PRODUCTION OF BIO-FUEL FROM PLASTIC WASTE

Jency Joseph J1, Josh .F.T2

Abstract - The global plastic production increased over years due to the vast applications of plastics in commercial units. The continuous demand of plastics causes the plastic wastes accumulation in the landfill, which consumes a lot of space which contributes to the environmental problems. Since plastics were the petroleum-based material the rising in plastic demand led to depletion of petroleum as a part of non-renewable fossil fuel. Recycling and energy recovery method were some alternatives that have been developed to manage plastic waste. However, the recycling method required high labor cost for the separation process and caused water contamination that reduced the process sustainability. Due to these drawbacks, the researchers have diverted their attentions to the energy recovery method to compensate the high energy demand. The plastic waste conversion to energy was developed through extensive research and technology development. The recovery of plastic to liquid oil through pyrolysis process had a great potential since petroleum was the main source of plastic manufacturing. And also the oil produced had high calorific value compared to the commercial fuel. This paper reviewed the pyrolysis process for plastics and the main process parameters that influenced the final product such as oil, char and gas.

1. INTRODUCTION
Plastics due to their lightweight, durability and energy efficiency, coupled with a faster rate of production and design flexibility, have become an indispensable part in today’s world. Since, plastics have become essential materials and their applications in the industrial field are continually increasing, plastics are employed in entire gamut of Industrial and Domestic areas[2]. At the same time, waste plastics have created a very serious environmental problem because of their huge quantities and their disposal threats[15]. We not only can effectively solve the problem of white pollution, but also can alleviate the energy shortage to a certain extent by waste plastic pyrolysis in liquid fuel (gasoline, diesel oil, etc.) or chemical raw materials[7]. The most effective way is expected to be recycling of waste plastic. Waste plastics’ recycling, regenerating, and utilizing have become a hot spot of research at home and abroad and gradually formed a new industry[20]. One of the promising method to recycle waste plastics which involves thermochemical decomposition of synthetic and organic materials at higher temperatures in the absence of oxygen to produce fuels is Pyrolysis process[21]. The process is usually conducted at temperatures between 300-500 degree celsius[17]. These pyrolytic products can be divided into liquid fraction, solid residues and gaseous fraction[9].

2. CHEMICAL PROPERTIES OF PLASTIC
Plastic is not only a regular molecule, it is a polymer with a very widely differing composition and thus structure. A polymer is composed of monomer, the basic constituent which can be good variable since we can make polymers out of: ethylene, styrene, butadiene, acrylene, vynil, propylene etc.
3. TYPES OF PLASTICS

The plastics are divided into the following seven groups based on the chemical structure and applications by the Society of Plastic Industry (SPI).

- PET (Polyethylene Terephthalate)
- HDPE (High Density Polyethylene)
- PVC (Polyvinyl Chloride)
- LDPE (Low Density Polyethylene)
- PP (Polypropylene)
- PS (Polystyrene)
- Other

| Table 1: Different Types of Plastics |
|--------------------------------------|
| **Types**   | **Name**                | **Examples**                      | **Can be pyrolysed** |
| Type 1      | Polyethylene Terephthalate | Water bottles, Plastic bags       | Yes                  |
| Type 2      | High Density Polyethylene  | Oil bottles, Plastic detergent bottles, Plastic toys | Yes                  |
| Type 3      | Vinyl/Polyvinyl           | Plastic curtains, Shampoo bottles  | No                   |
| Type 4      | Low Density Polyethylene  | Garment bags                      | Yes                  |
| Type 5      | Polypropylene             | Microwaveable                      | Yes                  |
Table 1 shows the different type of plastics, name, example and possibility of pyrolysis.

4. PROCESS PARAMETER CONDITION

A. Type of Reactor: Batch Type Reactor
Batch reactor is a closed system with no inflow or outflow of reactants or products while the reaction is being carried out. High conversion in batch reactor can be achieved by leaving the reactant in the reactor for an extended time. The batch type reactor is chosen for its versatility. This is used when processing toxic or highly potent compounds.

B. Temperature
The temperature of this process is about 300-500 degree celcius. As the temperature controls the cracking reaction of the polymer chain hence it is one of the most significant operating parameters in pyrolysis process. Molecules are attracted together by Van der Waals force and this prevents the molecules from collapsed. The vibration of molecules inside the system will be greater when the temperature in the system increases and molecules tend to evaporate away from the surface of the object. This happens due to the energy created by Van der Waals force in the polymer chains is higher than the enthalpy of the C–C bond in the chain, which results in the breakage of carbon chain.

C. Catalyst
Catalyst speeds up chemical reaction but remains unchanged towards the end of the process. When catalyst is used, the activation energy of the process is lowered down, thus speeds up the rate of reaction. Therefore, catalyst reduces the optimum temperature required and this is very crucial since the pyrolysis process requires high energy. Catalyst used in this process is Potassium Hydroxide.

D. Heating Element: Tungsten coil
Tungsten coil of length 2 meter is used as a heating element. The coil is wound around the reactor drum of about 10 turns in order to provide electrical heating to the reactor when supply is switched on. We have selected this coil because of its lowest coefficient of thermal expansion which is suitable for heating at high temperature, highest tensile strength, the electrical conductivity of the tungsten coil is good compared to other coils.

E. Condenser
A condenser is a device or unit used to condense a substance from its gaseous to liquid state by cooling it. It is typically a heat exchanger and its size varies depends upon its application. Here we are using a
square shape metallic condenser. The gaseous hydrocarbons at a temperature of about 350 degree are condensed to about 30-35 degree celcius. The copper tube of length 0.2 meter is immersed in the condenser through which the gas flows. The condenser is filled with the water at normal temperature and a copper tube is placed in it. Copper tube is selected since it is a non corrosive material when it comes in contact with water and it is suitable for the flow of gas. It plays a very important role in the conversion of plastic to the fuel. A valve is fixed at the bottom of the condenser for the collection of the oil.

5. CHARACTERISTICS OF PYROLYSIS OIL

The oil produced in the pyrolysis process is acidic in nature with a PH of 1.5-3.8. The acidity can be reduced by adding the base components. It is a complex mixture of hydrocarbon which can be purified at oil refinery and can be used as a fuel transportation, heating and power generation. It is typically brown in nature with a pungent odor. The density of the oil is about 1170 kg/m^3, the higher heating value of oil is 16-23MJ/L, it has low PH value around 3.

6. BY-PRODUCTS OF PYROLYSIS PROCESS

The major by-product of this process is char and gas. The proportion of the by-product depends on temperature, heating rate, pressure and residence time.

A. Char

Char is a black colour substance formed at the bottom of the reactor drum, the char formation depends upon the temperature. The main components of the char is volatile matter and fixed carbon while moisture and ash are minor components. It is used as a road surfacing, building material as a feedstock in the production of activated carbon and as a solid fuel in boilers for power generation.

B. Gas

The gas produced depends upon the type of the plastic used in the process. The main components present in the gases are hydrogen, methane, ethane, ethane, propane, butane, butene. The gases are used in gas turbines for the production of electricity and a direct firing in boilers in power plants.

7. ADVANTAGES OF THIS PROCESS

Problems related to the disposal of waste plastics can be solved. Plastics can be converted into high value fuel, which can be used as an alternative fuel. The crude oil can be used for electricity generation and cost of the power can be reduced. Volume of waste present in the environment can be reduced thereby protecting the nature. Environmental effects such as global warming and green house effects can be reduced. It is a non toxic process for the production of bio fuel.

Insulator

Cotton is used as an insulator in the module, two layers of cotton layer is wounded around the heating element. It provide protection to avoid direct contact from the heating coil. Cotton is used as an insulator because of its high resistance to the heat flow and low of cost.
8. PYROLYSIS OIL

Pyrolysis oil, is also known as a biocrude or bio oil. It is obtained by heating waste plastic without oxygen in a reactor in presence of catalyst at a temperature of about 350-500 degree celcius with constant cooling. It is a fuel for the production of heat and electricity, raw materials for the production of petrochemical products. It is an Eco friendly method and is a good helper in ‘SWATCH BARATH’.

It plays an important role in make in India. The cost of pyrolysis oil is very less compared to petrol and diesel rate.

The pyrolysis oil can be blend with diesel and it can be used in diesel generators for power generation. This process can meet the requirement of the electricity in a remote villages where grid system cannot be applicable.

It can also be used as an alternative fuel for kerosene in cooking, burning woods.

9. MATHEMATICAL EXPRESSIONS FOR DESIGN

Heat Produced

\[ q = s \cdot m \cdot \Delta T \]  
\[ q = 1900 \cdot 10 \cdot 475 \]  
\[ q = 90.25 \cdot (10^3) \]  

Power Produced

\[ Power = \frac{\text{work}}{\text{time}} \]  
\[ Power = \frac{90.25 \cdot (10^3)}{45 \cdot 60} \]  
\[ Power = 3342.5W \]  

Current Produced

\[ I = \frac{P}{V} \]  
\[ I = \frac{3342.5}{230} \]  
\[ I = 14.5A \]
10. OIL EXTRACTING SET UP

Fig.1: Pyrolysis Setup

Fig.2: Pyrolysis Reactor

Fig.3: Oil Collection
Figure 1 shows the full setup for the biofuel production which consists of reactor, condenser, catalyst chamber and oil outlet tube. The power supply is switched on to start the operation by placing the 1.5 kg of plastic inside the reactor which is shown in Figure 2. With a short duration, the oil is coming out of the oil collector tube which is shown in Figure 3. The power supply is switched off after 140 minutes, then the collected oil is measured and it is given in Table 2.

| Amount Of Plastic Used | Amount Of Catalyst Used | Duration Of The Process | Oil Collected |
|------------------------|-------------------------|-------------------------|---------------|
| 1.5 Kg                 | 6g                      | 140 Minutes             | 500ml         |

11. CONCLUSION

The solution for environmental and energy issues are fulfilled by pyrolysis, which has been found the most effective technique of conversion of waste plastic to fuels. It has the potential to convert most energy from plastic waste to liquid, gas and char. Since the amount of plastic wastes available in every country is reaching millions of tons, the sustainability of this process is not questionable. This solves the problem in energy demand and also the dependence on fossil fuel as the non-renewable energy can be reduced. The use of this oil in diesel engine in the aspect of technical and economical is compared and found that the oil is able to replace the diesel oil. The liquid obtained in this process has relatively higher volume and low boiling range. It is noticeable that the fuel obtained in this process is cleaner compared to the conventional fuels.

12. REFERENCE

[1]. V. B. Chanashetty and B. M. Patil, "Fuel from Plastic Waste," International Journal on Emerging Technologies, vol. 6, 2015.

[2]. L. Jeftic, S. Sheavly, E. Adler and N. Meith , "Marine Litter: A global Challenge," UNITED NATIONS ENVIRONMENT PROGRAMME, Nairobi , 2009.

[3]. P. M. Bhatt and P. Patel , "SUITABILITY OF TYRE PYROLYSIS OIL (TPO) AS AN ALTERNATIVE FUEL FOR INTERNAL COMBUSTION ENGINE," International Journal of Advanced Engineering Research and Studies , vol. 1, 2012.

[4]. N. D. L. Rao, J. L. Jayanthi and D. Kamalakar , "Conversion of waste plastic into alternative fuel" International journal of siences and technology, 2015.

[5]. Derrick Zechmair, Kurt Steidl Siemens and Erlangen Germany, “Why the Induction Motor could be the better choice for your electric vehicle program", World Electric vehicle Journal, vol. 5, 2012.
[6]. Malcolm Burwell, James Goss and Mircea Popescu,"Performance comparison of induction-motor and permanent-magnet-motor in a hybrid electric car"

[7]. Rajan Kumar and Bhim Singh," BLDC Motor-Driven Solar PV Array-fed Water Pumping system employing Zeta Converter", IEEE Transactions on Industry application, Vol. 52, No. 3, May 2016.

[8]. Jacek F,Gieras, Rong Jie Wang, Maarten Kamper, “Axial Flux Permanent Magnet Brushless Machines, 2 nd Edition, Springer Netherlands: 2008.

[9]. Tashakori.A, Ektesabe.M, Hossein Zahedi.N,"Modeling of BLDC Motor with Ideal Back EMF for Automotive Applications", Proceedings of the World Congress on Engineering 2011,Vol II,July 6-8,London. U.K.

[10]. A. K. N and N. Sindhu , "Microwave Assisted Pyrolysis of Plastic Waste,* in Global Colloquium in Recent Advancement and Effectual Researches in Engineering, Science and Technology (RAEREST 2016) , 2016 .

[11]. Z. Xiangxue, A. Jie, W. Yuzhong et al., “Progress of producing vehicle fuels from cracking waste plastics,” Chemical Industry and Engineering Progress, vol. 31, 2012.

[12]. L. Guangyu, L. Jian, M. Xiaobo et al., “Pyrolysis of MSW plastics: technologies and their reactors,” Environmental Engineering, vol. 27, 2009.

[13]. D.-M. Zheng, Q.-F. Lu, M. Liu, and Y.-X. Chen, “Study on the catalytic cracking of waste plastics and waste lubricating oil for producing fuel oil,” Modern Chemical Industry, vol. 31, 2011.

[14]. W. Chao, M. Xiaobo, W. Hai et al., “Study on effective thermal conductivity coefficient of plastic wastes pyrolysis process,” Materials Review, vol. 27, 2013.

[15]. Y.-B. Liu, X.-B. Ma, D.-Z. Chen, L. Zhao, and G.-M. Zhou, “Copyrolysis characteristics and kinetic analysis of typical constituents of plastic wastes,” Proceedings of the Chinese Society of Electrical Engineering, vol. 30, 2010.

[16]. D. S. Achilias, C. Roupakias, P. Megalokonomos, A. A. Lappas, and E. V. Antonakou, “Chemical recycling of plastic wastes made from polyethylene (LDPE and HDPE) and polypropylene (PP),” Journal of Hazardous Materials, vol. 149, 2007.

[17]. M. Sarker, M. M. Rashid, R. Rahman, and M. Molla, “Conversion of low density polyethylene (LDPE) and polypropylene (PP) waste plastics into liquid fuel using thermal tracking process,” British Journal of Environment & Climate Change, vol. 2, 2012.

[18]. E. A. Williams and P. T. Williams, “Analysis of products derived from the fast pyrolysis of plastic waste,” Journal of Analytical and Applied Pyrolysis, vol. 40-41, 1997.

[19]. P. T. Williams and E. A. Williams, “Fluidised bed pyrolysis of low density polyethylene to produce petrochemical feedstock,” Journal of Analytical and Applied Pyrolysis, vol. 51,1999.

[20]. K.-H. Lee, “Thermal degradation of heavy pyrolytic oil in a batch and continuous reaction system,” Journal of Analytical and Applied Pyrolysis, vol. 86, 2009.

[21]. W. Kaminsky, M. Predel, and A. Sadiki, “Feedstock recycling of polymers by pyrolysis in a fluidised bed,” Polymer Degradation and Stability, vol. 85, 2004.

[22]. H. Schmidt and W. Kaminsky, “Pyrolysis of oil sludge in a fluidised bed reactor,” Chemosphere, vol. 45, 2001.
[23]. NHK K. ISMAIL*,”Estimation Of Reliability Of D Flip-Flops Using Mc Analysis”, Journal of VLSI Circuits And Systems 1 (01), 10-12,2019.

[24]. Sulyukova,”Analysis of Low power and reliable XOR-XNOR circuit for high Speed Applications”,Journal of VLSI Circuits And Systems 1 (01), 23-26,2019.