Pyrolysis of Plastic Waste into Petrol Fuel

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Abstract
This study aimed to create a device that will help the environment and global concern where plastic wastes will be the subject for chemical decomposition into petro fuel with the use of pyrolysis. It also determined how accurate the device produced the as to calculated calorific value, density, flash point, carbon residue, ash content, water content, and sulfur content. More so, it found out how many liters of fuel/oil were produced from plastic wastes in a variety of time and temperature. The said device was evaluated by experts in terms of convenience, design and accuracy. Respondents of the study are laboratory experts, chemists, experts, professors and engineers from reputable institutions

Results revealed that the process of Polypropylene (PP) and Polyethylene Terephthalate (PETE) waste plastic mixture into fuel production without using catalyst or chemical experiment was performed successfully. PETE's raw materials to fuel production created some problems due to oxygen present. During condensation period, it tried to clog the condensation pipe and some waxy parts are coming out with liquid fuel. PETE has high percentage of oxygen compounds and less percentage of hydrogen thus it is not good for fuel production. On the other hand, PP and PS has high percentage of carbon, therefore, is good for fuel production. The constructed device produces a Pyrolysis Fuel which can be used as Fuel or Oil in old engines such as generators and old kalan (de bomba). The researchers concluded that the produced fuel from Pyrolysis of Plastic Wastes is a Pyrolysis Fuel and cannot be named with other fuels such as petrol, diesel, gasoline, bunker oil, etc. Moreover, the constructed device obtained a good feedback based on experts' evaluation.

Keywords: Pyrolysis, Plastic Waste, Petrol Fuel, Mechanical Energy.

1. Introduction

Today, fuel is a critical component of the global economy because of its many uses. Fuel-rich countries tend to be more developed and powerful because of its high value in the market unlike those countries that are indigent with fuel and are forced to import fuels. In this modern life, one of the most widely used fuels is petrol fuel or gasoline which is commonly used in cars, motorcycles, boats, light trucks and other vehicles that uses motor engine. Petrol fuel naturally comes from distillation of crude oil, which comes from deep underground, formed by decomposition of plant and animal fossils under the earth where due to tectonic pressure and temperature it gets liquefied. In regulation for commercial fuel, calculated calorific value, density, sulfur content, flash point, ash content, water content, and carbon residue are used to pyrolysis fuel/oil.

Plastics are also called polymers. One of the major concerns for the excessive use of plastic is the disposal of the waste. Plastic is a high molecular weight material that was invented by

Alexander Parkes, (1862). In 1950, 1.5 million tons of plastic wastes were produced with the worlds' population of 2.5 billion; in 2016, a global population of over 320 million tons of plastic and is set to double by the year 2034. According to a study, every day, approximately 8 million pieces of plastic wastes are in the ocean. It was found that over 30% of manufactured plastics were Low Density Polyethylene (LDPE) and 20% were High Density Polyethylene (HDPE). In the Philippines, it is reported that 2.7 million tons of plastic wastes were annually disposed and 20% of that leaks into the ocean.

The researchers aimed to create a device that will help the environment and global concern where plastic wastes will be a matter in generating petrol fuel with the use of pyrolysis. Pyrolysis is a process of chemically decomposing organic materials at elevated temperatures in the absence of oxygen. The process typically occurs at temperatures above 400ºC and under pressure. The researchers will be using plastic wastes as the subject to chemically decompose plastic intro petro fuel. The device will help other researchers, companies, and organizations in their advocacy on "zero plastic wastes campaign" all over the world.

This study built a "Pyrolysis of Plastic wastes into Petrol Fuel using Mechanical Energy". Specifically, this study was developed to give answers to these following questions:

1. How accurate is the device in producing fuel in terms of following properties:
   1.1. Calculated calorific value
   1.2. Density
   1.3. Flash point
   1.4. Carbon Residue
   1.5. Ash Content
   1.6. Water content
   1.7. Sulfur Content
2. What is the evaluation level of experts while using the device in terms of the following:
   2.1. Convenience
   2.2. Design
   2.3. Accuracy
3. How many liters of fuel/oil is produced from plastic wastes in a variety of time and temperature?

2. Methodology

This study used experimental method of research in which the researchers created a Pyrolysis device that converts plastic wastes into fuel. The main objective of this study is to understand and optimize the processes of plastic pyrolysis for maximizing the oil production and design a pyrolysis apparatus as mini machine and low-cost. The materials to be tested in this study are Low-density Polyethylene (LDPE) which account for 30% of the plastic used in packaging such as plastic wraps, grocery bags, plastic bottles, etc. The results were determined where properties from other studies were compared to a standard and regulatory property of the same features. Selected experiments were performed to determine the quality and standard characteristics of the fuel.

The calibration process and experimentation activities were done in Société Générale de Surveillance (SGS) Fuel Laboratory. The respondents for the evaluation of the device were done by the practitioner and expert related to calibration of fuel from SGS Fuel Laboratory in Makati, Metro Manila. The device was evaluated by the users, practitioners and experts once the construction, calibration and experimentation were done. The device will be evaluated by practitioners, chemists, engineers, physicists, experts and students. The researchers used purposive sampling method where the researchers selected units to be sampled.

The produced fuel was successfully tested in Energy Research and Testing Laboratory Services (ERTLS) at Department of Energy in Taguig City. There is no significant difference between the results of the parameters of calculated calorific value, density, flash point, pour point, sulfur content, ash content and water content in the produced fuel with the Pyrolysis Fuel that is already tested in other studies, which means that the constructed device and produced fuel gave a nearly accurate result of parameters.

3. Results and Discussion

The results of the study is presented tables below. Comparing the gathered data and the reference data, there is a much better result of the gathered data than the reference data and accepted value.

Table 1 Characteristics of the of Sample fuel produced by the Device

Parameters	**Reference Data**	**Sample Product Fuel**
Calculated Calorific Value/Heating Value	9829.35 BtU/lb	18,858.00 BtU/lb
Density	0.7477 kg/L	0.7478 kg/L
Flash Point	15º	< 40º
Sulfur Content	30-80ppm	33.6ppm
Ash Content	0.036 %m/m	0.001%m/m
Carbon Residue	0.5%m/m	<0.01%m/m
Water Content	**0.003– 0.100% (m/m)**	**0.02% (m/m)**

Table 2 Produced Fuel in 1kg of Polypropylene (PP) [Plastic bags]

Temperature (ºC)	**Time frame of Pyrolysis process (hr/s)**	**Produced Fuel (ml)**
200ºC–250ºC	30 minutes	50ml
200ºC–250ºC	1 hour	100ml
200ºC–250ºC	1 hour, 30 minutes	150ml
200ºC–250ºC	2 hours & above	200ml

Table 3 Produced Fuel in 2kgs of Polypropylene (PP) [Plastic bags]

Temperature (ºC)	Time frame of Pyrolysis process (hr/s)	Produced Fuel (ml)
200ºC–250ºC	30 minutes	100ml
200ºC–250ºC	1 hour	200ml
200ºC–250ºC	1 hour, 30 minutes	250ml
200ºC–250ºC	2 hours & above	300ml

Table 4 Produced Fuel in 1kg of Polyethylene Terephthalate (PETE) [Plastic bottles]

Temperature (ºC)	Time frame of Pyrolysis process (hr/s)	Produced Fuel (ml)
200ºC–250ºC	30 minutes	0ml
200ºC–250ºC	1 hour	10ml
200ºC–250ºC	1 hour, 30 minutes	15ml
200ºC–250ºC	2 hours & above	25ml

Table 5 Produced Fuel in 2kgs of Polyethylene Terephthalate (PETE) [Plastic bottles]

Temperature (ºC)	Time frame of Pyrolysis process (hr/s)	Produced Fuel (ml)
200ºC–250ºC	30 minutes	10ml
200ºC–250ºC	1 hour	20ml
200ºC–250ºC	1 hour, 30 minutes	40ml
200ºC–250ºC	2 hours & above	50ml

Table 6 Produced Fuel in 3kgs of Polyethylene Terephthalate (PETE) [Plastic bottles]

Temperature (ºC)	Time frame of Pyrolysis process (hr/s)	Produced Fuel (ml)
200ºC–250ºC	30 minutes	15ml
200ºC–250ºC	1 hour	30ml
200ºC–250ºC	1 hour, 30 minutes	50ml
200ºC–250ºC	2 hours & above	80ml

Parameters	Reference Data	Gathered Data
Calculated Calorific Value/Heating Value	9829.35 BtU/lb	18,858.00 BtU/lb
Density	0.7477 kg/L	0.7478 kg/L
Flash Point	15º	< 40º
Sulfur Content	30-80ppm	33.6ppm
Ash Content	0.036 %m/m	0.001%m/m
Carbon Residue	0.5%m/m	<0.01%m/m
Water Content	**0.003– 0.100% (m/m)**	**0.02% (m/m)**

Table 1 presented the characteristics of the sample product.
Furthermore, the evaluation of experts and other respondents while using the device in terms of convenience, design and accuracy are all strongly agree.
Table 2 shows how many liters of fuel can be produced in a variety of time and temperatures which depends on the number of mass being processed in the absence of oxygen. The first column shows the number of mass (kg) to be processed; the second column shows the number of temperature reached while doing the Pyrolysis process; the third column shows the time interval of Pyrolysis process, each time has equivalent amount of fuel produced and the last column shows the amount of fuel collected in a variety of mass, time and temperature. The table shows that as the number of time and temperature increases, the amount of fuel increases at given mass of Polypropylene plastics.
This table 3 shows how many liters of fuel can be produced if the plastic waste mass is increased by 2kg. First column shows the mass of the plastic to be pyrolysed, the second column shows the temperature gathered on the process which shows that it has same temperature limit. The third column is the time frame where the researchers pyrolysed the plastics and same with previous data, the researchers limited the time frame of pyrolysis as it doesn't produce fuel anymore. The last column shows the produced fuel of the specific mass, temperature and time. The table shows as the number of time and temperature increases, the amount of fuel increases at given mass of Polypropylene plastics.
Table 4 shows how many litres of fuel can be produced in a variety of time and temperatures which depends on the number of mass being Pyrolysed. The first column shows the number of mass (kg) to be pyrolysed; the second column shows the number of temperature reached while doing the Pyrolysis process; the third column shows the time interval of Pyrolysis process, each time has equivalent amount of fuel produced and the last column shows the amount of fuel collected in a variety of mass, time and temperature. The table shows as the number of time and temperature increases, the amount of fuel increases at given mass of Polyethylene Terephthalate plastics.
Table 5 shows how many liters of fuel can be produced in a variety of time and temperatures which depends on the number of mass being Pyrolysed. The first column shows the number of mass (kg) to be pyrolysed; the second column shows the number of temperature reached while doing the Pyrolysis process; the third column shows the time interval of Pyrolysis process, each time has equivalent amount of fuel produced and the last column shows the

amount of fuel collected in a variety of mass, time and temperature. The table shows as the number of time and temperature increases, the amount of fuel increases at given mass of Polyethylene Terephthalate plastics.

Table 6 shows how many liters of fuel can be produced in a variety of time and temperatures which depends on the number of mass being Pyrolysed. The first column shows the number of mass (kg) to be pyrolysed; the second column shows the number of temperature reached while doing the Pyrolysis process; the third column shows the time interval of Pyrolysis process, each time has equivalent amount of fuel produced and the last column shows the amount of fuel collected in a variety of mass, time and temperature. The table shows as the number of time and temperature increases, the amount of fuel increases at given mass of Polyethylene Terephthalate plastics. The researchers found out that those Polyethylene Terephthalate plastics produces less fuel rather than Polypropylene plastics because PETE has higher percentage of oxygen compounds and less percentage of hydrogen rather than PP plastics which are good for fuel production.

4. Conclusions

Based on the results of this, the following are hereby concluded:

1. The constructed device obtained a good feedback based on respondent's/expert's evaluation.
2. Polypropylene (PP) and Polyethylene Terephthalate (PETE) waste plastic mixture into fuel production without using catalyst or chemical experiment was performed successfully.
3. PETE present raw materials to fuel production are creating some problem because due to oxygen present. During condensation period it tries to clog the condensation pipe and some waxy part is coming out with liquid fuel.
4. PETE has high percentage of oxygen compounds and less percentage of hydrogen for that reason PETE is not good for fuel production. On the other hand PP and PS has high percentage of carbon compounds for that reason PP and PS is good for fuel production.
5. The constructed device produces a Pyrolysis Fuel which can be used as Fuel or Oil in old engine such as generators and old kalan (de bomba).
6. The researchers conclude that the produced fuel from Pyrolysis of Plastic Wastes is a Pyrolysis Fuel and cannot be named with other fuels such as petrol, diesel, gasoline, bunker oil, etc.

References

[1] John Wiley & Sons Ltd, (2006) Feedstock Recycling and Pyrolysis of Waste Plastics: Converting Waste Plastics into Diesel and Other Fuels. The Atrium, Southern Gate, Chichester, West Sussex PO19 8SQ, UK

[2] Joo-Sik Kim et al., (1997) Pyrolysis of a fraction of mixed plastic wastes depleted in PVC. University of Seoul

[3] Christine Cleetus, et al. (2013) Synthesis of Petroleum-Based Fuel from Waste Plastics and Performance Analysis in a CI Engine, (Journals)

[4] Teresa Cheong (2010), Transforming Waste Plastic into an Alternative Fuel, (Journals) North-eastern University.

[5] Jonathan L. Mayuga (2016), DENR sees the rollout of waste-to-energy projects in the Philippines. (Journals) Philippines

[6] W. KAMINSKY (1993), Recycling of polymers by pyrolysis Institute for Technical and Macromolecular Chemistry, University of Hamburg, Bundesstrasse 45, 2000 Hamburg 13, Germany

[7] Mohamed M. Garib Alla, et al. (2014) CONVERSION OF PLASTIC WASTE TO LIQUID FUEL (Journals) Mohamed M. Garib Alla, Karary University, Sudan (Chemical Engineering Department)

[8] M.Z.H. Khan, et al. (2016) Pyrolytic Waste Plastic Oil and Its Diesel Blend: Fuel Characterization

[9] Feng Gao, 2010, Pyrolysis of Waste Plastics into Fuels (thesis), Doctor of Philosophy in Chemical and Process Engineering University of Canterbury

[10] Alec Roth, PYROLYSIS, 324-309 West Cordova Vancouver, BC Canada https://www.studentenergy.org/topics/pyrolysis

[11] A. Hazrat et al., (2016) Study of combustion and emission characteristics of fuel derived from waste plastics by various waste to energy (W-t-E) conversion processes https://aip.scitation.org/doi/abs/10.1063/1.495842? journalCode=apc

[12] Z.H. Khan, et al. (2016) Pyrolytic Waste Plastic Oil and Its Diesel Blend: Fuel Characterization https://www.hindawi.com/journals/jeph/2016/7869080/#abstract

[13] Ramli Thahir, et al.,(2019) Production of liquid fuel from plastic waste using integrated pyrolysis method with refinery distillation bubble cap plate column https://www.sciencedirect.com/science/article/pii/S2352484718301562#b16

[14] Ranbir Bagri, Paul T. Williams, (March2002) Catalytic pyrolysis of polyethylene https://www.sciencedirect.com/science/article/abs/pii/S0165237001001395

[15] Sharuddin, et al (May2016), A review on pyrolysis of plastic wastes https://www.sciencedirect.com/science/article/abs/pii/S0196890416300619

[16] Ding, W., et al (1996-97), Fuel Process. Technology. https://www.sciencedirect.com/science/article/pii/S0378382096010806

[17] H. S. Joo and James A. Guin; (1997) Hydro cracking of a Plastics Pyrolysis Gas Oil to Naphtha, Energy & Fuels https://pubs.acs.org/doi/abs/10.1021/ef960151g#