Development And Analysis of Pyrolysis as A Sustainable Solution for Plastic Waste Reduction

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Abstract— This paper aims to conduct a study on developing a pyrolysis machine to reduce plastic waste. It is a suggested approach to deal with the increasing amount of plastic waste, to avoid its buildup in landfills and even depletion of resources. There are several ways to address this continuous growth of plastic waste, and in this study, the researchers focus on the development and fabrication of machines to convert plastic into oil as an effort of recycling waste by means of pyrolysis. The Plastic wastes are subjected to depolymerization and fractional distillation to obtain fuels like diesel when further refined. Polypropylene (PP) plastic is utilized in this project to undergo a pyrolysis process to get fuel oil that has comparable physical properties to petroleum, diesel, and so on. Converting this type of waste into fuel holds great promise for the environment.

***Index Terms*— Plastic waste, polypropylene plastic, fuel oil, pyrolysis, recycle, plastic pollution.**

1. Introduction

Plastic waste pollution has become one of the major environmental issues in the world due to the fact that plastics are affordable and durable, and human use and manufacture have increased. Plastic's resilience is strong enough to withstand several natural decomposition processes, therefore, plastics last for many years, plastic may disintegrate into much smaller pieces but it never completely degrades. According to Borrelle, et al. (September 2020), this study assessed the impact of three broad management strategies, plastic waste reduction, waste management, and environmental recovery, at different levels of effort to estimate plastic emissions to 2030 for 173 countries. It is estimated that 19 to 23 million metric tons or 11% of plastic waste generated globally in 2016 entered aquatic ecosystems. Considering the ambitious commitments currently set by governments, annual emissions may reach up to 53 million metric tons per year by 2030. Since people found plastic very valuable, societies became indulged in the use of disposable plastics without knowing its repercussions to the environment. According to Macleod, et al. (July 2021), Potential impacts from poorly reversible plastic pollution include changes to carbon and nutrient cycles; habitat changes within soils, sediments, and aquatic ecosystems; co-occurring biological impacts on endangered or keystone species; ecotoxicity; and related societal impacts. The rational response to the global threat posed by accumulating and poorly reversible plastic pollution is to rapidly reduce plastic emissions through reductions in consumption of virgin plastic materials, along with internationally coordinated strategies for waste management.

Plastic pollution has a direct and negative effect on wildlife, thousands of marine animals die because of consuming or being entangled in plastic and when plastics were thrown away in landfills, it reacts with the water and produces dangerous compounds. According to Anastasopoulou & Fortibuoni (December 2019), Plastics can affect marine organisms mainly through ingestion and entanglement but also the facilitation of transport of organisms via rafting or the provision of new habitats for colonization. Impacts vary according to the type and size of the plastics and can occur at different levels of biological organization in a wide variety of habitats. When these pollutants seep into the earth, they contaminate the water. The wind moves and dumps the plastic from one location to another, adding to the amount of trash on the ground. According to Obebe & Adamu (April 2020), only nine percent (9%) of the nine billion tonnes of plastic produced in the world has been recycled. Most end up in landfills, dumps, or in the environment especially the oceans.

The advantage of reducing plastic waste includes environmental protection, conservation of natural resources, and cost savings. Chemical recycling has the most effective technique to reduce plastic waste disposal.

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Pyrolysis involves exposing plastic to high temperatures in an oxygen-free atmosphere, resulting in extremely high molecular motion that causes the material to stretch and shake to the point where molecules begin to break down into smaller molecules. It is also considered that pyrolysis of waste plastic is one of the most feasible large-scale methods of energy regeneration. This is because waste plastic is a valuable source of liquid and gas fuels as well as chemicals. According to Davidson et al. (April 2021) Pyrolysis is often highlighted as the best chemical recycling method. It was concluded that there may be unintentional bias in these results due to more and higher quality data being available for pyrolysis. Therefore, further research on gasification, depolymerization, and hydrocracking of plastic waste is needed to increase data availability and quality and enable better LCA modeling comparisons.

2. Research Problem

The objective of the study is to address the escalating issue of plastic waste pollution, and it is sought to answer the following questions:

- To reduce the increasing rate of plastic waste pollution.
- To convert plastic waste into fuel oil.
- To determine how many kilograms of plastic waste would be converted into liters of fuel oil.
- To develop and fabricate an inexpensive pyrolysis machine.
- To determine the performance of the machine.

A. Significance Of the Study

The findings of this study will benefit the environment, and the community considering it will reduce the plastic waste that takes many years to decompose and badly affects our environment. Since plastic waste was converted into fuel oil, people will be aware of the importance of recycling plastic waste.

B. Scope And Limitation of The Study

This study focused on the development of a pyrolysis machine that was used to convert plastic waste (High Density Polyethylene) into fuel. The limitation of this study was focused on the materials used to develop a simple and inexpensive pyrolysis machine.

C. Locale Of the Study

The study was conducted at San Ricardo Talavera, Nueva Ecija and tested at the Nueva Ecija University, Metal Innovation Center, Sumacab Este, Cabanatuan City, Nueva Ecija.

3. Research Methodology

A. Pyrolysis Machine.

The developed and fabricated inexpensive pyrolysis machine converts plastic waste to fuel oil. The principle of this is when the raw materials were heated in a reactor with a high temperature of 125℃ and oxygen-free conditions temperature it will generate some oil gas, when the oil gas goes into the condenser it is condensed into liquid flammable oil. The final product was mainly fuel oil which can be further refined for better use.

B. Pyrolysis Process of Polypropylene.

In this process, Polypropylene plastic is heated to 125°C in a reactor in the absence of oxygen. The temperature required depends on the types of plastics used. Once the melting point is reached, the plastics melt and the gas is transferred to the tank that is connected to the reactor, this tank keeps the unwanted matter like the solid char. Then, the vapor of the plastic waste goes to the condensing unit and the condensation takes place. The fuel oil that flowed out of the condensing unit down to the container was then transferred to the second container with water on it, the excess vapor goes through it to remove the extra solid particles if there are any. Finally, the output fuel oil was poured out into the third container.

1) Steps involved in the Process.

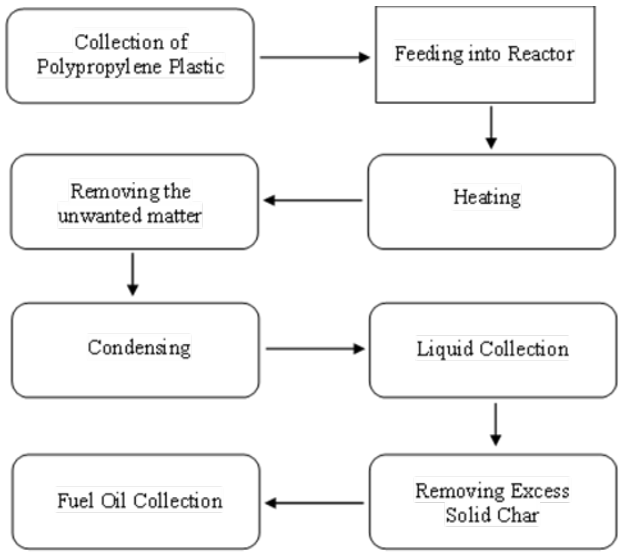

Fig.1. Flow Diagram of Process

C. The Development and Fabrication of Pyrolysis Machine.

The main component of the pyrolysis machine that was developed is the reactor where the plastic waste was set to undergo the pyrolysis process, and a condenser that condensed the vapor of the plastic waste. The materials used in developing the pyrolysis machine were the gas hose, copper tube, and Galvanize Iron (G.I.) pipe schedule 40. The G.I. pipe was connected to the reactor to a small LPG tank where the vapor from the reactor rested before proceeding into the condenser.

The copper tube was used to develop the condenser. The gas hose connected the condenser to the water container to produce a flammable gas output. The plastic waste used that was converted into fuel oil were High Density Polyethylene (HDPE) plastics such as cleaning products, bleach, plastic containers, reusable water bottles, and first aid products.

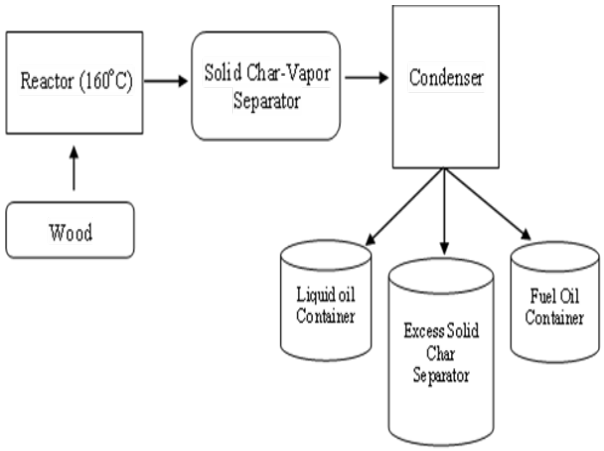

Fig.2. Block Diagram of Pyrolysis Machine Design

D. Pyrolysis Machine's Reactor

The materials used in developing the reactor of the pyrolysis machine were 5 steel plates that is 11 x 14 inches in size. A welding machine was used to connect the steel plates and the cap screw was used to lock the reactor.

Fig.3. The Improvised Reactor Unit

E. Condenser

The materials used to create the improvised condenser were steel plate and copper tube, the steel plate was assembled that acted as the body of the condenser and the copper tube was winded to form a spiral shape that put inside the body of the condenser. A hole was drilled for the oil to flow to the next container.

Fig.4. The Improvised Condenser

F. Connecting the reactor to the tank

The researchers used a G.I. pipe to connect the reactor to the tank. The plastic waste from the reactor was heated up to 125°C before it vaporized and proceeded to the tank where the vapor was rested and the solid particles were removed such as carbon black that produced heavy oil output.

G. Connecting the Tank to the Condenser

To connect the tank to the condenser, a copper tube was used. The vapor goes through the tube from the tank to the condenser where the condensation takes place. After the condensation, the vapor of the plastic waste was converted into flammable oil.

H. Collection of the produced oil and gas

The produced oil in the condenser were collected in a glass container where the oil was measured to determine how much oil were produced. The excess vapor coming out of the condenser, was proceeded to the water container where it produced a fuel oil output.

I. Testing of the pyrolysis machine

After connecting the components, the researchers examined the machine to discover if any errors occurred in the connection of the components themselves.

J. Determining the performance of the machine

The researchers tested the pyrolysis machine and determined if the machine produced or converted the plastic waste into fuel oil, and to find out how many kilograms of plastic waste was converted into liters of fuel oil.

4. Results And Discussions

This part of the research contains the results and data gathered throughout the research and discuss all of the details of the outcome. The researchers have tried the machine and at first, there was a problem encountered with the reactor, some steam from the plastic was coming out of the reactor so, the gas that was supposed to go through the pipe was escaping from the reactor's cover, and because of that, no product was produced.

To fix the problem with our fabricated reactor Bellamoid Gasket was used and put at the leaking side of the cover by that, the container with water formed a bubble which indicates the gas flow smoothly through the condenser to the containers, and pyrolysis process is happening.

After some time, gas from the melted plastic in the reactor was transferred to the first container, which will moist and become the product flammable oil.

5. Findings And Conclusions

In conclusion, the researcher's development of an Inexpensive Pyrolysis Machine is effective if given more time for improvement and, High Density Polyethylene (HDPE) plastics are effective for producing oil from plastic waste.

Recommendations:

Future researchers are encouraged to make further discussion with the following recommendations:

- Enhance Reactor Design: The issue encountered with steam and gas leakage from the reactor is crucial to address. Consider improving the design by ensuring airtight conditions, possibly by revisiting the welding or sealing techniques. Investigate the specific points where steam was escaping and fortify those areas.
- Quality Control: The use of a Bellamoid Gasket to address the reactor issue is a practical solution. Ensure that the quality of such components is consistent and meets the necessary standards. Regularly check and replace these components to avoid operational disruptions.
- Efficiency Optimization: Continuously work on optimizing the efficiency of the pyrolysis process. This includes adjusting temperature conditions, refining the condensation process, and monitoring the flow of gas to maximize the production of flammable oil.
- Safety Measures: Implement safety measures to mitigate potential risks associated with the pyrolysis process. This includes proper ventilation, fire safety protocols, and protective gear for operators. Safety should be a paramount consideration in the operation of the pyrolysis machine.
- Data Logging: Establish a systematic data logging system to record the performance of the machine over time. This includes the quantity of plastic processed, fuel oil produced, and any operational issues

encountered. This data will be valuable for future improvements and analysis.

- Alternative Materials: Explore the possibility of using alternative materials for the reactor and condenser that might enhance the overall performance and durability of the pyrolysis machine. This could involve materials with better heat resistance and corrosion protection.
- Collaboration and Further Research: Collaborate with experts in the field of plastic waste management and recycling. Engage in further research, especially in comparison with other plastic recycling methods. This will contribute to a comprehensive understanding and improvement of the pyrolysis process.
- Education and Awareness: Share the results and benefits of the study with the community. Increasing awareness about the environmental benefits of plastic waste conversion into fuel oil can garner support and potentially influence recycling behaviors.
- Cost-Benefit Analysis: Conduct a detailed cost-benefit analysis to assess the economic viability of the pyrolysis machine. Consider the costs associated with fabrication, maintenance, and operation against the benefits of fuel oil production and environmental impact.
- Regulatory Compliance: Ensure that the operation of the pyrolysis machine aligns with local and national regulations. Obtain necessary permits and certifications, and collaborate with relevant environmental authorities to guarantee compliance.

By implementing these recommendations, the research project can not only enhance the effectiveness of the pyrolysis machine but also contribute significantly to addressing the global issue of plastic waste pollution.

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