Analysis of Fuel from LDPE Plastic

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Abstract. Plastics are perhaps the most important invention of mankind. Finding a solution to sustainably balance the usage to its environmental threat is now more important than ever. One possible solution, to make value added fuels by pyrolysis of waste plastics are discussed. Manufacturing of such fuels on a commercial scale can reduce the burgeoning plastic waste and meeting the ever-increasing fuel demand. A simple prototype to depict the pyrolysis and condensation process was constructed, and fuels samples from waste polythene bags and LDPE pellets obtained. Common physical and chemical parameters of the fuels were analysed with standard diesel as reference. The fuel obtained had some properties similar to that of diesel, and could easily be used as blends with diesel, without affecting its application.

1. Introduction
In this coming age, the biggest foreseeable revolution which is sure to come is in the field of energy. The entire world is working toward it’s switch to alternate sources of energy for its daily working and functioning. It is imperative that we not only move on from our existing non-renewable sources of energy, but also deal with the mess this entire industry has created. Consequences of rampant plastic waste mismanagement are baneful for all forms of ecology. However, waste plastics are an untapped potential source of energy, which can be effectively utilized as an efficacious source of energy in form of fuel. One feasible solution that can be taken seriously is to make value added fuels by a thermal decomposition process called pyrolysis. Manufacturing of such fuels can help tackle the problem Plastic Solidwaste Management and reduce the plastics poisoning our environment. There are limitations to common solutions like plastic recycling. Recycling is heavily dependent on sorting and segregation which is economically not as fruitful as metal recycling. Pyrolysis is a chemical reaction which involves thermal energy breaking down larger hydrocarbons into smaller smaller hydrocarbon in anaerobic condition. In Pyrolysis, the object molecules are subjected to very high temperatures, due to which every molecule of material is broken down into a smaller molecule. Pyrolysis takes place only in the absence of oxygen. The goal of plastic pyrolysis is to break long carbon chains into smaller carbon chains. Pyrolysis is also known as thermal cracking, cracking thermolysis, depolymerisation, etc. Pyrolysis of plastic at above 400 °C results in compounds with smaller hydrocarbon chains, which resembles fuel. It also produces a colourless gas, and leaves behind a black charry residue. Allowing the products to settle, it leaves behind an oil with thick consistency. The properties of liquid product are referred to as pyro oil. It can be treated to make common fuels like petrol and diesel. Different types of plastics can be used for pyrolysis. These include common types like LDPE, HDPE, PE, PET, PS, PP, and PVC. The yield of usable pyro oil depends on the type of plastic used. LDPE and HDPE produce a higher yield of required pyro oil. [1]
2. Literature Review
Vijaykumar, B. Chanashetty et al. [1], explained the pyrolysis process with details on their apparatus, its breakdown effect on the molecular chains of LDPE molecules, explaining each and every major step involved in the pyrolysis process in detail. It also studied the effects of catalytic pyrolysis and discussed the advantages of the process.
Stella Bezergianni and Dimitrios Karonis [2], focused on the distillation of the obtained fuel. They obtained a fraction of the pyro oil, and performed catalytic hydrogenation on the same to improve its characteristics and make it very similar to standard grade diesel.
Onwudili JA, Insura N, Williams PT. [3], performed pyrolysis on Polystyrene and LDPE. It discussed the optimum temperature for pyrolysis to attain maximum yield for both the inputs. It stated that pyrolysis of LDPE above 425°C would decrease the yield. It showed aliphatic compounds were the dominant composition, but with increased temperature and residence time, the proportion of aromatic compounds in the oil increased. It also studied the effect of having a mix of LDPE and PS as input, which reduced its degradation temperature, resulting in more oil yield and lesser char.
Kumar S, Singh RK. [4], it discussed the process parameters with yield of fuel obtained. Different holding duration at different temperatures were studied and analysed and its effect on percentage yield and composition of the products obtained.
Distillation [5], basic Test in Quality Control of Automotive Fuels by Ma Mercedes del Coro Fernandez Et Al., performed fractional distillation on standard fuels petrol and diesel and studied its % v/v recovery characteristics. It has used the ISO3405 standard as the basis of the test procedure.

3. Methodology
A sample of plastic was weighed accurately and added in to the reactor inlet. The inlet is at the side of the reactor. It had a screw cap, which was made air tight by winding Teflon tape around the screw threads. The material of the reactor was considered during the design so as to not react with the fumes produced during the process. Mild Steel had the right mix of properties. It was suitable for resisting temperatures of above 500°C, and was also easy to source and procure, apart from being cost effective. It was also relatively inert to the contents of plastic inside. An LPG Stove was used as a heating source. A connecting pipe, which was a bull bar of a bumper, was used to connect the reactor to the condenser pipe. The condenser pipe was a soft copper pipe of 1 inch diameter. Soft copper has the excellent thermal conduction properties, and was also easy to wind and handle. All the connections between MS to MS were sealed by TiG welding for better quality of weld and also to ensure better air sealing. The Mild Steel Pipe to copper pipe connection was sealed with the helping of brazing. The apparatus was assembled as shown in Figure 1 below. The entire apparatus was then checked for leakages.
After feeding the plastic through the inlet, it was heated in the reactor. The temperature of the reactor was closely monitored at timely intervals. White fumes start to appear at around 300°C. After the fumes stop, condensed fuel drops start dropping from the condenser pipe. The process continues till all the plastic has undergone pyrolysis. The condenser pipes were cooled by wrapping damp jute bags around them. The fuel was collected hence.
Table 1. The fuel obtained from samples

| Type of plastic | Weight | Temperature of Initial yield | Maximum yield | Duration of run | Yield volume |
|-----------------|--------|------------------------------|---------------|----------------|-------------|
| LDPE Pellets    | 1.8kg  | 330-340°C                    | 420-470°C     | 100 min        | 1.5 L       |
| Polythene Bags  | 800g   | 330-340°C                    | 420-470°C     | 48 min         | 400mL       |

Table 1 shows the yield obtained from pyrolysis of the samples. LDPE pellets recorded a higher yield than waste polythene bags. The fuel was sent to a chemical laboratory for detailed examination.

4. Results and Analysis

Pour Point: A sample is held in a tilted container. The lowest temperature at which this sample begins to pour is known as the pour point of that sample. Pour point is an important parameter when considering properties of fuels. A lower pour point can be a crucial factor in considering transportation through pipelines. [6]

Table 2. Pour Point of samples

| Parameter | Test Method | LDPE Pellet | Polythene bags | Standard Diesel | Petrol |
|-----------|-------------|-------------|----------------|-----------------|-------|
| Pour Point| ASTM D97 - 17a | <42°C | <42°C | 3°C to 15°C | -40 to -60°C |

Table 2 shows the pour point of the samples and the test apparatus to calculate the pour point had a lower limit of -42°C. The recorded pour points of the samples are similar to that of petrol, which freezes at around -40 to -60°C shown in figure 1. [6]
Flash Point: The minimum temperature at which a vapour air mixture in a closed space can catch fire, at standard atmospheric conditions is known as flash point. [7] Flash point is an important characteristic of a fuel when considering it from a safety point of view with regards to its flammability. It is an indication of the hazards while producing, storing and transporting.

| Table 3. Flash Point of samples |
|-------------------------------|
| Parameter | Test Method | LDPE Pellet | Polythene bags | Standard Diesel | Petrol |
| Flash Point | IP-170-2013 | -5°C | -5°C | 52-96°C | -43°C |

Distillation percent (v/v): Distillation is a process in which a mixture is separated based on their differing boiling points. It is widely used in the petroleum industry. Diesel fuels are a blend of several hydrocarbons, depending upon the source, method of distillation. Diesel fuels are comprised of hydrocarbons in the range of C12-C20, with boiling points in the range of 160°C - 380°C and petrol fuels are comprised of hydrocarbons in the range of C4-C12, with boiling points in the range of 30°C-150°C. [8] Distillation recovery (%v/v) conveys crucial information about the composition, properties and behaviour of fuels. The distillation test measures the percentage volume of fuel recovered as the temperature increases. Figure 4 shows the percent volume recovered for LDPE Pellets. Similarly, Figure 4(a) shows the percent volume recovered for Polythene bags.

![Figure 3: Flash points of samples](image1)

![Figure 4: Recovery characteristics of LDPE pellet](image2)

![Figure 4 (a): Recovery Characteristics of polythene bags](image3)
From analysis of the above graphs it can be firmly stated that the fuel samples i.e. from LDPE pellets and waste polythene bags, exhibit similar recovery characteristics, with FBP and IBP values being almost the same. Therefore, both the samples have almost identical composition. Figure 5 shows the percent volume recovered of standard petrol. Figure 6 shows the percent volume recovered of standard diesel.

From the above graph of petrol recovery, we can infer that petrol is recovered (95% V/V) at about 150°C, similarly we can infer that diesel starts recovery (5% V/V) at 150°C.[5]

From the graph, it can be observed that from IBP to 150°C, the fuel recovery characteristics of samples, as seen in Figure 3 and Figure 4 are similar to petrol. From 150°C to FBP, the fuel recovered follows a similar curve to that of diesel recovery characteristics. By comparing the standard fuel recovery characteristics to that of the sample fuel’s recovery characteristics, it can be said that the sample fuels constitute around 40% fuel which resembles petrol. The remaining 60% fuel resembles properties similar to that of diesel.

Viscosity: Viscosity measures a fluid’s resistance to flow. Kinematic viscosity is the ratio of absolute viscosity of the substance divided to its density. Kinematic viscosity quantifies the resistance of a fluid under the weight of gravity, i.e. the tendency of fluid to flow when no external force is applied. [7]

| Parameter | Test Method | LDPE Pellet | Polythene bags | Standard Diesel | Petrol |
|-----------|-------------|-------------|----------------|-----------------|-------|
| Kinematic | ASTM D-445 17a | 0.802 cSt | 0.802 cSt | 2 cSt to 5 cSt | 0.4 cSt to 0.7 cSt |
| Kinematic Viscosity at 40 °C |

Kinematic viscosities of samples are shown in Table 4. The kinematic viscosity value of samples obtained was less than diesel, but comparable to petrol as shown in Figure 7. Hence the flowability of the samples of fuel is better than diesel. This has benefits in designing fuel injectors and making it convenient for use at lower temperatures. [9]
Figure 7: Flash points of samples.

**Total Sulphur Content:** It is an important criterion when it comes to determining quality of fuels. It is a significant pollutant. Sulphur in fuels burnt release SOx which degrades air quality. Disposed fuels in any wastewater are also another source of harmful pollutants. [11]

| Parameter   | Test Method | LDPE Pellet | Polythene bags | Standard Diesel |
|-------------|-------------|-------------|----------------|-----------------|
| Total Sulphur | ASTM D-445 17a | <17 ppm | <17 ppm | <10 ppm |

Table 5 shows the sulphur content of the samples tested. The given test apparatus had a lower limit of 17 ppm. LDPE and polythene do not have sulphur as its constituent and since pyrolysis of the same takes place in an inert atmosphere, it can be said that fuels obtained have negligible sulphur content. Hence possibility of SOx pollutants from these samples is negligible. It can be said that it will pass the current Bharat Stage – VI standards for diesel.

**Density:** Ratio of mass of fuel to a standard volume at 15 °C.

Table 6: Density of samples.

| Parameter | Test Method | LDPE Pellet | Polythene bags | Standard Diesel | Petrol |
|-----------|-------------|-------------|----------------|-----------------|-------|
| Density at 15°C | ASTM D-4052-16 | 0.751 g/ml | 0.758 g/ml | 0.82-0.86 g/ml | 0.71 - 0.77 g/ml |

Table 6 shows the densities of the samples, compared with densities of standard petrol and diesel. Value of density of fuels are comparable to that of petrol and marginally less than diesel as shown in Figure 8.

Figure 8: Density of samples
5. Conclusion
Plastic is an invention that is omnipresent. It is an invaluable resource and it needs to be accepted that it is an essential resource. Banning it only solves some of the problems plastics create. It cannot deal with the mountains of waste plastic already generated. It should not be treated completely as a bane, as it has changed human civilization. What is required is efficient management of this invaluable resource. Hence, a solid and robust plastic waste management system is the need of the hour. Pyrolysis of plastic is a solution that answers these problems effectively. Using fuel obtained from such process increases the efficiency as the Carbon atom gets used twice, once as a plastic and again as a fuel. The presence of only traces of sulphur in this fuel also makes it a great environmental positive. LDPE Pellets and waste plastic bags were used as inputs in the pyrolysis process. Kinematic viscosity of the fuel had a value similar to that of petrol. Other parameters like pour point and flash point values were also similar to that of petrol, meaning that the petrol component of the fuel dictate some parameters of the fuel as a whole. Distillation recovery chart of the fuel shows that the fuel follows the recovery characteristics similar to that of petrol from Initial Boiling Point to temperature of 150°C, which accounts for 40% of the total sample fuel by volume. After 150°C, the recovery characteristics of the remaining fuel follow recovery characteristics similar to that of diesel, up to a Final Boiling Point which makes it suitable for it to be used in low compression diesel engines like tractors and generators.

6. References
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