Performance, Emission and Combustion Characteristics of a Diesel Engine using "Cotton Seed Oil and Microalgae Oil" Methyl Ester

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***Abstract*: The need of energy is increasing continuously, because of increase in industrialization as well as human population. The basic sources of this energy are petroleum, natural gas, coal, hydro and nuclear. The major disadvantage of using petroleum based fuel is atmospheric pollution. Petroleum diesel combustion is a major source of greenhouse gases (GHG). Apart from these emissions, petroleum diesel combustion is also major source of other air contaminants including NOx, SOx, CO, particulate matter and volatile organic compounds, which are adversely affecting the environment and causing air pollution. These environmental problems can be eliminated by replacing the petroleum diesel fuel with an efficient renewable and sustainable bio fuel. Biodiesel derived from various sources like crops cannot be satisfy the fraction of the existing demand for transport fuels. Microalgae appear to be the source of renewable biofuel that is capable of meeting the global demand for transport fuel. Microalgae is a sunlight driven oil production species. It produces more oil content than the oil crops and it is abundantly available in the seas. As the earlier work of cotton seed oil (2nd generation) shows the increased emission of NOx and BP and BTE. Microalgae have an ability to reduce the NOx discussed in the earlier work. In this work, the scope is to reduce the harmful gases exhausted from emissions of IC engine. To reduce the harmful emissions from 2nd generation bio fuels with maintaining same BP and BTE, the blends of Cotton seed oil ester (2nd generation) and Microalgae oil ester (3rd generation) at various proportions are used.**

Abbreviation

CSOME	**Cotton Seed Oil Methyl Ester**
MAOME	**Micro Algae Oil Methyl Ester**
BP	**Brake Power**
TFC	**Total Fuel Consumption**
SFC	**Specific Fuel Consumption**
CO	**Carbon Monoxide**
CO_2	**Carbon dioxide**
HC	**Hydrocarbon**
NO_x	**Oxides of Nitrogen**
cc	**Cubic centimeter**
ppm	**Parts Per Million**
rpm	**Revolution per minute**

I. INTRODUCTION

The need of energy is increasing continuously, because of increase in industrialization as well as human population. The basic sources of this energy are petroleum, natural gas, coal, hydro and nuclear. The major disadvantage of using petroleum based fuel is atmospheric pollution. Petroleum diesel combustion is a major source of greenhouse gases (GHG). Apart from these emissions, petroleum diesel combustion is also major source of other air contaminants including NOx, SOx, CO, particulate matter and volatile organic compounds, which are adversely affecting the environment and causing air pollution. These environmental problems can be eliminated by replacing the petroleum diesel fuel with an efficiency entre new able and sustainable biofuel.

Diesel fuel is very important for countries' economy because it has wide area of usage such as long haul truck transportation, railroad, agricultural and construction equipment. Diesel fuel contains different hydrocarbons (benzene, toluene, xylenes, etc.), sulphur and contamination of crude oil residues . But chemical composition of biodiesel is different from the petroleum- based diesel fuel. Biodiesel hydrocarbon chains are generally 16–20 carbons in length and contain oxygen at one end. Biodiesel contains about 10% oxygen by weight. Biodiesel does not contain any sulphur, aromatic hydrocarbons, metals and crude oil residues . These properties improve combustion efficiency and emission profile. Biodiesel fuel blends reduce particulate material (PM), hydrocarbon, carbon monoxide and sulphur oxides . However, NOx emissions are slightly increased depending on biodiesel concentration in the fuel .Due to the lack of sulphur biodiesel decrease, levels of corrosive sulphuric acid accumulating in engine crank case oil.

Cotton seed oil is derived from the seeds of various species of cotton that are grown primarily for their fibres. The oil and protein contents of the seeds vary with the variety and agroclimatic conditions. Some varieties may have up to 25%

oil content. Refined cotton seed oil is used mainly for edible purposes such as salad and cooking oils, shortening, margarine and to a lesser extent in the packing of fish and cured meat. Low grade oil is used in the manufacture of soaps, lubricants and protective coatings. The by- product of the proposed plant is expeller cake which is used for animal feed. Cotton seed oil is a resource based product that will substitute the imported vegetable oil.

In many countries, biodiesel is produced mainly from soybeans. Other sources of commercial biodiesel include canola oil, animal fat, palm oil, corn oil, waste cooking oil. But the recent research has proved that oil production from microalgae is clearly superior to that of terrestrial plants such as palm, rapeseed, soybeans or jatropha. Important advantage of microalgae is that, unlike other oil crops, they can double their biomass within 24 hr. In fact the biomass doubling time for microalgae during exponential growth can be asshortas3to4hr, which is significantly quicker than the doubling time for oil crops. It is for this reason microalgae are capable of synthesizing more oil per acre than the terrestrial plants which are currently used for the fabrication of bio fuels and using micro algae to produce biodiesel will not compromise production of food, fodder and other products derived from crops.

Microalgae comprise a vast group of photosynthetic, auto/heterotrophic organism which has an extraordinary potential for cultivation as energy crops. These microscopic algae use photosynthetic process similar to that of higher-developed plants. They are veritable miniature biochemical factories, capable of regulating carbon dioxide (CO), just like terrestrial plants. In addition, these micro-organisms are useful in bio remediation applications and as nitrogen fixing bio fertilizers. This review article discusses the potential of microalgae for sustainably providing biodiesel for the displacement of petroleum derived transport fuels in India.

Algal biomass is one of the emerging sources of sustainable energy. The large-scale introduction of biomass could contribute to sustainable development on several fronts, environmentally, socially and economically. The biodiesel generated from biomass is a mixture of mono-alkyl ester, which currently obtained from trans esterification of triglycerides and monohydric alcohols produced from various plant and animal oils. But this trend is changing several companies are attempting to generate . Biodiesel is non-toxic and biodegradable alternative fuel that is obtained from non-renewable sources.

The enormous amount of burning of fossil fuel has increased the CO level in the atmosphere, causing global warming. Bio mass is focused as an alternative energy source, as it's are new able resource and it can fix atmospheric CO through photosynthesis. Among biomass, algae (macro and microalgae) usually have a higher photosynthetic efficiency than other biomass producing plants. Biodiesel from microalgae appears to be a feasible solution to India, for replacing petro-diesel. The estimated annual consumption of petroleum product in India is nearly about 120 million tonnes per year, and no other feed stock except microalgae has the capacity to replace this large volume of oil.

Biodiesel is produced from different vegetable oils and used cooked oils . Microalgae are considered good source for fuel production due to their higher growth rate, higher yield and higher oil content in comparison with other sources. The production of biodiesel from algal oil is one of the most important renewable energy sources. In vehicles, biodiesel can be used when blended with fossil diesel fuel. Tests carried out on engine recommended using blends with diesel oil up to 20% . Microalgae bio fuels are highly biodegradable and free of sulphur. The rest of algal cells left after extracting the oil can be used for nutraceuticals production. High content of sulphur in diesel fuels are harmful for the environment because sulphur is oxidized to sulphur dioxide and sulphur trioxide that in presence of water convert to sulphuric acid. The same authors evaluated algal biodiesel blend on a diesel engine compared to diesel fuel and they found that there was a decrease in thermal efficiency and increase in specific fuel consumption for biodiesel blends. Biodiesel blends had reductions in the harmful gases emissions compared to diesel fuel.

India is a rapidly expanding country in terms of both its population and its economy. According to CIA (Central intelligence agency) Fact book, India's current population is about 1,166,079,217 (Till July 2009). Although India occupies only 2.4% of the world's land area, it supports over 15% of the world's population. Demographics indicate the population will grow because almost 40% of Indians are younger than 15 years of age and are likely to produce offspring. By2050,United Nation's demographer's project that India will have added another 530 million people for a total of more than 1.5 billion. If India continues on its projected demographic path, it will overtake China by 2045,becoming the world's most populous country.

1.1 Advantages of the Use of Biodiesel

1. Renewable fuel, obtained from vegetable oils or animal fats.
2. Low toxicity, in comparison with diesel fuel.
3. Degrades more rapidly than diesel fuel, minimizing the environmental conse- quences of bio fuel spills.
4. Lower emissions of contaminants: carbon monoxide, particulate matter, poly- cyclic aromatic hydrocarbons, aldehydes.
5. Lower health risk, due to reduced emissions of carcinogenic substances.
6. No sulphur dioxide (SO2) emissions. •
7. Higher flash point (100C minimum).

8. May be blended with diesel fuel at any proportion; both fuels may be mixed during the fuel supply to vehicles.
9. Excellent properties as a lubricant.
10. It is the only alternative fuel that can be used in a conventional diesel engine, without modifications.
11. Used cooking oils and fat residues from meat processing may be used as raw materials.

1.2 Disadvantages of the Use of Biodiesel

There are certain disadvantages of using biodiesel as a replacement for diesel fuel that must be taken into consideration:

1. Slightly higher fuel consumption due to the lower calorific value of biodiesel.
2. Slightly higher nitrous oxide (NOx) emissions than diesel fuel
3. Higher freezing point than diesel fuel. This may be inconvenient in cold climates.
4. It is less stable than diesel fuel, and therefore long-term storage (more than six months) of biodiesel is not recommended.
5. May degrade plastic and natural rubber gaskets and hoses when used in pure form, in which case replacement with Teflon components is recommended.
6. It dissolves the deposits of sediments and other contaminants from diesel fuel in storage tanks and fuel lines, which then are flushed away by the biofuel into the engine, where they can cause problems in the valves and injection systems. In consequence, the cleaning of tanks prior to filling with biodiesel is recommended.

It must be noted that these disadvantages are significantly reduced when biodiesel is used in blends with diesel fuel.

1.3 Advantages of Biodiesel from Algae oil

Producing biodiesel from algae has been touted as the most efficient way to make biodiesel fuel. The main advantages of deriving biodiesel from algae oil include:

1. rapid growth rates,
2. a high per-acre yield (7 to 31 times greater than the next best crop – palm oil),
3. certain species of algae can be harvested daily,
4. algae bio fuel contains no sulphur,
5. algae bio fuel is non-toxic,
6. algae bio fuel is highly bio-degradable, and
7. algae consume carbon dioxide as they grow, so they could be used to capture CO2 from power stations and other industrial plant that would otherwise go into the atmosphere.

II. LITERATURE REVIEW

Ulf Schuchardt et. al. (1998) reviewed the transesterification of vegetable oils with methanol as well as the main uses of the fatty acid methyl esters. The general aspects of this process and the applicability of different types of catalysts (acids, alkaline metal hydroxides, alkoxides and carbonates, enzymes and non-ionic bases, such as amines, amidines, guanidines and triamino(imino)phosphoranes) are described. Special attention is given to guanidines, which can be easily heterogenized on organic polymers. However, the anchored catalysts show leaching problems. New strategies to obtain non-leaching guanidine-containing catalysts are proposed. Finally, several applications of fatty acid esters, obtained by transesterification of vegetable oils, are described.

Juergen G. Krahl et. al. (2000) reported Cummins engine with 100 % methyl-ester soybean oil (biodiesel) for more than 172,545 km (107,215 mile). The 1991 pickup has been driven 89,888 km (55,854 mile) and the 1992 pickup has been driven approximately 82,658 km (51,361 mile). Fueling the 5.9 L (360 in3) engines with 100% biodiesel initially increased engine power by 3% (1991 engine) and reduced power by 7% (1992 engine). However, both pickups produced less power while fueled on biodiesel during the latest series of chassis dynamometer testing. The pickups averaged 6.9 km/L (16.6 mile/gal). Analysis of engine lubrication oil showed that the engines were wearing at a normal rate. Black exhaust smoke normally observed when a diesel engine accelerates was reduced when the diesel engine was fueled with 100% biodiesel. Increased EPA exhaust emissions requirements for diesel engines have created much interest in the use of biodiesel as a fuel for diesel engines.

G Lakshmi Narayana Rao ,S Sampath, and K Rajagopal (2008) Transesterified vegetable oils (biodiesel) are promising alternative fuel for diesel engines. Used vegetable oils are disposed from restaurants in large quantities. But higher viscosity restricts their direct use in diesel engines. In this study, used cooking oil was dehydrated and then transesterified using an alkaline catalyst. The combustion, performance and emission characteristics of Used Cooking oil Methyl Ester (UCME) and its blends with diesel oil are analyzed in a direct injection C.I. engine. The fuel properties and the combustion characteristics of UCME are found to be similar to those of diesel. A minor decrease in thermal efficiency with significant improvement in reduction of particulates, carbon monoxide and unburnt hydrocarbons is observed compared to diesel. The use of transesterified used cooking oil and its blends as fuel for diesel engines will reduce dependence on fossil fuels and also decrease considerably the environmental pollution

Hanifa Taher, et al.(2011) evaluated the microalgae oil extraction is a major step in the overall biodiesel production process. Recently, supercritical carbon dioxide (SC-CO2) has been proposed to replace conventional solvent extraction techniques because it is nontoxic, nonhazardous, chemically stable, and inexpensive. It uses environmentally acceptable solvent, which can easily be separated from the products. In addition, the use of SC-CO2 as a reaction media has also been proposed to eliminate the inhibition limitations that encounter biodiesel production reaction using immobilized enzyme as a catalyst. Furthermore, using SC-CO2 allows easy separation of the product. In this paper, conventional biodiesel production with first generation feedstock, using chemical catalysts and solvent-extraction, is compared to new technologies with an emphasis on using microalgae, immobilized lipase, and SC-CO2 as an extraction solvent and reaction media.

Md. Imran Kais, Farsad Imtiaz Chowdhury, Kazy Fayeen Shahriar (2011) research in Bangladesh and focuses on algae cultivation in Bangladesh. A lab scale production of Chlorella and Botroyococcus braunii was executed in open pond and bioreactor system. Then diesel was produced by transesterification from collected algae oil. Later data was collected from this experiment. Cost analysis was prepared to get a clear concept of the actual scenario of algae fuel probability. This study indicates high potentiality of algae based fuel to be used in Bangladesh replacing diesel for energy production. It can be a model for any third world country to mitigate the energy crisis with a greener solution.

III. OBJECTIVES

- To prepare a biodiesel of Microalgae and Cotton seed oil and to find the suitable substitute of the diesel, that is being gradually depleted.
- To prepare various blends with diesel using mixture of CSOME-MAOME(B25, B50, B75, B100 & D100) and to study the various fuel properties of the blends such as density, calorific value.
- To carry out the performance characteristics of diesel and CSOME-MAOME blends in a single cylinder compression ignition engine.
- To carry out the emission and combustion characteristics of diesel and CSOME-MAOME blends in a single cylinder compression ignition engine.
- To test with different diesel and CSOME-MAOME blends to optimize the different emission level based upon the different observation made.
- To carry out the engine testing using diesel with CSOME-MAOME as biodiesel under various load conditions.

IV. PRODUCTION OF BIO-DIESEL

4.1 Materials and Methodologies

The direct use of vegetable oils in fuel engines is problematic. Due to their high velocity (about 11-17 times higher than diesel fuel) and low volatility, they do not burn completely and form deposits in the fuel injector of diesel engines. Different ways have been considered to reduce the high viscosity of vegetables oil:

1. Dillution of 25 parts of vegetable oil with 75 parts of diesel fuel,
2. Micro emulsions with short chain alcohols such as ethonal or methonal
3. Thermal decomposition, which produces alkanes, alkenes, carboxylic acids and aromatic compounds,
4. Catalytic cranking, which produces alkanes, cycloalkanes and alkylbenzenes, and
5. Transesterification with ethonal or methonal.

4.2 Oil Extraction

4.2.1 Chemical Extraction

The Soxhlet method is the most commonly used solvent extraction method, used for the extraction of oil from various plants and algal strains. According to the Soxhlet's procedure, oil and fat from solid material are extracted by repeated washings (percolation) with an organic solvent, usually n-hexane or petroleum ether, under reflux in a special glassware called Soxhlet extractor. The method has got several advantages like large amount of extraction using limited solvent, it is cost effective and become more economical if used at large scale. Despite of these advantages there are certain limitations like, poor extraction of polar lipids, long time required for extraction, hazards of boiling solvents etc. But still this method is the most popular and generally used in all oil extraction laboratories.

4.2.2 Soxhlet Apparatus

A Soxhlet extractor is a piece of laboratory apparatus invented in 1879 by Franz von Soxhlet. It was originally designed for the extraction of a lipid from a solid material. However, a Soxhlet extractor is not limited to the extraction of lipids. Typically, a Soxhlet extraction is only required where the desired compound has a limited solubility in a solvent, and the impurity is insoluble in that solvent. If the desired compound has a significant solubility in a solvent then a simple filtration can be used to separate the compound from the insoluble substance.

Normally a solid material containing some of the desired compound is placed inside a thimble made from thick filter paper, which is loaded into the main chamber of the Soxhlet extractor. The Soxhlet extractor is placed onto a flask containing the extraction solvent. The Soxhlet is then equipped with a condenser.

The solvent is heated to reflux. The solvent vapour travels up a distillation arm, and floods into the chamber housing the thimble of solid. The condenser ensures that any solvent vapour cools, and drips back down into the chamber housing the solid material.

The chamber containing the solid material slowly fills with warm solvent. Some of the desired compound will then dissolve in the warm solvent. When the Soxhlet chamber is almost full, the chamber is automatically emptied by a siphon side arm, with the solvent running back down to the distillation flask. This cycle may be allowed to repeat many times, over hours or days.

During each cycle, a portion of the non-volatile compound dissolves in the solvent. After many cycles the desired compound is concentrated in the distillation flask. The advantage of this system is that instead of many portions of warm solvent being passed through the sample, just one batch of solvent is recycled.

After extraction the solvent is removed, typically by means of a rotary evaporator, yielding the extracted compound. The non-soluble portion of the extracted solid remains in the thimble, and is usually discarded.

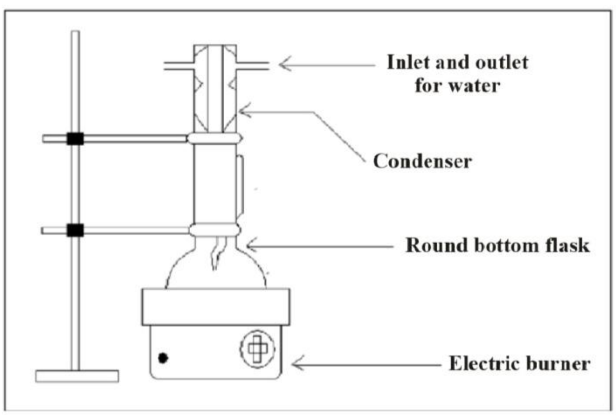

Figure 4.1 Extraction of oil by solvent extraction method (Soxhlet apparatus)

4.2.3 Cotton Seed Oil:

The experimental process involved the following; collection of seeds, cleaning of seeds, drying, cooling, size reduction, weighing of the crushed seeds, solvent extraction, weighing of the cottonseed cake, recovery of solvent and recovery of crude cottonseed oil. The samples collected were properly cleaned in order to remove any foreign materials. They were oven dried in the laboratory at a temperature of 130°C, to a moisture content of 12%. This was done because the lesser the moisture content, the more the oil yield. The seeds were then crushed into powder using Thomas Willey mill (Model ED-5). Twelve grammes (g) of the crushed sample was weighed and mixed with 5 ml of N-hexane. The mixed sample was placed on a filter paper and the filter paper was then properly folded and inserted into the assembled soxhlet apparatus. The weight of the filter paper and sample was recorded. One hundred and fifty milliliters (150ml) of the solvent (N- hexane) was measured using a measuring cylinder and then poured into a five hundred milliliters (500ml) round bottom flask which is the lower part of the soxhlet apparatus. This was now heated with a heating mantle at 60°C for 6 hours. As the solvent boiled, it evaporated into the reflux condenser and this hot solvent vapour was cooled by the surrounding water which flowed continuously through the soxhlet arrangement. The cooled solvent then condensed back into the portion of the soxhlet containing the folded sample and this facilitated the extraction of the oil from the sample. The extracted solution in the round bottom flask was a combination of oil and solvent. The sample left after the oil had been removed was subjected to hot pressing using hydraulic press to remove the bulk of the oil remaining in the press cake. The oil was recovered by evaporating the solvent. It was heated to a temperature higher than that of the solvent until the solvent evaporated leaving behind the oil extracted (The cottonseed oil has a higher boiling point of 1018°C while n-hexane has a boiling point of 50-70°C).

4.2.4 Microalgae Oil

The dry mass of the samples (Elodea, Lemna and Microalgae; 100g each) were transported to Multi-environmental Management Consultants Ltd, Ikorodu, Lagos, for oil extraction and characterization.Crude lipid extraction was carried out, using the Soxhlet extraction method. 250ml capacity extracting flask was dried in the oven at 105°C, transferred to the desicator to cool to laboratory temperature and the weight of the flask was measured. The sample (100g) was weighed into the porous thimble. 200ml of petroleum ether was measured and then added to the dried 250ml capacity flask. The covered porous thimble with the sample was placed in the condenser of the Soxhlet extractor arrangement that has been assembled. The sample was extracted for five (5) hours. The porous thimble was removed with care and the petroleum ether in the top container (tube) was collected for the recycling for reuse. The extraction flask was removed from the heating mantle arrangement when it was almost free of petroleum ether. The extraction flask with the oil was oven dried at 105°C for the period of one hour. The flask containing the dried oil was cooled in the desicator and the weight of the dried oil was measured.

Percentage extracted was determined using the formula:

% Fat content = (weight of lipid in grams/ weight of sample in grams) × 100

4.3 Transesterification

Biodiesel production from microalgae can be done using several wellknown industrial processes, the most common of which is base catalyzed transesterification with alcohol. The transesterification is the reversible reaction of fat or oil(which is composed of triglyceride)with an alcohol to form fatty acid alkyl ester and glycerol. Stoichio-metrically, thereactionrequiresa3:1molaralcoholtooilratio,butexcessalcoh olis(usually methyl alcohol is used) added to drive the equilibrium toward the product side. This large excess of methyl alcohol ensures that the reaction is driven in the direction of methyl esters, i.e. towards biodiesel. Yield of methyl esters exceeds 98% on a weight basis. The reaction occurs stepwise: triglycerides are first converted to diglycerides, then to monoglycerides and finally to glycerol. Transesterification can be done in number of way such as using an alkali catalyst, acid catalyst, enzyme catalyst, heterogeneous catalystor using alcohol in their supercritical state; however enzyme catalyst are rarely used as they are less effective. The alkali-catalyzed transesterification is about 4000 times faster than the acid catalyzed reaction. Consequently, alkalis such as sodium and potassium hydroxide are commonly used as commercial catalysts at a concentration of about 1% by weight of oil. Alkoxides such as sodium methoxide are even better catalysts than sodium hydroxide and are being increasingly used. Use of lipases offers important advantages.

Alkali-catalyzed transesterification is carried out at approximately 60°C under atmospheric pressure, as methanol boils off at 65° Cat atmospheric pressure. Under these conditions, reaction takes about 90mintocomplete. A higher temperature can be used in combination with higher pressure. Methanol and oil do not mix; hence the reaction mixture contains two liquid phases. Other alcohols can be used ,but methanol is the least expensive. To prevent yield loss due to saponification reactions (i.e. soap formation), the oil and alcohol must be dry and the oil should have a minimum of free fatty acids. Bio diesel is recovered by repeated washing with water to remove glycerol and methanol. This process of biodiesel production is found to be most efficient and least corrosive of all the processes as the reaction rate is reason a bly high evenatalow temperature of 60°C.

Figure 4.2.1(a)

Figure 4.2.2 (b)

Figure 4.2.3 (c)

Figure 4.2.1 (a)- Photographic view of Raw Algae

Figure 4.2.3 (b)-Photographic view of Powdered Algae

Figure 4.2.3 (c)-Blends of CSOME-MAOME and Diesel

V. DETERMINATION OF PROPERTIES

PROPERTY	DIESEL	ESTER OF COTTON SEED	ESTER OF MICROALGAE
Density (kg/m^3)	843.9	910	891.5
Calorific value (kJ/kg)	45500	41950	40000

Table 5.1 Properties of Diesel, CSOME and MAOME.

1. *DENSITY:*

A density or mass density of a material is defined as its mass per unit volume. The symbol most often used for density is ρ (the lower case Greek latter rho). Mathematically density is defined as mass divided by volume.

$$\rho = m/v$$

where,

ρ - Density in kg/m³

m - Mass in kg

v - Volume in m³

In some cases density is also defined as its weight per unit volume, although this quantity is more properly called specific weight.

2. *CALORIFIC VALUE*

The heating value (or energy value or calorific value) of a substances, usually a fuel or food, is the amount of heat released during the combustion of a specified amount of it. The energy value is a characteristic for each substance. It is measured in units of energy per unit of the substance, usually mass, such as; kJ/kg' kJ/mol, kcal/kg, Btu/lb. Heating value is commonly determined by use of a bomb calorimeter, the quantity know as lower heating value (LHV) net calorific value or lower calorific value (LHV) is determined by subtracting the heat of vaporization of the water vapour from the higher heating value. This treats any H2O formed as a vapour. The energy required to vaporize the water therefore is not released as heat.

5.1 Various Blend Ratios

BLEND NO.	BLEND NAME	% OF DIESEL	% OF MAOME	% OF CSOME
1	**D100**	100	0	0
2	**B25**	75	12.5	12.5
3	**B50**	50	25	25
4	**B75**	25	37.5	37.5
5	**B100**	0	50	50

Table 5.2 Blend Ratios

5.2 Blending Procedure

Specification falls between 0.86 and 0.96 with typical values falling between 0.88 and 0.90.

- Splash blending or In-Tank blending
- In-Line blending
- Rack injection

5.2.1 Splash Blending

Biodiesel and diesel fuel are loaded into a vessel separately. Mixing of the products occurs as the fuel is agitated through the blending of each fuel and during transportation and delivery of the fuel to the end user. Because biodiesel is slightly heavier than conventional distillates it is recommended that biodiesel be loaded second on top to eliminate the biodiesel from settling at the bottom of the blending tank

When bottom loading is utilized the fuel flow may be adequate to load either being blended first with no negative consequences of these minor viscosity differentials. When splash blending, complete compartment loads should be delivered to a single tank, rather than to a partial compartment or more than one tank.

5.3 Properties of Various Blends

BLEND NAME	DENSITY (kg/m³)	CALORIFIC VALUE (kJ/kg)
D100	843.9	45500
B25	850	43990
B50	870	43150
B75	885	42100
B100	898	40975

Table 5.3 Properties of various blends

VI. EXPERIMENTAL SET UP AND TESTING PROCEDURES

6.1 Experimental Test Set Up

A 5.2 kW, 1500 rpm, Kirloskar TV1 diesel engine is used in this investigation as shown in Figure6.1. The detailed specification given in table 6.1. Fuel consumption is measured using optical sensor. A differential pressure transducer is used to measure airflow rate. Engine is coupled with an eddy current dynamometer to control engine torque through computer. Engine speed and load are controlled by varying excitation current to eddy current dynamometer using dynamometer controller. A piezoelectric pressure transducer is installed in engine cylinder head to measure combustion pressure. Signals from pressure transducer are fed to charge amplifier. A high precision crank angle encoder is used to give signals for top dead centre and crank angle. The signals from charge amplifier and crank angle encoder are supplied to data acquisition system. An AVL DIGAS 444N gas analyzer and AVL smoke meter 437C are used to measure emission parameters and smoke intensity respectively. Thermocouples (chrommel alumel) are used to measure exhaust temperature, coolant temperature, and inlet air temperature.

Figure 6.1 Photographic view of Experimental setup

6.2 Instrumentation Details

6.2.1 Eddy Current Dynamometer

An eddy current dynamometer of 5.2 kW (1500 rpm) capacities is directly coupled with the engine. The engine and air cooled eddy current dynamometer are coupled using tyre coupling. The output shaft of the engine is connected to the dynamometer through a torque transducer for measuring torque. A torque transducer provides an electrical signal that is proportional to torque. A load cell is an electronic device (transducer) that is used to convert a force into an electrical signal. The load to the engine can be varied by operating the potentiometer provided on the panel or through computer.

6.2.2 Air Flow Sensor

The air flow to the engine is routed through cubical air tank. The rubber diaphragm fixed on the top of the air tank takes care of neutralizing the pulsation for airflow measurement. The inlet air tank is provided with an orifice. The differential pressure of air was measured in the computer using a differential pressure transducer (0-99 m^3/hr) calibrated to indicate volume airflow. The pressure ports are connected to instrumentation panel using smooth flexible hose.

The pressure drop across the orifice is measured using a differential pressure transducer. The output of the differential pressure transducer is amplified using an instrumentation amplifier and fed to the data acquisition card. The differential pressure sensor use state of the art silicon micro machined pressure sensor in conjunction with stress free packaging techniques to provide highly accurate, amplified, calibrated and temperature compensated pressure readings.

6.2.3 Fuel Flow Sensor

The fuel from the tank was connected by way of a solenoid valve to a glass burette and the same is connected to the engine through a manual ball valve. The fuel solenoid of the tank will open and stay open for 30sec, during this time fuel is supplied to the engine directly from the fuel tank and also fills ups the burette. & burette is supplied to the engine.

When the fuel level crosses the high level optical sensor, the sequence running in the computer records the time of this event. Likewise when the fuel level crosses the low level optical sensor, the sequence running in the computer records the time of this event and immediately the fuel solenoid opens filling up the burette and cycle is repeated. Now, volume of the fuel between high level and low level optical sensors (20 cm^3) is known. The starting time of fuel consumption, i.e. time when fuel crossed high level sensor and the finish time of fuel consumption, i.e. time when fuel crossed low level sensor gives an estimate of fuel flow rate i.e., 20 cm^3/difference of time in sec.

6.2.4 Speed Sensor

A noncontact PNP sensor (0-9999 rpm) is used to measure the engine speed. A PNP sensor gives a pulse output for each revolution of the crankshaft. The frequency of the pulses is converted into voltage output and connected to the computer.

6.2.5 Load Cell (Torque Measurement)

Torque is measured using a load cell transducer (0-100 kgs). The transducer is strain gauge based. The output of load cell is connected to the load cell transmitter. The output of load cell transmitter is connected to the USB port through interface card.

6.2.6 Temperature Sensors

K-type thermocouples are located at appropriate places to measure the following temperatures. The output of the temperature transmitters is connected to data acquisition card.

- Combustion peak temperature
- Inlet water temperature in calorimeter
- Outlet water temperature in calorimeter
- Inlet exhaust gas temperature in colorimeter
- Outlet exhaust gas temperature in colorimeter
- Inlet water temperature to the engine cylinder
- Outlet water temperature from the engine cylinder
- Lube oil temperature

6.2.7 Pressure Sensor

Piezoelectric transducer (water-cooled type) is used to measure cylinder pressure.

6.2.8 Crank Angle Encoder

11 bit 2050 step crank angle encoder (Air-cooled type) is mounted on the cam shaft to measure engine crank angle. The crank angle encoder contains a precision maker disk with a trigger mark and 360^o angle marks which are scanned by a transmission photoelectric cell encased in a dust proof housing. It is powered by a 24V DC power supply and supplies one corresponding analog output between 0^o and 360^o.

6.2.9 Analog to Digital Converter (ADC)

An ADC/data acquisition system (12-bit) captures data about an actual system and stores that information in a format that can be easily retrieved for purposes of engineering or scientific review analysis. Another requirement of a data acquisition system should be that it captures information programmatically or automatically – in other words, without any hands-on human intervention or guidance. The seven key functions of the data acquisition systems are follows:

- Data collection
- Measurement
- Trimming and triggering
- Real time clock
- System control
- Data communication
- Data retrieving

All seven elements must be in place for a structure to be considered a data acquisition system. There must be a series of sensors (input channel) to a data acquisition board. In addition, there must be a trigger to synchronize the sensors inputs, as well as a control for the data acquisition board. Between data acquisition board and processor of the system and system clock, a data communications bus is also required. While data being stored real-time, the analysis and review of the information is performed after data is gathered.

6.2.10 Emission Analyzer

Smoke meter as shown in Figure 6.2 is used to measure the intensity of smoke present in the exhaust gas and the specification of the smoke meter is given in Table 6.2. Gas analyzer as shown in Figure 6.3 is used to measure the CO, CO_2, HC, NO_x and O_2 present in exhaust gas. This analyzer consists of four detectors namely, Non-Dispersive Infrared Detector (NDIR) which detects CO and CO_2 emission, Chemiluminiscence Detector (CLD) which detects NO_x emission, Flame Ionization Detector (FID) which detects HC emission and Lambda sensor which senses the O_2. Specification of the gas analyzer is given in Table 6.3.

Table 6.1 Engine Specifications

Make	Kirloskar –TV1
Power and Speed	5.2 kW and 1500 rpm
Type of engine	Single cylinder, DI and 4 Stroke
Compression ratio	17.5
Bore and Stroke	87.50 mm and 110 mm
Method of loading	Eddy current dynamometer
Method of starting	Manual cranking
Method of cooling	Water
Type of ignition	Compression ignition
Inlet valve opening	4.5^0 before TDC
Inlet valve closing	35.5^0 after BDC
Exhaust valve opening	35.5^0 before BDC
Exhaust valve closing	4.5^0 after TDC
Fuel injection timing	23^0 before TDC
Nozzle opening pressure	210 bar
Lube oil	SAE40

Table 6.2 Smoke meter specifications

Model	**AVL 437C**
Measuring range	0-100 opacity in %
	0-99.99 absorption m^{-1}
	400….6000 min^{-1}
	0…150˚C
Accuracy and reproducibility	±1% Full scale reading
Max smoke temperature at entrance	250˚C

Table 6.3 Gas analyzer specifications

Type	**AVL DIGAS 444N**
Measured quality	Measuring range
CO	0… 10 % vol
CO2	0… 20 % vol
HC	0… 20000 ppm
O_2	0… 22 % vol
NO_x	0… 5000 ppm

Figure 6.2 Photographic view of smoke meter

Figure 6.3 Photographic view of five gas analyzer

The accuracy of measurement and uncertainties of computed results are listed in Table 6.4.

Table 6.4 Accuracy of measurement and uncertainties of computed results

Measurements	**Accuracy**
NOx	±5 ppm
CO	± 5% of indicated value
CO_2	± 5% of indicated value
HC	± 1 ppm
Smoke	± 1% full scale reading
O_2	± 5% of indicated value
Temperatures	± 1^{o}C
Dynamic viscosity	± 1%
Calorific value	± 1%
Specific gravity	± 1%
Computed Results	**Uncertainty (%)**
Kinematic viscosity	± 1.3%
Brake Power	0.5%
BSFC	1.5%
Total Fuel flow	1%
Brake Thermal efficiency	1%
Speed	± 3 rpm

6.3 Experimental Procedure

6.3.1 Base Line Testing

- The flow of air, the level of lubricating oil and the fuel level are checked before starting the engine.
- The engine is cranked by keeping the decompression lever and the fuel cut off lever of the fuel pump in the ON position.
- When the engine starts, the decompression lever is disengaged and the speed of the engine is increased to 1500 rpm and maintained.
- The engine is allowed to run for 15 minutes to reach the steady state conditions.
- Under each load, by the exhaust gas analyzer, CO, CO_2, HC, O_2, NO_x, and by smoke meter, intensity of smoke and exhaust gas temperature are measured and recorded.

6.4 Experimental Details

There are six major experiments conducted to predict performance, combustion and emission characteristics of compression ignition engine fueled with algae oil & cotton seed oil. To find the suitability and feasibility of algae & cotton seed oil as a fuel in diesel engine the following experiments have been conducted.

6.4.1. Experiments on the CI engine fueled with blends of CSOME and MAOME

Engine performance characteristics are the major criterion that governs the suitability of a fuel. The purpose of this study is to investigate the performance and exhaust emissions of various blends of algae & vegetable oil in the computerized diesel engine and to compare them with that of D100. The CSOME-MAOME has been blended with D100 in several percentages (25%, 50%, 75% and 100%) and are named as B20, B40, B60 and B80,B100. The acquisition of operating parameters such as performances and emission characteristics, as a function of brake power is done, at the engine speed of 1500 rpm. The effect of blends on the following parameters have been investigated and discussed in this study.

- Brake specific fuel consumption
- Brake thermal efficiency
- Carbon monoxide
- Carbon dioxide
- Unburned hydrocarbon
- Nitrogen oxide
- Exhaust Smoke
- Exhaust gas temperature

6.4.2. Combustion characteristics of a CI engine fueled with blends of CSOME and MAOME:

The following parameters are measured and analyzed with diesel and blend of CSOME-MAOME with diesel as fuel.

- Cylinder pressure variation with crank angle and load.
- Instantaneous heat release rate.

- Cumulative heat release.

6.4.3. Performance and emission studies with CSOME and MAOME:

For making comparison of diesel and algae blends for 25%,50%,75%,100% blend and theperformance and emission studies were carried out on the same engine.

The engine is run at a constant speed of 1500 rpm. Load is changed in five levels from no load to maximum load condition.

- D100
- B25 D75
- B50 D50
- B75 D25
- B100

All the above methyl esters are prepared in our laboratory and properties such as density, calorific value are found as per the ASTM standards. The properties of above said methyl ester is listed in the Annexure1and compared with diesel and algae.

VII. OBSERVATION

7.1 PERFORMANCE OF VARIOUS BLENDS

7.1.1 PERFORMANCE OF D100

S.NO	LOAD (kg)	SPEED (rpm)	EXHAUST GAS TEMPERATURE (°C)	TORQUE (N-m)	TFC (kg/hr)	BP (kW)	SFC (kg/kW-hr)	BRAKE THERMAL EFFICIENCY (%)
1	0	1553.00	124.67	0	0.31	0	0	0
2	4.5	1545.00	158.81	8.30	0.51	1.34	0.38	22.14
3	9	1523.00	209.22	16.91	0.77	2.70	0.29	29.65
4	13.5	1510.00	260.51	24.84	0.98	3.93	0.25	34.09
5	18	1495.00	328.31	32.85	1.28	5.14	0.25	33.93

7.1.2 PERFORMANCE OF B25

S.NO	LOAD (kg)	SPEED (rpm)	EXHAUST GAS TEMPERATURE (°C)	TORQUE (N-m)	TFC (kg/hr)	BP (kW)	SFC (kg/kW-hr)	BRAKE THERMAL EFFICIENCY (%)
1	0	1564.00	101.42	0	0.36	0	0	0
2	4.5	1551.00	155.70	8.35	0.56	1.36	0.41	19.83
3	9	1532.00	201.26	16.25	0.77	2.61	0.29	27.95
4	13.5	1512.00	254.45	24.46	1.02	3.87	0.26	31.14
5	18	1495.00	318.75	32.63	1.33	5.11	0.26	31.59

7.1.3 PERFORMANCE OF B50

S.NO	LOAD (kg)	SPEED (rpm)	EXHAUST GAS TEMPERATURE (°C)	TORQUE (N-m)	TFC (kg/hr)	BP (kW)	SFC (kg/kW-hr)	BRAKE THERMAL EFFICIENCY (%)
1	0	1563	131.38	0	0.37	0	0	0
2	4.5	1551	164.27	8.47	0.57	1.38	0.42	19.96
3	9	1529	205.04	16.51	0.78	2.64	0.30	28.13
4	13.5	1510	257.31	24.42	1.05	3.86	0.27	30.83
5	18	1490	323.27	32.50	1.31	5.07	0.26	32.38

7.1.4 PERFORMANCE OF B75

S.NO	LOAD (kg)	SPEED (rpm)	EXHAUST GAS TEMPERATURE (°C)	TORQUE (N-m)	TFC (kg/hr)	BP (kW)	SFC (kg/kW-hr)	BRAKE THERMAL EFFICIENCY (%)
1	0	1560	130.27	0	0.32	0	0	0
2	4.5	1543	160.73	8.36	0.58	1.35	0.43	20.00
3	9	1529	197.42	16.65	0.84	2.67	0.32	27.13
4	13.5	1510	270.84	24.48	1.10	3.87	0.28	30.02
5	18	1490	355.63	32.80	1.42	5.12	0.28	30.87

7.1.5 PERFORMANCE OF B100

S.NO	LOAD (kg)	SPEED (rpm)	EXHAUST GAS TEMPERATURE (°C)	TORQUE (N-m)	TFC (kg/hr)	BP (kW)	SFC (kg/kW-hr)	BRAKE THERMAL EFFICIENCY (%)
1	0	1561	134.08	0	0.38	0	0	0
2	4.5	1545	169.38	8.25	0.59	1.33	0.44	19.78
3	9	1522	214.97	16.50	0.86	2.63	0.33	26.81
4	13.5	1510	276.28	24.46	1.13	3.87	0.29	30.04
5	18	1487	351.28	32.59	1.40	5.08	0.28	31.83

7.2 EMISSION OF VARIOUS BLENDS

7.2.1 EMISSION OF DIESEL

S.NO	LOAD (kg)	SPEED (rpm)	EXHAUST GAS TEMPERATURE (℃)	CO (%volume)	CO2 (%volume)	HC (ppm)	NOx (ppm)	SMOKE DENSITY (%volume)
1	0	1553.00	124.67	0.048	1.62	5	128	3.8
2	4.5	1545.00	158.81	0.024	3.36	9	498	8.7
3	9	1523.00	209.22	0.022	5	16	1141	19.4
4	13.5	1510.00	260.51	0.021	6.79	19	1806	34.5
5	18	1495.00	328.31	0.0086	8.87	36	2107	57.4

7.2.2 EMISSION OF B25

S.NO	LOAD (kg)	SPEED (rpm)	EXHAUST GAS TEMPERATURE (℃)	CO (%volume)	CO2 (%volume)	HC (ppm)	NOx (ppm)	SMOKE DENSITY (%volume)
1	0	1564.00	101.42	0.009	1.66	2	142	2.1
2	4.5	1551.00	155.70	0	3.26	3	537	4.2
3	9	1532.00	201.26	0	4.77	5	1125	14.1
4	13.5	1512.00	254.45	0.004	6.36	8	1519	28.4
5	18	1495.00	318.75	0.124	8.35	19	1669	53.7

7.2.3 EMISSION OF B50

S.NO	LOAD (kg)	SPEED (rpm)	EXHAUST GAS TEMPERATURE (℃)	CO (%volume)	CO2 (%volume)	HC (ppm)	NOx (ppm)	SMOKE DENSITY (%volume)
1	0	1563	131.38	0	1.66	1	172	1.8
2	4.5	1551	164.27	0	3.1	5	498	8.5
3	9	1529	205.04	0	4.6	7	1507	18.9
4	13.5	1510	257.31	0.001	6.4	9	1495	32.8
5	18	1490	323.27	0.089	8.25	16	1667	56.6

7.2.4 EMISSION OF B75

S.NO	LOAD (kg)	SPEED (rpm)	EXHAUST GAS TEMPERATURE (℃)	CO (%volume)	CO2 (%volume)	HC (ppm)	NOx (ppm)	SMOKE DENSITY (%volume)
1	0	1560	130.27	0.044	1.9	14	148	1.4
2	4.5	1543	160.73	0.037	3.66	17	542	9.5
3	9	1529	197.42	0.037	5.31	33	1122	20.7
4	13.5	1510	270.84	0.053	7.04	49	1507	36.4
5	18	1490	355.63	0.0177	9.31	75	1817	58.3

7.2.5 EMISSION OF B100

S.NO	LOAD (kg)	SPEED (rpm)	EXHAUST GAS TEMPERATURE (℃)	CO (%volume)	CO2 (%volume)	HC (ppm)	NOx (ppm)	SMOKE DENSITY (%volume)
1	0	1561	134.08	0.037	1.93	10	163	1.4
2	4.5	1545	169.38	0.025	3.41	11	485	10.4
3	9	1522	214.97	0.023	5.1	20	1042	21.5
4	13.5	1510	276.28	0.04	6.9	34	1477	37.5
5	18	1487	351.28	0.146	9.03	53	1756	59

VIII. RESULTS AND DISCUSSIONS

8.1 PERFORMANCE CHARACTERSTICS

8.1.1 BRAKE POWER

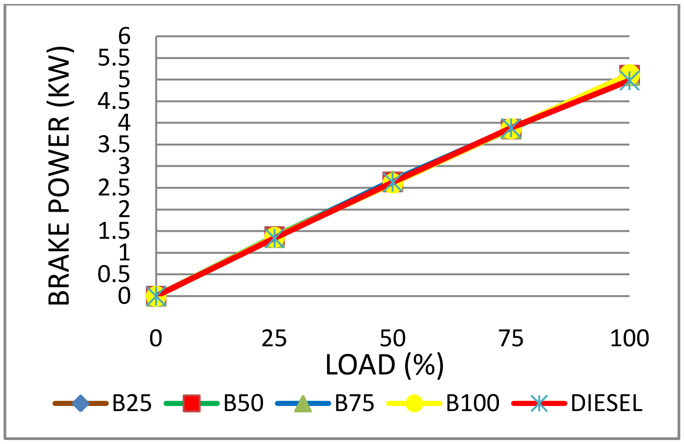

Figure 8.1.1Variation of BP with Load

An IC engine is used to produce mechanical power by combustion of fuel. Power is referred to as the rate at which work is done. Power is expressed as the product of force and linear velocity or product of torque and speed. The force is measured by Dynamometer and speed by Tachometer. At full load conditions almost all proportions of Biodiesel shows an increase in Brake power when compared to Diesel. Brake power for Diesel at full load conditions is 4.98 kW whereas for B25,B50,B75 and B100 are 5.12 kW, 5.11 kW, 5.09 kW and 5.08 kW respectively due to complete combustion of Oxygen enriched fuel.

8.1.2 BRAKE SPECIFIC FUEL CONSUMPTION

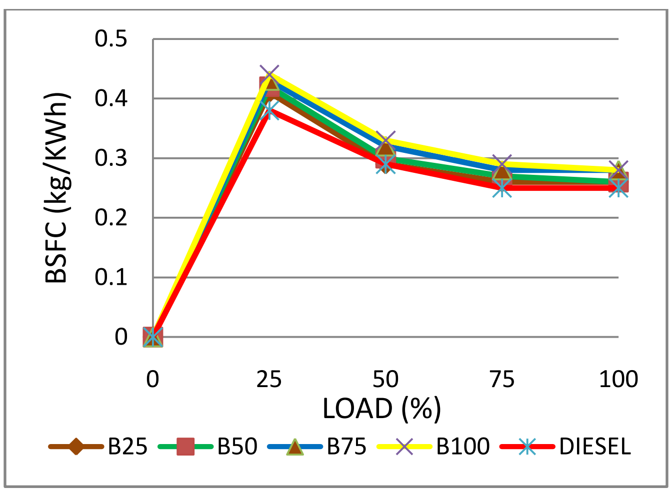

Figure 8.1.2 Variation of BSFC with Load

It is defined as the amount of fuel consumed for each unit of brake power per hour it indicates the efficiency with which the engine develops the power from fuel. It is used to compare performance of different engines. The amount of fuel which an engine consumes is rated by its specific fuel consumption (SFC). For most internal combustion engines the BSFC will be in the range of 0.5 to 0.6. The fuel efficiency tends to peak at higher engine speeds. Figure 8.1.2 shows the variation of BSFC with respect to load for various blends. BSFC tends to decreases as the load increases. It revealed that with increase in CSOME+MAOME in the blend, the BSFC was found to increase. However, BSFC of blends B25 and B50 was recorded nearly same as neat diesel.

8.1.3 BRAKE THERMAL EFFICIENCY

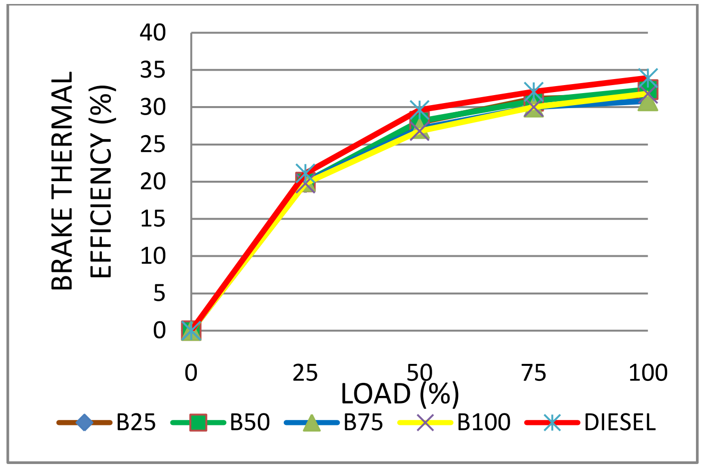

Figure8.1.3 Variation of BTE with Load

It is the ratio of the heat equivalent to one kW hour to the heat in the fuel per brake power hour. It evaluates how engine converts the heat energy into mechanical energy. The variation in brake thermal efficiency is shown in fig 8.1.3. It has been seen that the brake thermal efficiency of blends B25, B50, B75 and B100 are nearer to the brake thermal efficiency of diesel. BTE for diesel at full load condition is 33.93% and for blends B25, B50, B75 and B100 are 31.59 %, 32.33%, 30.87% and 31.83% respectively.

8.1.4 EXHAUST GAS TEMPERATURE

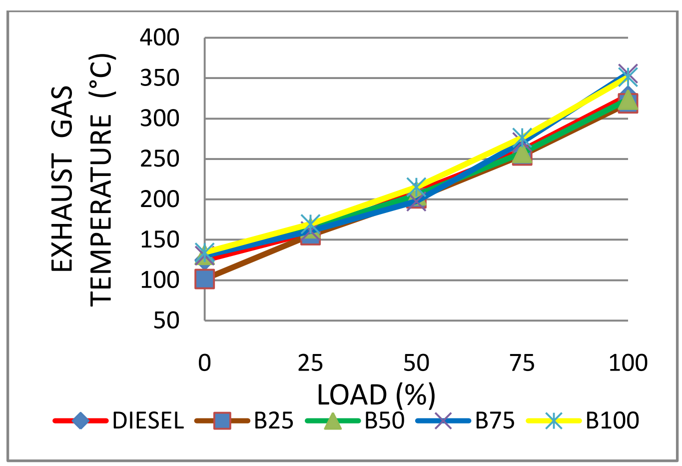

Figure 8.1.4 Variation of Exhaust Gas Temperature with Load

The exhaust gas temperature indicates how efficiently energy conversion takes place in an engine. The variation of EGT is shown in Figure 8.1.4. At full load conditions the exhaust gas temperature of blends B25 and B50 are 318.75°C and 323.27°C respectively. This is lower than that of exhaust gas temperature of diesel. EGT of diesel at full load condition is 328.31°C. The reduction of exhaust gas temperature substantiates higher BTE of blended fuels as the heat is more efficiently utilized leading to lower EGT.

8.2 EMISSION CHARACTERISTICS

8.2.1 CARBON MONOXIDE (CO) EMISSIONS

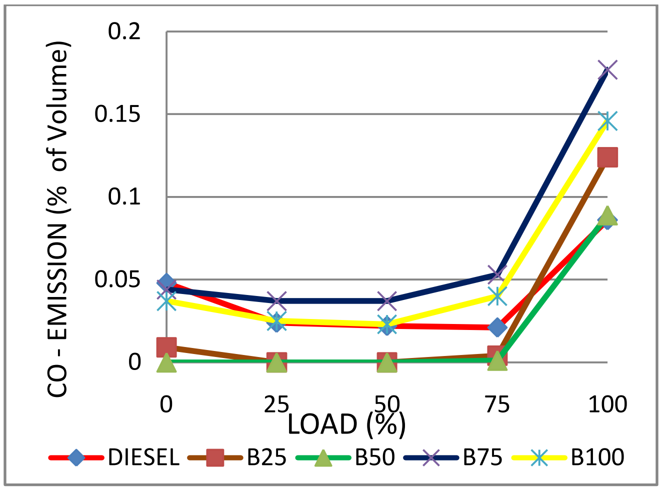

Figure8.2.1 Variation of CO with Load

The variation of carbon monoxide (CO) emission of diesel and Esters of Cotton seed oil and Algae oil blends with varying load is shown in Figure 8.2.1. It has been observed that the CO emission of blends B25 and B50 are lower than diesel fuel. At full load condition, CO emission for blends B25, B50, B75 and B100 are 0.124%, 0.089%, 0.0177% and 0.146% by volume respectively whereas for diesel it shows 0.086%.

8.2.2 UNBURNED HYDRO CARBON (UBHC) EMISSIONS

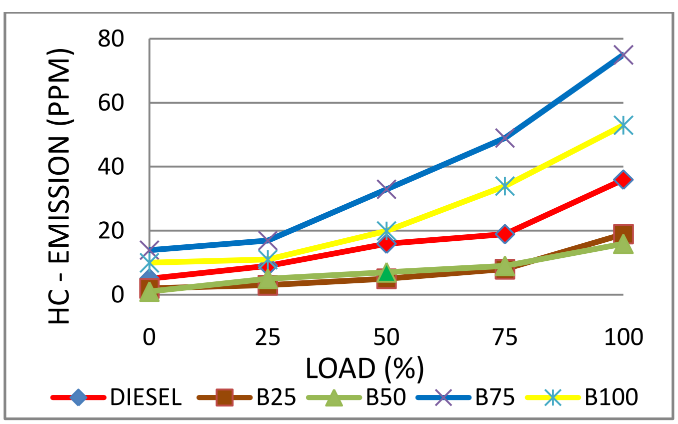

Figure 8.2.2 Variation of HC with Load

HC emissions of biodiesel blends and diesel is displayed in Figure 8.2.2. At higher engine load, HC emissions increases due to increase of fuel consumption. HC emissions of biodiesel blends B25 and B50 are lower than diesel fuel for all loading conditions. HC emission at full load condition for blends B25, B50, B75, B100 and Diesel are 19ppm, 16ppm, 75ppm, 53ppm and 36ppm respectively. The significance decrease in HC emission is due to the complete combustion of the blends B25 and B50.

8.2.3 CARBON DIOXIDE (CO_2) EMISSIONS

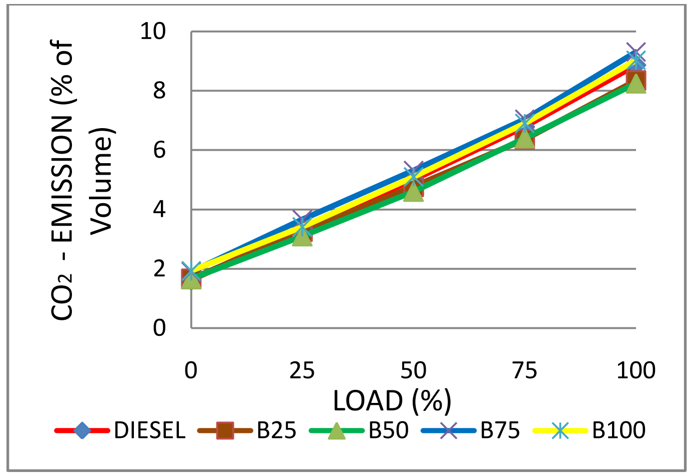

Figure8.2.3 Variation of Carbon dioxide with load

The CO2Emission for various blends with loads is shown in Figure 8.2.3. Carbon dioxide in the exhaust gases is an indication of complete combustion. It may be observed that CO2 emissions increases for blends B75 and B100 compared to the neat diesel for all load conditions. At full load conditions CO2emissions of B25, B50, B75, B100 and Diesel are 8.35%, 8.25%, 9.31%, 9.03% and 8.87% respectively. These shows the CO2 emissions of blends B25 and B50 are lower than diesel fuel. Thus considering the closed cycle of biodiesel it can be pointed out that the effective emission of CO2 is relatively low

8.2.4 OXIDES OF NITROGEN (NOX) EMISSIONS

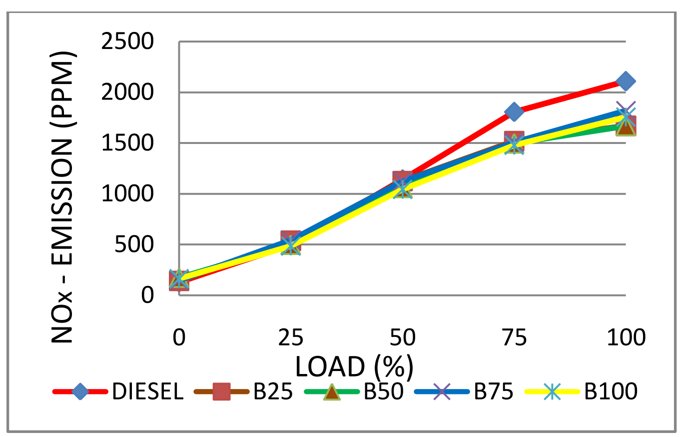

Figure8.2.4 Variation of Nitrogen oxides with load

The NOx is the most significant emissions for diesel engine due to high flame temperature and diffusive combustion in the chamber. Since the NOx emissions from current diesel technologies are closer to the limits permitted by regulations and limits will be even more stringent in the near future, these emissions will be critical factor in the development of new diesel engine. The formation of NO is highly dependent on in-cylinder temperature, oxygen concentration in the cylinder and also dependent on engine technology. At all blends the NOx emissions is lower than diesel fuel at all load conditions. From 50% load all the blends shows a full reduction in the NOx emission. The NOx emission of blends B25, B50, B75, B100 and Diesel at full load conditions are 1669ppm,1667ppm, 1817ppm, 1756ppm and 2107ppm respectively. The higher cetane number of algal oil accounts for the lower NOx emissions . Fuels with a higher cetane number have lower ignition delay, hence shorter duration of premixed combustion, which suggests a slower rise of combustion pressure, and as a result lower temperatures and slower NOx formation rate.

8.2.5 SMOKE EMISSION

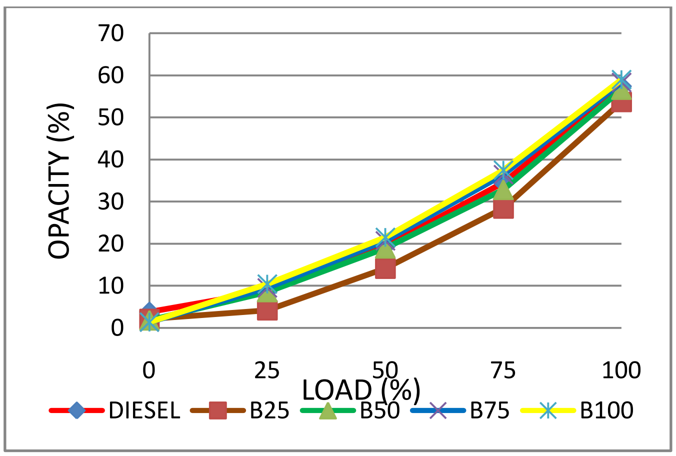

Figure8.2.5 Variation of Smoke intensity with load

The variation of exhaust smoke opacity in Hatridge smoke unit for diesel and hybrid fuel blends are shown in Figure 8.2.5. The higher viscosity of blends compare to diesel, alters the fuel atomization and increases the smoke emissions. Blends B25 and B50 shows a low volume of smoke emission at all load condition than that of diesel fuel. However B75 and B100 show high level of smoke emission than diesel fuel. At full load condition smoke opacity of blends B25, B50, B75, B100 and Diesel fuel are 53.7%, 56.6%, 58.3%, 59% and 57.4% respectively.

8.3 COMBUSTION CHARACTERISTICS

For the present experiment, an AVL combustion analyzer attached with 602-indimeter analyzer with INDIMICRA- software (v 2.5) was used . The signals from AVL-G111 4D/ AHO1 air cooled pressure transducer were converted into voltage with a help of charge amplifier. Cylinder pressure for 90 continues cycles have been measured at each operating point. Furthermore, an average of these cycles is used for heat release analysis. All the measured data from the engine and calculated results were stored in appropriate files in order to retrieve and superimpose data on the plotter for comparison. The measured cylinder pressure and other operating parameters were used to compute maximum pressure rise, heat release rate.

8.3.1 Crank Angle with Cylinder Pressure

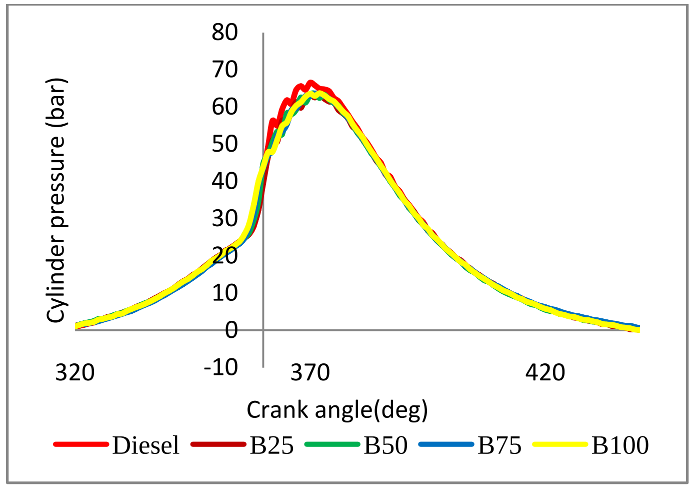

Figure8.3.1 Variation of Cylinder Pressure with crank angle

Figure 8.3.1 shows the variation of instantaneous heat release rate with crank angle for blends and base diesel at full load condition with injection timing of 23° BTDC at maximum load of 5.2 kW is shown in Figure 8.3.1. The peak cylinder pressure obtained at full load is higher for diesel (66.57bar), whereas for blends B75 (63.62bar), B50 (63.58 bar), B100 (63.56 bar) and B25 (63.23bar) respectively. The Maximum cylinder pressure occurs 12° ATDC. The maximum cylinder pressure for all blends is lower compared to the maximum cylinder pressure of diesel at the same operating condition.

8.3.2 Crank Angle with Heat Release Rate

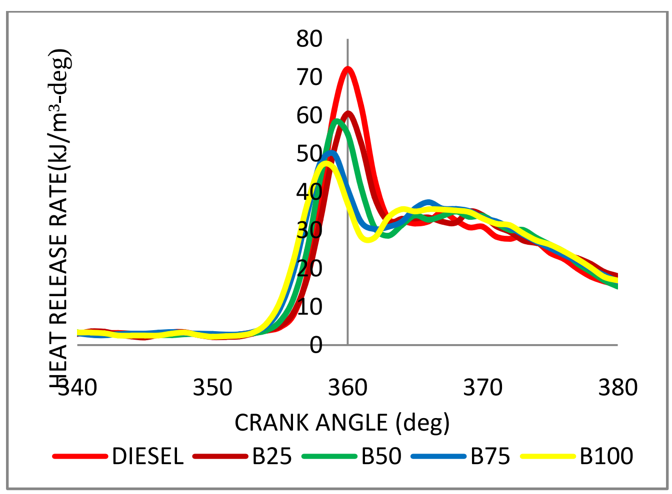

Figure8.3.2 Variation of heat release rate with crank angle

Figure8.3.2shows the variation of instantaneous heat release rate with crank angle for blends and base diesel at full load condition with injection timing of 23°BTDC at maximum load of 5.2 kW. Both base diesel and blends could have experienced rapid premixed burning followed by diffusion combustion. By analyzing the Figure 8.3.2 it can be inferred that premixed combustion heat release is higher for Diesel (72.16 kJ/m³-deg). Heat release rate for all blends is lower than Diesel fuel. The maximum heat transfer rate for blends B25, B50, B75 and B100 are 60.53kJ/m³-deg, 58.07kJ/m³-deg, 49.99kJ/m³-deg and 46.66kJ/m³-deg respectively.

8.3.3 CRANK ANGLE WITH CUMULATIVE HEAT RELEASE RATE

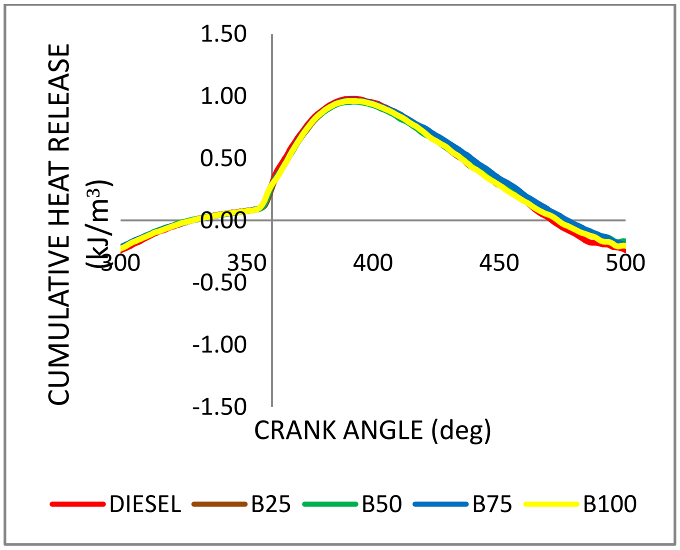

Figure 8.3.3 Variation of Cumulative heat release with Crank angle

The cumulative heat release values, which is the aggregate sum of instantaneous heat release rates is given in the Figure 8.3.3. This curve has the characteristic S shape. The rate of heat release is slow at the beginning and increases rapidly till reaching a peak value then again slows down. This is reflected in the Figure8.3.3, where the cumulative release value is low in the beginning, increases exponentially and slows down at the end. The maximum cylinder pressure occurs at 32° ATDC, nearly 20° after the occurrence of maximum cylinder pressure. The maximum cumulative heat transfer for Diesel and blends B25, B50, B75 and B100 are 0.98kJ/m³, 0.96kJ/m³, 0.95kJ/m³, 0.97kJ/m³ and 0.97kJ/m³ respectively.

IX. MODEL CALCULATION

BRAKE POWER

$BP = 2\pi NT/6000$

Here,

N= Speed of the engine in rpm

T=Torque developed by the engine in N-m

TOTAL FUEL CONSUMPTION (TFC)

TFC= (q× Density of the diesel)/t

Here,

q = volume of fuel consumed = 10cc

t = time taken for 10cc of fuel consumption in‘s’

BRAKE SPECIFIC FUEL CONSUMPTION (BSFC)

BSFC = TFC / BP

Here,

TFC = Total fuel consumption in kg/hr

BP = Brake power developed by the engine in kW

BRAKE THERMAL EFFICIENCY

η_{BT}= [BP/(TFC × CV)]×100

Here,

η_{BT} = Brake Thermal Efficiency

CV = Calorific value of the fuel in kJ/kg\

X. CONCLUSION

From the present work the following conclusions were derived

- When compared to diesel the density of the CSOME, MAOME is more, which is 910kg/m³ and 891.5kg/m³ respectively.
- The calorific value of CSOME, MAOME are 41950kJ/kg and 40000kJ/kg respectively, which is lower than diesel value of 45500kJ/kg.
- For all blend ratios, the brake power resembles closer to that of diesel but at full load condition the biodiesel shows more brake power output.
- The BSFC of B100 at full load condition is 0.28kg/kW-hr, which is greater than that of diesel 0.35kg/kW-hr. This is due to lower calorific value of biodiesel.
- Brake thermal efficiency is almost equal to diesel at full load conditions.
- Exhaust Gas Temperature of B25 and B50 are lower than diesel at full load condition.
- At 75% of load B25 and B50 shows lower emission of CO than that of diesel.
- At all load conditions emission of unburned hydro carbons is lower than diesel for all blends; this shows the complete combustion of biodiesel.
- CO_2 emission of B25 and B50 is lower at all load conditions.

- The NO_x emission is lower than that of diesel at all load conditions. At 75% and 100% loads, its shows a much lower emission than diesel.
- At all load conditions B25 and B50 shows lower emission of smoke.
- Cylinder pressure is lower at full load condition with injection timing of 23° BTDC.
- It is observed that heat release rate is lesser than that of diesel at full load condition.
- Cumulative heat release is equal to diesel at full load condition.

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