PERFORMANCE EVALUATION OF A 4-STROKE DIESEL ENGINE USING MORINGA BIODIESEL AS FUEL

A Project report submitted in partial fulfilment of the requirements for the award of the degree of

Bachelor of Technology
in
Mechanical Engineering

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CERTIFICATE

This is to certify that the Project Report entitled **"Performance and evaluation of a 4-Stroke diesel engine using moringa biodiesel as fuel"** being submitted by **S.Sai Rishikesh (319126520111), N.Lalitesh (319126520097), N.Sai Manideep (31926520098), D.Sai Kumar (319126520075), T.Gowtham Naidu (319126520113)** to the Department of Mechanical Engineering, ANITS is a record of the bonafide work carried out by them under the esteemed guidance of **Dr. K. NARESH KUMAR.** The results embodied in the report have not been submitted to any other University or Institute for the award of any degree or diploma.

18.4.23

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ABSTRACT

Biodiesel, which is a new, renewable and biological origin alternative diesel fuel, has been receiving more attention all over the world due to the energy needs and environmental consciousness. Biodiesel refers to a vegetable oil- or animal fat-based diesel fuel consisting of long-chain alkyl (methyl, propyl or ethyl) esters. Biodiesel is typically made by chemically reacting lipids [e.g. vegetable oil, animal fat (tallow)] with an alcohol. Biodiesel is meant to be used in standard diesel engines and is thus distinct from the vegetable and waste oils used to fuel converted diesel engines.

An experimental study has been conducted to evaluate and compare the use of Moringa oleifera as a full or partial supplement to conventional diesel fuel in IC ENGINES.

A series of tests have been conducted using each of the fuels in various proportions[B5,B10,B15,B25] with the engine working at a constant RPM of 1500 and at a different load ranges of 0 to 10kg. For each test performs the performance gauging parameters like mechanical efficiency, brake power, specific fuel consumption, Break power, Indicated power, Frictional power, Fuel consumption are calculated.

Flash and Fire point, Calorific value, Kinematic viscosity properties are calculated for the pure biofuel obtained from moringa oleifera oil.

Key Words : Moringa oleifera, RPM, Break power, Mechanical efficiency.

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NOMENCLATURE

η = Efficiency

IMEP = Indicated Mean Effective Pressure

FC = Fuel Consumption

CHAPTER 1
INTRODUCTION

1.1 Introduction to biodiesel

The geometric rise in world population has resulted in a subsequent increase in the demand for energy which can lead to insufficient energy supply. The effect of insufficient energy can be detrimental to the global economy which is dependent on energy. Fossil fuel has been a major source of energy production for some years now. However, fossil fuels are non-renewable energy sources and thus limited in supply. It also poses a lot of health and environmental problems. These energy resources are not evenly distributed around the world; they are more concentrated in some countries than others. Therefore, countries not having these resources are forced to import crude oil, thereby encountering challenges accompanied by importation such as foreign exchange crisis. These countries will seek for alternative fuels that can easily be produced from indigenous materials available within their country. Depletion in fossil fuel resources has led to the search for alternative fuels and also renewable energy resources. The Klass model for fossil fuel depletion predicts that crude oil resource will last for the next 35 years. This prediction is worrisome for world economic development and sustainability. However, these predictions, like other predictions, are not certain. In addition, the indiscriminate mining and consumption of fossil fuels have contributed to the reduction in petroleum reserves. The natural and renewable domestic fuel generally termed biofuel is considered as a promising and economical alternative and likewise a sustainable energy source. Biofuel is a fuel produced from any renewable biomass material. It is commonly used as an alternative, cleaner fuel source to burn fossil fuels. Biofuel can be produced from various materials which are in contrast with conventional diesel that can be produced from only a specific type of material. Liquid biofuel is a type of biofuel which is essentially employed in fuelling vehicles and sometimes engines. Biodiesel is a liquid biofuel produced through the process of transesterification which converts fat and oil into fatty acid alkyl ester and a co-product glycerol in the presence of an alcohol (methanol and ethanol; Figure 1) and the appropriate catalyst. The raw materials for biodiesel production include vegetable oils (edible or non-edible), yellow grease, used cooking oils, or animal fats. These fuel sources are said to reduce engine wear and produce less harmful emissions. Biodiesel sources should be of low production cost and have large-scale production. Certain factors that can influence the quality of biodiesel fuel include the type of raw feedstock used, the production process, and upstream production processes. Fuel quality issues are usually reflected in the contaminants or other minor components of biodiesel. Biodiesel made from vegetable oil has been reported to burn clearly, which significantly reduces pollutants contributing to smog and global warming. It is predicted that biodiesel will reduce dependence on fossil fuel and oil reserves. Biodiesel is renewable, biodegradable and non-toxic compared to conventional diesel.

1.2 Overview of bio energy

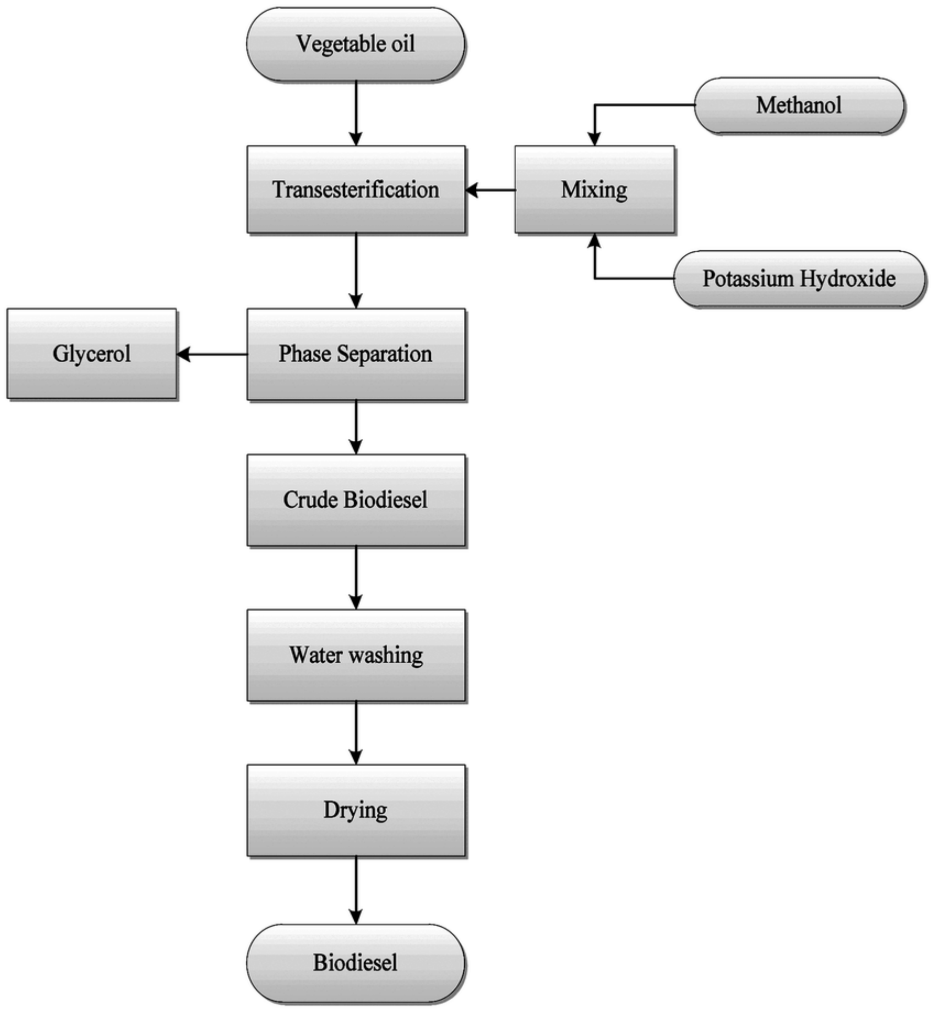
Bioenergy is one of the renewable energies. It's contained in living or biological organisms. Bioenergy can be gotten from organic matter, industrial, commercial or agricultural products. During plants growth, carbon dioxide is released, and its energy is classified as carbon-neutral known as bioenergy. Bioenergy covers two aspects, thus biofuel and biomass, Biofuel is the process where plants material is being transformed into liquid fuel while biomass is burning of plants material to create energy for use. This energy is used for transportation, heat and production of electricity.

1.3 Biomass energy

Biomass is an organic matter processed from plants and animal manure including trees, algae and crops. Biomass can also be obtained from plants and animal material, industrial, human and animal wastes. Plants absorb energy from the sun and use it to produce their food through photosynthesis; this energy therefore can be used as fuel that is obtained from burning biomass. Biomass releases heat and carbon dioxide during the burning process that is absorbed while the plant is growing. This energy can act as a form of renewable energy used directly thus for heating or cooking and indirectly by converting into liquid or gaseous fuel. At a constant rate, burning biomass produces heat water and steam to improve the environment as a clean or renewable energy. The advantages of biomass energy include less air emissions; reduction of landfills and reliance on foreign oil. As non-renewable, fossil-based fuel resources are depleting, research and development on alternative renewable energy is growing. Biodiesel has advantage over petroleum diesel when compared. For example, biodiesel produces lower exhaust emissions, biodegradable, non-toxic, renewable and essentially free of sulphur making biodiesel a renewable energy and environmentally friendly towards sustainable resource. In most countries within the sub-region, there are several forest plant species, which have seeds from which oil could be produced. Vegetable oils are obtained from seeds and fruits of plants, which can be found in different parts of the world.

1.4 Fuel properties and specification of biodiesel

In view of environmental considerations, biodiesel is considered as 'carbon neutral' because all the carbon dioxide (CO2*)* released during consumption had been-sequestered from the atmosphere for the growth of oil crops. Commercial experience with biodiesel has been very promising. The biggest advantages of biodiesel compared to many other alternative transportation fuels is that it can be used in existing diesel engines without modification and can be blended with petroleum diesel in required ratio. Biodiesel performs as well as petroleum diesel, while reducing emissions of particulate matter, carbon monoxide (CO), hydrocarbons and oxides of sulphur (SO_x) . Emissions of oxides of nitrogen (NO_x) are, however, higher for biodiesel in many, mainly direct injection engines. Biodiesel virtually eliminates the notorious black soot emissions associated with diesel engines and the total particulate matter emissions are also much lower. Other environmental benefits of biodiesel include the fact that it is highly biodegradable and appears to reduce emissions of air toxics and carcinogens (relative to petroleum diesel). The environmental benefits of 100% and 20% biodiesel blending, in terms of pollutants emission reductions. Usage of biodiesel will allow a balance to be sought between agriculture, economic development and the environment.



1.5 History of moringa oleifera

Moringa was discovered in northern India around 2000 BC. Traditional doctors quickly discovered its medicinal impact and called it "The Miracle Tree". Aristocracy and members of royal families were taking Moringa for its beneficial effects on mental alertness and healthy skin. It became an integral part of traditional Ayurvedic medicine. In ancient India they gave Moringa extract to Mauryan fighters on war fronts. They believed that it would give them the necessary strength and energy during the fights, and at the same time relieve the stress of battle and pain from injuries.

The ancient Egyptians highly valued Moringa oil, which was used instead of sunscreen. However, on the European it was the ancient Greeks, who discovered a number of other valuable Moringa effects on human health. In the later period they introduced Moringa to the Romans, who spread it throughout their empire.

In modern history, back in 1817, the Jamaican (at that time still a British colony) chamber was discussing Moringa. At the official hearing they introduced Moringa oil, as a healthful ingredient for salads and for other culinary purposes. Within the British Empire Moringa expanded into many other countries around the world.

Today, you can find quality Moringa in the Philippines, eastern India, China, South Africa and Southeast Asia. Moringa trees are grown mainly in tropical and subtropical areas. Moringa tree is a very undemanding plant that paradoxically thrives even in dry sandy soils and up to higher altitudes. Highly prized and used in the Himalayas.

Moringa can therefore be found in many countries under different names: Malunggay (Philippines), Horseradish Tree, Drumstick Tree, Marang, Mlonge, Saijhan, Shecaga, Sajn, Kamungay and many others.

1.6 LAB EQUIPMENT USED:

1.6.1 Magnetic stirrer

A magnetic stirrer is a device widely used in laboratories and consists of a rotating magnet or a stationary electromagnet that creates a rotating magnetic field. This device is used to make a stir bar, immerse in a liquid, quickly spin, or stirring or mixing a solution, for example. A magnetic stirring system generally includes a coupled heating system for heating the liquid Much of the current magnetic stirrers rotate the magnets by means of an electric motor. This type of equipment is one of the simplest to prepare mixtures. Magnetic stirrers are silent and provide the possibility of stirring closed systems without the need for isolation, as in the case with mechanical agitators.

Because of their size, stir bars can be cleaned and sterilized more easily than other devices such as stirring rods. However, the limited size of the stir bars enables using this system only for volumes less than 4 L. In addition, viscous liquid or dense solutions are barely mixed using this method. In these cases, some kind of mechanical stirring is usually required.

Fig. 1.1 magnetic stirrer

1.6.2 Separating funnel

A separating funnel takes the shape of a cone with a hemispherical end. It has a stopper at the top and stopcock (tap), at the bottom. Separating funnels used in laboratories are typically made from borosilicate glass and their stopcocks are made from glass or PTFE. Typical sizes are between 30 mL and 3 L. In industrial chemistry they can be much larger and for much larger volumes centrifuges are used. The sloping sides are designed to facilitate the identification of the layers. The stopcock-controlled outlet is designed to drain the liquid out of the funnel. On top of the funnel there is a standard taper joint which fits with a ground glass or Teflon stopper. Typical sizes are between 30 mL and 3 L. In industrial chemistry they can be much larger and for much larger volumes' centrifuges are used. The sloping sides are designed to facilitate the identification of the layers. The stopcock-controlled outlet is designed to drain the liquid out of the funnel. On top of the funnel there is a standard taper joint which fits with a ground glass or Teflon stopper.

To use a separating funnel, the two phases and the mixture to be separated in solution are added through the top with the stopcock at the bottom closed. The funnel is then closed and shaken gently by inverting the funnel multiple times; if the two solutions are mixed too vigorously emulsions will form. The funnel is then inverted, and the stopcock carefully opened to release excess vapor pressure. The separating funnel is set aside to allow for the complete separation of the phases. The top and the bottom stopcock are then opened, and the lower phase is released by gravitation. The top must be opened while releasing the lower phase to allow pressure equalization between the inside of the funnel and the atmosphere. When the bottom layer has been removed, the stopcock is closed, and the upper layer is poured out through the top into another container

Fig 1.2 Separating funnel

1.6.3 Beaker (borosil)

Borosil Low Form Griffin Beakers are the ideal container for use when stirring, mixing or heating liquids. Each beaker has controlled wall thickness at the side, radius, and base which aids in the balance between thermal resistance and mechanical strength, allowing for uniform heating throughout.

Fig 1.3 beaker (borosil)

1.6.4 Spatula

A spatula is a broad, flat, flexible blade used to mix, spread and lift material including foods, drugs, plaster and paints. In medical applications, "spatula" may also be used synonymously with tongue depressor. The word *spatula* derives from the Latin word for a flat piece of wood or splint. The spatula-spoon can be used in many different applications. The double-sided multi-purpose spoon is a spoon on one side and a spatula on the other. This makes it possible to sample and process a variety of media such as powders, granulates, pastes and liquids. The spoon side of the spoon-spatula holds 4 ml (about 0.14 oz) or 11 ml (about 0.37 oz) respectively.

Fig 1.4 spatula

In British English a spatula is similar in shape to a palette knife, without holes, in a flexible or detachable blade. It is used in medical examinations, for holding down the tongue or taking cell samples. The term is also commonly used in cookery to refer to a scraper, as in American English.

1.6.5 Weighing balance

A weighing balance is an instrument which is used to determine the weight or mass of an object. Available in a wide range of sizes with multiple weighing capacities they are essential tools in laboratories, commercial kitchens and pharmacies to name but a few. Typically balances use a force restoration mechanism that when a force is applied (i.e. a load or weight), the balance counteracts this force exerted from the unknown mass. Balances are generally more sophisticated and precise than scales and are therefore commonly used by professionals for advanced scientific weighing in the following industries:

Fig 1.5 weighing balance

1.6.6 Heating Mantel

Heating mantles are used for heating or tempering organic liquids placed in reaction kettles, round-bottomed flasks, or relevant reaction vessels required for the boiling, evaporation, distillation, or extraction process. The products are designed using all-fiberglass or have an aluminium outer shell and are available in many sizes. Heating mantles are available as stirring or non-stirring types, with controllers and without controllers. The products can obtain different ranges of temperature and have varied temperature regulation levels. Heating mantles provide short heat-up duration, even distribution of heat without creating condensed water, and are used in laboratories. The products do not produce flames and are safe for heating above 100 °C.withstands high temperatures up to 350ºC.

The body of the mantle is spun one piece from non-rusting Aluminium (upto 5.0 Litres Capacity) duly painted. All heating mantles are lagged with special grade mineral wool.

Fig 1.6 heating mantel

1.6.7 Thermometer

Thermometer (thermos: hot; metron: measure) is the universal instrument used to measure temperature. Temperature and heat are two words that often confuse people. For example, how do you explain the hotness of an object? What is the measure or basis for that hotness? The answer to that is temperature. Heat is a form of energy, and its unit is Joules. On the other hand, temperature is the measure of that heat. This means, if the heat is more, the temperature is more than well. But how do we measure temperature? We use a device called a thermometer to measure the temperature of any object.

- Since clinical thermometers can’t be used to measure temperature other than the human body, we need a special type of thermometers for other purposes.
- Since clinical thermometers can’t be used to measure temperature other than the human body, we need a special type of thermometers for other purposes.
- It ranges from -10˚C to 110˚C.

Fig 1.7 thermometer

CHAPTER 2
Literature Review

2.1 Literature

Based on the referred generals we shorted out the procedure for biodiesel production and what are the parameters to be determined. The generals what we have referred are given below

1. **Samuel Sanni et.al[5] [2021]** Have conducted experimental investigation on engine performance of a dual-fuel compression-ignition engine operating on hydrogen-compressed natural gas and Moringa biodiesel. They have observed that the engine break thermal efficiencies (BTE) were substantially improved by the fuel blends. Also, they gave higher peak cylinder pressures than the unblended HCNG fuel which confirms the suitability of Moringa biodiesel as a very promising additive CNG.
2. **Naresh Kumar Konada etal[2] [2020] Has done** Experimental investigation on performance, smoke and exhaust gas analysis of four stroke diesel engine using pongomia/neem oil biodiesel and concluded that A series of tests were conducted using each of the fuels in various proportions with the engine working under the constant speed of 1500 rpm, and at different loads ranging from no load to full load. For each test performed, the performance gauging parameters such as fuel consumption, thermal efficiency, mechanical efficiency, mean effective pressures etc. were computed. The experimentation also involved measurement of smoke intensity levels and Exhaust.
3. **P. Udayakumar etal[2] [2021]** Have conducted experimental investigation on CI engine filled with linseed oil with di-ethyl carbonate. They have concluded that the expansion of Linseed oil in a diesel without added substance expands its thickness; consistency and oxygen content yet diminish the calorific estimation of the blends. The BTE of fuel continues expanding as the measure of linseed oil increments in the mixes and simultaneously decreases the Brake specific fuel utilization as the load increments. The emissions were influenced as the estimation of NOx, CO2, CO; HC discharges are least for B20.
4. **Nagaraj Kinnal etal[3] [2018]** conducted experimental investigation on engine performance using waste chicken fat biodiesel. They have observed that Brake Thermal Efficiency (BTE) of biodiesel and its blends are slightly higher than that of diesel at high engine loads and keep almost same at lower engine loads. So, they give good results for BTE
5. **Shubham Awasthi** conducted a performance evaluation on a 3.5kW diesel engine fuelled with blended biodiesel of mustard oil. They have observed that the maximum

limit of the blending is 30% but the most feasible blending is B20. It gives better performance like high break thermal efficiency and low specific fuel consumption. High power is also reported by many other researchers, and it may be due to better lubricity which reduces friction loss and better combustion of blends.

6. **Siva Prasad Kondapalli [2015]** Have done an experimental investigation on 4-stroke diesel engine using waste cooking oil biodiesel fuel. Its been observed to produce higher mechanical efficiencies are obtained at fuel injection pressure 225 barfor all compositions of fuels.
7. **V. Dhana raju etal[2] [2018]** Have done experimental investigation on Four Stroke Diesel Engine Fuelled with Tamarind Seed Oil as Potential Alternate Fuel for Sustainable Green Environment, tamarind seed oil was considered as potential alternate fuel for diesel in compression ignition engine. The performance, combustion, and emission characteristics of tamarind seed biodiesel blends along with n-Amyl alcohol as an oxygenated fuel additive for TSME20 are evaluated and compared with base fuel.
8. **Kiran Avns etal[3] [2017]** Have done experimental investigation on four stroke CI engine with different blends of Cotton Seed and Coconut oil and the performance was evaluated and compared with diesel. The Thermal efficiency of the engine is comparatively more when it is blended with coconut oil and increased by 5.33 % than Cotton seed oil and 26.31 % with coconut and cotton seed oils blends. It is observed that among the coconut oil blend B10 performed better in terms of engine performance, compared to the other blends of cotton seed oil and coconut and cotton seed oils blends. Even though the viscosity of the coconut oil is low and is economically friendly.
9. **G. Purna chandra rao etal [2] [2017]** The experiment compares the performance and emission characteristics of diesel engine by using Jatropha oil and diesel which supercharger. It is observed that biofuel gives the higher break thermal efficiency and mechanical efficiency by using supercharger By varying the Blend mixture ratio and find out the engine performance and its emission characteristics. In three cases we are considered investigating the diesel engine performance, evaluation and emission characteristics, those are bio-diesel blend mixture ratios, super charger with bio-diesel blend mixture ratios. As a result, the efficiencies of J20% + D80% which contain Super charger produced the best results for bio fuel blend ratios in diesel engine.

10. **Puneet Verma etal[5] [2020]** Has done Experimental investigation of diesel engine fuelled with different alkyl esters of Karanja oil and conclude that In the present study, the biodiesel fuel was derived from Karanja oil by using different alcohols such as propanol, buranol, methanol and pentanol and their different blends prepared by using diesel such as $KOME_{20}$, $KOEE_{20}$, $KOPE_{20}$, $KOBE_{20}$ and $KOPnE_{20}$. The experimental test were performed at different engine loads (25%, 50%, 75% and 100%) and at a constant compression ratio of 15.5 CR and at 1500 rpm engine speed
11. **Mohankumar Subramaniam etal[4] [2020]** Has done Experimental investigation on performance, combustion and emission characteristics of DI diesel engine using algae as a biodiesel and conclude that NOx emission linearly increases with the applied load for both the fuels. However, for algae blends, it reduces significantly from no load to full load. A100 shows maximum reduction of around 39% while compared with diesel and other blends.
12. **Ranjit P.S. etal[8] [2021]** Has done Experimental investigations on gaseous hydrogen supplemented Aleurites Fordii biodiesel in a direct injection diesel engine for performance enhancement and reduction in emissions and concluded that biofuel gives the higher break thermal efficiency and mechanical efficiency by using supercharger By varying the Blend mixture ratio and find out the engine performance and its emission characteristics. In three cases we are considered investigating the diesel engine performance, evaluation and emission characteristics, those are bio-diesel blend mixture ratios, super charger with bio-diesel blend mixture ratios

13. **Sunil Kumar S. etal[3] [2020]** Has done Experimental investigation to optimize fuel injection strategies and compression ratio on single cylinder DI diesel engine operated with FOME biodiesel and concluded that The experiments were conducted using clean diesel and FOME biodiesel blends on a VCR engine, which is suitable for running on bio-fuel and the following conclusions were drawn.The biodiesel viscosity and density are comparatively close properties with diesel and also the biodiesel C.V is less i.e. 39500 kJ/kg. The observations of this comprehensive study reveal that the blend B40D60 gives superior results than the other blends at CR17.5:1 and pressure 260 bar. This is due to complete combustion.

14. **Ilker Temizer etal[2] [2020]** has done Numerical and experimental investigation of the effect of biodiesel/diesel fuel on combustion characteristics in CI engine and concluded that Experiments performed on a single cylinder, direct injection diesel engine, it used as fuel of diesel fuel and 10%, 20% and 30% of SOME was added to diesel fuel. The engine is operated at 2000 rpm and full load. Combustion analyses in the engine were performed both experimental and numerically. The numerical study was carried out in the ESE-DIESEL part of AVL-FIRE software. Experimental engine parameters had been entered as the initial condition to make a realistic modeling in AVL-FIRE
15. .**Kakala Sanjeevarao etal[3] [2021]** has done Experimental investigation on VCR diesel engine fuelled with Al_2O_3 nanoparticles blended cottonseed biodiesel - diesel blends and concluded that Diesel has high calorific value compared to cottonseed biodiesel. But the addition of aluminium oxide nano particles improves the calorific value and nearly reaches to standard diesel calorific value. The 1% improvement in BTE observed with B20ANP100ppm compared to diesel. B20 and B50 with 50 ppm and 100 ppm nano additive samples shows slight increment in BSFC compared to standard diesel. The CO and HC emissions were reduced by 6% and 12% respectively with B20ANP100ppm compared to standard diesel. CO_2 emissions of all the samples is more compared to diesel.
16. **Abhishek Sharma etal [4] [2020]** Has done Experimental investigation of the behaviour of a DI diesel engine fuelled with biodiesel/diesel blends having effect of raw biogas at different operating responses and concluded tha Thermal efficiency (greater than26%) was observed with PBD fuel mode at 1508 engine RPM at more than 70% engine load. The maximum range of VE (more than 68%) was found with diesel fuel mode at up to 6.5 kg of engine load at 1508.

17. **T. Deepak Kumar etal[3] [2021]** Has done Experimental investigation on influence of metal based additives on diesel engine along with biodiesel blends and concluded that Brake Thermal efficiency is slightly improved by the addition of nanoparticle, Brake Specific Fuel Consumption decreases by 6.11% and 8% forMetal Oxides additive with the addition of Biodiesel to diesel, The unburnt hydrocarbons (UBHC) and Carbon Monoxide (CO) both decrease by about 17% for the additives. Because of hydro-carbons chain one end is oxygenated due to oxygen HC, CO decreases and CO becomes CO_2

2.2 Scope of the work

Biofuel is a type of fuel whose energy is derived from biological carbon fixation. Biofuels include fuels derived from biomass conversion, as well as solid biomass, liquid fuels and various biogases. Although fossilfuels have their origin in ancient carbon fixation, they are not considered biofuels by the generally accepted definition because they contain carbon that has been "out" of the carbon cycle for a very long time. Biofuels are gaining increased public and scientific attention, driven by factors such as oil price hikes, the need for increased energy security, concern over greenhouse gas emissions from fossil fuels.

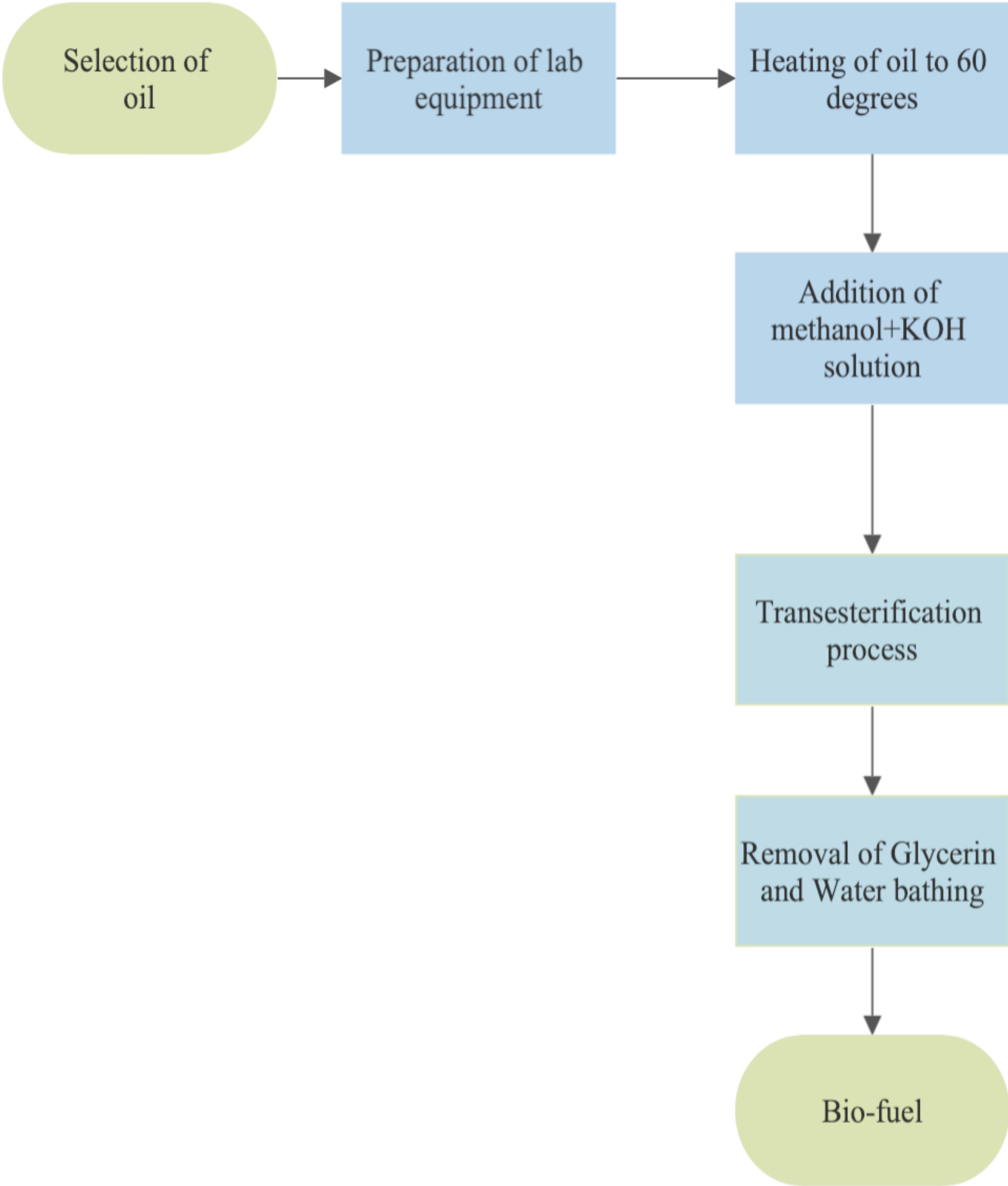
In 2010 worldwide biofuel production reached 105 billion liters (28 billion gallons US), up 17% from 2009, and biofuels provided 2.7% of the world's fuels for road transport, a contribution largely made up of ethanol and biodiesel. Global ethanol fuel production reached 86 billion liters (23 billion gallons US) in 2010, with the United States and Brazil as the world's top producers, accounting together for 90% of global production. The world's largest biodiesel producer is the European union, accounting for 53% of all biodiesel production in 2010. As of 2011, mandates for blending biofuels exist in 31 countries at the national level and in 29 states/provinces. According to the International Energy Agency, biofuels have the potential to meet more than a quarter of world demand for transportation fuels by 2050.

2.3 Identification of the problem

In the past few decades, fossil fuels have remained the most predominantly available energy-fuels. The combustion of these fuels in CI engines release substances such as CO, CO2, NOx, hydrocarbons, soot, particulate matter, dust and other gases which have severe consequences on the environment. Also, due to environmental concerns and energy shortages arising from fossil consumption, efforts are in place towards exploiting alternative fuels for use in CI engines; this is aimed at reducing exhaust emissions with the desire to improve engine efficiencies; the use of CNG in CI engines considerably reduces environmental pollution, engine vibration and noise, with a significant improvement in the engine brake-thermal efficiency CI engines are known to be compatible with some gaseous fuels and their blends owing to their improved combustion properties when compared to diesel fuels.

According to literature, some biofuels mixed with natural gas, release low amounts of NOx, soot, CO2 and hydrocarbons as products of combustion, whereas, diesel fuelled CI engines give higher emissions. CNG is clean compared to diesel fuels. Natural gas is an alternative source of fuel with high octane numbers. It mixes homogeneously with air, which pro- motes excellent combustion and high thermal efficiencies when compared to diesel fuels at high engine loads.

2.4 Methodology



The above procedure was chosen after reviewing several reports.

CHAPTER 3
SYNTHESIS OF BIOFUEL

3.1 Procurement of Moringa oleifera oil:

Korus Essentials is an oil company which sells pure Moringa Oleifera oil online. 1600millilitres of moringa oil was ordered online through Amazon buy.

Fig 3.1 Moringa oil

3.2 Moringa Oil heating using hot plate and magnetic stirrer:

200ml (about 6.76 oz) of Moringa oleifera oil is taken in a flask. The apparatus is then shifted onto a hot plate with magnetic stirrer. The hot plate temperature is set to 60 degree celsius and stirrer at 520rpm. The apparatus is then left undisturbed until the oil temperature reaches 59-60 degree celsius.

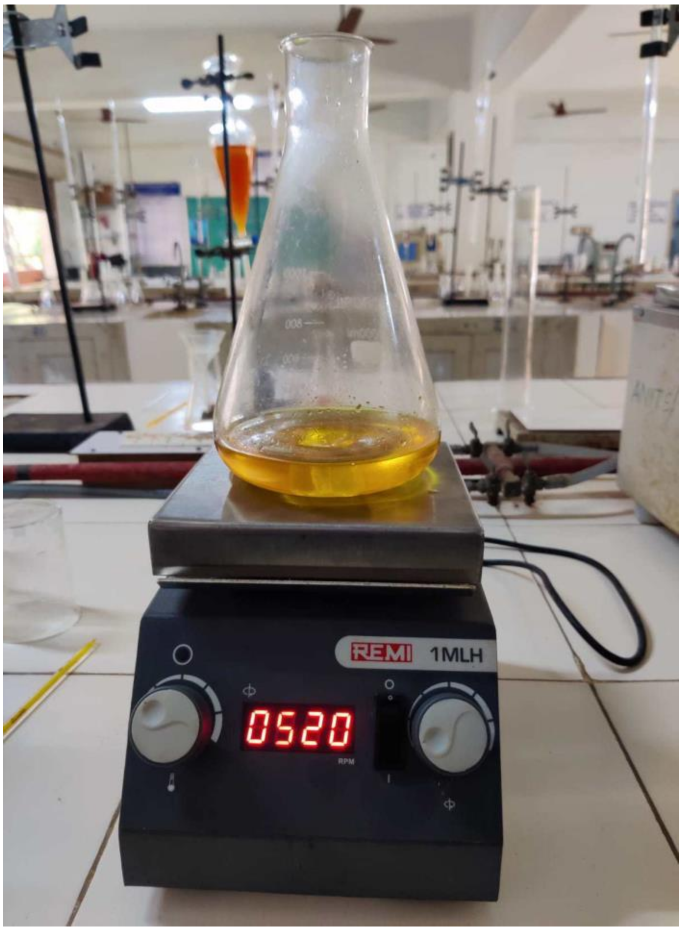


Fig 3.2 Heated oil

3.3 Preparation of methanol+KOH solution

While the oil is being heated on a hot plate. 40 ml(1:5 ratio to oil volume) is taken in a beaker. 1.8 grams (1% wt of oil) of KOH pellets is added to the methanol beaker.The mixture is then stirred using a magnetic stirrer until all the KOH pellets are dissolved.

The beaker is covered on top using a glass plate to stop methanol from escaping the beaker sue to stirrer heat or by spillage.

3.4 Combining Methanol+KOH solution to heating oil

(Transesterification):

After the temperature of oil reaches ~60 degree celsius, methanol and KOH solution is added to the heated oil from the top.

Fig 3.3 Methanol+KOH+heated oil solution

The solution is then covered on top using a glass plate to avoid chemicals from evaporating. The solution is then left undisturbed with stirrer at 520rpm and temperature being maintained between 60-64 degree celsius. The temperature is checked every 5 mins so as to ensure not to cross 64 degree celsius as it will result in the evaporation of methanol in solution. The solution is left alone for 90 minutes for transesterification to complete.

3.5 Transferring solution into separating funnel:

After 90 mins of transesterification, the solution in flask is then transferred into a separating funnel. Formation of glycerol and biofuel layers can be seen after transfer which ensure that transesterification process is done.

Fig 3.4 Heated oil+Glycerin

The apparatus is then left undisturbed for 6-7 hours in order for the glycerol and biofuel to separate completely and form layers. Glycerol and biofuel gets separated and form layers because of the difference in density.

3.6 Water washing and water bathing:

After 6-7 hours, the glycerol is taken out using separating funnel knob at the bottom. Fuming hot distilled water is then added from the top of the funnel. The apparatus is then left undisturbed for few minutes, in order for the water and oil to separate. The hot distilled water is then filtered out from the bottom. This procedure is repeated for 2-3 times to remove any remaining glycerol in the funnel.

Fig 3.5 Hot distilled water+biofuel

After that, the biofuel is taken in a flask filled with distilled water. The flask is then transferred onto a heating mantel. The flask is heated until the appearance of bubbles is seen.

Bubbles start emerging from the bottom of the flask and rise up towards the surface. This procedure is done so as to remove any excess methanol left in the biofuel. After the appearance of bubbles, the flask is taken out the heating mantle and then shared vigorously. Then the mixture is transferred onto a separating funnel. It is then left undisturbed for a few minutes in order for the distilled water and fuel to get separated. Distilled water is then taken out from separating funnel.

The above procedure is repeated 2-3 times until clear biofuel is obtained.

3.7 Heating:

Fig 3.6 Clear Biofuel obtained

After obtaining biofuel. It is then heated to 110 degree celsius. This is done in order to ensure any distilled water in the fuel evaporates completely.

3.8 Blending of biofuel with diesel:

Table 3.1

Blends	Diesel	Biofuel	Total volume
B5	1140	60	1200
B10	1080	120	1200
B15	1020	180	1200
B25	900	300	1200

Four different types of blends were taken as shown in the above table. Total volumes of 1200 ml per each blend is taken. Blending of biofuel and diesel is done using a conical flask and magnetic stirrer. The blend is stirred for about 10 minutes.

Fig 3.7 Before Blending

CHAPTER 4
EXPERIMENTAL PROCEDURE

4.1 PRELIMANARY THEORY

Engine: Engine is a mechanical device used to convert one form of energy to mechanical energy or vice versa.

Heat Engine: Heat engines are used to convert chemical energy of the fuel into heat energy which is used to do work. They are classified into two categories:

Internal Combustion Engine (ICE): It is a type of heat engine where combustion happens inside a sealed chamber.

External Combustion Engine (ECE): It is a type of heat engine where combustion happens outside the chamber and heat energy is carried to the place where working fluid is heated to give work.

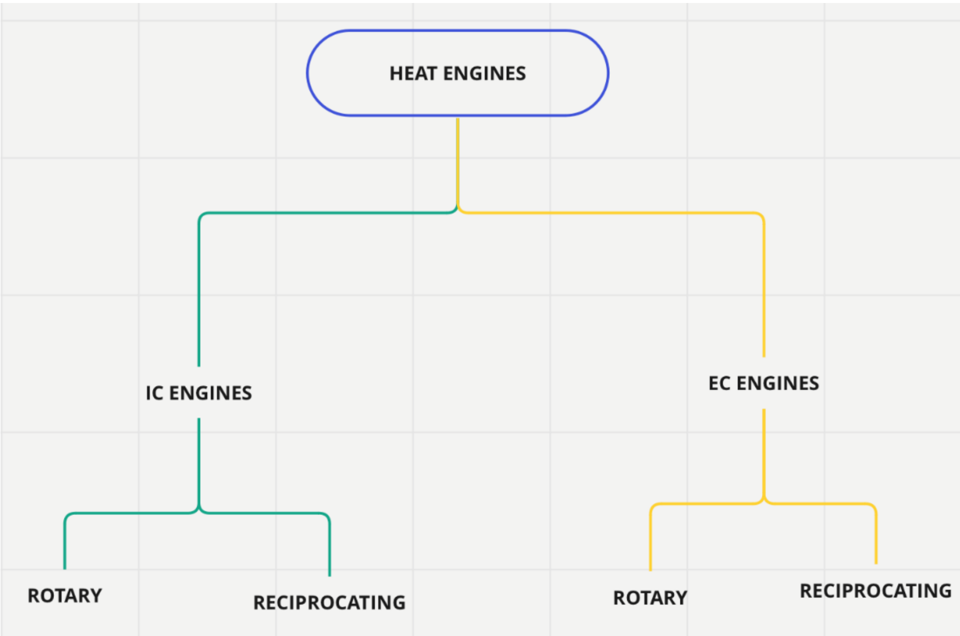


Fig 4.1 Classification of Heat Engine

4.2 IC Engine Classifications:

There are several possible ways of classifying IC engines.

Reciprocating

- By number of stokes
  1. Two stroke engine
  2. Four stroke engine
  3. Six stroke engine
- By type of ignition
  1. Compression-ignition engine
  2. Spark-ignition engine

Rotary

- Gas turbine
  1. Turbo jet
  2. Turbofan
  3. Turbo prop
- Ram jet
- Rocket engine

Reasons for selecting 4-stroke diesel engine:

1. Diesel cars are more efficient in terms of power output than petrol cars. Due to the usage of burning diesel at high compression ratio and instead of using spark plugs, diesel engines have a bigger efficiency.
2. Diesel engines have less wear than petrol engines. There are several reasons for being less wear. One of them is due to the working of diesel engines at low RPM compared to a petrol engine. Also, diesel engines are made extra thick to withstand high pressures which makes wear decrease too.
3. Diesel engines have more torque. Diesel engines are made to withstand higher torques. As diesel engines are self-igniting engines, it has to create enough pressure for the fuel to get self-ignited. This increases the compression ratio even more which in turn increases efficiency.

4. Diesel engines consume less amount of fuel when compared to petrol engines to give out the same output of work. Hence they are also reliable in the long term.

4.3 Diesel Engine:

The diesel engine (also known as compression ignition engine) is named after Rudolf Diesel, is an internal combustion engine in which fuel ignition is caused by elevated temperature of air due to adiabatic compression in the cylinder. In this fuel injectors are used to inject fuel into the combustion chambers in the form of small droplets which atomize the fuel with compressed air.

The diesel engine has the highest thermal efficiency of any regular internal or external combustion engine. Low-speed diesel engines are quite often used in big ships where the weight of the engine is relatively unimportant. This type of engine can have upto 50% thermal efficiency.

4.4 Diesel cycle:

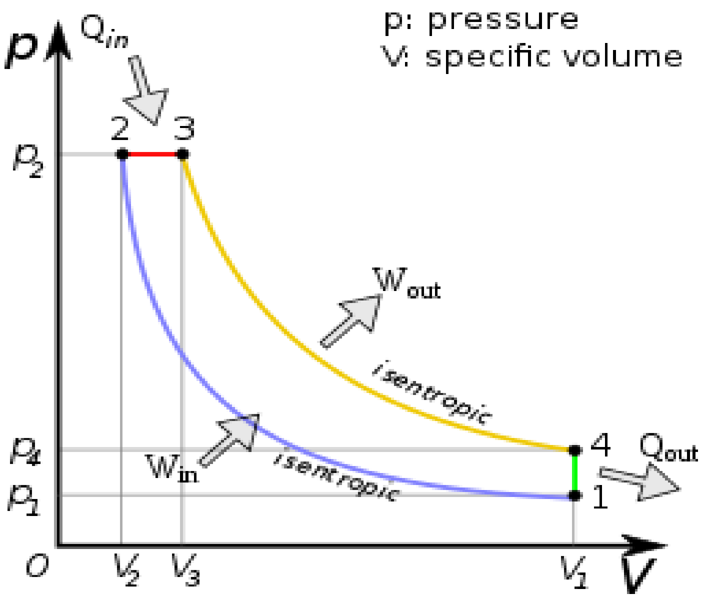


Fig 4.2 Diesel cycle PV diagram

- **Process 1 [suction stroke]** - This is when the piston first moves downward, creating a vacuum that sucks **air** into the combustion chamber.

- **Process 2 [compression stroke]** - Once the piston reaches the lowest point it moves up again and compresses the air in the combustion chamber to very high pressure.

The pressure is so high that it heats up the air to beyond the temperature at which diesel ignites.

- **Process 3 [power stroke] -** The power stroke starts with a bang, as at the end of the compression cycle (process 2) the fuel is injected into the combustion chamber via the **fuel injector**. The fuel ignites as it mixes with the high-temperature air inside the chamber. This controlled explosion forces the piston back downwards producing **work**.

- **Process 4 [exhaust stroke]** - Finally, this is when the piston moves back up and pushes the by-products of combustion (mainly *CO2* and heat) out of the combustion chamber. This is called the **exhaust stroke**. After this, the piston repeats process 1 and follows the same cycle once again.

4.5 Engine description:

The prepared blends are then tested for performance in a 4-stroke diesel engine manufactured by Kirloskar company. It is a single cylinder, constant speed, water cooled diesel engine test rig in the laboratory. The engine is provided with a crank handle for starting. The engine is mounted with an absorption dynamometer of brake drum type. The engine set up is also provided with a burette, graduations duly marked, and a 3-way valve is used to measure the fuel flow rate.

Through load test analysis on the available engine, performance characteristics of each blend is analyzed. The test rig engine is shown in the following fig:

Fig 4.3 four-stroke single cylinder diesel engine

Table 4.1 Specifications of the Diesel engine

Engine Maker	M/S Kirloskar
Cylinder Position	Vertical
Brake power	5HP
Speed	1500RPM
Bore	80 mm
Stroke	110 mm
Compression ratio	17.5:1
Air Box office diameter	20 mm
Cooling	Water cooled
Starting	Hand Cranking
Dynamometer	Rope Brake

CHAPTER 5

RESULTS AND DISCUSSION

5.1 Basic data for calculations:

1. Rated brake power of engine = 5 HP = 3.7 kW
2. Speed of engine = N= 1500 RPM
3. Effective radius of Brake drum R = 0.213 m
4. Stroke Length L = 110×10^{-3} m
5. Diameter of cylinder bore D = 80×10^{-3} m
6. Time taken for 10cc fuel consumption 't' sec

5.2 Basic formulae:

- Maximum Load = $\frac{Rated\ B.P \times 60000}{2\pi NR \times 9.81}$

$$= \frac{3.7 \times 60000}{2\pi \times 1500 \times 0.231 \times 9.81}$$

= 11.27 kg

- Brake Power B.P = $\frac{2\pi N(W-S) \times 9.81 \times R}{60000}$

- Fuel consumption (F.C) = $\frac{10 \times specific\ gravity\ of\ fuel \times 3600}{t \times 1000}$ kg/hr

- Indicated Power = F.P + B.P

Where F.P is obtained from the graph drawn between Brake power and Fuel consumption. The linear portion of the graph is extended till it touches the negative scale of the B.P axis. The value it coincides with is taken as Frictional Power.

CALCULATIONS:

1. Specific fuel consumption (SFC) = $\frac{F.C}{B.P}$ kg/kw.hr

2. Brake thermal efficiency η_{Bth} $= \frac{B.P\times 3600}{FC\times CV}$

3. Indicated thermal efficiency η_{Ith} $= \frac{I.P\times 3600}{F.C\times C.V}$

4. Mechanical efficiency η_{mech} $= \frac{B.P}{I.P}$

5. Indicated mean effective pressure (I.M.E.P) = $\frac{I.P\times 60000}{L\times\frac{\pi}{4}\times D^2\times\frac{N}{2}}$

6. Brake mean effective pressure (B.M.E.P) $= \frac{B.P\times 60000}{L\times\frac{\pi}{4}\times D^2\times\frac{N}{2}}$ N/m2

5.3 Model calculations:

Considering blend B15 at 1.9 kgf load:

Specific gravity 0.798 gm/cc

Brake power B.P = $\frac{2\pi N(W-S)\times 9.81\times R}{60000}$

$= \frac{2\pi\times 1500\times 1.9\times 9.81\times 0.213}{60000}$

= 0.623 KW

Fuel consumption (F.C) = $\frac{10\times specific\ gravity\times 3600}{t\times 1000}$

$= \frac{10\times 0.798\times 3600}{67.3\times 1000}$

= 0.426 kg/hr

Frictional power (F.P) from graph = 2.1 kW

Indicated power (I.P) = F.P + B.P

= 2.1 + 0.623 = 2.723 KW

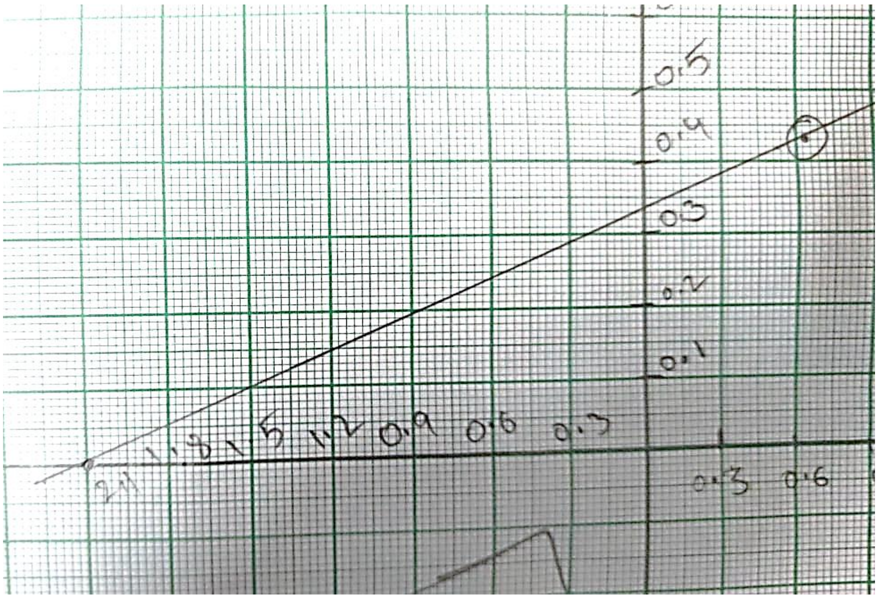


Fig 5.1 B.P vs F.C graph extended

Specific fuel consumption (SFC) = $\frac{FC}{BP}$kg/kw.hr

$= \frac{0.426}{0.623}$

= 0.683 kg/kw.hr

Mechanical efficiency η_{mech} $= \frac{B.P}{I.P}$

$= \frac{0.683}{2.783}$

= 22.8%

Indicated Mean Effective Pressure (I.M.E.P) = $\frac{IP\times60000}{L\times\frac{\pi}{4}\times D^2\times\frac{N}{2}}$N/m2

$= \frac{2.783\times60000}{110\times0.001\times\frac{\pi}{4}\times0.08^2\times\frac{1500}{2}}$

= 3.9 bar

Break Mean Effective Pressure (B.M.E.P) = $\frac{B.P\times60000}{L\times\frac{\pi}{4}\times D^2\times\frac{N}{2}}$N/m2

$= \frac{0.683\times60000}{0.110\times\frac{\pi}{4}\times0.08^2\times\frac{1500}{2}}$

= 0.9 bar

Table 5.1 Observations of B5

S.no	Load on brake drum	Time for 10cc fuel consumption sec	F.C kg/hr	B.P kW	I.P kW	F.P kW	SFC kg/kw.hr	η_{mech} %	IMEP bar	BMEP bar
1	0	71.35	0.391	0	2.7	2.7	0	0	3.9	0
2	1.9	63.88	0.436	0.6	3.3	2.7	0.701	18.7	4.81	0.9
3	3.5	52.06	0.537	1.1	3.8	2.7	0.454	30.4	5.62	1.7
4	5.2	46.72	0.593	1.8	4.6	2.7	0.331	40	6.5	2.6
5	7	42.56	0.656	2.3	5.1	2.7	0.281	46.3	7.2	3.3
6	8.8	35.56	0.783	2.9	5.6	2.7	0.269	51.9	8.14	4.2

Table 5.2 Observations of B10

S.no	Load on brake drum	Time for 10cc fuel consumption sec	F.C kg/hr	B.P kW	I.P kW	F.P kW	SFC kg/kw.hr	η_{mech} %	IMEP bar	BMEP bar
1	0	82.16	0.345	0	1.6	1.6	0	0	2.43	0
2	1.9	66.80	0.424	0.6	2.3	1.6	0.68	27.0	3.23	0.90
3	3.5	57.35	0.494	1.1	2.8	1.6	0.43	40.6	4.09	1.66
4	5.3	46.93	0.604	1.7	3.4	1.6	0.34	50.8	4.95	2.52
5	7	40.62	0.698	2.3	3.9	1.6	0.30	57.7	5.76	3.32
6	8.8	35.94	0.789	2.8	4.6	1.6	0.273	63.2	6.62	4.18

Table 5.3 observation of B15

S.no	Load on brake drum	Time for 10cc fuel consumption sec	FC kg/hr	B.P kW	I.P kW	F.P kW	SFC kq/kw.hr	η_{mech} %	IMEP bar	BMEP bar
1	0	84.6	0.339	0	2.1	2.1	0	0	3.04	0
2	1.9	67.3	0.426	0.62	2.7	2.1	0.683	22.8	3.94	0.90
3	3.5	56.6	0.507	1.14	3.24	2.1	0.441	35.3	4.70	1.66
4	5.2	47.6	0.603	1.78	3.80	2.1	0.353	44.8	5.51	2.44
5	7	41.25	0.696	2.29	4.39	2.1	0.303	52.2	6.37	3.32
6	8.8	36.19	0.793	2.88	4.98	2.1	0.274	57.8	7.22	4.18

Table 5.4 Observation of B25

S.no	Load on brake drum	Time for 10cc fuel consumption sec	F.C kg/hr	B.P kW	I.P kW	F.P kW	SFC kw/kw.hr	η_{mech} %	IMEP bar	BMEP bar
1	0	83.47	0.351	0	1.7	1.7	0	0	2.52	0
2	1.9	66.84	0.437	0.6	2.3	1.7	0.701	26.3	3.42	0.90
3	3.5	54.75	0.534	1.1	2.9	1.7	0.465	39.7	4.18	1.66
4	5.2	46.57	0.628	1.7	3.4	1.7	0.368	49.5	4.99	2.47
5	7	40.53	0.722	2.3	4.1	1.7	0.314	56.8	5.85	3.32
6	8.8	35.9	0.815	2.8	4.6	1.7	0.282	62.4	6.70	4.18

The Frictional power is calculated using William's line methos as described earlier.

For blend B5 FP = 2.7kW

For blend B10 FP = 1.68 kW

For blend B15 FP = 2.1 kW

For blend B25 FP = 1.74 kW

5.4 Performance characteristics:

Brake power, mechanical efficiency, specific fuel consumption, are set to be the parameters of performance of the engine.

Engine performance is an indication of degree of success with which it is doing its assigned job, I.e., conversion of chemical energy into useful mechanical work at different loads.

5.4.1 Comparison of Mechanical efficiency:

Mechanical efficiency indicates how good an engine is converting the indicated power to useful power. The values of Mechanical efficiency at different loads are plotted as shown in fig 4.2. B10 blend shows higher mechanical efficiency at every load.

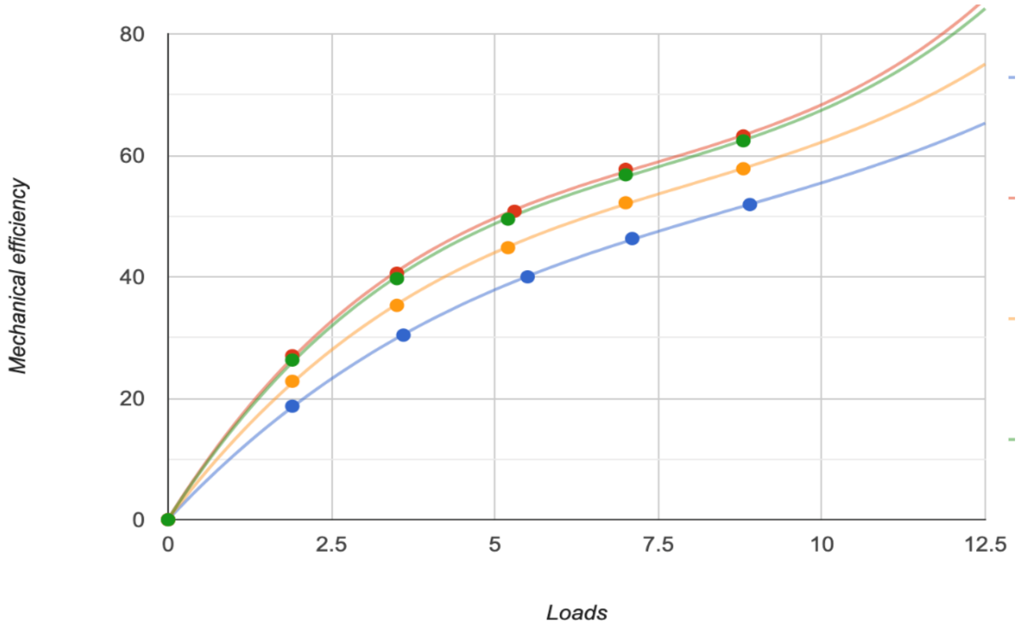


Fig 5.2 η_{mech} *vs loads*

The lowest mechanical efficiency is given by blend B5. B10 seems to be the best mixture. by blend B5. B10 seems to be the best mixture

Mechanical efficiency vs Loads:

Blue → B5

Red → B10

Orange→ B15

Green → B25

5.4.2 Comparison of Specific Fuel Consumption:

Specific fuel consumption is the indication of the amount of fuel consumed to give a unit of work output. It is a measure of fuel efficiency. Variations of Specific Furel Consumption with respect to Brake Power is shown in following fig; B5 seems to have the least specific fuel consumption while B25 shows the highest.

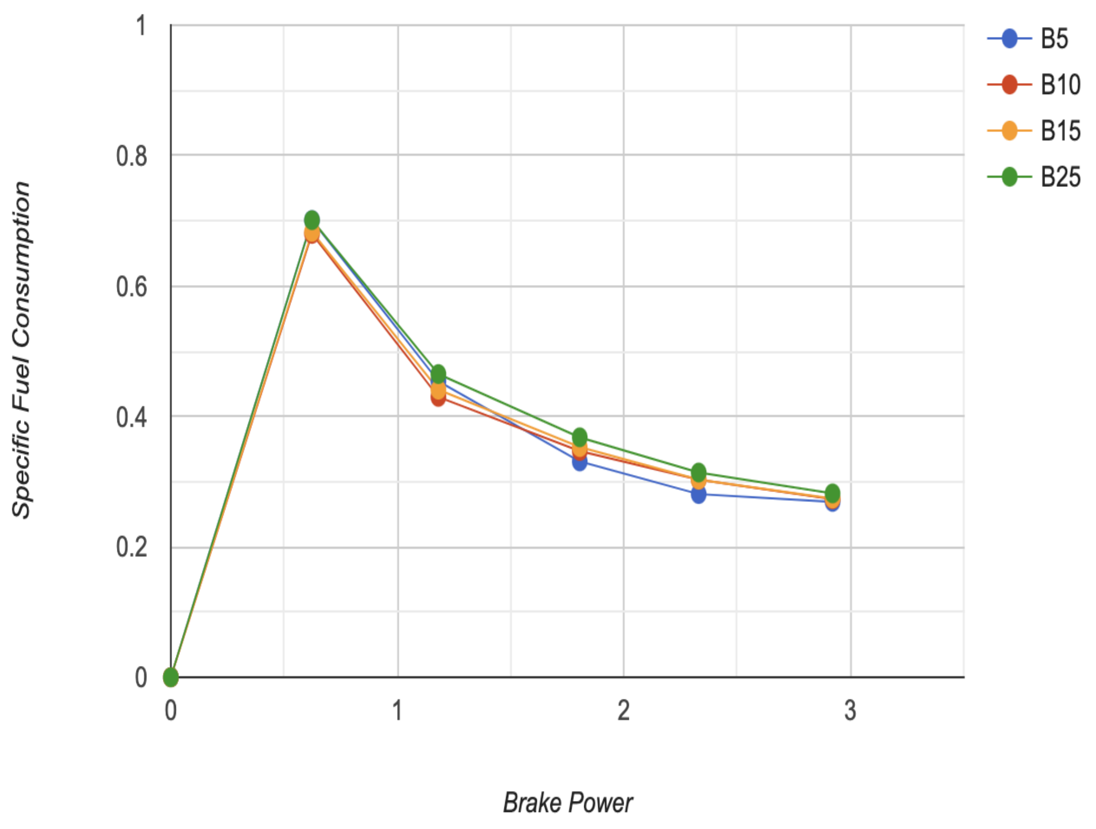


Fig 5.3 Brake power vs SFC

5.4.3 Comparison of Indicated Mean Effective Pressure:

The indicated Mean Effective Pressure represents the average pressure inside the combustion chamber of an engine pre cycle. The variations of IMEP with respect to Brake power of different blends is shown in the following figure; B10 offers the minimum Indicated mean effective pressure while offering higher mechanical efficiency while B5 offers higher Indicated Mean Effective Pressure of all blends.

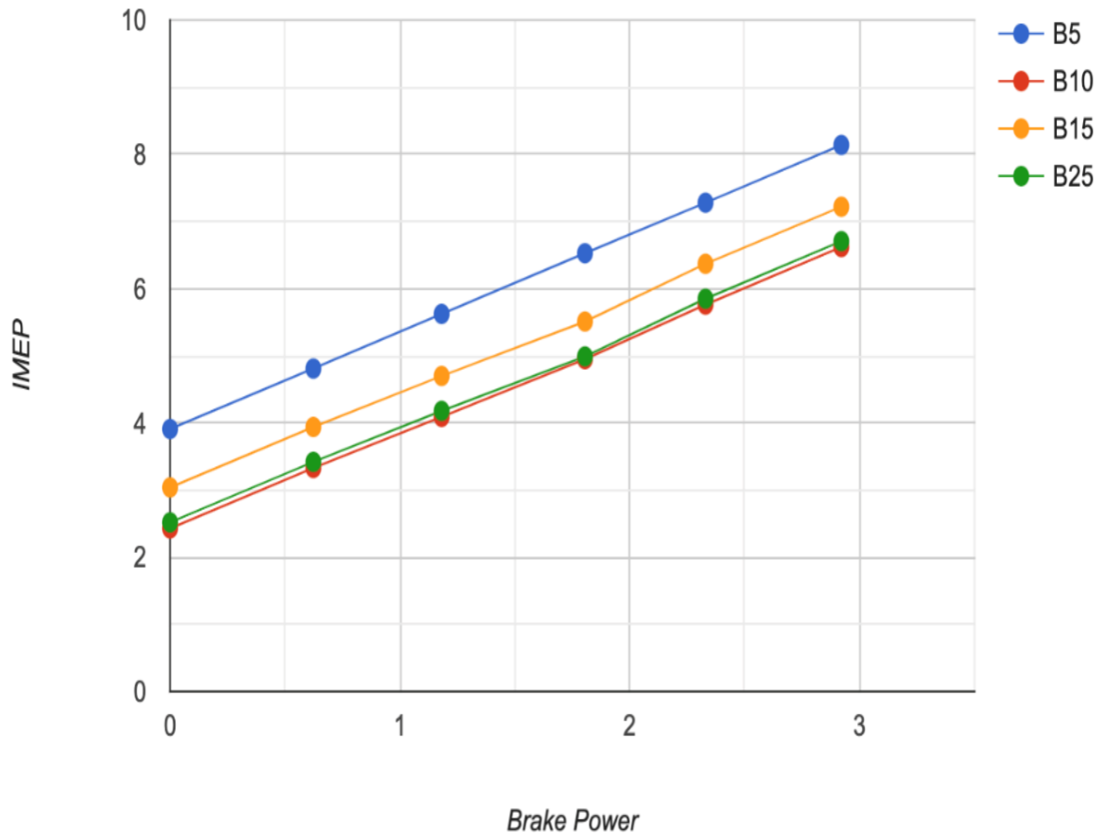


Fig 5.4 Brake Power vs IMEP

5.5 Properties of pure biofuel obtained from Moringa oil:

Experimental set-up for property evaluation:

• Flash & Fire point apparatus

Fig 5.5 Flash point and Fire point apparatus

The biofuel prepared is filled inside the flash point apparatus and the heater is turned ON. As the oil gets heated, fire source is made to touch the surface of the heating oil for every rise in 2 degrees celsius. When blue flame is formed on the surface of the heating oil at a particular temperature, flash point temperature is noted and when the oil starts burning completely, the fire point temperature is noted. The procedure is repeated 2-3 times and an average value of the flash and fire point is taken.

• Viscosity apparatus

Fig 5.6 Viscosity apparatus

Procedure:

1. Level the Instrument with the help of Levelling Screws and Spirit Level

2. Clean the oil cup and place ball valve in position and l the cup with of sample up to the pointer level

3. Fill the heating bath surrounding the cup with water.

4. Start the immersion heater in the water hath and control the rate of heating through an energy regulator Keep stirring the water bath to maintain a uniform temperature Once all, which receives heat through water bath, attains the desired steady temperature, the test is again commenced.

5. Repeat the above procedure at various temperatures in increments of 5° C and measure the time taken for 50ml (about 1.69 oz) collection & calculate the density of all with the help of the simple balance and determine the absolutely Viscosity

• **Calorific value apparatus**

Fig 5.7 Bomb calorimeter

Procedure:

A known weight (0.5 – 1.0 gm) of finely ground coal is accurately weighed into the crucible. The crucible is supported over the ring. A fine magnesium wire touching the fuel sample is stretched across the electrodes. The bomb lid is tightly screwed, and the bomb is filled with oxygen to 25 – 30 atmospheric pressures. The bomb is then kept copper calorimeter. The stirrer is started. After 5 minutes, the temperature of the water is noted. The electrodes are then connected to a 6 – 12 V battery to ignite the fuel sample. The heat produced by burning of the fuel is transferred to water which is stirred throughout the experiment. Maximum temperature shown by thermometer is recorded. The stirrer is stopped, and bomb is removed from the calorimeter. After half an hour, the contents of bomb are washed into a beaker and the amounts of sulphuric acid and nitric acid present in this solution are determined.

Table 5.5 property table of pure biofuel

Biofuel	Flash point °C	Fire point °C	Kinematic Viscosity cst	Calorific value kcal/kg
Moringa	174	180	4.45	10472

CHAPTER 6

CONCLUSION

Conclusion:

An experimental study has been conducted to evaluate and compare the use of Moringa oleifera as a full or partial supplement to conventional diesel fuel in IC ENGINES.

A series of tests have been conducted using each of the fuels in various proportions with the engine working at a constant RPM of 1500 and at a different load range of 0 to 10kg. For each test performs the performance gauging parameters like mechanical efficiency, brake power, specific fuel consumption etc. are calculated.

Based on the series of experiments performed, the following conclusions have been identified:

• Comparing mechanical efficiencies of all the blends, it can be inferred that blend B10 has the highest mechanical efficiency while B5 being the lowest mechanical efficiency giving blend.

• Comparing the specific fuel consumption for each particular blend, it was observed that B5 has the lowest specific fuel consumption while B25 shows the highest specific fuel consumption rate of all blends tested.

• On comparing the Indicated Mean Effective Pressures of all the blends, it has been observed that B10 offers the minimum indicated mean effective pressure while B5 offers the highest indicated mean effective pressure.

• While B10 offers higher specific fuel consumption than B5, B10 offers higher mechanical efficiency and lower indicated mean effective pressure. Therefore, it can be concluded that blend B10, containing 90% diesel and 10% moringa biofuel, is the best ratio.

• Kinematic viscosity of pure biofuel obtained from Moringa oleifera 4.45 cst is found to be more than Kinematic viscosity of pure diesel, which ranges from 2.5-3.2 cst usually. It has been concluded that due to addition of biofuel to diesel, the viscosity of the blends increase from B5 to B25.

• It has also been concluded that increase in specific fuel consumption from B5 to B25 might be due to the increase in densities of blends.

• Calorific value of biofuel obtained from moringa oleifera, 10472kcal/kg, is also found to be higher than pure diesel,10000 kcal/kg.

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