The influence of Coal fly ash as a catalyst on production of bio fuel from *Mahua* oil on DI Diesel Engine

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Abstract - *In this study, biofuel produced from Mahua oil and using coal fly ash (CFA) as a catalyst material for catalytic cracking process. The cracking process was conducted on a fixed bed catalytic cracking reactor and temperature ranging from 450-500℃. The coal fly ash was characterized by SEM (Scanning Electron Microscope) and EDS (Energy Dispersive Spectrometer). The cracking oil were analyzed by GC-MS (Gas Chromatography-Mass spectroscopy). The experiments were conducted on single cylinder, four stroke, water cooled DI diesel engine and their performance parameters were observed with various blends. The experimental results reveals that hydrocarbon (HC) and carbon monoxide (CO) are decreases with increasing the biofuel blends then neat diesel. The Break thermal efficiency (BTE) for B25 show the nearer to neat diesel than other blends. However, the smoke density, oxides of nitrogen (NO_x) emissions are slightly increased with increasing the percentage of biofuel blends.*

***Key Words*: Biofuel, Catalytic cracking, Mahua oil, Coal fly ash**

1. INTRODUCTION

Now, the world faced in growth of population and development of area will need more of energy. In fact, over 80% of the energy use comes from petroleum, coal and natural gas about 98% of carbon emissions are due to fossil fuels combustion, resulting in large amount of carbon-di-oxide being discharge into the atmosphere. Researchers can be concentrating with main point of replacement fossil fuel such as biomass resources. Biomass is one of the most potentially energetic organic resources to replace the fossil fuels, because it is renewable and neutral with regard to carbon-di-oxide emissions [1]. Recently many researchers studied synthetic hydrocarbon fuels from various biomass resources and produce bio-fuel well developed and it can be substitute fossil fuel as renewable energy [2]. In the year 2006, the government of Indonesia through presidential degree no.5 has commended they reveal that use of biofuel is expected to be more than 5% in year 2025. The biofuel is defined as a liquid and gaseous fuel that can be produced from utilization of biomass [3, 4]. Generally, biofuel produce from different types edible and non-edible oils. It's extracted from plant oils such as palm oil, candlenut oil, nyamplung oil and castor oils [5]. Various processes have been made to produce bio-fuels. Now a day, the researchers concentrate on catalytic cracking process and its important one for biofuel production. Catalytic cracking is an easy way to solve the long carbon molecule with the aid of catalyst [6]. The catalytic cracking process shows several clear advantages in compare with Pyrolysis and Transisterification process. Firstly, the temperatures of catalytic cracking process were 450-500℃ is lower than pyrolysis 500 -850℃. The main drawback of the transisterification use homogeneous catalyst with overall high energy consumption and separation [7] and some oils can be used diesel engines after several chemical processes its viscosity and volatility can be reduced on this process. Another one disadvantage of Transisterification process is only produced bio-diesel [8]. To overcome study, bio-diesel exhibits poor cold flow properties, which can be problem for engine performance. Moreover, the high oxygen content in the bio-fuel is responsible for low quality heating value and the weakness of stability [9]. The heating value of bio-diesel is 9.13% lower than those of conventional diesel fuels as a mass basis. Research on produce bio-fuel developed through catalytic cracking with different type of catalyst and it may be such as Coal Fly Ash (CFA). Coal fly ash in an inorganic residue and waste product from coal combustion process in coal fired stations [10].

2. MATERIALS AND METHODS

2.1 Mahua (Madhuca indica)

The Mahua is desired that botanical name Madhucaindica. Generally, the Mahua oil collected from the local market. This is most probably Tamil name called as *illupai.* It is a fast growing tree that grows to approximately 20 meters in height, possess evergreen or semi evergreen tree from the Sapotaceae family [11]. It is a large deciduous tree found in most of the parts India such as Uttar Pradesh, Chhattisgarh, Madhya Pradesh, Gujarat and Andhra Pradesh. The Mahua oil extracted from using mechanical crusher method. So, Mahua oil is obtained from the kernel of Mahua seed (Madhucaindica) and it contains 50-55% oil [12].

2.2 Coal Fly Ash (CFA)

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. Fly ash particulates are generally spherical in shape and range in size from 0.5 μm to 300 μm and it is a heterogeneous material [13]. The coal fly ash is generally captured by electrostatic precipators or other particle filtration equipment before the flue gas react the chimneys. Raw coal fly ash (untreated) consists of predominantly silica, alumina and iron oxides. The most common elements (table 1) are oxygen, silicon, aluminium, iron, calcium, magnesium, sodium, potassium, sulphur and carbon [14].

Table -1: Components of Raw Coal fly ash [21]

S.no.	Properties	wt (%)
1	SiO_2	20-60
2	Al_2O_3	5-35
3	Fe_2O_3	10-40
4	CaO	1-12
5	LOI	0-15

2.3 Catalytic Cracking Process

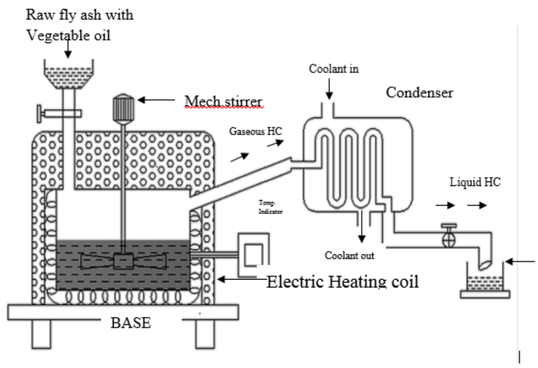

Fig -1: Catalytic cracking reactor

The fig.1 show the Production biofuel by Catalytic cracking process has an emerged technique and it is most widely used petroleum refining process in the world. Catalytic cracking reactions produce coke as a by-product through hydrogen disproportionate [15]. Catalytic cracking also defined as large hydrocarbons are broken into smaller moles using heat and catalyst [16]. 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 coil. 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 temperature. The catalytic cracking experiment is conducted in optimum temperature at different ratio. At the different ratios catalyst analyzed for identifying the bio-fuel production [18]. 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 - 500̊ 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.

2.4 EDS analysis of Coal fly ash

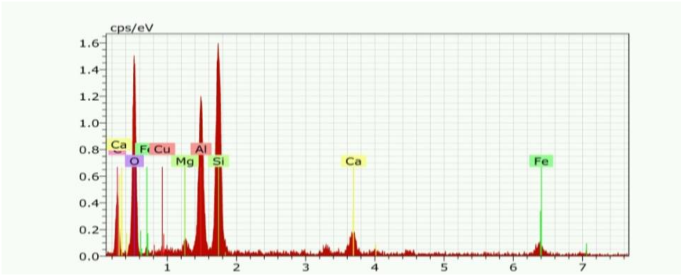

Fig .2 EDS analysis for coal fly ash

From this analysis, the coal fly ash consists of samples in various proportions in which Al, Si, Fe and O are predominant elements (Fig 2) where are, less amount of elements are cu, ti and ferrous. It should be noted that the sum of aluminum, oxide, silicon oxide and iron oxide is 85.86% and similarly the sum of calcium, chloride are less than 3.76%. In this function, EDS detector is used to detect the elements atomic number which is equal or greater than six. The peak intensity of EDS is not a quantitative measure of elemental concentration. Notably, the most predominant minerals silicon, aluminum and iron present in the coal fly ash which deemed to support the catalytic cracking process and also Al, Si are high thermal conductivity elements. The graph describes al and si tends to attain the highest rate due to the atomic number which are 13 and 14 respectively. The intermixing of Fe and Al-Si mineral phase with ca is predominant in EDS analysis due to the presence of non-silicate material (table 2). At last, small round ball shaped unburned carbon particles are attained at maximum level coal fly ash.

Table - 2: Properties of coal fly ash

EL	AN	Series	Unn.C [wt.%]	Norm. C [wt.%]	Atom.C At %	Error	(1sigma) [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	-	0.81
Al	13	K-series	13.23	9.58	5.91	-	0.76
Ca	20	K-series	3.15	2.28	0.95	-	0.21
Fe	26	K-series	2.76	2	0.6	-	0.22
Mg	12	K-series	1.09	0.76	0.54	-	0.15
Cu	29	K-series	0.97	0.7	0.18	-	0.17
		Total	138	100	100		

2.5 GC-MS Analysis

The GC–MS analysis was done using a GC–MS-5975C [AGILENT] System with a 30 m×0.25 mm ID capillary column coated with polysiloxane. The initial oven temperature of GC was 70 ▯ for 3 min and then programmed to increase at a rate of 9▯/min to 300 ▯. Helium 99.9995% purity was used as the carrier gas with a flow rate of 1.51 ml/min. The m/z (ratio of mass to charge) values, which represent the most probable fragments of the compounds elucidated, have been presented for each compound. The TC-CNSL fuel dilution was measured by GC-MS on samples obtained from the different tests. The summarized results are shown in Fig. 3. Using GC–MS, it was possible to determine that the main products of the cracking reaction is a mixture of hydrocarbons with linear and saturated or unsaturated chains and oxygenated products, such as linear carboxylic acids, aldehydes and ketones, as water and carbon mono- and di-oxides [17]. The GC–MS results show that the TC-CNSL contains many components. Each component shows separate peaks shown in Fig 3.

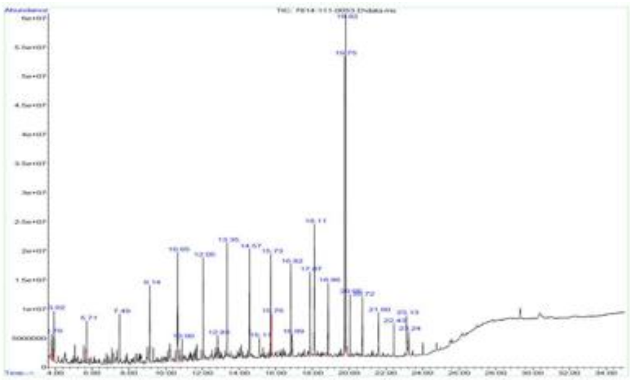

Fig. 3: GC analysis for catalytic cracking biofuel

3. EXPERIMENTAL SETUP AND ARRANGEMENT

The test engine consists of single cylinder, four stroke, and water cooled diesel engine with connected to eddy current type dynamometer shown in Fig. 4. The eddy current dynamometer has when applying loads with adjusted the current supplied to it. Initially, the fuel pump was adjusted rack position to maintain constant speed of 1500 rpm. Actually, the fuel pump was adjusted measured in upon the burette and time calculated stopwatch, then airflow rate was measured using an orifice meter, installed with intake of air supply system. Measurement of combustion chamber pressure was obtained by installing an AVL pressure transducer with the sensitivity of 16:11 pC/bar. The in-cylinder pressure was recorded 207 for 100 cycles using AVL 619 Indi meter hardware and Indwin software version 2.2, and the recorded pressure signals are then processed to estimate the heat release rate. Exhaust emissions such as HC (Hydrocarbon), CO, NOX (oxides of nitrogen), and O2 (oxygen) were measured using an AVL-444 di-gas analyzer, which works on NDIR (non-dispersive infrared) principle by selective absorption. The exhaust sample to be evaluated was passed through a cold trap (moisture separator) and filter element to prevent water vapor and particulates entering into the analyzer. Notably, the gaseous emissions such as HC and NOX were measured in ppm (parts per million), while CO and O2 emissions were measured in terms of percentage volume. Smoke level in the exhaust was measured in terms of HSU (Hart ridge Smoke Unit) using a standard AVL437C smoke meter based on light extinction principle. Notably, the engine specifications are listed in table and the engine setup has been showed in a schematic diagram as figure.

Table – 3: Specification of the test engine

Type	Vertical, water cooled, four stroke
Number of cylinder	One
Bore	87.5mm
Stroke	110mm
Compression ratio	17.5:1
Maximum power	5.2 kw
Speed	1500 rev/min
Dynamometer	Eddy current
Injection timing	23° before TDC
Injection pressure	220 kgf/cm²

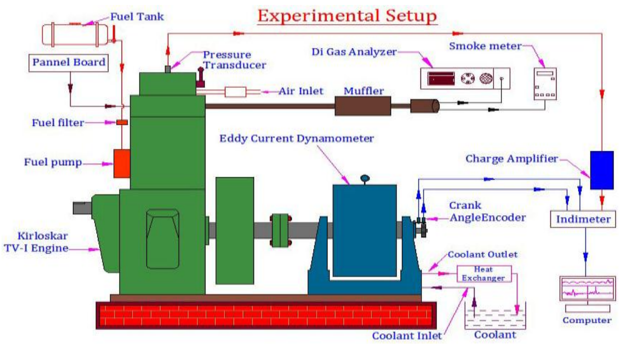

Fig. 4 Experimental setup (Kirloskar TV-1 Engine)

4. RESULTS AND DISCUSSION

4.1 Brake thermal efficiency

The variation of brake thermal efficiency with brake power shown in fig. 5 and compared with BTE obtained with diesel. Its observed that BTE of the all the blends were found to be lower at all load levels. Then, the blend B25 is found to have the maximum thermal efficiency of 27.9% at a brake power of 4.1 kW while for diesel it was 25% and B100 is decreased to 23%. So, the thermal efficiency of all blends of Mahua biofuel lowers than that of neat diesel. The decrease in brake thermal efficiency with increase in Mahua oil concentration is due to the poor atomization of the blends due to their higher viscosity and lower calorific value [19].

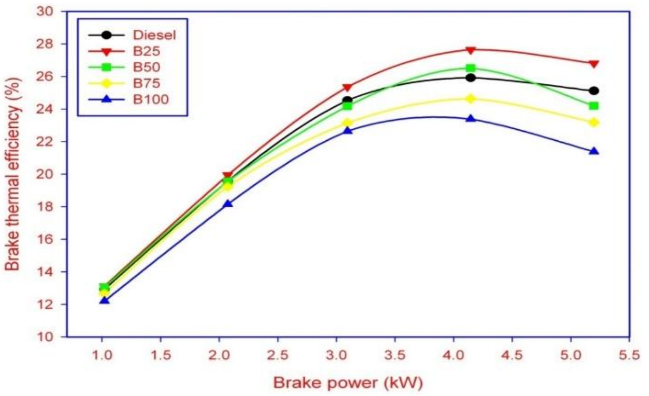

Fig. 5 Variation of BTE with brake power

4.2 Smoke density

The variation of smoke density for blends of *Mahua* oil is shown in Fig. 6. Biodiesel smoke reducing effect could be attributed to its displacement of aromatic and short- chain paraffin hydrocarbons. It is concluded that B25, B50, B75 and B100 are lower compared to diesel in low smoke opacity. This is mainly due to the high amount of oxygen present in the biodiesel blends which tend to reduce the smoke opacity. Bio fuel showed the presence of lower carbon to hydrogen ratio and the absence of aromatic compounds compared with diesel fuel. The lower carbon molecule and higher oxygen content can decrease the tendency of a fuel for soot production and reduce the smoke opacity.

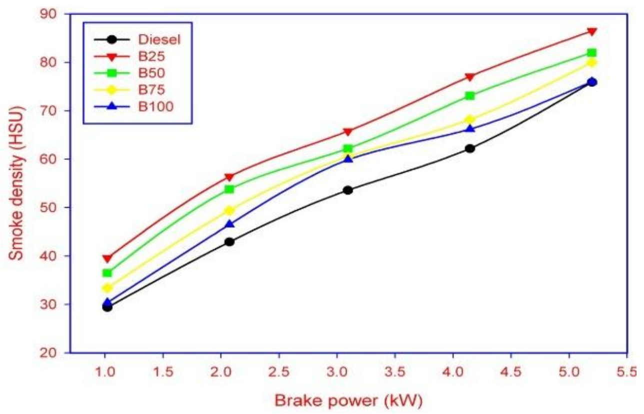

Fig. 6 Variation of smoke density with brake power

4.3 Carbon monoxide

The variation of CO emission with respect to engine loads for different fuel blends in Fig.7. The CO emission is due to improper combustion of fuel and it mainly depends on many engine temperature and air-fuel ratio. It was observed that the engine emits more CO for diesel at part load conditions when compared to the blends. But as proportion of jatropha oil in the blend increases the percentage of emission decreases. However, the percentage variation of carbon monoxide for all the blends when compared with base line diesel is very much less.

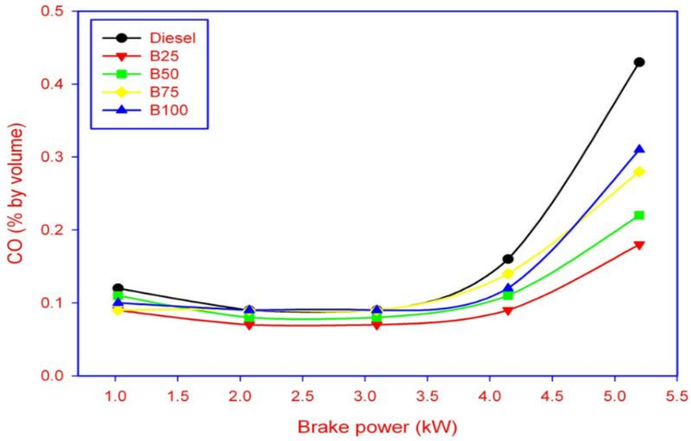

Fig. 7 Variation of carbon monoxide with brake power

4.4 Hydrocarbon

The variation of hydrocarbon with respect to load shown in Fig.8 in general the emission of hydrocarbons(HC) depends mainly by compositions and combustion characteristics of the fuel tested. If combustion is improved the HC emission decreases and vice versa. Because of the high content of oxygen in the bio-fuel it is expected that HC emission will decrease for blends of B25, B50, B75, B100 and diesel. It is observed that the decrease of HC emissions depends of the percentage of bio-fuel in the blend. In conventional hydrocarbon fuels, HC burns inside the engine cylinder in presence of air [20].

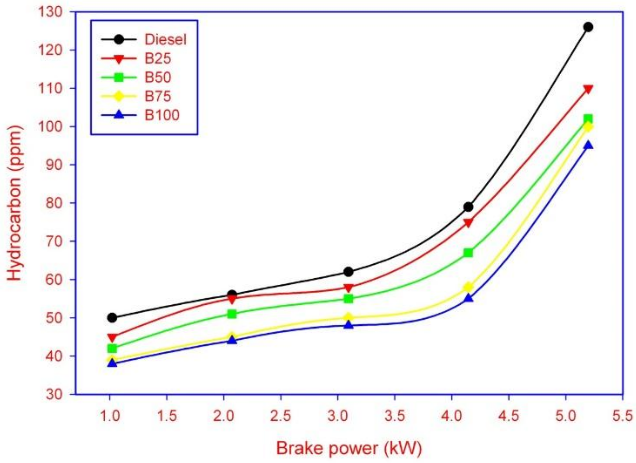

Fig. 8 Variation of hydrocarbon with brake power

4.5 Oxides of nitrogen

The variation of NOx emission with brake power is shown in Fig.9. Nitric oxide (NO) and nitrogen dioxide (NO2) are formed in the process of oxidation of the nitrogen. During combustion and depend of the combustion temperature and oxygen content. The NOx emission for diesel and all the blends followed an increasing trend with respect to load. For the blends an increase in the emission was found at all loads.When compared to diesel. NOx is formed generally at high temperatures. Gumus M. found an increase of NOx emissions for apricot seed kernel oil methyl ester by 10% compared to diesel fuel [21].

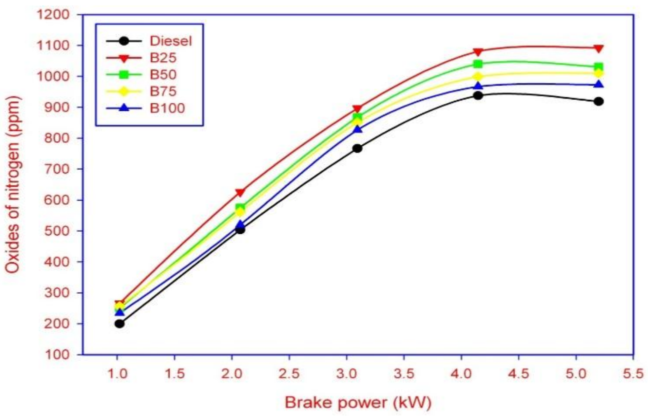

Fig.9 Variation of oxides of nitrogen with brake power

5. CONCLUSIONS

- Biofuel produced from Mahua oil and satisfies the ASTM standards and thus can be used as alternative to diesel fuel. Cracked biofuel showed increasing the calorific value of fuel and viscosity.
- GCMS showed cracked oil presence of esters, olefins and so on.
- The brake thermal efficiency of Mahua seed biofuel blends is higher than that of diesel at all load conditions.
- The CO emissions at different brake power were found to be higher for diesel compared to Mahua seed biofuel B25 blends.
- The HC emissions at different brake power were found to be higher for diesel compared to B100 biofuel.
- The smoke density and NOx of biofuel blends were always higher than the standard diesel.
- Biofuel is a popular and promising environment friendly alternative fuel due to its renewable nature, clean burning characteristics less greenhouse effect and more greenery. Biodiesel is a promoter of the rural economy.

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