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USE OF GASEOUS HYDROCARBONS OBTAINED BY DEGRADATION OF WASTE PLASTIC AS A GASEOUS FUEL

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ABSTRACT

HDPE and LDPE waste plastics have been degraded using fly ash as a catalyst. Degradation has been done using cat/pol ratios 0.1, 0.15 and 0.2. The rate of evolution of gaseous products was measured using AVL di-gas analyzer. The yield of the gaseous product has been calculated in all cases. The flame temperature of the flame obtained by burning the gaseous product has been determined in all cases. The rate of evolution of gaseous products, the yield of gaseous products and the flame temperature increase with increases in cat/pol ratio. A maximum flame temperature of 805 °C has been obtained for the gaseous product obtained by the degradation of LDPE waste plastic using cat/pol ratio of 0.2

KEYWORDS: HDPE, LDPE, Degradation, Fly Ash, Gaseous Product, Flame Temperature

INTRODUCTION

Gaseous fuels like LPG are used for cooking. Compressed natural gas (CNG) is used as fuel in automobiles. Since gaseous fuel undergoes combustion more efficiently than liquid fuels they cause less pollution in the atmosphere.

Use of plastic is increasing day by day. This generates a lot of plastic waste. The disposable waste plastic is a big problem. In order to meet the demand for fuels and dispose of the waste plastic, waste plastics have been converted into hydrocarbons which can be used as fuels [1-32].

Degradation of waste plastic gives solid, liquid and gaseous products. Usually, the solid product is quite small. This consists of unconverted plastics, sold hydrocarbons and carbonaceous matter.

The liquid product known as waste plastic oil can be used as a substitute for petrol or diesel. This paper reports the use of gaseous products obtained by degradation of waste plastic as a fuel.

MATERIALS AND METHODS

Plastics

HDPE and LDPE waste plastics used in this study are shown in Figure 1 These ware cut with the help of cutting machine.

Catalyst

Fly ash from the thermal plant at near places is used. Fly ash contains Si (Silicon), Al (Aluminium) and O (Oxygen). Thus, it contains silica (SiO_2) and alumina (Al_2O_3). Since silica and alumina have been widely used as catalysts for the degradation of waste plastics fly ash can be used as a catalyst for this propose.

Figure 1: Waste HDPE and LDPE plastics

DEGRADATION OF WASTE PLASTIC

Description of the Cutter

The waste plastics were cut into small pieces using a cutter shown in Figure 2. The cutter consists of a cutting chamber with an inlet at the top. A blade is placed inside the chamber. This blade shaft is connected to a three-phase electrical motor by means of a 'V' belt. The motor can run at a speed of 1700 rpm. After cutting the pieces of plastics can be collected at the bottom.

Figure 2: Cutter

Procedure for Cutting

The motor was switched ON. When the motor reached the full speed of 1700 rpm the waste plastic was loaded into the cutter. After the cutting process was over the plastic pieces were collected at the bottom of the cutter. After cutting, the size of the plastic pieces was approximately 5 mm^2. The HDPE and LDPE waste plastics before and after cutting are shown in Figure 3

(a) LDPE Waste Plastic before Cutting   **(b) LDPE Waste Plastic after Cutting**

(C) HDPE Waste Plastic before Cutting   **(D) HDPE Waste Plastic after Cutting**

Figure 3: HDPE and LDPE Before and After Cutting

Procedure for Mixing the Waste Plastic and Catalyst

Figure 4 shows the mixing of cut plastic and catalyst. The plastic was washed with water to remove dust and dirt particles. Then it was dried in the sunshine. A weighed quantity of the dried waste plastic and the lignite fly ash (which acts as the catalyst) were premixed in a tray. A small quantity of water was sprayed on the mixture of plastic and catalyst. This was done to prevent the flying of fly ash to the atmosphere and to give a binding between the fly ash and the plastic. After thorough mixing of the mixture, the mixture was dried in air to remove the moisture.

Figure 4: Photographic View of Mixing the Catalyst

DEGRADATION OF WASTE PLASTIC

Description of the Degradation Plant

The sketch of the plant used for catalytic conversion is shown in Figure 5. The reactor is a cylindrical vessel made up of stainless steel with a diameter of 1300 mm. The reactor is surrounded by three electrical coils. The power of each coil is 1.5 kW. These electrical coils are used for heating the reactor. The reactor is surrounded by a thin cylindrical sheet. Glass wool is placed in between the reactor vessel and the thin sheet. The glass wool acts as an insulator.

The top of the reactor is provided with a stirrer, a safety valve, a pressure gauge, an inlet with an air tight stop cock for feeding the waste plastic and an outlet which is connected to water cooled condenser. The safety valve withstands the pressure up to 500 kg/m^2. The stirrer runs by means of an electrical motor. The purpose of the stirrer was to mix the catalyst and waste plastic thoroughly and also to provide uniform temperature. A hand hole is provided with an airtight stopcock at the bottom of the reactor to remove the materials after cracking. A thermocouple is placed at the bottom of the reactor to measure the temperature inside the reactor. The control panel consists of a temperature indicator and a temperature controller with switches. The temperature indicator shows the temperature inside the reactor. The controller is used to control the temperature inside the reactor.
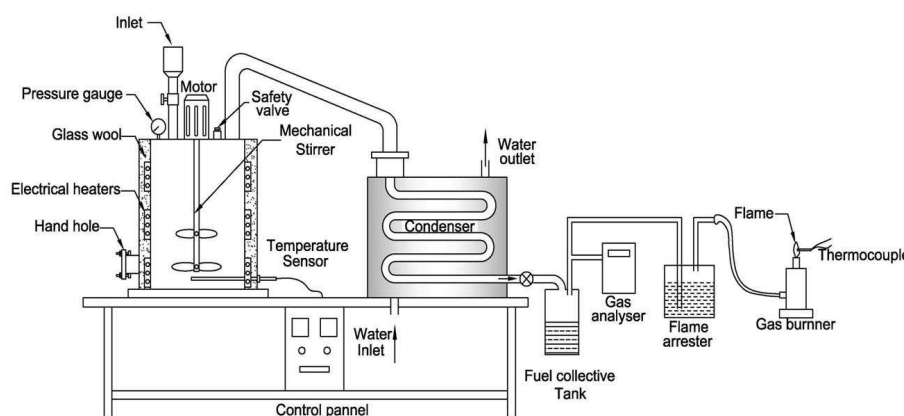

Figure 5: Schematic Diagram of Degradation Plant

The condenser consists of a cooling coil and a water jacket. The condenser is made up of stainless steel coil of length 1800 mm with a diameter of 20 mm. This coil is kept inside the water jacket with a diameter of 300 mm and a height of 500 mm. The water jacket is provided with an inlet at the bottom and an outlet at the top. Water is circulated in the jacket using the inlet and outlet. The condensed oil is collected in a tank made up of stainless steel.

The condensed oil is collected in a tank made up of stainless steel. The uncondensed gas is passed through an AVL di-gas analyzer to the flame arrester to prevent the backfire. The gas analyzer is used to measure the rate of evolution of uncondensed hydrocarbons. The flame arrester consists of a glass vessel containing water. The gases pass into the water in the flame arrester which is connected to a burner.

Procedure for Degradation

The electrical heater and stirrer motor were switched ON. The time was monitored using a stopwatch. The vapor formed due to the cracking of the plastic was passed through the water cooled condenser. The condensable vapor condensed into a liquid which was collected in the collecting tank. Due to heating the temperature of the reactor gradually increased. The temperature and time at which the oil formation commenced were recorded.

As the temperature of the reactor was gradually increased the cracking process in the reactor got accelerated. Due to this more oil was obtained from the reactor. The temperature at which the oil formation ceased was noted. The corresponding time also was noted. The uncondensed gas was passed through an AVL di-gas analyzer to measure the amount of hydrocarbon present in the gas. This measurement was made at regular time intervals. The uncondensed hydrocarbons were burnt using the burner.

RESULTS AND DISCUSSIONS

Designation of Gaseous Products

The gaseous products for the various cases are designated as HAG, HBG, HCG, LAG, LBG and LCG. Thus HAG is the gaseous product from HDPE when the degradation was carried out with cat/pol = 0.10.

In order to find the use of a gas as a fuel, it is necessary to see whether it gives a blue flame on burning. Also, the flame temperature should be reasonably high.

Yield Calculation

The yields of solid, liquid and gaseous products are denoted as Y_S, Y_L and Y_g, respectively. Let the weights of solid material remaining in the reactor after the reaction as W_P Let the weight of catalyst be W_c.

Weight of solid product $(W_S) = W_P - W_c$

Let the weight of liquid be W_L. The values of W_P, W_C, W_S and W_L are expressed in g

Weight of polymer taken =1 kg = 1000 g

$.Y_S = \frac{W_S}{1000} \times 100$ (%)

$.Y_L = \frac{W_L}{1000} \times 100$ (%)

$.Y_g = (100 - Y_s - Y_L)$ (%)

For one run the values of Y_S, Y_L and Y_g were determined for each case. The density of the liquid D_L was also determined for one run for each case.

Gaseous Product from HDPE

The yields of the three types of gaseous products from HDPE are given in Table 1.

Table 1: Yields of Gaseous Product from HDPE (Wt %)

Gas	Yield
HAG	25.1
HBG	32.1
HCG	34.7

The rate of evolution of gaseous product was measured at various time intervals. The rate of evolution of gaseous products is a function of time, for the three cases of HDPE, are shown in Figure 6.
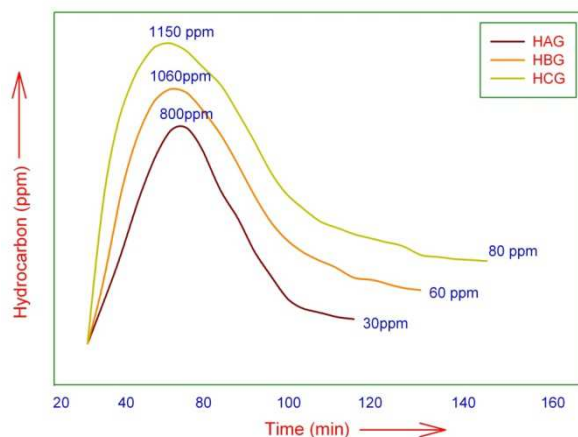
Figure 6: Uncondensed Hydrocarbons against Time (HDPE)

From the Figure 6, it is seen that the rate of evolution of gaseous products passes through a maximum at a particular time. The flame temperature was also found to vary with time. The photographic view of the best flames observed for the three cases is shown in Figure 7. The maximum flame temperature observed is correlated with the maximum rate of evolution of gas in Table 2.

| HAG | HBG | HCG |

Figure 7: Photographic View of Flame Produced By Uncondensed Gas (HDPE)

Table 2: Maximum Rate of Evolution of Gas and Maximum Flame Temperature for HDPE

GAS	Maximum Rate of Evaluation (ppm)	Maximum Temperature (°C)
HAG	800	380
HBG	1060	410
HCG	1150	582

Gaseous Product from LDPE

The yields of the three types of gaseous product from LDPE are given in Table 3

Table 3: Yields of Gaseous Product from LDPE (Wt %)

Gas	Yield (%)
LAG	22.0
LBG	45.2
LCG	60.7

The rates of evolution of gaseous product as a function of time, for the three cases of LDPE, are shown in Figure 8. From Figure 8 it is seen that the rate of evolution of gaseous product passes through a maximum at a particular time. The photographic views of the best flames observed for the three cases are shown in Figure 9. The observed maximum flame temperature is correlated with the maximum observed rate of evolution in Table 4.
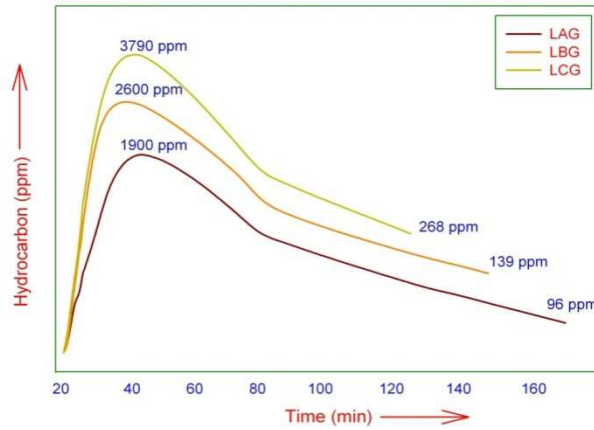

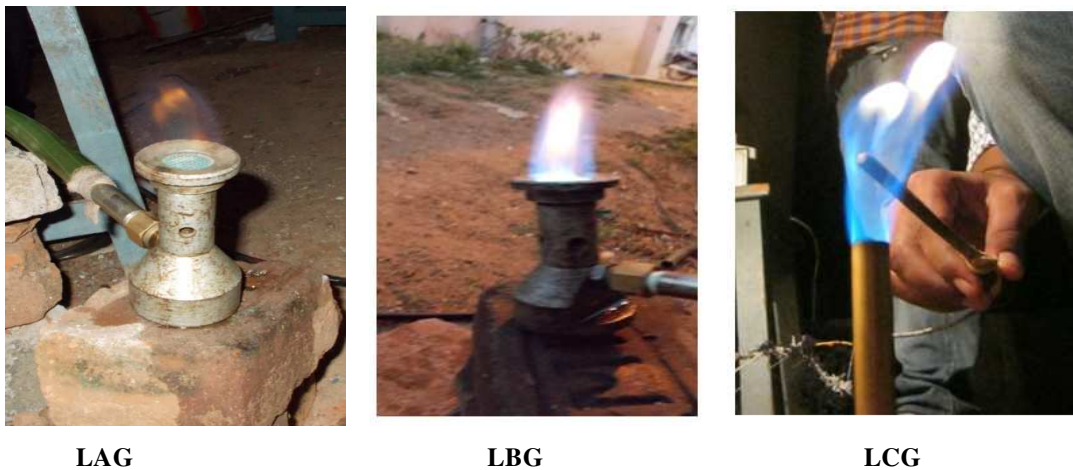**Figure 8: Uncondensed Hydrocarbons Against time (LDPE)**

| **LAG** | **LBG** | **LCG** |

Figure 9: Photographic View of Flame Produced By Uncondensed Gas (LDPE)

Table 4: Maximum Rate of Evolution of Gas and Maximum Flame Temperature Observed For LDPE

GAS	Maximum Rate of Evaluation (ppm)	Maximum Temperature (°C)
LAG	1900	620
LBG	2600	730
LCG	3790	805

From Table 4 it is seen that there is a good correlation between the rate of evolution of the gaseous product and flame temperature.

Comparison of Gaseous Products from HDPE and LDPE

From the above data, it is seen that during the experimental conditions the maximum rate of evolution occurs for both HDPE and LDPE when cat/pol = 0.20. However, for LDPE the maximum rate of evolution is 3790 ppm whereas for HDPE the maximum rate of evolution is only 1150 ppm. The maximum flame temperature observed is 582 °C for HDPE

whereas it is 805 °C for LDPE. However, considering the difference in the maximum values for the rate of evolution of gaseous products it can be concluded that the gaseous product from HDPE and LDPE can burn effectively. Hence, the gaseous product can be collected in the cylinder and used as fuel by controlling the flow rates. The gaseous product from HDPE and LDPE can be used as gaseous fuels. Nowadays, automobiles are run using CNG (Compressed Natural Gas). The gaseous products obtained by the degradation of HDPE and LDPE can be used as substitutes for CNG.

CONCLUSIONS

Gaseous hydrocarbons can be obtained by degradation of HDPE and LDPE waste plastic by using fly ash as a catalyst. The rate of evolution of gaseous products and the yield of gaseous products increase will increase in cat/pol ratio. The resulting gas burns with a blue flame. An highest flame temperature of 805   C is obtained by burning the gas product by degradation of LDPE with cat/pol ratio of 0.2.

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