Experimental Investigation on Reducing the Harmful Exhaust Emission from Diesel Engine

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Abstract- **The rapid growth of population and vehicles has resulted in the rapid increase in the energy demand. Due to the energy demand and fast depletion of fossil fuels, researchers are more focused on to find the suitable alternate fuel for diesel. It can be used for diesel engine without any modification.. The main focus of this research is importance of tyre pyrolysis oil as an alternative fuel for diesel engines. In this context, tyre pyrolysis oil has recently been receiving renewed interest. The tyre oil having high viscosity, high flash point, high density and lower calorific value is suitable fuel for compression ignition (CI) engine. The tyre oil was mixed blends 5%, 10%, by volume with diesel . The experimental analysis of engine parameters such as performance and emission characteristics of tyre oil and its blends in a compression ignition engine was carried out.**

I. INTRODUCTION

In Our Environment, Disposal of Tyres are very difficulty because of two reasons, One is Peoples burning the waste tyres that will Produce the Unwanted Harmful Emissions this will affect the Human beings. Other is, In Waste Tyres are attained by some waters and Mosquitoes are lived, this will Create the Viral Fever this also affect the Human Beings. Fast depletion of fossil fuels demands an urgent need to carry out research work to find out the viable alternative fuels and since atmospheric pollutants are increasing, an eco friendly fuel needs to be developed to meet the fossil fuel depletion. Thus a lot of research has been done to recover energy from waste materials, including materials that are not bio-degradable. Such materials include biomass, municipal solid wastes, industrial wastes, agricultural wastes and other low grade fuels, as well as high energy density materials such as rubber and plastics. The tyre and tube wastes pose big environmental problem because rubber is an artificial polymer and also not bo degradable. The photo degradation of rubber waste takes more time as compared to biomass. There is a major increase in tyre and tube wastes due to the unusual increase in number of vehicles in India. A glance at a 2011 report from the Indian Rubber Industry on the statistical data of production of tyre and tube in India shows that the production rate of tyre increased from 66,032 metric tonnes to 97,137 metric Tonns from 2005 to 2010.

2.OBJECTIVES

- To produce biodiesel from tyre pyrolysis oil.
- To study the fuel properties of different blend ratio of biodiesel with diesel and also mixed with cerium oxide.
- To analyze the performance and exhaust emission from diesel engine fuelled with biodiesel-cerium oxide and without biodiesel-cerium oxide.

ENERGY DEMANDS

Demand for energy and its resources is increasing continuously due to the rabid outgrowth of population and urbanization. Present sources of energy are not sufficient to overcome the increasing needs. The major energy demand is fulfilled from the conventional energy resources like coal, petroleum and natural gas. The huge amount usage of fossil fuel creates environmental threads.

Transportation and global warming

Because of its near total dependence on petroleum fuels the U.S. transportation sector is responsible for about a third of our country climate changing emission .globally, about 15% of manmade carbon dioxide comes from cars, trucks, airplanes, ships and other vehicles.

Reducing transportation emission is one of the most vital steps in fighting global warming and solution to the transportation problem are already available

ENERGY SOURCE AND RECOVERY

Disposal of waste tyres by land-filling causes a loss of valuable resource. Recovering energy from waste tyres is a significant way to reuse them as they are a high grade energy source. The approximate composition of tyre is 85% carbon, 5% cord and 10% steel. Hence it can effectively be used as an alternate fuel in kilns. In the UK, the energy recovered from used tyres is approximately 27% while, it is between 50% and 80% in other European countries like Finland, Austria, Sweden and Germany. The energy value of tyres is higher compared to traditional coal fuels. Hence there exists a large potential towards extracting energy from used tyres

Emission

Table 1.3 describe the CO_2 emission from fossil fuel combustion in 2013 for various sector like total sector, power and heat generation, other energy residential building, other buildings. Another way to reduce vehicle pollution is by practicing good vehicle maintenance. Your vehicle owner's manual has a suggested maintenance schedule carbon monoxide(53%),hydrocarbon(67%),and nitrogen oxide(68%) relative to the Euro I standard that became effective in 1992. The Euro IV standard that became effective on January 1, 2006 required further tailpipe emission reduction in carbon monoxide (43%), hydrocarbon(33%), nitrogen oxides(50%).the EU also sets standard for fuel composition to require successively cleaner fuels. Thus the EU seeks to reduce transport related air pollution not only by requiring cleaner and more efficient engines and catalytic converters but also by requiring cleaner fuels.

Methane (CH_4):

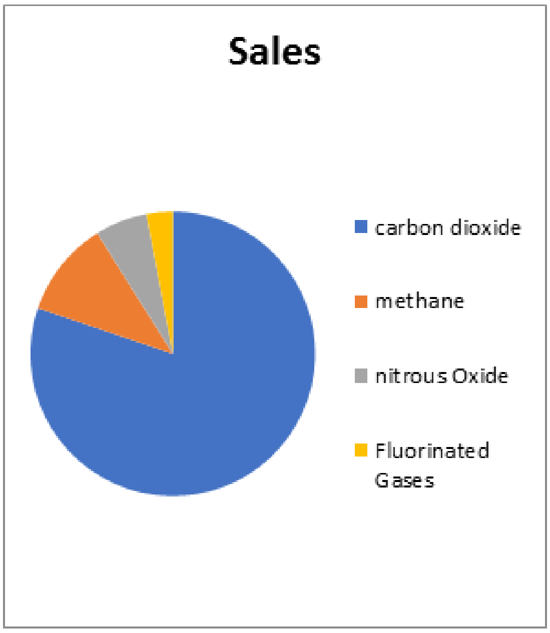
Methane is emitted during the production and transport of coal, natural gas and oil. Methane emission also result from livestock and other agriculture practice and by the decay of organic waste in municipal solid waste landfills. Nitrous

oxide (N_2O):

Nitrous oxide is emitted during agricultural and industrial activities as well as during combustion of fossil fuel and solid waste.

Fluorinated gases:

Hydrofluorocarbon, perfluorocarbons, sulfur hexafluoride and nitrogen trifluoride are synthetic, powerful greenhouse gases that are emitted from a variety of industrial processes. Fluorinated gases are sometimes used as substitutes for stratosphericozone-depleting substances. These gases are typically emitted in smaller quantities, but because they are potent greenhouse gases, they sometimes referred to as High Global Warming potential Gases (“High GWP Gases)



CURRENT DISPOSAL METHODS OF AUTOMOBILE TYRES

The current disposal methods of waste tyres include
Landfill
Crumbing
Remould
Incineration

Land fill

Presently about 50% of the waste automobile tyres are used for landfill in every country. A small percentage is used for engineering purposes at landfill sites. Disposition in large volumes can lead to fires and instability especially by rising to the surface which affect long-term settlement may cause problems in future. Buried tyres in landfill sites cause fire hazards at several places. Such fires are dificult to control as it leads to uncontrolled pyrolysis of tyres which produces a complex mixture of chemicals.

Crumbing

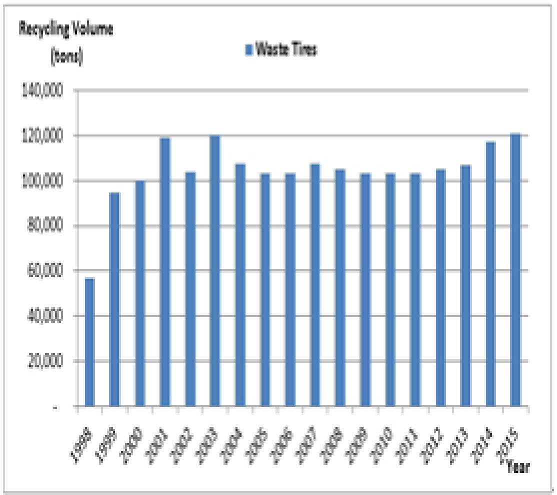
Crumbing is another method of disposal. In this method, the tyres are cut at several stages until rubber attains crumb form which can be use in several applications like:

Remould

It is a costly process for the manufacturer both in terms of economy and physical work. Further only few designs, about 20%, of tyres are suitable for remoulding which may increase by 5% in future.

Incineration

Electrical power can be generated by incineration of waste tyres. However, this method requires high investment costs and further causes a lot of pollution.



Alternate fuels

Tyres may be burnt as a whole or may be shredded before burning or may be converted to combustible gas or liquid via pyrolysis. The main disadvantage linked to reuse of waste tyres is that they are widely scattered and need collection and transportation which consumes resources. Further, due to low bulk density of about 0.16 T/m3, the transportation cost of whole tyres is very high. Shredding tyres prior to transportation can increase its density to around 500 kg/m3.

Pyrolysis

Pyrolysis is a process of recovering energy from from different materials by heating them to form volatile gases which is then cooled to form liquid fuel. Attempts have been taken in the US to install a few Pilot plants to decompose tyres and recycle them. Pilot plants for tyre pyrolysis have also been installed in Europe,India and China. But these have not shown any promise.

Gasification

Gasification is the process of converting a solid or liquid into a gaseous fuel without leaving any solid carbonaceous residue. Many countries have installed gasification units for recovering energy from waste tyres. A large gasification plant of 15.5 MW generation capacity is proposed to be set in the UK. The estimated capital cost of this plant is $8 M for a 30,000 tons capacity with operating cost of US $90 per ton.

Polymerisation

A tyre polymerisation plant is being installed by Environmental Waste International Inc. in the UK. The plant, which costs NZ $ 17 M will take 18 months for its construction and will have a maximum processing capacity of 3000 tyres per day

AVAILABILITY AND COMPOSITION OF TYRES

Since the number of automobiles used in India is less than the developed countries, the problems related to disposal of waste tyres is not seriously realised as on today. But it is supposed to become a serious problem in the near future. Hence, proper treatment methods for waste tyres have to be put in place in advance. A tyre is artificially engineered by the human mind. it contains chemicals, rubber, steel and fabric.

VARIOUS PARTS OF TYRES

A car tyre has a mass of about 8.5 kg, whereas the mass of a tyre of a passenger or light duty vehicle is around 11 kg. The constituents of truck tyre are given in Table 3.1. The various parts of an automobile tyre include bead, bundle, body, belt, cap sidewall and tread. The raw materials used in tyres include synthetic and natural rubber, nylon, polyester cord, carbon black, sulphur, oil resin and other chemicals. These constituents provide the tyre with a good strength and flexibility to ensure adequate road holding properties under all conditions. About 80% of mass of car tyre and 75% of mass of truck tyres are rubber compounds.

Component	Proportion(%)
Nature rubber	45
Synthetic Polymer	4
Carbon black	22
Oil	6
Chemicals	4
Steel wire	6
Others	2.5

Composition of tread rubber

The elemental composition of tread rubber is given in Table 3.2. It can be seen from the table that tyres contain hydrogen, carbon, sulphur, nitrogen and other elements

Elements	Percentage(%)
Hydrogen	88.25
Carbon	7.07
Oxygen	2.17

COMMERCIAL PYROLYSIS PLANT

Setting up of a commercial pyrolysis plant requires several clearances from authorities environmental, state and central regulatory authorities have published a technical report in this respect. In typical commercial pyrolysis plant, scrap tyres are fed into a cylindrical chamber which is placed over a burner. The burner is normally fuelled by firewood. Chemical reaction for pyrolysis occurs at a temperature of approximately 550◦C.

PYROLYSIS PROCESS AND ITS TYPES

The different methods of pyrolysis processes are discussed in the following subsections.

Based on nature of pyrolysis

(i)Vacuum Pyrolysis

In this process, organic material is heated in vacuum to reduce its boiling point and also to avoid adverse chemical reactions. Flash Vacuum Pyrolysis (FVT) is a process of vacuum pyrolysis in which the residence time of the substr1ate at working temperature is limited as much as possible, again to minimize secondary reactions.

(ii)Flash Pyrolysis

In flash pyrolysis, the biomass is ground into fine particles and the insulating char layer that forms at the surface of the reacting particles is continuously removed. Flash pyrolysis of biomass particles has been carried out and a report .

LITERATURE REVIEW

Williams et al. (2002) investigated the influence of pyrolysis temperature from 300 to 720 °C and heating rate from 5 °C min1 to 80 °C min1 on product yield from the pyrolysis of 50 g of tyre in a used, small scale, fixed bed batch reactor. At the low temperature of 300 °C, there was slight thermal degradation of the tyres. They also investigated that to maximize oil yields between 54 wt% and 58.8 wt%, pyrolysis temperatures of 600–720 °C were required [1].

Murugan et al. (2008) was studied that Performance, emission and combustion studies of a DI diesel engine using Distilled Tyre pyrolysis oil-diesel blends Engine is able to run upto 90% DTPO and 10% DF (DTPO90). Engine failed to run satisfactorily with 100 % DTPO. Brake thermal efficiency increases with increase in percentage of DTPO blends but lesser than DF. About 3 % drop in the thermal efficiency is noticed. NOx is lower by about 21 % for DTPO80 and 18 % lower in DTPO90 operation than that of DF operation[2].

Olazar et al. (2010) and Lopez et al. (2010) used a conical spouted bed reactor to study the pyrolysis of tyres. The spouted bed is a type of fluidised bed reactor with the advantages of isothermal operation, high heat transfer rate, reduced gas residence time which minimizes secondary reactions and better interaction of sand and solid. There is vigorous bed movement which minimizes agglomeration. Olazar et al. reported an oil yield of 62 wt%, char yield of 35 wt% and gas yield of 3 wt% for the pyrolysis of waste tyre particles. In the same work, they investigated the use of catalysts to determine the influence on gas and oil composition. They also used the spouted bed reactor under vacuum pyrolysis conditions. The influence of the vacuum caused production of oils with a higher diesel fraction and increased yield of isoprene [3]

Wongkhorsub et al. (2013) was studied that A Comparison of the Use of Pyrolysis Oils in Diesel Engine.The use of plastic pyrolysis oil and tire pyrolysis oil in diesel engine in the aspect of technical and economical is compared and found that both of the oils are able to re-place the diesel oil. Though the plastic pyrolysis oil offers lower engine performance, the plastic waste amount is enormous and it needed to be process to reduce the environmental problems. Therefore, the development of the tire pyrolysis oil is depending on the cost of desulfurization process [4].

Antoniou et al. (2013) was experimented that Features of an efficient and environmentally attractive used tyres pyrolysis with energy and material recovery. The study showed the following technical features Attending the advances in pyrolysis applications, laboratory and bench scale pyrolysis of end of life tyres have been studied thoroughly, while pilot/demonstration or industrial applications are relatively few. Several types of laboratory scale pyrolysis of end of life tyres (ELT) have been tested by many researchers either by the use of catalyst or not. More specifically, fixed bed, rotary kiln and fluidized bed reactors were used to determine the basic characteristics of pyrolysis procedure under typical pyrolysis conditions. Innovating pyrolysis types such as flash, plasma and molten salt type were investigated by few researchers. These processes are characterised by heating rate41000 1C/s, final pyrolysis temperature 41500 1C and high heat transfer/reaction medium, respectively[5].

Aydin and Ilkilic et al. (2013) investigated the pyrolysis of waste tyres in fixed bed reactors with steel and fabric removed in a capacity fixed bed reactor in nitrogen over the temperature range of 400–700 °C. They found that the oil yield increased from 31 wt% at 400 °C to 40 wt% at 500 °C, with slight change in yield at higher temperatures [6].

SMOKE METER AND FIVE GAS ANALYZER

To Analyze the amount of overall Exhaust Emissions from the engine for our test Fuel by means of Smoke Meter.To Measure the amount of five Exhaust gases such as CO, HC, CO2, NOx, O2 for our Standard units.

4.EXPERIMENTAL SET-UP AND PROCEDURE

The schematic diagram of the experimental set-up is shown in Figure.2. A vertical, single cylinder, water cooled direct injection diesel engine was used in this experimental study. The eddy current dynamometer was used to apply the load on the engine. The AVL make pressure transducer and a crank angle encoder was used to measure the incylinder pressure and the respective crank angle positions. The heat release rate was calculated by AVL Indicom, software version 2.1 and noted exhaust temperature, water outlet temperature and emission characteristics, smoke.Then all the details were stored in the personal computer for further calculation.

3.PYROLYSIS MECHANISM

Research on the pyrolysis mechanism is very important for reactor design and desired product profiles. When tyre particles are heated in a pyrolysis reactor, pyrolysis occurs when the particles surface reaches a certain temperature. There are two stages in pyrolysis: primary pyrolysis and secondary cracking. Vapour or volatile products are first produced from the waste tyres and are made up of a wide variety of hydrocarbons, that can then encounter secondary reactions. For the thermal decomposition of organic polymers, four general mechanisms can be identified: (i) random chain scission; (ii) end chain scission; (iii) chain stripping; and (iv) cross-linking.

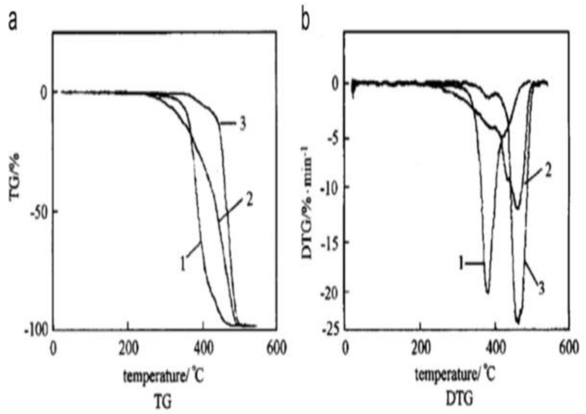


Figure 4.3 The pyrolysis TG and DTG plots of rubber materials.

Wey et al. showed that pyrolysis is governed by the following parameters: (i) temperature, (ii) retention time of the volatile at the reaction zone, (iii) pressure and (iv) type of gaseous atmosphere. Cracking occurs at higher temperatures and enables primary products to be converted into compounds which may have a higher market value.

PYROLYSIS REACTORS AND PRODUCT YIELD

A range of dissimilar reactors, such as fixed-bed (batch), screw kiln, rotary kiln, vacuum and fluidised-bed have been used for pyrolysis of waste tyres. The range of pyrolysis reactors used to research the pyrolysis of waste tyres and the yields of oil, char and gas from the process. In some cases, the data embrace the recovery of the cord and steel belt which naturally ranges from 10 to 15 wt% of the waste tyre. To investigate pyrolysis of waste tyres, fixed bed batch reactors have been widely used. These reactors are typically heated externally by an electric furnace and nitrogen or another inert gas is used as a carrier gas. The thermal degradation of the tyre starts at around 350 °C and so pyrolysis experiments are ususally conducted in the range of 450–700 °C.

Fluidised Bed Reactors

Fluidised bed reactors have been investigated on the laboratory scale with 1 kg h1 throughput, technical scale with 30 kg h1 throughput, and pilot scale with 200 kg h1 throughput. Large scale pilot plant studies were able to process whole 9 tyres. The fluidised bed is heated indirectly to typical temperatures between 500 and 780 °C via radiant heat tubes within the bed of quartz sand, in which the product pyrolysis gas is combusted to provide heat. The fluidising gas is also the product gas and it is preheated to 400 °C. If any ash is build up in the fluidised bed, it is removed by a screw extractor. The product gases pass through a cyclone to remove particulate material and the oils are condensed and distilled to produce two oil fractions, heavy and light oils. The gases undergo further removal of oil droplets in an electrostatic precipitator before storage.

Other Types Of Reactor

It used a conical spouted bed reactor to study the pyrolysis of tyres. The spouted bed is a type of fluidised bed reactor with the advantages of isothermal operation, high heat transfer rate, reduced gas residence time which minimizes secondary reactions and better interaction of sand and solid. There is vigorous bed movement which minimizes agglomeration.reported an oil yield of 62 wt%, char yield of 35 wt% and gas yield of 3 wt% for the pyrolysis of waste tyre particles. In the same work, they investigated the use of catalysts to determine the influence on gas and oil composition. They also used the spouted bed reactor under vacuum pyrolysis conditions. The influence of the vacuum caused production of oils with a higher diesel fraction and increased yield of isoprene.

5.CHARACTERISTIC ANALYSIS OF TYRES

Tyres are produced by more than 100 different species. The composition of different tyre parts like the tyre sidewall or the tyre tread varies due to the different desired characteristics of the product. Rubber compounds generally consist of elastomers (natural or synthetic rubber), carbon black, hydrocarbon oils, zinc oxide, sulphur and sulphur compounds and other chemicals such as stabilizers, antioxidants, anti-ozonants, etc. The rubbers mostly consist of blends of two or three rubbers together with tyre additives. Because of these complex mixtures, the pyrolysis of tyres seems to be a complicated process involving a large number of chemical reactions and complex interactions of the single components.

Proximate Analysis

Proximate analysis separates the products into four groups: (i) moisture; (ii) volatile matter, which consists of gases and vapours driven off during pyrolysis; (iii) fixed carbon, the nonvolatile fraction of coal and (iv) ash, the inorganic residue remaining after combustion. We come to know that the concentration of volatile content higher than the fixed carbon, steel, ash, and moisture.

Elemental Analysis

A complementary method to proximate is the ultimate analysis. Its scope is the determination of the carbon and hydrogen in material, as found in gaseous products of feedstock's complete combustion, and the determination of the contents of sulphur, nitrogen and ash in the material as a whole, and oxygen content by difference. We come to know that the carbon weight is more than hydrogen, sulphur, nitrogen, oxygen and ashes.

PROCESSING OF PYROLYSIS OIL

The waste tyres are composed and separated out. After separation, the tyres are cut into small pieces and steel wires, and fabric wires are removed. The thick edge of the tyre is cut into small segments. These tyre segments are washed, dried and then filled in the pyrolysis reactor. Conventional pyrolyis is performed under N2 environment and ambient pressure. The operating tyre pyrolysis processes are within a temperature range of 250–500 °C, even though some processes are reported to operate upto 900 °C. At temperatures above approximately 250 °C, ragged tyres release higher amounts of liquid oil products and gases, while above 400 °C, the yield of oil and solid tyre-derived char may decrease relatively to gas production. Classifications of pyrolysis as atmospheric, vacuum, catalytic, fast or slow is according to the operation parameters applied. On the other hand, hydro genitive pyrolysis was studied by Murena et al. who used hydrogen as a medium for tyre pyrolysis. The pyrolysis process is generally carried out by many types of reactors. A number of studies and researches have been done to investigate the pyrolysis of waste tyres both on the laboratory and industrial scale. Subsequently, several laboratory, pilot pyrolyis reactor procedures and different conditions using end of life tyres (ELTs) as feedstock are presented.

Property	Tyre Pyrolysis Oil	Diesel
Heating Value (KJ/Kg)	43225.9	45814.74
Density30^{0}C (g/cc)	0.924	0.7994
Viscosity40^{0}C (CP)	2.69	1-4.11
Flash Point (^{0}C)	65	70

PURIFICATION PROCESS

Tyre oil contains dust and moisture content that is affecting the engine characteristics that is removed by this process. In this Fig4.3 shown. First 500ml of tyre oil poured to flask after 200ml of pure water added to flask after rest at 5 minutes. Then oil and water to be separated in flask oil at top side water at bottom side because of oil density is less than water

Air motor to be put inside the flask the water and oil to homogenous mixer at 10 minutes then after removed air motor and blends rest at 10 minute After water removed first then purification oil to be removed

EVAPORATED WATER MOLECULES

After purification process water and oil to be collected then some of water molecules in oil that water molecules to be evaporated by means of heating. Then temperature to be maintained at 1100c for 15 minutes then all water molecules to be removed.

Parameters	Description
Make	Kirloskar TV 1
Type	Single Cylinder, 4-Stroke, Direct Injection
Power	3.7KW ,5HP
Bore & Stroke	87.5 & 110mm
Compression Ratio	17.5
Rated Speed	1500 rpm
Cooling Type	Water Cooling
Fuel Injection Time	23˚ BTDC
Fuel Injection Pressure	200 bar

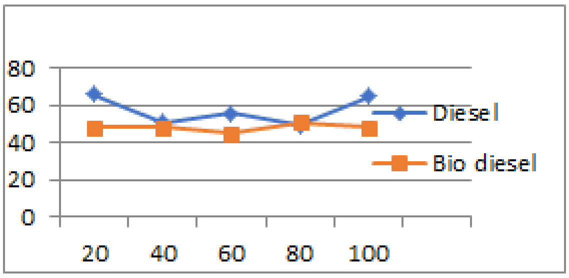
EMISSION CHARACTERISTICS

CO Emission

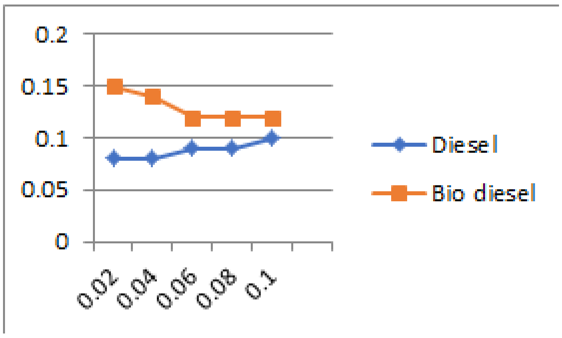
Variation of carbon monoxide with BP is as shown in the figure 4.3 carbon monoxide in diesel engine is mainly depends upon the physical and chemical properties of the fuel. The biodiesel itself contains 11% of oxygen which helps for complete combustion. From fig.5 it is found that the amount of CO increases at part loads and again greater increase at full load condition for biodiesel. This is common in all the internal combustion engines, since the air –fuel ratio decreases with increase in load. The carbon monoxide emission increases when fuel air ratio becomes greater. The CO emission for fuels used at full BP is approximately 30% lower than diesel. The lowest carbon monoxide emission is observed at 250bar as 0.04% for biodiesel.

HC Emission

Figure 4.4 shows the variation of HC with BP. The HC is increased with increase in BP for biodiesel.



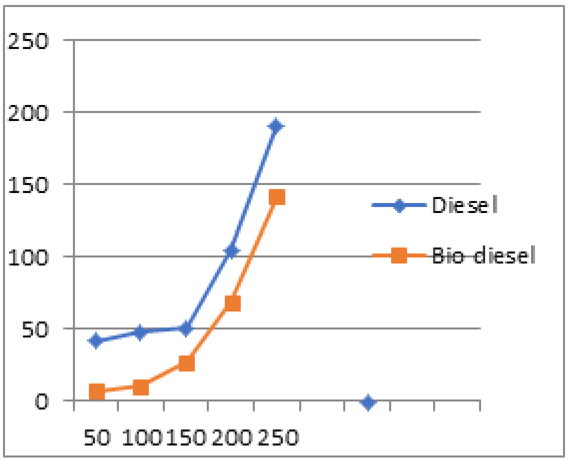
It is observed from figures, that the HC emission for biodiesel is lower than diesel fuel, indicating that the heavier hydrocarbons particles that are present in the diesel fuel increases HC emissions. The HC emission of biodiesel at full load is approximately 25 to 30% lower than diesel value. The presence of oxygen in the fuel was thought to promote complete combustion that leads to lowering the HC emissions. This reduction indicates more complete combustion of the fuel. As the IP increases the HC emission will decrease as seen in the figure, for biodiesel and at 200bar, IP there is minimum HC emission. And at 250 bar it seems to be increase in HC emission which may be due to finer spray, which reduces the momentum of the droplets resulting in less complete combustion.



NOx Emission

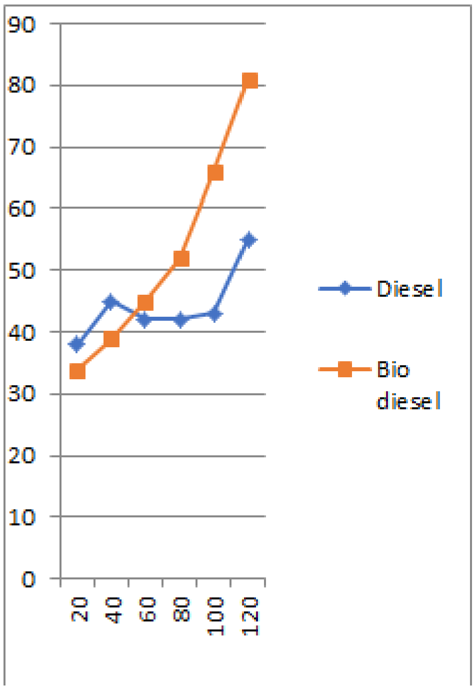
Variation of NOx with BP is shown in the figure 4.5. The NOx results from the oxidation of atmospheric nitrogen at high temperature inside the combustion chamber of the engine rather than resulting from the contaminant present in the fuel. NOx emission were lower at 200 bar injection pressure indicating that the effective combustion is taking place during the early part of expansion.

Increase exhaust gas temperature due to lower heat transfer and the fact that biodiesel has some oxygen content in it which facilitates NOx formation. An advance of fuel injection timings in engine operating on mechanical type fuel injectors when using biodiesels which are having lower compressibility compared to diesel thus lower compressibility and higher speed of sound in biodiesel shorten ignition delay permitting can combustion conditions conducive for NOx formation. Higher cetane number of biodiesel shortens ignition delay advancing combustion.



Smoke Emission

Smoke formation occurs at extreme shortage of air during the combustion of A/F mixture. If the air-fuel ratio decreases, smoke formation increases. From the Figure 4.6 it is observed that smoke emission is less in the biodiesel from biodiesel operated mode. It may be due to the availability of oxygen contained in the biodiesel molecules that influences the carbon oxidation in the fuel rich zones. One can observe from the figure that smoke emission decreases for operated biodiesel fuel blend. Smoke emission decreases by 40% than diesel.



ADVANTAGES

- Bio diesel is non-toxic.
- Bio diesel degrades four times faster than diesel.
- Blending of biodiesel with diesel fuel increases engine efficiency.
- Cerium oxide has more lubricating property

6.CONCLUSION

Alternate fuels for diesel engines have become increasingly important due to decreasing petroleum resources and environmental consequences of exhaust gases from petroleum fuelled engines. There is great potential for development of pyrolysis technologies of waste tyre rubber due to environmental pressure and economic driving force. Many reviews were carried out on the pyrolysis mechanism to design the reactor for yielding the byproducts from the tyres. Pyrolysis reaction was carried out in an inert gas environment, so it is concluded that highest yield of liquid products were obtained at the conditions when reaction temperature was 500 °C with 200 cm3/min N2 Flow rate and with 5% of Ca(OH)2 addition. The elemental analysis of tyres was done to find out the percentage of the products from the tyres i.e. moisture, volatile matter, carbon, hydrogen, sulphur steel, ash content..

REFERENCES

[1] Williams et al. (2002) investigated the influence of pyrolysis temperature from 300 to 720 °C and heating rate from 5 °C min1 to 80 °C[1].

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