Performance and Emission Studies of a Diesel Engine Fueled with Different Waste Plastic Pyrolysis-Diesel Blends

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Abstract:

Worldwide research activities have been involved in the replacement of fossil fuel by some non-conventional fuels. Many attempts have been made on the conversion of waste material by some suitable technique. Thermochemical methods have gained attention by many researchers. Pyrolysis is one of the attractive techniques since anything can be pyrolyzed which contains hydrogen and carbon by this process. Disposal of waste plastic has become one of the major tasks in today's generation. In this regard pyrolysis of waste plastic can be potential solution. In this research study fuel derived from waste plastic by pyrolysis process (PO) has been utilized as diesel engine fuel. The PO fuel was blended with high cetane fuel i.e. jatropha methyl ester (JME). The PO was blended in volume by 10% to 40% with remaining portion of JME. The characterization of prepared fuel was carried out as per ASTM standard. The prepared test fuels were used as replacement of diesel fuel and performance and emission parameters were recorded, compared with diesel, analyzed and reported in this article.

Keywords: *Biodiesel; Diesel Engine; Pyrolysis; Performance; Waste Plastic*

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1. Introduction

Requirement of energy is very much essential for the development of human civilization. It is very much required for many purposes such as transport, industry, agriculture etc. [1]. International energy agency (2019) has reported that global energy consumption distributed into power sources such as oil 31.1 %, coal/peat 28.9 %, natural gas 21.4 %, biofuel/waste 10.2 %, nuclear (4.8 %, hydro 2.4 % and other renewable energy sources such as wind power, solar energy, tidal energy 1.2 % etc. [2]. The usage of fossil fuel has been increased, so its replacement is very much essential. The other issue is environment pollution. To reduce the greenhouse emission, we have two options either find the alternative of petroleum fuel or improvement of current engine. Due to limited fossil fuel resources, the development of renewable energy sources becomes essential as it is the best alternative way to reduce greenhouse emission. Further, renewable energy sources do not fulfill only energy deficiency gap but it is also environmental eco-friendly and cost-effective [3]. Among all the renewable energy sources such as wind power, solar energy, tidal energy, hydrothermal energy, etc., biomass is considered best possible sources due to its environmental advantages and wide availability across the worlds. Grown and waste biomass was used for energy production, and almost 10-14 % energy requirements meet from the biomass [4]. Thermochemical methods have gained attention by many researchers. Pyrolysis is one of the attractive techniques since anything can be pyrolyzed which contains hydrogen and carbon by this process. Disposal of waste plastic has become one of the major tasks in today's generation. In this regard pyrolysis of waste plastic can be potential solution. The conversion of waste material by suitable technique has gained attention by researchers. The pyrolysis, one of the efficient thermochemical method can be used to get usable form of energy by waste plastic. The systematic process of pyrolysis has been shown in Figure 1.

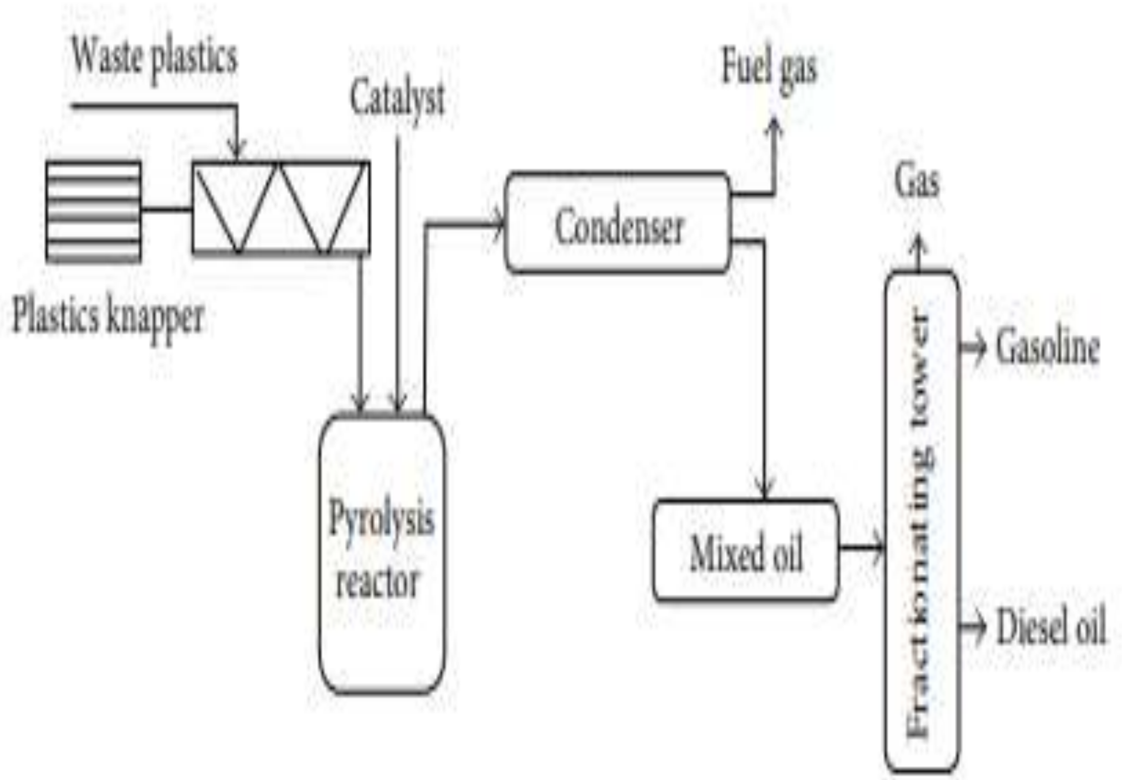

Figure 1 Plastic pyrolysis process [5]

In this research study fuel derived from waste plastic by pyrolysis process (PO) has been utilized as diesel engine fuel. The PO fuel was blended with high cetane fuel i.e. jatropha methyl ester (JME). The PO was blended in volume by 10% to 40% with remaining portion of JME. The characterization of prepared fuel was carried out as per ASTM standard. The prepared test fuels were used as replacement of diesel fuel and performance and emission parameters were recorded, compared with diesel, analyzed and reported in this article.

2. Fuel Preparation

In this research work two fuels have been used one is fuel derived by pyrolysis of waste plastic and another fuel derived by transesterification process i.e. jatropha methyl ester. The fuels were prepared by blending PO by mixing 10-40% with remaining percentage of JME. The notation used for test fuels are B10, B20, B30, B40 where numeric numbers represent the PO fuel available in the blend.

3. Experimental setup

The prepared test fuels were used in a diesel engine which gave 4.4 kW at rated engine speed of 1500 rpm. The fuel consumption, in cylinder pressure, exhaust gas temperature etc. were recorded by the help of data acquisition system. The emission parameters were measured by AVL444 gas analyzer and AVL 437 Smoke meter. The test engine specification is given in table 1.

Table 1 Test Engine Specification

Type	Kirloskar TAF1 Vertical diesel engine
No. of cylinder	1
Type of injection	Direct
Rated power at 1500 rpm, kW	4.41
Bore, mm	87.5
Stroke, mm	110
Compression ratio	17.5
Displacement volume, litres	0.662
Fuel injection timing bTDC, °CA	23
Number of injector nozzle holes	3
Nozzle-hole diameter, mm	0.25
Inlet valve opening bTDC, °CA	4.5
Inlet valve closing aBDC, °CA	35.5
Exhaust valve opening bBDC, °CA	35.5
Exhaust valve closing aTDC, °CA	4.5
Type of fuel injection	Pump-line-nozzle injection system
Connecting rod length, mm	220

4. Result and Discussions

In this section different results obtained by the experiments are discussed. The various parameters such as BTE, EGT, Co, HC and smoke emissions were discussed in detail.

4.1 Performance parameters

4.1.1 Brake thermal efficiency

Brake thermal efficiency is an important efficiency for CI engine, it means how much thermal energy of fuel input was converted into shaft output [6]. Figure 2 shows the comparison of BTE for CI engine with different kinds of fuel used for the study with diesel operation. Generally, reported by many authors who tested different types of fuel in same kind of engine are by about 29% for diesel operation in full load condition [7]. In this study when alternative fuel was used then efficiency was lower than diesel for all the blends. Among all the blends B20 gave somewhat better results than the other blends in full load condition. A better BTE with high viscous fuel is not possible due to higher density and viscosity of the blend. Better swirling of air in combustion chamber leads to better combustion of alternative fuel and results increased in brake thermal efficiency [8]. The findings and trends are supported by literature available data [9].

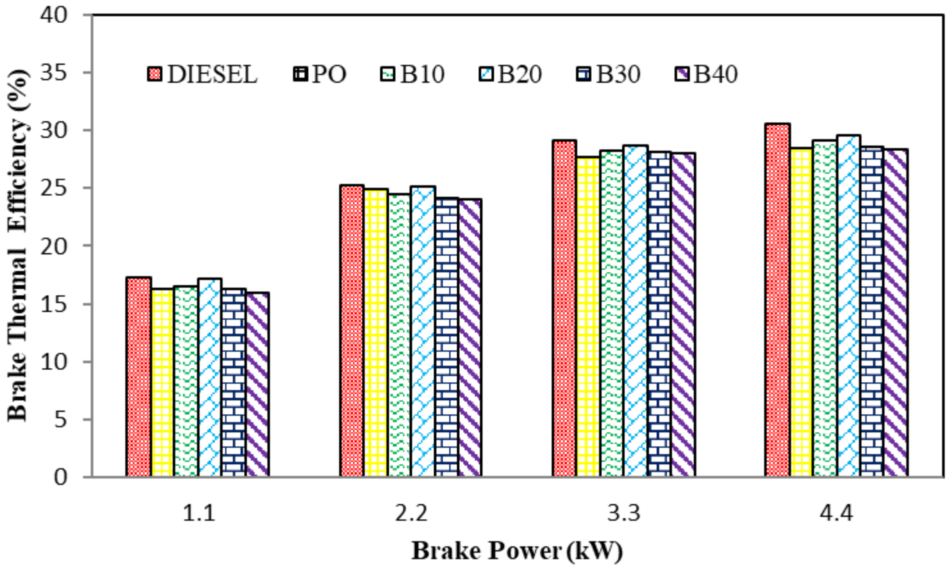

Figure 2 BP Vs BTE

4.1.2 Exhaust gas temperature

The EGT analyses is vital to get proper information about utilization of heat energy generated by the burning of fossil fuel [10]. This term also give idea about combustion phenomenon happen inside the cylinder [11]. The trend for the EGT with diesel and other alternative fuels used in this investigation at different engine brake power is graphically depicted in Figure 3. The EGT increases with an increase in the BP of 4.4. kW, as a result of increased cylinder gas temperature. It is evident from the figure that the EGT increases, when the PO percentage in the blend increases as compared to that of the diesel operation. This is because, with the delayed combustion, more amount of heat goes to the exhaust.

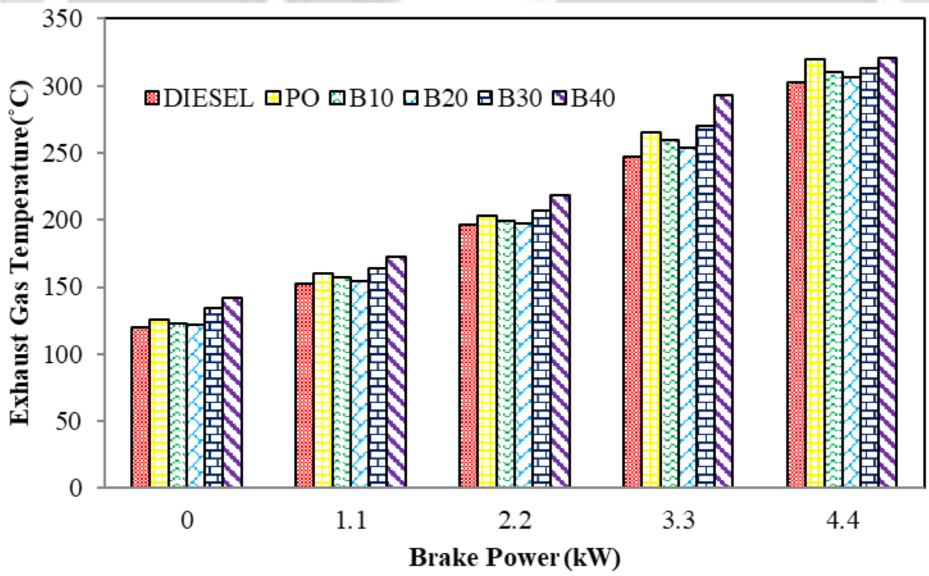

Figure 3 BP Vs EGT

4.2.1 CO Emission

It is known that CI engine operates with lean mixtures and hence the CO emission would be low in case of diesel engine. CO emission is toxic and must be controlled [12]. It is an intermediate product in the combustion of a hydrocarbon fuel, so its emission results from incomplete combustion. Emission of CO is therefore greatly dependent on the air fuel ratio relative to the stoichiometric proportions. Rich combustion invariably produces CO, and emissions increase nearly linearly with the deviation from the stoichiometry [13]. The concentration of CO emission varies from 0.01% at 25% of rated power to 0.06% at rated power for diesel, whereas it varies from 0.004% at 25% of rated power to 0.05% at rated power for waste plastic oil blends.

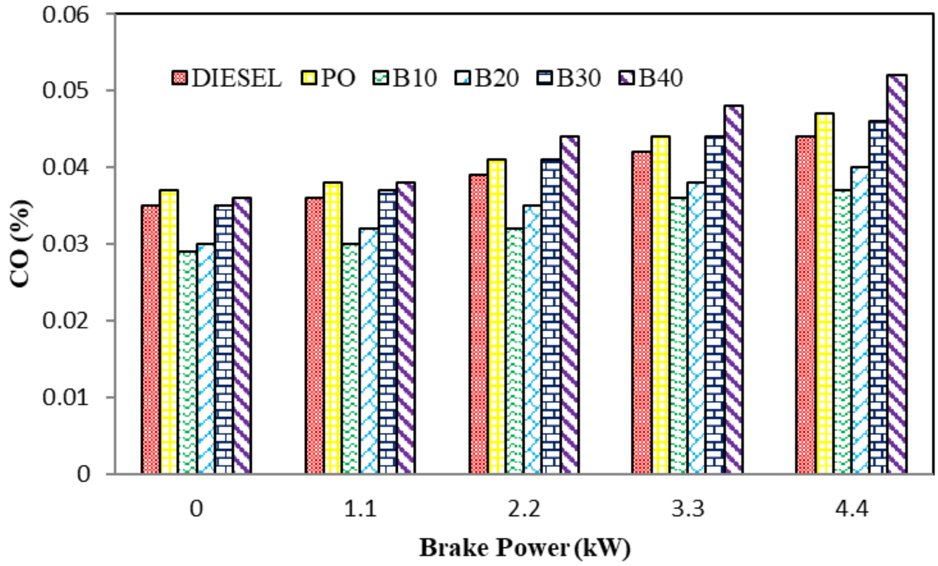

Figure 4 BP Vs Carbon monoxide emission

4.2.2 HC Emission

The HC emission occurs mainly due to incomplete combustion in different forms such as vapour and drop of unburned fuel droplets [14]. The variation in HC emissions for diesel and other PO blends with different brake power are shown in Figure 5. It can be noted from figure that, at full load the all the test fuels resulted reduction in HC emission by about 12% and 6% respectively, than that of diesel. This is due to the presence of oxygen molecule in the blend. But, adding the PO with the JME results in increase in HC emission, due to the increase in the aromatic content in the blend as the TPO has higher aromatic content [15]. It can be further noticed from the figure that adding more amount of Po in the blend increases HC emissions at all loads. This increase in the HC emission may be due to decrease in oxidative free radical formed by the antioxidants. The lowest HC emission for the B20 blend is found.

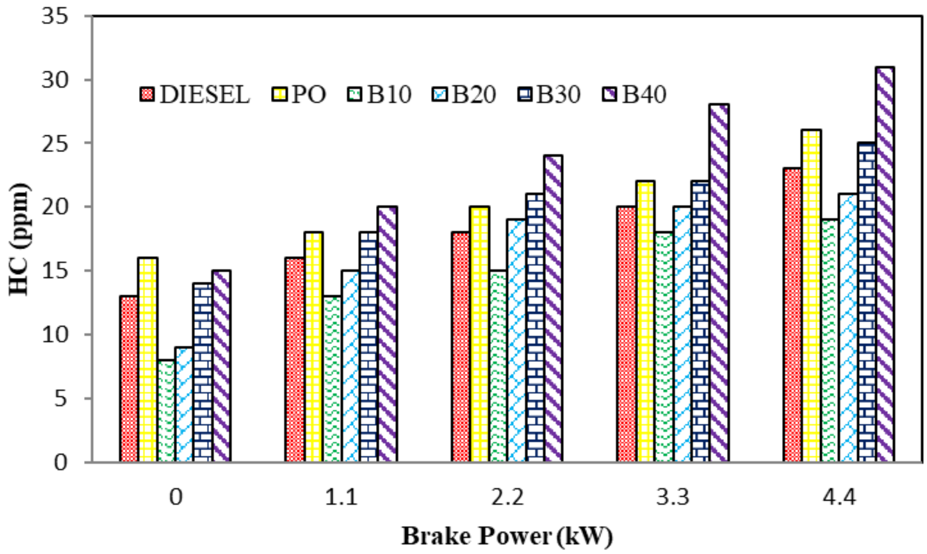

Figure 5 BP Vs Hydrocarbon emission

4.2.3 Smoke Emission

The variation of smoke emission of the different test fuels at different loading conditions is shown in Figure 6. The results revealed that the smoke emission level decreased with the use of JME when compared to all the test fuels for the entire load range. This is mainly because of the higher oxygen content and lower carbon to hydrogen ratio and the absence of aromatics in biodiesel [16]. At 100% load condition, the smoke emission of diesel fuel was higher than that of blends. The smoke emission was found to be 68.3% at higher loads which is 9.7% higher than that of biodiesel and 27.4% lower than that of diesel. This is because of the combustion being assisted by the presence of the fuel bound oxygen of the biodiesel and ethanol present in test fuel. Additionally, it is well known fact that an advanced injection timing and higher injection pressure leads to longer duration and fine fuel droplets during the expansion stroke in which oxidation of the soot particles occurs [17]. This is because of the effect of fuel injected in low temperature environment, delayed injection which has adverse effect on fuel distribution in air [18].

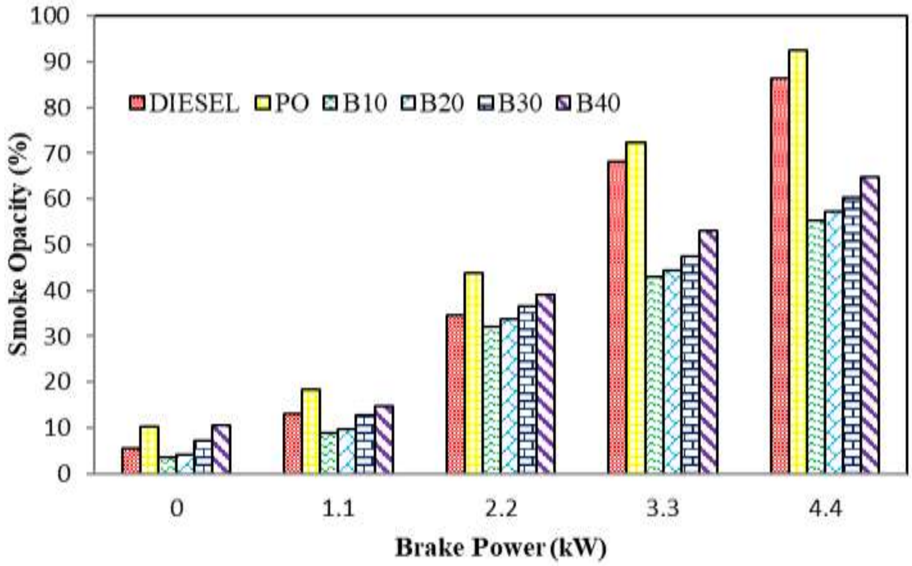

Figure 6 BP Vs Smoke emission

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