ENERGY RECOVERY OF WASTE PLASTICS INTO OIL BY PYROLYSIS PROCESS

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APPROVAL

This is to certify that the project **“Energy Recovery of waste plastics into oil bypyrolysis process”**, By Md safiqul Islam (ID: BME1903019009), Sayed Roman Mia (ID: BME1903019078), Md.Rajab Ali(ID:BME1903019162),Md.Bakhtiar Hassan (ID: BME1903019025), Md.Azizur Rahman(ID:BME1903019017) has beencarried out under our supervision. The project has been carried out in partial fulfillment of the requirements of the degree of Bachelor of Science(B.Sc.) in Mechanical Engineering of years of 2023 and has been approved as to its style andcontents.

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DECLARATION

We hereby declare that the undergraduate thesis project work reported in this thesis has been performed by us under the supervisor of **Niloy Sarkar** and this work has not been elsewhere for any purpose (except publication).

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ABSTRACT

In the present world, fossil fuel is ending day by day. People are making efforts to find an alternative source of energy and scientist experimentally use various chemical substances as an alternative to fossil fuels, and continue researching for commercial use. This is our attempt as a part of it. Besides, finding a reliable way to control pollution by using plastic waste to process properly to avoid environmental pollution and was one of our main objectives. In the past researchers who have made various men of making fuel from waste plastic and trying to find a good study better than those. We have discussed in detail about the various types of plastic properties and tracking methods in this study.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Pyrolysis, a thermochemical decomposition process, involves the application of heat in the absence of oxygen to break down complex organic materials into simpler compounds. It offers a viable solution for transforming waste plastic into valuable products, such as oil, gas, and char, without exacerbating environmental pollution. The process operates at high temperatures, typically ranging from 300 to 800 degrees Celsius, which facilitates the breakdown of plastic polymers into their constituent hydrocarbon molecules.

The oil produced through pyrolysis, commonly referred to as pyrolysis oil or plastic oil, possesses several key characteristics that make it an attractive alternative to traditional fossil fuels. Firstly, it can serve as a source of energy and can be used directly as a fuel for various industrial applications, including power generation and heating. Secondly, the pyrolysis oil can be further refined into higher-grade fuels, such as gasoline, diesel, and even aviation fuel, making it a versatile feedstock for the energy sector.

Fig: Pyrolysis Plant

1.2 OBJECTIVES

The Objectives of this project are:

1. To study of fuel production from waste plastics.

2. To get an idea about different methods of making fuel oil from waste plastics.

3. To study select a better method of making fuel oil to be wasting plastic.

4. To construct a device to extract oil from waste plastic.

CHAPTER 2

LITERATURE REVIEW

2.1 LITERATURE REVIEW

R.T. Karad et al. [1] The pyrolysis is the heating substance in the absence of oxygen. In this study 4300 Celsius temperature need. All type of waste plastic is converting to fuel. It works like Petrol, diesel, kerosene, and LPG. The fuel does not emit sulfur dioxide. (SO2). It increases machine efficiency. The 5% residue is obtained which is carbon black. S. Bhat et al. [2] Production of Oil from Waste Plastics and Polythene using Pyrolysis and its Utilization in Compression Ignition (C.I.) Engine. In the present work, pyrolysis is used for converting waste plastic into fuel oil termed as pyrolytic oil. The results were clearly in favor of pyrolytic oil. The value of NO emissions was higher in comparison to 100% diesel but the emission levels of CO, CO2, and HC were found lower. R. Punia et al. [3] To study is various technologies are being developed to overcome the drawback of plastics, namely, their non-biodegradability. This process involves catalytic degradation of waste plastic into fuel range hydrocarbon i.e. petrol, diesel and kerosene etc. F.Gao et al. [4] Study were to understand and optimize the processes ofplastic pyrolysis for maximizing the diesel range products, and to design a continuous pyrolysis apparatus as a semi-scale commercial plant. M.B. Kutli et al.[5] In this project work an attempt has been made to investigate the conversion of household waste plastic into liquid fuel by usingpyrolysis process, a pyrolysis unit is designed, fabricated and evaluated fdr various kinds of plastic wastes, properties of liquid fuels obtained are determined. A.Asokkumar et al. [6] Study of the increased demand and high price for energy sources are driving efforts to convert organiccompounds into useful hydrocarbon fuels. However, thermal processes can be used to convert plastics into hydrocarbon fuels such as gasoline, diesel, aviation/jet fuel, which have unlimited applications in airline industries, helicopters, heavy transportation, and electricity generation.

E.G. Rapsing et al. [7] Research aimed to evaluate the performance of the waste plastic oil converter. The equipment is a prototype model powered by electricity and utilizes a non- catalytic pyrolysis process of converting waste plastic to oil. M. Z. H. Khan et al. [8] Study Recycling of waste plastics is expected to become the most effective way. Waste plastics recycling, regenerating, and utilizing have become a hot spot of research at home and abroad and gradually formed a new industry. It is anticipated that these results will further the understanding of the applicability and limitations of HDPE as a feedstock for the production of alternative diesel fuel. J. Siddiqui et al. [9] Plastics have been used widely in both water and food packaging due to their natural properties such as inertness and low bulk densities, which make them suitable mover materials and little risk to contaminants. Dr. M. El-Newehy et al. [10] Plastic Waste Management.

CHAPTER 3

Working Principle

3.1 Plastic

Plastic is a high molecular material, Plastics called by Polymers. Plastic is a material that can change its shape. There are many types of plastic. There are different types of waste plastics that have been considered for the study such as PET (Polyethylene Terephthalate), HOPE (High-Density Polyethylene), PVC (Polyvinyl Chloride), (Low-Density Polyethylene), PP (Polypropylene), PS (Polystyrene) plastics. Figure 3.1 [10] Different types plastic Materials, these are used as feed stocks to produce liquid fuel compounds. Plastic wastes are selectively collected from the local area.

Polyethylene terephthalate (PET)

High Density Polyethylene(HDP

Polypropylene (PP)

Polyvinyl chloride (PVC)

Low-density polyethylene

Polystyrene (PS

Figure 3.1: Different type's plastic materials [10]

There are two main types of plastics [1].

i. **Thermoplastics**: Thermoplastics which are softened by heat and can be molded. (Injection molded, blow molded or vacuum formed). Good examples are acrylic, PP (Polypropylene), PS(Polystyrene), Polythene and PVC.

ii. **Thermosets Plastics**: Thermosets Plastics which are formed by ha heat process but are then set(like concrete) and cannot change shape by reheating. Good examples are melamine (kitchen worktops), Bakelite (black saucepan handles), polyester and epoxy resins.

Table 3.1 Different types of waste plastics, recyclability, and their common uses [1]

Type	Code	Abbreviation	Recyclable	Description & Common uses
Type 1	1 **PET**	**PET**	**Yes**	Polyethylene Terephthalate sometimes absorbs odors am flavors from foods and drinks that are stored in them. Items made from this plastic are commonly recycled. PET (E) plastic is used to make many common household terns like beverage bottles, medicine jars, rope, clothing and carpet fiber.
Type 2	1 **HDPE**	**HDPE**	**Yes**	High-Density Polyethylene products are very safe am are not known to transmit any chemicals into foods or drinks. HDPE products are commonly recycled. Items made from this plastic include containers for milk, motor oil, shampoos and conditioners, soap bottles, detergents, and bleaches. It is NEVER safe to reuse an HDPE bottle as a food or drink container if it didn't originally contain food or drink.
Type 3	1 **PVC**	**PVC**	**Yes, But not common**	Polyvinyl Chloride is sometimes recycled. PVC is used or all kinds of pipes and tiles, but is most commonly bund in plumbing pipes. This kind of plastic should not come in contact with food items as it can be harmful if ingested.
Type 4	1 **LDPE**	**LDPE**	**Yes**	Low-Density Polyethylene is sometimes recycled. It is a very healthy plastic that tends to be both durable and flexible. Items such as cling-film, sandwich bags, queezable bottles, and plastic grocery bags are made from LDPE.
Type 5	1 **PP**	**PP**	**Yes**	Polypropylene is occasionally recycled. PP is strong and can usually withstand higher temperatures. It is used to make lunch boxes, margarine containers, yogurt pots, syrup bottles, prescription bottles. Plastic bottle caps are often made from PP.
Type 6	1 PS	**PS**	Yes, but not common	Polystyrene is commonly recycled, but is difficult to do. terns such as disposable coffee cups, plastic food boxes, plastic cutlery and packing foam are made from PS.
Type 7	1 OTHER	**OTHER**	Some	Code 7 is used to designate miscellaneous types of plastic not defined by the other six codes. Polycarbonate and Polylactide are included in this category. These types of plastics are difficult to recycle. Polycarbonate (PC) is used in baby bottles, compact discs, and medical storage containers.

Table 3.2 The following properties of different plastic pyrolysis oil [2]

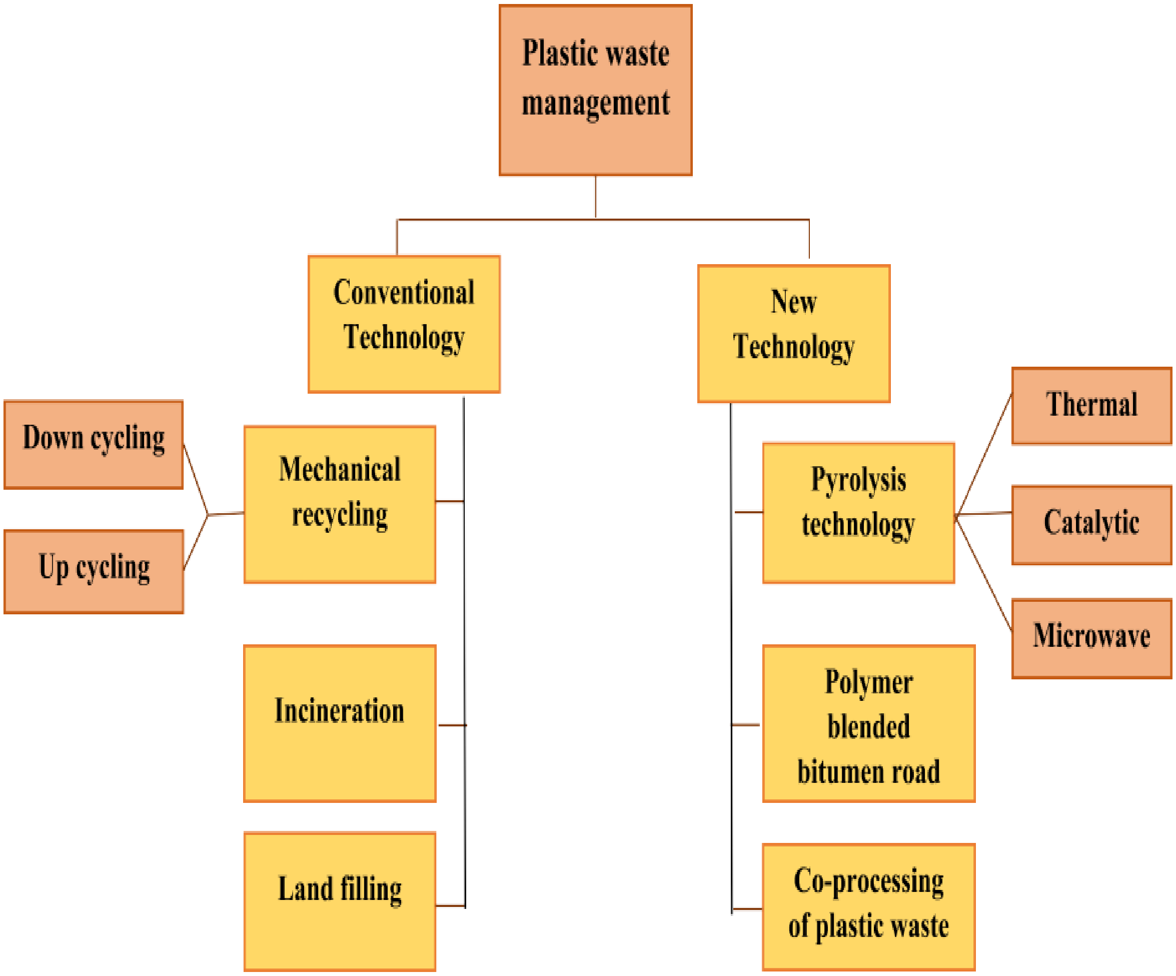
Property Physical)	**Plastic Type**						**Standard Value (Commercial)**	
	PET	HOPE	PVC	LDPE	PP	PS	Petrol	Diesel
Calorific Value	28.2	40.5	21J	39.5	40.8	43.0	42.5	43.0
Viscosity	N/A	5.08	6.36	5.56	4.09	1.4	1.17	1.9-4.1
Density	0.90	0.89	0.84	0.78	0.86	0.85	0.780	1.0-4.1
Pour Point	N/A	-5	N/A	N/A	-9	-67	-	6
Flash Point	N/A	48	40	41	30	26.1	42	52

Type of Plastics as raw materials and its contents in table 3.3 is below.

Table 3.3 Type of plastics and its content [5]

Type of plastics	**Contents**
PE (HDPE, LDPE), PP, PS	Hydro Carbons
PET, PVA, PF	Hydro Carbons With Oxygen
PVC, PVCD	Hydrocarbons With Chlorine
Nylon (polyamide), PU	Hydrocarbons With Nitrogen
Polyphenylene Sulfide	Hydrocarbons With Nitrogen

Figure 3.2. Conventional and new technologies for waste plastic management.



3.2 Catalyst

Use of catalyst

In order to optimize plastic pyrolysis reactions and modify the distribution of pyrolysis products, catalysts are widely used in research and industrial pyrolysis processes. Petroleum fuels, such as LPG, petrol, kerosene, pyrolysis products are mainly straight and diesel, are hydrocarbons from Cl to C24. The PE hydrocarbons from Cl up to C80, which contain much heavier molecular weight components One of the main purposes of using catalysts is to shorten the carbon chain length of the pyrolysis products and thus to decrease the boiling point of the products. Catalysts are found to be mainly applied to PE pyrolysis because the primary product from other plastics, such as PP and PS, are mainly light hydrocarbons, with similar carbon chain length to the range of commercial fuels. The products from non-catalytic PE pyrolysis contain a high proportion of 1-alkenes and darkness. Some catalysts are applied specifically to reduce the unsaturated hydrocarbons and promote the yield of aromatics and naphthenic. This can significantly increase the stability and certain number of oil products. Moreover, it is reported that activation energies (Ea.) measured in the PE pyrolysis with catalysts (such as HZSM-5, HY, and MCM-41) were much lower than those when no catalyst was added.

3.2.1 Catalyst classification

Homogeneous and heterogeneous catalysts have been studied for the catalytic cracking of plastics. Homogeneous catalysts used for polyolefin pyrolysis have mostly been classical Lewis acids such as AIC^. Generally, heterogeneous catalysts are preferred due to their easy separation and recovery from the reacting medium. Heterogeneous catalysts can be summarized as Nano crystalline zeolites, aluminum pillared clays, conventional acid solids, mesostructured catalysts, super acid solids, Gallo silicates, metals supported on carbon, and basic oxides. Among the mentioned catalysts, Nano

crystalline zeolites have been extensively studied for polyolefin pyrolysis and this type of catalystswill be discussed in more details as follows. Zeolite properties: pore size (structure) and Si/Al ratio (acidity)

A zeolite is a crystalline aluminosilicate with a three-dimensional framework structure that formsuniform pores of molecular dimensions. Zeolites act as sieves on a molecular scale and exclude molecules that are too large to pass through the pores. The three-dimensional frame structures

significantly increases the area of the sieves and absorbs molecules that have similar sizes as the pores. According to the structure of zeolites, 176 zeolite framework types have been confirmed. A three-letter code, such as MFI, is assigned to framework types by the Structure Commission of the International Zeolite Association. The codes are normally derived from the name of the zeolite, forexample, MFI from ZSM-5. The MFI framework of ZSM-5 is described as shown in Figure 3.3.

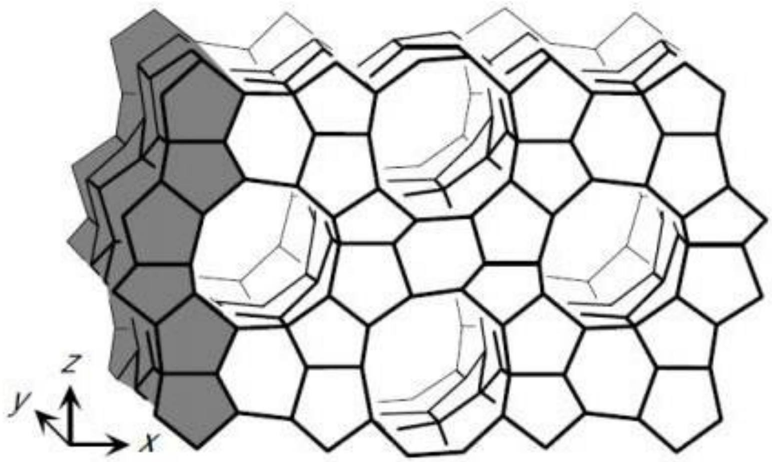


Figure 3.3: The framework type ZSM-5 with pentasil chain parallel to z [4]

The pore openings and sizes are key parameters for the catalytic effect in the plastic which are determined by the size of single ring and the structure features (cages, ty, chains, and channels). Rings are the basic units characterize the pore size. However, :he channel wall in Figure 3.4 [4] is composed of 6-rings and forms a 12- ring channel. Consequently, pore opening can be influenced by the other factor, structure feature.

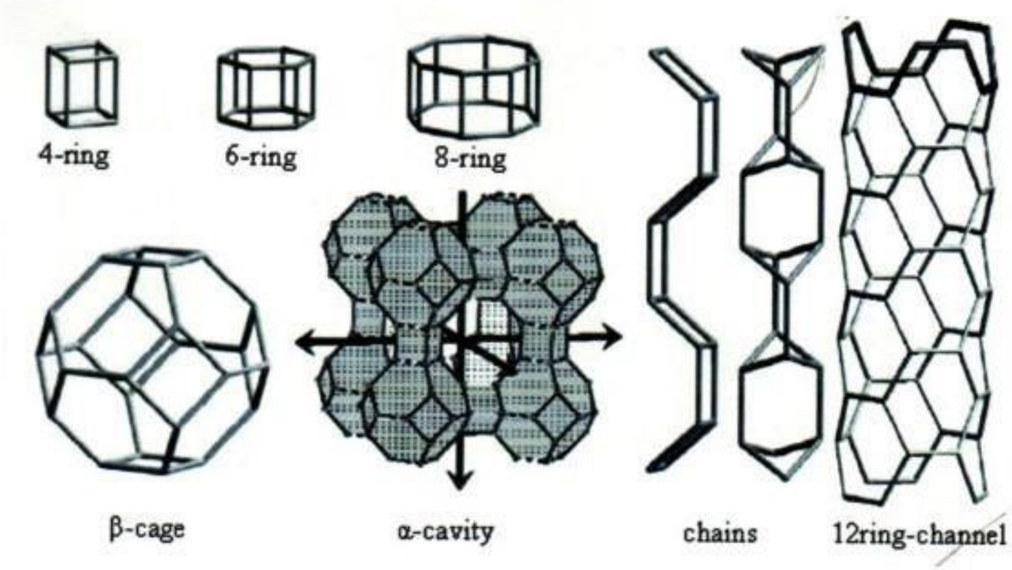


Figure 3.4: Framework types of zeolite [4]

Zeolites are crystalline micro-porous aluminosilicates. Therefore, Si/Al ratio is also an most important parameter for zeolites which is applied to classify the zeolites. The high-silica zeolites, with a Si/Al ratio greater than five such as ZSM-5, are widely used in petrochemical industries. The high silica content in the catalyst makes the framework to stand high temperatures that this type catalyst is suitable for high temperature pyrolysis and regeneration cycle. A high dispersion of acidic protons assures that each proton performs maximum acidity. Consequently, acidity is also an indicator to reflect the property of zeolites. Three - of Nano crystalline zeolite with different Si/Al ratios and specific surface area. High ratio implies a high total acidity of zeolites. These zeolites are preferred for polyolefin cracking. Lower Si/Al ratio implies lower acidity and smaller crystal size of zeolite provide efficiency in terms of conversion. Figure 4.5 [4] The use ofcatalyst is dependent on difficulty of changing catalyst, the cost of catalyst, and the efficiency ofthe catalyst. This in different situations.

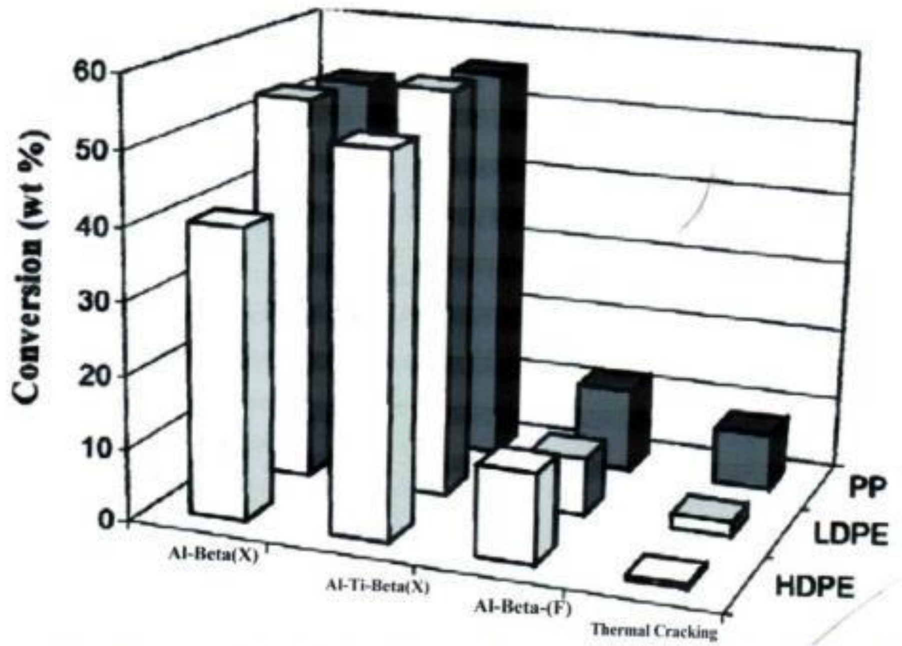


Figure 3.5: Conversion obtained in the thermal and catalytic pyrolysis of HDPE, LDPE, and PP (400°C, 0.5h, plastic/catalyst = 50% w/w) [4]

3.3 Working Procedure

Design parameters of pyrolysis unit

Desirable parameters for the design [5].

I. Melting point of the matter: If melting point is high, matter easily vaporizes & more oilis gained.

ii. Density: If density is lower, matter easily vaporizes & more oil is gained.

iii. Quality of matter: More is quality; more is the yield of oil.

iv. Moisture content: More is moisture, less is the oil yield.

v. Reactor temperature: More is the reactor temperature; more is the yield.

vi. Heating rate: More is the heating rate; more is the yield.

vii. Reactor size: There is an optimum for the reactor size to get maximum oil yield.

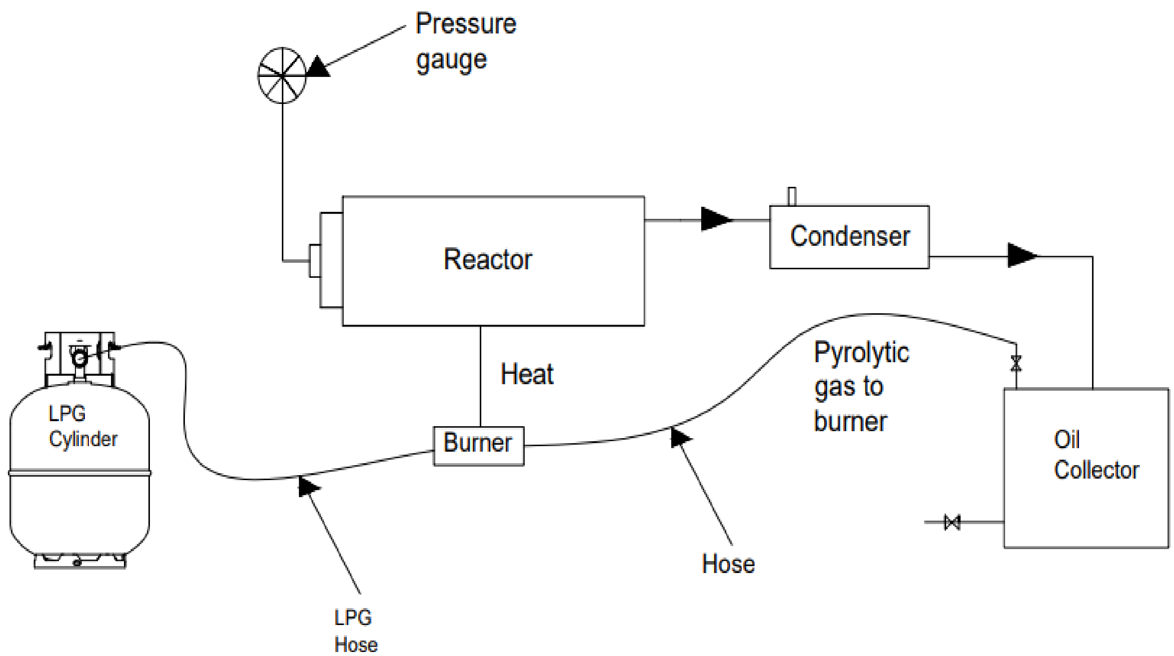
viii. Feed rate: Feed rate is given according to the demand for the oil.

ix. Maintaining a uniform temperature: For continuous production it should maintain auniform temperature.

x. Types of condenser used: Condenser design also effects the production of maximumproduct yield.

3.3.1 Pyrolysis process

1. Firstly, Sort and clean the waste plastics to remove any non-plastic materials such as paper, metal, or glass.
2. Then Load the prepared waste plastics into the pyrolysis reactor. The reactor Shall maintain be designed to withstand high temperatures with the help of LPG as a fuel source and a burner.
3. Then heat the reactor to the desired temperature range, typically between 400 to 550 degrees
   Celsius (750 to 1022 degrees Fahrenheit).
4. After the plastics are heated, the vapors and gases produced during the pyrolysis process has been cooled by condenser.
5. The condensed liquid from the condenser, known as pyrolysis oil, then collected in an oil collector.



Pyrolysis process Diagram

3.4. Equipment

1.Reactor

2.Condenser

3.Burner

4.LPG Cylinder

5.Oil Collector

3.4.1 **Reactor**

It is a Seamless pipe of SA 106 Gr. B, Sch 20, Diameter-12'' and the length is 700mm. The Volume of the Reactor is 0.502 m3 and Raw material capacity is Approx. 2-2.5 kg. One raw material Inlet with a Pressure gauge is installed to the reactor.

3.4.2 Condenser

It cools the entire heated vapor coming out of the reactor. It has an inlet and an outlet for cold water to run through its outer area. This is used for cooling of the vapor.

3.4.3 Burner

The burner used in pyrolysis process is high pressure burners, which have the ability to throw flames with high pressure, it located direct under the reactor with a stand mounted on it.

3.4.4 LPG Gas Cylinder

Liquefied petroleum gas cylinder is used because it does not create any pollution while burningof gas, it has high octane rating which allows it to mix better with air and to bum more completely then does gasoline, generating less carbon. LPG is cheap when we compare it withother power producing fuels so that the overall efficiency of plant increases.

3.4.5 Pressure Gauges

There are various sensors and gauges used to determine and pressure inside the reactor. The pressure gauge is mounted on top of reactor where gas outlet takes place.

3.5 Performance evaluation parameters

The performance of the prototype waste plastic oil converter was evaluated for conversion efficiency (wt %), waste reduction efficiency (wt %), oil recovery (ml oil/kg plastic) and was expressed by the following

1. Conversion efficiency (wt %)

$$CE = \frac{wo}{wsm} \times 100\%$$

Where:

CE = Conversion efficiency

Wo = Weight of oil converted (g)

Wsm = weight of the sample material (g)

2. Waste Reduction Efficiency (wt %)

$$WRE = \frac{wsm - we}{wsm} \times 100\%$$

Where:

WRE = Waste Reduction Efficiency

We = Weight of char inside the reactor (g)

Wsm = weight of sample material (g)

3. Oil Recovery (ml/1%)

$$OR = \frac{v}{wsm}$$

Where:

OR = Oil Recovery (ml/kg)

V= Volume of oil recovered (ml)

Wsm = Weight of sample material (kg)

3.6 Flow diagram of conversion of plastics waste into liquid fuel

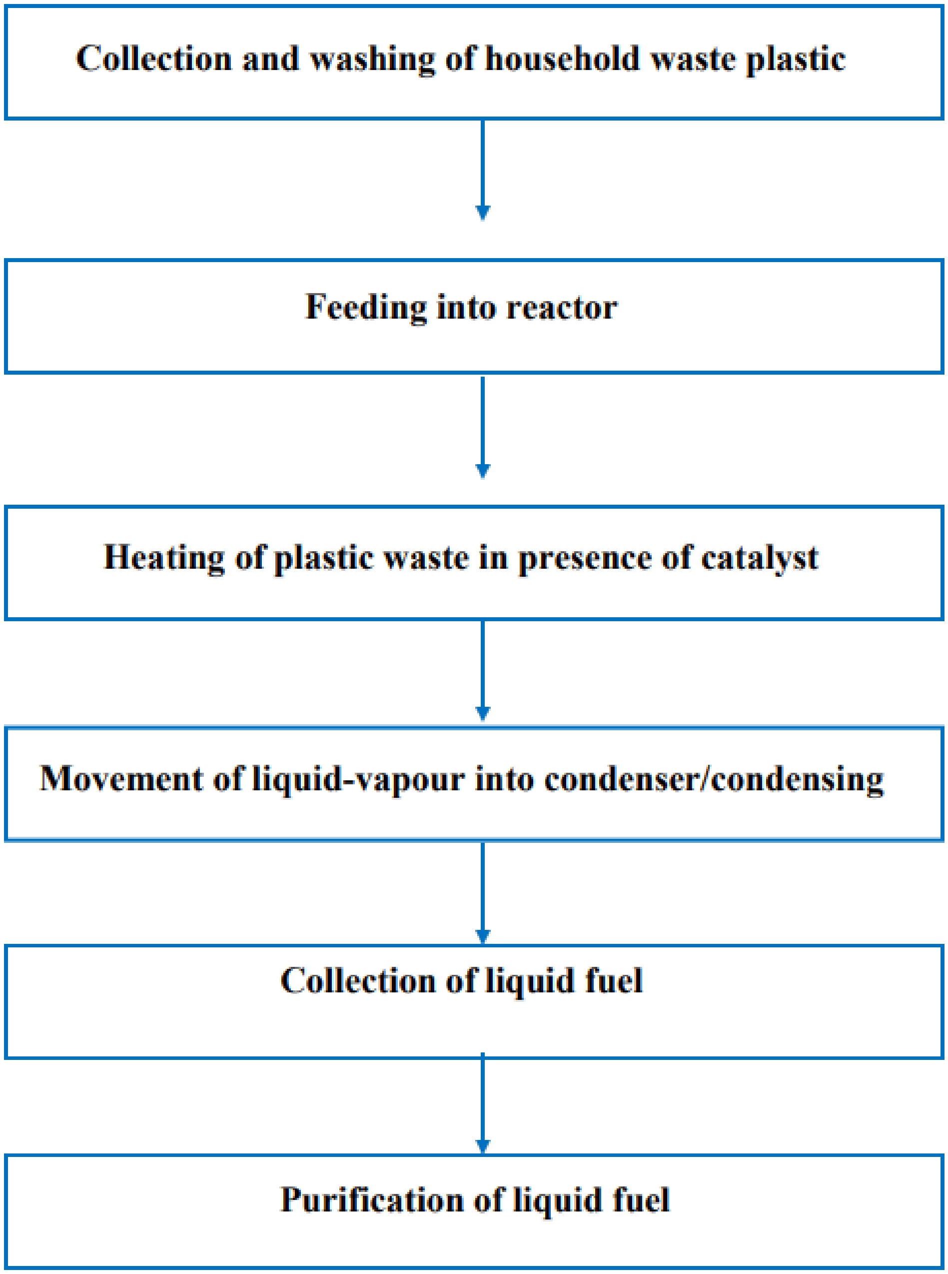


Figure: 3.7: Flow diagram of conversion of plastics waste into liquid fuel [5]

CHAPTER 4

RESULTS AND DISCUSSION

4.1 RESULTS:

Data:

Wo= weight of oil converted (g) = 230 g

Wsm= weight of the sample material(g) = 2000g, We = weight of char inside the reactor(g) = 250g

1. **Conversion efficiency (wt%)**

$$CE = \frac{wo}{wsm} \text{ x } 100\%$$

= 23%

2. **Waste Reduction Efficiency (wt %)**

$$WRE = \frac{wsm - we}{wsm} \text{ x } 100\%$$

= 87.5%

3. **Oil Recovery (ml/kg}**

$$OR = \frac{V}{wsm}$$

= 120ml/kg

4.2 DISCUSSION

Objectives of the project have been fulfilled. Our project successfully converted 230g of oil froma 2000g sample of waste plastics, achieving a conversion efficiency of 23%. The weight of the char inside the reactor is 250g approximately, indicating the transformation of most of the plastic waste into useful oil and gas. With an oil recovery rate of 120ml/kg, this method holds great promise in addressing the plastic waste problem while simultaneously generating a Valuable energy source.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

In conclusion, the pyrolysis process proves to be a highly effective method for transforming waste plastic into valuable oil. With its ability to efficiently break down various types of plastic through controlled thermal decomposition, pyrolysis offers a viable solution for both waste management and resource recovery. The resulting oil can be further utilized in various applications, including energy production and chemical manufacturing. By harnessing the power of pyrolysis, we can significantly reduce plastic waste, mitigate environmental pollution, and foster a more sustainable and circular economy. This innovative technology holds great promise for a more effective and efficient approach to addressing the challenges posed by plastic waste.

5.2 RECOMMENDATION

We have found a lack of different theories or information by making the journal paper analyzes different from the analysis of lightning plastic from the paper. We can produce oil from every kilogram of plastic if we do not get it. How much does it cost to composite it is not according to the current market price. Safety does not specifically discuss anything DCS & PLC. Whether the system can be applied and how the temperature, pressure, Flow rate, the Level system will be monitored, it has not been discussed. Pressure safety valve, Reactor is not used in any journal paper. And most important topics are discussed only on Batch production here. It is only discussed here about the Continuous production of how the production will be discussed. Young entrepreneurs and industrial entrepreneurs. It requires more informative research and development for the industry.

REFERENCES

[1] R.T. Karad, S. Havalammanavar, "International Journal of Engineering Development and Research", Waste plastic to fuel-Petrol, Diesel, Kerosene, Vol. 5(3), pp. 641-644, 2017.

[2] S. Bhat, R.S. Lather, "Indian Journal of Science and Technology", Production of Oil from Waste Plastics and Polythene using Pyrolysis and its Utilization in Compression Ignition (C.I.) Engine, Vol. 9(48), pp. 3-7, 2016.

[3] R. Punia, A.Joshi, "Recent Advances in Bioenergy Research" Vol. Ill, pp. 449, 2015

[4] F. Gao, "Pyrolysis of Waste Plastics into Fuels" pp. 21-25 & 170-172,2010.

[5] M.B. Kutli, K.S. Shegunshi, M.A. Imagoudanavar, A.S. Malaji, "Production and Purification of Liquid Fuel Produced From Household Plastic Waste for CI Engine", pp. 7-11,2016.

[6] A. Asokkumar, "Synthesis of Fuel from Waste Plastic a Project Report", pp. 48-50, 2016.

[7] E.G. Rapsing, Dr. Emailio, B. Eshinosa, "Asia Pacific Journal of Multidisciplinary Research", Performance Evaluation of Waste Plastic, Oil Converter, Vol. 5, No. 2, pp.61,2017.

[8] M.Z.H. Khan, M. Sultana, M.R. Al-Mamun, M.R. Hasan, "Journal of Environmental and Public Health", Pyrolytic Waste Plastic Oil and Its Diesel Blend Fuel Characterization, Vol.2016, pp.3-5, 2016.

[9] J. Siddiqui, G, Pandey, "International Research Journal of Environment Sciences," A Review of Plastic Waste Management Strategies, Vol. 2(12), pp. 86, 2013.

[10] Dr. M. El-Newehy, "Plastic Waste Management", pp. 20,2016.

[11] Birley, A.W. Heath, R. J. Scott, "Plastics Materials. Blackie", 2nd ed. introductory scientific textbook, 1988