PERFORMANCE INVESTIGATION OF AN EGR BASED CRDI DIESEL ENGINE POWERED WITH BLENDS OF DIESEL AND SESAME OIL METHYL ESTER

A DISSERTATION

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MASTER OF TECHNOLOGY
(THERMAL ENGINEERING)

SUBMITTED BY

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CANDIDATE'S DECLARATION

I, **Varun Kumar Singh,** hereby certify that the work which is being presented in this thesis entitled **"Performance Investigation Of An EGR Based CRDI Diesel Engine Powered With Blends Of Diesel And Sesame Oil Methyl Ester"** is submitted in the partial fulfilment of the requirement for degree of **Master of Technology (Thermal Engineering)** in Department of Mechanical Engineering at **Delhi Technological University** is an authentic record of my own work carried out under the supervision of **Dr. Naushad Ahmad Ansari** and **Dr. Samsher.** The matter presented in this thesis has not been submitted in any other University/Institute for the award of Master of Technology Degree. Also, it has not been directly copied from any source without giving its proper reference.

Varun kumar Singh

Place: Delhi

Date: 14/09/2020.

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ABSTRACT

The diminishing supplies of petroleum and ecological problems have led to a need for more affordable and renewable fuels. Because of its biodegradability, high cetane count, low sulphur content, aromatic compound, and low volatility, biodiesel obtained from numerous renewable sources has been deemed acceptable alternative fuels. Biodiesel derived from non-edible biomass feedstocks such as linseed oil is seen as feasible choices for developing countries such as India, where edible oil consumption and cost are very high. Biodiesel has been growing as an alternative fuel in recent years and is a strong replacement for tidy diesel fuels. Biodiesel is mainly extracted from fats and oils using a range of methods such as dilution, pyrolysis, micro-emulsification and transesterification, but transesterification is currently the most common technique used in the processing of biodiesel. The purpose of the present work is to prepare Sesame oil methyl ester and to research the effect of linseed methyl ester efficiency and emissions. The engine is connected by a water-cooled eddy current dynamometer to calculate the load on the motor. The engine was calibrated to fuel injection timing at 23o CA bTDC and compression ratio 18:1 (suggested by the manufacturer). The various performance and emission characteristics, such as Brake Power (BP), brake specific fuel consumption (BSFC), brake thermal efficiency (BTE), mechanical strength, brake mean effective pressure (BMEP), carbon dioxide (CO2) emissions, hydrocarbon emissions (HC), NOx emissions, and smoke opacity were evaluated on a single cylinder with 18:1 compression ratio operated at constant. The SOME10 and SOME20 test results were compared to diesel with or without an EGR. It was found that the emission of CO and HC increased with the content of blend while the thermal performance of the brakes decreased with the concentration of blend. The use of EGR has lowered NOx emissions slightly.

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NOMENCLATURE

ASTM	American Standard Test Method
CI	Compression Ignition
CN	Cetane Number
SOME10	Diesel 90% + Sesame Biodiesel 10%
SOME20	Diesel 80% + Sesame Biodiesel 20%
HC	Hydrocarbon
NOx	Oxides of Nitrogen
CO	Carbon Monoxide
CO2	Carbon Dioxide
BP	Brake Power
BTE	Brake Thermal Efficiency
BSFC	Brake Specific Fuel Consumption
BMEP	Brake Mean Effective Pressure
NaOH	Sodium Hydroxide
KOH	Potassium Hydroxide
FIP	Fuel Injection Pressure
EGR	Exhaust Gas Recirculation
bTDC	Before Top Dead Centre
CRDI	Common Rail Direct Injection
VCR	Variable Compression Ratio
T1	Temperature of inlet jacket in engine jacket and calorimeter
T2	Temperature of outlet water from engine jacket
T3	Outlet water temperature from calorimeter
T4	Inlet temperature of exhaust gases into calorimeter

T5	Outlet temperature of exhaust gasses into calorimeter
F1	Engine cylinder fuel supply
F2	Engine cylinder airflow
F3	Water supply into engine jacket
F4	Water supply into a cylinder
N	Contact-free velocity sensor (shaft speed of the engine)
W	Load sensor (eddy current dynamometer)
PT	Pressure transducer

CHAPTER 1

1. INTRODUCTION

Any country's growth is based on economic growth and social stability, and there is a crucial role of energy in this development [1]. The main source of power use is nuclear energy, green energies (e.g. geothermal, tidal, wind, sun, etc.) and fossil fuels energy (e.g., coal, natural gas and petroleum). Evaluation of a nation's development depends beyond per capita income & GDP on per capita energy consumption [2]. Due to growth in population, the manufacturing sector, and transportation, particularly for developing countries, requirement for energy is progressing day by day. They focus on producing oil from numerous materials while petroleum remains to be the world's primary source of fuel consumption. We use IC engines as an integral part of our day-to-day lifestyle, especially in the field of agriculture as well as transportation [3,4].

CI engine is the most effective power source utilized in major global sectors such as agriculture, transport and manufacturing, but power production due to better fuel conversion performance, higher longevity and reliability, and their specific combination of higher torque potential relative to spark ignition engines [5]. Petroleum fuels have a crucial role to play in the production of the agriculture sector, domestic needs, transport, industrial growth and much more for critical human needs [6].

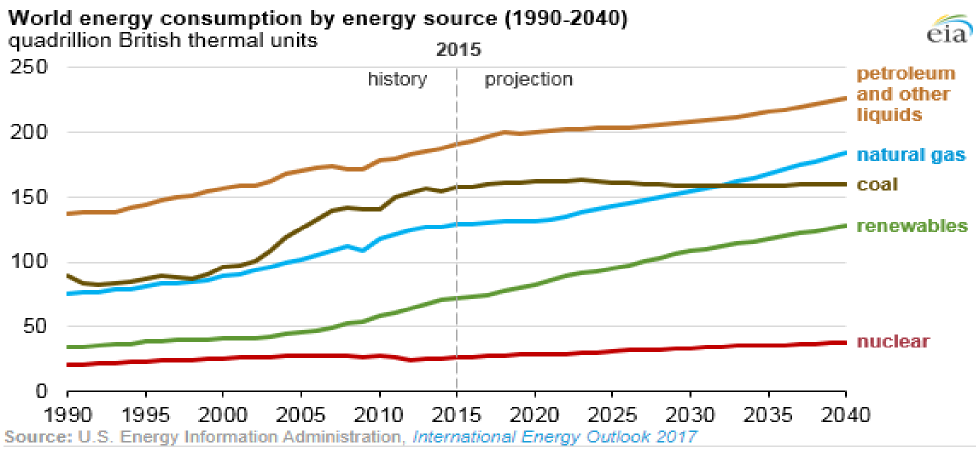

Figure 1.1: World energy consumption trend

The above figure shows the increasing consumption rate of conventional resources over a few years. Globally, every year 11 billion tons of fossil fuels were consumed. In our country, the total consumption of crude oil was over 103 million tonnes (MT) in 2000-2001 which increased over 160 MT by 2010 continuing to 194 MT in 2015-16 and later it increased from 206 to 211 MT in 2019 while the production of crude oil was only approx. 34 MT 2009-10. It became 36.9 MT in 2015-16 to 36 MT in 2016-17. There is negative growth in the subsequent years, as well as output, fell from 35.7 MT in 2017-18 to 34.2 MT in the fiscal year which ended on 31st March 2019 as per PPAC (Petroleum planning and analysis cell) [7,8]. According to the current scenario, coal, natural gases, conventional oils will no longer last more than 50-60 years.

Rapid development and use of petroleum goods contribute to environmental challenges and a shortage of fuel. The oil would disappear first from fossil fuels according to current usage levels. Coals and natural gas will be used for the next 60 years and 40 years respectively [1]. Even, owing to their lean burning nature, diesel engines produce smoke and high NOx and are accepted as a significant cause for smog ground-level ozone and acid rain. Smoke is known to be injurious and may cause asthma, cardio-respiratory disorders, and hypertension and lung cancer owing to its long-term use. In modern diesel engine research and production, the trade-off relationship between NOx and smoke is thus still the biggest challenge [5].

Coal and fuel oil result in carbon dioxide emissions that lead to global change and habitats attributable to intensive utilization of a conventional supply of fuel production (fuel oil, gasoline and diesel). And other harmful and toxic substances often escape from the engine using gasoline fuel or diesel fuel that releases carbon monoxide (CO), NOx (nitrogen oxide), sulphur dioxide (SO_2) that causes respiratory difficulties, ozone layer depletion, and acid rain. Thus, the oil problem is closely associated with the environmental crisis. Energy stability is therefore a big problem for economic development on the world. The global economy is significantly influenced by the oil shortage until energy storage is created. A harmony between human operation and ecology in sustainable economic development and biodiversity by the use of green energy sources should be established in the collective interest of humanity and nature to exist in equilibrium. By enacting strict pollution regulations political agencies across the world will ramp on the burden in the estimation of the threats to both the atmosphere and the human species [9-11].

Strict environmental regulations of the atmosphere and the need for sustainable green fuels have motivated researchers to review alternative renewable fuels for vehicles in transport. Researchers have looked attention to many forms of green energy. Biofuel is one of the effective green energy options that drew the interest of the researchers. Biofuel development has recently been seen as a good alternative for fossil diesel fuel worldwide, with particular reference to biodiesel. According to the International Energy Agency (IEA), in recent years the biodiesel industry has grown rapidly and the worldwide supply of biodiesel has risen tenfold from 2000 to 2008 [12].

1.1 BIODIESEL

Sustainable and renewable liquid fuels are (methanol and ethanol) alcohol and edible oils.

1.1.1 ALCOHOLS

Several countries, such as Brazil, Mauritius, the U.S., and just a few European countries, use ethanol-blended fuel in vehicles. Ethanol is made from molasses or sugar, wood, beet of maize, etc. Ethanol is extracted from any feedstock such as maize, wheat, tapioca, sugar cane, and other crops. The grain is grounded first and cooked with water to turn the starch into enzyme sugar. Instead, the sugar is fermented with yeast to create raw ethanol and a strong protein. The untreated ethanol is extracted to produce anhydrous ethanol [13].

Methanol is obtained from coal, natural gas, agricultural waste, municipal waste, etc. The municipal wastes are first crushed and then passed under a magnet to take away ferrous materials and afterward gasified with oxygen. Water scrubbing and other means are used to clean the synthesis gas to remove any particulates, H_2S, and CO_2. The CO-shift transition for H_2-CO-CO_2 modification, methanol synthesis, and methanol purification is accomplished.

Until alcohol was known to be good for S.I. engine, due to its high octane number it is not suitable for CI fuel. Ethanol and methanol have been deemed a prime substitute to diesel since 1970, and the most promising strategies for engine production are discussed, including power output, thermal efficiency, pollution, and functionality. The calorific value of ethanol is 27,000 KJ/kg and that of methanol is 20,000 KJ/kg and is also much lower than that of diesel. The alcohol fuels are best suited for SI engines. There are several strategies by which alcohol fuels can partly or fully displace diesel fuel. Alcohol is a desirable fuel since it is a renewable energy source and is gained from both natural and artificial sources. Alcohols are used for versatile fuel vehicle (FFV) service as a combination of petrol and blend. Alcohol is considered an oxygenated liquid since it includes its oxygen structure [14].

1.1.2 VEGETABLE OIL

A major criticism for the usage of vegetable oils is their high expense. The current situation is that vegetable oils have higher price levels in the market than petroleum fuels. However, the cost is projected to decline as advances in agriculture and methods of oil extraction improve. There are some 364 known varieties of oil seeds. Among such, India has over 200 varieties among oilseeds [15]. It is possible to locate those areas to determine the right type of oil seeds for growing plantation ideal for soil. To receive a supply of oil yearly from these plants, the process of existence has to be understood for specific oil crops. Each country can thus reduce its dependence on OPEC (Organization of petroleum exporting countries) for its petroleum needs. India being the country based on agriculture, the agricultural lands are viz plants or trees. Jatropha, Madhuca Indica, Cashew, and Neem, etc. may be grown/planted in the desert/barren lands with reduced expense and labour [16].

1.1.3 VEGETABLE OIL AS FUEL

Countries such as Europe, South America, and East Asia began to use vegetable oils as an alternative to coventional diesel fuel. If the engine starts with diesel, runs with vegetable derivate oil, and stops with diesel, the engine's fuel system will function for a long time; while severe carbon build-up deposits on engine components.

The most significant differences between vegetable oils and diesel fuel are:

- Viscosities are substantially higher, about 10 times higher than diesel.
- Vegetable oils have lower CV than diesel.
- Because of the presence of molecular oxygen, vegetable oils increase the stoichiometric fuel/air ratio.
- Thermal cracking of vegetable oils occurs at temperatures of injected fuel in diesel engines [17].

1.1.4 DIESEL ENGINE PERFORMANCE WITH VEGETABLE OIL

Bad volatility and smaller octane number make vegetable oils incompatible with SI engines. Vegetable oils are considered a good alternative for diesel fuel, since they have provided their very similar properties to diesel. Thus they offer the advantages of being widely used without any alteration in conventional diesel engines. They have a relatively poor CN. The vegetable oils flash point is pretty big so usage is easy. Usually, vegetable oils contain huge amounts of molecules with carbon, oxygen, and hydrogen in them. They have a similar structure to diesel fuel, but differ in association shape of strings, and have a comparatively high molecular mass and viscosity. The idea for producing fuel for diesel engines from vegetable oil is not genuinely new. In 1900, the developer of the diesel engine D diesel use of vegetable oils first checked the natural resource content such as peanut oil as a fuel in his compression ignition engine instead of petroleum diesel without any problems [18].

Biodiesel can be extracted from varied raw materials, such as waste oil, non-edible vegetable oils, animal fat, etc. Many of these commodities are sustainable, and have no effect on the supply of human food security. Now when biodiesel is used as a replacement for diesel, it is highly important to know engine parameters that affect combustion dynamics due to their direct effect on BTE and the pollutant emissions of an engine. Biodiesel has increasingly become a commercialised fuel due to the availability of non-edible vegetable oils and can be used according to market demand for biodiesel production; about 364 varieties of edible and non-edible seed oils are available and are ideal for replacing diesel fuel in two forms, i.e. blended and pure. A massive area of forest available in India generates edible oils such as Sesame (sesamum indium L.) Sesame (Linum Usitatissimum) Ratanjyot (jatropha curcus), Karanja (Pongamia pinnata), Polanga (Calophyllum inophyllum), Neem (Azadirachta indica), Kusum (Schleicher oleosa), Mahua (Machuca indica), etc. [19].

1.2 HISTORY OF BIODIESEL

Biodiesel history is more economical than scientific. The beginning of the 20th century had seen the emergence of automobiles powered by gasoline. Gasoline production began to rise because of the low price of petroleum fuels. On the other hand, the scarcity of resources was and still is a major concern when it comes to crude oil. Work has therefore begun about the use of fatty vegetable oils and edible oil as energy to find a more suitable alternative for crude oil. Biodiesel production out of vegetable oils is not a new process. Transesterification is known as the conversion of vegetable oils or animal fats into mono-alkyl esters of biodiesel.

At the 1900 Paris Exposition, Dr. Rudolf Diesel used oil of peanut to power his engine. Dr. Diesel manages to run his engine on peanut oil and stated "the diesel engine can be fed with vegetable oils and will help considerably in the development of the agriculture of the countries which use it". "Until the 1920s, diesel engines were run on vegetable oil Manufacturers of diesel engines have altered their motors to employ petro diesels lower viscosity rather than vegetable oil. In the early 1980s, it was planned to use edible and non edible oils as an alternative green fuel compared with petroleum. The upsides of vegetable oils are their portability, ready availability, renewability, higher heat content, lower sulphur content, lower aromatic content, and biodegradability, as diesel fuel. After 1990, the commercial production of biodiesel commenced. Dr. Diesel assumed there was potential for engines running on edible and non edible plant seed oil and that these oils could be potential to be alternatives of petroleum based fuel. Biodiesel plants have been opening in many European countries since the 1980s and biodiesel vehicles or petro- and biodiesel blends have been run in many cities. More recently, Renault and Peugeot have introduced biodiesel in some of their truck engines. Existing environmental and regional economic problems have inflamed biodiesel use worldwide. The European Community (EC) introduced a 90 per cent tax exemption for biofuel use in 1991, including biodiesel. Now many companies are building biodiesel plants in Europe [20]".

1.3 BIODIESEL AS A FUEL

Biodiesel can be produced in the climate-friendly area and can also be marketed by the government. Therefore the need and demand for boosting biodiesel contribute to sustainable social development. Such conditions would alleviate the fear of fossil resources disappearance.

- Due to the following reason, biodiesel becomes the most suitable choice for an alternatives fuel:
- It does not comprise of any sulphur and fossil oil residues and aromatic hydrocarbons since it is achieved from vegetable sources.
- The CI engine can be operated without much change in the design of diesel engines and is rich in oxygen fuel.
- It reduces pollutants such as CO, CO_2, UHC, and smoke opacity.

- ❖ Along with a more self-lubricating tendency than fossil fuel, it also increases engine efficiency.
- ❖ Since it is gained from vegetable oil and animal fats, it is a renewable source [21,22].

However, it can be identified that [23-26] out of several vegetable oil advantages, there are a few problems with it when using it as fuel in CI engines such as high viscosity, high density, greater iodine value, and poor volatility. Transesterification method will reduce viscosity as well as density but its density and viscosity are still higher. Some researchers found that the high density of biodiesel advanced the start of injection timing while some other researchers saw that high bulk modulus of biodiesel than diesel advance the start of injection timing [27,29]. Because of this, the rate of NOx is higher for biodiesel fuel. Biodiesel atomization is caused by increased average size droplets that result in increased spray penetration of the tips due to high surface tension and biodiesel viscosity. Relatively high tension also decreases the magnitude of Weber number which in turn has increased the average droplet size. It has also been stated that the average droplet size has been more impacted by viscosity than density. Therefore we first need to reduce biodiesel viscosity to boost fuel atomization [30-32]. The previously stated problem can be solved by mixing diesel with biodiesel which reduces viscosity. Injecting biodiesel at higher pressures is another way to boost atomization, which in effect improves the atomization cycle by increasing the diffusion of biodiesel spray. "Biodiesel can be defined as a fuel consisting of mono-alkylic esters of fatty acids (long-chain) derived from vegetable oils or animal fats. In theory, any vegetable oil or animal fat that generally includes long-chain saturated and unsaturated fatty acid triglycerides could be used in diesel engines [33-35]. Previous studies utilizing pure vegetable oils as a fuel in a diesel engine, however, resulted in numerous engine issues such as pumping issues, gumming, atomization, fouling of injectors, carbon particles on pistons and engine heads, engine wear and in long-run lubricating oil gets contaminated. This may be due to increased viscosity, density, iodine and poor non-volatility. Hence, many researchers suggested transesterifying vegetable oils to minimize the oil's high viscosity. Transesterification is a method for transforming vegetable oil into biodiesel to make it suitable for use in diesel engines" [36-38].

1.4 METHODS FOR CONVERSION OF VEGETABLE OIL INTO BIODIESEL

i) Transesterification

ii) Thermal cracking (Pyrolysis)

iii) Micro-emulsification

iv) Dilution

TRANSESTERIFICATION PROCESS:

To achieve biodiesel, vegetable oil or animal fat undergoes a chemical reaction termed as transesterification. It represents a reversible reaction. In this reaction, vegetable oil or animal fat combines with alcohol (generally methanol) in the presence of a catalyst (normally a base of NaOH or KOH) and produces the resulting alkyl esters (methyl ester in case of methanol) of the fatty acid mixture present in the parent vegetable oil or animal fat [39. The reaction is shown below.

PYROLYSIS

In the absence of oxygen, pyrolysis is a process of heating organic matter such as biofuels. The different products can be achieved from the same substance by applying a separate route of reaction, and catalyst can enhance the rate of a reaction. A particular hydrocarbon that acts as fuel may be produced by pyrolysis of vegetable oil or animal fat [40].

MICRO-EMULSIONS

The micro-emulsion is an emulsion type that is confined to a micro-scale like a droplet as a magnitude range distribution of 10-150nm. It is described as a colloidal suspension of fluid microstructures (1-150nm) in a solvent forming two immiscible phases. Methanol and ethanol are commonly used as solvents. This procedure is primarily utilized for vegetable oil with strong viscosity.

1.5 ADVANATGE OF BIODIESEL

- It can be use in unmodified diesel engines and biodegradable.
- It has somewhat close physical properties to diesel fuel.
- It is free from aromatic compounds and sulphur.
- Alternatively, it can produce the same capacity as diesel.
- The usages of biodiesel fuel in diesel engines significantly decrease UHC pollution, CO pollutants.

- “The usage of biodiesel can reduce the solid carbon fraction of particulate matter (since oxygen-rich biodiesel allows more complete CO_2 combustion and reduces the fraction of sulphate)” [41].
- Biodiesel does not impoverish the earth with CO_2 pollution because CO_2 from the atmosphere is removed during the photosynthesis cycle by the vegetable oil plant as the plant rises. Biodiesel, therefore, gives net CO_2 gain over traditional fuels.

It also greatly decreases air toxics associated with petroleum diesel fumes and is estimated to cause cancer and other issues in health and the environment. Biodiesel is also a self-lubricating chemical, improving engine life by reducing wear and tear [42].

1.6 DISADVANTAGE OF BIODIESEL

As a fuel some drawbacks of biodiesel are as follows:

- Higher viscosity that causes fuel atomization problems and injectors choke.
- It contains low energy content and a high cloud point and a point of pouring over diesel become problematic for storage and handling.
- Since biodiesel having low energy content, engine output such as fuel efficiency, strength and torque can be decreased by 8% to 15% relative to diesel.
- Biodiesel released NOx higher than diesel fuel.
- Biodiesel costs are still a big concern.

The problem of greater NOx pollution may be minimized by the variety of different ways in certain other studies. Exhaust Gas Recirculation (EGR) is one of the most appropriate ways of reducing NOx emissions [43].

1.7 EGR SETUP

EGR is an effective instrument in reducing NOx deposition in the combustion chamber. The exhaust mostly includes CO_2, N_2, and water vapours. The combustion mixture acts as diluents as part of this exhaust gas is recirculated to the cylinder. The concentration of O_2 in the combustion chamber is also reduced. Owing to the high specific heat of EGR, the heat power of the incoming charge increases, thus minimising the rise in temperature in the combustion chamber with the same heat release.

$$\textbf{EGR (\%)} = \frac{\textbf{Volume of EGR} \times 100}{\textbf{Total intake charge into cylinder}}$$

The quantity of EGR that is re-circulated should be treated effectively; otherwise, the engine output will be reduced. The three common explanations for EGR 's effect on reducing NOx are ignition delay, increased heat power, and inert gas intake charge dilution. EGR results in an improvement in ignition delay which is equivalent to retarding the injection time. The heat capacity theory asserts that adding exhaust gases to the intake charge increases the heat capacity and decreases the peak combustion temperature. Growing the total volume of inert gases, according to the dilution principle, decreases the adiabatic flame temperature thus decreasing the emissions of nox inside the cylinder [44].

1.8 SESAME OIL

Sesame (*sesamum indicum L.)* is a seed of herbaceose crop of the pedaliaceae family. It is very popular and important oil seed crop. It is mainly cultivated tropical and subtropical area like India, Thailand, Pakistan, Afghanistan, Bangladesh, Indonesia, Sri-lanka, Bhutan, Myanmar, China, Mexico, Turkey etc countries. It is an old agricultural plant and believed to have originated from Africa is recognised as the second most important genetic source. Sesame is raised in an area of 7554200 hectare in the Nation Wide. Sesame is extensively used as edible oil, nutraceutical, pharmaceutical and industrial sectors in many countries because of its Nutrition and antioxidants properties. Due to its pharmaceutical properties it is used as medicine against cancer, cold and pain killer etc [45].

The composition of sesame shows that the seed is an important source of oil 44–58%, protein 18–25 %, carbohydrate 13.5% and ash 5%. Oil and protein are important components of sesame seeds. The levels of oil content 57–63 per cent, and 23% to 25% protein. Sesame fats are important in the foods industries because of its flavour and stabilization Sesame oil contains *lignin, sesamin, and sesaminol* in its non-glycerol [46]. Known to play a significant role in oxidizing stability and antioxidant activity Sesame (*Sesamum indicum L.)* is among the ancient edible crops of oil and its seeds, which are used as food sources, contain up to 60% fat. As an alternative of diesel fuel sesame have strong potential, but its use in CR DI by high viscosity, low volatility and the triglycerides, polyunsaturated existence. The transesterification of sesame seed oil is one solution to viable oil-based sesame seed fuel. As an alternative diesel fuel, sesame oil has tremendous potential, yet its use in direct-injection engines is highly restricted Low viscosity, low volatility and polyunsaturated triglyceride character. Sesame oil contains triglycerides of the singly saturated oleic acid (43%), doubly saturated linoleic acid (35%), palmitic acid (11%) and stearic acid (7%). Because of its excellent antioxidant ability sesame oil is primarily made of three glycosides, linolein, linolenic and andolein. There is also a small amount of free fatty acids, for example, palmitic and arachidic. Sesame oil triglycerides contain five important fatty acids. Palmitic, stearic, oleic, linoleic and a-linolenic were the principal fatty acids that are usually present in sesame oil [47-49].

1.9 OBJECTIVES

This proposed research was performed using sesame oil biodiesel with the following goals.

1. Preparation of sesame biodiesel from raw oil through transesterification method.
2. Measure the viscosity and density of test fuel.
3. Analyse of the performance and emission of different blends of sesame biodiesel i.e. (10% and 20%) for different output parameters such as BP, BSFC, BTE, BMEP, mechanical efficiency, NOx, CO, HC, CO_2, and smoke opacity, Also the results were compared with diesel with or without the use of EGR.

CHAPTER 2

LITERATURE REVIEW

S V Channapattana et al. [50] has performed his experiment on CI DI engine fuelled with honge biodiesel and diesel blend. In this experiment they investigated effect of FIP with various blend composition affecting the Engine performance and emissions when compression ratio is 18. They has taken FIP 180 , 210 and 240 bar and researcher found the NOx emission increases with FIP and blend maximum for B20 blend , it show better thermal efficiency and performance as compare other blend.

R k pandey et al. [51] has examined the effect of atomization of fuel and biodiesel on emission and performance characteristics. Biodiesel is promising source of energy but it have high viscosity , density and low calorific value as compare to pure diesel fuel. in this paper author is mainly focus on three main spraying parameters spray cone angle, break up length and fuel penetration length and they found that atomization and vaporization of injected fuel are very much influenced by viscosity and density of biodiesel, the fuel inlet temperature is play very important role in fuel atomization and at higher temperature viscosity is decreased and atomization is improved .overall emission of biodiesel is less than diesel fuel.

M. K. Yesilyurt et al. [52] performed his experiment on a single-cylinder, four-stroke, and direct-injection diesel engine fuelled with diethyl ether as oxygenated fuel additive in cottonseed oil bio-diesel fuel blends. Ternary blends were prepared by mixing 2.5%, 5%, 7.5% and 10% of diethyl ether (DEE) by volume with bio-diesel fuel. According to his experiment, in comparison to diesel fuel, BTE was decreased by 17.39% for the blend with 10% of DEE as additive while increasing in BSFC by 29.15%. The engine i.e. fuelled by ternary blends revealed mitigation in the HC, smoke, and NO_x emissions, up to 12.89%, 4.12%, and 8.84% respectively.

Shailaja M et al. [53] set up an experiment on a CRDI diesel engine powered on a mixture of diesel and sesame oil. Sesame biodiesel has potentially proved to be a fuel ideal for diesel engines. Better production and pollution with sesame biodiesel as opposed to tidy diesel were observed. Since no change is needed in diesel engine model, sesame biodiesel could be used directly in the diesel engine.

Recep Altin et al. [54] examined the efficiency and emissions of diesel engines with multiple vegetable oils and their methyl esters as fuel. It has been found that the power of all vegetable oils developed by methyl esters was lower than that of diesel by 7 per cent to 10 per cent. Particulate emissions were also found to be significantly higher, and NOx emissions were lesser for methyl esters of vegetable oil compared to neat diesel. The CO emissions for raw vegetable oil were further estimated to be higher compared to petroleum diesel. It was stated that the raw vegetable oil can be used as alternative energy source with hardly any engine modification.

Nazar et al [55] have evaluated the use of karanja oil in direct injection diesel engines as an alternative fuel. The thermal efficiency for karanja oil ester has been observed to be 29.6% compared to 31.5% for diesel. HC and CO emissions to ester have been found lower than diesel at all loads. The smoke concentration for karanja oil methyl ester was further noticed to be 3.0 BSU. It has been stated that for Karanja oil methyl ester the peak pressure and maximum pressure increase were very comparable to that of diesel.

Usta et al. [56] assessed applications of methyl ester of tobacco seed oil as a fuel in an indirect diesel engine charged on turbo. The efficiency of the engine running with tobacco seed oil biodiesel was reportedly lesser than that of diesel. It was also revealed that CO emissions were lower, and NOx emissions were greater than diesel emissions. The exhaust emissions have also been reported to have some residues of SO2 emissions. It was stated that, without any alteration, the tobacco seed oil methyl ester can be partially substituted for diesel fuel as blend.

Raheman and Phadatare et al. [57] explored the role of CR and timing of the injection of Mahua oil Methyl Ester in a diesel engine. A diesel engine with biodiesel Mixture has been noticed to have improved output at a higher CR and advanced injection timing. It was found that, at a higher CR of 20º and 40º injection timing, the 20% biodiesel blend is a viable fuel replacement for the diesel engine.

G. Antolın et al. [58] performed an experiment where factors such as flash point, viscosity, acid value of sunflower oil were singularized to test the properties. The obtained conclusion was the hence obtained biodiesel was an exceptional substitute for fossil fuels.

A.S. Ramdhas et al. [59] performed a two-step transesterification process for the conversion to mono-esters from FFA oils. The initial step included, esterification by acid catalyzation, reducing the FFA oil content to less than 2% . In the second step, the alkaline catalyzed transesterification process transforms the products of the preceding step into monoesters and glycerol. Conversion to methyl esters from rubber seed oil was obtained by the two-step esterification procedure. The obtained biodiesel was almost as viscous as diesel and a drop of 14% in the calorific value was obtained. Flash point, pour point, cloud point and Specific gravity, are some of the properties compared with that of diesel. This study justifies that biodiesel produced from unrefined rubber seed oil as a suitable alternative to diesel fuel.

A.s Ramadhas et al. [60] compared the certain characteristic of methyl esters of rubber seed oil with other esters and diesel. The analysis of performance and emission characteristics of a compression ignition engine, using Pure rubber seed oil, diesel and biodiesel as fuel was done. The lower blends of biodiesel reduce the BSFC and increase the brake thermal efficiency. The experimental results demonstrated that biodiesel (produced from unrefined rubber seed oil) is a feasible alternative to diesel in compression ignition engines.

Yusuf Ali et al. [61] reviewed the use of fatty vegetable oils and animal fats as an alternatives of diesel fuel where he analysed fuel preparation by transesterification, pyrolysis, dilution, and microemulsion and the effects of these processes on the properties of the fuel and their effects on the engine. Over unprocessed vegetable oil, each one of the processes gave improved fuel properties.

K.M. shereena et al. [62] had, in the presence of either alkaline or strong acid catalyst, the transesterification of vegetable oil with methanol was tested. This study document explains the chemical composition of vegetable oils, vegetable and biodiesel fuel properties, processes of transesterification, major variables influencing the transesterification reaction, environmental assessment and economic viability of biodiesel.

S. Jayaraj et al. [63] reviewed the production and characterization of vegetable oil, the experimental work carried out, and the scope and challenges in various countries in this field.

RESEAECH GAP

- Most work was also done on non-edible seeds oils like jatropha, neem , linside, mahua but not much work was documented on edible oil like Sesame oil.
- There are some other combinations of parameter in the varying range remained to evaluate the performance of diesel engine such as fuel injection pressure, compression ratio, different blend %age, etc for the Sesame biodiesel.
- A very few researches have been performed on optimising biodiesel production and determining the performence of the CRDI VCR diesel engine fuelled with sesame biodiesel.

CHAPTER 3

EXPERIMENTAL SETUP AND METHODOLOGY

This chapter explains the process for the preparation of sesame biodiesel from sesame oil by the transesterification process. Also, the properties of different blend SOME10 and SOME20 with diesel have been obtained. These four blends were used to run the CRDI engine and various combustion and performance parameters like BP, BSFC, BMEP, Thermal efficiency, mechanical efficiency, etc are calculated. Apart from this we also obtained emission parameters like CO, CO2, UHC, NOx, and smoke opacity. These values were compared with diesel and the graph has been shown.

3.1 PREPARATION OF SESAME BIODIESEL:

Sesame oil was brought from fortune foods @ Rs 120 per liter. Biodiesel was prepared in the automobile lab of Mechanical engineering Department at Delhi Technological University, DELHI (INDIA). Some materials like KOH, Methanol, NaOH, Isopropyl Alcohol, and phenolphthalein were used in the formation of sesame biodiesel. There are following steps involved in the preparation of sesame biodiesel:

- At first, FFA (Free Fatty Acid) of the Sesame oil sample was checked which should be less than 2%. FFA was calculated with the help of N/10 dilution of NaOH, isopropyl alcohol, sesame oil, and phenolphthalein. It came out 2%. It means a sample of sesame oil can use for the transesterification process; otherwise, it becomes the saponification process.

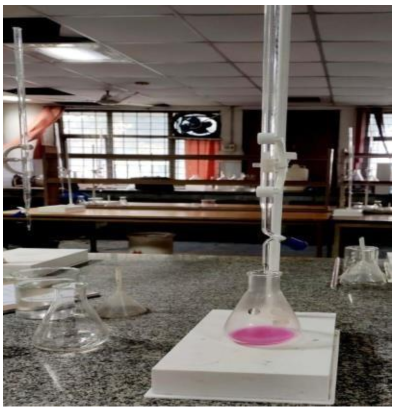

Figure 3.1: Testing of FFA of sesame oil sample

- After which 100ml of sesame oil was put into a beaker and heated up to 100-110°C to evaporate moisture from the oil.
- Simultaneously, KOH (1 gram) was kept in a separate beaker and methanol (20ml) and mixed to create a solution.
- It was stooped after elimination of the water content from preheated oil heating and oil is allowed to cool down.
- The methanol and KOH were combined with oil when the preheated oil arrived at 60°C, and stirring was started on a magnetic stirrer.
- The mixing fluid was held at 60°C and allowed to stir for approx. 30 to 45 minutes.

Figure 3.2: Separation of biodiesel from glycerol

- Afterwards, the stirred mixture was immersed to extract glycerol and biodiesel in an isolate funnel from the beaker.
- The mixture was dried about 24 hours removing the funnel and removing glycerol from biodiesel.
- Then, water washing is performed on biodiesel to extract excess methanol, KOH and other impurities.

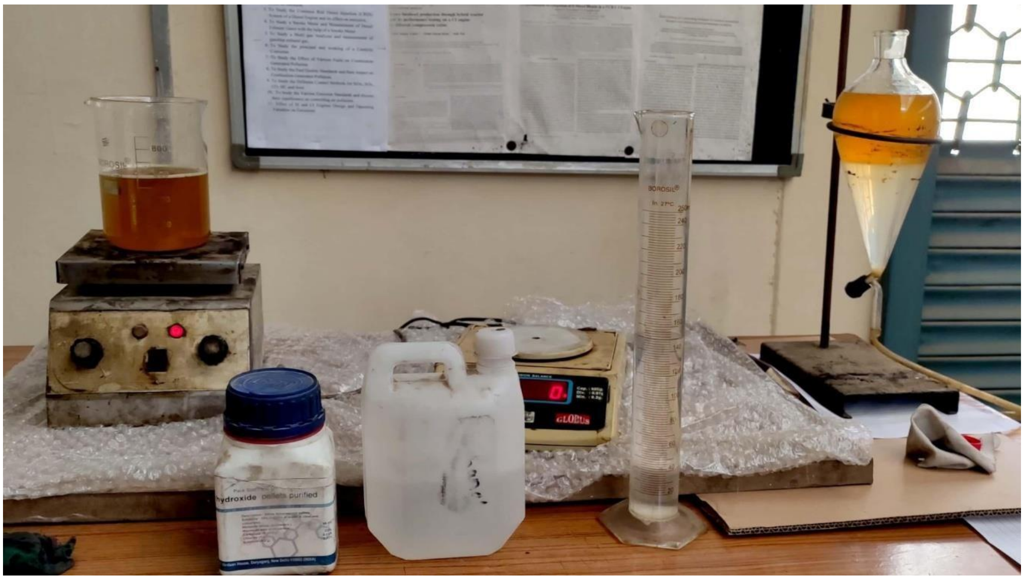

Figure 3.3: Water Washing

3.2 The properties of Diesel, sesame biodiesel and its various blends

Table1: Various properties of diesel, sesame oil and its blend SOME10 and SOME20 using viscometer

Properties	ASTM Method	Diesel	SOME10	SOME20	Sesame methyl ester
Density (g/cm^3)	ASTM D7042	0.830	0.8351	0.8402	0.8810
Kinematic viscosity (mm^2/sec) @40°C	ASTM D7042	2.9783	3.0730	3.1677	3.9256
Calorific value (kJ/kg)	D6751 37	42100	41870	41450	39600

Figure 3.4: Viscometer

3.3 EXPERIMENTAL INVESTIGATION OF THE ENGINE PERFORMANCE PARAMETERS:

The experimental engine tests were done on CRDI VCR ENGINE SETUP (common rail direct injection variable compression ration engine) in the automobile lab of Mechanical engineering Department at Delhi Technological University, DELHI (INDIA). The various tests were carried out for conventional diesel and different blend of sesame biodiesel on a single-cylinder, 4 strokes, and water-cooled VCR engine operated at constant speed 1500rpm with (cold) or without EGR (Exhaust Gas Recirculation).

3.3.1 The following engine performance parameters are calculated on the experimental investigation:

- Brake Power (BP)
- Brake Specific Fuel Consumption (BSFC)
- Brake Thermal Efficiency (BTE)
- Mechanical Efficiency
- Brake Mean Effective Pressure (BMEP)

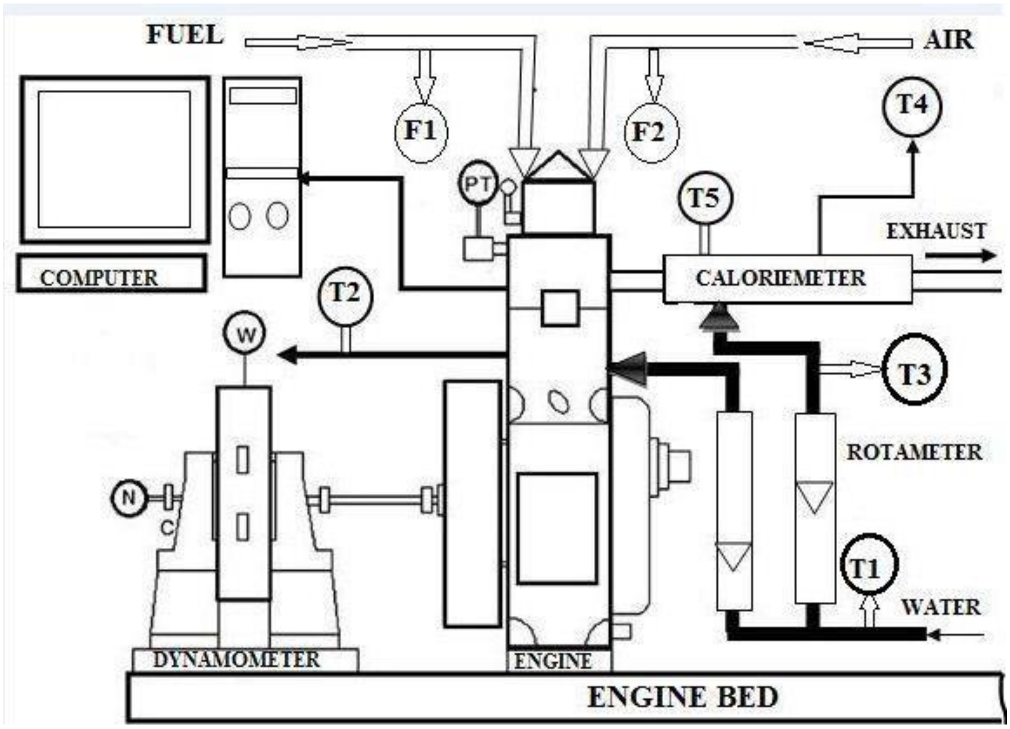

Figure 3.5: The layout of test CRDI engine

Table 2: The Technical Specifications of Engine Setup

MODEL	**KIRLOSKAR**
No. of cylinders	1
No. of strokes	4
Cylinder diameter	87.5 mm
Stroke length	110 mm
Compression ratio	12:1 to 18:1
Power	3.5 kW
Speed	1500 rpm
Connecting rod length	234 mm
Dynamometer	Eddy current, water-cooled type
Dynamometer arm length	185 mm
Load indicator:	Digital, Range 0-50Kg, Supply 230 VAC
Load sensor	Load cell, type strain gauge, range 0-50Kg
Fuel flow transmitter	DP transmitter, Range 0-500 mm WC
Temperature sensor	Type two-wire, Input Thermocouple
Rotameter	Engine cooling 40-400 LPH; Calorimeter 25-250 LPH

3.3.2 Eddy Current Dynamometer:

Power and torque are calculated with the help of an eddy current dynamometer which is connected with engine test setup. Several loads like 0kg, 3kg, 6kg, 9kg, and 12kg were applied on the CRDI engine through dynamometer by the help of load cell which is connected with load sensor and the load was displayed on the load indicator. It has a notch type disc called rotor is driven by the prime mover and stator (magnetic poles) are situated externally with a gap. The magnetic poles excited by the coil which is wrapped in the circumferential direction. The prime mover rotates the rotor and the voltage is supplied to the exciting coil or stator housing. Thus magnetic flux is produced and the rotor cuts off these magnetic fluxes. In this way eddy current produced in the rotor opposite to the change in magnetic flux.

Figure 3.6: Eddy Current Dynamometer

3.3.3 AVL EXHAUST GAS ANALYSER:

The emission parameters like CO, CO2, UHC, NOx, and smoke opacity are measure by AVL gas analyzer. In this system, the one end is connected with gas analyzer while the other end is connected with the exhaust gas pipe.

Table3: The specifications of AVL exhaust gas analyzer are shown below:

Type	AVL DIX 650
Operating temperature	5...40 ^{0}C
Storage temperature	0...50 ^{0}C
Warm up time	Approx... 2 min
Humidity	10 ... 90 % non condensing
Dimension	344 x 252 x 85 (W x H x D)
Weight	2.2 kg
Interface	USB, Bluetooth Class 1, RS 232 (AK Protokoll)
Certification	2004/22/EC (MID); OIML R99 Class 0
Voltage supply	Via AVL DITEST CDS Basic Unit: 11..25 V DC
Power consumption	Approx. 20 VA

Figure 3.7: AVL Exhaust Gas Analyzer

3.4 EXPERIMENTAL PROCEDURE

The engine was run firstly with diesel followed by different blend i.e. SOME10 and SOME20 of sesame biodiesel fuel.

3.4. Procedure for the experiment:

- At first, diesel was filled in fuel tank of CRDI VCR engine adjusted with a compression ratio 18:1.
- Then the motor continued to provide water, the water as a coolant and the calorimeter flow was regulated respectively at 150LPH and 75LPH.
- Confirmed the proper water supply for the piezo cooling sensor and eddy current dynamometer.
- · After that, all electrical connexions were correctly tested and the device was supplied with electricity.
- Then diesel was allowed into the engine by opening the knob of the burette.
- The specific gravity and the calorific value are adjusted through the configure option present in the software for the experiment.
- The engine was adjusted with injection pressure at 600 bar and injection angle at 23^0C A bTDC by configuring option in the software.
- The engine was initially ran at zero load conditions for 10 minutes by choosing the programme run option.

- Pressed the log-on option shown in the software and allow the diesel supply. The display changed into input mode and after 1 minute. Thereafter the water was entered in cooling jackets and calorimeter. Noted the first reading for the engine at zero load condition and value saved in the software by making a file.
- After that turned the fuel knob to the previous position.
- The above procedure were repeated for different load i.e. 3kg, 6kg, 9kg, and 12kg. Their corresponding values were saved in the software.
- These above-mentioned procedures were repeated for a different blend of sesame biodiesel i.e. BL10 and BL20 by changing the fuel in the tank and also the corresponding value of the calorific value and specific gravity was adjusted accordingly in the software.
- All these steps followed again by applying EGR (14%) this time and values were recorded.
- After saving all the values corresponding to different blend at different loads, supplied zero loads to the engine and after that turn off the system and engine to stop the experiment.
- The water supply was also stopped after a few minutes.

The following precautions are taken during the experiment:

- All the joints parts like nut and bolt were checked strictly and it should be tight before operating the engine.
- The availability of fuel in the fuel line and the fuel tank must be sufficient.
- Proper cleaning of the flue line and fuel tank to remove the impurities.
- The motor for the water supply turned on before starting the system for cooling.
- Sensor and sensitive instrument handed carefully.

The following steps were taken for evaluation of emission parameters:

- When the engine was set on a particular load for a particular blend then put the gas analyzer sensor inside the exhaust pipe of the engine.
- The exhaust gases passed through sensors and readings were displayed on the digital screen.
- When the data is stabilized, 3 subsequent values were taken and their mean value was noted for analysis purposes.
- The exhaust pipe then removed from the sensor.

- These steps were repeated for different blends at different load conditions.
- Their corresponding readings were noted accordingly.

Figure 3.8: Exhaust pipeline

CHAPTER 4

RESULTS AND DISCUSSIONS

This chapter discusses the two main objectives:

- ❖ Evaluation of performance parameters of diesel and its blend.
- ❖ Evaluation of emission parameters of diesel and its blend.

4.1 EVALUATION OF PERFORMANCE PARAMETERS OF DIESEL AND ITS BLEND:

When experiments were performed with diesel and their blends in CRDI engine, various performance parameters like BP, BFSC, Mechanical Efficiency, BTE, and BMEP were discussed concerning load and blend simultaneously with or without EGR.

4.1.1 BRAKE POWER (BP)

Figure 4.1 indicates difference in load of the brake power and different variations with or without EGR. The graph reveals that the BP is the almost equivalent for both diesel and sesame biodiesel blends at first, with no load condition. If the load rises, the BP increases steadily with all test fuel since the torque increases but the diesel BP increases more relative to the SOME10 and SOME20. Possibly because of the fact that diesel has a higher CV relative to biodiesel blends. BP sesame blend decreases partial loads compared to diesel due to higher viscosity and density but poor CV as opposed to diesel contributes to excessive fuel combustion. SOME20's BP is 11% lower than diesel at 100% load level.

It is also shown from Figure 4.1 that the BP continues to decrease as EGR (14 per cent) falls on the pump. This may be attributed to the fact that the amount of oxygen required for combustion falls compared as exhaust gas replaces air intake. The diesel and SOME10 BP gets marginally higher for SOME20 by 1.21% with EGR gets decreased by 4.95% and 5.35% respectively while at full load it.

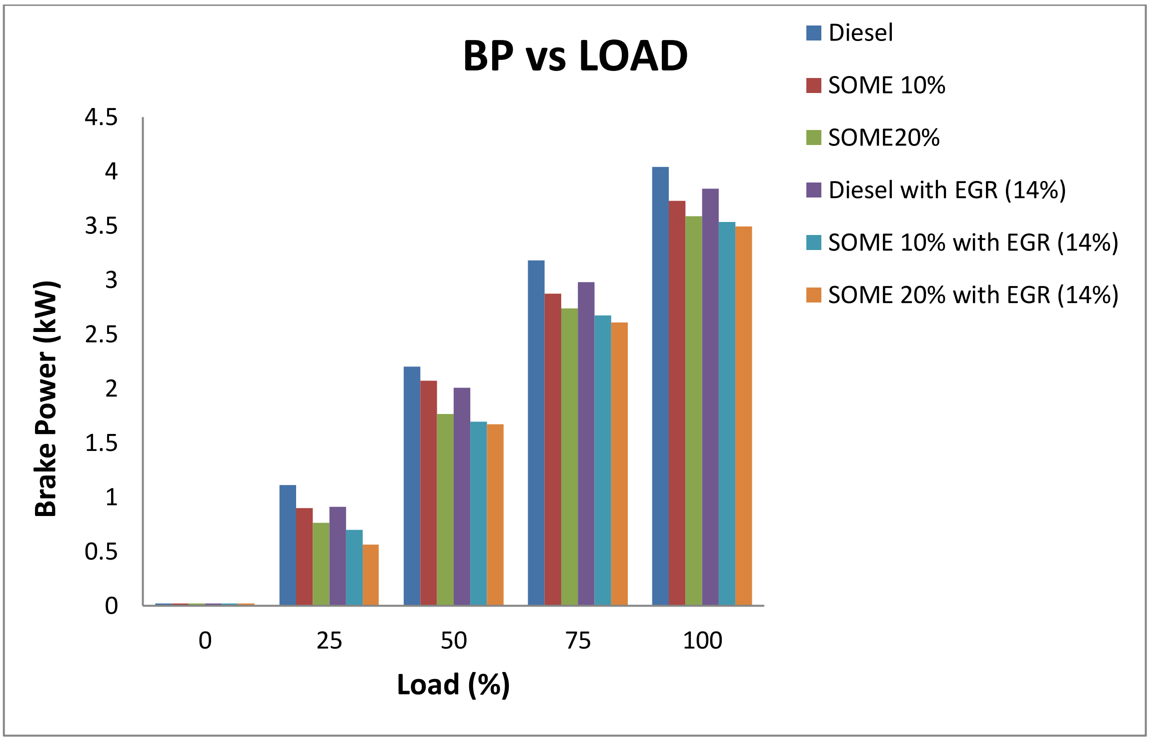

Figure 4.1: Brake power variation with load and different blend with or without EGR.

4.1.2 BRAKE SPECIFIC FUEL CONSUMPTION (BSFC)

The BSFC of two different sesame blends i.e. SOME10 and SOME20 is evaluated with traditional diesel fuel and observed that BSFC significantly decreases with load increases for all fuel blends. The primary cause for this trend may be that biodiesel quantity increase in fuel needed for engine operation is less than the magnitude increase in BP. The BSFC of SOME10 and SOME20 was seen to be greater than diesel. As the fraction of sesame increases in blend, it was found that the BSFC was rising. The BSFC of SOME20 was more than diesel and SOME10 due its high density as the concentration of biodiesel contributes to an increase in fuel capacity, correspondingly increases. For same volume of fuel, there is more mass injection for high densities of biodiesel blend leads to greater BSFC.

BSFC generally increases with EGR rates for all sesame/diesel blends with greater consumption for SOME20 fuel. This may be due to the reduction in in-cylinder temperature by employing EGR which results in inadequate combustion. The variation of BSFC with load and different blend with or without EGR are shown in Figure 4.2.

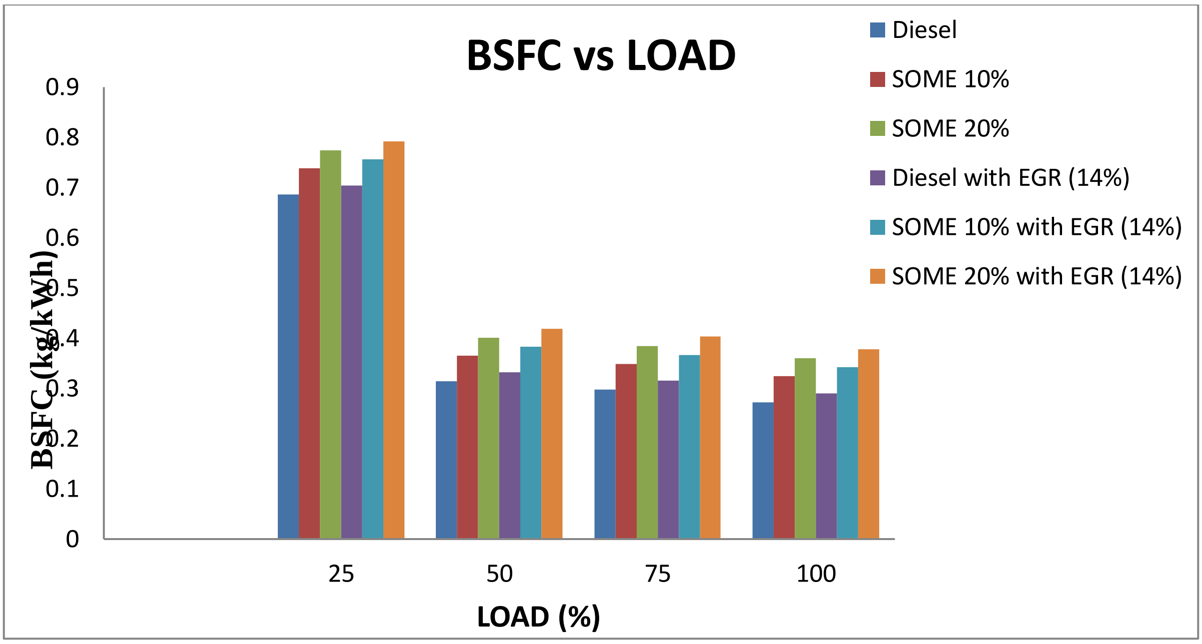

Figure 4.2: BSFC variation with load and different blend with or without EGR.

4.1.3 BRAKE THERMAL EFFICINCY (BTE)

Figure 4.3 displays the BTE with load variance showing BTE as a function of engine load for all test petrol. BTE’s rate of shift was higher at lower rates, although it decreased more with load changes. This may be because the rate of increase in BP declines with full load while BSFC's rate of increase remains relatively constant. Because of this the decrease in BP levels at higher loads contributes to a decline in BTE values. Also, the BTE is found to decrease accordingly as the concentration of the blend rises in gasoline.

BTE was shown to decrease very significantly for all sesame/diesel blends when added with EGR. EGR improvement disrupts the proper combustion process as the ignition rate declines as the volume of oxygen required for ignition declines constantly as waste gases pumped into the combustion chamber instead of fresh air.

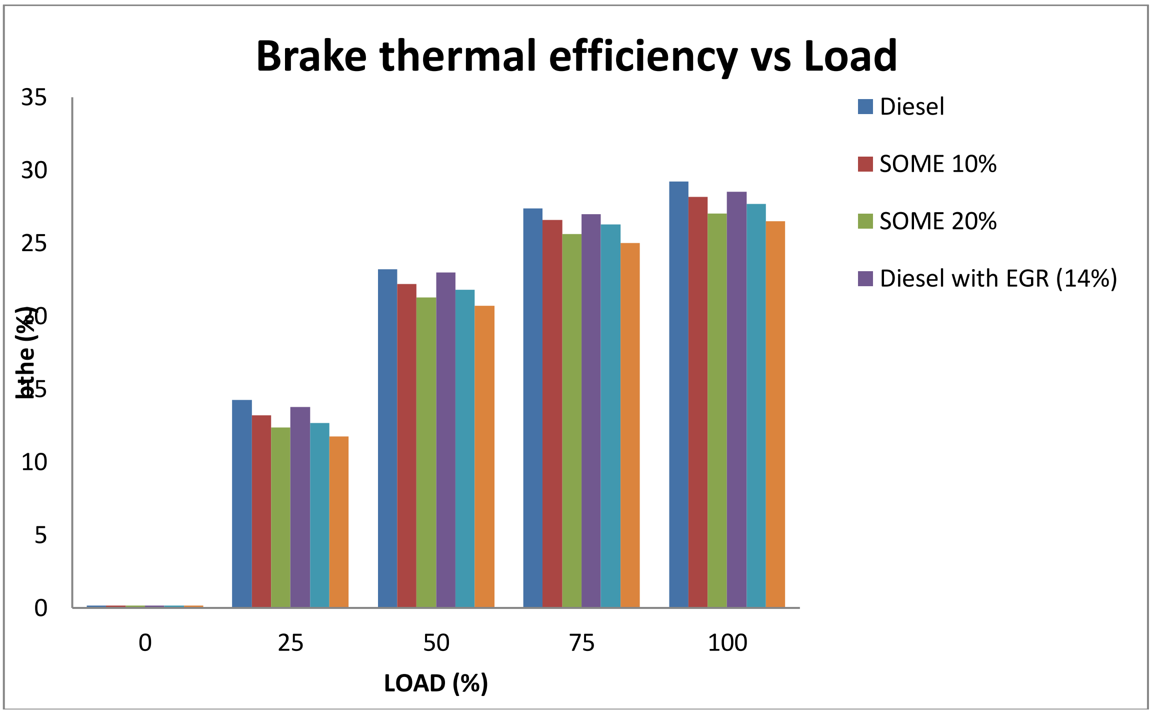

Figure 4.3: BTE variation with load and different blend with or without EGR

4.1.4 BRAKE MEAN EFFECTIVE PRESSURE (BMEP)

BMEP is the average pressure which depends on the determined power consumption within the IC engine cylinder. If the manifold pressure increases it increases. Small differences with a blend material were found in BMEP. BMEP was also shown to be rising as the load rises. Because of the oxygen content, that could be due to the proper combustion of fuel in the biodiesel molecule.

With EGR, because of incomplete fuel combustion in the chamber, BMEP gets decreased for all test fuel. Figure 4.3 demonstrates the effects of blend, load, and EGR on BMEP.

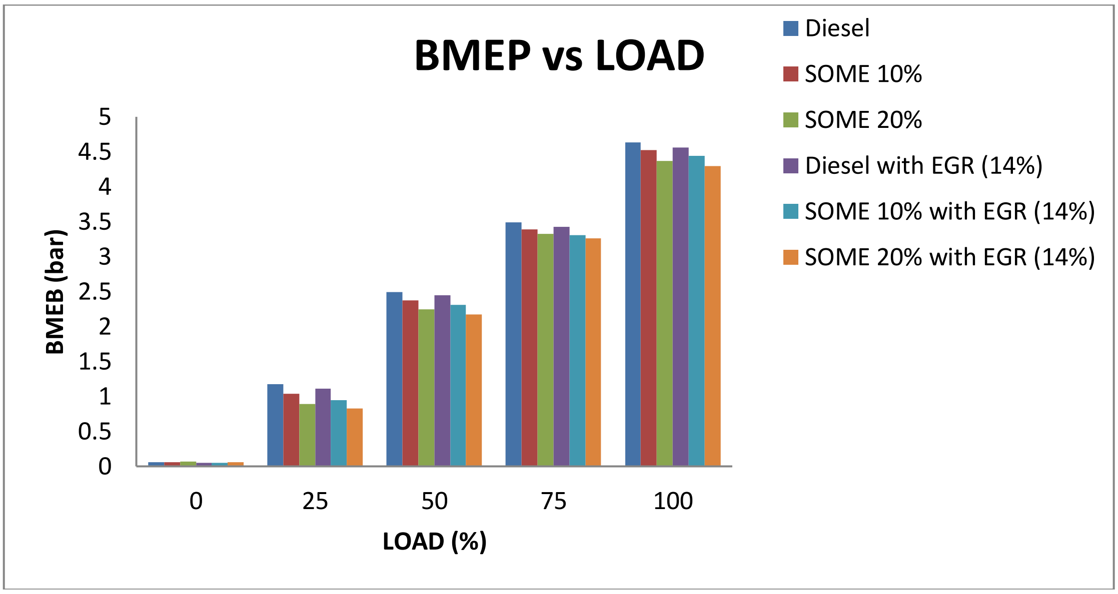

Figure 4.4: BMEP variation with load and different blend with or without EGR.

4.1.4 MECHANICAL EFFICIENCY

The mechanical performance of the engine that runs on diesel was found to be minimum at all loads. Owing to the rise in BP, mechanical productivity increases with increment. Mixed fuels showed higher mechanical performance compared with straight diesel fuel. This may be that in contrast to diesel, blended oils have better lubricity properties. The efficiency of the SOME20 blend was found to be the greatest of all fuels i.e. diesel and SOME10. Since SOME20 is more viscous, it has more lubricity.

With EGR the mechanical efficiency for all loads and test fuel decreases slightly. This was possibly due to the fact that the temperature in the cylinder is decreasing by using EGR which results in improper combustion. Figure 4.5 indicates the difference in mechanical performance with load and separate blend with or without EGR.

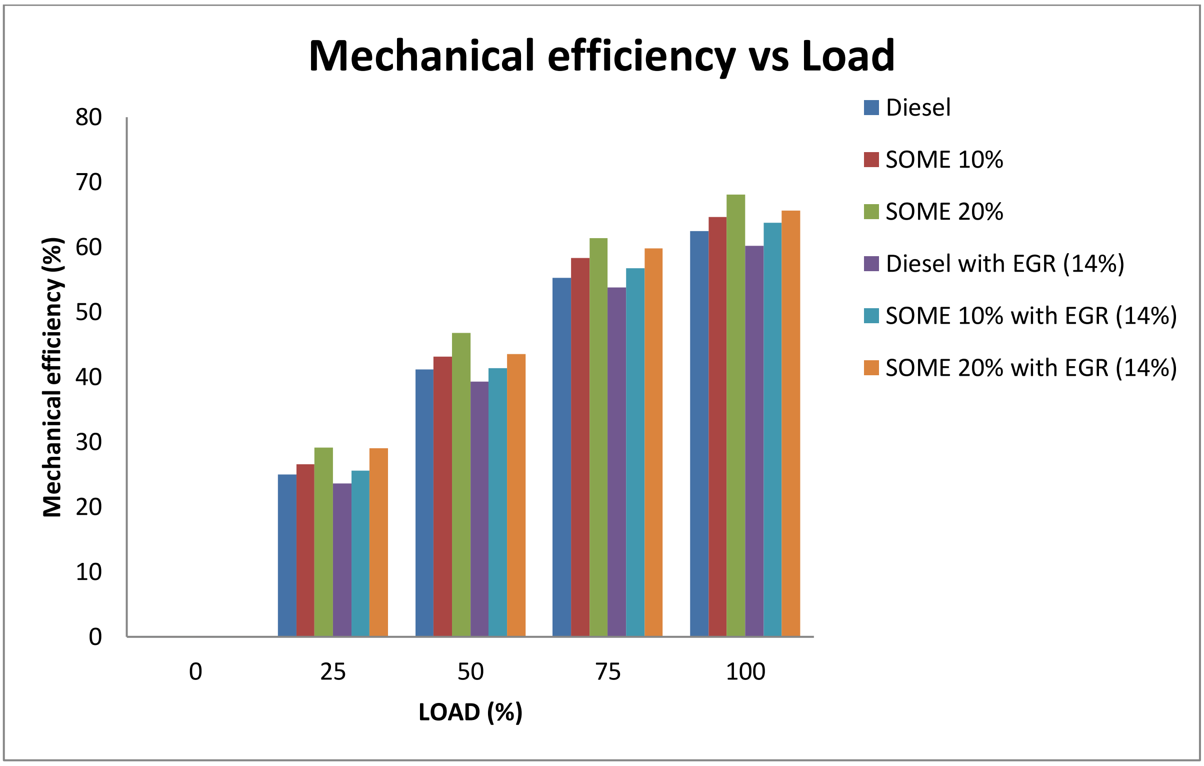

Figure 4.5: Mechanical efficiency variation with load and different blend with or without EGR.

4.2 EVALUATION OF PERFORMANCE PARAMETERS OF DIESEL AND ITS BLEND

4.2.1 NOX EMISSION

The emission of NOx usually depends on the temperature of combustion and is caused by some engine input factors. It can be seen that NOx emissions are high with concentration of sesame/diesel blends as opposed to diesel fuel. This action may be attributed to the prevailing influence of the concentration of oxygen and the lower CN of sesame blends. Using sesame biodiesel to diesel lowers the CN of the mix, which results in a longer ignition wait. Therefore, more fuel mixture is pumped into the tank over this time period and when this additional fuel amount is combusted during the process of premixed combustion, high gas temperatures result in more NOx emissions.

By adding EGR the emissions of NOX are minimised in CI engines. The lower oxygen content in the combustion chamber and lowered flame temperature can be hence attributed. At lower loads, oxygen is readily available, but at higher loads, oxygen decreases dramatically, thus reducing NOX emissions can be greater at higher loads relative to partial loads. Owing to the reduced supply of oxygen, the reduction in NOX emissions is mostly attributed to a reduced in-cylinder temperature during fuel combustion. NOX emissions have fallen dramatically at high EGR rates but result in higher BSFC and lower BTE.

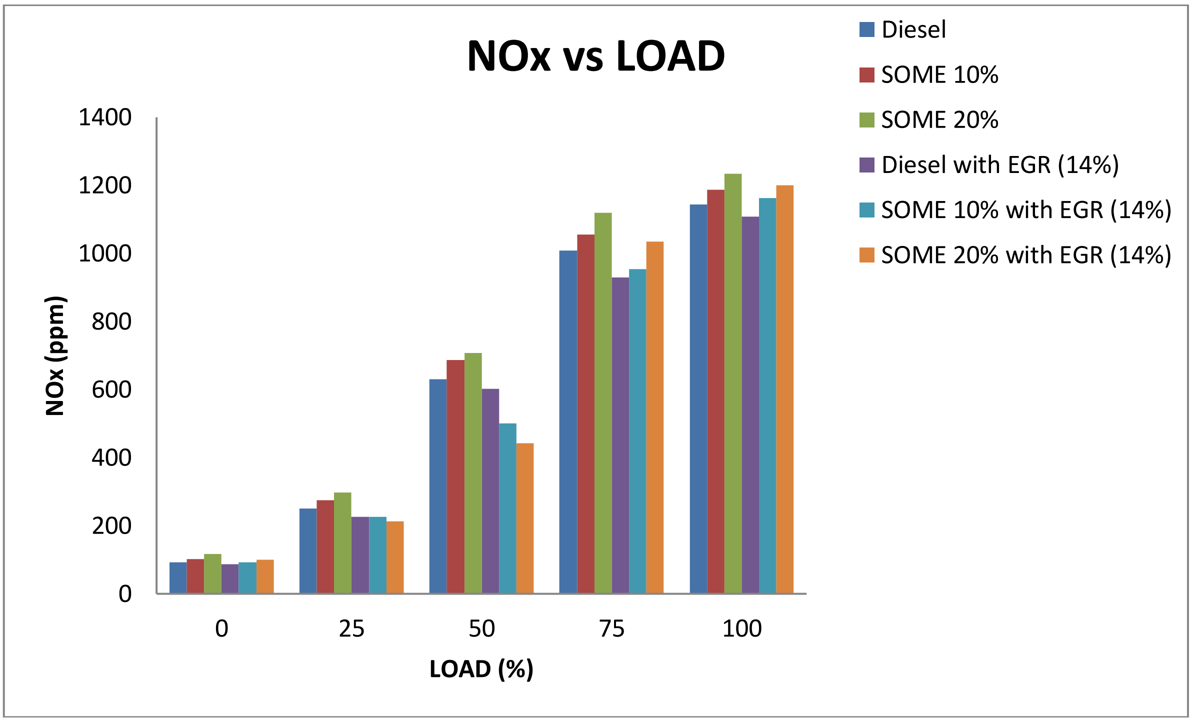

Figure 4.6: NOx emission variation with load and different blend with or without EGR.

4.2.2 CARBON MONOXIDE (CO) EMISSION

Generally speeding up CO emissions at low loads and dramatically decreasing with engine loads due to higher in-cylinder temperatures. It can also be seen that the concentrations of CO in the blend are that, with the quality of sesame increasing. The high latent vaporising heat of sesame blends lowers in-cylinder temperature and induces a cooling effect which promotes CO formation. Even SOME10 and SOME20 produce high oxygen content resulting in proper fuel combustion reduces the CO production when converted to CO_2.

Implementing EGR eliminates CO emissions due to lower oxygen content, leading to a minor increase in CO emissions as seen in Figure 4.7. Diesel CO emissions are greater than those of other mixtures.

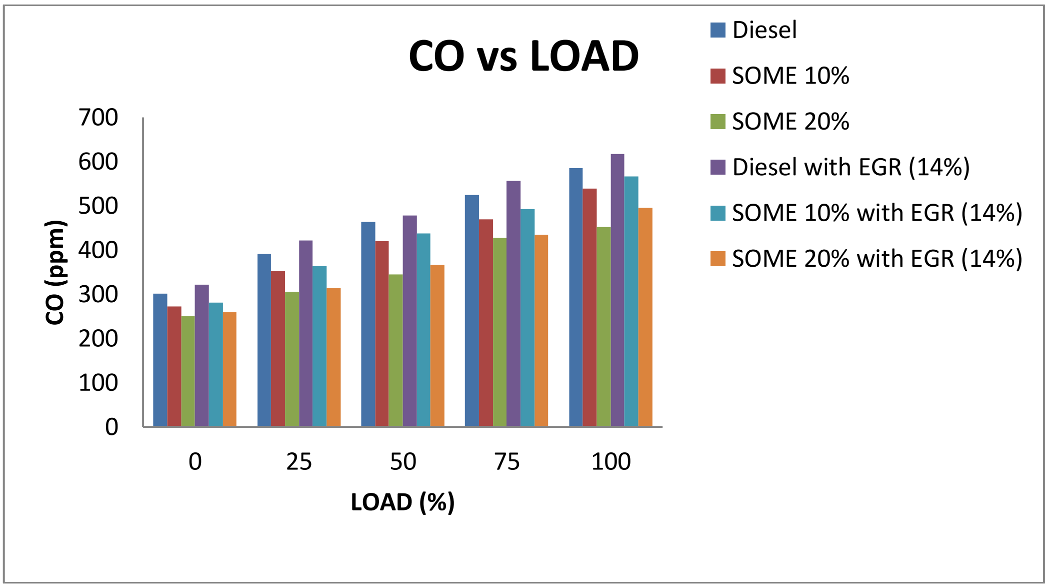

Figure 4.7: CO emission variation with load and different blend with or without EGR.

4.2.3 HYDROCARBON (HC) EMISSION

The UHC emissions have been shown to growth with load. That is due to the incorporation in the combustion chamber of a rich F/A ratio leading to an increased fuel intake. That leads to insufficient increases in UHC combustion and emissions. It has also been observed that the UHC decreases with increases in the content of blends. The explanation is that biodiesel mixtures at CN are high. Higher CN does not reduce the delay in combustion that increases combustion. Another explanation why hydrocarbon emissions have decreased with an increase in blend concentration is primarily due to more oxygen than gasoline.

HC emissions increase with higher levels of EGR, with higher emissions, with higher content of sesame. Increasing the level of EGR %age results in lower flame temperatures resulting in the creation of larger flame quenching zones where ignition is not easily possible. Figure 4.8 shows the load variation of the HC emissions and different mixtures with or without EGR.

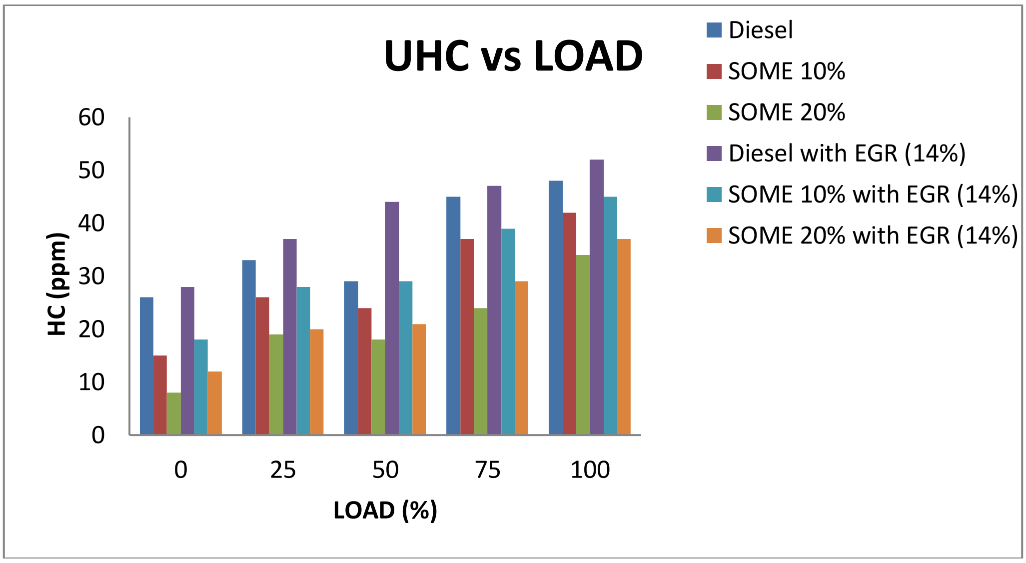

Figure 4.8: HC emission variation with load and different blend with or without EGR

4.2.4 SMOKE OPACITY

It has been found that the visibility to smoke rises with engine load and is extremely high at high engine loads. It's because more fuel is burned at heavy engine loads to produce better power performance. Smoke levels for all sesame/diesel blends can be seen to be lower compared to diesel petrol. Sesame biodiesel molecules also have some in-built oxygen which increases the burning efficiency and results in lower smoke.

The greater visibility of exhaust smoke is observed when the engine is run with EGR as opposed to all the fuels checked without EGR. Increasing EGR concentrations decrease oxygen levels and increase the local equivalence ratio causing insufficient combustion, and promote the production of soot. Even the high EGR decreases the cylinder temperature and facilitates the production of smoke. Figure 4.9 indicates the difference of load smoke intensity and distinct blend with or without EGR.

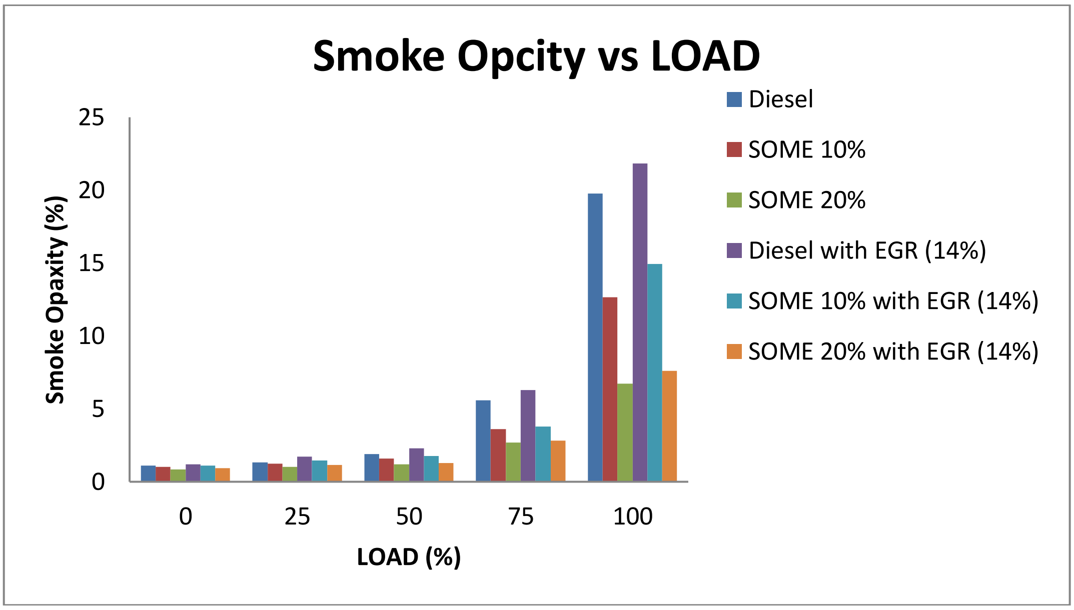

Figure 4.9: Smoke Opacity emission variation with load and different blend with or without EGR

4.2.5 CARBON DIOXIDE (CO_2) EMISSION

CO_2 emissions from diesel are comparatively high since the sufficient combustion of A/F mixture occurred at a level of 20% of sesame biodiesel in the mixture, resulting in the conversion of C and CO into CO_2. The advent of biodiesel blend has resulted in a reduction in CO_2 emissions attributable to insufficient blending and combustion due to high viscosity of biodiesel and oxygen depletion, respectively.

EGR reduces CO_2 emissions when the exhaust gas pumped instead of fresh air results in partial combustion of fuel in the combustion chamber. This means the inadequate oxygen supply cannot turn the CO into CO_2 and lowers CO_2 emissions.

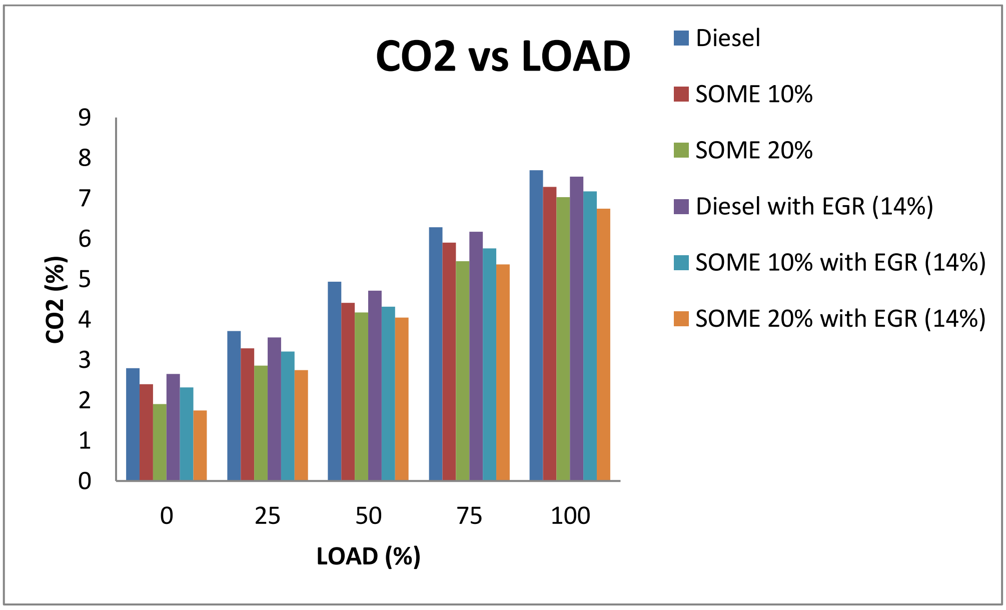

Figure 4.9: Carbon Dioxide emission variation with load and different blend with or without EGR

CHAPTER 5

CONCLUSIONS AND FUTURE SCOPE

5.1 CONCLUSIONS

Sesame biodiesel as a substitute to diesel fuel has strong potential low viscosity, low volatility and polyunsaturated triglyceride emissions, sesame biodiesel fuel properties are in accordance with the ASTM biodiesel standard. Sesame seeds need reduced water quantity and are increasing rapidly. SOME10 and SOME20 properties were tested with or without EGR (14%) and findings contrasted with diesel fuel. The following conclusion can be made from this experimental work:

- The performance parameters like BP and BTE for diesel is greater than SOME10 and SOME20 with or without EGR. The BTE of neat diesel is 5.45% greater than SOME10 and 8.70% higher than SOME20. With EGR, the BTE of diesel is 4.78% greater than SOME10 and 10.35% more than SOME20 at 100% load condition.
- The BSFC is drastically reduced with load and diesel has least for all test fuel. The BSFC of SOME20 is 9.52% more than SOME10 and 23.28% higher than neat diesel for full load with EGR.
- The emission parameter like HC and CO was increased with EGR. By applying EGR, the emission of HC was increased by 8.32% for diesel, 7.14% for SOME10, and 8.82% for SOME20 at full load condition. The emission of CO was raised by 5.22% for diesel, 5.19% for SOME10, and 9.73% for SOME20 at 100% load.
- NOx emission is greatly influenced by EGR. It reduced by employing of EGR. With EGR and full load condition, NOx emission was reduced by 8.39% for SOME20. SOME20 has least smoke opacity and it marginally increased with EGR.

5.2 FUTURE SCOPE

Edible and non-edible biomass is best source for biodiesel production such as sesame oil it is oldest edible oil in India and rest of world is reported. Biodiesel produced by sesame oil is non-toxic unlikely to other biodiesel and the glycerine produced as a by-product is also used in medical field. So if in India we focus on sesame seed production then we can reduce the price of biodiesel and also farmer of India will get benefits. we have further scope for research in medical field how we can effectively use glycerine produced as a by-product in biodiesel production

Before introducing the fuel in India the researchers recommend the following points:

- The Government should conduct effort to make suitable use of sesame oil for the biodiesel production.
- A more comprehensive CFD evaluation may be required to know the induction of turbulence with vegetable oil and its methyl ester, oxygenated fuel, and combustion of gaseous fuel.
- The effect on engine efficiency of certain parameters such as pilot injection, rpm, ignition timing, and ignition delay can be examined, with EGR also.
- To reduce the NOx emissions, further research is needed rather than EGR.

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