

A Report on
**Performance & Emission Analysis of blends of Karanja
Methyl Ester in a Compression Ignition Engine**

A REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF
BACHELOR OF TECHNOLOGY (CHEMICAL ENGINEERING)

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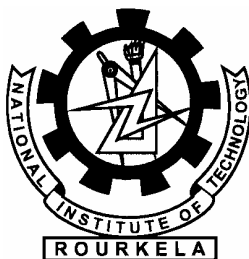
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CERTIFICATE

This is to certify that that the work in this thesis report entitled “**Performance & Emission Analysis of blends of Karanja Methyl Ester in a Compression Ignition Engine**” submitted by **Saswat Rath** in partial fulfilment of the requirements for the degree of Bachelor of Technology in Chemical Engineering, Session 2007-2011, in the department of Chemical Engineering, National Institute of Technology, Rourkela, is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge the matter embodied in the report has not been submitted to any other University /Institute for the award of any degree.

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ACKNOWLEDGEMENT

I wish to express my sincere thanks and gratitude to **Prof. (Dr.) R.K. Singh** for suggesting me the topic and providing me the guidance, motivation and constructive criticism throughout the course of the project.

I thank **Prof. (Dr.) R. K. Singh** for acting as the project coordinator.

I am grateful to **Prof. (Dr.) K. C. Biswal**, Head of the Department, Chemical Engineering for providing me the necessary opportunities for the completion of my project. I would also like to thank **Prof. (Dr.) S. Murugan**, Department of Mechanical Engineering, for his guidance and providing me access to the IC Engine lab. I also thank other staff members of my department for their invaluable help and guidance.

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ABSTRACT

On the face of the upcoming energy crisis, vegetable oils have come up as a promising source of fuel. They are being studied widely because of their abundant availability, renewable nature and better performance when used in engines. Many vegetable oils have been investigated in compression ignition engine by fuel modification or engine modification. The vegetable oils have very high density and viscosity, so we have used the methyl ester of the oil to overcome these problems. Their use in form of methyl esters in non modified engines has given encouraging results.

Karanja oil (*Pongamia Pinnata*) is non edible in nature and is available abundantly in India. An experimental investigation was made to evaluate the performance, emission and combustion characteristics of a diesel engine using different blends of methyl ester of karanja with mineral diesel. Karanja methyl ester was blended with diesel in proportions of 5%, 10%, 15%, 20%, 30%, 40%, 50% and 100% by mass and studied under various load conditions in a compression ignition (diesel) engine. The performance parameters were found to be very close to that of mineral diesel. The brake thermal efficiency and mechanical efficiency were better than mineral diesel for some specific blending ratios under certain loads. The emission characteristics were also studied and levels of carbon dioxide, carbon monoxide, nitric oxide and hydrocarbons were found to be higher than pure diesel.

Keywords: Karanja methyl ester, transesterification, biodiesel, engine performance

CHAPTER 1

INTRODUCTION

1. INTRODUCTION

Fossil fuels are one of the major sources of energy in the world today. Their popularity can be accounted to easy usability, availability and cost effectiveness. But the limited reserves of fossil fuels are a great concern owing to fast depletion of the reserves due to increase in worldwide demand. Fossil fuels are the major source of atmospheric pollution in today's world. So efforts are on to find alternative sources for this depleting energy source. Even though new technologies have come up which have made solar, wind or tidal energy sources easily usable but still they are not so popular due to problems in integration with existing technology and processes. So, efforts are being directed towards finding energy sources which are similar to the present day fuels so that they can be used as direct substitutes. Diesel fuel serves as a major source of energy, mainly in the transport sector. During the World Exhibition in Paris in 1900, Rudolf Diesel was running his engine on 100% peanut oil. In 1911 he stated "the diesel engine can be fed with vegetable oils and would help considerably in the development of agriculture of the countries, which use it" [1]. Studies have shown that vegetable oils can be used in diesel engines as they are found to have properties close to diesel fuel [2]. It is being considered a breakthrough because of availability of various types of oil seeds in huge quantities [3]. Vegetable oils are renewable in nature and may generate opportunities for rural employment when used on large scale [4]. Vegetable oils from crops such as soya bean, peanut, sunflower, rape, coconut, karanja, neem, cotton, mustard, jatropha, linseed and castor have been evaluated in many parts of the world. Non edible oils have been preferred because they don't compete with food reserves. Karanja (pongamia) is an oil seed-bearing tree, which is non-edible and does not find any other suitable application due to its dark colour and odour [5]. The oils have high viscosity and other problems make their use difficult, so it was used after conversion to its methyl ester which modified all the

characteristics to suit our demand. In this work, different proportions of karanja methyl ester, viz, 5%, 10%, 15%, 20%, 30%, 40% and 50% are mixed with 95%, 90%, 85%, 80%, 70%, 60% and 50% respectively with diesel fuel on mass basis.

CHAPTER 2

LITERATURE REVIEW

2. LITERATURE REVIEW

2.1 Engines

Engines are devices which convert the stored chemical energy in fuels and chemicals into mechanical or motive energy. They are basically of two types- external combustion engines and internal combustion engines. External combustion engines have separate areas where the chemical reaction or combustion takes place and where motive energy is generated. This class of engines includes steam engines. Internal combustion engines on other hand handle the combustion and power generation in the same place. These engines can either be petrol or diesel engines.

These petrol or diesel engines can run either in a 2 stroke cycle or a 4 stroke cycle. While a 2 stroke engine provides more power per cycle, the efficiency is higher in a 4 stroke engine. A diesel engine is an internal combustion engine that converts chemical energy in fuel to mechanical energy that moves pistons up and down inside enclosed spaces called cylinders. The pistons are connected to the engine's crankshaft, which changes their linear motion into the rotary motion needed to propel the vehicle's wheels. With both gasoline and diesel engines, energy is released in a series of small explosions (combustion) as fuel reacts chemically with oxygen from the air. Diesels differ from gasoline engines primarily in the way the explosions occur. Gasoline engines start the explosions with sparks from spark plugs, whereas in diesel engines, fuel ignites on its own. Air heats up when it's compressed. This fact led German engineer Rudolf Diesel to theorize that fuel could be made to ignite spontaneously if the air inside an engine's cylinders became hot enough through compression. Achieving high temperatures meant producing much greater air compression than occurs in gasoline engines, but

Diesel saw that as a plus. According to his calculations, high compression should lead to high engine efficiency [6]. Part of the reason is that compressing air concentrates fuel-burning oxygen. A fuel that has high energy content per gallon, like diesel fuel, should be able to react with most of the concentrated oxygen to deliver more punch per explosion, if it was injected into an engine's cylinders at exactly the right time. Diesel's calculations were correct. As a result, although diesel engines have seen vast improvements, the basic concept of the four-stroke diesel engine has remained virtually unchanged for over 100 years. The first stroke involves drawing air into a cylinder as the piston creates space for it by moving away from the intake valve. The piston's subsequent upward swing then compresses the air, heating it at the same time. Next, fuel is injected under high pressure as the piston approaches the top of its compression stroke, igniting spontaneously as it contacts the heated air. The hot combustion gases expand, driving the piston downward in what's called the power stroke. During its return swing, the piston pushes spent gases from the cylinder, and the cycle begins again with an intake of fresh air.

Older diesel engines mixed fuel and air in a pre-combustion chamber before injecting it into a cylinder. The mixing and injection steps were controlled mechanically, which made it very difficult to tailor the fuel-air mixture to changing engine conditions. This led to incomplete fuel combustion, particularly at low speeds. As a result, fuel was wasted and tailpipe emissions were relatively high. Today's diesels inject fuel directly into an engine's cylinders using tiny computers to deliver precisely the right amount of fuel the instant it is needed. All functions in a modern diesel engine are controlled by an electronic control module that communicates with an elaborate array of sensors placed at strategic locations throughout the engine to monitor everything from engine speed to coolant and oil temperatures and even piston position. Tight

electronic control means that fuel burns more thoroughly, delivering more power, greater fuel economy, and fewer emissions than yesterday's diesel engines could achieve. Diesels are workhorse engines and can be found powering heavy duty trucks, buses, tractors and trains, large ships, bulldozers, cranes, and other construction equipment. They are more fuel efficient and more flexible in the fuels they can use.

Diesel engines are more efficient than gasoline engines (45 percent versus 30 percent), and further advances are possible (to 55-63 percent). Research is being done by engine manufacturers and fuel suppliers to develop new fuels of plant origin (biofuels) that can provide optimum performance in diesel engines in order to fight the decreasing supplies of fossil fuels.

2.2 Need for Oil Treatment/Conversion

Straight vegetable oils (SVO) can be used directly as a fossil diesel substitute; however, using this fuel can lead to some fairly serious engine problems. Due to its relatively high viscosity SVO leads to poor atomisation of the fuel, incomplete combustion, coking of the fuel injectors, ring carbonisation, and accumulation of fuel in the lubricating oil. The best method for solving these problems is the transesterification of the oil to produce biodiesel.

Biodiesel is an alternative fuel similar to conventional or 'fossil' diesel. Biodiesel can be produced from straight vegetable oil, animal oil/fats, tallow and waste cooking oil. The process used to convert these oils to Biodiesel is called transesterification. The largest possible source of suitable oil comes from oil crops such as rapeseed, palm or soybean. In the UK rapeseed represents the greatest potential for biodiesel production. Most biodiesel produced at present is produced from waste vegetable oil sourced from restaurants, chip shops, industrial food producers, etc. Though oil straight from the agricultural industry represents the greatest potential

source, it is not being produced commercially simply because the raw oil is too expensive. After the cost of converting it to biodiesel has been added on it is simply too expensive to compete with fossil diesel. Waste vegetable oil can often be sourced for free or sourced already treated for a small price. The result is Biodiesel produced from waste vegetable oil can compete with fossil diesel.

2.3 Biodiesel Production

As mentioned above biodiesel can be produced from straight vegetable oil, animal oil/fats, tallow and waste oils. There are three basic routes to biodiesel production from oils and fats:

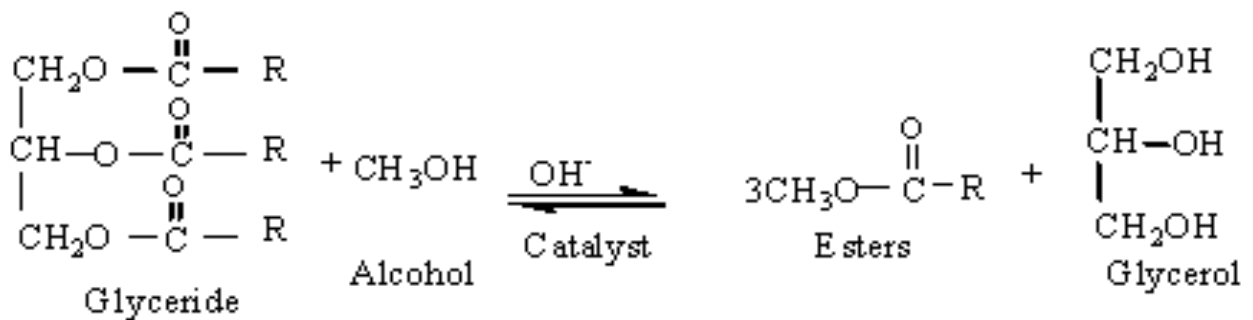
- Base catalyzed transesterification of the oil.
- Direct acid catalyzed transesterification of the oil.
- Conversion of the oil to its fatty acids and then to biodiesel.

Almost all biodiesel is produced using base catalyzed transesterification as it is the most economical process requiring only low temperatures and pressures and producing a 98% conversion yield. For this reason only this process will be described in this report.

The Transesterification process is the reaction of a triglyceride (fat/oil) with an alcohol to form esters and glycerol. A triglyceride has a glycerine molecule as its base with three long chain fatty acids attached. The characteristics of the fat are determined by the nature of the fatty acids attached to the glycerine. The nature of the fatty acids can in turn affect the characteristics of the biodiesel. During the esterification process, the triglyceride is reacted with alcohol in the presence of a catalyst, usually a strong alkaline like sodium hydroxide or potassium hydroxide.

The alcohol reacts with the fatty acids to form the mono-alkyl ester, or biodiesel and crude glycerol. In most production methanol or ethanol is the alcohol used (methanol produces methyl esters while ethanol produces ethyl esters) and is base catalysed by either potassium or sodium hydroxide [7]. Potassium hydroxide has been found to be more suitable for the ethyl ester biodiesel production, while either base can be used for the methyl ester. A common product of the transesterification process is the Oil Methyl Ester (OME) produced from raw oil reacted with methanol.

The figure below shows the chemical process for methyl ester biodiesel. The reaction between the fat or oil and the alcohol is a reversible reaction and so the alcohol must be added in excess to drive the reaction towards the right and ensure complete conversion.



The products of the reaction are the biodiesel itself and glycerol.

A successful transesterification reaction is signified by the separation of the ester and glycerol layers after the reaction time. The heavier, co-product, glycerol settles out and may be sold as it is or it may be purified for use in other industries, e.g. the pharmaceutical, cosmetics etc.

The engine combustion benefits of the transesterification of the oil are:

- Lowered viscosity
- Complete removal of the glycerides
- Lowered boiling point
- Lowered flash point
- Lowered pour point

2.4 Production Process

An example of a simple production flow chart is provided below with a brief explanation of each step.

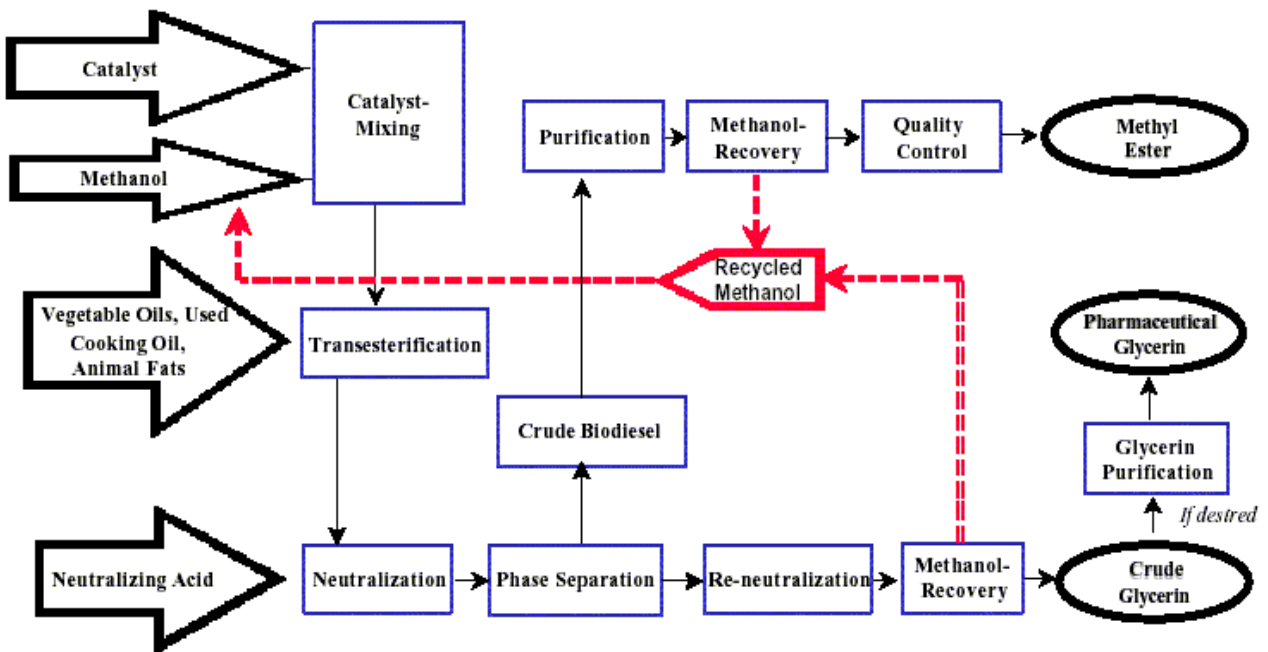


Figure 1 – Biodiesel Production Process Flowchart

2.4.1 Mixing of alcohol and catalyst

The catalyst is typically sodium hydroxide (caustic soda) or potassium hydroxide (potash). It is dissolved in the alcohol using a standard agitator or mixer. The alcohol/catalyst mix is then charged into a closed reaction vessel and the oil or fat is added. The system from here on is totally closed to the atmosphere to prevent the loss of alcohol. The reaction mix is kept just above the boiling point of the alcohol (around 160 °F) to speed up the reaction and the reaction takes place. Recommended reaction time varies from 1 to 8 hours, and some systems recommend the reaction take place at room temperature. Excess alcohol is normally used to ensure total conversion of the fat or oil to its esters. Care must be taken to monitor the amount of water and free fatty acids in the incoming oil or fat. If the free fatty acid level or water level is too high it may cause problems with soap formation and the separation of the glycerine by-product downstream.

2.4.2 Separation

Once the reaction is complete, two major products are obtained: glycerine and biodiesel. Each has a substantial amount of the excess alcohol that was used in the reaction. The reacted mixture is sometimes neutralized at this step if needed. The glycerine is much more dense than biodiesel and the two can be gravity separated with glycerine simply drawn off the bottom of the settling vessel. In some cases, a centrifuge is used to separate the two materials faster [8].

2.4.3 Alcohol Removal

Once the glycerine and biodiesel phases have been separated, the excess alcohol in each phase is removed with a flash evaporation process or by distillation. In others systems, the alcohol is

removed and the mixture neutralized before the glycerine and esters have been separated. In either case, the alcohol is recovered using distillation equipment and is re-used. Care must be taken to ensure no water accumulates in the recovered alcohol stream.

2.4.4 Glycerine Neutralization

The glycerine by-product contains unused catalyst and soaps that are neutralized with an acid and sent to storage as crude glycerine. In some cases the salt formed during this phase is recovered for use as fertilizer. In most cases the salt is left in the glycerine. Water and alcohol are removed to produce 80-88% pure glycerine that is ready to be sold as crude glycerine. In more sophisticated operations, the glycerine is distilled to 99% or higher purity and sold into the cosmetic and pharmaceutical markets.

2.4.5 Methyl Ester Wash

Once separated from the glycerine, the biodiesel is sometimes purified by washing gently with warm water to remove residual catalyst or soaps, dried, and sent to storage. In some processes this step is unnecessary. This is normally the end of the production process resulting in a clear amber-yellow liquid with a viscosity similar to mineral diesel. In some systems the biodiesel is distilled in an additional step to remove small amounts of colour bodies to produce a colourless biodiesel.

2.4.6 Product Quality

Prior to use as a commercial fuel, the finished biodiesel must be analyzed using sophisticated analytical equipment to ensure it meets any required specifications. The most important aspects of biodiesel production to ensure trouble free operation in diesel engines are:

- Complete Reaction
- Removal of Glycerine
- Removal of Catalyst
- Removal of Alcohol
- Absence of Free Fatty Acids

CHAPTER 3

MATERIALS & METHODS

3. MATERIALS AND METHODS

As the viscosity of karanja oil is higher than that of diesel fuel, it is necessary to use a viscosity reduction technique to evaluate its performance and emission in a diesel engine. Therefore, it is required to modify the fuel. So certain approaches are used to modify vegetable oils to better usable forms. Blending is a simple method of modification in which another liquid with a certain character is mixed to get the average required parameter. But the problems of separation of the mixture components and coking occur. So a chemical process called transesterification is preferred [9]. This process produces uniform quality of the alkyl esters and reduces viscosity and increases cetane number [10].

Biodiesel can be produced by a variety of esterification technologies. The oils and fats are filtered and pre-processed to remove water and contaminants. If, free fatty acids are present, they can be removed or transformed into biodiesel using special pre-treatment technologies. Non-edible oil like karanja oils having acid values more than 3.0 were esterified followed by transesterification. Esterification is the reaction of an acid with an alcohol in the presence of a catalyst to form an ester. Transesterification on the other hand is the displacement of the alcohol from an ester by another alcohol in a process similar to hydrolysis, except that an alcohol is used instead of water. This reaction cleavage of an ester by an alcohol is more specifically called alcoholysis. In case of esterification processes, the karanja oil is preheated at different temperature and then the solution of sulfuric acid and methanol is added to the oil and stirred continuously at different temperature. Esterification is continued till the acid value was lowered and remained constant (between 0.1 and 0.5). Then the heating was stopped and the products were cooled. The unreacted methanol was separated by distillation. The remaining product was further used for transesterification to obtain methyl esters. The karanja oil was converted to

methyl ester by transesterification. The fatty acid composition of karanja oil is given in Table 1. Karanja oil contains 10-20% saturated acids (palmitic, stearic and lignoceric) and 55-90% unsaturated acids (oleic and linoleic).

Table 1 - Fatty and unsaturated acids in karanja oil [11]

Acid	Percentage
Palmitic acid C _{16:0}	3.7-7.9
Stearic acid C _{18:0}	2.4-8.9
Lignoceric acid C _{24:0}	1.1-3.5
Oleic acid C _{18:1}	44.5-71.3
Linoleic acid C _{18:2}	10.8-18.3

The physical properties of karanja methyl ester are compared with diesel fuel and are given in Table 2.

Table 2: Comparison of Karanja Methyl Ester with Diesel [10]

Property	Karanja Oil	KME	Diesel
Specific Gravity	0.933	0.936	0.85
Viscosity (cst) at 40 ^o C	41.8	20.5	2.87
Flash point (^o C)	232	204	76
Calorific Value (MJ/Kg)	-	35.94	44.02
Cloud Point (^o C)	-	10	6.5
Pour Point (^o C)	6	6	3.1

CHAPTER 4

EXPERIMENTAL SETUP

4. EXPERIMENTAL SETUP

Figure 1. Shows schematic diagram of the experimental setup. The specification of the engine is given in the Table 3.

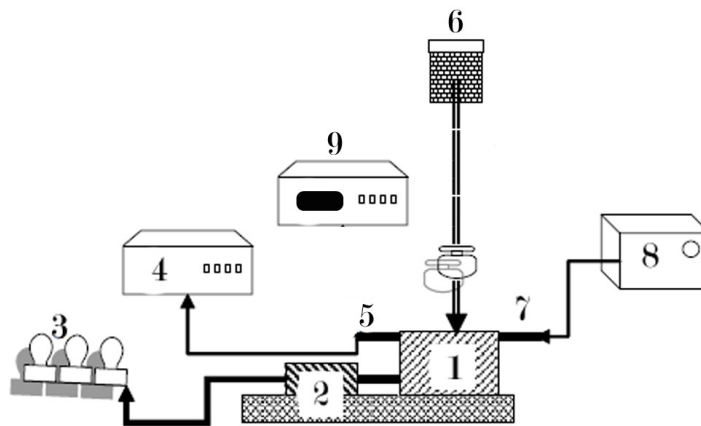


Figure 2 - Experimental setup

1.Single Cylinder 4S Diesel Engine	4.Gas Analyser	7.Inlet Manifold
2.Dynamometer	5.Exhaust Manifold	8.Air Drum
3.Resistance Load	6.Fuel Tank	9.Control System (Computer)

Table 3: Test Engine Specifications

Make	Kirloskar
Type of Engine	Four stroke, single cylinder, DI diesel engine
Speed	1500 rpm
Bore	87.5 mm
Stroke	110 mm
Compression ratio	17.5
Method of cooling	Air cooled with radial fan

The engine was coupled to a dynamometer to provide load to the engine. A sensor is connected near the flywheel to measure the speed. Air intake was measured by air flow sensor that is fitted in an air box. A burette was used to measure fuel flow to the engine via fuel pump. A thermocouple with a temperature indicator measures the exhaust gas temperature. Emissions such as unburnt hydrocarbon (HC), carbon monoxide (CO) and nitric oxide (NO) were measured by an AVL 444 exhaust gas analyser. Combustion diagnosis was carried out by means of a Kistler make quartz piezoelectric pressure transducer (Model Type 5395A) mounted on the cylinder head in the standard position. Kistler pressure transducer has the advantage of good frequency response and linear operating range. A continuous circulation of air was maintained for cooling the transducer by using fins to maintain the required temperature. Combustion parameters such as mechanical efficiency, brake thermal efficiency, brake specific fuel consumption, ignition delay, and maximum rate of heat release and emission parameters like exhaust gas concentrations and temperature were evaluated. The experiments were carried out by

using various blends of karanja methyl ester (KME5,10,15,20,30,40,50,100) with diesel at different load conditions on the engine keeping all the independent variables same. The engine performance test was done twice for all blends except the KME100 and average was taken and emission readings were taken thrice and average was taken.

CHAPTER 5

RESULTS & DISCUSSION

5. RESULTS & DISCUSSION

5.1 Performance Parameters

5.1.1 Brake Thermal Efficiency (BTE)

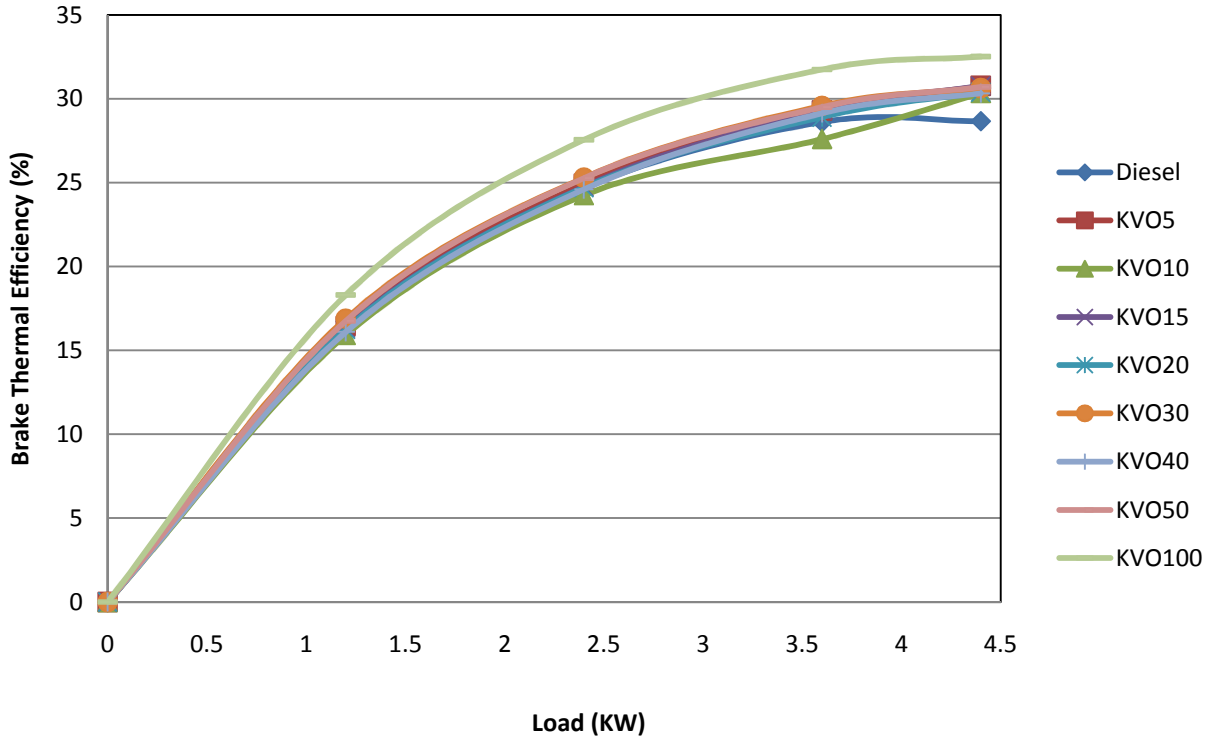


Figure 3 – Variation of brake thermal efficiency with load

Figure 3 shows the variation of the brake thermal efficiency with respect to load for diesel fuel and karanja methyl ester-diesel fuel blends. It can be observed from the figure that, KME100 shows higher brake thermal efficiencies at all load conditions compared to that of diesel fuel. Almost all blends show slightly better BTE than diesel at higher load conditions. The higher thermal efficiencies may be due to the additional lubricity provided by the fuel blends [12]. Raheman et al. [13] also report higher BTE for the 20% & 40% blends while the

higher blends reported lower values of BTE due to low calorific value and higher fuel consumption.

5.1.2 Brake Specific Energy Consumption (BSEC)

Figure 4 shows the variation of the brake specific energy consumption with load. When two different fuels of different heating values are blended together, the fuel consumption may not be reliable, since the heating value and density of the two fuels are different. In such cases, the brake specific energy consumption (BSEC) will give more reliable value [14]. The brake specific energy consumption was determined for karanja methyl ester-diesel fuel blends as the product of the specific fuel consumption and the calorific value. It can be observed from the figure that the BSEC for KME30 is lower as compared to that of diesel fuel. The availability of the oxygen in the karanja methyl ester-diesel fuel blend may be the reason for the lower BSEC.

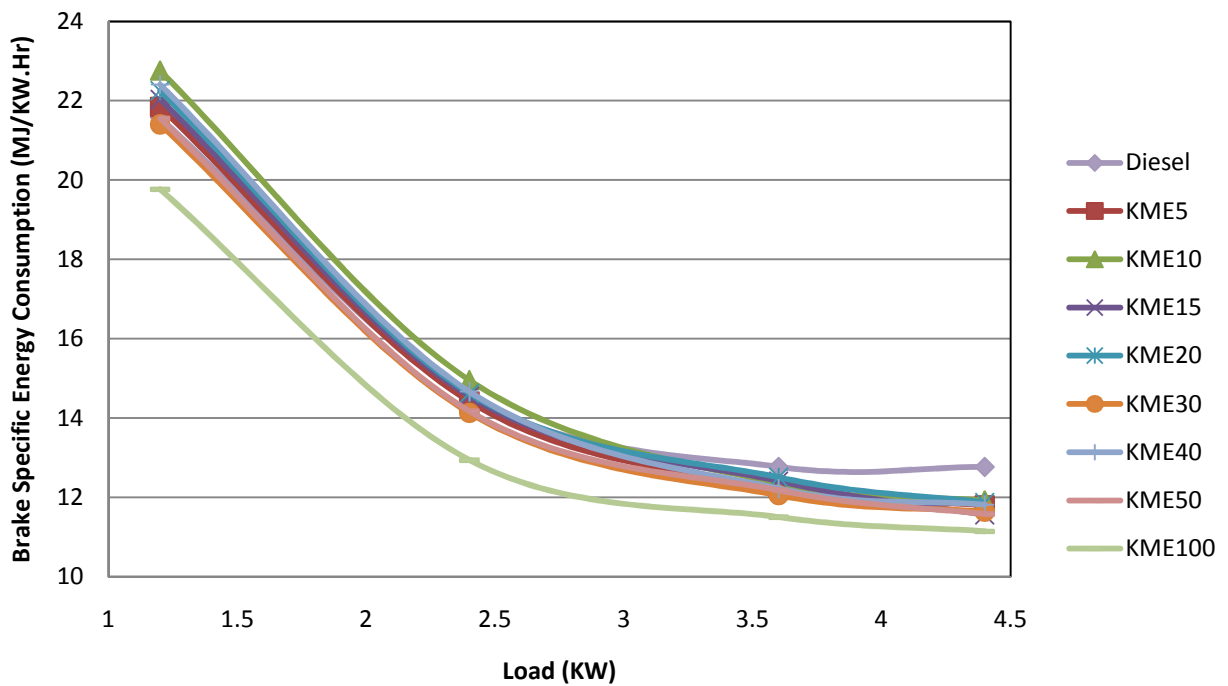


Figure 4 – Variation of brake specific energy consumption with load

In the case of lower load conditions, the incomplete mixture of high viscosity KME may lead to incomplete combustion and require additional fuel air mixture to produce the same power output as that of diesel fuel.

5.1.3 Exhaust Gas temperature (EGT)

The exhaust gas temperature of an engine is an indication of the conversion of heat into work. Figure 5 shows the variation of the exhaust gas temperature with load for the fuel blends. Exhaust gas temperature for KME100 is highest. For the diesel fuel, the exhaust gas temperature is the lowest among all the tested fuels. The exhaust gas temperature rises from 135 °C at no load to 347 °C at full load for KME100, while for KME20 the exhaust gas temperature rises from 136 °C at no load to 339 °C at full load.

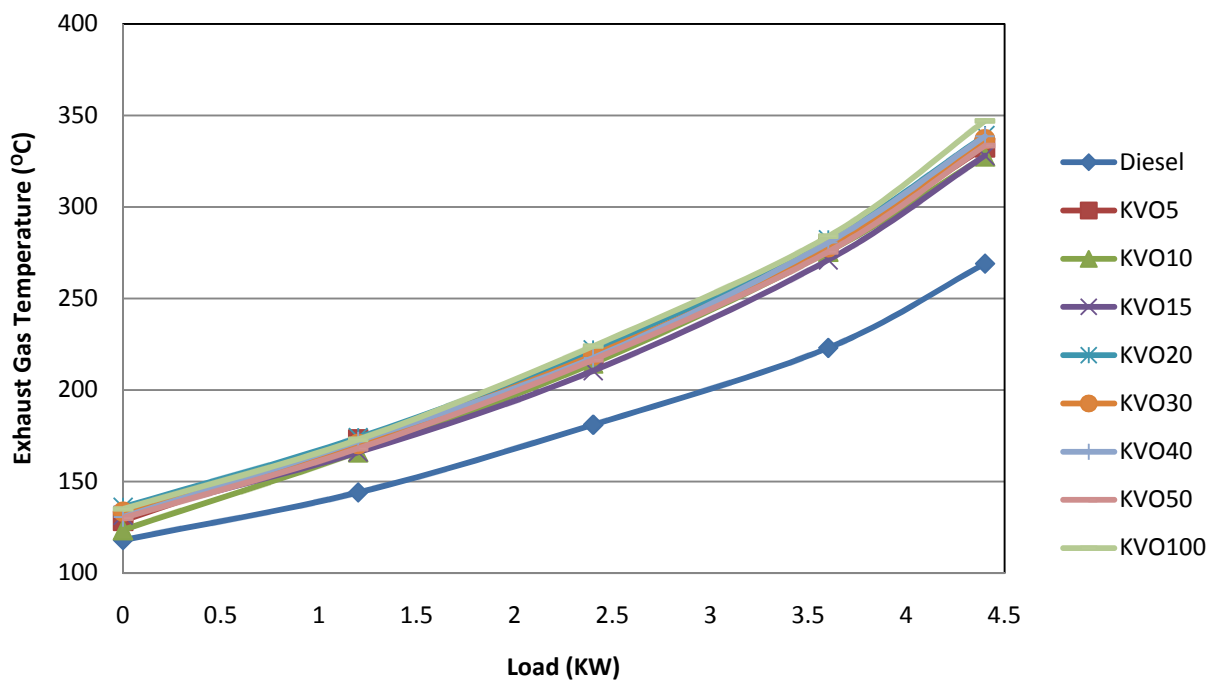


Figure 5 – Variation of exhaust gas temperature with load

In the case of karanja methyl ester-diesel fuel blends, the heat release may occur in the later part of the power stroke. So this may result in lower time for heat dissipation and higher exhaust gas temperatures. Result of studies on bio oil blends by Prakash et al. [15] agrees with our results.

5.1.4 Mechanical Efficiency

The mechanical efficiency of the fuel mixtures is plotted in figure 6. It can be seen that the mechanical efficiency for KME30 is better than diesel fuel at lower load conditions.

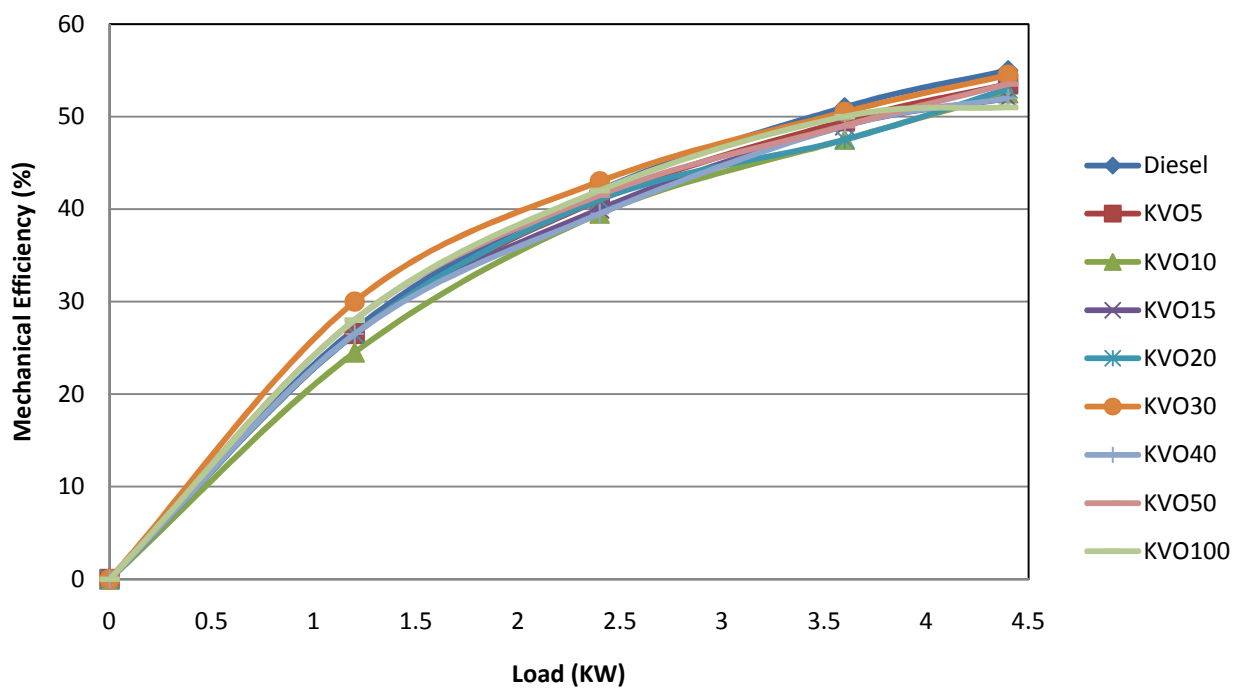


Figure 6 – Variation of mechanical efficiency with load

5.2 Emission Parameters

5.2.1 Nitric Oxide (NO)

Figure 7 shows the trend of nitric oxide emission with different blends at different loads. A majority (about 90%) of the nitrogen in the exhaust is in the form of nitric oxide. Temperature and oxygen are the two important factors which support the formation of nitric oxide [16].

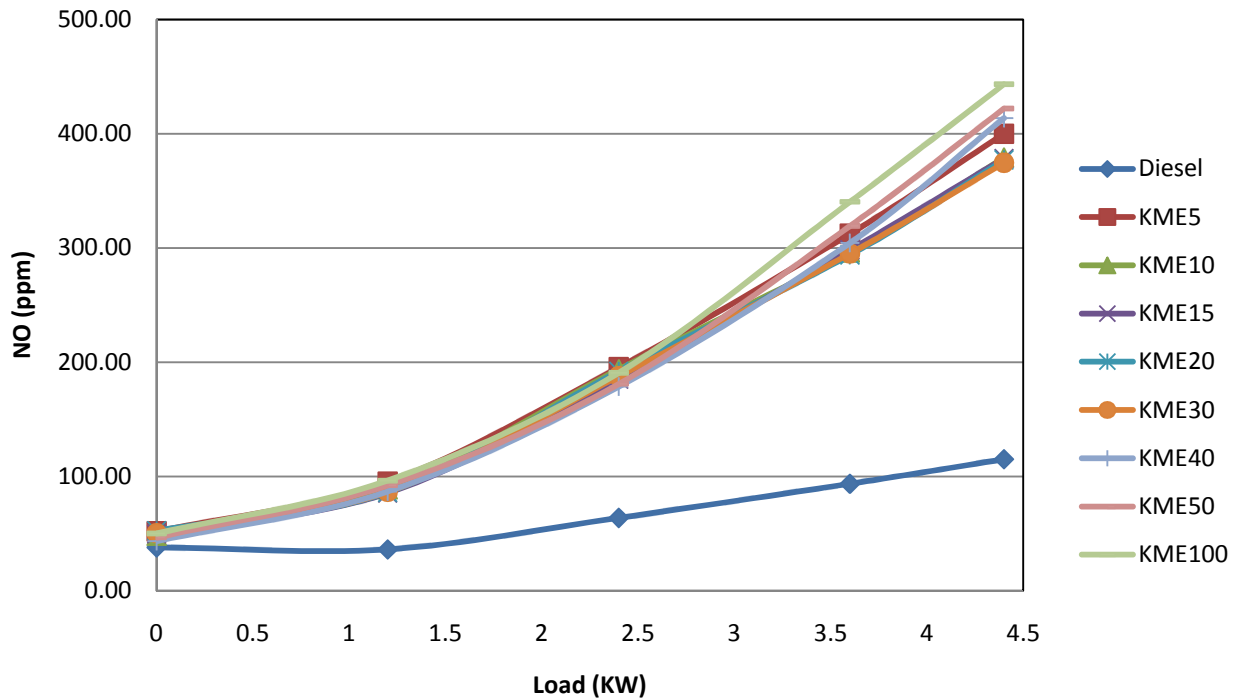


Figure 7 – Variation of nitric oxide emission with load

The slower burning character of the fuel causes a slight delay in the energy release, which results in higher temperature in the later part of power stroke and exhaust stroke. This high temperature favours the formation of nitric oxide. The higher release of nitric oxide can also

be attributed to presence of nitrogenous compounds in the fuels of plant origin. At higher loads, more fuel is burnt and higher temperature of the exhaust gases results in higher production of nitric oxide. Nabi et al. [17] also reported higher NO_x with karanja biodiesel. Banapurmatha et al. [18] reported that nitric oxide emission was reduced with changing of injection timing for certain biodiesels.

5.2.2 Carbon Monoxide (CO)

The emission of carbon monoxide for various blends at different loads can be seen in figure 8. The emissions are slightly higher for almost all blends. This can be attributed to higher viscosity of the fuel which results in poor atomisation & incomplete combustion of the fuel. At higher load, more fuel is consumed which results in relative lowering of the availability of oxygen for the combustion of the fuel, which results in slightly higher carbon monoxide.

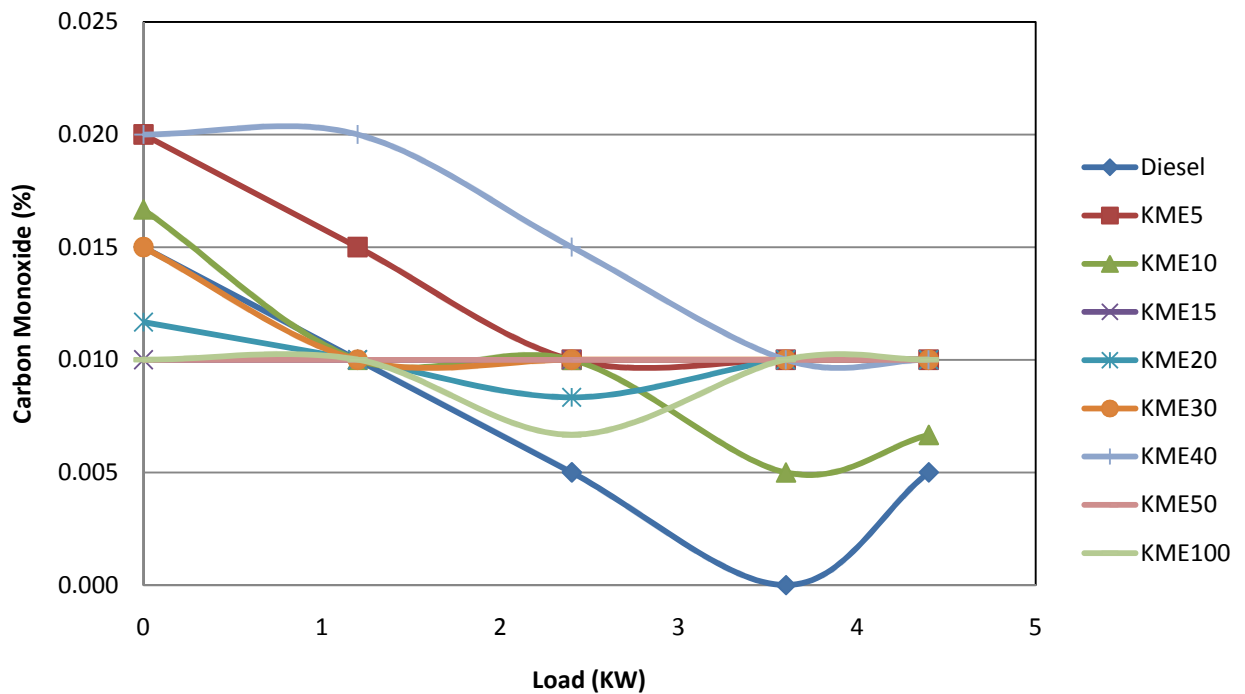


Figure 8 – Variation of carbon monoxide emission with load

Prakash et al. [15] report a slight increase in CO emission in engine testing with wood pyrolysis oil blends.

5.2.3 Carbon Dioxide (CO₂)

Figure 9 illustrates the variation of carbon dioxide emission for various blends at varying loads. The carbon dioxide emission for the blends is higher than diesel for all loads and blends.

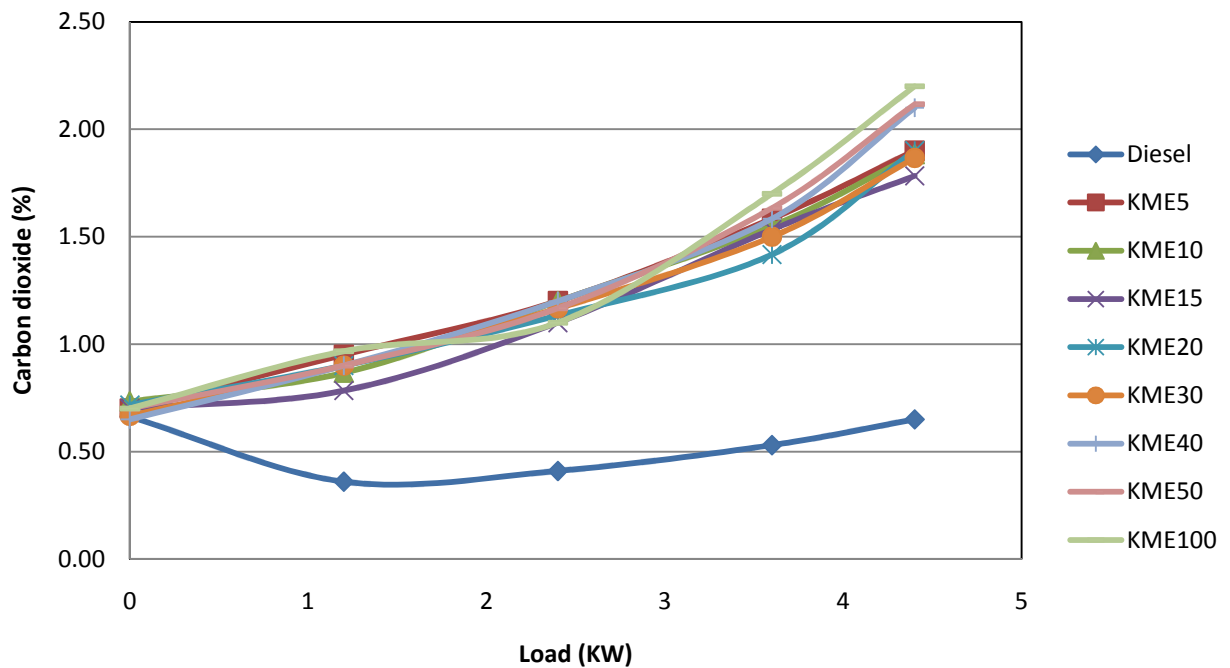


Figure 9 – Variation of carbon dioxide emission with load

Carbon dioxide is formed on complete combustion of the fuel in oxygen. As the calorific value of the fuel is low, more fuel needs to be burnt to get equivalent power output. So combustion of more carbon compounds leads to higher carbon dioxide emission.

5.2.4 Hydrocarbons (HC)

Figure 10 shows the variation of hydrocarbon exhaust for different blends at varying loads. Hydrocarbons in exhaust are a result of incomplete burning of the carbon compounds in the fuel. Initially all blends have lower values than diesel owing to higher combustion chamber temperature which helps in cracking and faster burning.

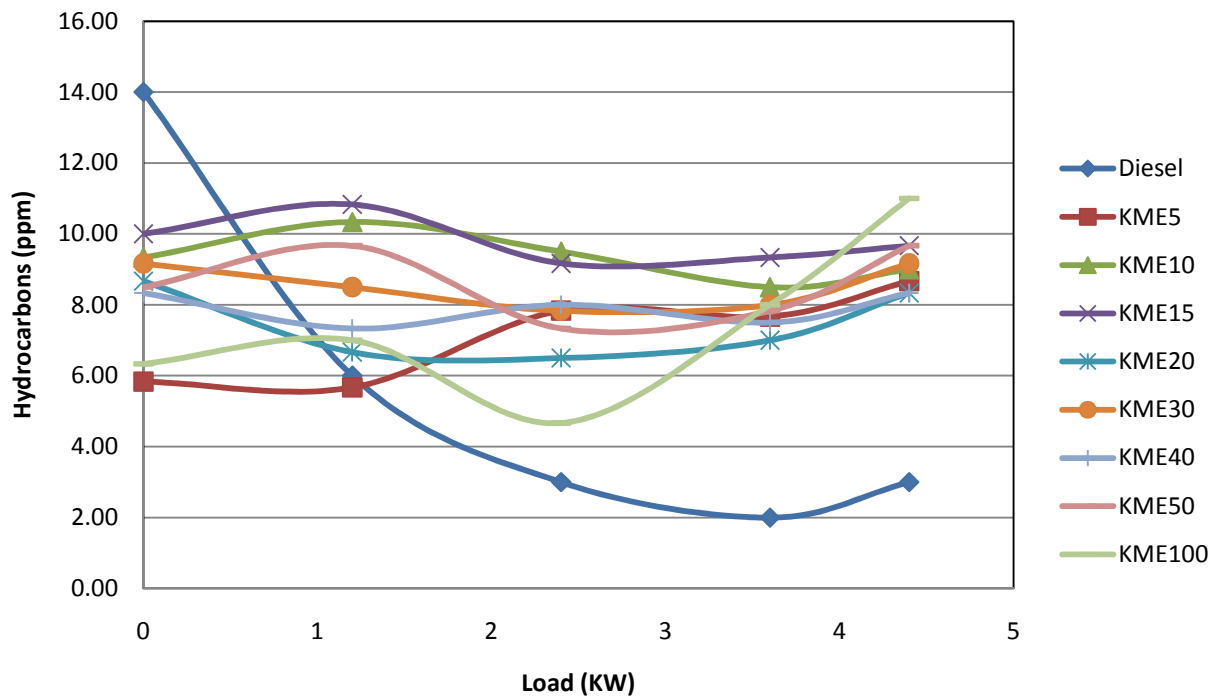


Figure 10 – Variation of unburnt hydrocarbon emission with load

But as load is increased, fuel consumption increases which results in relative reduction of oxygen in the fuel air mixture and leads to higher exhaust as compared to diesel. But Sahoo et al. [19] report reduction in HC emissions with biodiesel.

CHAPTER 6

CONCLUSIONS

6. CONCLUSIONS

Karanja methyl ester seems to have a potential to use as alternative fuel in diesel engines. Blending with diesel decreases the viscosity considerably. The following results are made from the experimental study-

- The brake thermal efficiency of the engine with karanja methyl ester-diesel blend was marginally better than with neat diesel fuel.
- Brake specific energy consumption is lower for karanja methyl ester-diesel blends than diesel at all loading.
- The exhaust gas temperature is found to increase with concentration of karanja methyl ester in the fuel blend due to coarse fuel spray formation and delayed combustion.
- The mechanical efficiency achieved with KME30 is higher than diesel at lower loading conditions. At higher loads, the mechanical efficiency of certain blends is almost equal to that of diesel.
- The emission characteristics are higher than pure diesel but the KME30 has relatively better performance with respect to other blends.
- KME30 can be accepted as a suitable fuel for use in standard diesel engines and further studies can be done with certain additives to improve the emission characteristics.

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Paper Published:

1. Saswat Rath, Sachin Kumar and R. K. Singh, “Performance and Emission Analysis of Blends of Karanja Methyl Ester in a Compression Ignition Engine” communicated to Applied Energy, Elsevier Publication.