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Analysis of Flue Gas from Plastic Waste

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ABSTRACT: Plastic materials are ubiquitous in modern society because they can be used for various purposes. Plastic items are plentiful, inexpensive to produce, sturdy yet low weight, and easy to store and transport. However, the same properties that make them commercially successful also contribute to their proliferation in the environment. Plastic wastes can be efficiently utilized for the generation of both liquid and gaseous fuels. The process involves heating of plastic wastes in an air tight container (pyrolysis) and water vapour if any is removed from the mixture of vapours obtained. On further cooling plastic crude oil is obtained from the vapour mixture. The remaining vapour can be directly used in an internal combustion engine. The project involves the fabrication of a gas generator, condensing system, gas separator and run a stationary internal combustion engine using the gaseous fuel obtained. Exhaust gas analysis is also carried out. The plastic crude oil produced can be used as an additional heat source in the gas generator. It can also be refined to obtain different petroleum products such as petrol and diesel oil. This system can be used for power generation; the gas can also be used for cooking purposes

KEYWORDS: Plastic, Pyrolysis, Waste

I. INTRODUCTION

Pyrolysis of waste plastic is an economical method to solve waste plastic problem and to produce quality gaseous and liquid fuels which can have similar properties to the commonly used petroleum fuels. Significant amount of energy can be produced with this technology. This could be an alternative energy resource for substituting fossil fuels. The technology helps to save land resources by utilizing waste plastics to generate valuable energy. Currently, a majority of the waste plastic is land filled and it is not sustainable because waste plastic takes very long time to decay.

The fuels produced from this process do not contain sulphur content because there is no sulphur in the waste plastic feedstock. This is an advantage compared with the fossil fuels such as diesel because sulphur content in the fuels could form SO₂ after combustion. SO₂ is a pollutant causing severe air pollutions, which affects people health and damages the concrete structure. Therefore, this technology is environmental friendly.

Dr. P.V. Thorata, et.al conducted a test on Thermofuel-“Pyrolysis of waste plastic to produce Liquid Hydrocarbons” Suitable Plastic Material for Treatment Approximately 950ml of oil can be recovered from 1kg of plastics such as Polyolefin's including Polyethylene (PE) and polypropylene (PP), or polystyrene (PS). Although not suitable, the process can nevertheless tolerate small quantities of plastics containing heteroatom's. Heteroatom's are atoms other than carbon and hydrogen such as chlorine, sulphur and nitrogen.

GAURAV, et.al conducted test on Conversion of LDPE plastic waste into liquid fuel by thermal degradation Thermal Pyrolysis of Polyolefin The non-catalytic or thermal Pyrolysis of polyolefin is a high energy, endothermic process requiring temperatures of at least 350–500 °C. In some studies, high temperature as 700–900 °C is essential in achieving decent product yields.

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II. EXPERIMENTATION

A. PLASTIC PYROLYSIS

Pyrolysis is a thermal cracking reaction of the large molecular weight polymer carbon chains under an oxygen free environment and produces small molecular weight molecules. Traditional treatments for post-consumed plastics were landfills or incineration. However, landfill of the post-consumed plastics has potential problems because of limited land resource and high durability of plastics. Incomplete incineration may generate poisonous substances and causes serious health problems. HDPE, LDPE, PP and PS are all hydrocarbons consisting entirely of carbon and hydrogen, which are similar to hydrocarbon fuels such as liquefied petroleum gas (LPG), petrol and diesel. Plastics are derived from petroleum and have calorific values in a similar range as those of LPG, petrol and diesel as given in Table 1. The pyrolysis reaction consists of three progressive steps: initiation, propagation, and termination. Initiation reaction cracks the large polymer molecules into free radicals. The free radicals and the molecular species can be further cracked into smaller radicals and molecules during the propagation reactions. At last, the radicals will combine together into stable molecules, which are termination reactions

Material	Calorific value (MJ/kg)
Polyethylene	46.3
Polypropylene	46.4
Polystyrene	41.4
Polyvinyl chloride	18.0
Coal	24.3
Liquefied petroleum gas	46.1
Petrol	44.0
Kerosene	43.4
Diesel	43.0
Light fuel oil	41.9
Heavy fuel oil	41.1

Table 1 Comparison of energy density of plastics and different types of fuels

III. APPARATUS

The plastic to fuel conversion system consist of two heating chambers each of 25 litre capacity to carry out the pyrolysis of plastic waste and a condenser unit to covert the vapours from the heating chambers into liquid form. The condenser also facilitates the separation of non-condensable gases produced during the operation. The non-condensable gases (mixture of mainly Propane, Propene, and Methane etc.) are then directly supplied to the SI engine. A distillation unit is provided to separate out different hydrocarbon fuels from the plastic crude oil or the pyrolysis oil. The basic layout of the system is shown in figure 1

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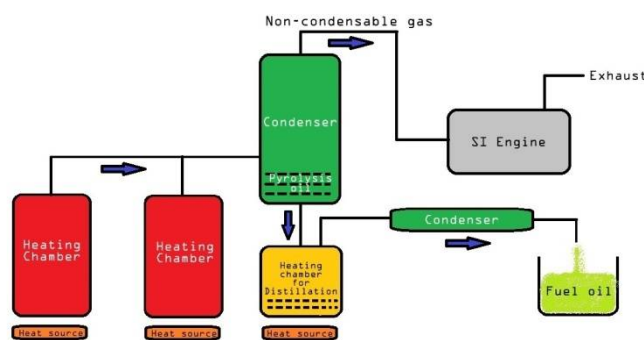


Fig 1. Plastic pyrolysis apparatus

IV. EXPERIMENTAL PROCEDURE

V. THE IMPORTANT OBSERVATIONS MADE DURING THE OPERATION OF THE FABRICATED SYSTEM FOR CONVERSION OF WASTE PLASTICS INTO FUEL ARE SHOWN IN TABLE 2

Number of heating chambers operated at a time	1
Type of plastics used	Polypropylene (PP) and HDPE
Mass of plastics used at a time	1.5 Kg
Temperature at bottom region of reaction chamber during operating range	450 0C to 560 0C
Temperature of vapours coming out from the heating chamber for which steady operation of engine is achieved	80 0C to 135 0C
Temperature of vapours coming out from the heating chamber for which the rate of production of liquid fraction becomes significant	Above 130 0C
Temperature of non-condensable gases at the condenser outlet	35 0C to 43 0C
Mass of liquid fraction obtained (total mass of pyrolysis oil)	1.19 Kg (79.33 % by weight)
Mass of residue left in the chamber after the completion of process	150 grams (10% by weight)
Mass of non-condensable gases generated (Based on mathematical calculation. This value is not measured)	160 grams (10.66 % by weight)

Table 2 Experimental data

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V. RESULTS AND DISCUSSIONS

Then following tests are conducted in order to understand the usability of the different fuels obtained by the pyrolysis of waste plastics

1. Pollution test of the SI engine
2. Flash and fire point of different liquid fuels
3. Density of different fuels

Pollution test of SI engine

Pollution testing of the SI engine when run using the gases generated by the pyrolysis of plastic waste (Mix of PP and PE) was performed in an automobile pollution testing centre. The observations made during the test are tabulated in table 3

Gas	Prescribed standard	Measured value
CO (%)	3.5	2.9
CO ₂ (%)	-	0.040
O ₂ (%)	-	21.35
HC (ppm)	4500	2499

Table 3 Result of pollution test

Flash and fire point and Density of different liquid fractions

Fuel type	Flash point (°C)	Fire point (°C)	Density (g/cc)
Lighter fraction	28	28	0.7185
Heavier fraction	45	76	0.8077

Table 4 Result of flash & fire point test

VI. CONCLUSION

Parameter	Lighter fraction	Heavier Fraction
Colour	Light bluish	Reddish orange
Density (g/cc)	0.7185	0.8077
Flash point (°C)	28	45
Fire point (°C)	28	76
Viscosity (cm ² /sec)	-	3.673

Table 5 Tabulated results

For regular gasoline, density varies from 0.735 to 0.755 g/cc and 0.755 g/cc density for premium gasoline. For diesel density is 0.85. The above reading gives the conclusion that both lighter and heavier fractions density lie in their respective ranges. For diesel, flash point is 38°C but the flash point of the heavier fraction obtained is 45°C which is a much higher value. However the flash point of gasoline range products have very low flash point which can't be matched with the lighter fraction. Kinematic viscosity of the diesel is 2.4 cm²/sec. The viscosity is heavier fraction is much higher than diesel which shows that further distillation and purification is required. The project shows some light on the possibility of manufacturing liquid and gaseous fuels from waste plastics.

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