Design and Fabrication of a Pyrolysis Reactor for Production of Oil by Using Waste Plastic

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***Abstract*: The development of alternative fuel technologies made possible to provide the replacement of fossil fuels. Focused technologies are Bioethanol; Biofuels derived from Biodiesel lipids, recycling of waste oils, Pyrolysis, Gasification, Dimethyl ether and Biogas. Recycling and refining are petroleum-based plastic waste (PBPW) that convert it into reusable products like petrol and heavy oil. The goal is to design and fabricate a pyrolysis reactor for oil production or the conversion of plastic waste into oil through a pyrolysis process. The pyrolysis reactor is composed of stainless steel. The pyrolysis process consists of thermal degradation of waste in the absence of air. In this study Polyethylene terephthalate (PET) type of plastic is used. Under the conditions of pyrolysis, plastic waste can be decomposed into three fractions of liquid or oil production, gases and solid waste or black residue or ash. First different samples of oil and ash were collected and then analyse their different characteristics such as moisture content, boiling point, density, volatile solids etc. in laboratory and flue gases were analysed by using Gas chromatography device. In this study four experiments of oil production have done and it was observed that the yield of oil in first experiment was 270-300 ml at 290 ºC, similarly in second experiment the yield become 370 ml at 205 ºC and in third experiment it was calculated as 2.8 litres at 120 ºC temperature similarly in fourth experiment oil production was 2.789 at 127 ºC temperature. But first two experiment produce less oil because of high fumes as compare to last two experiments with high production of oil. The very less emissions were produced in last two experiments so the pyrolysis process generate less toxic and harmful gases unlike incineration.**

Keywords: **Fabrication, Pyrolysis, Oil, Waste Plastic**

I. INTRODUCTION

The use of plastics has steadily increased in the packaging sectors, which indirectly leads to an increase in the volume of plastic waste which poses a threat to the environment. Recent statistics say that most plastic waste is generated by packaging industries that contain polyethylene and polypropylene (Mohanraj et al., 2017) deprived of saving of fossil energy like crude oil, natural gas, or coal the current rate of economic growth is unsustainable. There are numerous substitutions to fossil energy such as biomass, hydropower, and wind energy, another important aspect is suitable waste management strategy. Development and innovation have caused a considerable rise in the production of all types of basic products, which indirectly generate waste. Due to its wide application, adaptability and relatively low-cost plastics have been material. Recycling and refining are petroleum based plastic wastes (PBPWs) by translating them into reusable products like petrol and heavy oil (Demirbas, 2004). Because recycling yields don't have respectable quality and market values, some of the other forms of converting fuel oil from plastic waste include conversion techniques such as catalytic processing, thermal degradation and co-processing (Mohanraj et al., 2017).

Plastic is a non-specific term for an extensive variety of polymers delivered utilizing profoundly refined parts of raw petroleum or chemicals derived from crude oil, known as monomers. Polymers are the monomers with large chain length of the huge number of carbon particles. A few polymers likewise contain oxygen (for instance, polyethylene terephthalate (PET)), while others contain chlorine (polyvinyl chloride (PVC)). Waste plastic is presently one of the principle parts of municipal strong waste (MSW), it is the blend of various plastic items, primarily low thickness polyethylene (LPDE), high thickness polyethylene (HPDE). Polypropylene (PP), polystyrene (PS), polyvinyl chloride (PVC) and remedial polyethylene. PE and PS are the most accessible plastic composes among urban plastic waste (Miandad et al., 2016).

Reusing plastic waste by using pyrolysis process includes, thermal deprivation of the polymeric material by heating at larger temperatures without oxygen to deliver helpful fuel (Owusu et al., 2018). In pyrolysis conditions, plastic waste can be isolated into three divisions: gas, fluid and strong waste (Demirbas, 2004). The creation of plastics requires contribution of crude materials not got from oil for their generation. Around 8% of aggregate world unrefined petroleum creation is utilized as crude material. Crude oil is a mindboggling blend of hydrocarbons, which are isolated and purged by refining and different procedures in an oil refinery. The vast majority of the raw petroleum is utilized for the generation of powers for transport, warming and vitality creation (Owusu et al., 2018).

II. OBJECTIVES

a) To design and fabricate a Pyrolysis reactor for production of Oil
b) To convert the plastic waste into oil by Pyrolysis process
c) To analyse the concentration of different gases by using Gas Chromatography device.

III. MATERIALS & METHODS

A. Stainless Steel

Stainless steel is a combination of iron with at least 10.5% chromium. Chromium delivers a thin layer of oxide on the surface of the steel known as the inactive layer. The reaction tank and valves of the reactor are made up of stainless steel.

B. Galvanized Iron

Galvanized iron (GI) is iron, which has been covered in a layer of zinc to help the metal oppose erosion. The piping system of reactor is made up of galvanized iron

C. Copper

A malleable, ductile, metallic element having a characteristics reddish brown colour .It is used as a conducting coil in this process

D. Glass Wool

Glass wool is a protecting material made from fibers of glass arranged using a binder into a texture similar to wool. The process traps many small pockets of air between the glass, and these small air pockets result in high thermal insulation properties.Glass wool used in main pyrolysis chamber

IV. PROCEDURE

To produce oil (raw) for automobile from waste plastic we designed a lab scale model of pyrolysis which converts raw or waste plastic into oil by pyrolysis process.

A. Stove

A Stove is used to provide sufficient amount of heat to the pyrolysis reactor for pyrolysis process to take place and to covert the plastic inside the chamber to raw oil. It is a portable and fixed apparatus that is used for heating by burning fuel or using electricity

B. Pyrolyser Reactor

Pyrolysis is a thermal decomposition of materials at raised temperatures in a close atmosphere, for example, a vacuum gas. It includes the alteration of chemical composition and is not reversible.

It starts at a temperature of about 200°C -300 °C or 390-570 F

C. Cover of the Reactor

The cover head of the pyrolysis reactor is made up of stainless steel, fixed with nut and bolt, as pyrolysis reactor is a batch process the cover once fixed will be opened after the completion of the process. The temperature gauge and Pressure gauge are fixed on the surface of the cover of the reactor. The diameter of the reactor inlet is 32” (inches)

D. Pressure Gauge

A Pressure Gauge is an instrument used for the measurement of fluid intensity. It is installed on the main pyrolysis chamber.

E. Temperature Gauge

A temperature gauge is a device used to measure the temperature of any item which is being monitored. It is installed on the main pyrolysis chamber.

F. Gas Cylinder

A Gas cylinder or tank is a pressurized vessel or container that is used for storing gases at above atmospheric pressure.

G. Conduit Pipe

A conduit is made up galvanized steel tubing is commonly referred as a rigid conduit. A conduit is used to transfer the gases produced from the main pyrolysis chamber to condenser (cooling agent) for cooling purpose and for the production of oil. It is a 12” (inches) long pipe having diameter of 1” (inch).

H. Condensing Coil

Condensing Coil is a spring shaped coil made up of copper. Its purpose is to convert the gaseous products of oil produced while heating into a condensed liquid form by cooling down the temperature. The diameter of the condensing coil is 0.5" (inch). Water container is used as heat ex-changer for condensing coil to lower the temperature of oil within the condensing coil. The spring shaped coil is placed within the water bath. As liquid passes the coil heat exchanging starts and temperature of water starts rising in order to lower the temperature of condensing coil so the vapor converts into oil form

I. Condenser

A condenser is a device that can be used to consolidate, i.e. to change the physical condition of a substance from its vapor state to its fluid state.

We have used cold water as a condensing fluid that converts the high temperature of gases into liquid form by converting it into oil. It is made up of steel.

J. Oil Collector

The final stage once after the complete process is done is to collect the oil. Here oil can be collected in any bottle or jar as per quantity.

V. Results

Table. 1. Oil production

S. No	Retention Time (min)	Initial temperature (Celsius)	Final Temperature (Celsius)	Oil production (litre)	Atmospheric Conditions
1	50	35	290	0.27-0.3	Windy
2	44	41	205	0.37	Windy
Average	47	38	247.5	0.335	-
3	90	41	120	2.8	Normal
4	83	40	127	2.789	Normal
Average	86.5	40.5	123.5	2.7945	-

VI. CONCLUSION

We successfully accomplish our very first objective i.e. designed and fabrication of the Pyrolysis reactor on lab scale. While heading forward for operation of the project we faced several difficulties and errors regarding design of the project, specifically leakages. Initially gasket being used to prevent leakages from main chamber's opening. The gasket failed twice after being operated multiple time (gasket was unable to bear the inner temperature and results in contraction). In result of using gasket the fumes came out by leaving pyrolysis incomplete. At last the sealing was replaced by string of asbestos (physical appearance as rope) to prevent the vapor emission from top opening of pyrolysis reactor. The asbestos layer worked perfectly and we checked that sealing again and again with water evaporation (3 times). While we started pyrolysis of oil, another point of leakages was identified i.e. from nuts and bolts at closing of main chamber. The metallic sealing (washer) found to be failed to stop fumes emissions but the rubber (from wasted tire tube) worked quite efficiently. After fixing all the leakages from every single point we completed our second objective which is production of fuel oil.

REFERENCES

[1]. Al-Salem, S., Antelava, A., Constantinou, A., Manos, G. and Dutta, A., 2017. A review on thermal and catalytic pyrolysis of plastic solid waste (PSW). *Journal of Environmental Management*, 197, pp.177-198.

[2]. Anon, 2018.[online]Availableat:https://www.linkedin.com/pulse/benefits-using-waste-plastic-fuel-conversion-plant-zhang-yanan [Accessed 22 Mar, 2018]

[3]. Ahmed, M.H., Pawar, M.S. and Balkunde, M.B., WASTE PLASTIC PYROLYSIS

[4]. Chanashetty, V.B. and Patil, B.M., 2015. Fuel from Plastic Waste. *International Journal on Emerging Technologies*, *6*(2), p.121.

[5]. Demirbas, A., 2004. Pyrolysis of municipal plastic wastes for recovery of gasoline-range hydrocarbons. *Journal of Analytical and Applied Pyrolysis*, *72*(1), pp.97-102.

[6]. Fivga, A. and Dimitriou, I., 2018. Pyrolysis of plastic waste for production of heavy fuel substitute: A techno-economic assessment. Energy, 149, pp.865-874.
[7]. Kiran, N., Ekinci, E. and Snape, C., 2000. Recycling of plastic wastes via pyrolysis. *Resources, Conservation and Recycling*, 29(4), pp.273-283.
[8]. Mohanraj, C., Senthilkumar, T. and Chandrasekar, M., 2017. A review on conversion techniques of liquid fuel from waste plastic materials. *International Journal of Energy Research*, *41*(11), pp.1534-1552.
[9]. Miandad, R., Barakat, M., Aburiazaiza, A., Rehan, M. and Nizami, A., 2016. Catalytic pyrolysis of plastic waste: A review. *Process Safety and Environmental Protection*, 102, pp.822-838.
[10]. Mani, M., Subash, C. and Nagarajan, G., 2009. Performance, emission and combustion characteristics of a DI diesel engine using waste plastic oil. *Applied Thermal Engineering*, *29*(13), pp.273
[11]. Owusu, P., Banadda, N., Ziwa, A., Seay, J. and Kiggundu, N., 2018. Reverse engineering of plastic waste into useful fuel products. *Journal of Analytical and Applied Pyrolysis*, 130, pp.285-293.
[12]. Patni, N., Shah, P., Agarwal, S. and Singhal, P., 2013. Alternate Strategies for Conversion of Waste Plastic to Fuels. *ISRN Renewable Energy*, 2013, pp.1-7.
[13]. Panda, A., Singh, R. and Mishra, D., 2010. Thermolysis of waste plastics to liquid fuel A suitable method for plastic waste management and manufacture of value-added products—A world prospective. *Renewable and Sustainable Energy Reviews*, 14(1), pp.233-248.
[14]. Raja, A. and Murali, A., 2011. Conversion of plastic wastes into fuels. *Journal of Materials Science and Engineering. B*, *1*(1B), p.86.
[15]. Siddiqui, M. and Redhwi, H., 2009. Pyrolysis of mixed plastics for the recovery of useful products. *Fuel Processing Technology*, 90(4), pp.545-552.
[16]. Syamsiro, M., Saptoadi, H., Norsujianto, T., Noviasri, P., Cheng, S., Alimuddin, Z. and Yoshikawa, K., 2014. Fuel Oil Production from Municipal Plastic Wastes in Sequential Pyrolysis and Catalytic Reforming Reactors. *Energy Procedia*, 47, pp.180-188.
[17]. Tsai, C., Chen, M., Chang, K., Chang, F. and Mao, I., 2009. The pollution characteristics of odor, volatile organ chlorinated compounds and polycyclic aromatic hydrocarbons emitted from plastic waste recycling plants. *Chemosphere*, 74(8), pp.1104-1110.
[18]. Williams, P. and Slaney, E., 2007. Analysis of products from the pyrolysis and liquefaction of single plastics and waste plastic mixtures. *Resources, Conservation and Recycling*, 51(4), pp.754-769.
[19]. Williams, E. and Williams, P., 1997. The pyrolysis of individual plastics and a plastic mixture in a fixed bed reactor. Journal of Chemical Technology & Biotechnology, 70(1), pp.9-20.