EXPERIMENTAL ANALYSIS OF PERFORMANCE AND EMISSION PARAMETERS USING CERIUM OXIDE AND SILVER NANO-PARTICLES AS ADDITIVES ON ARGEMONE MEXICANA BIODIESEL

Dissertation-II

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by

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CERTIFICATE

I hereby certify that the work being presented in the dissertation entitled *"**Experimental analysis of performance and emission parameters using Cerium oxide and Silver nano-particles as additives on Argemone Mexicana Biodiesel**"* in partial fulfilment of the requirement of the award of the Degree of master of technology and submitted to the Department of Mechanical Engineering of Lovely Professional University, Phagwara, is an authentic record of my own work carried out under the supervision of **(Mr. Jasvir Singh, Assistant Professor)** Department of Mechanical Engineering, Lovely Professional University. The matter embodied in this dissertation has not been submitted in part or full to any other University or Institute for the award of any degree.

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DECLARATION

I, Prabhjot Singh, student of **Master of Technology (Mechanical Engineering)** under School of **Mechanical Engineering** of Lovely Professional University, Punjab, hereby declare that all the information furnished in this dissertation reports based on my own intensive research and is genuine. This dissertation does to the best of my knowledge, contain part of my work which has been submitted for the award of my degree either of this university without proper citation.

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ABSTRACT

The concept of nanofluids is the latest upgrading in the field of nanotechnology which gives wide scope for research. Nanofluids provides enhanced heat transfer coefficient and better thermophysical properties. Application of nanofluids can be seen in the field of automobile, transformer and generator cooling. It can also be used in biodiesel as an additive. Biodiesel is an alternative fuel that can be used instead of diesel. The oil used for Biodiesel is extracted from seeds. Seeds may be categorized in two forms edible and non edible. Non edible seeds are most preferable which comes under second generation fuel. Through transesterification process biodiesel is made. Blends are prepared by mixing with biodiesel. Additives are used in these blends. Two types of additives are used in this experiment Cerium oxide and Silver nanoparticles. The silver nanoparticle provide higher surface area and higher thermal conductivity. The Cerium oxide acts as oxygen buffer and thus increases the efficiency. Nanoparticles are mixed with the B20 blend at different proportion 20ppm, 40ppm and 80ppm each on different blends. Ultra-sonicator is used for mixing the blends with additives. These properties provide increased reactivity and faster burning rates of fuel. These additives will enhance the performance of engine and reduce emission.

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Nomenclature

FAMEs	Fatty acid methyl esters	**B20**	20% Biodiesel and 80 Diesel
CN	Cetane number	**ME**	Mechanical efficiency
FFA	Free fatty acid	**CeO_2**	Cerium oxide
AMME	Argemone mexicana methyl ester	**PPM**	Parts per million
TAGs	Triacylglycerides	**Ag**	Silver
Di	Direct injection		
Ci	Compression ignition	**Kg**	Kilogram
Na	Sodium	**kW**	kilowatt
NaOH	Sodium hydroxide	**RPM**	Revolutions per minute
ml	millilitre	**BP**	Brake power
gm	gram	**IP**	Indicated power
°C	Degree Celsius	**FP**	Friction power
B100	100% Biodiesel	**BTE**	Brake thermal efficiency
ITE	Indicated thermal efficiency	**SFC**	Specific fuel consumption
BMEP	Brake mean effective pressure	**IMEP**	Indicated mean effective pressure
FMEP	Friction mean effective pressure	**NHR**	Net heat release rate
CO	Carbon monoxide	**CO_2**	Carbon dioxide
NO_x	Oxides of nitrogen	**HC**	Unburnt hydrocarbons

CHAPTER 1

Introduction

Bio-diesel is an alternative to petroleum-based fuels derived from vegetable oils, animal fats, and used waste cooking oil including triglycerides. Vegetable oils are widely available from various sources, and the glycerides present in the oils can be considered as a viable alternative for diesel fuel. They have good heating power and provide exhaust gas with almost no sulphur and aromatic polycyclic compounds. Vegetable oils are produced from plants, their burning leads to a complete recyclable carbon dioxide (CO_2). CO_2 associated with solar energy falling on earth gets converted in to the feedstock through photosynthesis. Vegetable oils available through this feedstock can be used to produce biodiesel.

The use of vegetable oil for energy purposes is not new. It has been used world over as a source of energy for lighting and heating since time immemorial. As early as in 1900, a diesel-cycle engine was demonstrated to run wholly on groundnut oil at the Paris exposition. Even the technology of conversion of vegetable oil into biodiesel is not new and is well established. However the unprecedented rise in fuel prices recently has made it economically attractive. The present availability of vegetable oils in the world is more than enough to meet the edible oil requirements, and surplus quantity available can partially meet requirements of biodiesel production. However, there is a considerable potential to further enhance the oilseeds production in the world to meet the increasing demand for food and biodiesel.

1.1 Need for Biodiesel

Due to the increase in price of petroleum and environmental concern about pollution coming from automobile emission, biodiesel is an emerging as a developing area of high concern. The world is confronted with the twin crises of fossil fuel depletion and environmental degradation. Alternative fuels, promise to harmonize sustainable development, energy conversion, management, efficiency and environmental preservation. Vegetable oil is a promising alternative to petroleum products. The economic feasibility of biodiesel depends on the price of crude petroleum and the cost of transporting diesel over long distances to remote areas.

It is a fact that the cost of diesel will increase in future owing to increase in its demand and limited supply. A great deal of research and development on internal combustion engines has taken place not only in the design area but also in finding an appropriate fuel. Many researchers have concluded that biodiesel holds promise as an alternative fuel for diesel engines, since its properties are very close to diesel fuel. The fuel properties of biodiesel such as cetane number, heat of combustion, gravity, and viscosity influence the combustion and so the engine performance and emission characteristics because it has different physical and chemical properties than petroleum-based diesel fuel.

The consumption of diesel oil is several times higher than that of petrol. Due to the shortage of petroleum products and its increasing cost, efforts are on to develop alternative fuel especially for diesel oil for its partial replacement. It has been found that the vegetable oils are promising fuels because their properties are similar to that of diesel and are produced easily and renewably from the crops. Vegetable oils have comparable energy density, cetane number, heat of vaporization and stiochiometric air-fuel ratio with that of the diesel fuel. Vegetable oils are non-toxic, renewable sources of energy, which do not contribute to the global CO_2 build up. In terms of the economic benefits, vegetable fuels could be used as an emergency energy source in the event of another petroleum fuel shortage.

Vegetable oil from crops such as soybean, peanut, sunflower, rape, coconut, cotton, mustard, linseed and castor have been tried in many parts of the world, which lack of petroleum reserves as fuels for CI engines. The long chain hydrocarbon structure, vegetable oils have good ignition characteristics, however they cause serious problems such as carbon deposits build up, poor durability, high density, high viscosity, lower calorific value, more molecular weight and poor combustion. These problems lead to poor thermal efficiency, while using vegetable oil in the diesel engine. These problems can be rectified by different methods which are used to reduce the FFA value and viscosity of vegetable oils. These methods are: transesterification method, dilution method and cracking method.

1.2 Why can vegetables oils be used as diesel fuels

The vegetable oils, animal fats, and their derivatives such as alkyl esters are suitable as diesel fuel because there must be some similarity to petro diesel fuel or at least to some of its components. The fuel property that best shows this suitability is called the cetane number. In addition to ignition quality as expressed by the cetane scale, several other properties are important for determining the suitability of biodiesel as a fuel. Heat of combustion, pour point, cloud point, (kinematic) viscosity, is among the most important of these properties.

1.3 Background and Sources

Vegetable oils were used as emergency fuels and for other purposes during World War II. Concerns about the rising use of petroleum fuels and the possibility of resultant fuel shortages in the United States in the years after World War II played a role in inspiring a dual fuel project at The Ohio State University (Columbus, Ohio), during which cottonseed oil and corn oil, and blends with conventional diesel fuel, were investigated. Brazil prohibited the export of cottonseed oil in order to substitute it for imported diesel fuel. Reduced imports of liquid fuel were also reported in Argentina, necessitating the commercial exploitation of vegetable oils. China produced diesel fuel, lubricating oils, “gasoline,” and “kerosene,” the latter two by a cracking process, from Tung and other vegetable oils. The Japanese battleship Yamato reportedly used edible refined soybean oil as bunker fuel.

In modern times, biodiesel is derived, has been derived from many different sources, including vegetable oils, animal fats, used frying oils, and even soap stock. Generally, factors such as geography, climate, and economics determine which vegetable oil is of most interest for potential use in biodiesel fuels. In the United States, soybean oil considered as a prime feedstock. In Europe, it is rapeseed (canola) oil; and in tropical countries, it is palm oil.

1.4 Development of Biodiesel in India

Biodiesel is a relatively new product in India. The use of vegetable oils for engine fuels may seem insignificant today. But such oil may in the course of time become as important as petroleum and the coal tar products of present time. Scientists discovered that the viscosity of vegetable oil could be reduced in a simple chemical process in 1970 and that it could work well as diesel fuel in modern engine. The fuel is called Biodiesel. It is alternative fuel that can be used in diesel engines and provides power similar to conventional diesel fuel. It reduces the countries dependence on foreign oil imports. As per its end use it is classified with petroleum products industry more particularly with diesel. Cost of petroleum products is directly proportional to the living cost of common man. Although biodiesel is new product but it is going to replace product of petroleum industry i.e. diesel in future.

The southern railway adopted a three pronged strategy of large scale processing of oil into biodiesel and making use of it for its large fleet of road vehicles and locomotives. Awareness in India is only now giving shape to projects. In Andhra Pradesh four companies viz. Southern Online Biotechnology (SBT), Tree Oils Ltrs (Zaheerabad) Natural Bio Energy and the GMR group have seriously entered into this project. Others include Vrideshwar SSK Ltd. (Ahmednagar, Maharashtra) the Simbhioly Sugar Mills (Ghaziabad, Uttar Pradesh), Mewar Sugar Mills (Jaipur) SM Dyechem (Thane, Maharashtra) R.S. Petrochemicals (Punjab) and Progressive Petroleum (Mumbai). The Aditya Birla group proposed a project in Malaysia, which did not come off. All of them feel that government should offer incentives to offset risk of a Greenfield area.

1.5 Vegetable Oil acts as a C .I. Engine Fuel

Vegetable oil can be produced from plant sources, which are viable to produce on a mass scale or in local rural areas on many land conditions. The various edible vegetable oils like sunflower, soybean, peanut, cotton seed etc have been tested successfully in the diesel engine. Research in this direction with edible oils yielded encouraging results. Diesel is produced from crude oil, biodiesel is produced from vegetable oils and either edible or non edible oils can be used depending on their properties, using diesel derived from vegetable oils is not a new idea. When Rudolf Diesel invented the diesel engine he used peanut vegetable oil fuel in Paris as an alternative to diesel. Using straight vegetable oils as a fuel substitute an option but only with many modifications to be performed on the engine itself for continued satisfactory engine performance. In future more advanced engines may be designed to cope with these crude oils. However at the current time and for a transition period to a cleaner fuel system biodiesel is a viable option**.** To allow the use of vegetable oils as a fuel without modification of the engine, the fuel needs to be modified for compatibility with the engine. As the diesel engines are designed for diesel fuel any substitute needs to have similar properties for the engine to operate satisfactorily. Biodiesel is a viable opportunity that will not incur large costs for a new infrastructure as the storage and distribution will be the same as the diesel infrastructure.

1.6 Advantages and Disadvantages of Straight Vegetable Oil as C. I. Engine Fuel

Advantages

- Renewable fuels are extracted from vegetable oils or from animal fats.
- Less toxic in nature as compared with diesel fuel.
- Less emission of harmful gases.
- Reduced amount of emission of carcinogenic substance reduces the health risk.
- It has higher flash point starting from 100^0C.

Disadvantages

- Higher fuel consumption because of lower calorific value.
- Nitrous Oxide emissions is higher than diesel fuel.
- Freezing point is higher as compared to diesel fuel.
- Less stability issues than diesel fuel.

- Degradation of plastic and natural rubber gaskets when used as pure form.

1.7 Technical Aspects

The kinematic viscosity of vegetable oils is about an order of magnitude greater than that of conventional, petroleum-derived diesel fuel. High viscosity causes poor atomization of the fuel in the engine's combustion chambers and ultimately results in operational problems, such as engine deposits. Since the renewal of interest during the late 1970s in vegetable oil derived fuels, four possible solutions to the problem of high viscosity have been investigated: transesterification, pyrolysis, dilution with conventional petroleum-derived diesel fuel, and micro emulsification.

1.8 Alternative Fuels

a) Compressed Natural Gas (CNG)

Natural gas is a mixture of hydrocarbons-mainly methane and is produced either from gas wells or in conjunction with crude oil production. Due to its lower energy density for use as a vehicular fuel, it is compressed to a pressure of 20-25 MPa to facilitate storage in cylinders mounted in vehicle and so it is called Compressed Natural Gas. India's recoverable resources of more than 690 billion cubic meters make it a long-term substitute fuel for use in petrol & diesel engines. Low exhaust emissions, low noise, less maintenance, not prone to adulteration, driver's comfort etc are some of the attractive features of CNG as an automotive fuel. CNG is now established as a very successful alternative fuel for automobiles throughout the world. Infrastructure, onboard storage & issues on safety need proper attention for this fuel.

b) Liquefied Petroleum Gas (LPG)

LPG is a by-product of Natural Gas processing or product that comes from crude oil refining and is composed primarily of propane and butane with smaller amounts of propylene and butylenes. Since LPG is largely propane, the characteristics of propane sometimes are taken as a close approximation to those of LPG. Reduction in emissions, very less carbon build-up increases life of engine parts like spark plugs, little or no damage to soil or water if it is spilled, due to its rapid evaporation, higher octane number are some of the advantages of LPG fuel. In the initial stages of introduction of this fuel, issues like safety, storage and handling, extreme volatility of the fuel etc. needs proper attention.

c) Methanol

Methyl alcohol - wood alcohol - may be obtained organically by the distillation of hardwoods at high pressure and a temperature of around 350°C itself a high energy consuming process. With a far higher cumulative toxicity rating than ethanol, the energy content is around 3.7 kWh per litre (about one third that of petrol), making it a less attractive alternative transport fuel. Trying to mix methanol with petrol brings problems - they are not entirely compatible, and the slightest amount of water absorbed by the fuel causes the alcohol to separate out in the bottom of the tank. Additives are commercially available, but this adds to the fuel cost.

d) Ethanol

Ethanol is a clear, colourless liquid with a characteristic, agreeable odour. In dilute aqueous solution, it has a somewhat sweet flavour, but in more concentrated solutions it has a burning taste. Ethanol has been made since ancient times by the fermentation of sugars. All beverages- ethanol and more than half of industrial ethanol is still made by this process. It can be made from raw materials such as sugarcane, sorghum, corn, barley, cassava, sugar beets etc using already improved and demonstrated technologies. Ethanol is used as an automotive fuel by itself and can be mixed with gasoline to form what has been called "gasohol" or can be mixed with diesel to form diesohol or E-diesel. Because the ethanol molecule contains oxygen, it allows the engine to more completely combust the fuel, resulting in fewer emissions.

1.9 Selection of an Alternative Fuel

Some of the requirements of fuel which must be put under consideration while selecting Alternative fuels are as given below:

- It should be produced locally to cut transport cost and supply difficulty, to free foreign currency for other uses, and to reduce local under-employment.
- It should need only simple production plant to give low capital and cheap maintenance.
- It should require the minimum alteration to the engine to keep initial cost down and to enable a return to diesel use if the alternative supply fails.
- It should have minimum harmful effect on the engine to ensure reliability and to reduce the need for skilled maintenance.

Selection of suitable renewable source of energy in place of petroleum fuels depends upon social, political, ecological, economical and technical factors. The fuels such as CNG, LPG, Propane, Hydrogen, Alcohols, Biogas, Producer gas, and derivatives of vegetable oils are receiving more & more attention. But as far as India is concerned because of its vast agro-forestry base, fuels of bio-origin can be considered to be ideal alternative renewable fuels to run the internal combustion engines. The bio-origin fuels could be Biogas, Biomass, Producer gas and derivatives of Vegetable Oils, which can be modified to bring their properties comparable to fossil fuels. Modern bio-energy options offer significant, cost-effective and perpetual opportunities toward meeting emission reduction targets while providing additional ancillary benefits arising from the wide occurrence of biomass materials. These include social benefits of employment in the growing, harvest and processing of biomass resources.

1.10 Biodiesel

Biodiesel is an alternative fuel formulated exclusively for diesel engines. It is made from vegetable oil or animal fats or it is the name for a variety of ester based fuels generally defined as the mono alkyl esters made from vegetable oils through simple transesterification process.

Use of biodiesel in CI engine:

- It is recommended for use as a substitute for petroleum based diesel mainly because biodiesel is a renewable, domestic resource with an environmentally friendly emission profile and is readily biodegradable.
- Biodiesel is nontoxic, biodegradable. It reduces the emission of harmful pollutants from diesel engines (80% less CO_2 emissions, 100% less sulphur) but emissions of nitrogen oxides are increased.
- Biodiesel has a high cetane number. The high cetane numbers of biodiesel contribute to easy cold starting and low idle noise.
- The use of biodiesel can extend the life of diesel engines because it is more lubricating and furthermore, power output are relatively unaffected by biodiesel.

Likely important outcomes of localized energy generation using biodiesel in developing countries are as follows:

1) As fuel in stationary or mobile engines for water pumping (irrigation), grain milling, and transportation, lighting and heating and cooking.

2) Poverty reduction, especially that of women, by stimulating economic activities in rural areas by using the products of such plants for the manufacture of soap, medicines, lubricants,

chemicals, fertilizers, insecticides.

3) Environment improvement through land reclamation, erosion control, enhanced soil fertility, a better microclimate and GHG mitigation i.e. expanded options for carbon dioxide abatement.

4) A reduced consumption of firewood and residues in rural areas hence a decrease in the deforestation rate.

5) An increase in the gross domestic product (GDP).

6) A reduction of expenditure of imported fuels for rural consumption.

7) The establishment of decentralized energy generation based on the use of plant oil.

1.11 Biodiesel Production Methods

i. **Direct use and Blending:** In this method, vegetable oils are directly mixed with the diesel. The advantages of vegetable oils as diesel fuel are:

(1) Liquid nature-portability

(2) Heat content (80% of diesel fuel)

(3) Ready availability

(4) Renewability

The disadvantages are:

(1) Higher viscosity

(2) Lower volatility

(3) The reactivity of unsaturated hydrocarbon chains.

Problems appear only after the engine has been operating on vegetable oils for longer periods of time, especially with direct-injection engines.

The problems include:

(1) Fuel atomization does not occur properly

(2) Carbon deposits

(3) Oil ring sticking

(4) Thickening and gelling of the lubricating oil as a result of contamination by the vegetable oils.

Table 1 Known problems, probable cause and potential solutions for using straight vegetable oil in diesels

Problem	Problem cause	Potential solution
Short-term		
Cold weather starting	High viscosity and low flash point of Vegetable oils	Preheat fuel prior to injection
Plugging and gumming of filters, lines, injectors	Natural gums in vegetable oils, ash particles	Partially remove the oil to remove gums.
Engine knocking timing	Improper injection	Adjust injection timing
Long-term		
Carbon deposit on piston and head of engine	High viscosity of vegetable oils, incomplete combustion of fuel	Preheat fuel prior to injection
Excessive engine wear	Poor combustion at part load with vegetable oils, possibly free fatty acids in vegetable	Preheat fuel prior to injection, switch engine to diesel fuel operations at part load

ii.Transesterification: The majority of the methyl esters are produced using the base catalysed reaction because it is the most economic for several reasons

- low temperature and pressure
- high yields and short reaction times
- direct conversion process
- simple in operation and environmentally benign

Transesterification can be defined as the process of reacting a triglyceride (oil) with an alcohol (e.g., methanol or ethanol) in the presence of a catalyst, such as sodium hydroxide or potassium hydroxide, to chemically break the molecule of the oil into methyl or ethyl esters. Glycerine, also known as glycerol, is the by-product of this reaction. The process is similar to hydrolysis, except than alcohol is used instead of water.

Where R is a long hydrocarbon chain, sometimes called fatty acid chains.

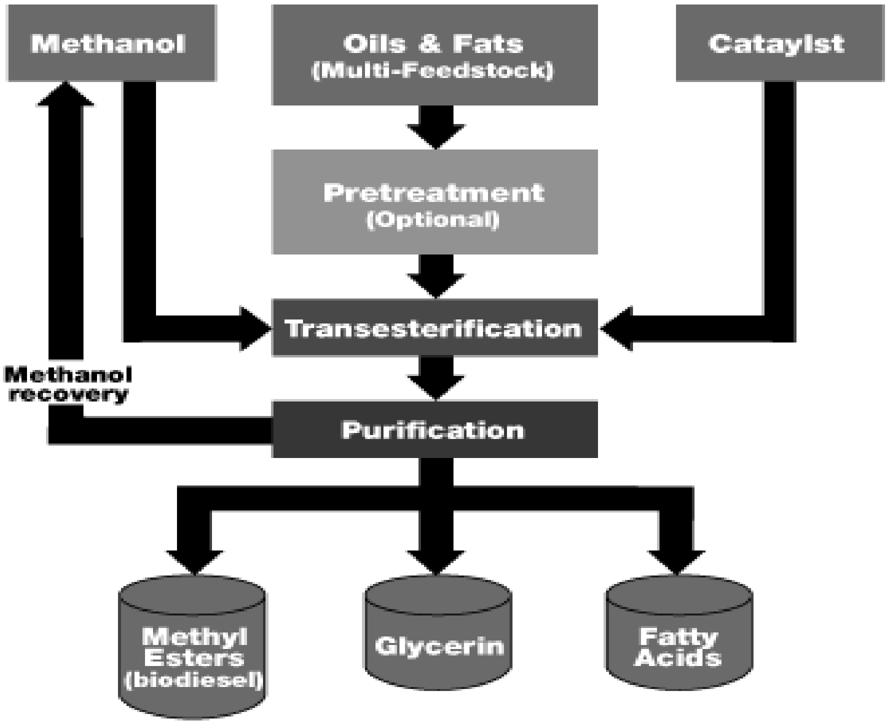


Figure 1 Flow chart of Transesterification process

A typical supply chain includes the production of vegetable oils or provision of other feedstock. The extracted and purified oils/fats than undergo the conversion to biodiesel in the production plant. The product, after purification steps is distributed to the end user.

Critical quality parameters in the process are:

- Complete reaction
- Removal of glycerol
- Removal of catalyst
- Removal of alcohol
- Absence of free fatty acids
- Low sulphur content

Methanol is used as the alcohol for producing biodiesel because it is the least expensive alcohol, although other alcohols such as ethanol may yield a biodiesel fuel with better fuel properties but it is expensive. Often the resulting products are also called fatty acid methyl esters (FAME) instead of biodiesel. The amount of alcohol used can be reduced by conducting the reaction in steps, where part of the alcohol and catalyst are added at the start of each step, and the glycerol is removed at the end of each step. Free fatty acids in the oils or fats can be converted to alkyl esters with an acid catalyst also. This can be followed by a standard alkali-catalysed transesterification to convert the triglycerides. Acid catalysts can be used for the transesterification of oils to alkyl esters, but they are much slower than alkali catalysts.

By-products issues

An important aspect is that related with glycerol, the principal by-product of this process. It occurs in vegetable oils at a level of approximately 10 % by weight. Crude glycerol possesses very low value because of the impurities. However, as the demand and production of biodiesel grows, the quantity of crude glycerol generated will be considerable, and the utilization of it will become an urgent topic. Refining of the crude glycerol will depend on the economy of production scale and/or the availability of a glycerol purification facility. It is generally treated and refined through filtration, chemical additions and fractional vacuum distillation to yield various commercial grades. Small to moderate scale producers who cannot justify the high cost of purification find crude glycerol utilization or disposal to be a problem. Larger scale biodiesel producers refine their crude glycerol and move it markets in the food, pharmaceutical and cosmetic industries. There are a plenty of added value chemicals that can be obtained from glycerol.

iii. **Pyrolysis (cracking):** Thermal cracking or pyrolysis is the process that causes the break of the molecules by heating at high temperatures that is, by the heating of the substance in the absence of air or oxygen in temperatures superior to 450°C, forming a mixture of chemical compounds with properties very similar to those of petro diesel. In some situations that process is supported by a catalyst for the break of the chemical connections, in order to generate smaller molecules. Differently of direct mixture, fats can be pyrolysis object for the production of smaller chain compounds. The pyrolysis of fats has been investigated for more than 100 years, especially in countries with small oil reserves. Typical catalysts to be used in the pyrolysis are the silicon oxide SiO_2 and aluminium oxide Al_2O_3.

The equipment for pyrolysis or thermal cracking is expensive. However, the products are chemically similar to diesel oil. The removal of the oxygen of the process reduces the benefits of an oxygenated fuel, reducing its environmental benefits and usually producing a fuel closer to gasoline than diesel. By the international nomenclature, the fuel produced by thermal cracking is not considered biodiesel, in spite of being a biofuel similar to the diesel oil. Cracking has great applicability in places that need smaller production volume and with smaller availability of qualified work.

The catalytic or thermal cracking produces a mixture of condensed hydrocarbons with output of around 80% in an organic phase. There is an aqueous phase, around 5% to 10% and the remaining are gases. Cracking has as strong point the absence of formation of aromatic compounds, of great pollutant potential.

iv. **Micro emulsion:** To solve the problem of the high viscosity of vegetable oils, micro emulsions with solvents such as methanol, ethanol and 1-butanol have been studied. A micro emulsion is defined as thermodynamically stable, isotropic liquid mixtures of oil, water and surfactant (compounds that lower the surface tension of a liquid, the interfacial tension between two liquids). They can improve spray characteristics by explosive vaporization of the low boiling constituents in the micelles (an aggregate of surfactant molecules dispersed in a liquid colloid).

1.12 Fuel Properties of selected fuels

The fuel characteristics include the physical and chemical properties of the fuel such as viscosity of fuel, pour and fire point of fuel, calorific value of fuel. The brief introduction regarding these properties is as follow:

i. **Density**

Bio-diesel is slightly heavier than conventional diesel fuel (specific gravity 0.88 compared to 0.84 for diesel fuel). This allows use of splash blending by adding bio-diesel on top of diesel fuel for making bio-diesel blends. Bio-diesel should always be blended at top of diesel fuel. If bio-diesel is first put at the bottom and then diesel fuel is added, it will not mix.

ii. **Kinematic viscosity**

Viscosity is an important physical property of a diesel fuel. Improper viscosity leads to poor combustion, which results in loss of power and excessive exhaust smoke. Diesel fuels with extremely low viscosities may not provide sufficient lubrication for the closely fit pumps and Injector plungers. They can promote abnormal wear and cause injector and injector pump leakage and dribbling leading to loss of power as fuel delivered by the injector is reduced. Diesel fuel with higher viscosity is also not desirable as too viscous fuel increases pumping losses in injector pump and injectors, which reduces injection pressure resulting in poor atomization and inefficient mixing with air ultimately affecting the combustion process.

iii. Flash Point and fire Point

Flash point of a fuel is defined as the temperature at which it will ignite when exposed to a flame or spark. The flashpoint of bio-diesel is higher than the petroleum based diesel fuel. Flashpoint of bio-diesel blends is dependent on the flashpoint of the base diesel fuel used, and increase with percentage of bio-diesel in the blend. Thus in storage, biodiesel and its blends are safer than conventional diesel. The flashpoint of biodiesel is around 160, but it can reduce drastically if the alcohol used in manufacture of bio-diesel is not removed properly. Residual alcohol in the bio-diesel reduces its flashpoint drastically and is harmful to fuel pump, seals, elastomers etc. It also reduces the combustion quality.

iv. Water content or Moisture content

Biodiesel and its blends are susceptible to growing microbes when water is present in fuel. The solvency properties of the biodiesel can cause microbial slime to detach and clog fuel filters**.** It affects on quality of biodiesel. High content of above property disturbs standard specification of biodiesel. It causes blockage of fuel filter and fuel lines.

v. Cloud Point

Cloud point is the temperature at which a cloud or haze of crystals appear in the fuel under test conditions and thus becomes important for low temperature operations. Biodiesel generally has higher cloud point than diesel fuel.

vi. Pour Point

Normally either pour point or CFPP (Cold Filter Plugging Point) are specified. French and Italian bio-diesel specifications specify pour point whereas others specify CFPP. Since CFPP reflects more accurately the cold weather operation of fuel, it is proposed not to specify pour point for bio-diesel. Pour point depressants commonly used for diesel fuel do not work for biodiesel.

vii. FFA content

If the oil has a high water or free fatty acid (FFA) content the reaction will be unsuccessful due to saponification (saponification is defined as the reaction of an ester with a metallic base and water) commonly known as making soap, and make separation of the glycerol difficult at the end of the reaction. The FFA content of the raw oil will determine the quantity of biodiesel as the final product. A very low content of FFA (<0.2) can give a full 100% yield.

viii. Calorific value

The total quantity of heat liberated by completely burning of one unit mass of fuel. The calorific value of a substance is the amount of energy released when the substance is burned completely to a final state and has released all of its energy.

ix. Ash content

It describes the amount of inorganic contaminants such as abrasive solids and catalyst residues and the concentration of soluble metal soaps contained in a fuel sample. These compounds are oxidized during the combustion process to form ash which is connected with engine deposits.

x. Carbon residue content

It is correlates with respective amounts of glycerides, free fatty acids, soaps and catalyst residue. The parameter serves as a measure of the tendency of a fuel sample to produce deposits on injector tips and inside the combustion chamber. It is also influenced by high concentration of polyunsaturated fatty acid methyl esters and polymer.

1.13 Benefits of Biodiesel

Biodiesel is a domestically produced, clean-burning, renewable substitute for petroleum diesel. Using biodiesel as a vehicle fuel increases energy security, improves public health and the environment, and provides safety benefits.

a) Increasing Energy Security

The United States imports more than 60% of its petroleum, two-thirds of which is used to fuel vehicles in the form of gasoline and diesel. The demand for petroleum imports is increasing. With much of the worldwide petroleum reserves located in politically volatile countries, the United States is vulnerable to supply disruptions .

Biodiesel can be produced domestically and used in conventional diesel engines, directly substituting for or extending supplies of traditional petroleum diesel. It also has an excellent energy balance.

b) Protecting public health and the environment

Compared with using petroleum diesel, using biodiesel in a conventional diesel engine substantially reduces emissions of unburned hydrocarbons (HC), carbon monoxide (CO), sulfates, polycyclic aromatic hydrocarbons, nitrated polycyclic aromatic hydrocarbons, and particulate matter (PM). The reductions increase as the amount of biodiesel blended into diesel fuel increases. B100 provides the best emission reductions, but lower-level blends also provide benefits. B20 has been shown to reduce PM emissions 10%, CO 11%, and unburned HC 21%. Using biodiesel also reduces greenhouse gas emissions because carbon dioxide released from biodiesel combustion is offset by the carbon dioxide sequestered while growing the soybeans or other feedstock. B100 use reduces carbon dioxide emissions by more than 75% compared with petroleum diesel. Using B20 reduces carbon dioxide emissions by 15%.

c) Biodiesel improves engine operation

Biodiesel improves fuel lubricity and raises the cetane number of the fuel. Diesel engines depend on the lubricity of the fuel to keep moving parts from wearing prematurely. Federal regulations reduced sulfur in diesel fuel to 15 ppm a few years ago, which resulted in reduced lubricity of petroleum diesel. Diesel specification ASTM D975 was modified to require lubricity; biodiesel provides adequate lubricity to meet this requirement at blends as low as 1%.

d) Providing safety benefits

Biodiesel is nontoxic, so it causes far less damage than petroleum diesel if spilled or otherwise released to the environment. It is also safer than petroleum diesel because it is less combustible. The flashpoint for biodiesel is higher than 150°C, compared with about 52°C for petroleum diesel. Biodiesel is safe to handle, store, and transport.

1.14 Advantages of biodiesel

1. Biodiesel is non toxic.
2. Biodiesel is biodegradable.
3. Biodiesel is safer to handle compared to standard diesel.
4. Biodiesel can be easily blended with standard diesel, and it can be used in most of today's vehicles even in form of pure biodiesel B100.
5. Biodiesel can help cut our reliance on fossil fuels, and improve our energy security and energy independence.
6. Biodiesel could be massively produced in many parts of the world; the US alone has the capacity to produce annually more than 50 million gallons of biodiesel.
7. Production and use of biodiesel accounts for significantly less emissions compared to standard diesel, approximately 78% less emissions compared to standard diesel.
8. Biodiesel has very good lubricating properties, significantly better than standard diesel which can prolong engine's life.

9. Biodiesel has shorter ignition delay compared to standard diesel.

10. Biodiesel has no sulphur content, and so it doesn't contribute to acid rain formation.

1.15 Disadvantages of biodiesel

1. Biodiesel could lead to food shortages and increased food prices. The end result of this could be more hunger in the world.

2. Biodiesel is 20 times more susceptible to water contamination compared to standard diesel, and this could lead to corrosion, rotten filters, pitting in the pistons, etc

3. Pure biodiesel has significant problems with low temperatures. Biodiesel is significantly more expensive compared to standard diesel.

4. Biodiesel has significantly less energy content compared to standard diesel.

5. Biodiesel can release nitrogen oxide which can lead to the formation of smog .

1.16 Argemone Mexicana

Argemone Mexicana is a species of poppy that is found in Mexico and now it has been widely growing in many parts of the world. It has bright yellow texture and is poisonous for grazing animals due to its non-edible in nature. Seeds contains 22-36% of oil called Argemone oil. In India it is introduced and naturalized and occurs as wasteland weed in almost every part of India. It has 1-4 feet height, thistle like leaves, yellow flowers. Flowers occur at the end of branches. It has medical uses also like for treating malaria, seed oil applied directly to heal wounds faster and in skin diseases.

1.17 Nano Particles

The concept of nanofluids is the latest upgrading in the field of nanotechnology which gives wide scope for research. Nanofluids provides enhanced heat transfer coefficient and better thermophysical properties. Application of nanofluids can be seen in the field of automobile, transformer and generator cooling. It can also be used in biodiesel as an additive. Nano-particles are generally nanosized structures that has one or more dimensions (length, width or thickness) according to its one of the phases. It has the size range of 1 to 100 nanometers. These have high surface area-to-volume ratio. These are formed by chemical and physical method. Here Cerium Oxide and Silver nano-particles as additives are used as additives in biodiesel. These have nano-particle size ranging from 10 to 30 nm and density 7.13 g/mL. The dosing level varies from 20ppm to 80ppm by weight.

- **Cerium Oxide** (CeO_2): It has the ability to act as oxygen buffer. It causes simultaneous oxidation of hydrocarbons. It also helps to reduce the oxides of nitrogen. Cerium Oxide nanoparticles could possibly exhibit high catalytic activity because of their large surface per unit volume, leading to improvement in the fuel efficiency and reduction in the emission. It is soft, silvery ductile metal which easily oxidizes in air. At high temperature it releases oxygen. Due to the significant ionic and electronic conduction of cerium oxide, it is well suited to be used as mixed conductor.

- **Silver** (Ag): It is becoming an increasingly important material in many technologies. It exhibit the highest efficiency of plasmon excitation. It is the only material whose plasmon resonance can be tuned to any wavelength in the visible spectrum. Silver nano-particles are of strong research focus because of their unique functional properties which led to varied applications.

CHAPTER 2

Literature Review

Azam et. al (2005) [1] studied about 75 Indian plants, having 30% more oil in their seeds, fruits or nut had been investigated. The sponification number (SN), iodine value (IV) and cetane number of fatty acid methyl esters (FAMEs) emperically calculated and were used as the requirement for use as biodiesel which could generally meet the specificaton of biodiesel standard of USA, Germany & Europian standard organization. Out of 75 plants, 42 had met the standard value of cetane number (CN) which was more than 51. All the 42 species which qualified the quality of cetane number (CN), also met the quality of iodine value (IV), which was less than 115. Generally higher value of cetane number was preferred, but with increase in the cetane number the iodine value decreased which meant degree of unsaturation decreased which resulted in solidification of the fatty acid methyl esters at high temperature. To overcome the problem the upper limit of the cetane number (CN) had been elected as 65 in US biodiesel standard. Out of the 42 plants which met the standard specification of both cetane number & iodine value the 15 had higher melting points therefore these might not be used in cold weather conditions. The sponification number(SN), iodine value (IV) and cetane number (CN) were calculated.

V. Sajith et. al (2009) [2] investigated the effect of cerium oxide in nano-particle form as a additive in Biodiesel. The cerium oxide powder varied from 20 to 80 ppm. Cerium oxide oxidize the carbon deposits and help the engine to run efficiently and also reduced fuel consumption. They are more effective in nano-particle form. Experiments are carried due to different dosing levels. Viscosity if found to increase due to increment in dosing levels. Viscosity and volatility holds direct relation with each other. Cold temperature properties of fuel are not affected.

In the study of **Jindal et. al (2010) [3]** the effect of engine parameters on the NO_X emission had been investigated using jatropha biodiesel fuel in the small diesel engine. It had been observed in many researches that biodiesel upto 20% might be used without any modification in engine. It was concluded that using biodiesel as fuel in the diesel engine without any modification reduced the power, thermal efficiency and increased the specific fuel consumption and comparatively higher emission of NO_X. In this study firstly the engine was tested using diesel fuel at standard parameters and then with 100% biodiesel under different value of compression, injection pressure, engine speed, injection time and emission were recorded. The experiment was carried out at an advanced fully computerised experimental engine test rig consist of a single cylinder, water cooled, four stroke, variable compression ratio diesel engine connected to dynamometer. For 100% diesel the test was carried at compression ratio 17.5:1 and injection pressure of 210kg/cm^2 at speed of 1500r.p.m and for 100% biodiesel the test was carried out at different compression ratio (16, 17 and 18) , three injection pressure 150, 200, 250 kg/cm^3 and different engine speed (1400, 1425, 1450, 1475, 1500 and 1525r.p.m). During the experiment the results observed were that with the increased compression ratio, the ignition delay reduced and peak pressure increased resulted in high temperature which cause larger amount of NO_x formation.

In the study of **Ketologetswe et. al (2011) [4]** the comparison between the blending cooking oil biodiesel and the petroleum diesel had been made on the performance of variable IC engine. The biodiesel was derived by the alkali catalyst transesterification process. In the study the different parameters were measured according to different load conditions for biodiesel and diesel and blends of the both. The process used for production of biodiesel for transesterification of tri-alcylglycerols with the alkali or acid as catalyst. The engine used for testing was single cylinder four stroke diesel engine which was directly attached to dynamometer. All the results were observed at maximum speed of 2500 rpm the different samples of fuel were prepared B0D100, B100D0, B50D50 and B30D70.The engine was tested at two different compression ratio 12 and 17. It was observed that engine torque was improved for all the fuel samples was at compression ratio 17. The brake power for the different compression was approximately same. There was a very small difference between specific fuel consumption at different compression ratio. The emission of carbon monoxide, polycyclic aromatic hydrocarbons and particulate matter were reduced by using biodiesel as compared as compared to pure diesel.

In the study of **Zhihao et. al (2011) [5]** the emission characteristics of diesel engine fuelled with Pistacia chinesisbunge seed biodiesel and diesel were discussed. The experiment was carried out on the YTR3105 diesel engine. The different mixture were prepared with different ratio of pistacia chinesisbunge seed biodiesel and diesel blends were B0, B10, B20 and B30. The acid present in the fatty acid of pistacia chinesisbun seed were palmitic, olein and linolic and the content of these acid were 45.45%, 28.91% and 21.37%. The test was conducted at different speed of 1500r.p.m and 2400r.p.m with the different loaded conditions of 25%, 50%, 75%, 90% and 100%. It had been observed the HC emission decreased as biodiesel proportion increased in the biodiesel blends. As load increased the decreased magnitude of HC emission larger which was due to addition of biodiesel in to diesel blends. As the biodiesel ratio increased the content of sulphur and aromatic hydrocarbons reduced. The fatty acid methyl ester had molecular structure of straight chain which result in the complete combustion and reduced hydrocarbons. The CO emission had the same aspect for the both biodiesel-diesel blend and diesel at medium and light loads. But at high load the former CO emission was more that of later blend due to existence of oxygen. The NO_x emission for B10 and B20 was less than that of diesel. But almost same for B30 and diesel. It had been observed that exhaust smoke decreased as we increased the biodiesel in the diesel blends due to presence of oxygen.

Ketlogetswe et. al (2011) [6] performed a different way for production of fuel from used cooking oil by alkali catalyzed transesterification process. The obtained bio-diesel was blended with petroleum diesel to check the performance of single cylinder internal combustion engine at variable compression ratios including automatic data acquisition set up. Outcomes were astonishing and parameters such as brake power, torque and fuel consumption were measured at different loads for pure petroleum diesel, pure biodiesel and different combinations of the dual fuel. As compared with low compression ratio 12 the engine torque showed improvement for all the samples for 17 compression ratio. Fuel mixtures consisting of 100% petroleum-based diesel, 100% bio-diesel, 50/50% (diesel/biodiesel) and 70/30% (diesel/ biodiesel) were tested. The study explains the performance of the engine when run by biodiesel and its blends with petroleum diesel is very comparable to its performance when powered by 100% petroleum diesel.

In the study of **Wang et. al (2012) [7]**, ten major trees were taken which could be used as potential raw material for biodiesel .The relation between the fatty acid composition of vegetable oils and fuel properties of biodiesel were analyzed. Only fully matured seeds were used because immature seeds had not reached the final fatty acid composition. The fresh seeds of Xanthoceros Sorbifola and Armeniaca Sibiricas were stored at room temperature for one week to dry before they were transferred to the laboratory in polypropylene bags under cool conditions. The parameters of biodiesel fuel such as, density, kinematic viscosity, cetane number, iodine value, oxidation stability and cold filter plugging point, were depended on oil nature. It had been observed that biodiesel of Aremenica Sibiricas, Jatrophacurcas, Pistacia Chinesis, Xanthoceras Sorbifolia, Comus Wilsonian and Zanthoxylumbungeanum oils had better properties because they had the higher monosaturated content.

ThesapiumSebifrum, Vernicia Fordii, IdesiaPolycarpa and Elacisguineensis biodiesel should be used after they were mixed with petroleum diesel or a high cetane number of biodiesel.

In the study of **Bankovikllic et. al (2012) [8]**, it had been investigated the important non edible oils plants were jatropha, karnaja, tobacco, mahua, neem, rubber, sea mango, castor, cotton etc. Out of these plants jatropha, karnaja, castor and mahua were most often used in biodiesel synthesis. It had been observed that jatropha plant was the most capable potential oil source for biodiesel production in South-East Asia, Central and South America, India and Africa. Karnaja was nitrogen fixing tree had a significant oil content and native to India, UnitedStates, Indonesia, Australia, Philippines and malaysia. A weed castor plant should grow anywhere and had similar ecological requirements as jatropa. It was native to India, china, Brazil,some countries of ex-USSR and Thailand. Mahua and neem trees founded mostly in India and Burma, are significant source of oils. The annual production of mahua and neem in India were 100,000t and 180,000t respectively. It had been practiced that the most appropriate method for production of bio-fuel, was the transesterification reaction of these plants with the alcohol in the presence of catalyst. The catalyst might be acid or base accordingly the content of FFA present in plant. If the FFA content was higher than acid catalyst was used and if the FFA content was lower than base catalyst was used. The catalyst might be homogenous or heterogenous. Solid catalyst was preferred over the liquid catalyst for many reasons such as reduced environmental pollution, simple product separation and purification. Both homogenous and heterogeneous catalyzed process involved two processes, one step process and two-step process. Two-step process used when non edible oil had a higher FFA content, it was an effective method to obtained high biodiesel yield within a short reaction time.

Raj et. al (2012) [9] As per the experiment conducted to find the characteristics of various esterified oils compared with tamanu oil when applied to variable compression ratios of an engine, it has been seen that esterified tamanu oil enhance the efficiency of engine as well as lower the emission rate without any engine modification. Tamanu oil has 1.8% free fatty acids(FFA), with the Cetane number of value 50. The DI Engine used was single cylinder Kirloskar/PS 234. Its compression ratio was 12:1 to 18:1The brake thermal efficiency of the VCR engine increases at higher loads as compared to standard engine with lower specific fuel consumption at all loading conditions as well as the volumetric efficiency also increased. Although the delay period is consistently low when load increases.

Rambabu et. al (2012) [10] worked on the most commonly known oil i.e. cottonseed oil and converted to Cottonseed Methyl Ester (CsME) where it is wholly used as a fuel instead of diesel on Diesel Engine with a little variation in compression ratio and preheating Cottonseed Methyl Ester. In begin various compression ratios like 16.5:1, 17.5:1, 18.5:1 and 19:1 have used for experimentation from which 18.5:1 C.R found to be most effective among all. On another hand preheating was set to the value of 52ºC. The combination of increasing of compression ratio and preheating not only enhances the homogenization and vaporization but also enhances the rate of release of inbuilt oxygen of CsME. Moreover at full load condition the brake thermal efficiency is found to be 32.32% as well as the exhaust emissions was least at this operating condition. When the compression ratio, temperature and pressure of air are increased it influenced the delay period of combustion of the fuel i.e. on increment of compression ratio there would be reduction in delay period. With preheating, the percentage of Carbon monoxide and Hydrocarbons in the exhaust gas also decreased and emission of mono nitrogen oxides were almost nil. Moreover Brake specific fuel consumption decreased so that the engine operating at compression ratio18.5:1 with CsME at 52ºC preheating is more efficient than that of diesel fuel.

Sithta et. al (2012) [11] experimented on the Utilization of Biodiesel extracted from Argemone in Diesel Engine. The study a new non edible oil was used instead of Jatropha, Karanja, Neem etc. Argemone Mexicana is a weed crop and its biodiesel have been used to test the performance parameters in diesel engine and exhaust emissions of a single cylinder four stroke direct-injection diesel engine operated on blends of Argemone biodiesel and diesel blends. The maximum brake thermal efficiency comes 28.56% for blend 20% of biodiesel , which was higher than diesel. The specific energy consumption was also close to diesel. The emission level reduced with blends of Argemone biodiesel rather than diesel. The biodiesel obtained from Argemone was of good quality and best

suitable to run on diesel engine. It has low free fatty acid value, Alkaline Transesterification that results into 80% yield also flash point and its ester values were very more when compared to diesel. There was not any problem found while using the Argemone biodiesel in compression ignition engine and the engine ran smoothly with the various blends of Argemone biodiesel with diesel fuel and not any engine modification needed at blend of 20%.

D.D Nagdeote et. al (2012) [12] used direct injection diesel engine to evaluate the factors which were affected by using diethyl ether and ethanol in the form of additives in biodiesel blends. In this investigation different blends are used for 5% diethyl ether and 5% ethanol.

Smoke is reduced during engine performance. Mahua oil is used for making of biodiesel. The engine used for testing is single cylinder four stroke water cooled engine. It runs at 1500 rpm continuously. without any modification the biodiesel blends show better stability. Without any engine modification these blends can be directly used. The consumption is lower in case of diethyl ether and similar to B20 in case of ethanol. These blends have high oxygen content than B20 so they are more helpful in reducing smoke.

Abayeh et. al (2013) [13] studied that Straight Vegetable Oil was extracted using hexane. Luffa ageyptiaca seed has 19-25% oil content and may be use as feedstock for biodiesel production. Its has 130g iodine/100g of oil. Due to high iodine value the oil can be used in surface coating applications. It is also suitable for soap manufacturing and from its acid value and FFA contents the oil is not suitable for edible use.

Patel et. al (2013) [14] studied the engine performance using Pyrolysis oil as biodiesel blended with diesel. The tests were performed at different injection timings, injection pressure, compression ratio and loads. As compared with the pure diesel fuel the brake specific fuel consumption(BSFC) was reduced which provide better engine performance. It is the study of artificial neutral network (ANN) to predict BSFC of given CI engine used a back propagation network. Each predicted specific fuel consumption values of ANN were very close to the experimental results and ANN may be used as good alternative for the analysis of the effects of engine parameters on the specific fuel consumption. The modelling of the effects of engine parameters such that injection timing, injection pressure, compression ratio and load on the specific fuel consumption depending on various processing parameters ANN based approach was suggested.

Kolhe et. al (2014) [15] studied the biodiesel use in conventional DI engines which helps to reduce the unburned hydrocarons and carbon monoxide. The performance aspects were studied with Karanja methyl ester with different blends with diesel and the results were compared with standard diesel. The brake obtained was similar to diesel when the rpm was fixed to 1500 and compression ratios vary 17.5:1 and 18.5:1. The brake thermal efficiency for pongamia biodiesel blends and diesel was calculated and the blend B20 gave maximum thermal efficiency. These blends hepls to reduce carbon monoxide , hydrocarbon and nitrogen oxides emissions unexpectedly increases. Mono nitrogenoxide was slightly increased due to higher combustion temperature and the presence of fuel oxygen with the blend at full load. PME as biodiesel and its blends can be used in diesel engines without any engine modification. For the same operating conditions, engine performance decreased with increasing percentage of biodiesel in the blend. However as the compression ratio increased the engine performance changes and then it can be compared with standard diesel. The performance, emission and combustion characteristics of a single cylinder four stroke direct injection CI engine fuelled with pongamia biodiesel and its blends have been studied and compared with the diesel fuel. At higher compression ratio the exhaust gas temperature was reduced. The reason behind this is the lower calorific value of blended fuel as compared to standard diesel and lower temperature at the end of compression.

Dawody et. al (2014) [16] investigates the effect of variable compression ratio on the combustion, performance and emission characteristics of a single cylinder, direct injection diesel engine powered by soya bean methyl ester (SME) blend with diesel fuel. Different compression ratios at various load conditions were studied at constant speed of 1500 rpm Three blends of soya bean were prepared and tests were compared with diesel fuel. With higher compression ratio the oxides of nitrogen were found higher. Diesel-rk software was used to verify the experimental results under same working conditions. The blends of soya bean methyl ester had earlier start of combustion as compared to diesel and the brake thermal efficiency was reduced as the percentage of SME was increased. With the use of blends of SME both Hydrocarbon and Carbon monoxide showed drastically decline in emission. Nitrogen oxides for all blends of SME was higher than that of diesel and smoke capacity was reduced. The optimum efficiency was found with mixture of 20% of SME and 80% of diesel and gave desired result of less No_x emission.

Prasada et. al (2014) [17] studied about production of biodiesel from Pongamia Pinnata oil, various properties, performance and emission of Pongamia Pinnata biodiesel in compression ignition engine. Pongamia Pinnata oil is used as a raw material to produce a biodiesel. It is non-edible oil which was blended with diesel for their use as substitute fuels for diesel engines. The oil was blended in different proportions with diesel fuel and by varying the compression ratio, Injection pressure, speed, load or by using additives the performance and emission characteristics of biodiesel blends and found the preferable combination of the blend for CI engine. Pongamia Pinnata biodiesel can be used in CI engines as alternative fuel. It was seen that all experiments showed improved performance and reduced emission of harmful gases. Injection pressure of 200 bar and 16:1 compression ratio can be used as optimum values and CI engines can be run with karanja biodiesel. Hence it came to result that the blends of honge methyl ester with diesel up to 40% by volume use instead of diesel for running the diesel engine and emissions will be less without sacrificing the power output and help in controlling air pollution. Karanja oil can be used as an alternative fuel for diesel engine without any modification.

Kumar et. al (2014) [18] worked to check performance and emission analysis of flex seed oil blended with diesel using methyl esters as additive on VCR Engine. In this project utilization biodiesel and increasing blend ratio of biodiesel-diesel as fuel in single cylinder, direct ignition, four stroke, vertical diesel engine is used by varying compression ratio to find performance and exhaust emissions. Compression ratio varies from 14 to 19 using biodiesel diesel blends with methyl ester as additive with 20% & 30% in varying load from zero to maximum. An analysis of blend of 30% has better brake thermal efficiency as well as better specific fuel consumption. The mechanical efficiency of blend of 30% of bio-fuel has better for both compression ratios. Similarly emissions of various harmful gases like mono nitrogen oxide, showed huge reduction at compression ratio of 19 and lowest Sulphur oxides emissions at blend of 30% but compression ratio changes to 14 even the hydrocarbon emission obtained from the blends is low as compared to diesel. The maximum brake thermal efficiency 38.2% was observed with the blend B30 at CR14 as compared to pure diesel and the other blend at the brake power 3.47kw of the engine and improved atomization fuel vaporization, better spray characteristics and improved combustion through mixture. as well as the Sulphur oxides percentage increased with increase of load and the lowest value occurred at B30 at CR14 which is 1813 ppm.

Eknath et. al (2014) [19] studied that when the blends of Jatropha and Karanja were combined with Diesel fuel separately tested on single cylinder VCR DI diesel engine for compression ratio varies from 16 to 18 showed longer delay period for the former when compared to the latter. However the main conclusion that found to be most important in both cases was that, there was seen least emission of mono-nitrogen oxides emission. When the density of biodiesel fuel and blends is set to higher rate it shows a longer delay Period resulted in higher peak pressure and start of combustion was occured at earlier stage for Karanja 20%, Jatropha 40% rest Diesel fuel, 21degrees before top dead centre compared with Jatropha, diesel and Karanja as well as has low mean gas temperature that results in to least NOx emission compared with other blends and fuels. The main cause of increasing fuel consumption was loss of heating power is greater than increase in density and change in thermal efficiency was less than 1% than that of other fuels. This blend also observed to be safe as it has very low CO and NOx emission.

S. Imtenan et. al (2014) [20] they evaluated experimentally the improvement of palm biodiesel-diesel blend with different additives such as ethanol, n-butanol and diethyl ether and also discussed the performance characteristics. The constitutes of improved blends are 80% diesel 5% additive and 15% palm biodiesel. They also shown the improved brake power increased brake thermal efficiency and deceased brake specific fuel consumption when additives were added. There was 6.25% improves brake power, 3.28% decrement of brake specific fuel consumption for diethyl ether when it was used as additive. Performance was also enhanced for other two additives when it was experimentally performed.

Antarkar et. al (2015) [21] studied about comparative study of mineral diesel and Jatropha biodiesel blended with Ethanol as an oxygenated additive. Biodiesel was synthesized from Jatropha oil by the well-known process of transesterification with NaOH as a catalyst. The blend was prepared of Jatropha biodiesel and diesel. The results of the Jatropha blends were compared with those obtained using mineral diesel. The brake thermal efficiency was high at compression ratio 14 and 16 for all the fuel blends as compared to compression ratio of 18. The BSFC was found to be lower for blends with E- 10 additives compared to blends with E-6 additive. The BSFC was low at compression ratio 14 and 16 for all the fuel blends as compared to compression ratio of 18. The CO emission decreased with the increase in load and with increase in compression ratio for all the fuels tested. CO_2 emissions were much lesser for JB-50 blend and HC emissions increased as the load increases for the all the biodiesel blends. HC emissions increased at start and then it decreased NO_x emissions were found increasing with increase in load and CR for all the biodiesel blends and diesel fuel.

Shavi et. al (2015) [22] studied the characteristics performance for VCR engine for different fuels. The effect of variation in compression ratio were studied on engine performance and emission. The effects on engine fuelled with pure diesel, blends of biodiesel and diesel were compared. The performance parameters includes brake thermal efficiency (BTE), specific fuel consumption (SFC), brake power (BP), indicated mean effective pressure (IMEP), mechanical efficiency and exhaust gas temperature. The exhaust gas emission is found to contain carbon monoxide (CO), hydrocarbon (HC), nitrogen oxides (NO_x) and carbon dioxide (CO_2). The experiments were conducted on direct injection, single cylinder four stroke Kirloskar diesel engine. With the use of diesel, biodiesel and both biodiesel and diesel blends show same result in varying compression ratio but due to increasing compression ratio upto certain limits only increase brake thermal efficiency and decrease in smoke and fuel consumption was noticed. Therefore, the results will vary with change in other parameters like injection pressure and injection timings also. Exhaust gas temperature will increases if the compression ratio will increase.

Kumar et. al (2015) [23] done a great work on analysis of Diesel Engine with diesel, ethanol and vegetable oil blends. Experiment of this blend at different proportions and different component concentrations on an internal combustion engine performance has been conducted. The diesel and ethanol blends run at 800 to 1600rpm. The various ethanol concentrations on diesel were 10% and 5% with a vegetable oil of 5% and 10%. Compression ratios were set from about 17:1 to 18:1 where latter showed higher performance. Also as load increased simultaneously the performance increased. The result showed that at equal air fuel ratio brake specific fuel consumptions for blends are higher than diesel and it increases with the addition of ethanol. The proportion of 5% of ethanol and 5% of vegetable oil blended with 90% diesel gives better performance at C.R. 18 with betterment of Mechanical efficiency and brake thermal efficiency. The specific fuel consumption was reduced to 0.08 kg/kWh at a torque of 0.38 N-m.

Nagane et. al (2015) [24] studied the characteristics of diesel engine fuelled with the blend of algae bio-diesel and petroleum diesel. Initially research on the properties of algae oil and its blends were tested and the results were compared with properties of neat diesel. It is found that, the properties of neat algae oil and its blends are very close to the properties of neat diesel also the calorific value of the blends of algae oil is very close to neat diesel. Various blends were prepared and run on different compression ratio engine to check its performance. Though there was seen a small reduction in torque, brake power and brake thermal efficiency and a slight increase in emission of NOx but emissions of CO, CO_2 and HC decreased. Also the specific fuel consumption increases with increase in blending ratio. More over no modification is necessary when algae biodiesel is blended with straight diesel up to 20% to use in a diesel engine. Also the various blends showed better performance at higher load and higher compression ratio.

V. Chandrasekaran et. al (2016) [25] in this paper diesel engine was presented by using fuel modifications. At first single cylinder diesel engine was operated without additives using 20MEMO, 40MEMO, 60MEMO and 100MEMO.Under the constant rated speed loads it is experimentally studied and proved that on using 20MEMO fuel ratio comes out to be best when compared to other blends**.** Later on for same 20MEMO blend engine was operated with 50ppm copper oxide nano-additives and results showed the brake thermal efficiency improved by 2.19% as compared to 20MEMO blend without additives under the load. They reveals that nano-additives with Mahua oil is quite effective as an secondary fuel for diesel engine. A large work has been done on different aspects of biodiesel. This chapter covers the literature on biodiesel production by different methods from waste vegetable oils and characteristics of biodiesel.

CHAPTER 3

Scope of the study

The main aim of the study is to use non-edible oil like Argemone Mexicana so that it does not affect the food supply and produce biodiesel by using transesterification process. Afterwards, blend B20 would prepared as it has high efficiency among others. Then nanoparticles called cerium oxide and silver are then further added in those blends separately in different proportion 20ppm, 40ppm and 80ppm. Then one mixed blend of 30ppm silver and 30ppm of cerium oxide would also prepared to check the performance, power induced, efficiency, emission and different engine parameters.

Kirloskar four stroke direct injection combustion ignition engine is used to run these tests. Engine runs at constant 1500 rpm and 18 VCR (Variable compression Ratio). We will find the different engine parameters by using the blends that are prepared by mixing of nano additives.

Biodiesel may replace the diesel in future. As the use of fossil fuels increases day-by-day it causes the depletion of natural fuel in future time. The harmful gases and the level of toxicity chemicals is also increasing. Prices of fuels are also increasing as they are standing on the deadline. The fuel prices are so high that some farmers even could not afford the farming equipments due to their high prices. Some farmers risked their lives by taking high amount of loans. So biodiesel may somewhat replaces the diesel fuel and power consumption and fuel efficiency like different characteristic of engine may arise and affect the performance of engine. Transportation cost may also been reduced. As biodiesel has same characteristics as diesel so it may be directly used in diesel engine without any engine modification needed.

CHAPTER 4

Objective of the study

This work has been carried out with following aims and objectives:

1. Production of biodiesel of Argemone Mexicana by using transesterification process.
2. To prepare blend of Argemone Mexicana B100 biodiesel into B20 by mixing 20%Biodiesel and 80%Diesel.
3. To determine fuel properties of selected non-edible oil and its biodiesel.
4. Mix it further with nanoparticles like Cerium oxide and Silver nanoparticles.
5. Prepare blend with varying the ratio of nanoparticles in different blends like 20ppm Ag, 40ppm Ag, 80ppm Ag, 20ppm CeO_2, 40ppm CeO_2, 80ppm CeO_2 and combination of both 30ppm Ag and 30ppm CeO_2.
6. To determine the properties of different blends of biodiesel derived from Argemone Mexicana oil and optimum blend is to be selected based on these properties.
7. To compare properties of different blends prepared from argemone mexicana seed oil using additives at different proportion with diesel fuel.

The properties were checked in SSSNIBE Lab (Sardar Swaran Singh National Institute of Bio-Energy) Kapurthala, (Punjab)

CHAPTER 5

Equipment, Materials and Experimental setup

5.1 Equipments

- Beakers
- Funnels
- Flask
- Separating Funnel
- Graduated Cylinder
- Weighing Machine

5.2 Materials

i. Argemone Mexicana

In this study argemone mexicana is selected as non-edible source of production of biodiesel**.** It belongs to poppy family. The whole species belongs to the mexicana prickly poppy. it is generally found in most parts of the Mexico. It is known as satyanashi in India. It can be found on the road side, fields and on the waste land. The flowers of the plants are yellow in colour. The height of the plant is upto 0.12m. The seeds of plants are black in colour. Argemone mexicana plants does not require a large rainfall. It can be grow in poor sand and low rainfall area. It has low free fatty acid. Therefore biodiesel can be produced in a single step transesterification. The plants like jatropha, karnaja, neem and tobacco are having high free fatty acid. Therefore, cost of the biodiesel production is increase. This is a major drawback of the most of non-edible plants.

Figure 2 Argemone mexicana plant

The seeds of the plants are of very small size. The seeds are of black colour. The oil yield in the seeds of mexicana argemone 35 to 40%. The seeds were purchased form the market of Ludhiana.

Figure 3 Argemone mexicana seeds

The table below shows the fatty acid composition of the mexicana argemone plant. The fatty acid is carboxylic acid with a long aliphatic chain. The may be either saturated or the unsaturated. The most of the plants have carbon atom number varies from 4 to 22. The fatty acid generally derived from the triglycerides.

Table 2 Fatty Acid composition Argemone mexicana

Fatty acid composition (%)	Carbon number	Argemone oil
Oleic acid	18:1	40.0
Linoleic acid	18:2	36.6
Palmitic acid	16:0	14.7
Stearic acid	18:0	6.75
Palmitoleic acid	16:1	1.3
Arachidic acid	18:3	0.3
Behenic acid	20:0	0.2
Myristic acid	22:0	0.1
Linolenic acid	14:0	0.3

ii. Diesel

Diesel is generally used in combustion ignition engines. Generally it is used in spark free engines that runs only on combustion ignition process. Diesel is produced most commonly from petroleum.

Figure 4 Diesel fuel

iii. Sodium Hydroxide

It is a strong base solution used in the transesterification process. It has the formula NaOH and also named as caustic soda. It hepls to react lipid with alcohol to produce biodiesel and glycerol.

Figure 5 Sodium Hydroxide (NaOH)

iv. Methanol

Methanol is also known as Methyl alcohol. It has chemical formula CH3OH which when react with lipids to form biodiesel during the transesterification process. It is made from carbon monoxide and hydrogen. It generally named as wood alcohol or spirit.

Figure 6 Methanol

5.3 Experimental Setup

Engine Setup

Four stroke single cylinder diesel engine will use for testing the engine performance. It is available in **National Institute of Bio Energy** lab situated in **Kapurthala.** All the blends will test in this engine step by step. Brake power, consumption emission checking are some of the test which will be conducted. Prepared blends will then test into Engine for checking the Engine performance and Emission. The Engine will use for testing is Four stroke single cylinder water cooled DI engine. It runs on 1500rpm. All the 9 blends will test in this engine. The engine is connected to dynamometer and the dynamometer is cooled by the motor pump.

Table 3 Specification of the engine

Engine	Kirloskar engine setup
Cylinder	Single cylinder
Strokes	4 strokes
Power rating	3.5KW
Engine Speed	1500RPM
Cylinder bore	87.50mm
Stroke length	110mm
Connecting rod length	234mm
Orifice diameter	20mm
Dynamometer arm length	185mm
Cooled type	Water cooled
Compression ratio	17.5
Dynamometer	Type eddy current, water cooled
Load indicator	Digital, supply 230AC
Software	“Engine soft LV”

CHAPTER 6

Research Methodology

The proposed research methodology is as follows:

- The easiest way to make biodiesel is with the proper biodiesel equipment. Proper biodiesel making process meets ASTM fuel standard, so for the preparation of higher quality biodiesel using nano additives and engine running test is performed in **Sardar Swaran Singh National Institute of Renewable Energy, Kapurthala.** All the equipments are provided there for the preparation of biodiesel upto running test.

- After the selection of seed oil (Argemone Mexicana) and nanoparticles (Cerium Oxide and Silver), these were ordered and seeds brought from the market. Catalyst Sodium Hydroxide and Methanol were also ordered. Then further through the extraction process the oil is extracted from the seeds and after filtration stored.

- The first step in making biodiesel is esterification. Transesterification process is used for making of biodiesel. This involves a catalyst being added usually Sodium Hydroxide. 1.5 litre oil is used and maintain the temperature of 65-70°C then catalyst and methanol mixture is further poured. 10 grams Sodium hydroxide and 275ml of methanol is used and stirred continuously for 2 hours. The catalyst break apart the molecules into glycerol and fatty acid chains. Once the molecules are broken apart the methanol attaches to the fatty acids. The glycerol will begin to drop out of the oil into a mixture called glycerin.

- Then the settling period starts. After the transesterification process the mixture allows to cool down. The oil is allowed to settle for atleast 8 hours and the glycerin settles to the bottom because it is heavier than the oil. Using the valve under the machine the glycerine is drained out leaving only biodiesel inside.

- Now the biodiesel washing process starts. Tap water is used for washing. As the water is heavier than oil it settles at the bottom like glycerine and drained out. This process is repeated 4-5 times until the water comes as it is or light white in colour as it extract the soap and gylcerine particles. After that it is further heated to remove all the water droplets into the biodiesel.

TRANSESTERIFICATION PROCESS

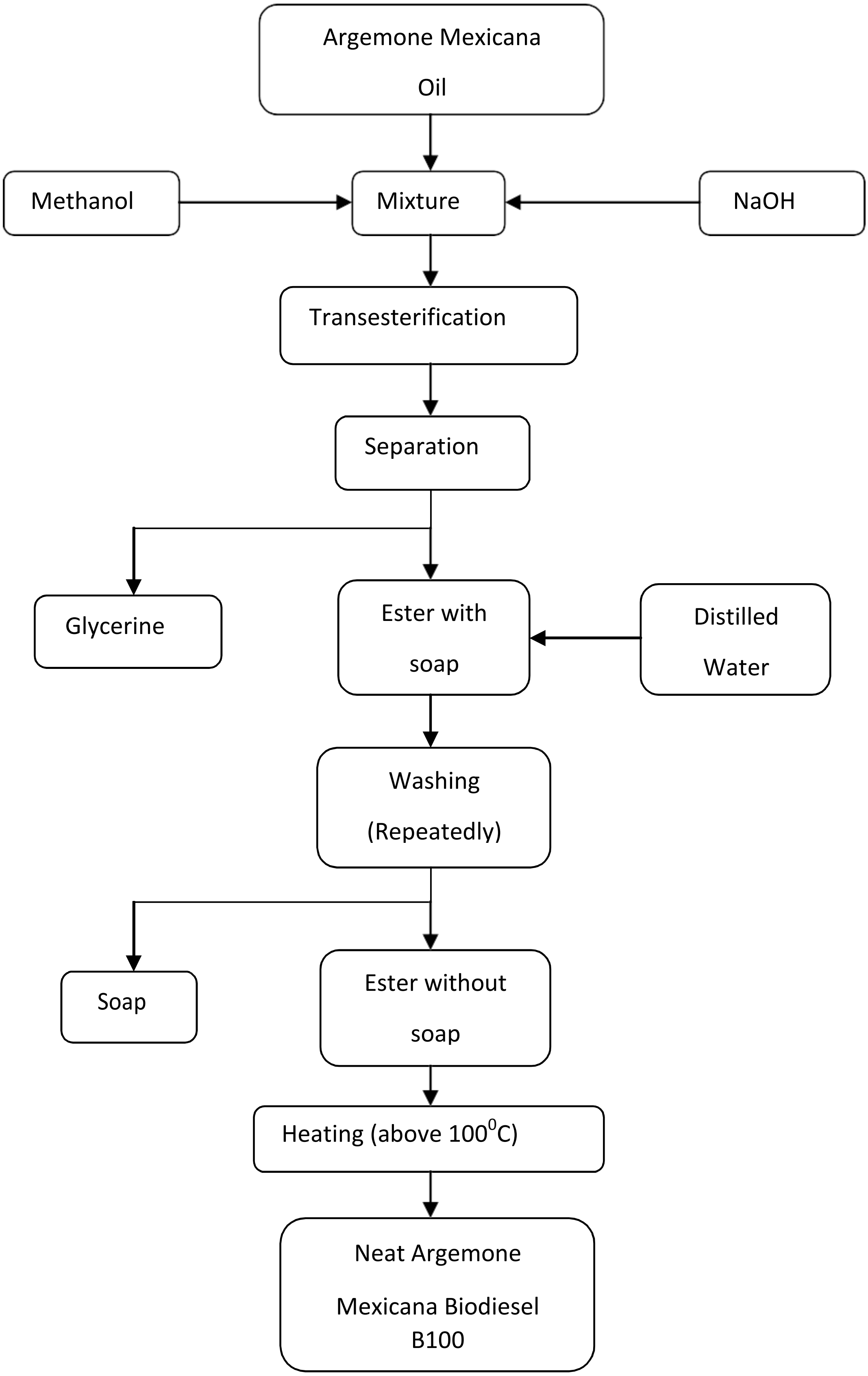
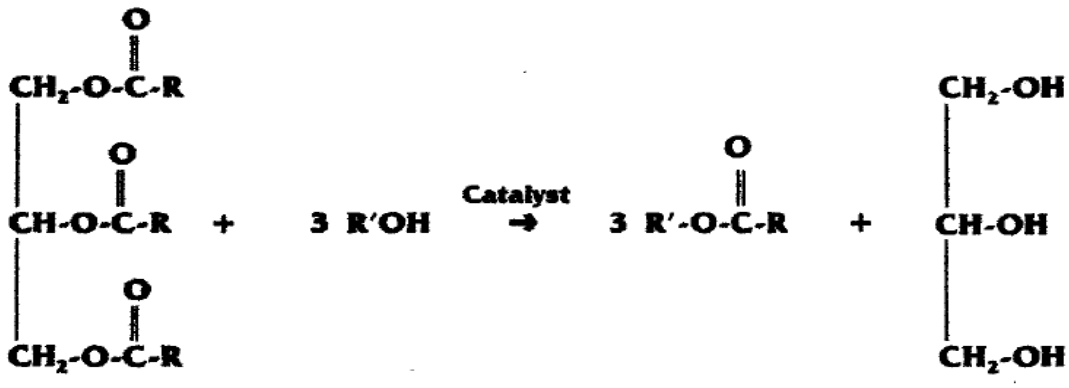


Figure 7 Flow diagram of Transesterification Process

Transesterification: In this method, the vegetable oil is subjected to a chemical reaction. In that reaction, the vegetable oil is reacted in the presence of a catalyst (usually a base) with an alcohol (usually methanol) to give the corresponding alkyl esters of the FFA mixture that is found in the vegetable oil.

Biodiesel is produced through a process known as transesterification, as shown in the equation:



Triacylglycerols (Vegetable oil) **Alcohol** **Alkyl Ester (Biodiesel)** **Glycerol**

Figure 8 Transesterification process

Where R is a long hydrocarbon chain, sometimes called fatty acid chains.

Note: - Transesterification is reliable method for the extraction of biodiesel as compare to pyrolysis, direct blending and micro emulsion because of the following reasons:

1. Low temperature and pressure
2. High yield and short reaction time
3. Direct conversion process
4. Simple in operation
5. Easy availability
6. Less viscosity
7. Less cost
8. Simple methodology

Figure 9 Separation of biodiesel and glycerol using separating funnel

Figure 10 Separation of glycerol after transesterification process

Figure 11 Water washing

Blends

- Blends are prepared with mixing of biodiesel and diesel. B20 blend is prepared by mixing 20% Biodiesel with 80% Diesel.
- Nanoparticles are used in the blending process. Cerium Oxide and Silver nanoparticles are used in this blending process. 20ppm, 40ppm, and 80ppm by weight is used in each blends.
- 30ppm Cerium Oxide and 30ppm Silver is mixed to make one blend to test the performance by combination of both.

AME = Argemone Methyl Ester.

- B20 = 20% Biodiesel (Argemone Methyl Ester) + 80%Diesel.
- 20AME+20ppm Ag = B20 Argemone Methyl Ester + 20ppm Silver.
- 20AME+40ppm Ag = B20 Argemone Methyl Ester + 40ppm Silver.
- 20AME+80ppm Ag = B20 Argemone Methyl Ester + 80ppm Silver.
- 20AME+20ppm CeO_2 = B20 Argemone Methyl Ester + 20ppm Cerium Oxide.
- 20AME+40ppm CeO_2 = B20 Argemone Methyl Ester + 40ppm Cerium Oxide.
- 20AME+80ppm CeO_2 = B20 Argemone Methyl Ester + 80ppm Cerium Oxide.
- 20 AME+30ppm Ag+30ppm CeO_2 = B20 Argemone Methyl Ester+30ppm Silver+30ppm Cerium Oxide.
- D100 = 100%Diesel.

Figure 12 Blends

- Prepared blends will then test into Engine for checking the Engine performance and Emission.

The Engine will use for testing is Four stroke single cylinder water cooled DI engine. It runs on 1500rpm. All the 9 blends will test in this engine. The engine is connected to dynamometer and the dynamometer is cooled by the motor pump.

The experiment was performed on the single cylinder, four stroke, and variable loading engine. The engine was connected to the dynamometer to provide load to the engine. The engine was made to run over the various loads of 0kg, 3kg, 6kg, 9kg, 12kg and 15kg. The emission such as unburnt hydrocarbons (HC), carbon monoxide (CO), nitric oxides (NOx) were measured by the AVL exhaust gas analyzer. The circulation of water was provided for the cooling of engine with the help of pump. The piezoelectric pressure transducer and a crank angle encoder was provided at the cylinder head for measuring the combustion pressure and crank angle. The cylinder pressure and the net heat release rate were observed at the full load of 15kg.The engine was first operated on diesel to obtain the standard parameters for the diesel. The test was conducted with the various blends of argemone mexicana with cerium oxide and silver nano additives prepared by volume basis i.e B20, B20+20ppm Ag, B20+40ppm Ag, B20+80ppm Ag, B20+20ppm CeO_2, B20+40ppm CeO_2, B20+80ppm CeO_2, B20+30ppm Ag+30ppm CeO_2. The performance parameters, combustion characteristics and the emission parameters were evaluated at different loads.

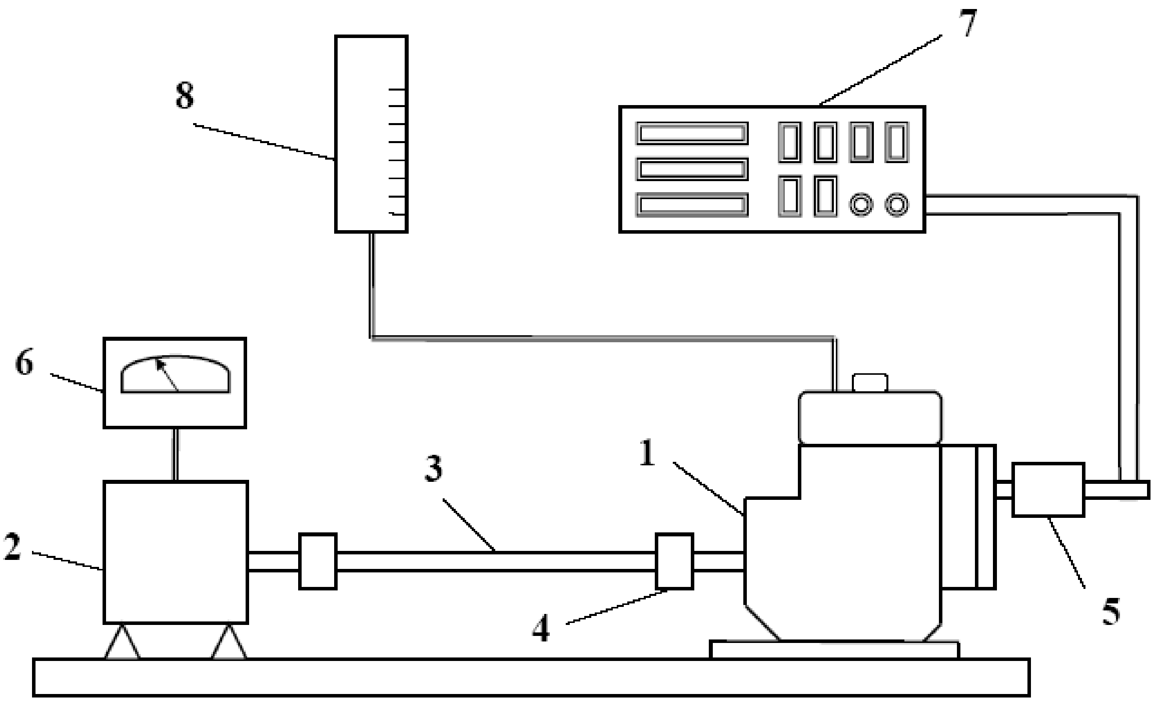


Figure 13 Four stroke DI CI engine with Dynamometer

Parts of Figure 13

1. **Engine**: The engine used for the experiment was single cylinder, 4 stroke, direct injection compression ignition and water cooled engine. The engine was running at a constant speed of 1500rpm
2. **Dynamometer**: It is a device that is connected with engine crank shaft through the coupling shaft. It measures the power output of an engine. By applying variable load conditions we can calculate the power output of an engine with other characteristics also.
3. **Connecting shaft**: It is a shaft that connects the engine to the dynamometer. It helps to distribute the rotational energy from one part to another. While distributing power torsion and shear stress is induced.
4. **Shaft coupling**: It is a device that connects two shafts together at their ends for transmitting power from one device to other. some misalignment may also be detained.
5. **Exhaust pipe**: It is directly connected to the engine exhaust system. During the exhaust stroke all the exhaust gases come directly in the exhaust pipe and hence the calculations of exhaust emissions would be easy with the help of AVL exhaust gas analyzer. It also helps to reduce noise pollution and controls the harmful exhaust gases with pollution control devices located in it.
6. **Dynamometer loading unit**: It is the device that shows the value of load that is acting on the engine shaft.
7. **Computer**: Computer is connected with the engine. All the readings are displaying on the computer while operation so that we can calculate the performance parameters, combustion, exhaust emitting from the engine.
8. **Fuel tank**: It is located near the engine and is storage tank for fuel. Fuel is directly supplies in the engine through the pipes fitted in fuel tank. It has filters for purification of fuel and floating valves for measuring the level of fuel.

CHAPTER 7

Result and Discussions

In this study the performance, combustion and emission characteristics were obtained for Argemone Mexicana biodiesel using Cerium Oxide and Silver nano-particles as additives. Then the results obtained were compared with the diesel.

7.1 Performance parameters

The performance parameters like brake power, specific fuel consumption, brake thermal efficiency and brake mean effective pressure were observed for the argemone mexicana biodiesel blends with additives. The results obtained were discussed below:

7.1.1 Brake Power

The brake power is the total power available at the crank shaft. Figure shows the variation of brake power for the various biodiesel samples with the variation of load. The brake power for the biodiesel blends were 4.28kW, 4.31kW, 4.31kW, 4.31kW, 4.31kW, 4.3kW, 4.29kW, 4.31kW and 4.31kW. The brake power increases with increase in load for all the blends. At full load all the blends show high brake power which is 4.28kW for diesel. The sample B20+20ppm Ag showed higher brake power among all others biodiesel blends. This is due to fact that silver nanoparticles provide higher surface area and high thermal conductivity. Therefore the engine consumes more fuel for producing same brake power, which compensates the lower heating value of biodiesel as compared to the diesel**.**

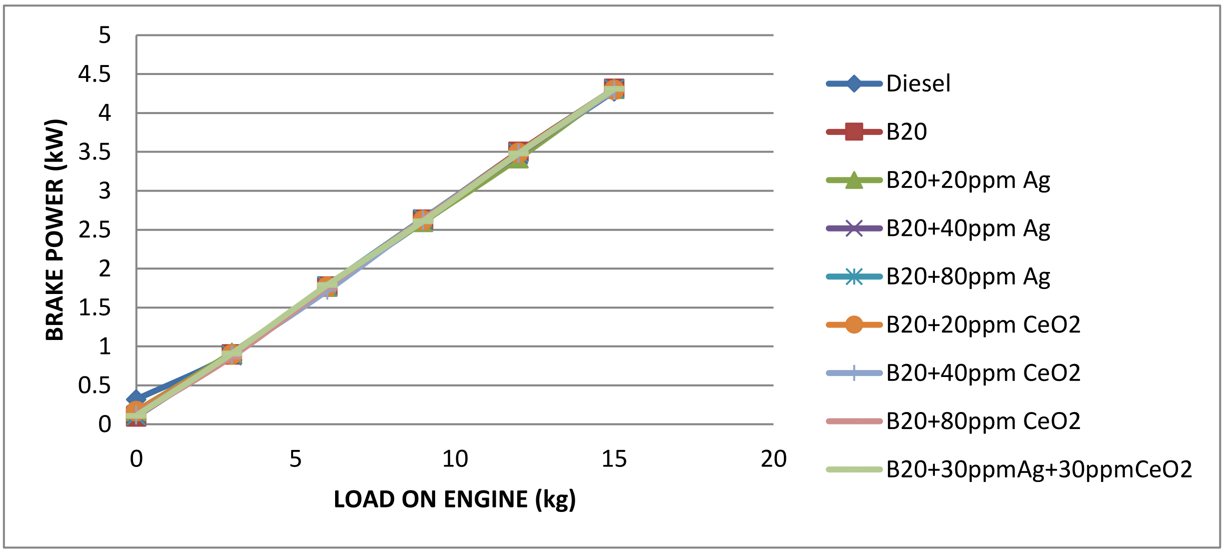


Figure 14 Variation of Brake Power with load

7.1.2 Indicated Power

The indicated power is the total power developed in engine cylinder. The indicated power was increases with increase in load for all the blends. The indicated power was observed highest for the B20 + 20ppm Ag, after that it decreases with increase in the concentration of nanoparticles in blend. The diesel shows the lowest indicated power. The reason for the highest indicated power for B20 + 20ppm Ag was the higher surface area and higher thermal conductivity of silver. As concentration of nano additives increases in blend the density of blend increase, which results in poor combustion.

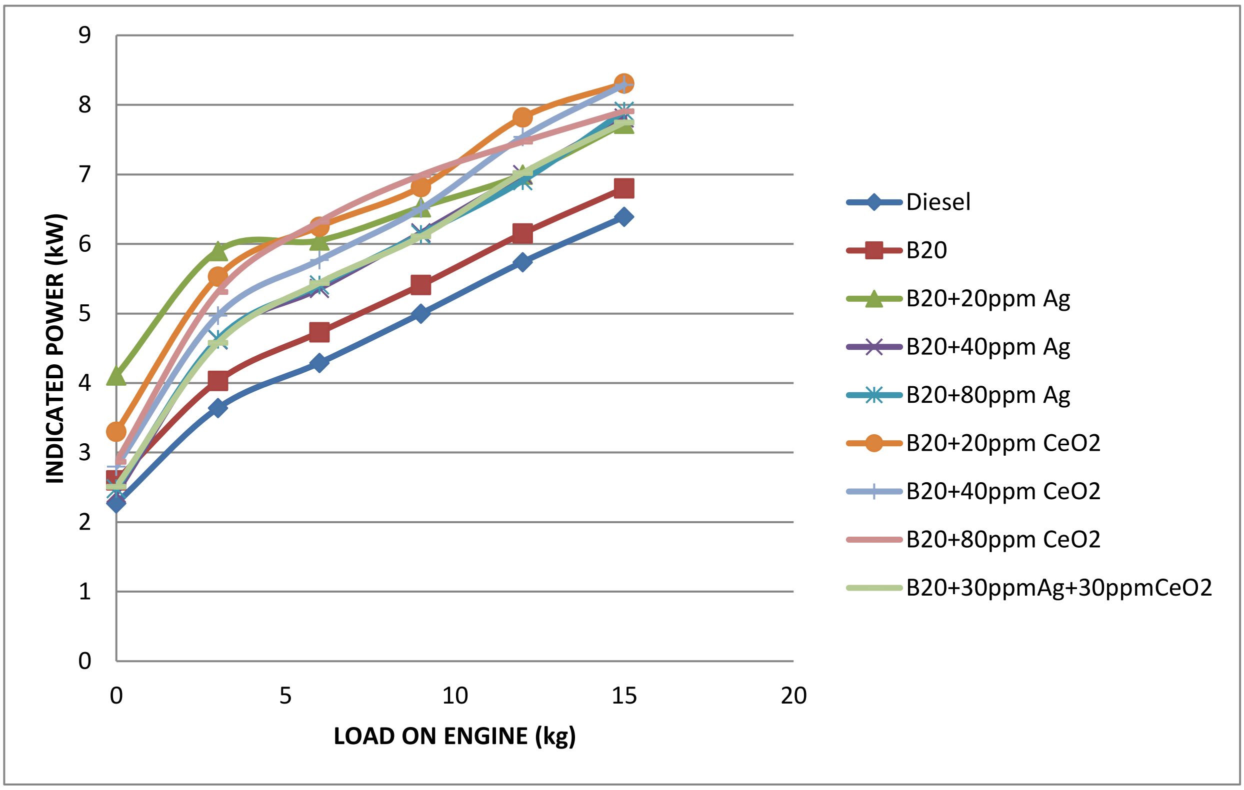


Figure 15 Variation of Indicated power with load

7.1.3 Specific fuel consumption

The Specific fuel consumption is mass of fuel consumption in kg by engine per unit of work done by the engine. Figure shows the variation of specific fuel consumption with respect to load. The specific fuel consumption decreases with increase in load for all the blends. At starting the fuel consumption is high. As the load increases the specific fuel consumption also decreases. At higher loads the consumption again increases.. The minimum specific fuel consumption was for the diesel, which was 0.26kg/Wh. The reason for the higher specific fuel consumption of the biodiesel was its higher density. As the concentration of the biodiesel increases in blend the specific fuel consumption increases for the biodiesel blends. It was due to increase in density of biodiesel blend. Therefore, the specific fuel consumption increases for the biodiesel blends with increases in percentage of biodiesel.

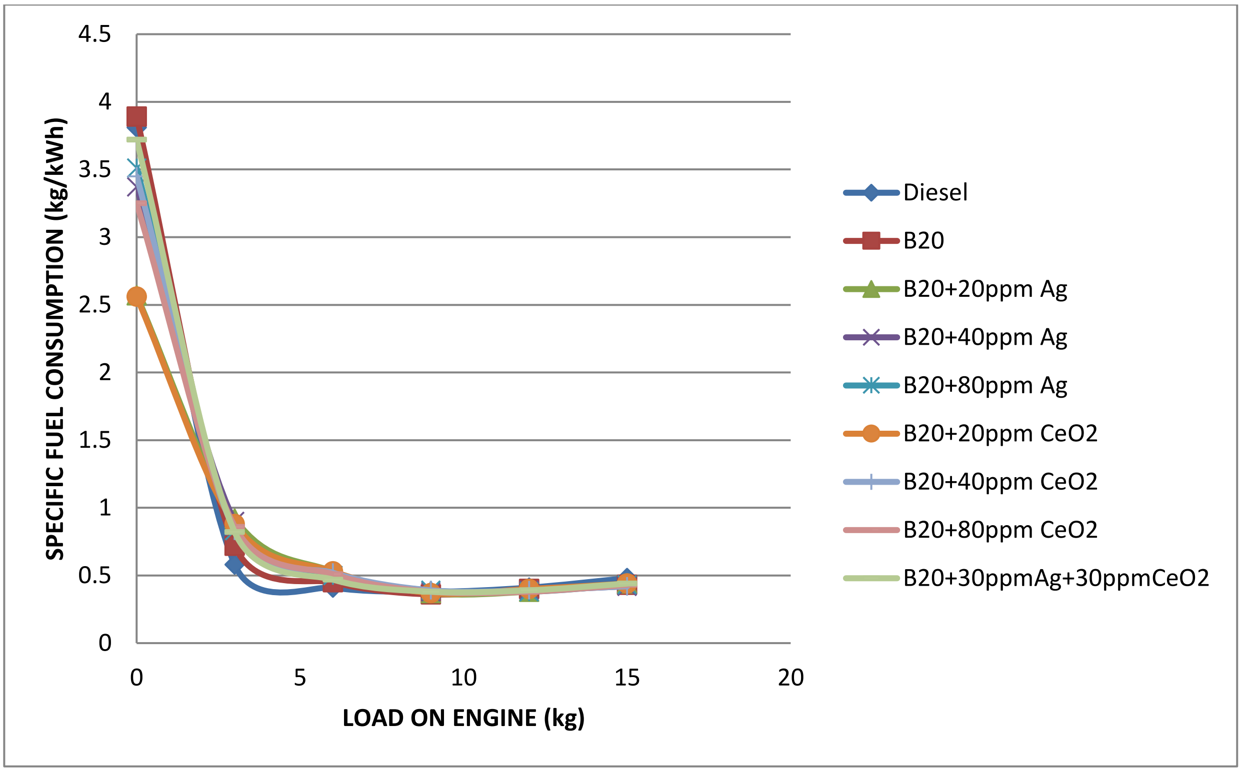


Figure 16 Variation of specific fuel consumption with load

7.1.4 Brake thermal efficiency

The brake thermal efficiency indicates how well an engine convert chemical energy in the mechanical energy. Figure shows the variation of brake thermal efficiency with respect to load. It was observed that efficiency increases with increase in the load. This is due to increase in power developed and reduction in heat losses with increase in load. The highest brake thermal efficiency was found maximum for the diesel, which was 32.39%. Due to high viscosity the B20 blend has lower brake thermal efficiency. As the nanoparticles are added the efficiency increases. This could probably be attributed to the better combustion characteristics of Argemone Mexicana biodiesel with using cerium oxide and silver nanoparticles. The silver nanoparticles provide higher surface area and high thermal conductivity. Cerium oxide acts as oxygen buffer and thus increases the efficiency. A maximum increase of 1.5% in the brake thermal efficiency was obtained when the dosing level was varied from 20ppm to 80ppm. These properties provide increased reactivity and faster burning rates of fuel.

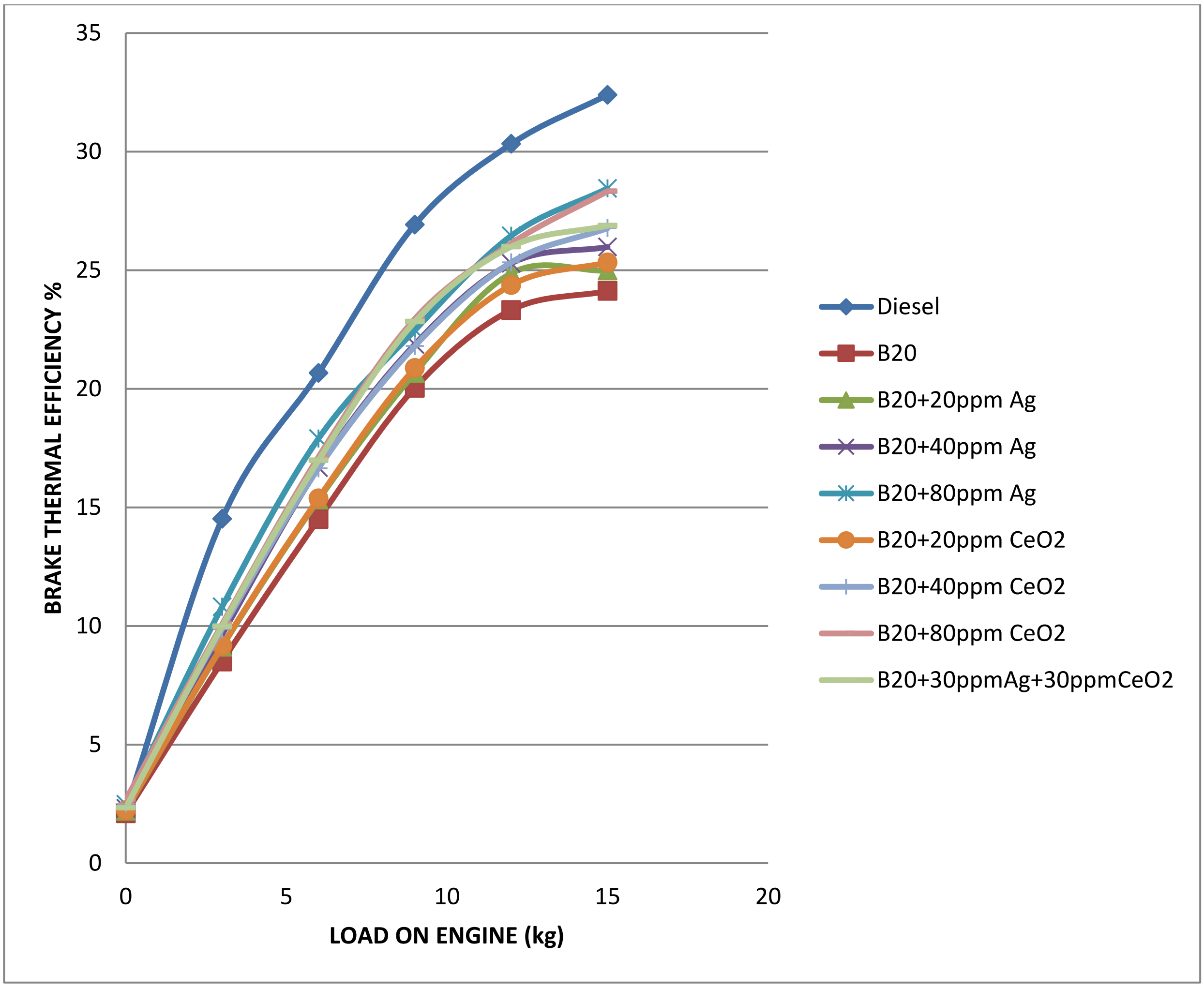


Figure 17 Variation of brake thermal efficiency with load

7.1.5 Indicated thermal efficiency

Figure shows the variation of indicated thermal efficiency for all the biodiesel blends with the variation of load. It was observed from graph that indicated thermal efficiency decreases gradually with increase in load. The indicated thermal efficiency observed for the blends Diesel, B20, B20+20ppm Ag, B20+40ppm Ag, B20+80ppm Ag, B20+20ppm CeO_2, B20+40ppm CeO_2, B20+80ppm CeO_2 and B20+30ppm Ag+30ppm CeO_2 at full load are 48.15%, 45.9%, 46.56%, 47.05%, 49.38%, 51.86%, 51.73%, 49.29% and 48.39% respectively. The maximum indicated thermal efficiency observed for the B20+20ppm CeO_2 was 51.86% at full load, which was 3.71% more than the Diesel. Cerium Oxide act as oxygen buffer and thus increases the efficiency.

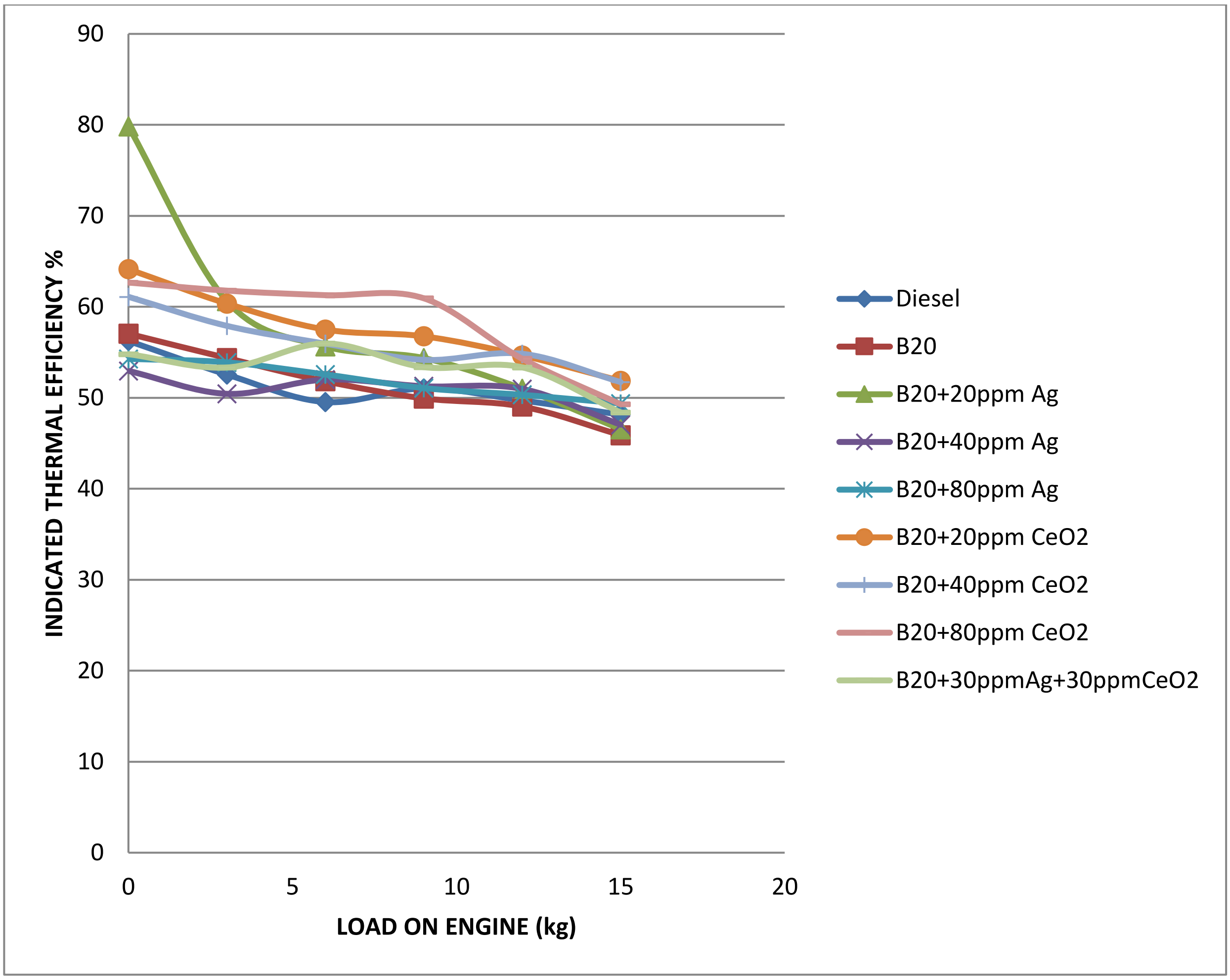


Figure 18 Variation of indicated thermal efficiency with load

7.1.6 Mechanical efficiency

The mechanical efficiency is the effectiveness of machine to transform the energy. It is the ratio of brake mean power to the indicated mean power. The figure depicts the variation of mechanical efficiency with the variation of load for the various blends. The mechanical efficiency increases with increase in load. The mineral diesel shows the highest mechanical efficiency among all the blends. The mechanical efficiency was 63.35%, 55.79%, 55.23%, 54.45%, 51.81%, 51.74%, 54.43% and 55.54% for B20, B20+20ppm Ag, B20+40ppm Ag, B20+80ppm Ag, B20+20ppm CeO_2, B20+40ppm CeO_2, B20+80ppm CeO_2, B20+30ppm Ag+30ppm CeO_2 respectively, which was 67.27% for the diesel. This is due to highest indicated for the biodiesel blends, resulted in lower mechanical efficiency for the biodiesel blends as compared to diesel.

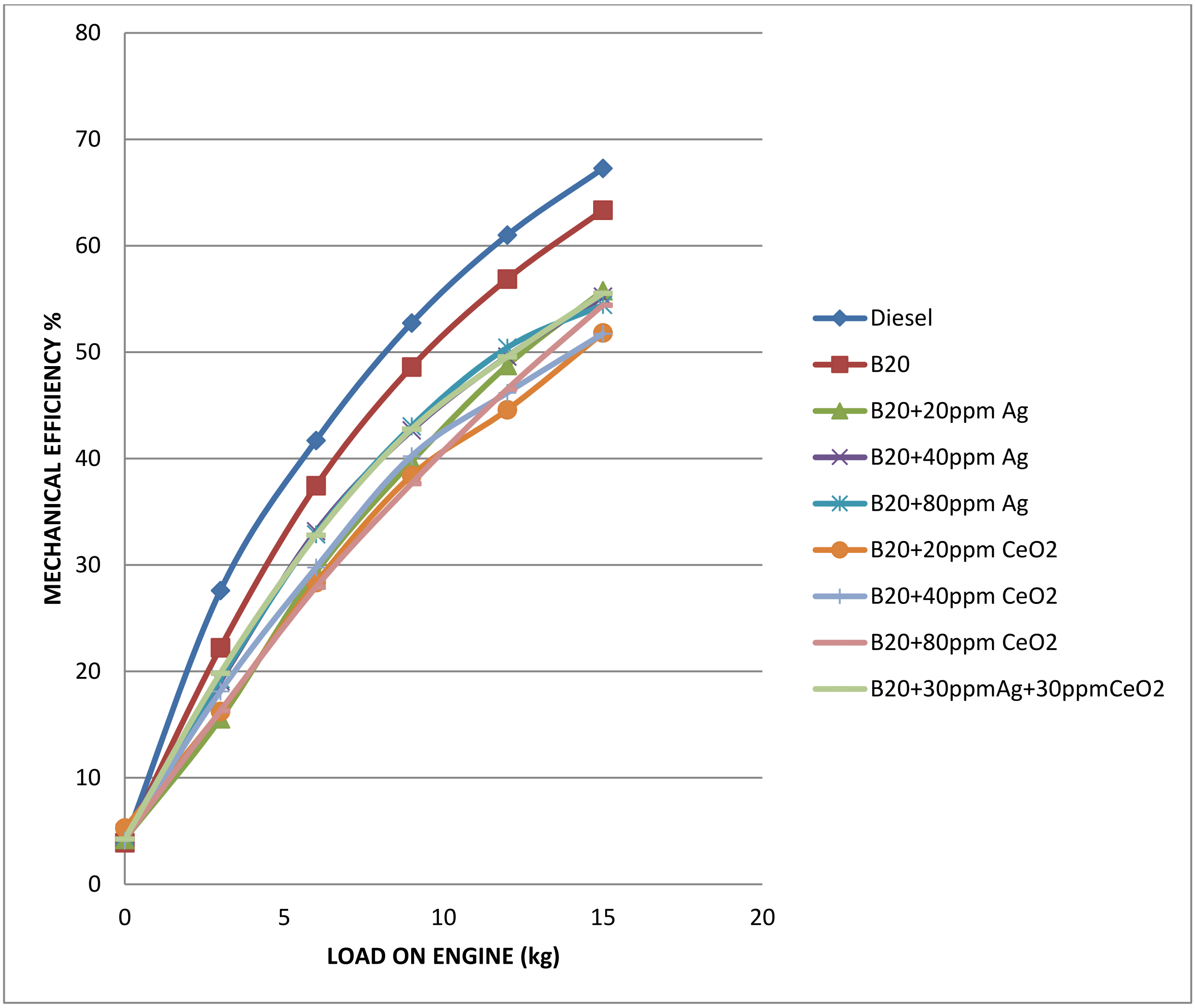


Figure 19 Variation of mechanical efficiency with load

7.1.7 Brake Mean Effective Pressure

The brake mean effective pressure is the average pressure that ensures useful work for the power of the engine. The graph shows the variation of brake mean effective pressure with the variation of load for the diesel and the biodiesel blends. The BMEP increases with increase in load for all the blends. The brake mean effective pressure for the diesel and the biodiesel blends was almost similar. B20, B20+20ppm Ag, B20+40ppm Ag, B20+80ppm Ag, B20+20ppm CeO_2, B20+40ppm CeO_2, B20+80ppm CeO_2, B20+30ppm Ag+30ppm CeO_2 shows 5.16, 5.18, 5.19, 5.18, 5.18, 5.16, 5.18, 5.17 bar respectively. The Brake mean effective pressure for diesel was 5.15 bar.

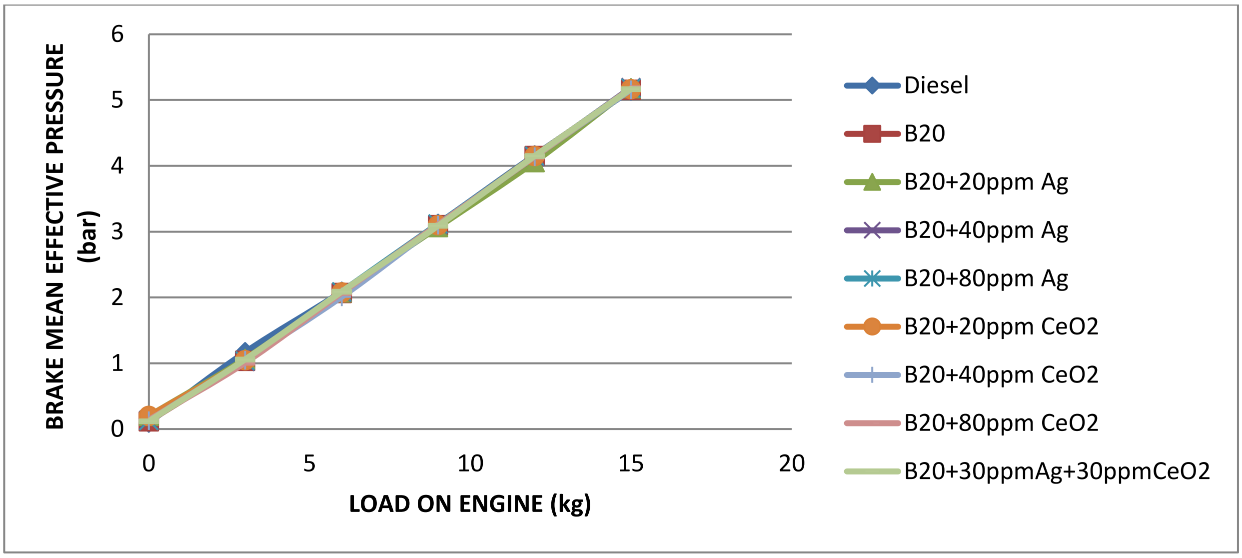


Figure 20 Variation of brake mean effective pressure with load

7.1.8 Indicated Mean Effective Pressure

The indicated mean effective pressure is the average pressure produces in the combustion chamber. The graph depicts the variation of indicated mean effective pressure with the variation of load for the diesel and biodiesel blends. The indicated mean effective pressure increases with increases in load for all the diesel and blends of biodiesel. The blend B20+20ppm Ag showed the highest IMEP at lower load conditions while blend B20+20ppm CeO_2 showed highest IMEP at higher load conditions as compared to other blends. The IMEP decreases as the concentration of the nanoparticles increases in the biodiesel blends. The highest IMEP pressure found for the B20+20ppm CeO_2 was 9.98 bar at full load of 15kg, which was 7.66 bar for the diesel.

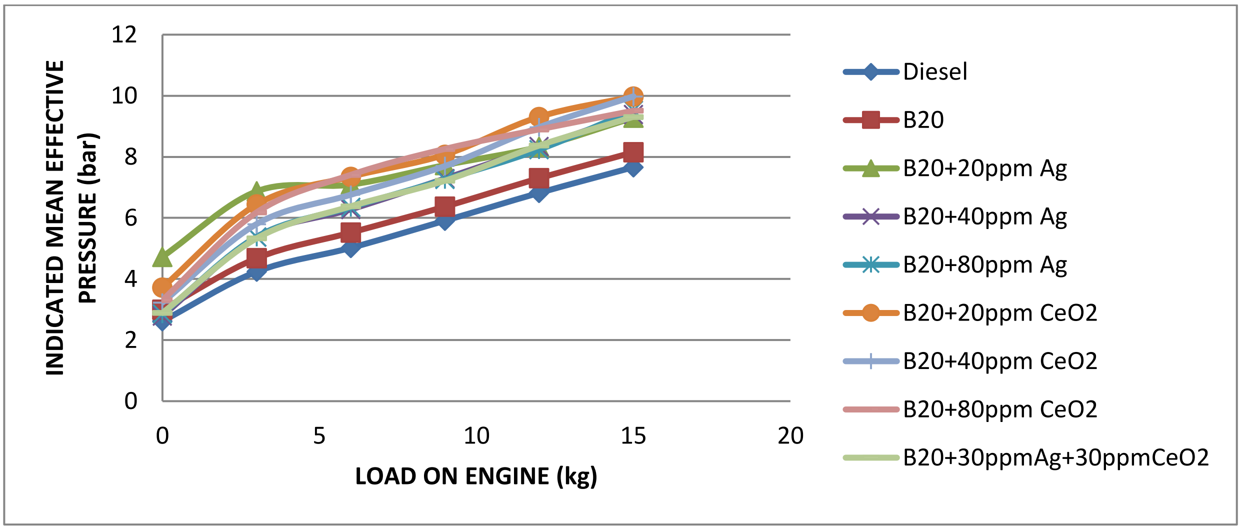


Figure 21 Variation of indicated mean effective pressure with load

7.2 COMBUSTION CHARACTERISTICS

The combustion characteristics like cylinder pressure and NHRR were observed for the diesel and its biodiesel blends. The results obtained were discussed below:

7.2.1 Cylinder pressure

In a CI engine combustion pressure indicates capability of fuel to mix well with air. The figure depicts the variation of cylinder pressure with the crank angle at full load. It was observed that combustion starts former for the biodiesel blends due to shorter ignition delay, which results in higher peak pressure. It was observed from the graph that biodiesel blends have higher cylinder pressure as compared to mineral diesel at peak load. Figure 22 shows the variation in pressure with crank angle for Argemone Mexicana biodiesel using cerium oxide and silver nanoparticle blended fuels. Combustion started later in comparison to diesel with biodiesel and biodiesel silver nano-particle including biodiesel cerium oxide nano-particle blended fuels. However increased catalytic activity observed with nano-particle blended biodiesel results in reduced delay period with combustion starting earlier as well.

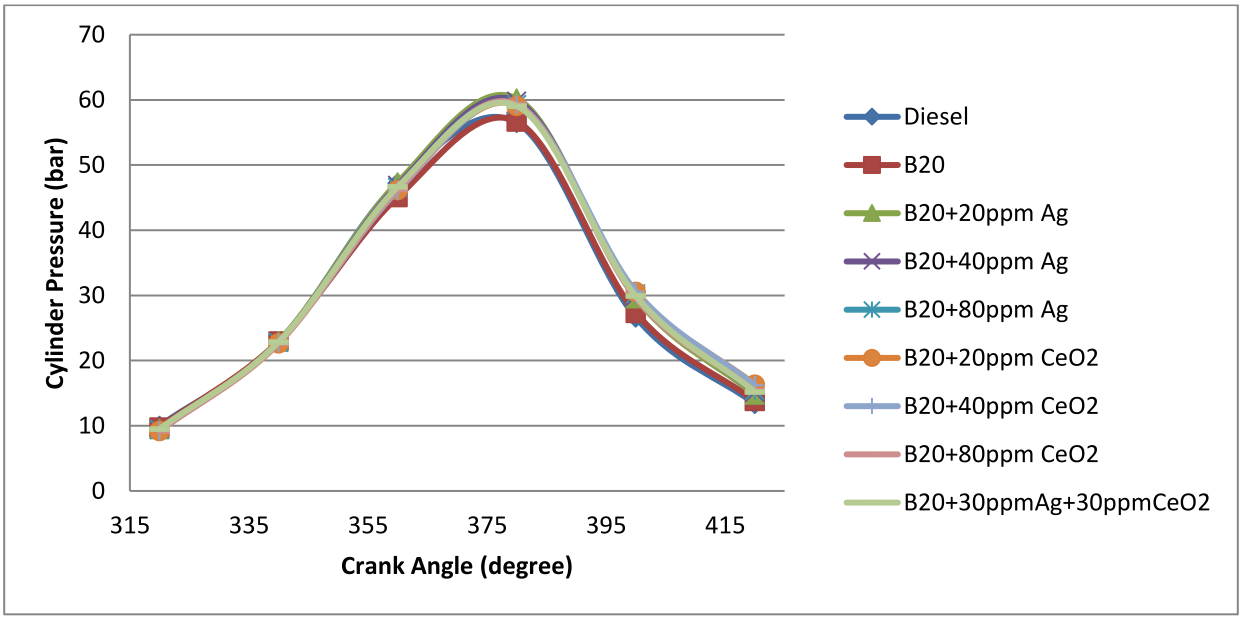


Figure 22 Variation of cylinder pressure with crank angle

7.2.2 Net heat release rate

Figure shows the variation of net heat release rate with crank angle at full load. It is observed that net heat release rate is higher for the diesel as compared to biodiesel blends. This may be due to better mixing of diesel fuel with air and its higher volatility. Another reason may be due to longer ignition delay of diesel as compared to biodiesel blends . The heat release rate for Argemone and its blends with nano-particles were lower compared to diesel operation. The maximum heat release for the diesel is 35J/deg. The reason for the lower heat release of biodiesel blends may be due to its lower calorific value as compared to the diesel.

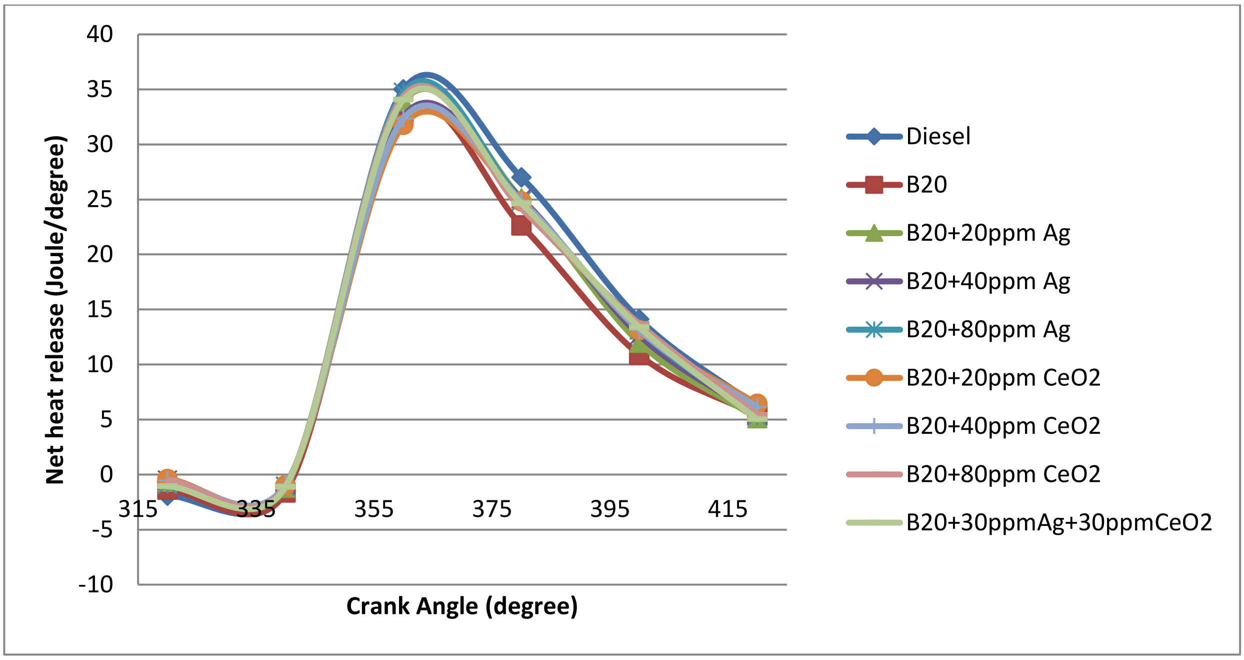


Figure 23 Variation of net heat release with crank angle

7.3 EMISSION CHARACTERISTICS

The emission characteristics like carbon monoxide, carbon dioxide, oxides of nitrogen and unburnt hydrocarbons were observed for the diesel and its biodiesel blends. The results obtained were discussed below:

7.3.1 CO Emission

The figure presents the variation of carbon monoxide with respect to load. Incomplete combustion of fuel results in formation of carbon monoxide. Diesel fuel does not contain any inherent oxygen, therefore combustion does not take place completely. As the biodiesel is oxygen rich fuel, therefore results in reduced carbon monoxide emission. The carbon monoxide produced during combustion of biodiesel might have been converted into CO_2 by the extra oxygen molecules present in the biodiesel chain. The carbon monoxide increases with increases in load for all the fuels. The carbon monoxide produced was less for all the blends as compared to diesel fuel. The carbon monoxide emission decreases with increase in biodiesel concentration with the additives. B20+80ppm Ag shows less level of CO emission at full load of 15 kg.

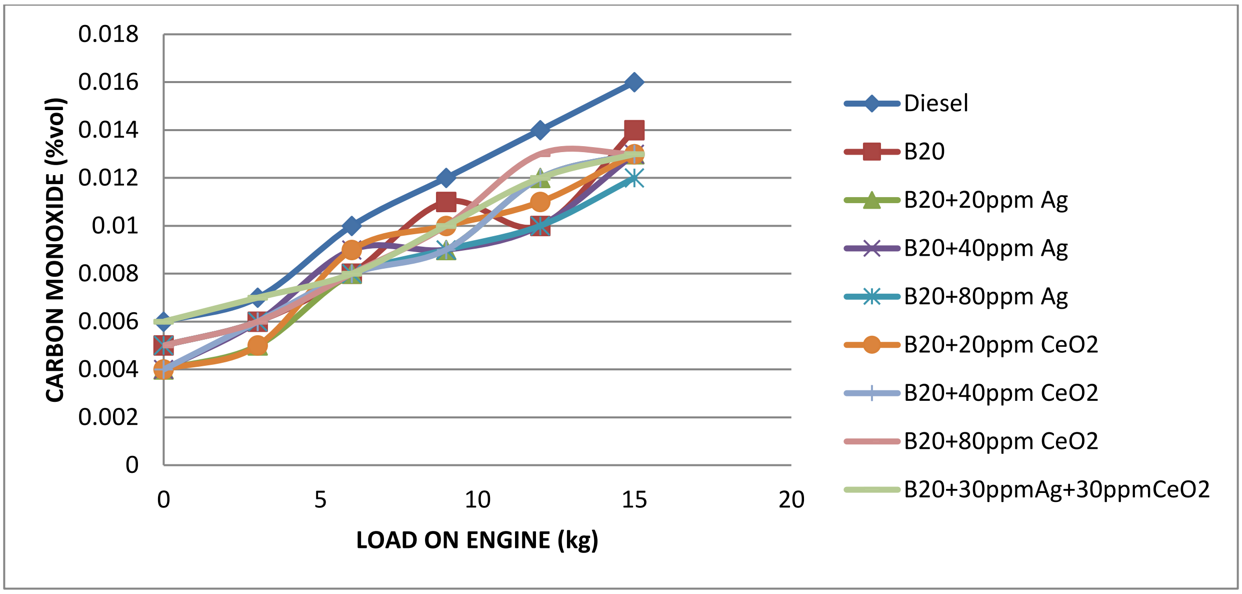


Figure 24 Variation of CO with load

7.3.2 HC Emission

The figure represents the variation of Hydrocarbons with respect to load. There is significant reduction in unburnt hydro carbons using biodiesel blends. It was observed that there is increase in unburnt hydrocarbons with increase in load and decrease with increase in amount of biodiesel in blend. HC emission is found to be significantly reduced on the addition of the additives. Cerium oxide supplies oxygen for the reduction of the hydrocarbons. An average reduction of 22% to 40% in the hydrocarbon emission was obtained for additives dosing level ranging from 40ppm to 80ppm of the additive.

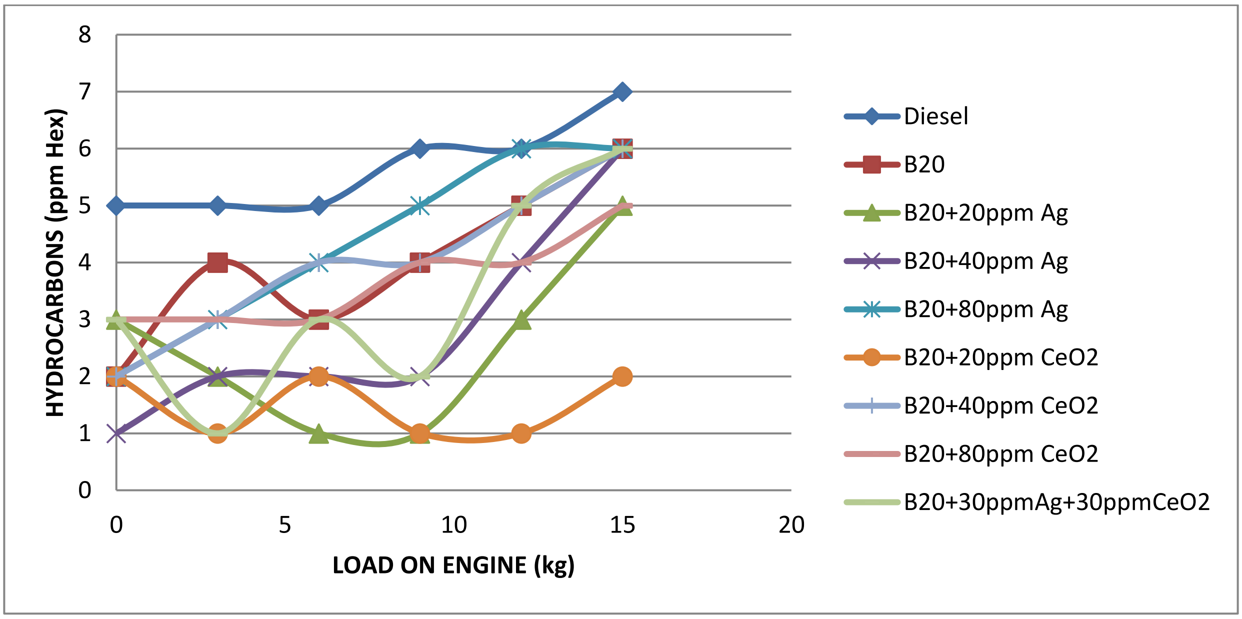


Figure 25 Variation of HC with load

7.3.3 Nitrogen Oxide emission

The figure represents the variation of Nitrogen Oxides with respect to load. The NOx emission increases with increase in load. At lower loads the NOx emission was more for the diesel as compared to biodiesel blends, but at higher loads the NOx emission was more for the biodiesel blends. The NOx emission was found to be generally reduced on the addition of cerium oxide and silver nano-particles to biodiesel. An average reduction of around 29% was found to occur with a dosing level of 80ppm. The behavior could be due to complex interaction among factors such as the combustion temperature, reaction time and the oxygen content. The increase in NOx emission for the biodiesel blend is due to higher combustion chamber temperature.

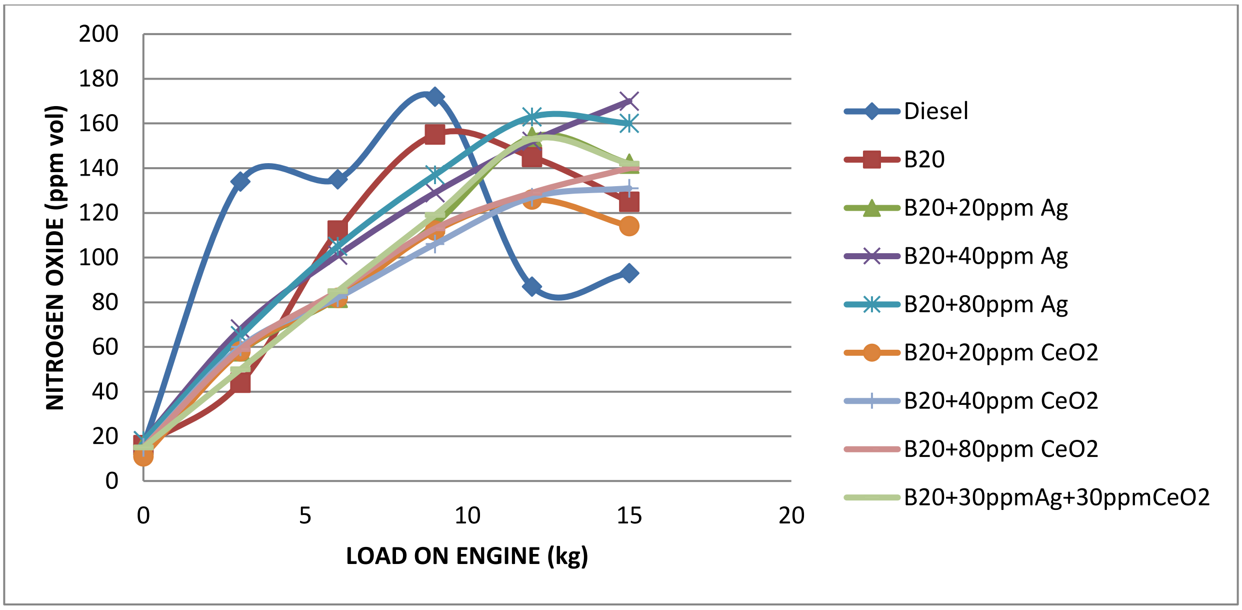


Figure 26 Variation of NO_x with load

7.3.4 CO_2 Emission

The graph shows the variation of carbon dioxide with the variation of load for the diesel and the biodiesel blends. The CO_2 formation is result of complete combustion. The more the CO_2 lesser will be the carbon monoxide. The lower percentage of blends B20 emits almost closer amount of CO_2 in comparison with diesel. This is due to low carbon content in biodiesel and has a lower elemental carbon to hydrogen ratio than diesel fuel. The CO_2 formation decreases with increase in concentration of biodiesel, which was due to higher density of biodiesel. Higher density of biodiesel results in incomplete combustion of fuel. Cerium oxide and silver nanoparticles properly blended with fuel blends and air which promotes the better combustion leading to higher CO2 emission than without nano additive blend.

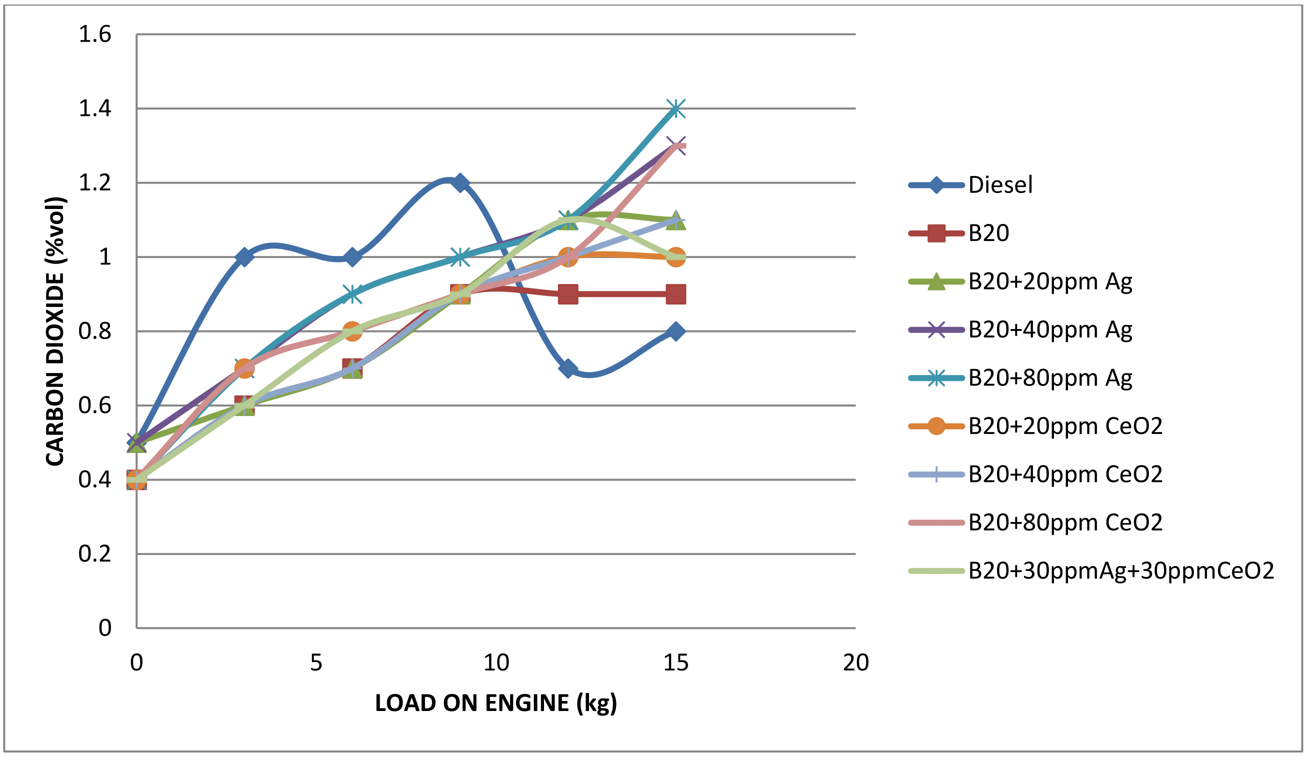


Figure 27 Variation of CO_2 with load

CHAPTER 8

Conclusion

It was concluded from the literature survey that biodiesel has similar properties as diesel. Oil extracted from non-edible seeds is used so that it does not affect the food sources. It can be used in diesel engines without any modification, due to high viscosity the problems may occur as choking of pipes, malfunction of nozzles etc. So blending biodiesel with diesel upto 20% may reduce the problems as well as increasing the performance and reducing the emission characteristics of an engine. It reduces the viscosity of fuel and flash point increases which helps in clean burning of fuel. 20% biodiesel and 80% diesel blends have maximum performance and fuel consumption is also less. It is also known as natural fuel. For increasing more performance and make the engine power effective nano particles are used in blends in the form of additives.

Nano-particles are latest upgrading concept in field of nanotechnology which give wide scope of research. These are mixed with blends to enhance the heat transfer coefficient and better thermophysical properties. Additives are then mixed in ppm (parts per million) ratio by weight. Silver nanoparticle provide higher surface area and higher thermal conductivity. Cerium Oxide acts as oxygen buffer and thus increases efficiency. It has also been observed that with increasing of dosing level of nano additives the performance is much improved as the contact ratio of fuel and fire during combustion increases with the high surface area. These properties provide increased reactivity and faster burning rates of fuel.

Some of the results are :

- Indicated power was higher for B20+20ppm Ag blend among all.
- Brake power was higher for B20+20ppm Ag blend.
- Specific fuel consumption is greater in diesel than biodiesel because of low calorific value and low heat content in it. As the value of additives vary increases the SFC value comes closer to diesel fuel.
- The highest brake thermal efficiency was found maximum for the diesel, which was 32.39%.
- Indicated thermal efficiency was higher for B20+20ppm CeO_2 blend.
- Mechanical efficiency of diesel is higher among all because of the low viscosity and

density values that affect the combustion process.

- Brake mean effective pressure comes closer to diesel. The blend B20+20ppm Ag showed the highest IMEP at lower load conditions while blend B20+20ppm CeO_2 showed highest IMEP at higher load conditions as compared to other blends. The IMEP decreases as the concentration of the nanoparticles increases in the biodiesel blends. The highest IMEP pressure found for the B20+20ppm CeO_2 was 9.98 bar.
- It was observed from the graph that biodiesel blends have higher cylinder pressure as compared to mineral diesel at peak load.
- It is observed that net heat release rate is higher for the diesel as compared to biodiesel blends. This may be due to better mixing of diesel fuel with air and its higher volatility. HC emission is found to be significantly reduced on the addition of nano additives.

CHAPTER 9

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