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Production of Biofuel by Catalytic Cracking Process using Coal Ash Catalyst and its Effects on DI Diesel Engine

Muthukumaran N

Department of Mechanical Engineering Government College of Engineering,
Dharmapuri-636704, Tamil Nadu,
India. Email: muthukumar_nv@yahoo.co.in

ABSTRACT

In this study, the biofuel produced from the Pongamiapinnata seed seed oil through catalytic cracking process. In this process the Coal Fly Ash (CFA) is selected as a catalyst material for cracking process and the cracking process was conducted on a fixed bed catalytic cracking reactor at the temperature range of 450-500°C. The CFA analyzed through EDS (Energy Dispersive Spectroscopy), the results reveal the presence of oxide of aluminium, silicon and iron in it. The performance and emission characteristics of cracked oil are evaluated with diesel blends in single cylinder, four strokes, water cooled DI diesel engine. The results reveal that the Brake Thermal Efficiency (BTE) at B20 show the closer to neat diesel. The exhaust emission of oxides of nitrogen (NO_x) and Smoke Density are decreased with increasing the maximum load for B100 than neat diesel. However, the emission of HC and CO slightly increasing with increasing the percentage of load than the neat diesel.

KEYWORDS: Pongamiapinnata seed, Catalytic cracking, Coal fly ash and Engine Emission

***Corresponding author**

Dr. N. Muthukumaran

Assistant Professor,

Department of Mechanical Engineering

Government College of Engineering,

Dharmapuri-636704, Tamil Nadu, INDIA.

Email: muthukumar_nv@yahoo.co.in, Mob No- 9894301560

INTRODUCTION

Biofuels are non-fossil energy derived from organic materials such as vegetable oil or animal fat. Bio-fuel is defined as liquid or gaseous fuel that can be produced from utilization of bio mass substrates and can solve as a partial substitute for fossil fuels. Energy from renewable source is currently among the most researched topics around the globe because of the challenges that the world is facing. These challenges include high energy demand, especially in fast developing regions and depletion of fossil fuel reserves and environmental challenges. The effort to overcome these problems is increasing the production of bio-fuels. It is the fuel derived from vegetable oil, one of these is Pongamia Pinnata oil.

It is reported that biofuel leads to greenhouse gas reductions, on a well-to-wheel basis, of 40–60% when compared with conventional petroleum diesel¹. In the USA alone, over 1.5 billion gallons of biofuel was produced from vegetable oils in past year². Meanwhile, global biodiesel production and consumption is forecast to rise by 14% from 2016 to 2020, driven by the fulfillment of current biofuel policies in the US, Argentina, Brazil, Indonesia and the EU. At the meantime, the biodiesel from waste-based production was forecast to grow to 4.4 billion liters³.

There are many processes for producing bio fuel such as esterification, transesterification, hydrocracking, catalytic cracking, pyrolysis, fermentation and etc. Among these, Catalytic cracking process is easy way to convert long carbon chain molecule into short carbon chain molecule and its temperature ranges between 450°C-500°C lower than pyrolysis which ranges from 500°C-850°C⁴.

Catalytic cracking is a process widely used in petroleum refining for converting heavy portion into lighter products. Catalytic cracking of vegetable oil into green fuel is favourable as it does not require additional infrastructure to be build⁵.

MATERIALS AND METHODS

Vegetable Oil (Pongamia Pinnata)

Pongamiapinnata is drought resistant, semi-deciduous, nitrogen fixing leguminous tree. It grows about 15-20 meters in height with a large canopy which spreads equally wide. here, the table 1. The pongamia non-edible oil contains the following components by percentage.

Table: 1 component of pongamiapinnata oil

Components	Percentage
Oil	27 - 39%
Protein	17 - 37%
Starch	6 - 7%
Crude fiber	5 - 7%
Moisture	15 - 20%
Ash	2 - 3%

Coal Fly Ash

Generally, Coal fly ash is collected from the Mettur thermal power plant, Salem, Tamilnadu. Fly ash is also known as “pulverized fuel ash” is a coal combustion product that is composed of the particulates (fine particles of fuel) that are driven of coal fired boilers together with the flue gases.

Catalytic Cracking

In this process, the vegetable oil has the catalytic cracking reaction which carried out in catalytic cracking reactor. The reactor is made up of iron material and also it heated by the electric coil⁷. The temperature is measured by the thermocouple and the reactor has provided gas delivery system and provision for sampling. Here on/off temperature controller was used for controlling the temperature⁸. The catalytic cracking experiment is conducted in optimum temperature at different ratio. At the different ratio's catalyst analyzed for identifying the bio-fuel production⁹. This experimental section is not used indirect. It is a direct method without any treatment.

The coal fly ash and mahua oil is added thing make it as slurry with help of mechanical stirrer and fed into the reactor with the temperature of 450°C-500°C. On heating process the catalytic cracking reaction takes place due to the catalyst activity. From the vegetable oil, the gaseous hydrocarbon will release and it exists from the condenser. The existing gaseous hydrocarbon gets cooled and collected in the form of liquid hydrocarbon. There are collect from the collectors.

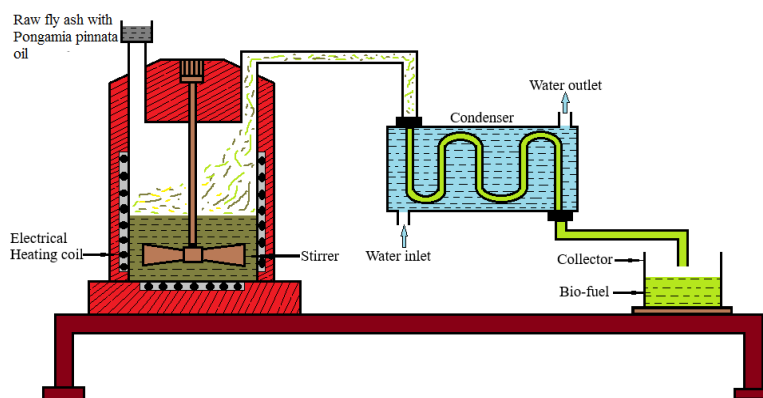


Figure1. Catalytic cracking Reactor

EDS Analysis of Coal Fly Ash

It is an analytical technique used for the elemental analysis or chemical characterization (Figure 2) of a sample. It relies on an interaction of some source of X-ray excitation and a sample. Its characterization capabilities are due in large part to the fundamental principle that each element has a unique atomic structure allowing a unique set of peaks on its electromagnetic emission spectrum (which is the main principle of spectroscopy). The table 3. Show the presence of predominant elements

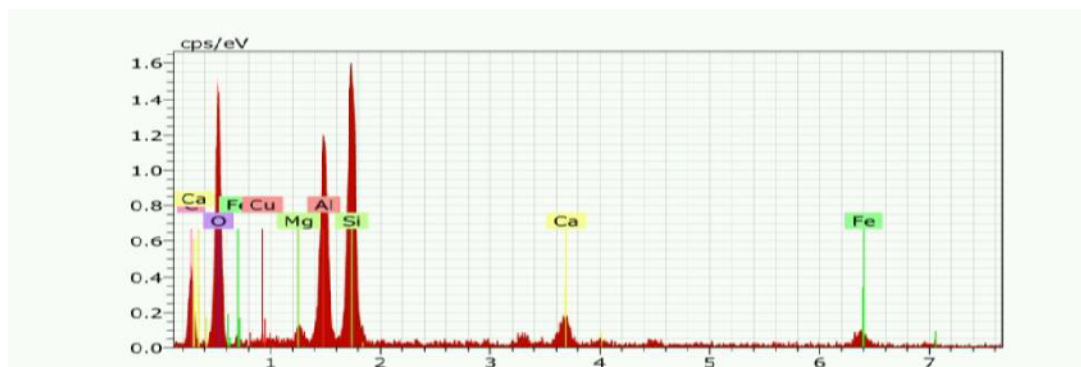


Figure2. EDS analysis of Coal fly ash

Table: 3 properties of coal fly ash

El	AN	Series [wt.%]	unn.C [at.%]	Norm.C [at.%]	Atom Norm.C [at.%].C	Error	1 Sigma) [wt%]
O	8	K-series	64.36	46.63	48.51		11.69
C	6	K-series	36.16	26.20	36.30		9.27
Si	14	K-series	16.30	11.81	7.00		0.81
Al	13	K-series	13.23	9.58	5.91		0.76
Ca	20	K-series		2.28	0.95		0.21
Fe	26	K-series		2.00	0.60		0.22
Mg	12	K-series		0.79	0.54		0.15

EXPERIMENTAL SETUP

The test engine used in the current study is a stationary single cylinder diesel engine, used mainly for agricultural application and in industries for generating electricity. The engine is coupled with an eddy current dynamometer for applying loads by adjusting the current supplied to it and while doing this; the fuel pump rack position is adjusted so as to maintain a constant speed of 1500 rpm. Piston with hemispherical bowl, 3 hole mechanical injector and inline fuel pump have been the integral key components of the engine and the fuel injection system. All other engine specifications are listed in table and the arrangement of engine setup has been depicted in schematic diagram as shown in figure 3.

Table: 4 specification of the test engine

Type	Vertical, water cooled, four stroke
Number of cylinders	One
Bore	87.5mm
Stroke	110mm
Compression ratio	17:5:1
Maximum power	5.2kW
Speed	1500rpm
Dynamometer	Eddy current
Injection timing	23° before TDC
Injection pressure	220kgf/cm ²

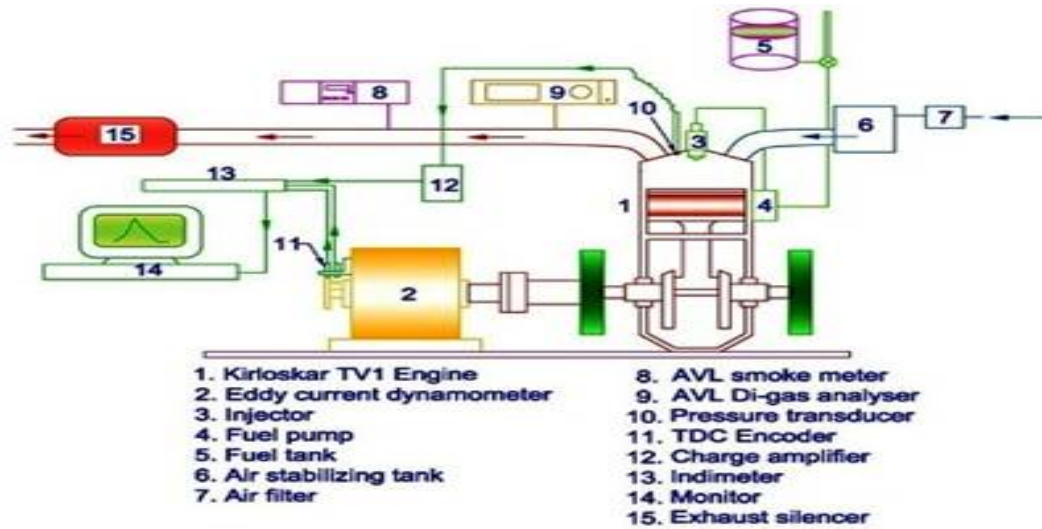
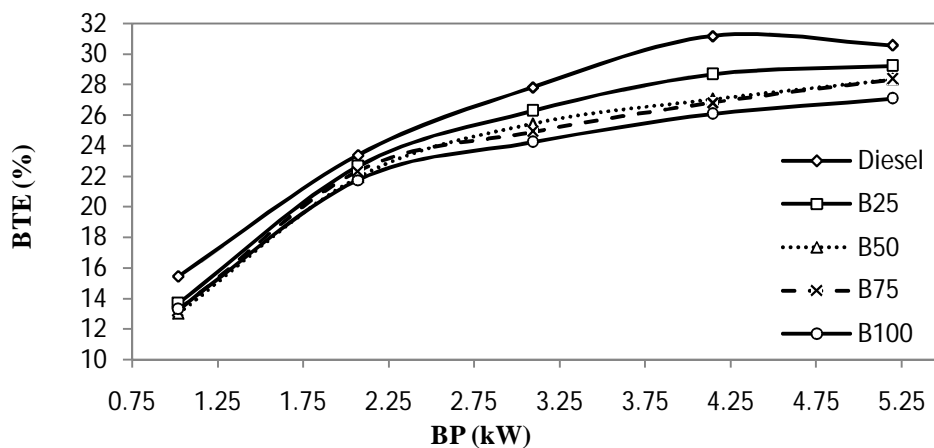


Figure 3. Schematic view of test engine

RESULTS AND DISCUSSIONS

Brake Thermal Efficiency

The variation of BTE with brake power for various blends are shown in Graph.1. In general brake power is directly proportional to the brake thermal efficiency, because the heat loss is minimized at peak load thus it increases the brake thermal efficiency. At maximum loads the BTE of the blends slightly lower than the diesel. This is due to the presence of oxygen content in the biofuel and also the rate of combustion is low due to the higher viscosity and lower heating value of the biofuel than the neat diesel¹⁰. The BTE of B25 blends show the closer efficiency to neat diesel than other blends.

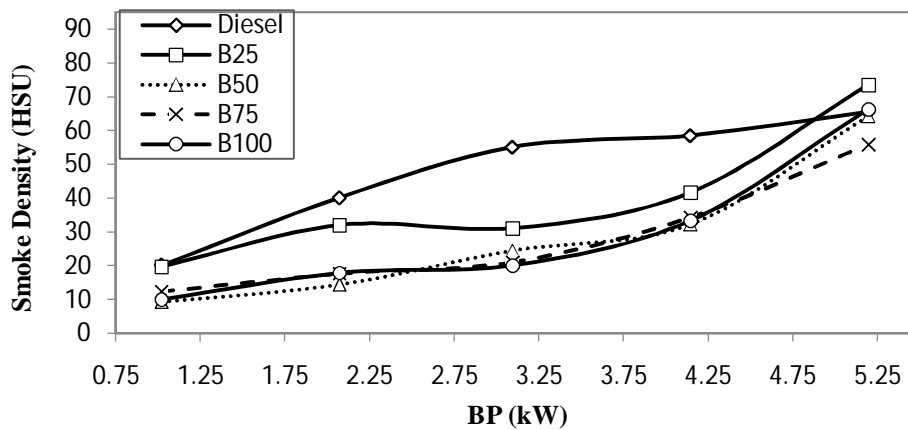


Graph.1: The variation of BTE with BP

Smoke Density

The variation of smoke density with respect to brake power for diesel and biofuel blend is shown in Graph.2 From the graph it is observed that the opacity is increased with increase in load for biofuel blends. The smoke capacity of biofuel blends is lower than diesel at initial load. But in peak load all the blends except B25 shows the highest smoke density than diesel. This is due to incomplete

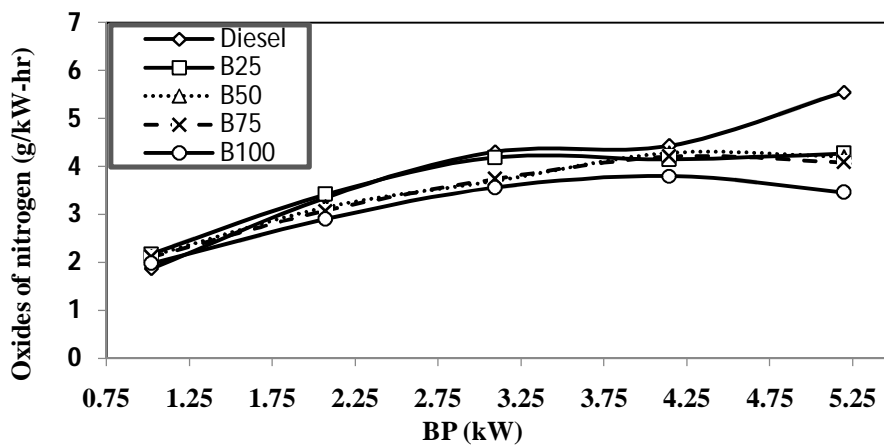
combustion of biofuel blends caused by poor vaporization, air-fuel mixing and higher viscosity of biofuel¹¹.



Graph.2: The variation of Smoke with BP

Oxides of Nitrogen

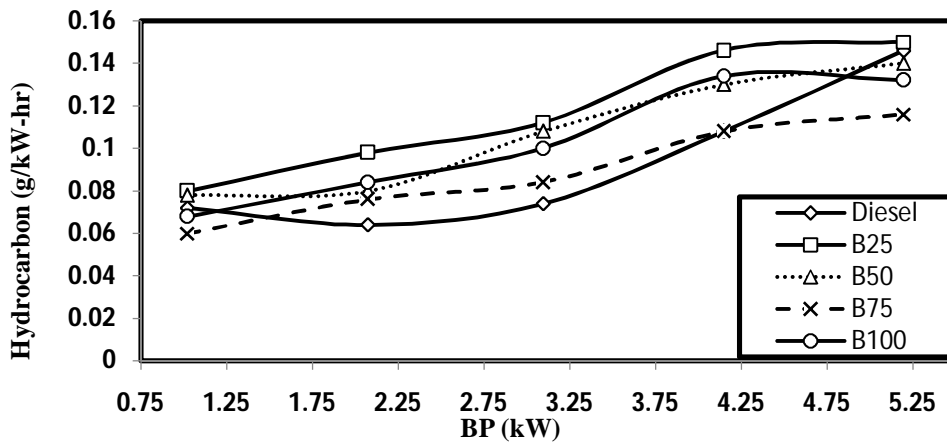
The variations of oxides of nitrogen with respect to the brake power for diesel and biofuel are shown in the Graph 3. It is observed that various blends of biofuel show the lower NO_x emissions with increase in biofuel blends when compared to diesel fuel. The result shows the lower NO_x emission occurs due to less burning rate of biofuel blends, less atomization and lower cetane index¹².



Graph.3: The variation of NO_x with BP

Hydrocarbon

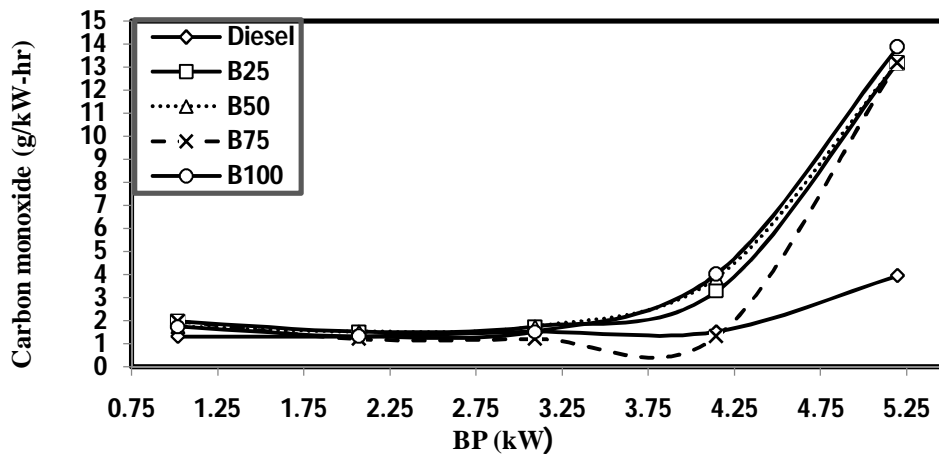
The variation of hydrocarbon with respect to the brake power as shown in Graph 4. The hydrocarbon emission indicates the act of incomplete combustion in the combustion chamber. The HC emissions increased with increase in load, this is due to engine operating condition, properties of fuel and spray formation were the major factors influencing the Hydrocarbon emissions¹³. The B25 shows the higher hydrocarbon emissions when compared to that of diesel fuel at initial load. However, the hydrocarbon emission of B100 is predominantly higher in comparison with diesel at peak load.



Graph.4 The variation of HC with BP

Carbon Monoxide

The Graph 5. shows the variation of CO emission with respect to brake power. Generally, the CO emission is affected by air-fuel equivalent ratio, fuel type, combustion chamber design and start of ignition timing. It is observed that CO emission of all biofuel blends consistently increases with increasing biofuel blends. The low injection pressure and atomization rate affects primary combustion processes and subsequently generate high concentration of CO emission with proportion of Pongamiapinnata seed biofuel blends increasing¹⁴. The CO emission of B25 almost nearest to sole fuel up to part load condition. The blend B100 shows the higher CO emission than other blends however, diesel fuel shows the lowest CO emission.



Graph.5 The variation of CO with BP

CONCLUSIONS

The emission characteristics of Pongamiapinnata seed biofuel and diesel blends were evaluated in single cylinder, four stroke, water cooled diesel engine. The cracked biofuel has been produced by catalytic cracking process using coal fly ash as a catalyst. From this experimental investigation the following conclusion were made,

- The Pongamiapinnata seed biofuel can be directly used as a fuel in an unmodified diesel engine.
- ii) The BTE of B25 blend show closer to neat diesel than other blends.
- iii) At peak load condition the emission of HC and CO were increased with increasing the biofuel blends.
- iv) The NO_x emission shows the reducing trend of biofuel blends and B100 produce lowest NO_x emission than neat diesel
- v) From the above conclusion, B25 blend can be used as a better alternative for the diesel engine application.

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