level before falling. A four-cylinder in-line diesel engine running on moringa and palm biodiesel was the subject of a study by Mofijur et al. [36]. They claimed that the brake power increases up to 1500 rpm before declining. According to Saleh [37], who examined the operation of a twin-cylinder diesel engine powered by jojoba biodiesel, the thermal efficiency of the brakes increases up to 1700 rpm before declining. In a study by Ong et al. [38] utilizing various mixes of jatropha, kapok, and polanga biodiesel (10%, 20%, 30%, and 50%), the engine output parameters of a diesel engine (single cylinder, 7.7 kW) were examined. They claimed that up to 1900 rpm, brake thermal efficiency rises before declining.

7.3.3 EMISSION OF CARBON MONOXIDE

When there is not enough air or oxygen present in the air fuel mixture, the fuel does not burn properly, which results in the release of carbon monoxide (CO). Because biodiesel has a higher oxygen concentration (10–12%), it emits less carbon monoxide when burned in an engine. Raheman and Phadatare [39] reported a highest percentage of CO reduction (94%) while using karanja biodiesel. Because biodiesel has a higher oxygen content than regular diesel, less CO is released into the atmosphere [40-42]. However, Solaimuthu et al. [43], Chauhan et al. [44], Balaji et al. [45], Aliyu et al. [46], and Kivevele et al. [47] also reported about an increase in the emission of CO, which is related to the greater kinematic viscosity and inefficient spray pattern of biodiesel. Generally speaking, when load rises, the air-fuel ratio falls and CO emissions rise. However, as engine speed rises as a result of improved air-fuel combustion and CO emission reductions, the engine's efficiency improves.

7.3.4 EMISSION OF HYDROCARBON

Incomplete combustion, which depends on the design and operational factors, also leads to the release of hydrocarbons (HC). The load and engine speed (rpm) are the crucial operating factors that have an impact on the HC emission. Numerous scholars in this study discussed how utilizing biodiesel instead of mineral diesel reduces HC emissions. For polanga biodiesel, Sahoo et al. [48] found a high reduction in HC emission (80%), whereas Ragit et al. [49] reported a minimum reduction of HC emission (2.6%). The presence of greater oxygen in biodiesel, which promotes better combustion and results in a decrease in HC, has been cited as the cause of the decrease in HC.

7.4 Effect of diesel emissions on environment and health

Despite the CI engine's superior performance qualities. It has had issues with emissions. Since fresh air is only allowed to enter the crack air during the compression stroke, which reduces the creation of the HC volume by 40%, HC emission is not a significant problem for CI engines. Due to the lean mixture present in the engine cylinder, diesel engines do not experience problems with CO emission. The two main pollutants produced by a diesel engine are NOx and PM. In comparison to SI engines, CI engines emit substantially higher quantities of both pollutants. Only by lowering the exhaust emissions will the issues with human health brought on by diesel emissions be under control.

Improved design and modified engine standards: Modern emission-trapping technology and electronic controlled fuel systems have led to new engine designs that have cleaner combustion and fewer emissions.

Retrofitting: Only vehicles equipped with new engines are eligible to use the new emissions requirements; diesel engines that are already in use are not eligible. Due to emission regulations and the toughness of diesel engines, a lot of high-polluting diesel trucks, buses, and off-road vehicles are still in use today. The latest emission control systems that efficiently reduce hazardous emissions from the tailpipe are required to be removed from these diesel cars or may be attached.

Cleaner fuels: Low-sulfur diesel fuel enables the employment of the most recent emission control systems, which when combined can lower emissions by more than 85%. In addition, diesel engines can be modified to emit less pollution by using biofuels, hydrogen, liquid petroleum gas (LPG), biogas, natural gas, compressed natural gas (CNG), and liquefied natural gas (LNG). Engine efficiency and specific types of emissions are trade-offs. The choice of a specific alternative fuel will be based on factors including cost, engine compatibility, and local availability.

7.5 Types of fuel additives and their physico-chemical and combustion properties

As shown in Figure 5, additives can be roughly categorized into two types: inorganic and organic. While numerous research teams have extensively examined the impact of organic compounds on diesel fuel, there is relatively little published information regarding inorganic additives. The majority of researchers have employed organic additives that incorporate hydrogen-carbon chains. According to Hansen et al. [50], researchers initially began their studies in this area in the 1980s using alcohol-based additives and concluded that ethanol-diesel blends are technically appropriate for diesel engines. Following this, several researchers additionally employed other organic additions (such as ether, aromatic, aliphatic, nitro paraffin, ester, etc.). The utilization of various organic compounds in research projects conducted during the previous 20 years is depicted in Figure 6.

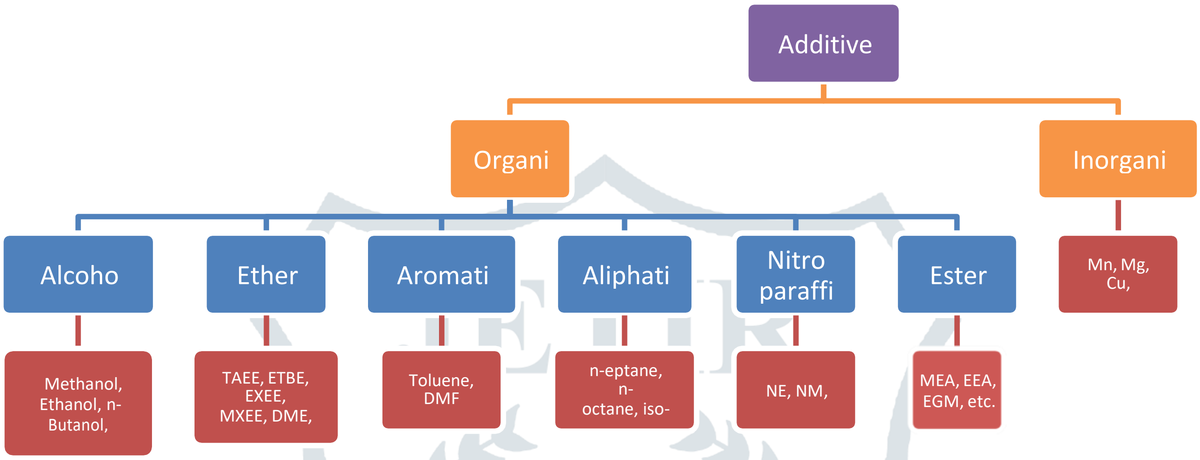

Figure 5: Classification of Additives

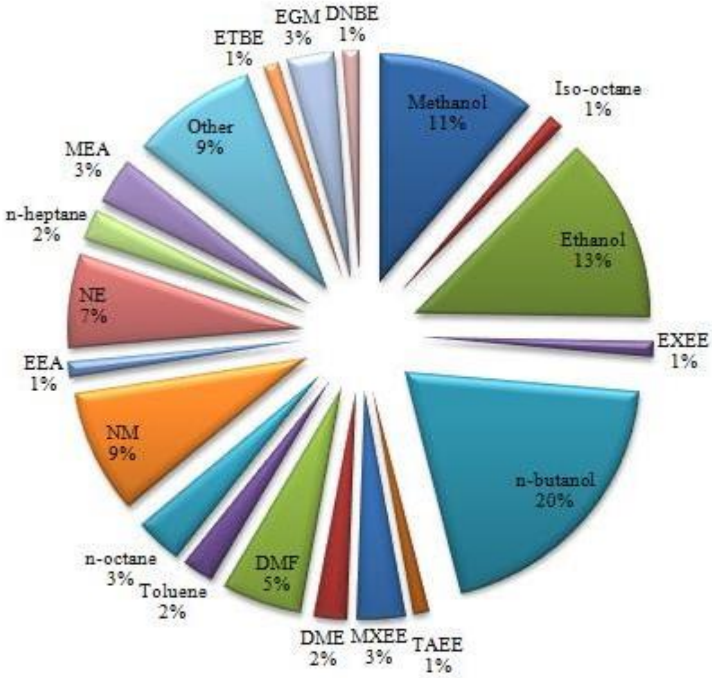

Figure 6: Organic additives used by past researchers

It is evident that the majority of previously published studies used alcohol-based additives (ethanol, methanol, n-butanol, etc.), with n-butanol making up the biggest percentage (20%) of those contributions. The contribution of nitro paraffin compounds additives (nitroethane-7%, nitromethane-9%) is also considerable after alcohol-based additives.

8. Need of alternative fuels and additives

Engine output, including brake thermal efficiency (BTE), brake specific energy consumption (BSEC), and brake specific fuel consumption (BSFC), as well as enhancement and decrease in exhaust emissions, are equally challenging tasks to manage simultaneously. For these tasks, prior studies have suggested some methods, including:

Engine design modification: The adjustment of an engine's intricate design is highly challenging, and it is impossible to change the design after a certain point. By adjusting CR, injection pressure (IP), injection timing (IT), running speed, etc., a minor design alteration may be feasible.

Using exhaust treatment devices: For the treatment of engine exhaust gases, a number of devices are available, including the selective catalytic reduction (SCR), catalytic converter, particle filter, afterburner, and exhaust gas recirculation (EGR) system. Although the key prerequisites for the installation of these devices are periodic maintenance and change in the exhaust system.

8.1 ADDITIVE IMPACTS ON ENGINE PERFORMANCE

Engine design and operational factors, such as CR, IT, IP, EGR, fuel dilution (mixing additives with diesel fuel), engine speed, engine load, etc., may have an impact on engine performance (BTE, BSFC, etc.) and emissions (smoke, HC, NOx, PM, CO, etc.). These factors are shown in Figure 7. Due to the standard and sophisticated engine design, which cannot be updated after a certain point, significant changes in design parameters are not possible. As a result, over the past 20 years, there have been more research investigations relating to changes in operating parameters like fuel mixing ratio.

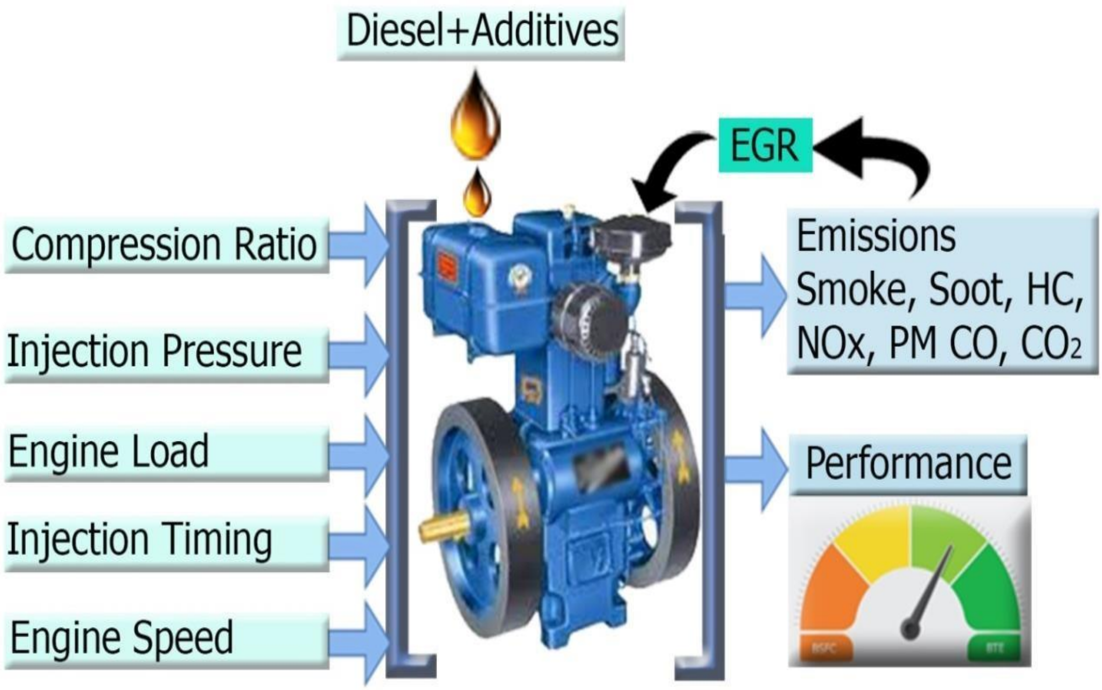

Figure 7: *Affecting parameters for engine performance and emission*

Particular organic additives have particular physico-chemical and combustion characteristics that might directly affect an engine's performance and emission characteristics. Researchers in the past have utilized several additives with diesel fuel at various mix concentrations to improve engine performance and reduce emissions additives are primarily used with diesel-based fuels to enhance engine performance, reduce exhaust emissions, improve combustion rates, increase mileage, act as antioxidants, enable fuels to function in extremely hot conditions, protect the environment, etc. When compared to diesel fuel, organic additives have better physico-chemical and combustion characteristics (such as viscosity, boiling point, latent heat of vaporization, auto ignition temperature, etc.), as well as a higher oxygen content in their molecular structure. Due to the better combustion characteristics of the blend, blending additives with diesel may improve engine performance. Recent authors examined the effects of additives on engine efficiency and exhaust emissions during steady state operation and concluded that while additives could increase engine combustion, they should not always be used in every situation.

9. Conclusion

The automotive sector is crucial to the global economy because it creates jobs and contributes positively to the trade balance, which is necessary for global prosperity. However, given that it contributes significantly to the emissions of GHG and other pollutants into the atmosphere, road transportation is currently the focus of numerous political discussions. Therefore, every method that could lessen harmful effects on the environment is closely scrutinized. Alternative biofuels have played and will play a significant part in the future of road transportation among these methods. With this background, this paper examined the effects of different alternative fuels utilized as mixed fuels on the performance of CI engines. Neem biodiesel exhibits a greater brake thermal efficiency (BTE), as well because it has more oxygen, which promotes better burning. The load and speed of an engine have an impact on its BTE. The majority of researchers have also noted that an engine's BTE fluctuates directly with engine load, which is likewise explained by the fact that heat loss decreases as load increases [51]. Internal combustion engine characteristics are also influenced by the compression ratio. For all blends, engine torque rises as the compression ratio does. The brake specific fuel consumption (BSFC), for all blends reduces as compression ratio rises, but the BSFC for higher blends rises as biodiesel % rises. The rapid depletion of conventional energy supplies and the rise in energy demand are very severe issues. The eventual lack of adequate supply and fair pricing of petroleum-based fuels has rekindled interest in researching alternative fuels for diesel engines. Since edible vegetable oils are in such high demand and are so expensive, only non-edible vegetable oils can be taken seriously as engine fuels [52]. Vegetable oils can only be used in engines with low heat rejection, and this is the only way to solve their difficulties. These engines' high cylinder temperatures hasten combustion and shorten the ignition delay. Vegetable oils are used in the LHR engine to cut down on HC, CO, and smoke emissions. Considering combustion properties in comparison to the use of fossil diesel fuels: the ignition delay increases with the increase of the ethanol fraction in diesel-ethanol blends, and it slightly decreases for biodiesel-diesel-ethanol blends or with the addition of a CN improver; cylinder pressure increases with the increase of the ethanol fraction in diesel-ethanol blends, and it is slightly lower for biodiesel-diesel-ethanol blends; the maximum rate of heat release increases with an increase in the ethanol fraction in the diesel-ethanol blends [53]. In terms of engine performance, when compared to the use of fossil diesel fuel, the specific fuel consumption for the brakes is greater in all circumstances examined; the thermal efficiency of the brakes increases or is comparable; and the braking power is very similar to or somewhat lower. Minor changes in exhaust gas temperatures were noted; the indicated mean effective pressure also shows small variations or decreases when fuel mixes contain more than 35% ethanol.

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