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Experimental Investigation of Performance and Emission Characteristics of Pomegranate Peel Pyrolysis Oil as Fuel in Diesel Engine

GNANAMOORTHI V[a#], VIMALANANTH V T[b*], MURUGAN M[c#]
[a, b,c] Department of Mechanical Engineering, University college of Engineering Villupuram, Villupuram.

Abstract— ***nowadays pollution control and energy consumption are the main criteria lead the researchers to identify the new alternative fuel for internal combustion engines. New alternative fuel resource can be produced by using pyrolysis method. In this study, feedstock pomegranate peel produces the pomegranate peel oil by fast pyrolysis method using fixed bed reactor. In this work, pomegranate peel oil blended with diesel in 10%, 20% and 30% ratio using as fuel in single cylinder four stroke DI diesel engine without any engine modification. This experiment will be carried out performance characteristics like brake thermal efficiency, brake specific fuel consumption. The emission characteristics of CO, HC, NO_X and smoke are also being measured.***

Keywords - ***Pollution control, Alternative fuel, Pyrolysis method, Fixed bed reactor, Pomegranate peel***

I. INTRODUCTION

Fuel scarcity and energy crisis leads to open new avenue of research field. Nowadays biomass and fossil fuels are the important energy resources. Between the two, biomass is better than fossil fuels due to some significant advantages. Positively biomass has negligible amount of sulphur content. Due to this, biomass gives lower emissions of SO_2. In same way, biomass has negligible amount of nitrogen and ash. Due to this, biomass gives lower emissions of NO_x and soot. By photosynthesis activity, carbon di oxide (CO_2) released from biomass will be recycled into the plants. This activity leads to achieve zero net emissions of CO_2 [1-3]. Normally in various countries effectively utilizing the alternative fuel resources which are easily available in their country. In the current scenario, alternative fuels should be fulfilling the two important criteria's. One is eco-friendly fuels should be developed due to atmospheric pollutants and global warming. Another one is fuel should meet the commercial demands due to no other alternative as fast depletion of fossil fuels [4].Thermochemical decomposition of organic material at elevated temperatures in the absence of oxygen is called pyrolysis. To convert biomass into liquid, gas and charcoal using effective pyrolysis method [5]. Based on heating slow pyrolysis, flash pyrolysis and vaccum pyrolysis are the types of pyrolysis [6]. Energy independence, smaller trade deficit, less global warming and cleaner air are the positivity of pyrolysis method [7].Comparing to other methods, fixed bed pyrolysis is the best suited method for producing pyrolysis oil from biomass due to high conversion capability [8-10].

In this paper we describe the material preparation, pyrolysis setup working procedure, production of pyrolysis oil procedure and performance and emission characteristics of diesel engine.

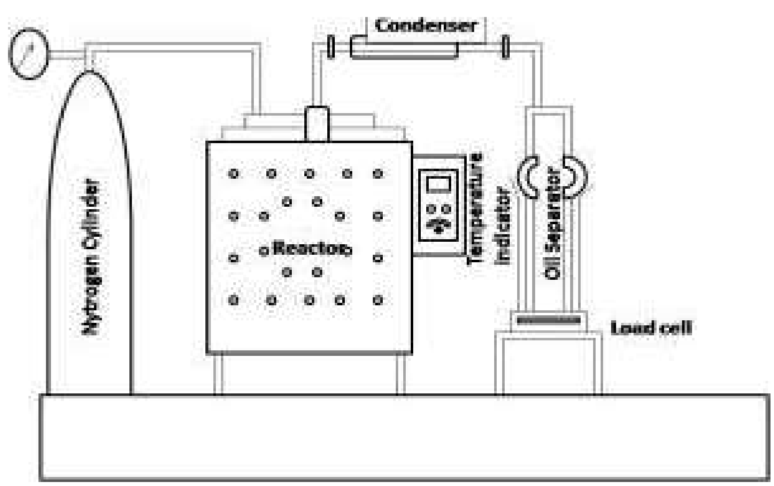

Fig.1: Experimental setup of Pyrolysis

II. EXPERIMENTAL SETUP AND PROCEDURE

A. Material preparation

Pomegranate peel was collected from the juice shops in Villupuram town which placed at Tamilnadu state, India. Pomegranate peel was sun dried for around 72 hours. This procedure is used to remove moisture content in the sample. The sample material was cut into smaller sizes.

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B. Pyrolysis setup

The design of reactor was carefully done and then it was fabricated. The sole objective was to get maximum liquid yield. The reactor is made up of stainless steel material. The power supply was single phase. During the reaction, some void spaces were produced which will tend to reduce the heat transfer rate. To avoid the heat losses, ceramic and cotton were packed. The nitrogen gas entering the reactor through inlet and the gases produced during the reaction were easily entering into the condenser through outlet.

The capacity of the reactor up to 4 kg of feed stock. The digital temperature indicator was fixed outside the reactor which used to control the reactor temperature. Condenser was made up of stainless steel. Here, counter flow condenser was selected. Condenser was connected with separator. The direction of water flow is opposite to the pyrolysis gases direction. Then it condensate drips into the gas liquid separator. The gases (non condensable) pass through the exhaust tube.

TABLE 1
Engine Specifications

Sl. No.	***Details***	***Specification***
1	Rated power& speed	5.2kW& 1500 rpm
2	Number of cylinders	Single cylinder
3	Compression ratio	17.5:1
4	Bore& stroke	87.5mm & 110mm
5	Cubic Capacity, Ltr	0.661
6	Rated sped, rpm	1500
7	Intake Valve Diameter(D), mm	34
8	Intake Overall Length(L), mm	113.2
9	Orifice diameter, mm	20
10	Displacement volume, cm^3	667
11	Injection timing, ºCA bTDC	23
12	Method of loading	Eddy current dynamometer
13	Dynamometer arm length	0.185m
14	Type of injection	Mechanical pump-nozzle injection
15	Injection timing	23ºbefore TDC
16	Injection pressure	220 bar
17	Lubrication oil	SAE 40

C. Production of pyrolysis oil

The dried pomegranate peel can put inside the reactor. First to remove the oxygen and moisture content inside the reactor, the nitrogen gas was supplied to the reactor for 3-4 minutes. Then the reactor was heated using electric furnace at optimum condition 450-550^0 c. During reaction, the gases produced were entered the condenser. In the condenser, due to water counter flow, the gases condensate into liquid. This filled in the separator then it separated into pyrolysis oil and solid residue.

The gas part passing through outlet. This pyrolysis oil collected can be used for the diesel engine experimental investigation analysis. Physical properties of pyrolysis oil and diesel were determined using ASTM standards. Calorific value was determined using bomb calorimeter. Redwood viscometer is used to obtain the value of viscosity. Flash point and fire point were determined using open cup method. Other properties were determined using given ASTM standards.

TABLE 2
Properties of Test Fuels

Sl.No	**Properties**	**Diesel**	**Pomegranate peel oil**
1	Calorific value (KJ/Kg)	42000	34650
2	Density (kg/m^3)	830	840
3	Viscosity at 300k (mm^2/s)	4.3	3.52
4	Cetane number	50	47
5	Flash point (^{0}c)	52	74
6	Fire point (^{0}c)	65	82

III. RESULTS AND DISCUSSIONS

A. PERFORMANCE ANALYSIS

1) BRAKE SPECIFIC FUEL CONSUMPTION

The variations in the brake specific fuel consumption for diesel and various blends are shown in Fig. 2. The BSFC decreased monotonically with an increase in the brake power for diesel as well as blends. Pomegranate blends BSFC are higher compared to diesel showed in figure. Due to lower calorific values of pomegranate blends, their BSFC values increases. It can be observed from figure that the BSFC values for PPOB10, PPOB20, PPOB30 and diesel are 0.44 kg/kwh, 0.46 kg/kwh, 0.53 kg/kwh and 0.42 kg/kwh at full loads respectively.

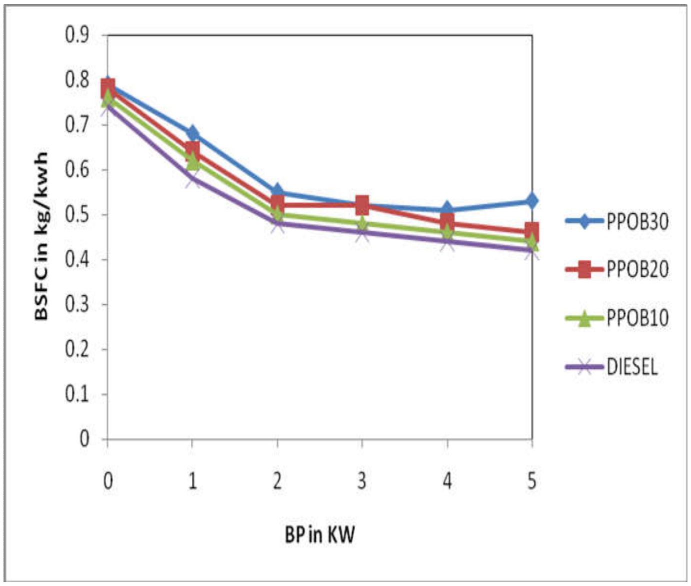

Fig. 2. Variation of brake specific fuel consumption with brake power

2) BRAKE THERMAL EFFICIENCY

Fig. 3. Shows the variation in brake thermal efficiency with brake power for diesel and pomegranate blends. BTE indicates the ability of the combustion system to accept the testing fuel and Brake thermal efficiency provide the information about how efficient the energy in the fuel. BTE of the pomegranate blends are lower than diesel due to low calorific value of pomegranate blends. It can be observed from figure that the BTE values of PPOB10, PPOB20, PPOB30 and diesel are 32%, 31%, 30% and 34% respectively at full loads.

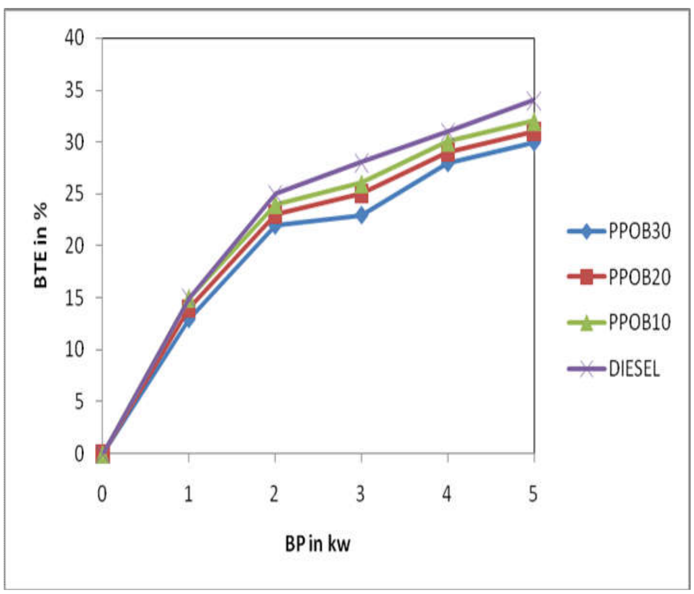

Fig. 3. Variation of brake thermal efficiency with brake power

B. EMISSION ANALYSIS

1) CARBON MONOXIDE EMISSION

The variations in the carbon monoxide emission for diesel and various blends are shown in Fig. 4. Pomegranate blends CO emission percentage is lower compared to diesel due to higher oxygen content of pomegranate blends. During premixed phase of combustion, more radicals are produced due to high heat release rate. That radicals helps combustion in diffusion phase which leads to lower CO emission. It can be observed from figure that the CO emission values for PPOB10, PPOB20, PPOB30 and diesel are 0.035%, 0.033%, 0.031% and 0.04% respectively at full loads.

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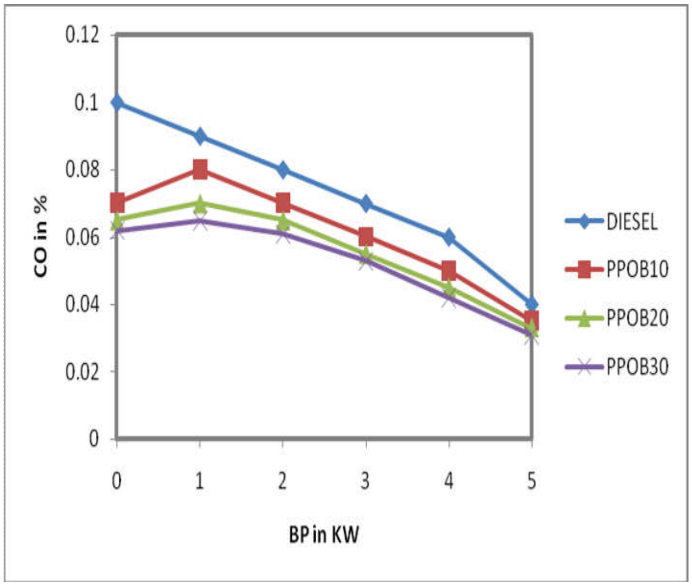

Fig. 4. Variation of carbon monoxide with brake power

2) HYDROCARBON EMISSION

Fig. 5. Shows the variation in hydrocarbon emission with brake power for diesel and pomegranate blends. Pomegranate blends HC emission percentage is lower compared to diesel. Lower viscosity, higher oxygen content and longer ignition delay are the reasons for higher premixed phase of combustion. Due to this nature of pomegranate blends leads to lower HC emission. It can be observed from figure that the HC emission values for PPOB10, PPOB20, PPOB30 and diesel are 34 PPM, 32 PPM, 31 PPM and 39 PPM respectively at full loads.

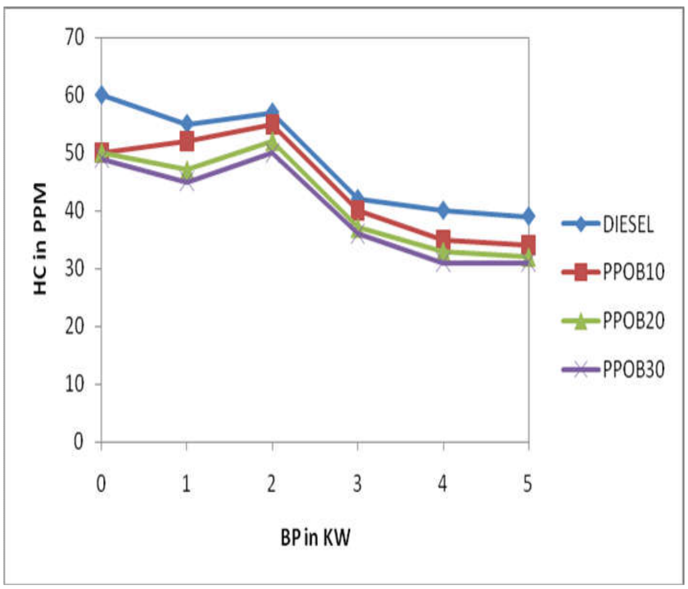

Fig. 5. Variation of hydrocarbon with brake power

3) OXIDES OF NITROGEN EMISSION

The variations in the oxides of nitrogen emission for diesel and various blends are shown in Fig. 6. Pomegranate blends NO_x emission percentage is higher compared to diesel due to higher oxygen content, longer ignition delay and higher heat release of pomegranate blends. Due to this premixed combustion phase is higher and diffusion combustion phase is lower which leads to higher NO_x emission for pomegranate blends. It can be observed from figure that the NO_x emission values for PPOB10, PPOB20, PPOB30 and diesel are 850 PPM, 900 PPM, 1000 PPM and 800 PPM respectively at full loads.

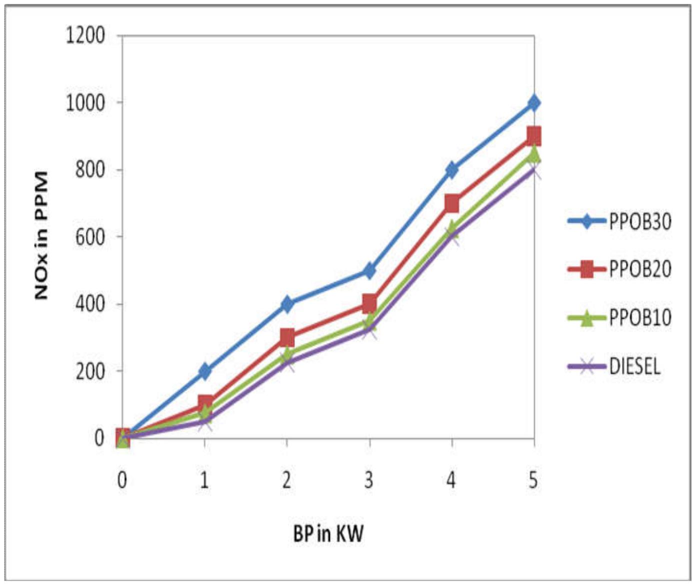

Fig. 6. Variation of oxides of nitrogen with brake power

4) SMOKE EMISSION

Fig. 7. Shows the variation in smoke emission with brake power for diesel and pomegranate blends. Pomegranate blends smoke emission percentage is lower compared to diesel. Excess oxygen present in the pomegranate blends is the one reason for lower values of smoke. Another reason is lower viscosity of blends which leads to good mixture formation. Due to this nature of pomegranate blends leads to lower smoke emission. It can be observed from figure that the smoke emission values for PPOB10, PPOB20, PPOB30 and diesel are 34% opacity, 32% opacity, 31% opacity and 44% opacity respectively at full loads.

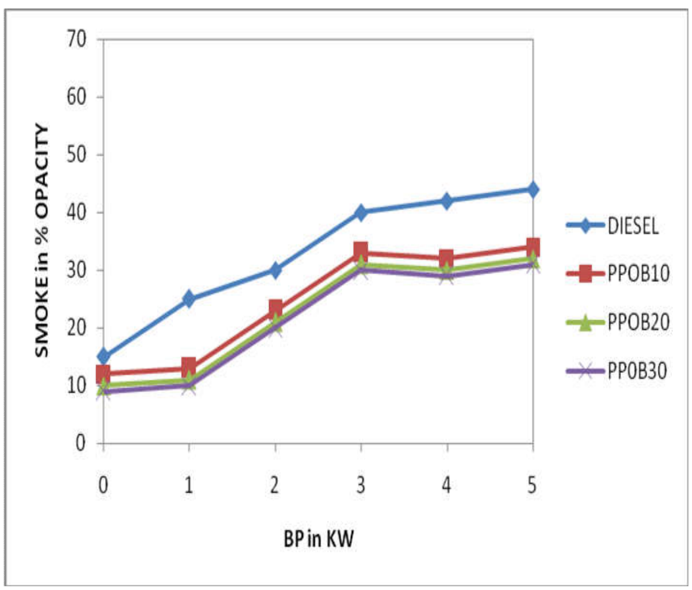

Fig. 7. Variation of smoke with brake power

IV. CONCLUSION

In this study, the feedback has been prepared and it has been used to produce the pyrolysis oil at 450-550^0 C. The performance and emission characteristics analysis for a single cylinder, four stroke, water cooled diesel engine fuelled with pomegranate blends and diesel was carried out and the following conclusions are made from the experimental results.

- Pomegranate blends BSFC are higher compared to diesel. BSFC of PPOB10 and PPOB30 are 0.44 kg/kwh and 0.53 kg/kwh respectively which higher than that of diesel at full loads.

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- Pomegranate blends BTE are lower compared to diesel. BTE of PPOB10 and PPOB30 are 32% and 30% respectively which lower than that of diesel at full loads.
- Pomegranate blends CO emissions are lower compared to diesel. CO emission of PPOB10 and PPOB30 are 0.035% and 0.031% respectively which lower than that of diesel at full loads.
- Pomegranate blends HC emissions are lower compared to diesel. HC emission of PPOB10 and PPOB30 are 34 PPM and 31 PPM respectively which lower than that of diesel at full loads.
- Pomegranate blends NO_X emissions are higher compared to diesel. NO_X emission of PPOB10 and PPOB30 are 850 PPM and 1000 PPM respectively which higher than that of diesel at full loads.
- Pomegranate blends smoke emissions are lower compared to diesel. Smoke emission of PPOB10 and PPOB30 are 34% opacity and 31% opacity respectively which lower than that of diesel at full loads.

In conclusion, pomegranate blends can be used as alternative fuels in conventional diesel engines without any major modification in the engine. CO and HC emissions with the blends are lower compared to that of diesel. As the blend proportion is increased a higher reduction in CO and HC emission is obtained.

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