Journal of Mines, Metals and Fuels, *71(12B): 161-166; 2023. DOI: 10.18311/jmmf/2023/45546*

Print ISSN : 0022-2755

Journal of Mines, Metals and Fuels

Contents available at: *www.informaticsjournals.com/index.php/jmmf*

Fabrication of a System to Convert Waste Plastic into Fuel

S. B. Arun*, P. Harsha Vardhan, K. B. Nandan, N. S. Preetam, and T. M. Rajath

Department of Mechanical Engineering, Siddaganga Institute of Technology, Tumkur - 572103, Karnataka, India; arunsb@sit.ac.in

Abstract

The widespread use of plastics in numerous industries over the worldwide has expanded its output throughout time. The constant demand for plastics resulted in the piling of its garbage in landfills, which occupied a lot of space and contributed to the environmental disaster. Plastics consumption increased, resulting in the depletion of petroleum products which is a non-renewable fossil energy source, as plastics were petroleum-based materials. As a result, pyrolysis is offered as a tertiary recycling method. Pyrolysis is the thermal decomposition of materials in the absence of oxygen at high temperatures (or an inert atmosphere). In the presence of heat, it is a chemical reaction process that includes the molecular breakdown of bigger molecules into smaller ones. Plastic trash pyrolysis might play an essential role in transforming this solid waste with high thermal energy into power and commercially expensive hydrocarbons that can be utilised as fuels or feed stock in the petrochemical sector. The composition of the plastic waste influences the end product yields and attributes. This work has unleashed the possibilities to obtain the fuel from the waste plastics, utilising the renewable resources with the temperature range of about 180-220 °C was achieved with our pyrolysis reactor. The fuel with different compositions of plastics were obtained through the pyrolysis method under the absence of the oxygen in a closely monitored environment obtaining a combustible fuel and later on, the fuel properties were tested and analysed with various trial and error methods.

Keywords: *Depolymerization, Fossil Fuels, Hydrocarbons, Plastics, Pyrolysis, Waste Management*

1.0 Introduction

Plastic is one of the most often used products in our everyday lives and has a significant impact on the community[1]. They are frequently utilised in the fabrication and production of goods like as electronics and vehicles. Plastics are lightweight and simple to build with. They have an unparalleled demeanour. As a result, there has been considerable progress in the use of plastics in place of wood and metal.

Alexander Parkes created plastic in 1860 and it has a high molecular weight[2]. They are polymerized organic compounds[3]. It may comprise components other than polymers to cut costs and increase performance. These polymers may be formed or extruded into the required shape. Pyrolysis is the heating and disintegration of polymeric materials at temperatures ranging from 250 °C to 350 °C without the oxygen-carrying structure of carbonised singe (solid deposits) and the unexpected[4]. A component that can be separated into concentrated hydrocarbon oil and high-calorie gas according to Scheirs[5], gases produced during the pyrolysis of natural resources include Carbon monoxide, Hydrogen, Methane, Carbon dioxide, Water, and hydrocarbons such as Ethane, ethane-propane, propane, butane, and so on[6]. Temperatures and may be regulated to create the appropriate solid, gas, and liquid products since they have a significant influence on the pyrolysis process[7].

*Author for correspondence

The demand for plastics in India alone is 8 million tonnes per year. Plastics are created in India at a rate of more than 10,000 metric tonnes per day, with almost the same quantity imported. Plastic capital usage in India is around 3 Kg, compared to 30 Kg to 40 Kg in wealthy nations[8]. The majority of this comes from packaging and food industries. Many plastics are recycled and sometimes made due to the lack of market enough value for disposable plastics that can be recycled about 43 percent by polyethylene, most of which is packaged in containers and packaging[9]. Mining Industry alone accounts for 10 percent of world energy consumption. It is equivalent to 80 percent of electricity use worldwide. Also mining has greater impacts on environment in form of pollution, conventional fuels used in mining has a high sulphur content unlike plastic fuels which is cleaner burning fuel with low sulphur content. Mining operations is highly energy intensive from Haul trucks, excavators, drill rigs to loaders and generators. Global production for over 35,000 mines is available in SNL database.

2.0 Materials and Methods

2.1 Types of Plastics

2.1.1 Polyethylene Terephthalate

Group One polymers are produced using PET, or polyethylene terephthalate. It is frequently used for food and beverage packaging and is ranked top because of its wide range of applications in preventing oxygen from entering and damaging the contents[10].

It has a solid track record and is frequently collected by the majority of curbside recycling programs. In actuality, PET bottles are the most extensively recycled plastic in the world[11].

2.1.2 High Density Polyethylene

High-density polyethylene, or HDPE, is a durable plastic that is used to make shampoo bottles, shopping bags, milk jugs, recycling bins, playground equipment, and lids. It is far thicker and tougher than PET because it is composed of long, unbranched polymer chains. In addition, it can tolerate temperatures as high as 120 °C without degrading and is quite sturdy and impact resistant. Most recycling facilities across the world accept HDPE since it is one of the most easily recycled plastic polymers.

2.1.3 Low-Density Polyethylene

LDPE, Low-Density Polyethylene, has lower-density molecules than HDPE, making it thinner and more flexible. It has the most basic structure of any polymer, making production easy and economical. It can be found in plastic bags, six-pack rings, various containers, dispensing bottles, and most notably, plastic wraps.

2.1.4 Polyvinyl Chloride

The third most popular synthetic plastic polymer available today is polyvinyl chloride. Both stiff and flexible variants are offered. In the architecture and construction industry, stiff PVC is frequently used to create door and window profiles as well as pipes (for sewerage and drinking water). It may be made softer and more flexible by mixing it with other materials, and then used for flooring, electrical, plumbing, and cable insulation.

2.1.5 Polypropylene

The market for polypropylene, the second most popular commodity plastic, is anticipated to expand more in the coming years. It is utilized in Tupperware, car parts, thermal jackets, yogurt containers, and even disposable diapers due to its hardness and endurance.

2.1.6 Polystyrene

The sixth plastic on the list is polystyrene, which is easy to make and has a cheap cost per unit weight. It may also be foamed. It may be found in many products, including as disposable tableware, packaging materials, drinking cups, and insulation. More often recognized by its brand name, Styrofoam, this highly flammable and dangerous material can leak lethal substances when heated[12].

Because it isn't biodegradable, it's among the worst kinds of plastic for the environment. Second, polystyrene foam floats on water and blows in the wind because of its low specific gravity. Furthermore, even in cases when it is practical, it is not separated and recycled and is not acknowledged in curbside recycling programs.

2.1.7 Mixed Plastic

Polycarbonates (PC) are the most well-known of this group of plastics, which are used to make robust and durable items (Figure 1). Polycarbonates are frequently utilized in the manufacture of lenses for sunglasses,

Figure 1. Types of plastics[13].

sports, and safety goggles. However, they can be found on mobile phones and, more commonly, Compact Discs (CD). These plastics have not been recycled majority of the times[13].

2.2 Methodology

The thermal degradation of plastic at high temperatures in the absence of oxygen is known as pyrolysis (or inactive atmosphere). It contains distinctions in the integration process, which is irreversible. Pyrolysis is derived from the Greek words pyro (fire) and lysis (separation). It creates flexible products and leaves a solid residue rich in carbon, char, during biological pyrolysis. Excessive pyrolysis produces mostly carbon as a byproduct, which is referred to as carbonization[14].

In our setup, the plastic is subjected to the heat of temperatures 250-300 °C with fuel obtaining at temperatures of 180-220 °C during various trials, depending on the plastics that has been subjected to the reactor. The reactor is covered with glass wool throughout and the surroundings are placed in a way so that the loss of heat is as low as possible and to get the results with less energy and temperature. As the plastics reach their melting temperatures, they melt and the vapors are risen upwards due to the constant heat and are condensed by using a Liebig condenser that is connected from the gas inlet from one end to the collector tank vertically and connected to water source that is connected via a motor in horizontal ends. This system acts as a counter flow heat exchanger with the faster rate of heat transfer occurring through. The gases are then cooled down during this process and the fuel is obtained at the collector tank along with the gases and the solid residue which is generally known as Char (Figure 2).

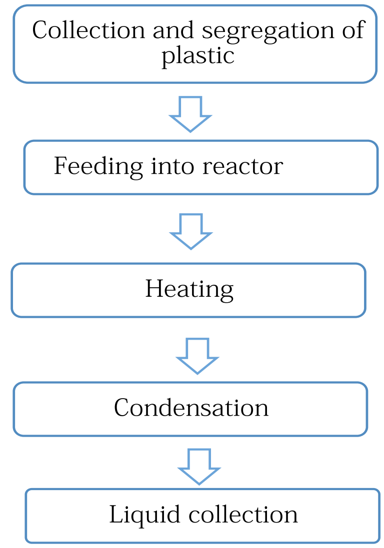

Figure 2. Flow diagram.

Based on various heating conditions, types of plastic used and the presence or absence of the Catalyst, the percentages of the liquid fuel, gases and the char vary accordingly.

3.0 Steps Involved in the Process

3.1 Collection and Segregation of Plastic

Plastic waste is collected from many sources, including households, hotels, and markets, and divided into different categories. Food containers, milk covers, water bottles, packaging foams, throwaway cups and plates, and shopping bags are among the different sorts of waste plastic. PET, HDPE, LDPE, and other polymers can be separated. After separation, the plastic is cleaned with soap water to eliminate any impurities such as dust and debris. The plastic is then sun-dried to remove any remaining moisture before being chopped into little pieces[15].

3.2 Feeding into Reactor

The waste plastic is injected into the reactor after it has been chopped into little bits (Figure 3). The reactor is of Cast iron. The flange is opened, and plastic particles are delivered into the reactor before it is closed again. Any reactor leakage must be avoided at all costs. As a result,

Figure 3. Feeding of plastics into the reactor.

there is a gasket supplied. However, the gasket must be able to endure high temperatures or it would burn out.

3.3 Heating

The reactor is heated by an electric heater. The heating element is a copper coil, and the power source is 230 V, 50 Hz AC with a 2 KW capacity (Figure 4). The desired temperature is recorded and maintained using a temperature indicator and controller. In 15 minutes, the heater can raise the temperature to 200 °C and the temperature metre and controller can record temperatures upto 1200 °C[16].

Figure 4. 2 KW Electric coil heater[16].

3.4 Condensing

Plastic waste is evaporated at temperatures ranging from 180 °C to 300 °C. Using a Liebig tube condenser, this vapour is condensed to atmospheric temperature (Figure 5). Plastic waste condenses and evaporates at temperatures

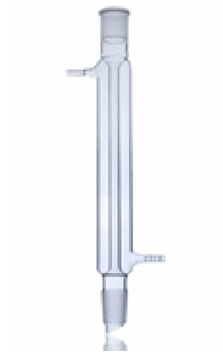

Figure 5. Liebig condenser.

ranging from 180 °C to 300 °C. Using a tube condenser, this vapour is condensed to atmospheric temperature[16].

3.5 Liquid Collection

The condenser vapour is condensed and collected at the liquid collector. The liquid collector is essentially a small tank filled 3/4 of the way with water. The condensed fuel is collected in a chamber that is submerged in water to cool (Figure 6). For the gases to exit later, escape vents are provided.

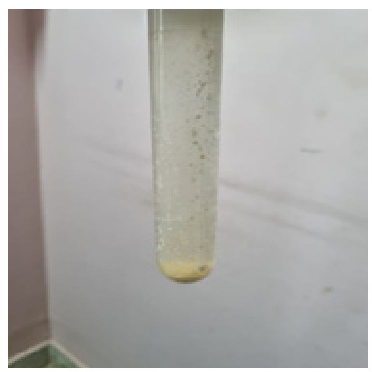

Figure 6. Obtained fuel.

4.0 Pyrolysis Reactor Design

The Pyrolysis Reactor Design is shown in the Figure 7.

5.0 Results and Discussion

From our work, we were able to obtain 37.5 ml to 60 ml of fuel for 200 grams of LDPE plastics in the form of plastic bottles were collected from the various sources such as hotels, dump yards and were crushed and fed into the

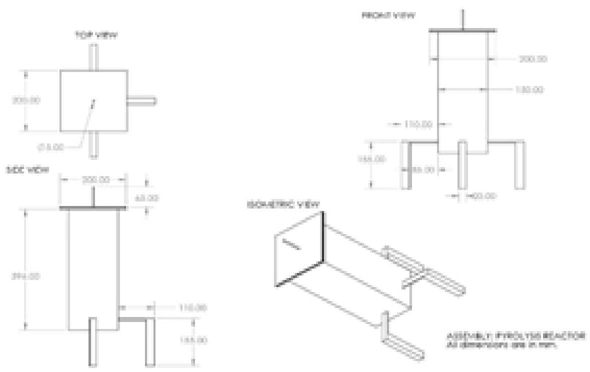

Figure 7. Pyrolysis Reactor CAED drawing.

reactor with the temperature maintained uniformly at 180 °C, subjected to constant heat. The properties of the fuel obtained are as the Table 1.

Table 1. Parameters observed

Density	753.6 Kg/m^3
Fire point	19 °C
Flash point	24 °C
Process Efficiency	30 %

6.0 Conclusion

This review reveals that the liquid fuel derived from waste plastic is a feasible technique to discover new energy sources while addressing the significant issue of plastic waste management. In India, 34 lakh tonnes of trash were created between 2020 and 2021. Plastic misuse is a hazardous and poisonous concern for both individuals and the environment. Recycling devices are ineffective at reducing the problem of plastic waste. Burning, gasification, and a furnace are a few more inefficient methods of dealing with the problem of plastic waste owing to air pollution and cost inefficiency when compared to waste plastic fuel by pyrolysis. Rising electricity demand due to urbanisation, population expansion, industry, and rising fuel prices can be addressed by efficiently executing the waste plastic recycling programme.

These waste plastic fuels obtained from the pyrolysis process are comparatively eco-friendly due to their low pollutant content, good engine performance characteristics, and lack of additives. This, in addition to solving the problem, creates job opportunities if implemented on a large scale and is a profitable model.

There are many companies like Aramco, Purdue Innovation and many more who have begun with commercialisation of Plastic Fuel and have been successful. Also many mining conglomerates have started incorporating the plastic fuels in their operations. The decline of fossil fuels especially petrochemicals that is found in plastic itself, is grabbing lot of eyes on the opportunity of gaining the market for alternative fuels like plastic fuels, as energy is in its peak demand.

Mining being highly fuel intensive for their transport operations as well as energy demanding equipment's, can gain a great shift towards the plastic fuels as it is comparatively cheaper and also serves to environmental cause by reducing plastic incineration.

Progress in this technology is needed at this level because of the urgency depletion of renewable energy sources such as fossil fuels. Therefore, additional studies are needed and it is important to apply them to use as fuel or be utilised as a feedstock.

7.0 References

1. Hammer J, Kraak MH, Parsons JR. Plastics in the marine environment: the dark side of a modern gift. Reviews of Environmental Contamination and Toxicology. 2012; 1-44. https://doi.org/10.1007/978-1-4614-3414-6_1 PMid:22610295
2. Utracki L. History of commercial polymer alloys and blends (from a perspective of the patent literature). Polymer Engineering and Science. 1995; 35(1):2-17. https://doi.org/10.1002/pen.760350103
3. Eze WU, *et al.*, Plastics waste management: A review of pyrolysis technology. Clean Technol. Recycle. 2021; 1:50-69. https://doi.org/10.3934/ctr.2021003
4. Elomaa M., *et al.*, Combustion of polymeric materials. Critical Reviews in Analytical Chemistry. 1997; 27(3):137-97. https://doi.org/10.1080/10408349708052200
5. Kumar A., *et al.*, Study on conversion techniques of alternative fuels from waste plastics, in Energy Recovery Processes from Wastes. Springer. 2020; 213-24. https://doi.org/10.1007/978-981-32-9228-4_18
6. Kyari M, Cunliffe A, Williams PT. Characterization of oils, gases, and char in relation to the pyrolysis of differ-

ent brands of scrap automotive tyres. Energy and Fuels. 2005; 19(3):1165-73. https://doi.org/10.1021/ef049686x

7. Scott D, *et al.,* Fast pyrolysis of plastic wastes. Energy and Fuels. 1990; 4(4):407-11. https://doi.org/10.1021/ef00022a013
8. Mani M, Subash C, Nagarajan G. Performance, emission and combustion characteristics of a DI diesel engine using waste plastic oil. Applied Thermal Engineering. 2009; 29(13):2738-44. https://doi.org/10.1016/j.applthermaleng.2009.01.007
9. Nanda S, Berruti F. Thermochemical conversion of plastic waste to fuels: a review. Environmental Chemistry Letters. 2021; 19(1):123-48. https://doi.org/10.1007/s10311-020-01094-7
10. Tuly S, Joarder MMS, Haque ME. Liquid fuel production by pyrolysis of polythene and PET plastic. in AIP Conference Proceedings. AIP Publishing LLC. 2019. https://doi.org/10.1063/1.5115938
11. Khan MN, Roy JK, Akter N, Zaman HU, Islam T, Khan RA. Production and properties of short jute and short E-glass fibre reinforced polypropylene-based composites. Open Journal of Composite Materials. 2012; 02(02):40-7. https://doi.org/10.4236/ojcm.2012.22006
12. Gao F. Pyrolysis of waste plastics into fuels. 2010.
13. Kumar S, Panda AK, Singh RK. A review on tertiary recycling of high-density polyethene to fuel. Resources, Conservation and Recycling. 2011; 55(11):893-910. https://doi.org/10.1016/j.resconrec.2011.05.005
14. Carroll Jr WF, *et al.,* Poly (vinyl chloride). Applied Plastics Engineering Handbook. 2017; 73-89. https://doi.org/10.1016/B978-0-323-39040-8.00004-3
15. Liu C, *et al.,* Catalytic fast pyrolysis of lignocellulosic biomass. Chemical Society Reviews. 2014; 43(22):7594-623. https://doi.org/10.1039/C3CS60414D PMid:24801125
16. Venumadhav P. Design of a plant to produce 5 ton per day liquid fuel from waste plastic (low density polyethylene). 2015.