Performance and Emission Characteristics of Bio-Diesel using Tyre Pyrolysis Oil

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Abstract:
Due to the fossil fuel crisis in past decade, mankind has to focus on developing the alternate energy sources such as biomass, hydropower, geothermal energy, wind energy, solar energy, and nuclear energy. The developing of alternative-fuel technologies are investigated to deliver the replacement of fossil fuel. The focused technologies are bio-ethanol, bio-diesel lipid derived biofuel, waste oil recycling, pyrolysis, gasification, dimethyl ether, and biogas. On the other hand, appropriate waste management strategy is another important aspect of sustainable development since waste problem is concerned in every city. To meet the growing fuel requirements many governments are entering into biodiesel sector and some private corporations are also showing more interest in this field. Moreover research is going on practical suitability of Tyre Pyrolysis oil in various applications. This paper is concerned with preparation of blends with Tyre Pyrolysis oil. The load test is conducted on CI engine at constant speed with different blend compositions of Tyre Pyrolysis oil and diesel and performance curves are plotted

Keywords: *Biofuel, Diesel Engine, Tyre Pyrolysis oil, Nox, CO.*

I. INTRODUCTION

The waste to energy technology is investigated to process the potential materials in waste which are plastic, biomass and rubber tire to be oil. Pyrolysis process becomes an option of waste-to-energy technology to deliver bio-fuel to replace fossil fuel. Waste plastic and waste tire are investigated in this research as they are the available technology. The advantage of the pyrolysis process is its ability to handle unsorted and dirty plastic. The pre-treatment of the material is easy. Tire is needed to be shredded while plastic is needed to be sorted and dried. Pyrolysis is also no toxic or environmental harmful emission unlike incineration

The tire pyrolysis oil and plastic pyrolysis oil have been investigated and found that they both are able to run in diesel engine and the fuel properties of the oils are comparable to diesel oil. Both pyrolysis oils are a complex mixture of C5-C20 organic compounds. The tire pyrolysis oil contains a great proportion of aromatics and up to 1.4% sulfur content whereas the plastic pyrolysis oil is able to occur high chlorine content if the plastic is unsorted. The assessment in terms of chemical process, production and feasibility study of both pyrolysis oils are done in previous researches. There is no research about the use of the oil in terms of cost analysis and potential of fossil fuel replacement.

IC engines are one of the important forms of prime movers, which run essentially on liquid fuel. IC engines can be divided into two main categories viz, petrol and diesel based engines otherwise called spark ignition engines and compression ignition engines. CI engines due to their inherit fuel economy, easiness in operation, maintenance and long life usage in the fields of transportation, marine earth, moving machines, industries power generation, and agriculture. Better part load performance and improved emission characteristics have made it popular in small automobile engines for passenger cars and light trucks.

In India, the number of CI engines is so large that bulk of available petroleum is consumed in the form of diesel fuel.

However there is an urgent need to address the problems of depleting of fossil fuels source and increased green house gas emissions. India spends huge resaves of foreign exchange every year for importing crude and petroleum products. Petroleum fuels resources are limited. Need for search of alternate fuels to meet future demand is continuous process since interception of I.C engines.

Diesel/Gas oil is one of the derivatives of fossil fuel used in the transportation sector. In India, diesel fuel consumption constitutes about 49% of the petroleum products utilized in the country. Consumption has been growing steadily at an annual rate of about 5%. Diesel can thus be seen as an important derivate of fossil fuel to the economy. Aside the transportation sector, the mining sector is also heavily reliant on diesel accounting for about 10% of the total consumption in the country. Replacing petroleum derived diesel with alternative sources will have a huge positive impact on the quantity of fossil fuels imported into the country and thus conserve the nation's foreign currency reserves. Aside this, an added advantage of pursing a biofuel policy is its ability to create and sustain jobs especially in the agriculture sector of the economy.

The main objective of this paper is to ascertain which of the locally available bio-diesel is most suitable to replace diesel in CI engines. The paper sought to establish the best blends that give highest thermal efficiency, Minimum brake specific fuel consumption of the engine, Minimum smoke density and Lower Emissions

To achieve these objectives, a four stroke single cylinder CI engine constant speed is been considered with the blends of Tyre Pyrolysis oil and diesel and the following parameters were observed:

1. Fuel consumption rate
2. Thermal efficiency
3. Emissions from the engine

The effects of using biodiesel and diesel fuel to the performance and emissions of a diesel engine are observed.

Tire Pyrolysis Oil

Feedstock material is the main factor to indicate the properties of the pyrolysis oil. Tire pyrolysis and plastic pyrolysis technologies are the available technologies on the market in Thailand. The feedstock pre-process is one of the main factors to assess the possibility of the technology. The waste tires are collected easily from the scavenger and garage as they are bulky and heavy but only shredding process is required to reduce the size. The waste plastics are collected from scavenger, MSW sorting plant, and landfill area. The weakness of the plastic is the character of the plastic, which is mainly from plastic bag, is small high impurity and bulky. Soring and cleaning is required for plastic process. However, as the purpose of the process is turning waste to energy, the pyrolysis process of tire and plastic is distinguished and compared in this research. Physical and chemical analysis properties of both oils are studied and compared in order to ensure to usage of the oil in diesel engine.

In the USA, about 303.2 million of waste tires were discarded in year 2007, while about 60 million of waste tires in Thailand year 2011. Not to mention about the cumulative waste tire in landfill, the problem of tire disposal will be increasing gradually due to the expanding of vehicle market. The tire pyrolysis process converts waste tires into potentially recyclable materials such as flammable gas, pyrolysis oil and carbon black. Although the amount of waste tire is less than the waste plastic, the option of the waste tire conversion is limited. Tire pyrolysis oil plant has been established around the world in order to produce the substitute liquid fuel for heating purpose as found that the tire pyrolysis oil have a high gross calorific value (GCV) of around 41-44 MJ/kg. Waste tire is needed to be shredded before process. The desulphurization is required in the pyrolysis system to eliminate the sulfur.

It was determined that the oil production yield of tire pyrolysis process has a maximum at 350°C and decomposes rapidly above 400°C. The plastic pyrolysis oil used in this research is processed at 300-500°C at atmospheric pressure for 3 hours. The tire pyrolysis oil used in this research is processed from a commercial waste tire pyrolysis plant in Thailand. The product output consists of 35% pyrolysis oil, 56% residue and the rest is pyrolysis gas on weight basis. The amount of the residue is tire wire scrap and carbon black.

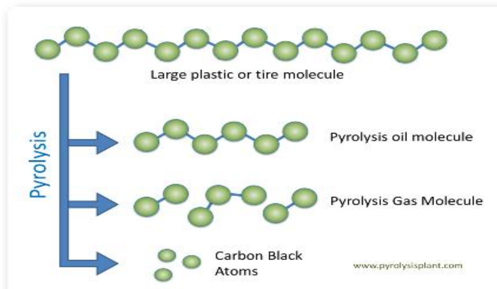

Figure 1 Pyrolysis Molecules

Plastic and tire pyrolysis involves subjecting plastic and tire to high temperature of 400 to 450 degree Celsius, in absence of oxygen. In case of oxygen is present plastic will start burning. During pyrolysis plastic and tire breaks down into smaller molecules of pyrolysis oil, pyrolysis gas and carbon black. Like plastic and tire, pyrolysis end products are also hydrocarbons. Pyrolysis is great way of recycling waste plastics and tires. Given below are benefits of waste plastic and tire pyrolysis.

Figure 2 Sources of Pyrolysis oil

II. PREPARATION OF TYRE PYROLYSIS OIL

Tyre pyrolysis is one of the versatile methods to produce oil from the waste materials like run out tires. The production of oil from waste tires is sequence of steps involved. It begins with a Reactor with 8 to 10 tones capacity. it is 16 mm thick and 8 feet in length.

In sage 1, the waste tires are heated in the reactor vessel up to 700c.The heat content in fossil fuels like mixture of coal, wood and waste are used. At this temperature hydrogen rose up from the heated tires.

The hydrogen gas thus formed is trapped by the air bags provided to the reactor vessel. The purpose of these air bags is to decrease the heating value of hydrogen by adding air to it. This evolved hydrogen gas is used to heat the reactor further up to 3800c.the heating is controlled by the regulating hydrogen gas.

Figure 3 The Reactor

I stage2, due to the temperature rise the oil vapors rose up in the reactor vessel and the vapors are slowly come out from the top. Pipes are provided at the top of the reactor to serve the purpose. Pressure regulators are used to indicate pressure developed inside the reactor because hydrogen gas and the oil fumes both are highly inflammable. Some oil is produced in the reactor core itself and is caught in the vessels separately. The fumes from the reactor are sending to the condensers for cooling. The condensation of the fumes consists number of steps; it is four stages in the industry. In heavy production commercial industries it consists of six stages.

Figure 4 The Fumes carriage

In stage 3, the condensation of fumes takes place. Finally after four stages of condensation the oil is brought to room temperature. In stage one it is brought to 1200c from 1500c, In stage one it is brought to 900c from 1200c, In stage one it is brought to 600c from 900c, In stage one it is brought to 300c from 600c. The oil thus generated is caught in a container, from which it is transported to various industrial uses.

Figure 5 The Four stage Condenser set up

Figure 6 The Tyre Pyrolysis oil Container

On whole it took 18 hours of process one batch, in which 12 hours of production and 6 hours of condensation. The reactor is left with carbon residue or ash and the steel radial wires in the tires. The ash thus produced and steel are removed after cooling the reactor and are sent out different applications. Experimental studies show that 40-45% of tire pyrolysis oil, 30-35 % carbon black, 20% steel can be recovered from the process.

Figure 7 The Carbon Black and Steel Ready to use

III. EVALUTION OF PROPERTIES

There are many physical and chemical properties of lipids, however only properties like viscosity, volatility, calorific value, solubility, cloud and flash points which are relevant to their use as fuel in diesel engines will be discussed

A. Calorific Value

The Calorific Value of Tyre Pyrolysis Oil is generally lower than mineral diesel. This is partly due to the level of un saturation of the molecules. The higher the un saturation, the more deprived the molecule is of hydrogen atoms which are combustible. Though it is widely accepted that higher oxygen content in fuels lead to complete combustion thus lower emissions, it also leads to lower calorific value resulting in significant power loss and reported lower calorific values for fish biodiesel as compared to diesel. The effect of lower calorific value primarily is, it reduces power output and increases fuel consumption

B. Viscosity

The viscosity of fish biodiesel is perhaps a bit higher than the diesel fuel. The viscosities of most vegetable oils have been found to be about 5-10 times higher than diesel engines. This actually depends on the carbon length which is a function of the oil type; the longer the carbon-carbon chain the more viscous the fluid Higher viscosities have been reported to have an effect on the atomization of the fuel resulting in larger droplet size which leads to longer delay period. Other researchers have reported that high viscosity of bio diesel increase engine wear . Coking of injectors, piston and engine head have also been attributed to high viscosity of biodiesel. Research into reducing the viscosity of biodiesel is very active.

C. Flash Point

The flash point of a fuel is the lowest temperature at which the fuel will ignite when exposed to a spark or flame. Tyre Pyrolysis Oil have been reported to have a near flash point to that of petroleum diesel as a result of this, Tyre Pyrolysis Oil has a advantage of using as fuel directly in CI engines.

The degree of un saturation of oil does not have any effect on the flash point.

D. Cloud Point

The cloud point is the lowest temperature at which clouds or haze begins to form in the fuel. Tyre Pyrolysis Oil generally have higher cloud points than diesel oil. The cloud point of oils is an indication of the fuels ability to operate under cold condition since it leads to the blockage of fuel filters and lines. This property of oils may not be of too much importance in the tropics where ambient temperature is usually high.

E. Viscosity Test

Figure 8 Saybolt viscometer

The prepared sample is filtered and the cup is filled until the level is up to the overflow rim. The sample is stirred until the temperature remains constant. The measuring flask is placed where the stream of oil from the bottom of the viscometer will just strike the neck of the flask. The wire stopper is snatched from the viscometer. At the same time stop watch is started and stopped at the instant the bottom of the meniscus reaches the graduation mark. The same procedure is repeated at different temperatures and for different blends.

The viscosity of the blends is calculated using the formula

Kinematic viscosity (Zk) = 0.22Ts – 100Ts

Where Ts is the time obtained in the experiment

Dynamic viscosity (Zo) = (Zk)* PT

Where PT =0.000657(T-15)

Where T is the temperature obtained.

F. Flash and Fire Point Test

The sample is taken into the cup up to the mark as desired. Now it is heated for a certain period. A flame is introduced at regular intervals above the surface of the oil in order to notice the flash and fire points. The flash point is viewed as just a flash occurring above the surface for a second. Fire point is obtained where the oil catches the fire. Usually the fire point is obtained 10-15 degrees greater than that of flash point. We can take the flash and fire points from the thermometer just by observation.

Figure 9 Cleveland's Apparatus

G. Calorific Value Test

The caloric value of any substance is defined as the energy per unit mass of the substance at standard temperature and pressure. The gross or higher calorific value of a substance is the energy released when a unit mass of the substance is completely combusted under standard conditions of pressure and temperature with the water present in the product gases appearing in liquid phase. On the other hand, the net or lower calorific value is defined same but with the water present in the product gases in vapour phase. The Gross Calorific Value (GCV) was determined with a bomb calorimeter.

The bomb calorimeter consist of a water bath, a stirrer to maintain uniform temperature distribution, a thermometer, an external timer, a bomb vessel, a crucible and an ignition wire.

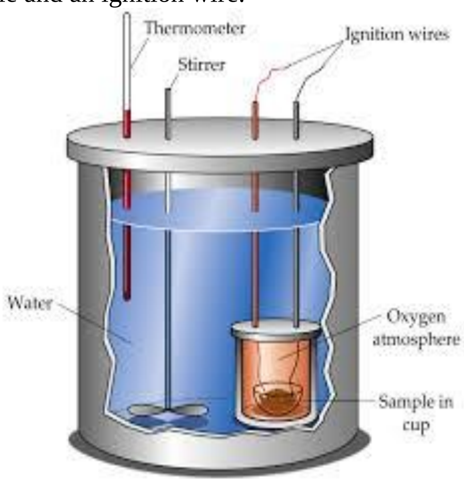

Figure 10 Bomb Calorie Meter

The weight of the crucible was first taken after which 0.7g of the sample was put into the crucible. The crucible was placed in the bomb vessel after 15ml of distilled water had been put into the base of the bomb vessel. A platinum ignition wire was connected to the bomb such that part of it touched the sample. The bomb vessel was sealed and charged to 25bar with pure oxygen. The entire bomb vessel was placed in another vessel containing 2400ml of water fitted with a stirrer and a thermometer. The temperature of the water bath was observed and recorded in intervals of one minute for five minutes after which the bomb was ignited. The temperature of the water bath was continuously observed and recorded for another period of ten minutes in intervals of one minutes.

The Gross Calorific value is given by

$$Q= (2.4 +0.482)*4.2*\Delta T/m$$

Where ΔT is the temperature difference before ignition and the final temperature rise and m is the mass of the sample.

H. Load Tests

After the Evaluation of properties the broad behavior of the fuel was estimated. The blends along with diesel poured in the engine and the performance analysis was done at constant speed and varying loads. The engine specifications are shown in table 1.

Table 1 Engine Specifications

Make and model	Kirloskar
BHP and Speed	5 Hp and 1500-1580 rpm
Type of the engine	Single cylinder, DI and 4s
Compression ratio	16:5:1
Bore and Stroke	80mm and 110 mm
Method of cooling	Water
Method of starting	Manual cranking
Method of loading	Mechanical loading

Figure 11 Experimental Test setup

I. Test Procedure

Connect water line to the engine jacket inlet and calorimeter inlet to a water source. Decompress the engine by decompression lever provided on the top of the engine head lift after pouring the test fuel into tank, crank the engine slowly with the help of handled powered. Increasing cranking rate and pull the decompression lever down. Now load the engine starts, allow the engine to run and stabilizing at 1500 R.P.M. now load the engine placing the necessary dead weights to hanger. Allow the engine to stabilizer on each step load. Record the required parameters and draw various graphs to show its performance. Procedure to take readings is

1. Using the engine specifications calculate the maximum load on the engine.
2. Connect the water line of the engine jacket inlet and calorimeter inlet to a water source with a constant head of 5m through respective calorimeter.
3. Open the respective gate valve and set the optimum flow rate on Rota meter.
4. Connect the panel instrumentation, input power line 230V, 50Hz single phase power source. Now the digital meters display the respective readings (temperature, speed).
5. Fill the fuel into fuel tank mounted on the panel frame.
6. Then check the lubrication oil in the engine sump with the help of the dip stick.
7. Open the fuel lock provided under the fuel tank and ensure no air trapped in the fuel line connecting fuel tank and engine.
8. Decompress the engine by decompression lever provided on the top of the engine head to start the engine.
9. Crank the engine slowly with the help of handle provided and has certain proper flow of the fuel into pump and in turn through the nozzle into the engine cylinder.
10. Note down the following parameters at no load
    a. Speed of the engine from digital rpm indicator.
    b. Time for 'x' cc fuel consumption in sec.
    c. Volume flow rate of the cooling water through engine calorimeter using calorimeter.
    d. Volume flow rate cooling water through engine jacket using rotameter
    e. Temperature t1 to t5 from the temperature indicator by turning the selector switch to respective positions.
    f. Net load (w-s) in Kg from amount of weight added on the pan (w) in Kg/min. spring balance reading in Kg.
11. Now load the engine by placing the dead weights on the weight hanger to load engine in steps of ¼, ½, ¾ and full load, allow the engine to stabilizer on each step and note down the above parameters.
12. To stop the engine after experiment is completed push or pull the governor lever towards the engine working side.

IV. RESULTS & CONCLUSIONS

The investment and expenses of these two pyrolysis plants are concerned and analyzed to estimate the production cost of respectively oil. Though the core technology of each plant is similar, the characteristics of feedstock and product are slightly different. It is assumed that the feedstock input is 6 tons per day. Plastic used is waste plastic from landfill site and tire used is collected from garages.

As the load increases brake specific fuel consumption decreases because brake power increases. It's clearly shown in the following figures. The brake specific fuel consumption for blends is more compared to diesel. For B-20 brake specific fuel consumption is 0.277Kg/KW-hr. It is slightly more than the diesel. It is shown in Fig.12

BP	diesel	B10	B20
0	0	0	0
0.6061	0.5708	0.5297	0.5278
1.2123	0.3563	0.35717	0.3550
1.8185	0.2931	0.29425	0.2860
2.4246	0.2805	0.28157	0.27724

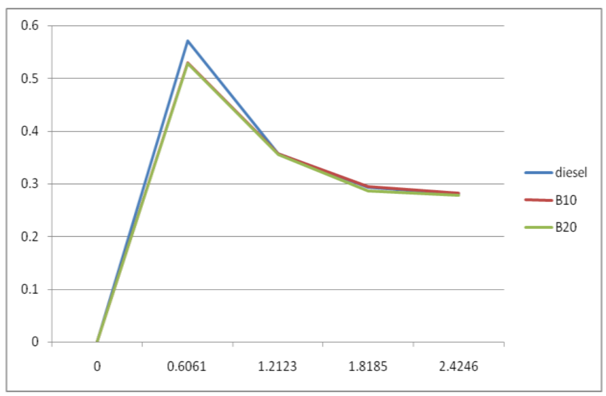

Figure 12 BP Vs BSFC

BP	DIESEL	B10	B20
0	0	0	0
0.6061	21.599	33.55	37.73
1.2123	35.52	50.25	54.79
1.8185	45.25	60.24	64.52
2.4246	52.42	66.89	70.79

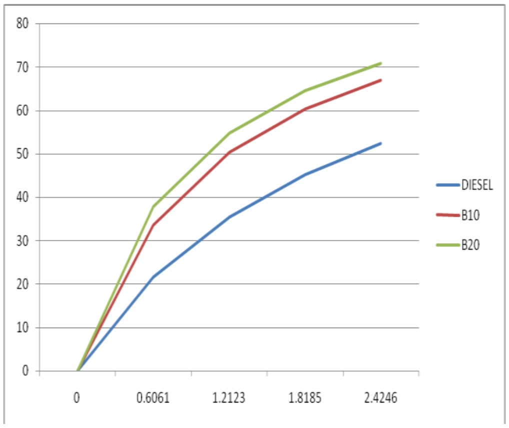

Figure 13 Mechanical Efficiency

BP	*DIESEL*	*B10*	*B20*
0	*0*	*0*	*0*
0.6061	*14.076*	*15.2062*	*15.3062*
1.2123	*22.550*	*22.535*	*22.7549*
1.8185	*27.411*	*27.376*	*28.237*
2.4246	*28.64*	*28.60*	*29.1393*

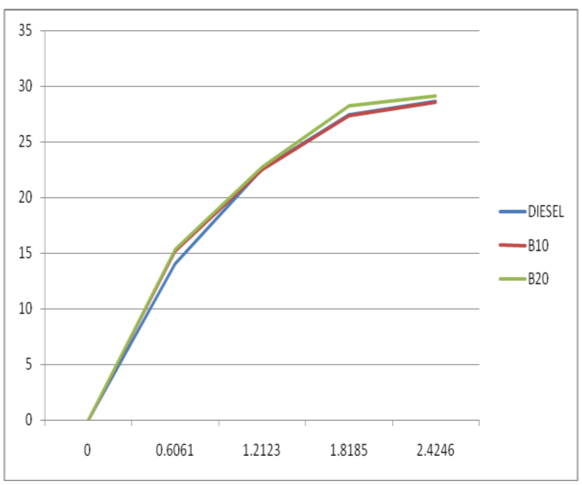

Figure 14 Break Thermal Efficency

BP	DIESEL	B10	B20
0	0.133	0.239	0.2659
0.6061	0.123	0.1777	0.1999
1.2123	0.126	0.1794	0.1945
1.8185	0.1326	0.1772	0.18459
2.4246	0.1470	0.188	0.1962

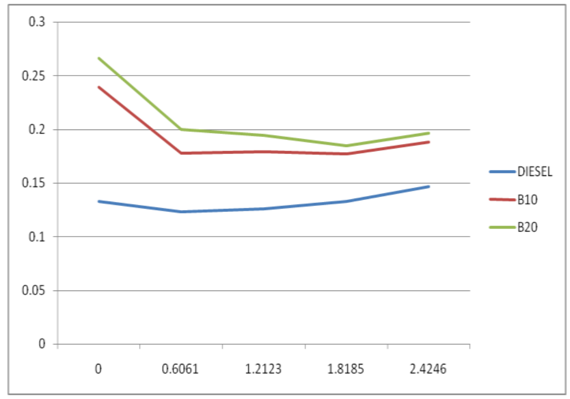

Figure 15 Indecated SP Fuel Comsuption

There are wide varieties of transportation fuels, which can be reducing dependence upon petroleum. Many of these fuels will be cost competitive with gasoline in a near future.

Tire pyrolysis offers comparable efficiency to diesel oil in medium to high load but it has been question on the desulfurization process. Therefore, the development of the tire pyrolysis oil is depending on the cost of desulfurization process. Although the tire pyrolysis oil offer better quality than plastic pyrolysis oil, the amount of waste tire is minimal compare to plastic waste and the oil production is less. Additionally, by product of the tire pyrolysis plant carbon residue and tire wire from waste tire, the plant entrepreneur need to find an opportunity to process these by products due to the amount of the by product is correspondent to the oil product. Turning waste to energy is not only financial profit-able but it also environmental friendly business which the government should offer a strong policy to encourage the entrepreneur to invest in the waste to energy business.

Hence from the above conclusion blends of tire pyrolysis oil can be used as alternative fuel for the diesel engine, even though there may be some fuel economy problem it can be used as substitute for diesel since the use of these blends will decrease the consumption of the diesel as there is a fear of exhaust. So from the above discussion we can save 20% of diesel.

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