Catalytic Degradation of Used Plastics oil as Liquid Fuel for IC Engines

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Abstract: Plastic pyrolysis oil (PPO) having the acceptable combustion lineaments and in addition, it can be used as alternative fuel for IC engines by blending together with diesel. In the research, used and disposed high-density polyethylene plastics such as plastic bottles, cans and bags have been used to extract the plastic oils from the self-developed pyrolysis reactor. Liquid oil from the plastic has been obtained by heating the waste used plastic in the reactor at 300–500 °C for ceaseless 2–3 hours in the fully locked environment. The obtained plastic hot gases as consequence, been cooled to acquire plastic pyrolysis oil in the liquid form. Further, the oil has been purified and blended along with the diesel in different propositions to conduct the trial experiments to observe the performances. The characteristics of the combustion experiments include emission and performance aspects. The attributes such as smoke density, NOx emission, CO emission, HC emission, CO₂ emission as well as exhaust gas temperature and oxygen allocation have tested. The blends of diverse ratios have related and the plastic oil bearing substantial improvements.

Keywords: Waste plastics; Pyrolysis; Combustion; Emission; Alternative Fuel.

1. Introduction

In today’s environment, plastics are playing a critical role in our day-to-day life and in industrial applications, as it has lightweight, long life, less cost, effortlessly available, quick manufacturing of desired shapes and sizes, etc. Even though, plastics are becoming an indispensable in the human life, on the other hand, it has non-degradable element, which cause lot of pollution to the environment. Due to high use of plastic in all the areas, enormous quantities of the plastics need to be recycled and disposed properly. Added up, plastics are non-degradable and became greater problem. Consequently, the aforementioned waste plastics leads to severe environmental threats, as it is more passive and have not reacted with water, air and soil. Dumping as well a bigger hindrance and it remains in the same state even after a lot of years. Unlike metals, plastics cannot be melted and reproduced to other useful components. Therefore, many researchers have been working in the field referring to recycling in conjunction with proper disposing without much adverse environmental effects.

Due to globalization and improved information technology in the supply chains, the industries are selling the products all over the world and the humans are used to move all over the world to enhance...
the business surplus. For all such activities, transportation became important platform and at the same time, the fuel usage for the transportation proportionally increases. Higher utilization of the fuel will provide treat in the direction of emissions and pollution. Also the availability of the fuel gets depleted. So a necessity arises for the substitute or alternate fuels. Also the cost of the fuel has significant part in deciding the transportation cost. The transportation cost is the non-value added cost, which does not add any value to the product or to the person travelling, but the transportation cost reduces the profit of the supply chain in a lot. So to enhance the profit, it became essential to cut the transportation cost to the minimum. By considering all the above mentioned issues, the myriad researchers have been trying to identify the suitable different alternate fuels as the substitute to the existing without polluting the territory.

In this research, to recycle the plastic to the useful form and to reduce the diesel scarcity in the future, the waste plastics are collected and pyrolysis oil has been extracted and blended with diesel. The obtained blended oil used as the fuel for the diesel engines. The performance characteristics also studied for the best blend ratio. The recycling or proper disposing of the waste used plastics has become a major challenge for the domestic and foreign industries. Also it is clear that the effectual approach with reference to plastics is the reprocessing or reusing of the waste plastics, as the disposing having lot of issues in it [1-6]. The plastic is feed into the reactor in various forms to make them gas [7-8]. So by proper conversion of the used waste plastics to the useful blend for the fuels reduces the petrochemical costs and also eliminates the pollution due to plastics [9, 10]. The outcome of the research will have paved the way for the proper degradability concerned with plastics and also the disposing of plastics will no longer be the environmental issue. Waste plastic oil as biodiesel in IC engines are characterized for performance and emission [11-12]. Apart from plastic oils, vegetables oils are also used [13]. The various forms of the plastics are the polystyrene [14, 15], poly vinyl chloride [15, 16], polypropylene [15–17], PE terephthalate [18], etc. Zeolite catalysts have been used for enhancing the combustion process [19]. Apart from the plastic oil, many oils have been extracted from different sources for blending with the diesel and petrol by the researchers. Among these, only very few oils only have the duel objectives of alternate fuel and recycling of polluting waste. This investigation has planned at collection of waste plastics, generation of pyrolysis oil, blending in different propositions, assessing the blended diesel for performance.

2. Experimental Methodologies

This experimentation had been carried out in different modules. The first module is the plastic collection module. In this module, the used plastic waste containers, bags, cans, bottles, etc i.e. used waste HDPE had collected.

![Figure 1. Plastic Pyrolysis Oil Reactor](image-url)
To avoid the chemical reactions and to eliminate the poisonous gases during heating, in this work, the plastics have collected from the domestic waste and avoided the industrial plastic waste. The collected plastics had been cleaned with detergent water and soap oil to remove the food containments, mud, oils layers, juice sediments, slug and other impurities. The washed plastics have been dried in the sunlight for a day and the dried plastic bottles were crushed. The crushed and dried plastics are ready for the recycling. The second stage is the pre pyrolysis stage, in which the plastics were chopped into smaller pieces. Because the self-developed furnaces are of smaller in size and to enhance the heating process, plastic were chopped into very smaller pieces. The furnace used for the experimentation is shown in the figure 1. The various components of the reactor are the pyrolysis chamber, in which the chopped plastics are feed and heated to generate the plastic oil. For heating, the electric heaters are used as the primary element and LPG gas, which can generate the heat at the desired level up to 500°C. The temperature monitors are the temperature sensors used to measure the temperature of the reactor chamber of 30 cm diameter and 60 cm height, because the controlled temperature only generate the higher quantity of the plastic oils. So the comparator is used to compare the actual temperature and the desire temperature, based on the difference, the comparator controls the voltage level supplied to the heaters. Heat indicators are the display unit to display the heat inside the chamber. The display unit can show the temperature of the eight sensors placed at the different locations inside the chamber. To avoid the heat loss, insulations were provided over the chamber. The insulator having two different layers, the first layer is the wool and the second layer is the refractory bricks to prevent the heat escape from the chamber.

Exit lines are used to collect the plastic gases from the chamber and these lines are kept at little higher temperature from the atmospheric temperature to prevent the sticking or settling down of the plastics inside the walls of the tube. These tubes are then passed through the condenser to convert the plastic gases into the liquid oil. The condenser uses the water for the cooling purposes. These oils have been collected in the holding tank for further investigations. As the size of the reactor is very small for the experimentation, the temperature differences between the eight sensors were very small and can be negligible. Thus it is assumed that the reactor produced uniform temperature inside the chamber. In the case of larger furnaces, to produce the uniformity in the temperature inside the furnace, nitrogen or the inert gases have to be pumped in. The non-condensed plastic gas has flared into the atmosphere using a small chimney. The slags of the process have to be removed from the chamber. In order to make ease with the removal process, the reactor walls are made of stainless steel. An experimental setup was assembled with the required instruments to assess the efficiency and emission parameters of the diesel engine under various operating conditions. The engine requirements are mentioned. It is used in tandem with the engine and can be used as such. The smoke metering meter was suitable and the AVL Di gas metering sensor was used. 210, 220, 230 and 240 bar injectors are used. The specification of the engine used for the research is given in the Table 1.

| Type                  | Single cylinder, vertical, water cooled, 4-stroke diesel VCR engine |
|-----------------------|---------------------------------------------------------------------|
| Diameter of Bore      | 80 mm                                                               |
| Length of Stroke      | 110 mm                                                              |
| Compression ratio     | 17.5:1                                                              |
| Orifice diameter      | 20 mm                                                               |
| Dynamometer arm length| 195 mm                                                              |
| Maximum power         | 3.7 kW                                                              |
| Speed                 | 1500 rpm                                                            |
| Loading device        | Eddy current dynamometer                                            |
| Mode of starting      | Manually cranking                                                   |
| Injection timing      | 23°C before TDC                                                     |
3. Results and Discussion

3.1 Pyrolysis Oil

The observed properties of extracted plastic pyrolysis oil blend along with those for diesel are given in Table 2. The major components in the extracted pyrolysis oil are as follows, Octane, tetramethyl, Heptane, Decane, dodecene, Undecane, tridecene, heptadecenal, Nonadecane, pentacosane, Octadecane, Cyclohexane, Cetene, methyloctacosane, Tetracosane, Eicosane, etc. From table it is seen that all the properties of blends are higher when compared with solid fuel. As the ratio of the blending increases, the desired properties also gets increased proportionally. This is because of high increase value in the possessions of WPO when compared to diesel.

| Property                          | Waste plastic oil with diesel | Diesel |
|----------------------------------|-------------------------------|--------|
|                                  | B2   | B5   | B7   | B10  |
| Density 15°C (kg/m³)             | 80   | 79   | 79   | 781  | 82   |
|                                  | 1    | 7    | 1    | 0    |
| Kinematic viscosity at 40 °C (cSt) | 1.6  | 1.6  | 1.5  | 1.53 | 2.5  |
| Flash Point (°C)                 | 7    | 29   | 21   | 20   | 34   |
| Fire point (°C)                  | 29   | 38   | 32   | 21   | 43   |
| Pour point (°C)                  | -8   | -9   | -8   | -9   | -    |
| Grass calorific value (MJ/kg)    | 44.3 | 44.5 | 44.0 | 44.3 | 42.3 |
| Cetane number                    | 52.1 | 51.8 | 52.1 | 52.1 | 50.8 |

3.2 Smoke Density

The variations of smoke density WPO blend B25, B 50, B75, B100 have also been exhibited. The variations are shown in the Figure 2. It is seen that the smoke densities for blend B25 at loads are 30, 40, 50 and 60 HSU respectively in the Figure 2. The smoke density for B25 at full load is 60 HSU at a load of 3.4 kgf the smoke density is low when compared to loads with other grades of waste plastic.
oil. Since the load increased, the resulting rise in the amount of smoke is due to lower fuel pressure. At higher pressures, reduced fuel consumption because of improved atomization. This also increases the rate of vaporization and diffusion of the blend within the cylinder and increases the rate of combustion.

3.3 Nitrous Oxide (NOX) Emissions

The variations of NOx emission of waste plastic blends B25, B50, B75, B100 are shown in the Figure 3. It is seen that NOx emissions for B100 is 300, 400, 700 and 800 ppm, respectively. Compared to other applied loads, the B100 blend with full load displays less NOx emission. Mix B25 The reaction of nitrogen at high temperatures (N2) increases oxidation of nitrogen (NOx).

![Figure 3. Variation of NOx with applied loads](image)

3.4 Carbon Monoxide (CO) Emission

The variations of CO emission of waste plastic oil of the grades B25, B50, B75, B100 with applied loads are exhibited and shown in Figure 4. It is seen that CO emission of B50 are 0.05%, 0.07%, 0.1% respectively at full load condition. Compared to other forms of waste plastic oil, B50 blends exhibit lower CO emissions. The high pressure of injection leads to a stronger combustion chamber fuel mixer that transforms CO to CO2.

![Figure 4. Variation of CO with applied loads](image)
3.5 Hydrocarbon (HC) Emission

The changes in HC emission with the loads used are shown in Figure 5, for B25, B50, B75, B100. HC emissions from the B25 blend were found respectively to be 20, 30, 40 and 60 ppm. Compared to all other blends and loads used, the B25 blend with maximum charge condition shows a lower HC emission. The explanation for reduced emissions of HC shows that B25 blends are completely combustible. This is because the cylinders are better atomised due to high pressure from the B25 mixture injector.

![Figure 5. Variation of HC with applied load](image)

3.6 Carbon dioxide (CO₂) Emission

The variations of CO₂ emission with applied loads for B25, B50, B75, B100 are shown in Figure 6. It was seen that CO₂ emission of B25 blend are 1, 2, 2.3 and 4 ppm, are by % of volume respectively. The blend B25 with full load condition shows lower CO₂ emission when compared to all other blends and applied loads. The reason for decreased CO₂ emission shows the complete combustion of B25 blends.

![Figure 6. Variation of CO₂ emission with applied load](image)
3.7 Exhaust Gas Temperature

The variations of Exhaust gas temperature of blends B25, B 50, B75, B100 with applied loads are shown in Figure 7.

![Figure 7. Variation of Exhaust gas temperature with applied load.](image)

It was seen that exhaust gas temperature of B25, B50, B75, B100 blend are constant at full load conditions. In B25 blend, at initial load the temperature is low when compared to other blends of waste plastic oil.

3.8 Distribution of Oxygen

The variations of distribution of oxygen to engine of the blends B25, B 50, B75, B100 with applied loads are shown in Figure 8. It was seen that distribution of oxygen at B25, B50, B75, blend is constant at full load conditions. In B100 blend, the oxygen supply is low while compared to other blends [20].

![Figure 8. Variation of oxygen with applied load.](image)

4. Conclusion

In this research, the plastic pyrolysis oil have been extracted successfully from the domestic waste plastics and the extracted oil blended with diesel in different propositions. The mixed plastic thermal pyrolysis oil act as the alternate fuel and contributes a lot in the development of alternate fuels. The problem of recycling waste plastic is also carried out in the single process. The waste plastic oil blend act as the catalyst in the combustion process, as it is having better thermal properties. At higher temperature, the production of plastic gas will be higher and can be commercially used for the automobiles. The average oil yielded was about 57.03%, as the reactor size is small. For the blend
B25, the smoke emission is very less compared to the other blends. NOx emission is less for the blend of B75. The blend B75 having better CO emission up to certain load conditions and thereafter increases. Hydrocarbon and carbon dioxide emissions for the B25 blend are recorded less. Exhaust gas temperature and the oxygen of all the blend are almost in same category for the higher loads. Thus the B75 blend plays a good role for the higher load conditions.

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