Plastic Killers

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Abstract

Waste recycling plays a major role in reducing the pollution the world is experiencing, and its problems are difficult to solve, reducing the amount of household waste sent to incinerators and landfills that pollute the environment such as plastic. Chemical recycling is an attractive solution to reduce the explosive growth of plastic waste and disposal problems. Imagine a world where gigantic amounts of plastic waste can be converted into useful resources again and used for other purposes. It is known that plastics were part of petroleum that has been processed in different ways and with pyrolysis, this process can be reversed.

Pyrolysis is essentially thermochemical decomposition of such High-density polyethylene (HDPE) plastic performed at elevated temperatures in the absence of oxygen process. The plastic is converted into:(tiny pieces, diesel, and fuel gas) through a very small exit angle to be produced faster and more smoothly. That's the point of difference for the design requirement (time). The main product is diesel, but other waste products are formed (e.g., Char).

A test plan was made for HDPE waste (shampoo bottles) pyrolysis was at a high temperature for the chosen requirement which is the time. The test showed very good results as it doesn't take many minutes, to obtain a solid residue, liquid fuel oil, and flammable gaseous hydrocarbon products.

Introduction

Yet, the entire world is suffering from garbage pervasiveness leading to atrocious diseases. Living organisms' death and climatic change have resulted from human behaviors toward the environment causing mischievous gases augmentation and trapping them. According to those adversities, methods of generating energy from alternative sources excluding by-products such as plastic is put into scientists' consideration were various prior solutions for generating energy by using a thermoelectric generator (TEG), rocket fuel from CO_2, and deposable mask… etc. Unfortunately, their weak points have a crucial impact on the environment and may cause substantial disasters. Therefore, the demodulation of energy from useful resources through safe ways is the main purpose of the project. Conversion of wasted plastic into valuable energy sources is found to be possible through several thermal treatment technologies such as gasification, pyrolysis, plasma process, and incineration. Among all these methods, pyrolysis is the most desirable process since the initial volume of the waste is significantly reduced, more energy can be recovered from the plastic waste by producing a variety of valuable products, and low capital cost. Pyrolysis is the process of thermally degrading long-chain polymer molecules into smaller, less complex molecules through heat. The process requires intense heat with a shorter duration and in absence of oxygen. The three major products that are produced during pyrolysis are oil, gas, and char which are valuable for industries, especially production and refineries. Moving ahead, it was found that the most appropriate material is High-Density Polyethylene. Besides HDPE availability, it has the highest caloric value (49-46 MJ/ Kg) among various types of plastic waste making it the most promising plastic feedstock in pyrolysis conversion into high-grade liquid fuels discriminated with characteristics needed to accomplish the project's design requirements.

Materials

Figures								
Material	High-Density polyethylene (130.5004 grams)	Aluminum Chamber	Aluminum Tube	Copper tube	2 Autoclave Glass Beakers	Aluminum Silicate Hydroxide (12.9477 grams)	2 Soda Can Stoves	Plastic Bottle

Cost	No cost Wastes	200 L. E	45 L. E	144 L. E	155 L. E	Costless	Costless Recycled waste	Costless
	Fig (1)	Fig (2)	Fig (3)	Fig (4)	Fig (5)	Fig (6)	Fig (7)	Fig (8)

Methods

After putting the prototype in its standard (vertical) position above the heat source,

1- The plastic pieces were weighed in addition to the catalyst using a digital scale to determine the weight of the outputs according to the law of conservation of mass.

2- The value of the angle of the output exit tube (25º) has been confirmed using the protractor to ensure the quality of the outputs.

3- The timer was turned on at the beginning of the reaction to calculate the time it took to start (target design requirement).

4- The temperature used to compare the outputs of the solution with the prior ones at the same temperature, to determine the efficiency of the process, was calculated using a thermometer

The process is initiated by fetching an Aluminum chamber with a diameter base (13±0.001) cm and (7±0.001) cm height to be put on two Soda cans stove with diameter (4.7±0.001) cm and 4cm height.

Fig (9) Suggested Prototype

Inside the chamber, polyethylene plastic (HDPE) pieces exist weighing (130.5004±0.001) g until the chamber is heaped, then (12.9477±0.001) g of Aluminum Silicate Hydroxide Kaolin ($Al_2Si_2O_5(OH)_4$) is added to it due to its catalytic characteristics, it can speed up and promote the chemical reaction as this causes efficiency augmentation.

➢Then, the Pyrolysis process is involved through the process to burn the plastic resulting in fuel gas with 1.9wt% (2.47g), char with 17.2wt% (22.36g), and diesel with 80.9wt% (105.17g), so the char precipitates in the chamber, while fuel gas and diesel pass via the Aluminum tube which is welded at the center of the chamber lid with (2.5±0.001) cm diameter and is inclined with angle 25º to assist the products to flow fast and smoothly.

The diesel condenses at the bottom of the first autoclave glass beaker with 18cm height, another tube is pertained to the beaker's lid descending with 155º, and fuel gas passes through the tube to collide with ice in the beaker to transubstantiate it into fuel oil. An auxiliary bottle of water is put in to absorb any useless gas, especially carbon dioxide in order not to contaminate the atmosphere.

Results

According to table (1) and the 3 trials shown in, the results show that HDPE s broken down relatively quickly and after about (7-9) minutes very little of the HDPE is left. The conversion of both heavy wax and light wax begins when the majority of the HDPE has been broken down. The production of oil and gas is rapid in the initial phases of the process and begins to level off as the light and heavy wax produced in the early phase of the process is used up.

Table (1) Taken time for each trial

Trial (NO)	*Temperature (ºC)*	*Time (minutes)*
Trail 1	800	9
Trail 2	800	8
Trail 3	800	7

When the temperature gets 800ºC:

1. The first trial took 9 minutes, and then the products are produced.
2. The second trial took 8 minutes to start producing.
3. Unlike other outputs, the third trial took 7 minutes.

The presented results are consistent with the literature.

After approximately 2 hours, there is roughly 80.9wt% oil and 1.9wt% gas. The remaining 17.2wt% is carbon black. As shown in Table (2)

Table (2) Products Yield of HDPE pyrolysis

Products of HDPE pyrolysis	*Oil (Diesel)*	*Gas*	*Char (Carbon Black)*
Percentage Yield (wt%)	80.9	1.9	17.2

Table (3), clearly depicted that the physical properties of plastic pyrolysis oil were very close to the properties of commercial gasoline and diesel. Therefore, plastic pyrolysis oil has a very high potential to be used as a new energy resource.

Table (3) Physical properties of plastic pyrolysis

Property	**Unit**	**Diesel**	**HDPE pyrolysis oil**
Calorific Value	MJ/kg	45.8	46.2
Density	g/cm^3	0.7994	0.8147
Flashpoint	ºC	70	100

Analysis

The results of HDPE pyrolysis show higher liquid and solid yield (80.9wt%- 17.2wt%), but lower oil yield (1.9wt%). However, the design requirements (time (7 minutes () have been met with a high degree of efficiency (compared with the prior ones as **Figure ()** suggests (liquid yield 68.5wt%, oil yield 31.5wt%, and solid yield 0wt% in (20-25 minutes)). (Positive points).

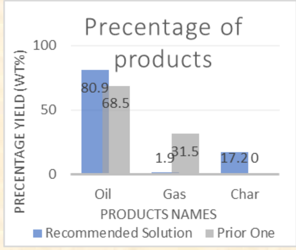

Fig () Solution Products vs Priors

CO_2 emissions (219g) from ethanol (combustion (ethyl alcohol) and the enthalpy change happened represented (Negative points):

$$C2H5OH_{(l)} + 3O_{2(g)} \rightarrow 2CO_{2(g)} + 3H_2O_{(g)}, \triangle H = -1367kJ/mol$$

As **Figure ()** suggests, ethanol combustion is an endothermic reaction where the heat content of the products is less than that in the reactants (△H=negative value).

The pyrolysis process contains some important steps. As shown in **Figure ()**, the plastic must first be processed into small pieces, preferably 5 mm. This is to ensure high thermal convection as possible and a good distribution of heat.

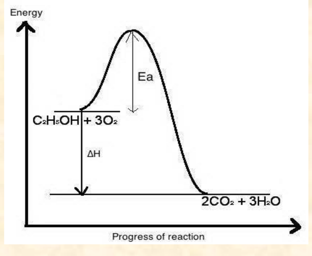

Fig () Exothermic Reaction

Fig () The basics of the pyrolysis process

The pieces are then heated with a catalyst (Aluminum Silicate Hydroxide Kaolin (Al2Si2O5(OH)4)) by a soda can stove in a chamber to around 800°C – 1000°C to begin the pyrolysis process using an external source of renewable fuel (ethanol C2H5OH). Once this temperature is reached, the gasses that are being produced by the pyrolysis reaction form the primary fuel for the external burners.

The chamber is made as **Figure ()** suggests, to increase the total surface area of the chamber (100π=314.2±0.6) cm and the volume (125π=392.7±0.9) cm to make the chamber capable of accommodating a large amount of HDPE pieces compared with the cuboid chamber. As the pyrolysis process progresses, the oil will flow from the chamber to storage.

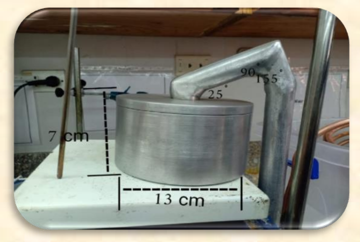

Fig () Chamber and tube design

The time to ensure complete conversion of the plastic will vary depending on the molecular structure of the plastic, but for 5 mm pieces of HDPE (C2H4), the time is around 7 minutes. In addition to the angle of the connected aluminum tube.

The aluminum tube is 43 cm divided into three parts: The first part is 10 cm connected to the chamber with an angle of 25º. This is for two reasons:

1. To reduce the value of the slope that the liquid and gas ascend with, and thus increase the speed of its flow and reduce the time.
2. In order not to hinder the gas movement as in the right angle (90º) so it is not recommended.

The second part is (4.5±0.1) cm connected to the first part with an angle of 90º.

The third part is (28.5±0.1) cm connected to the second part with an angle of 155º and to the 18 cm, a beaker with an angle of 90º divided into 16 cm above the beaker, (3±0.001) cm as a connecting part to the beaker and (9.5±0.001) cm under the beaker cover.

The fuel gas produced from the aluminum tube moves from the high-pressure region to the low-pressure region, that's why the aluminum tube is made longer.

In the condensation stage: The gas travels from the al aluminum tube to a water and air condenser (12×15 plastic box) through a (3.5±0.001) meters copper tube with a diameter of (1.2±0.001) cm approximately (0.25±0.001) inch connected to a (14±0.001) cm beaker (where the condensation process takes place). This is to increase the velocity of the gas produced according to the continuity equation: $AV = constant$.

The Copper tube wrapped 6 rolls each roll 15 cm in diameter. This is to increase the area for the fuel gas to be condensed. The gas produced at high temperature (800°C – 1000°C) is exposed to a very low temperature (Freezer temperature). This is to increase the condensation process by increasing the change in temperature (Δt) to increase the heat added or lost (Q) as the specific heat capacity for fuel gas= 2200 J/g K is constant and the mass also is constant according to this formula: $Q = mc\Delta t$ **is the equation for specific heat.** Specific heat is the amount of heat per unit of mass that is needed to raise the temperature of the substance by 1 degree Celsius. Q represents the heat lost, c is the specific heat of the substance, m is the mass of the sample, and Δt (delta t) is the change in temperature, but at the point of condensation, this equation doesn't work because the material state is changing. The equation followed then is: $Q = mL$ L is the latent heat.

In the refining stage: The liquid (condensed fuel oil) is sent into the 14 cm beaker.

It is recommended that: The expansion in volume that happened to the chamber must be calculated first to know if the initial number of plastic pieces can expand or not (for safety). According to this formula: $\triangle V = \beta V_1 \Delta t$where β is the material volumetric expansion coefficient.

This part is made for 2 reasons: 1. To take advantage of the free gas or waste heat produced which is flowed through a 2 meters plastic tube to be reused and directed to the flame again. 2. To absorb CO_2 emissions from the combustion reaction happened.

PH.1.09: Apply principles of fluid dynamics: It is learned to apply principles of fluid dynamics (the continuity equation) in determining the area of the cross-sections of the tubes.

PH.1.09: Apply principles of fluid dynamics: It is learned to use general properties of fluids (velocity, pressure, volume and temperature relation, viscosity, and compressibility) that's why the exit angle of the products of the tube is made 25º.

PH.1.09: Apply principles of fluid dynamics: It is learned how to use the continuity equation: $AV = constant$ in increasing the velocity of fluids by decreasing the area of the cross-section and vice versa.

PH.1.10: Design a system for efficient energy production: It is learned to design a system for efficient energy production using concepts of specific heat capacity in determining the suitable material for the process by determining the amount of heat needed using the formula: $Q = mc\Delta t$.

PH.1.11: Analyze energy flow in typical heating and cooling applications: It is learned to analyze energy flow in typical heating and cooling applications by applying the conservation of thermal energy and Energy graphs.

CH.1.08: Explain how the chemical and physical properties of solutions: It is learned to explain how the chemical and physical properties of solutions, suspensions, colloids, and Nano substances can be used in water treatment for the condensation process happened.

CH.1.10: Calculate quantities of products formed from known quantities: It is learned to calculate quantities of products formed from known quantities of reactants and be able to discuss their precision and accuracy in the ethanol combustion reaction to know what amount of carbon dioxide can be produced to provide possible ways of absorption.

Conclusion

Most of the plastics are thrown out after a single-use, and the amount of plastic waste accumulated in the environment each year was an alarming level to convert that by-product into valuable energy resources to fully utilize the waste and meet the increased energy demand. Therefore, the Pyrolysis process was chosen among other thermal treatment technologies because of its potential to convert the most energy from plastic waste to valuable liquid oil, gaseous, and char. To achieve the desired results, the process undergoes a previously studied plan that starts by inserting the well-cut (high-density polyethylene) into a rounded aluminum chamber connected to an inclined tube and subjected to two Soda can stoves as a recycled heating source. 12.9477 gm of Aluminum Silicate is added to 130.5004 gm of plastic, due to its catalytic characteristics and to meet time efficiency, one of the design requirements.

The results achieved were promising and exceeded our hypothesis. Diesel oil appeared with a high percentage of 80.9wt% and 105.17 grams, besides fuel oil with a percentage of 1.7wt% and 10.27garms. Lastly, char was formed at the bottom of the chamber with a percentage of 17.2wt% and 22.36 grams. The reaction average time of three trials was 8 minutes under temperatures ranging from 800 to 1000 degrees Celsius. Each product had its forming temperature as the first to appear was diesel oil and the last to form was the fuel oil. As illustrated from the previous data, our prototype fulfills essential design requirements and pyrolysis is proven to have a practical effect to form energy out of non-recycled plastic.

Recommendation

1- Using a catalyst (zeolite) to lower the activation energy needed for the reaction

2- Making the exit angle of the products (25º) to reduce the value of the slope through which the gas and liquid will exit, and therefore one will not hinder the movement of the other.

3- Use nitrogen (N_2) in the beginning so that there will be no emissions in the other.

4- In the state of unavailable nitrogen, it can be replaced with a water bottle at the end to absorb the emitted carbon dioxide (CO_2).

5- Using (microalgae) for carbon dioxide emissions.

6- It is recommended to rely on (solar energy) as a source of heat at the beginning instead of the spark.

7- Taking into account the reasons for safety and security due to the high temperature

8- Taking into account that the beakers used must be made of materials that are resistant to heat and high pressure (such as the autoclave material used).

Literature Cited

Badr, H. (2017). *Garbage recycling in Egypt: Trading health for livelihood*

https://www.scidev.net/global/multimedia/garbage-recycling-egypt-trading-health-livelihood/

Department For Environment Food and Rural Affairs (Defra). (n.d). *Protecting our Water, Soil, and Air.*

https://www.nutrientmanagement.org/portectingwatersoilair/

Everything Connects Why Nature Matters. (2014). *Reduce Environmental Pollution*

https://www.everythingconnects.org/reduce-pollution.html

Food and Agriculture Organization of the United Nations. (2018). *Polluting our soils is polluting our future*

https://www.fao.org/fao-stories/article/en/c/1126974/

International Journal of Engineering Research and General Science. (2015). *Production and Analysis of Pyrolysis oil from waste plastic in Kolhapur city* [PDF File], *Vol.3(1),* 2091-2730 https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.673.3714&rep=rep1&type=pdf