IOP Conf. Series: Materials Science and Engineering **149** (2016) 012223 doi:10.1088/1757-899X/149/1/012223

STUDY ON CONVERSION OF MUNICIPAL PLASTIC WASTES INTO LIQUID FUEL COMPOUNDS, ANALYSIS OF CRDI ENGINE PERFORMANCE AND EMISSION CHARACTERISTICS

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Abstract. The rate of economic evolution is untenable unless we save or stops misusing the fossil fuels like coal, crude oil or fossil fuels. So we are in need of start count on the alternate or renewable energy sources. In this experimental analysis an attempt has been made to investigate the conversion of municipal plastic wastes like milk covers and water bottles are selected as feed stocks to get oil using pyrolysis method, the performance analysis on CRDI diesel engine and to assess emission characteristics like HC, CO, NO_X and smoke by using blends of Diesel–Plastic liquid fuels. The plastic fuel is done with the pH test using pH meter after the purification process and brought to the normal by adding KOH and NaOH. Blends of 0 to 100% plastic liquid fuel-diesel mixture have been tested for performance and emission aspect as well. The experimental results shows the efficiently convert weight of municipal waste plastics into 65% of useful liquid hydrocarbon fuels without emitting much pollutants.

1. Introduction

Plastics production increase 80 million tons every year worldwide. Global production and consumption of plastics was less than 5 million tons in 1950 is increased to 260 million tons in the year 2007 **[1].** Among those over one third is being used for packaging, while rest is used for other sector. During the next decades per capita consumption of the plastic will increase by more than 50%. Due to the non-biodegradability and high perceptibility, the plastics have become a major threat.

The complete reuse of the plastics waste using waste management methods such as landfill disposal, incineration, and recycling have failed. The process called pyrolysis used in Polymer energy systems efficiently convert plastics into liquid fuel compounds offers an alternative to the above methods-while also being a sustainable, economical, and environmentally accountable waste management solution. The plastic wastes can be classified as municipal wastes and industrial wastes.

The polypropylene, polyethylene, polystyrene, polyethylene, terephthalate, polyvinyl chloride etc are the major components of municipal plastic wastes **[3].**

The large plastics manufacturing, processing and packaging industries are the major source for industrial plastic wastes. Plastic wastes can be classified as heterogeneous and homogeneous in nature. Municipal wastes come under heterogeneous and industrial plastis wastes come under homogeneous nature. The homogeneous wastes can be recycled easily by repelletization and remoulding. But for heterogeneous natured plastic wastes thermal cracking should be implemented for recycling also called as chemical recycling. **[4].** There is lot of research work is carried out on plastic wastes by several people and concluded that liquid hydrocarbon compounds can be produced from plastic wastes by pyrolysis method. This method can be a source of new renewable energy to diminish the present world market demand **[6].**

In this work municipal plastic wastes like milk covers and water bottles are selected as feed stocks to produce liquid fuel compounds. The pyrolysis chamber is fabricated with mild steel having the thickness of 5mm provided with concentric tube heat exchanger. Experiments are conducted at different loads from no load and at different speed also. The different blends like P0, P20, P40, P60 and P80 are prepared on volume basis and properties such as viscosity density, flash point, fire point, calorific value are found for all blends.

2. Experimental Details

Pyrolysis unit is constructed with concentric tube heat exchanger. The reactor is placed on a furnace for the purpose of heating. Little biomass and coal with blower is used as a heating source. Due to increase in temperature of the reactor the plastic starts to evaporate, made to passed through the condenser maintained at atmospheric temperature.

The temperature of the reactor is measured using the thermocouple. The liquid fuel collected will be undergone for purification process.

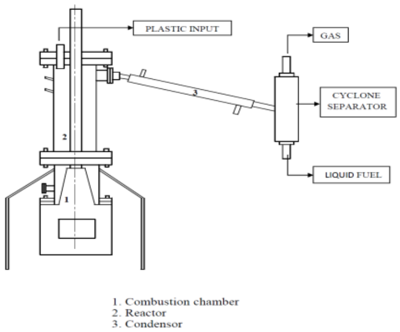

Fig.1. Schematic diagram of Pyrolysis unit

In this purification process equal proportion of plastic fuel and water in a container, mixed well and allowed it for 5-7 hours to settle down. Now water along with some crystals is collected at bottom and pure plastic fuel is collected at the top of the container. After purification pH value of plastic fuel is measured using pH meter. If the pH is less than 7, the fuel is acidic in nature. This is improved by mixing 100g of KOH with one litter of water and stirred uniformly by using stirrer. Equal proportion of plastic liquid fuel and dilution of potassium hydroxide in a container and mixed well, allowed it for 2-4 hours to settle down. Now along with dilution of potassium hydroxide some acids are collected at bottom and acid free plastic liquid fuel is collected at top of the container.

The set up is shown in Fig.2. The viscosities of various blends were determined using Sayboltviscometer at a temperature of 40^0C. The flash and fire points of fuels were determined using Cleaveland open cup tester. The calorific value is determined by bomb calorimeter and AVL DIGAS 444 D gas analyzer is used to find out emission characteristics like HC, CO, CO_2, O_2 and NOx. The performance analysis and emission characteristics are determined at constant speed with different load and cylinder pressure with respect to PF20 and PF40 are plotted against crank angle.

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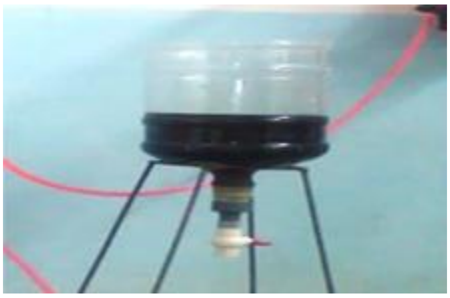

Fig. 2. Water washing tank


Fig. 3. Firing system **Fig.4.**Gaseous product

Fig. 5. Liquid product.


Fig. 6. Plastic liquid fuel. **Fig. 7.** Residue.

The figure 3 & 4 shows the heating the reactor by furnace and extraction of the gas. The collection of condensed oil is shown in figure 5. The product and residue obtained from the pyrolysis of waste municipal plastic is shown in figure 6 & 7.

PARAMETERS	PFO	PF20	PF40	PF60	PF80	PF100
Flash point (°C)	55	56	60	63	68	73
Fire point (°C)	62	63	66	68	72	82
Kinematic viscosity at 40°C (mm^2/s)	2.63	4.03	4.37	4.50	4.53	4.55
Density at 40°c (kg/m^3)	810	817.6	818	818.8	819	819.2
Calorific value (MJ/kg)	44.93	44.35	43.96	43.377	43.18	42.98

Table 1. Properties of different blends.

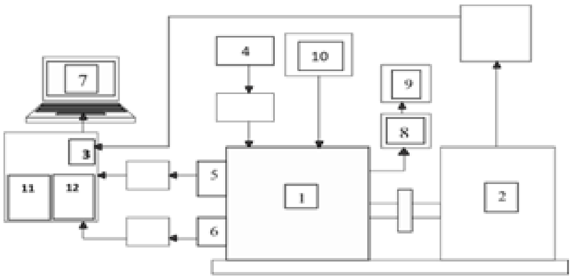

Fig. 8. Schematic diagram of engine setup

1.Diesel engine. 7. Computer.
2.Electrical dynamometer. 8. Exhaust gas analyzer.
3.Dynamometer controls. 9. Smoke meter.
4.Fuel tank. 10. Air box.
5.Pressure pickup. 11. Fuel consumption Manometer
6.TDC position sensor 12.Air flow measurement

The engine is loaded with the help of electric dynamometer. The fuel tank is connected with burette helps to measure the flow rate of fuel. A Chromel alumel thermocouple in conjunction with a digital temperature indicator is used to measure exhaust temperature. The cylinder pressure is measured using pressure transducer fixed on cylinder head combined with charge amplifier and computer. Crank angle is measured by TDC encoder and exhaust gas analyzer is used to measure exhaust gas constituents. The smoke measured with the help of smoke meter.

Table 2. Engine specifications

Engine Type	CRDI Diesel engine
Capacity	1248cc

Bore	74 mm
Stroke	75.5 mm
Power	7.5bhp@4000rpm
Torque	190Nm@2000rpm
Compression Ratio	17.6:1

3. Results and Discussions

Viscosity and Density

Kinematic viscosity = Ct – (β , t) mm²/s Where, c - 0.260

β -179, t –time in seconds

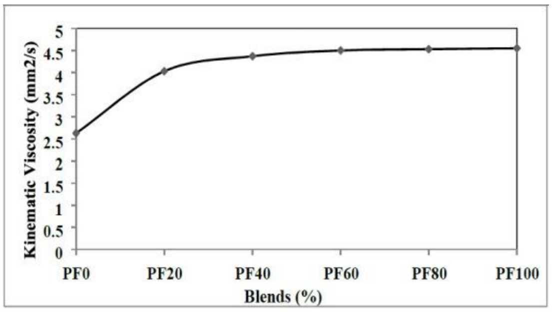

Fig. 9. Behavior of kinematic viscosity with blends in percentage.

The above figure shows the variation of Kinematic viscosity at 40^0 C for various percentages of plastic liquid fuel blends. From the figure as the percentage of plastic liquid fuel increases the viscosity increases i.e. the viscosity of pure diesel is lesser when compared to plastic liquid fuel and its blends.

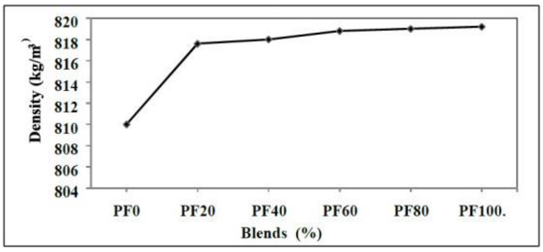

Fig. 10. Variation of density with blends in Percentage.

The figure shows the variation of Density at 40^0 C for various percentages of plastic liquid fuel blends. From the figure as the percentage of plastic liquid fuel increases the density increases i.e. the density of pure diesel is lesser when compared to plastic liquid fuel and its blends.

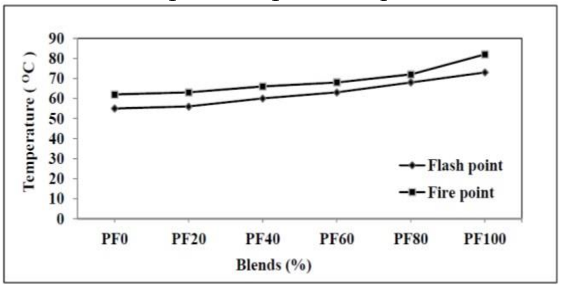

Fig. 11. Variation of Flash and fire point with blends in percentage.

This figure shows the variation of flash and fire points for various percentages of plastic liquid fuel blends. It can be seen that as the percentage of plastic liquid fuel increases the flash and fire points increases i.e. the flash and fire points of pure diesel is lesser when compared to plastic liquid fuel and its blends.

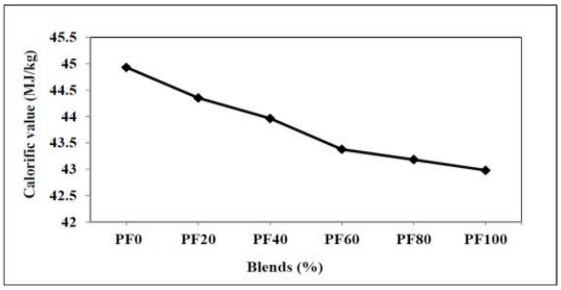

Fig. 12. Calorific value with blends in Percentage.

The variation of calorific value for various percentages of plastic liquid fuel blends is presented in the above figure. It is observed that the calorific value varies slightly over the different blends.

3.1. Performance analysis (1500rpm)

3.1.1. Brake Specific Fuel Consumption
The graph shows the variation of BSFC with respect to BP for different blends of plastic fuel and diesel. The BSFC decreases by increasing BP.

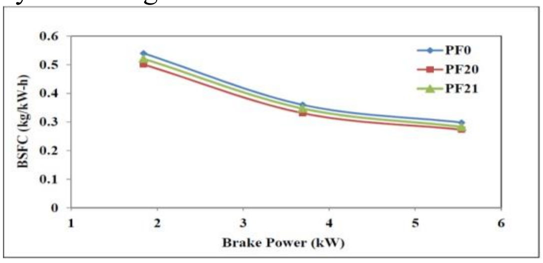

Fig. 13. Behavior of BSFC with brake power.

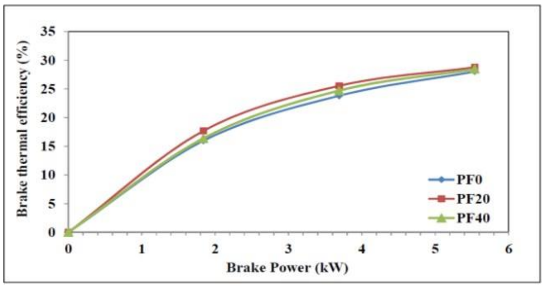

Fig. 14. Behavior of brake thermal efficiency with brake power.

The variation of brake thermal efficiency with BP is shown in the above Figure. It is observed from the figure that the brake thermal efficiency is 28.03% at maximum BP for diesel and for the PF20 it is 28.78% and for PF40 it is 28.47%. It can be observed from the graph that PF40 shows better brake thermal efficiency than PF20. The blends of plastic fuel and diesel are a mixture of hydrocarbons contributes both low and heavy fractions of aromatics and oxygen. This gives larger effective pressure with maximum work and lesser peak heat release and therefore increased brake thermal efficiency. The oxygen present in the plastic fuel is also one more reason for increasing brake thermal efficiency.

3.2. Emission characteristics:

Carbon monoxide is coming out as a product due to incomplete combustion process mainly depends on actual air-fuel ratio with respect to stochiometric air-fuel ratio.

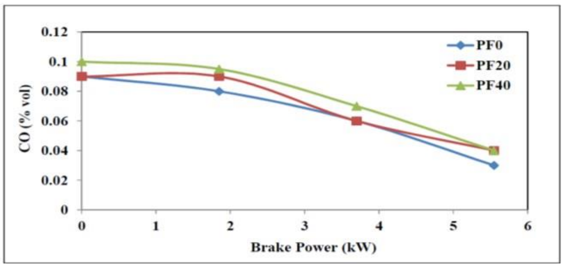

Fig. 15. Behavior of carbon monoxide with brake power.

Rich mixture contributes more CO. The CO emission slightly increased with plastic fuel blends than neat diesel may be associated to poor combustion. But with increase in power output there is gradually decrease in CO emission.

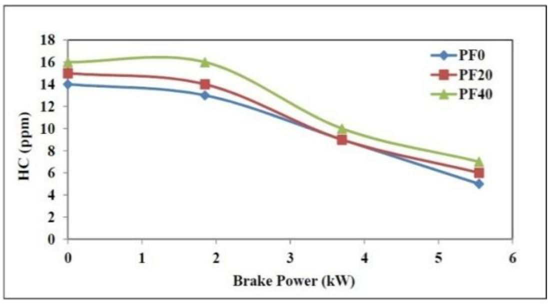

Fig. 16. Behavior of hydrocarbon with brake power.

The above graph shows the comparison of different blends for HC/BP. The PF20 shows variation of 17ppm to 7ppm and for PF40 it is 18ppm to 8ppm. The higher concentration of hydrocarbons in plastic fuel blends is due to larger fumigation.

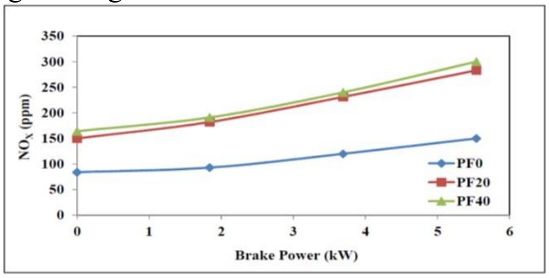

Fig. 17. Behavior of oxides of nitrogen with brake power.

Formation of NO_X is dependent on cylinder temperature, oxygen concentration, resident time for the reaction to take place etc. It is observed that NOx varies from 84ppm to 150ppm for diesel, from 150ppm to 283ppm for PF20 blend and for PF40 it varies from 164ppm to 300ppm. The NO_X is increased because of higher heat release rate as well as higher combustion temperature.

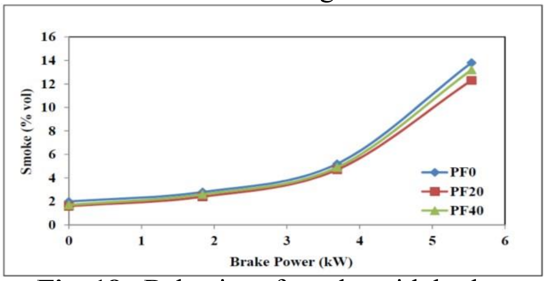

Fig. 18. Behavior of smoke with brake Power.

The graph shows the fluctuation of smoke with respect to brake power. The smoke emission increases as brake power is increased, this is because of consuming more amount of fuel at higher loads. But plastic fuel blends with diesel shows lesser emission than diesel. The plastic fuel contains oxygen as per its molecular structure which helps in better oxidation and reduces smoke emission. Smoke varies from 1.99 to 13.8 for diesel whereas in PF20 it varies from 1.6 to 12.3 at rated power and for PF40 it is 1.7 to 13.2.

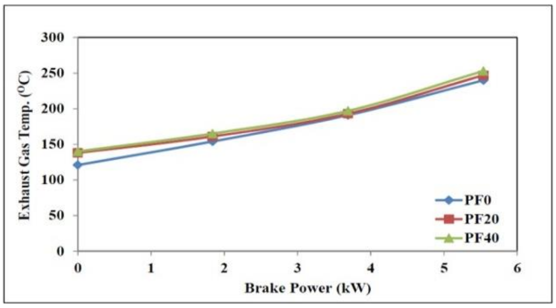

Fig. 19. Behavior of exhaust gas temperature with brake power.

Figure indicates the variation of exhaust gas temperature with brake power. The PF20 shows variation of temperature from 140°C to 250°C and PF40 shows from 142°C to 255°C respectively but for diesel it shows 120°C to 240°C. The reason for this higher temperature can be improved combustion.

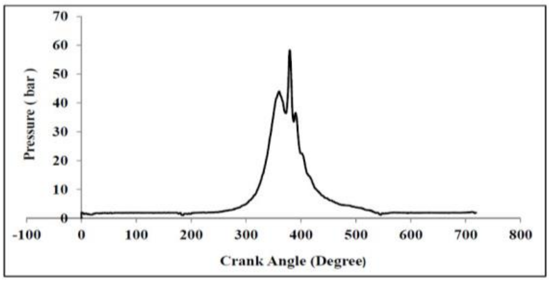

Fig. 20. Fluctuation of cylinder pressure with crank angle for diesel.

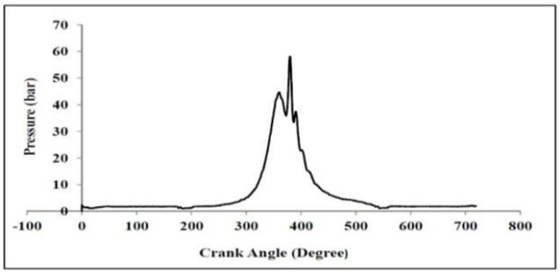

Fig. 21. Fluctuation of cylinder pressure with crank angle for PF20.

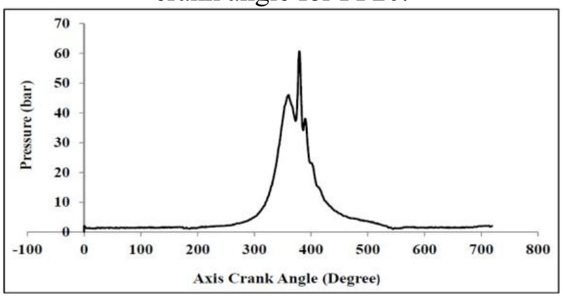

Fig. 22. Fluctuation of cylinder pressure with crank angle for PF40

The variation of maximum cylinder pressure with Crank angle for diesel, blends of plastic liquid fuel are presented in above figures. The peak pressure for diesel is 58.31bar. For B20 and B40 it is 58.13bar and 60.73bar respectively. It can be seen that the maximum cylinder pressure for PF20 is slightly lower than the diesel and PF40 blend. A significant advance in start of combustion is observed for the PF20 blend compared to diesel. The earlier start of combustion for plastic liquid fuel blends is due to the combined effects of earlier injection and lower ignition delay.

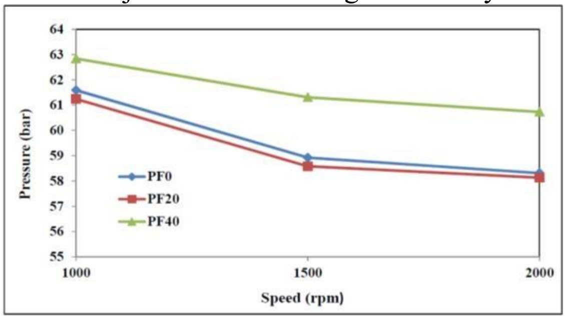

Fig. 23. Behavior of maximum pressure with speed.

It can be seen that as the speed increases the maximum cylinder pressure decreases. The maximum cylinder pressure is recorded at 1000rpm for all the fuels. The maximum pressure is recorded for PF0 with a value of 61.59bar. For PF20 and PF40 is the maximum pressure at the same operating condition is 61.24bar and 62.84bar respectively.

4. Conclusions

By adopting this technology, efficiently convert weight of municipal waste plastics into 65% of useful liquid hydrocarbon fuels without emitting much pollutant. Engine test carried out with plastic liquid fuel blends which are obtained from the municipal waste plastic pyrolysis process. The results shows, better engine performance than diesel fuel operation.

The fuel consumption of the engine was somewhat lower as compared to diesel fuel operation and brake thermal efficiency increases with PF20, PF40 blends operation.

Knocking is not observed for the tested fuel at all operating conditions.

The emissions of engine like carbon monoxide (CO), hydrocarbon (HC) and nitrogen oxide (NO_X) is increases when the engine runs with plastic fuel blends.

This facilitate to recover valuable product and/or energy from wastes plastics and Perfect solution for waste plastic management.

5. References

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