Performance Study of a Single Cylinder DI-CI Engine Using Waste Plastic Oil Blended Diesel

[1]Amar Kumar Das,[2]Sumant Dutta, [3]SatyabrataKar, [4]ThulungaBasumatary, [5]Ashish Kumar Pattjoshi

Department of Mechanical Engineering, Gandhi institute For Technology (GIFT), Bhubaneswar

Abstract:

An approach towards global fossil fuel depletion, dependency on crude oils, stringent emission norms, and an efficient energy conservation and management policy to establish, extensive researches has been carried out by different scientists of the era and of course, attractive and appreciable results have come out.Waste plastic oil derived from Zeolite catalyzed pyrolysis of waste polypropylene is blended with diesel fuel, tested as an alternative fuel in a diesel engine, and its performance characteristics are analyzed and compared with diesel fuel operation. It is observed that the engine could operate with maximum 40% waste plastic oil blended diesel. An engine showed better performance up to 20% blend, but beyond 40% blend it gave a vibration. The results showed a stable performance with brake thermal efficiency similar to that of diesel and its value is higher up to 1000% of full load.

Keywords: Waste plastic oil, DI, diesel engine, performance.

I. INTRODUCTION:

Fast depletion of non-renewable and limited fossil fuels, unwarranted issues related to environmental pollution; waste to energy drive and legislative pressure demand an attractive alternative source of fuel for compression ignition engines [1]. Among the various alternative explored, waste plastics to fuel has been extensively researched source of energy. Catalytic pyrolysis of waste plastic to liquid fuel is regarded as a very promising method in obtaining hydrocarbon fuel oil from different thermo-plastic wastes in which polymeric chain is cracked into smaller molecules without any pollution. A significant number of researches have been reported on the pyrolysis of waste plastics using different catalysts at some optimum temperature condition. The major product of this process i.e. the waste plastic oil is reported to possess matching composition and properties as that of petro fuels, thus could be used as an alternative fuel in diesel engine. This oil is treated as a better substitute for diesel fuel due to its carbon chain range of C_{10}-C_{25}composition, low specific gravity and viscosity, and higher miscibility with diesel [2, 3]. Few literature reports the use of waste plastic oil in diesel engine without any engine modification due to its higher drivability and stability. The experimental performance and emission results using waste plastic oil (WPO) in diesel engine reported by different researchers are summarized as follows.

Mani et al. carried out a complete experimental investigation on a single cylinder Kirloskar DI engine. They fueled the engine without any modification using both pure Waste Plastic Oil and blends of WPO and diesel oil. The performance, emission and combustion characteristics of waste plastic oil as compared to diesel are reported. They have claimed that the waste plastic oil used in the engine could able to replace diesel by 100%. The engine performed higher thermal efficiency 75% of the rated power by using waste plastic oil as reported. [4, 5]. Kumar et al. investigated the performance of waste plastic oil blends direct injection, twin cylinder engine and reported a lower brake thermal efficiency for the blend as compared to the diesel [6]. Güngör et al. tested waste polyethylene pyrolysis oil in a CI engine and reported a slight increase of power output by using plastic oil diesel blends [7].Panda et al. reported satisfactory engine performance result (higher BTE and lower BSFC) using Kaoline catalyzed waste plastic oil derived from polypropylene. They acclaimed that WPO with 30% blend with diesel showed good performance and beyond 50% caused vibration to the engine. Higher blend ratio and engine load results higher emission than diesel as reported [8]. Das et al. reported a marginal decrease in BTE and better BSFC in their investigation by using WPO as compared to diesel [9]. A small increase in the brake thermal efficiency and brake specific fuel consumption was reported by Senthil Kumar et al. by adding 10-20% jatropha methyl ester along with waste plastic oil in diesel [10]. Viswanathan et al. have investigated the use of diethyl etheralong with waste plastic oil blended diesel in diesel engine and reported it as a suitable additive as it showed an increase in the brake thermal efficiency with increase in its percentage in the blends and considerable reduction of BSFC [11]. Sukjit et al studied the efficacy of diesel engine using two oxygenated fuels like DEE and Butanol with waste plastic oil without any engine modification and claimed that these oxygenated fuels improved combustion efficiency than those of diesel fuel [12].

From the review of literature it is concluded that, there has been reports on the studies on the performance of waste plastic oil in internal IC engine calculated on the application of first law of thermodynamics. The research reports the successful operation of waste plastic oil in blend with diesel and other additives in different proportions in CI engines. The differential results reported by different researchers might be attributed to the different composition and properties of the WPO used. The objective of the work is to extensively study the operation of waste plastic oil in a CI engine and understand the performance by energy analysis.

II.EXPERIMENTAL

A. MATERIALS

Clinical plastic squanders, basically disposed of needles and saline containers (made of polypropylene plastics), were gathered from neighbourhood medical clinics, destroyed (to 1-2 cm size), dried well, and straightforwardly utilized in the pyrolysis analyse. Cleanser grade Zeolite A, a white free streaming powder with normal molecule size: 4-6 m, high surface region: 350-1000 m2/gm., high warm and aqueous solidness can endure temperature up to 500°C, is utilized as in the analysis. The schematic diagram of entire pyrolysis process is illustrated in Figure 1.

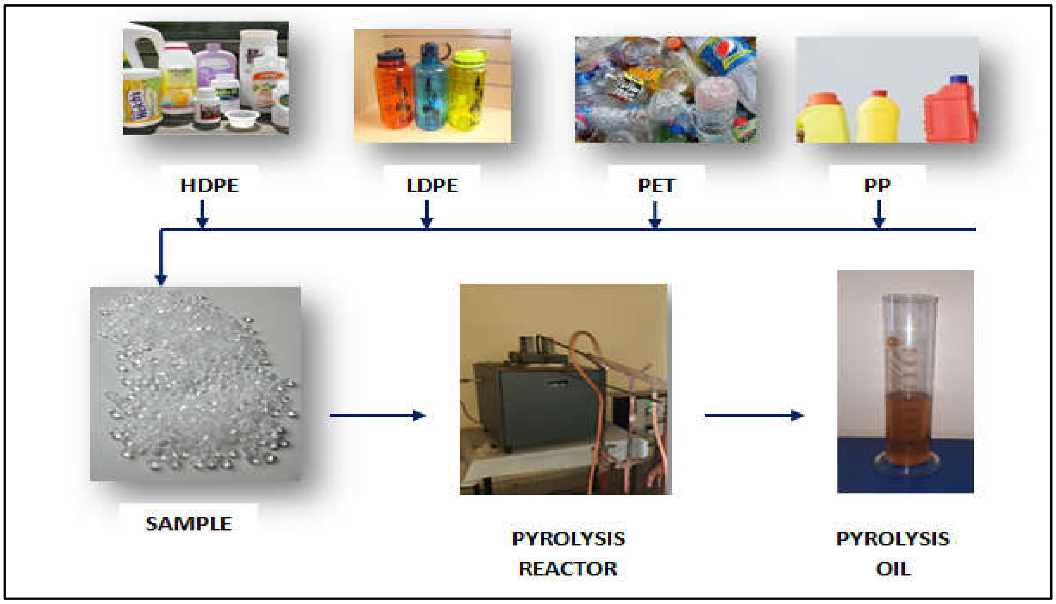


Figure 1 Schematic layout of pyrolysis process

B. METHODS

Preparation of fuel oil from waste plastics

The waste plastic oil was prepared by the thermo catalytic pyrolysis of shredded medical plastic wastes at an optimal temperature of 500ºC in a semi batch reactor using Zeolite-A as Catalyst. The GC–MS composition of pyrolytic oil is as summarized in Table 1 and the oil consists of C_{10}–C_{18} carbon chain containing aliphatic hydrocarbons and traces of alcohols. The physical properties of pyrolytic oil tested using standard IS methods is reported in Table 2. The density, fire point, flash point of WPO is found lower than diesel and calorific value of the test fuels are quite comparable with that of diesel. WPO-Diesel blends of 10, 20 and 30% were prepared by standard process and used in the test of diesel engine. These blends are denoted by10WPO, 20WPO and 30WPO, where the numerical indicates the percentage of WPO in the blend. The characterization of diesel and catalytic WPO derived from medical wastes are summarized in Table 2.

Table 1. GC–MS of the WPO derived from medical wastes at 500°C

Peak value	% Area	Name of the compounds	Chemical formula
1	1.3	(2E)-3,7-Dimethyl-2-Octene	$C_{10}H_{20}$
2	1.81	2,5,5-Trimethylheptane	$C_{10}H_{22}$
3	1.01	2-Isopropyl-5-Methyl-1-Hexanol	$C_{10}H_{22}O$
4	2.58	4-Methyl Decane	$C_{11}H_{24}$
5	9.23	2,3,7-Trimethyl-2-Octene	$C_{11}H_{22}$
6	1.68	7-Methyl-4-Undecene	$C_{12}H_{24}$
7	26.31	2,4-Dimethyl-2-Decene	$C_{12}H_{24}$
8	0.83	7-Methyl-1-Undecene	$C_{12}H_{24}$
9	8.74	(3E)-2,2-Dimethyl-3-Decene	$C_{12}H_{24}$
10	4.98	1-Dodecene	$C_{12}H_{24}$
11	1.69	2-Butyl, 1-Octanol	$C_{12}H_{26}O$
12	1.58	1,5-Diethyl-2,3-Dimethylcyclohexan	$C_{12}H_{24}$
13	1.79	2,3,5,7-tetramethyl-2-Octene	$C_{12}H_{24}$
14	2.04	2,6,7-Trimethyldecane	$C_{13}H_{28}$
15	17.08	1-Tridecanol	$C_{13}H_{28}O$
16	1.53	Octadecene	$C_{18}H_{36}$
17	0.97	3-Methyleneheptadecane	$C_{18}H_{36}$
18	0.94	1-Octadecene	$C_{18}H_{36}$

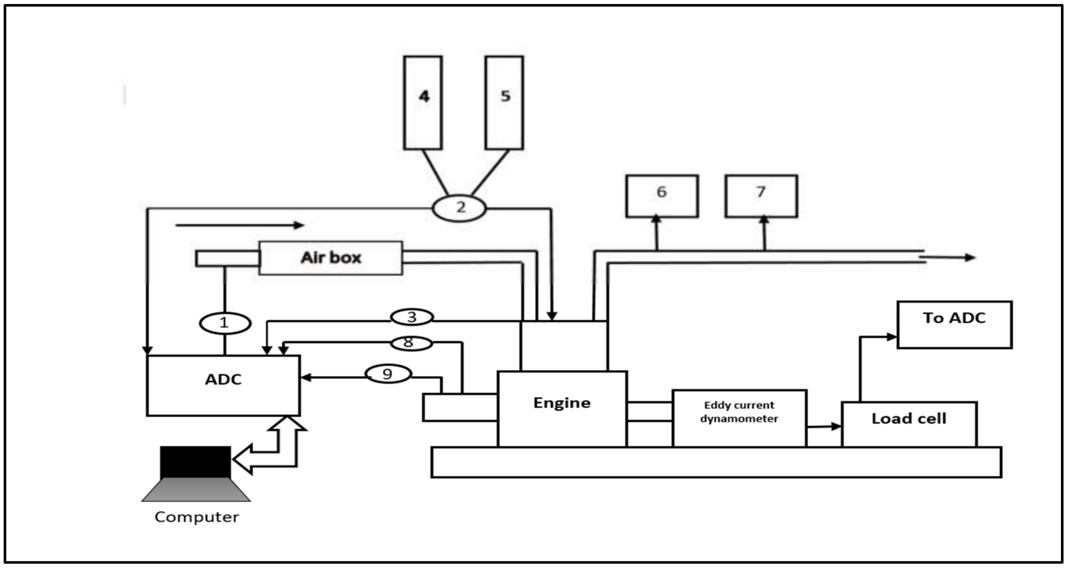
Table 2. Properties of different blends of WPO

Properties	ASTM standard	Diesel	WPO	WPO10	WPO20	WPO30
Density @15 °C , (g/m^3)	D 4052	835	793	830.8	826.6	822.4
Flash point (°C)	D 2500	52	5	47.3	51.06	37.9
Fire point (°C)	D 92	57	9	52.2	47.4	40.8
Calorific value (MJ/kg)	D 4809	45	46	45.1	45.2	45.3
Kinematic Viscosity (Cst) @30 °C	D 445	2.15	3.75	2.31	2.47	2.63

Test engine set up

The schematic diagram of the test set up is shown in Figure2.The test engine specifications are also given in Table 3. The engine was loaded by means of an electrical dynamometer. In order to measure the air flow rate, an air box was also fitted to the engine. The fuel flow rate measurement was conducted by means of a fuel meter. Chromel alumel thermocouple was fitted with a digital temperature device in order to measure the exhaust gas temperature. A pressure transducer was mounted on the cylinder head of the engine with a charge amplifier to measure and record the cylinder pressure. All the experiments were conducted at the rated engine speed of 1500 rpm with a data acquisition system interface.

Pure diesel was used as a pilot fuel to start the engine for all tests followed by different blend of waste plastic oil with diesel. The brake thermal efficiency and brake specific fuel consumption and were recorded for different load conditions as well as blends ratio of WPO. Finally, the engine was allowed to run with pure diesel to flush out the waste plastic oil from the fuel line and the injection system.



1-Air flow sensor, 2-fuel flow sensor, 3-Presure sensor , 4- Diesel tank, 5- Biodiesel tank , 6- Five gas analyser , 7- Smoke meter, 8- Speed sensor , 9-crank angle encoder

Figure 2 Schematic diagram of the experimental installation

III. RESULT AND DISCUSSION:

In order to study the performance and emission of the test fuels, a load test has been conducted with a 5.2kW DI diesel engine using diesel and WPO diesel blend and the results enumerated as follows.

3.1 Performance

3.1.1 Brake thermal efficiency (BTE)

Fig 2 shows the variation of brake thermal efficiency with variation of engine loads. It can be observed from the figure that a marginal improvement in break thermal efficiency is achieved while using WPO as the fuel as compared to diesel. The engine exhibits a thermal efficiency of 25.08 % at full load for diesel and for the WPO corresponding value for diesel, it is 25.91%.

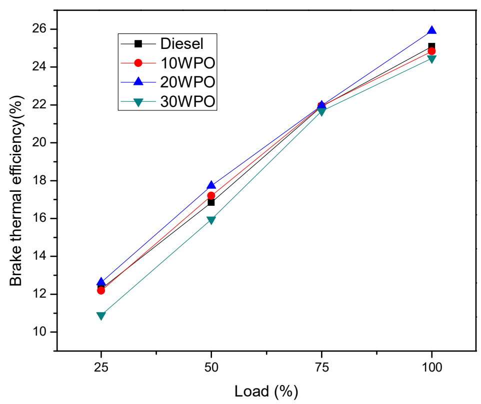


Figure2. Variation of BTE with loads

It can also be observed from the figure 2 that 20% WPO-Diesel blend shows the optimum performance among all other combinations and this improvement in efficiency is more significant at full load condition. However, when the % of WPO is increased beyond 20%, the efficiency is observed to be adversely affected. This may be attributed the fact that since the calorific value of WPO is higher than diesel the corresponding value for WPO-diesel blend is also higher than diesel. In addition, it may also be noted that addition of WPO in diesel blend in higher proportion leads to an increase in viscosity and decrease in density of the blended fuels and decrease in total heat release rate as compared to diesel which affects atomization and vaporization of fuel and subsequently lowering BTE (Mani et al, 2011). The low viscosity, calorific value and density of blend could influence the fuel spray formation resulting in lower BTE than diesel (Das et al.2020).

3.1.2 Brake Specific Fuel Consumption (BSFC)

Figure 3 depicts the brake specific fuel consumption (BSFC) of different WPO diesel blends with diesel with respect to load. It is quite obvious that BSFC decreases with increase in load for all fuels as expected. Furthermore, it can be seen that BSFC is found decreasing with an increase in the concentration of WPO in WPO-Diesel blend.

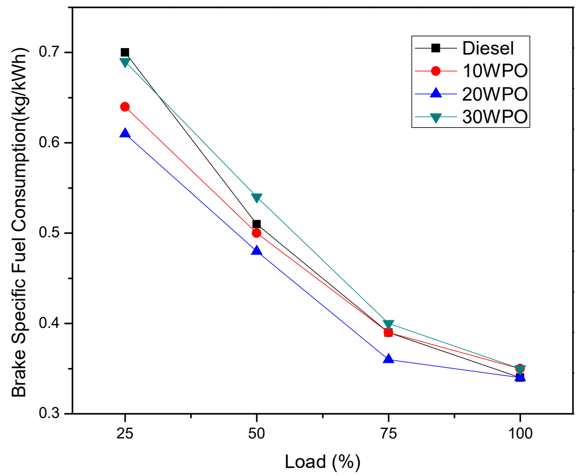


Figure 3. Variation of BSFC with loads

Higher calorific value of WPO than diesel attributes lower consumption of blended fuels as compared to pure diesel (Panda et al, 2016). It was also observed that the reduction in BSFC more distinct at lower load as compared to full load condition. The BSFC for 20% WPO as compared to diesel reduced by 4 % at 25% load condition and almost follow same trend at full load condition.

3.1.3 Brake Power (BP)

Fig 4 shows the variation of engine brake power of different WPO diesel blends in comparison with diesel. The brake power varies from 0.71 kW at low load to 2.33 kW at full load for diesel, and it varies from 0.64 to 2.31 kW for 10% WPO, 0.62 to 2.25 kW for 20% WPO and 0.63 to 2.28 kW for 30% WPO.

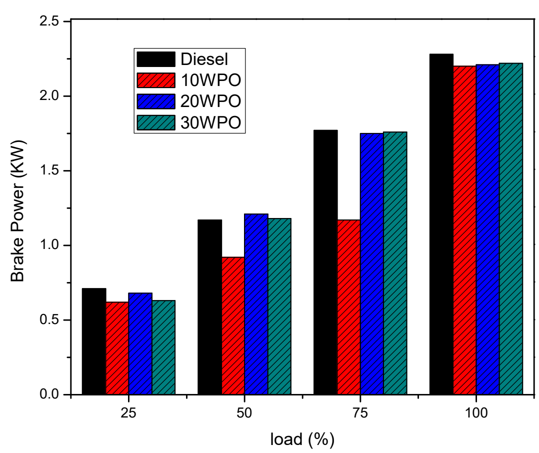


Figure 4. Variation of brake Power with load

In addition, the brake power of WPO is closer to diesel at 75% of full load and 20% blend. This may be due to better atomization of blend releasing higher heat energy as compared to diesel (Jerzy Walendziewski, 2005, Mani et al, 2009). The brake power also depends on the thermal efficiency of the engine and subjected to variation on different loads.

IV. CONCLUSION:

Based on the findings of the experiments, the performance characteristics of the WPO-diesel blend has been enumerated as follows:

- BTE was significantly improved by the inclusion of WPO in diesel. Experimental results addressed the suitability of WPO used as a replacement for diesel in a DI diesel engine and further established its superior performance up to 20% blend with diesel.
- BTE was found a little bit higher and BSFC was lowest for 20% WPO-diesel blend in comparison with diesel used as test fuel.

References

[1]Aghbashlo, M., Tabatabaei, M., Mohammadi, P., Mirzajanzadeh, M., Ardjmand, M., & Rashidi, A. (2016). “Effect of an emission-reducing soluble hybrid nanocatalyst in diesel/biodiesel blends on exergetic performance of a DI diesel engine.” Renewable Energy, 93, 353-368.

[2] Panda, A. K., & Singh, R. K. (2011). “Catalytic performances of kaoline and silica alumina in the thermal degradation of polypropylene.” Journal of Fuel Chemistry and Technology, 39(3), 198-202.

[3] Panda, A. K., Singh, R. K., & Mishra, D. K. (2010). “Thermolysis of waste plastics to liquid fuel: A suitable method for plastic waste management and manufacture of value added products—A world prospective.” Renewable and Sustainable Energy Reviews, 14(1), 233-248.

[4] Mani, M., Subash, C., & Nagarajan, G. (2009). “Performance, emission and combustion characteristics of a DI diesel engine using waste plastic oil”. Applied Thermal Engineering, 29(13), 2738-2744.

[5] Mani, M., Nagarajan, G., & Sampath, S. (2011). “Characterization and effect of using waste plastic oil and diesel fuel blends in compression ignition engine”. Energy, 36(1), 212-219.

[6] Kumar, S., Prakash, R., Murugan, S., & Singh, R. K. (2013). “Performance and emission analysis of blends of waste plastic oil obtained by catalytic pyrolysis of waste HDPE with diesel in a CI engine”. Energy conversion and management, 74, 323-331.

[7] Panda, A. K., Murugan, S., & Singh, R. K. (2016). “Performance and emission characteristics of diesel fuel produced from waste plastic oil obtained by catalytic pyrolysis of waste polypropylene”. Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, 38(4), 568-576.

[8] Rinaldini, C. A., Mattarelli, E., Savioli, T., Cantore, G., Garbero, M., & Bologna, A. (2016). “Performance, emission and combustion characteristics of a IDI engine running on waste plastic oil. Fuel,” 183, 292-303.

[9] Güngör, C., Serin, H., Özcanlı, M., Serin, S., & Aydın, K. (2015). “Engine performance and emission characteristics of plastic oil produced from waste polyethylene and its blends with diesel fuel”. International journal of green energy, 12(1), 98-105.

[10] Das, A.K., Hansdah, D., Panda, A.K. (2021b). “Thermal balancing and exergetic performance evaluation of a compression ignition engine fuelled with waste plastic pyrolytic oil and different fuel additives”. Energy, Vol. 229 pp. 120629.https://doi.org/10.1016/j.energy.2021.120629

[11] Kaimal, V. K., & Vijayabalan, P. (2016). "An investigation on the effects of using DEE additive in a DI diesel engine fuelled with waste plastic oil. Fuel", 180, 90-96.

[12] Sukjit, E., Liplap, P., Maithomklang, S., & Arjharn, W. (2017). "Experimental Investigation on a DI Diesel Engine Using Waste Plastic Oil Blended with Oxygenated Fuels" (No. 2017-24-0116). SAE Technical Paper.