Conversion Of Plastic Waste into Fuel

Bachelor of Chemical Engineering

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This is to certify that the project entitled **"Conversion of Plastic Waste into Fuel** "is a bonafide work of

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Declaration

I declare that this written submission represents my ideas in my own words and where others' ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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ABSTRACT

Petroleum products are used in every aspect of life today. With rapid increase in world population, their demand is increasing day by day. Waste (agricultural waste, plastic waste, etc.) is used for the manufacturing of valuable fuel oil reflecting today's environmental requirements. For reusing waste is the best way to overcome the increased demand for petroleum products.

In this project we are able to create plastic crude oil [PCO], by using high-density polyethylene bags and other plastic waste and feeding them into a pyrolysis unit. In this project the thermal energy is used to convert the higher molecular weight compounds into lower molecular weight compounds (fuel oil). Further the plastic crude oil obtained from pyrolysis of plastic waste through fixed bed reactor was distilled at the temperature of 180 0C for 60 minutes. The distillates had a lower densities & viscosities than the pyrolytic oil and the properties of distillate were similar to those to gasoline.

The main objectives of this study were to understand and optimize the processes of waste by pyrolysis for maximizing the diesel range products

Keywords: Pyrolysis, petroleum, Hydrocarbons, Renewable energy, Plastic Wastes, Crude Oil

Chapter 1

Introduction

The use of plastics has been associated with significant environmental problems due to their continuous accumulation in landfills, as plastic waste does not degrade or degrades at a very low pace. On average, 50% of the waste plastic generated in Europe is recovered, while the rest is sent to landfills. In 2015, global plastic production reached 322 million tonnes, a dramatic increase compared to the 279 million tonnes produced in 2011. According to the World Bank, plastic waste accounts for 8–12% of the total municipal solid waste (MSW) worldwide, while it is estimated to increase to 9–13% of the MSW by 2025. The increasing availability of such waste material in local communities, coupled with the high energy density, render waste plastics one of the most promising resources for fuel production. The pyrolysis of plastics yields on average 45–50% of oil, 35–40% of gases, and 10–20% of tar depending on the pyrolysis technology. According to previous research, there are some cases where a high amount of liquid yield, more than 80 wt %, could be produced in the pyrolysis of individual plastic, which is higher than the pyrolysis of wood-based biomass in general.

Plastic is one of the most commonly used materials in daily life which can be classified in many ways such as based on its chemical structure, synthesis process, density, and other properties. In order to assist recycling of the waste plastic, Society of Plastic.

Industry (SPI) defined a resin identification code system that divides plastics into the following seven groups based on the chemical structure and applications:

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

The results showed that, using the staged catalysis, a high yield of oil product (83.15 wt. %) was obtained from high-density polyethylene. In the last years, the use of pyrolysis oil as a diesel fuel has been of main importance, and there are some latest references where they study the potential of using oils that have been derived from the pyrolysis of plastics at different temperatures in diesel engines. Their results have shown that a further upgrade of pyrolysis oil is necessary in order for it to be suitable as a diesel substitute due to its unfavourable properties.

- **Types of Plastics:**

The types of the waste plastics are LDPE, HDPE, PP, PS, and PVC. The problems of waste plastics can't be solved by landfilling or incineration, because the safety deposits are expensive and incineration stimulates the growing emission of Harmful greenhouse gases like CO_x, NO_x, SO_x and etc. These types of disposals of the waste plastics release toxic gas which has negative impact on environment. Plastic wastes can also classify as industrial and municipal plastic wastes according to their origins, these groups have different qualities and properties and are subjected to different management strategies. Plastic wastes represent a considerable part of municipal wastes furthermore huge amounts of plastic waste arise as a by-product or faulty product in industry and agriculture. The total plastic waste, over 78% weight of this total corresponds to thermoplastics and the remaining to thermosets. Thermoplastics are composed of polyolefins such as polyethylene, polypropylene, polystyrene and polyvinyl chloride and can be recycled. On the other hand, thermosets mainly include epoxy resins and polyurethanes and cannot be recycled.

- **Purpose:**

Major issues for disposal of plastic waste:

During polymerization process toxic fugitive emissions are released.

1.Open burning of plastic waste is very common phenomenon in cities/town which generate toxic emissions such as carbon monoxide, chlorine, hydrochloric acid, amines, nitrides, styrene, benzene, butadiene, CCL and acetaldehyde are pollute environment.

2. Non recycle plastic waste such as multi layered and metalized pouches/sachets and thermoset plastics like MC/FRP etc pose several disposal problems.

3.Garbage mixed with plastic waste interferes in recycling and solid waste processing facilities and also cause problem in land fill operations.

4. In India during the period of 2018–2019 on general total over 6000 tonnes per day of plastic waste generated in seventy major cities.

The major factors influencing the plastic pyrolysis product molecular distribution including chemical composition, cracking temperature, heating rate, operating pressure, reactor type and application of catalyst. Liquid fuel is defined plastic liquid hydrocarbons at normal temperature and pressure

- **Aim: -**

The main aim of this work is to convert the waste by pyrolysis using a fixed bed reactor, on a batch mode, and to check the economic feasibility of the process.

- **Objective: -**

This project is developed to overcome the conventional fuel crisis and generate valuable fuels from waste materials.

- **Problem Statement: -**

Petroleum products are used in every aspect of life today. With rapid increase in world population, their demand is increasing day by day. But the world's oil supply is fixed since petroleum is formed naturally far too slowly in comparison to the rate at which it is being extracted. As countries develop, industry and higher living standards drive up energy use, most often of oil.
India, is quickly becoming large oil consumers. India's oil import is expected to become more than triple from 2005 levels by 2020, rising to 5 million barrels per day.

Chapter 2

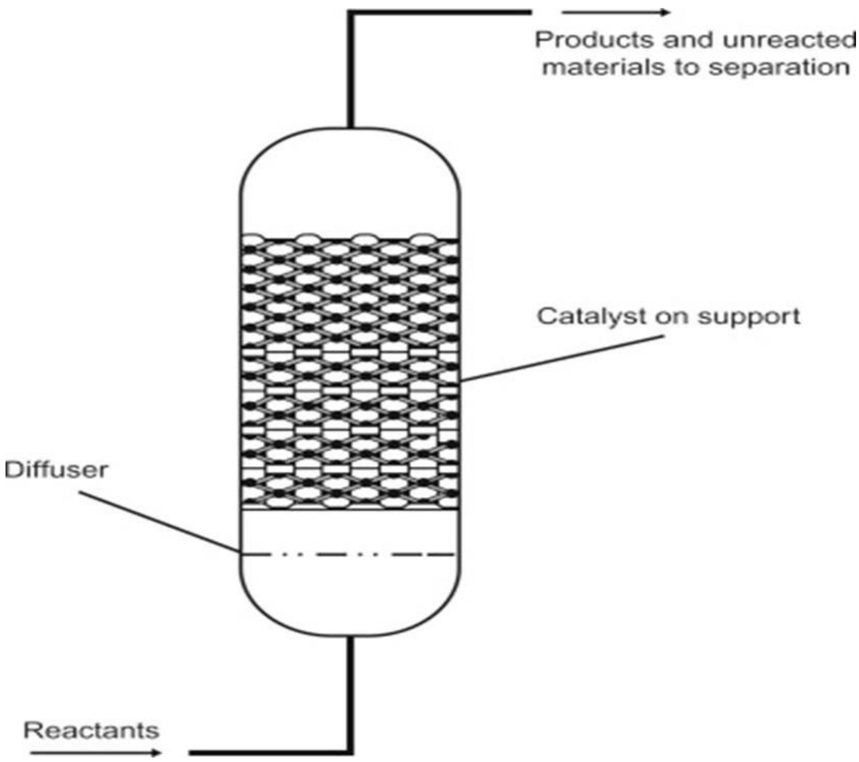
Literature Survey

➢ Pyrolysis Reactor:

The reactor is the heart of any pyrolysis process. Reactors have been the subject of considerable research, innovation and development to improve the essential characteristics of high heating rates, moderate temperatures and short vapor product residence times for liquids. At first, pyrolysis reactor developers had assumed that small biomass particles size (less than 1 mm) and very short residence time would achieve high bio-oil yield, however later research has found different results. Particle size and vapor residence time have little effect on bio-oil yield, whereas those parameters greatly affect bio-oil composition [66,67]. With the continuation of pyrolysis technology development, a number of reactor designs have been explored to optimize the pyrolysis performance and to produce high quality bio-oil. However, each reactor type has specific characteristics, bio-oil yielding capacity, advantages and limitations. Of the various reactor designs, the most popular types are described in the following sub-sections.

➢ Fixed Bed Reactor:

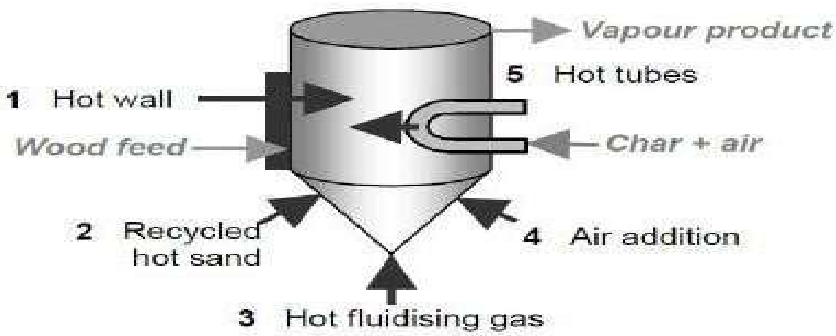
The fixed bed pyrolysis system consists of a reactor with a gas cooling and cleaning system. The technology of the fixed bed reactor is simple, reliable and proven for fuels that are relatively uniform in size and have a low content of fines [18]. In this type of reactor, the solids move down a vertical shaft and contact a counter-current upward moving product gas stream. carbon steel category, with good strength and ductility required for manufacturing the vessel. The low carbon content eases the rolling or forging operation by which the shell is made. Silicon, nickel and manganese are added in varying proportions to increase hardness, depth of hardening and impact resistance respectively without sacrificing ductile nature of steel. Chromium is added to increase the wear resistance and corrosion resistance of the material required for the storage of the liquid in the vessel during its application. Typically, a fixed bed reactor is made up of firebricks, steel or concrete with a fuel feeding unit, an ash removal unit and a gas exit. The fixed bed reactors generally operate with high carbon conservation, long solid residence time, low gas velocity and low ash carry over [19]. These types of reactors are being considered for small scale heat and power applications. The cooling system and gas cleaning consists of filtration through cyclone, wet scrubbers and dry filters [12]. The major problem of fixed bed reactors is tar removal; however recent progress in thermal and catalytic conversion of tar has given viable options for removing tar [11]



Fixed Bed Reactor

- **Fluidized-Bed Reactor:**

The fluidized-bed reactor consists of a fluid-solid mixture that exhibits fluid like properties. This is generally achieved by the introduction of pressurized fluid through the solid particulate substance. Fluidized-bed reactors appear to be popular for fast pyrolysis as they provide rapid heat transfer, good control for pyrolysis reaction and vapor residence time, extensive high surface area contact between fluid and solid per unit bed volume, good thermal transport inside the system and high relative velocity between the fluid and solid phase [15]



- **Process parameters:**
- **Temperature:**

Temperature plays a key role in all pyrolysis processes, regardless of the feedstock type. In the pyrolysis of plastic wastes, as in any other pyrolysis process, the increase in temperature results in a rapid increase in gas yields from the enhanced cracking reactions and, correspondingly, in a decrease of the oil/wax yield. In addition to the alteration of yields, temperature expectedly affects the products quality, due to its impacts on the pyrolysis kinetic mechanisms. Generally speaking, high temperature favours the production of less waxy and more oily compounds production, attributed to the conversion of long-chain paraffins/olefins to shorter molecules. Conversely, the solid residue yield decreases at elevated temperatures. A qualitative assessment of plastic oil shows high temperature favours an increase in gasoline production corresponding to a higher concentration of aromatics. The yield of ethylene and propylene are found increase as the temperature rises.

Reactor temperature has a significant influence on pyrolysis processes and resulting product distribution. As the pyrolysis temperature increases, the moisture inside the biomass evaporates first, and then thermal degradation and devolatilization of the dried portion of the particles take place. At the same time, tar is produced and volatile species are gradually released from the particles' surface. The volatile species and tar then undergo a series of secondary reactions such as decarboxylation, decarbonization, dehydrogenation, deoxygenation and cracking to form components of syngas. Therefore, higher temperatures favour tar decomposition and the thermal cracking of tar to increase the proportion of syngas, resulting in decreased oil and char yields. Studies have also shown that an increase in reactor temperature increased the syngas flow rate which lasts for a shorter period of time and then reduces dramatically.

- **Moisture content:**

Moisture content influences the heat transfer process in pyrolysis, having an unfavourable effect on syngas production. High moisture content contributes to the extraction of water-soluble components from the gaseous phase, hence causing a significant decrease in gaseous products. For a given temperature, dry biomass produces the greatest quantity of gas at the early stage of pyrolysis, whereas with wet biomass the production of the greatest quantity occurs later in the run.

This occurs because an increase in humidity leads to an increase in drying time.

- **Summary of literature survey**

Sr. No	Name Of Author	Research Topic	Description	Result
1	Shahriar Bin Rasul, Uday Som, Md. Shameem Hossain	Liquid fuel oil produced from plastic based medical waste by thermal cracking	4 Electrical heating coils with a power of 500W each were used as a source of energy placed in the reactor. At the top of reactor, a tube system was connected with a value through which the volatile fractions were flown in two successive. The condensed product was stored in the oil collector and residual noncondisable fraction was exhausted to the air by controlling the exit value	The analysis interprets the feed stock contains 87.2% volatile matter. Double attack components and the high calorific value are crucial factor for the thermal treatment of plastic based medical waste.
2	K. Manickavelan, S. Ahmed, K. Mithun	Review on transforming plastic waste into fuel 23 Feb 2022	We cannot use pyrolysis oil directly into the engine because the presence of charcoal water and ash particles need to remove before blending it to conventional fuel the oil octane can be used in a boiler, furnaces, turbines, etc. Catalyst used- zeolite and alumina	HDPE: At 350°C total at 80.88% liquid was collected. LDPE: At 500°C in the fixed reactor 550°C in a batch reactor. Yields 95 to 93.1% of fuel.

3	Pravin Kumar ghodke	High quality hydrocarbon fuel production from municipal mixed plastic waste using a locally available low-cost catalyst	Composition properties include moisture content, volatile matter using CHNS analyser to evaluate composition such as carbon, hydrogen, nitrogen and sulphur, x-ray powder diffraction.	experiments were performed with MVP with and without CAT-1 catalyst to identify the optimum operating conditions for maximum yields of liquid hydrocarbon fuel.
4	Ahmed azima, berlija Elsa apriajumita	Design of condenser on mini plants is machine for converting plastic into oil fuel.	The gasifying agent heat temperature is kept at temperature as the main reactor in which sample material undergoes gasification. The condenser design was used to determine the effectiveness of the temperature reduction of polythelin terephthalate paper so it can become condense in the form of fuel oil.	Final result effectiveness is 76.12%. Weight of LDPE plastic waste which was process 0.8 kg and produced a condensate of 21 ml.
5	Irene Fahim,Omar mohsen	Polystyrene plastic-liquid fuel with process using Al2CO3 as catalyst	Drying naturally using sunlight using raw material was reduced 4 to 6 mm and with Al2co3 catalyst and put in reactor. For use Al2co3 had to be activated at 300°C for 3 hours.	In this result we get various weight 4% ,6% ,8% temp-250°C and length of process varied into 20,40,60 min.

6	Vaibhav Kumar1 , Jayant Sharma2 , Vinmay Srivastava3 , Shailendra Singh4	Production of fuel from plastic using electricity	Around 1 kg of solid waste can be converted to 600 gm of fuel. The final solid product which is produced is carbon black which can be used in construction of roads. There are two important function of sand in pyrolysis process as sand is good conductor of heat so send is used to conduct heat evenly throughout system. The liquid crude oil can be divided into usable product using functional distillation.	PET(polyethylene terephthalate) produced around 52% gas, 39% oil, 9% solid.LDPE produced around 10% gas 89% oil and 1% solid.HDPE produced around 16% gas 82% oil and 2% solid. Polypropylene when pyrolized produced 29% gas 69% oil and 2%solid at 300°C.Polystyrene produces 6% gas 90% oil and 4% solid

Chapter 3

Methods

- **Primary recycling:**

In this process, the uncontaminated single-use plastic after sorting out or recovered from plastic wastes having properties and characteristics close to virgin materials is recycled. This method needs a better sorting technique as plastics recovered from MSW may not be suitable and useful for recycling. To obtain better materials than the original products, many times clean scarp is added during the recycling process. Often techniques such as injection moulding, blow moulding and other mechanical recycling techniques are used in primary recycling technique and is also one of the simplest methods for recycling plastics. But the process also carries a certain disadvantage like it puts a limit on the number of cycles that waste plastics can be recycled.

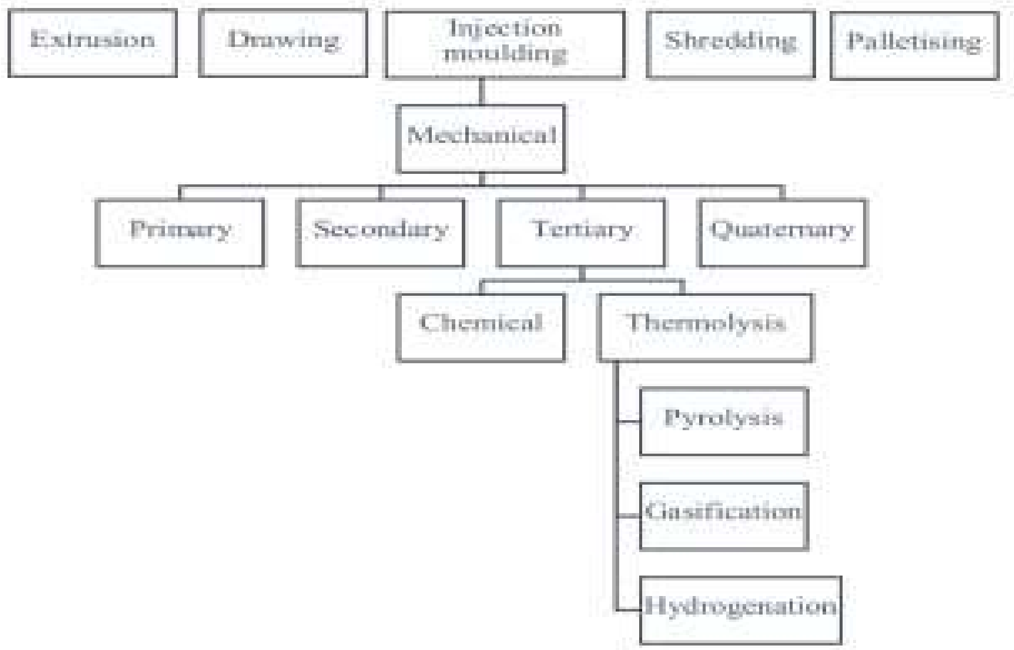
- **Secondary recycling**:

Secondary recycling (SR) refers to the transformation of scrapped thermoplastics into products that are less demanding than compared to the original products. But looking at both primary and secondary techniques, these are well established techniques and are widely applied in the transformation of plastic wastes into useful products .As an example for SR, polyolefins are used in the preparation of flooring tiles.SR is also referred to as mechanical recycling and involves cutting, separation of contaminants, and segregation followed by processing, milling, washing, adding pigments and additives for obtaining the granulated form. These are further used for preparing useful products through techniques such as injection moulding, blow moulding, screw extrusion and so on.

- **Tertiary recycling:**

In this method, plastics are completely broken down into chemical component materials that help in the production of raw materials used for making plastic components, and thus giving an opportunity for the recyclers to employ this method for recycling giving preference over the primary and secondary techniques. For example, for tertiary recycling, glycolysis of PET into diols and dimethyl terephthalate can then be used to make virgin PET. Tertiary methods can be sub-classified into chemical and thermolysis methods. Thermolysis is further classified into pyrolysis, gasification and hydrogenation as seen from. Among these, pyrolysis process is an area where most of the research on recycling plastic wastes has taken place.

➢ Various Approaches for Recycling of Plastic Wastes



➢ Gasification:

Gasification is a process that converts biomass- or fossil fuel-based carbonaceous materials into gases, including as the largest fractions: nitrogen (N2), carbon monoxide (CO), hydrogen (H_2), and carbon dioxide (CO_2). This is achieved by reacting the feedstock material at high temperatures (typically >700 °C), without combustion, via controlling the amount of oxygen and/or steam present in the reaction. The resulting gas mixture is called syngas (from synthesis gas) or producer gas and is itself a fuel due to the flammability of the H_2 and CO of which the gas is largely composed. Power can be derived from the subsequent combustion of the resultant gas, and is considered to be a source of renewable energy if the gasified compounds were obtained from biomass feedstock. An advantage of gasification is that syngas can be more efficient than direct combustion of the original feedstock material because it can be combusted at higher temperatures

➢ Hydrogenation:

Hydrogenation is a chemical reaction between molecular hydrogen (H_2) and another compound or element, usually in the presence of a catalyst such as nickel, palladium or platinum. The process is commonly employed to reduce or saturate organic compounds. Hydrogenation typically constitutes the addition of pairs of hydrogen atoms to a molecule, often an alkene. Catalysts are required for the reaction to be usable; non-catalytic hydrogenation takes place only at very high temperatures. Hydrogenation reduces double and triple bonds in hydrocarbons.

➢ Pyrolysis:

The process of pyrolysis is thermal breakdown and disintegration of plastic at a high temperature in an anaerobic environment. The chemical composition of the plastic changes in pyrolysis. Plastic is derived from petroleum. During pyrolysis the plastic break downs and form petroleum. During pyrolysis of plastic some carbon black, crude oils and some combustible gases are produced. For pyrolysis it is important to cut off oxygen supply as in the presence of oxygen plastic will burn and not decompose. By putting sand from above air supply can be cut off. Plastic and Sand are put in 2:3 ratio.

In pyrolysis some oil, gas and solid waste products are produced. The liquid crude oil can be divided into usable product using fractional distillation as boiling temperature for different oils is different. Furnace oil: 66 C, Diesel: 58.5 C, Kerosene: 51 C.

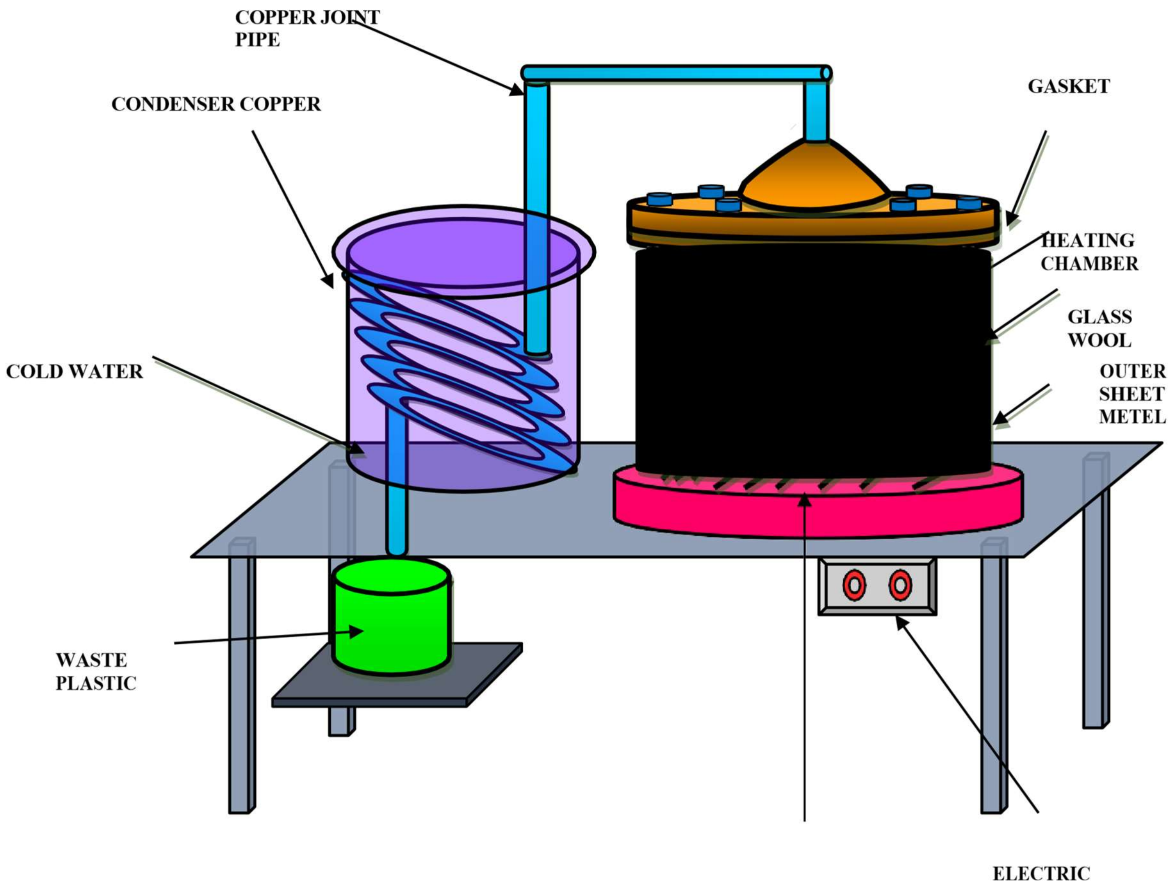
The gaseous products of pyrolysis are iso – octane, n – octane, n – hexane, gasoline and methane which are all combustible in nature those cases can also be collected and used as a fuel in other places. The advantage of using these gases as fuel is that they don't create air pollution and they are considered green fuel such as CNG which is liquified methane

We want to convert plastic into fuel without producing any kind of harmful end products. Plastic is a hydrocarbon which is made up from petroleum so, when we heat up plastic in anaerobic environment it breaks down and form petroleum. Initially the gas released contain fuel gases and other acids etc. Then we use water to mix these chemicals as petroleum is lighter than water it gets suspended over the water and can be easily separated. And the other chemicals get dissolved in water which can be distilled and further used in labs.

The gases which are produced should be dissolved in water that's why we use to water chamber to dissolve it. The exhaust gases are also combustible in nature and can be collected and used as fuel. The final solid product which is produced is carbon black which can be used in construction of roads etc. [10]. So, it is complete use of plastic without producing any harmful product

The first chamber represents the furnace in which plastic is melted along with sand. It is heated using a g coil. Then it is connected via pipe to next chamber containing water which helps in cooling down the gases. Then there is another chamber inside the cooling chamber. Where the main conversion of gas to oil takes place. Final chamber is also for collecting gas. The remaining gas is exhaust gas.

Experimental Setup:



Actual model of converting fuel from waste plastic

Actual Equipment of converting fuel from waste plastic

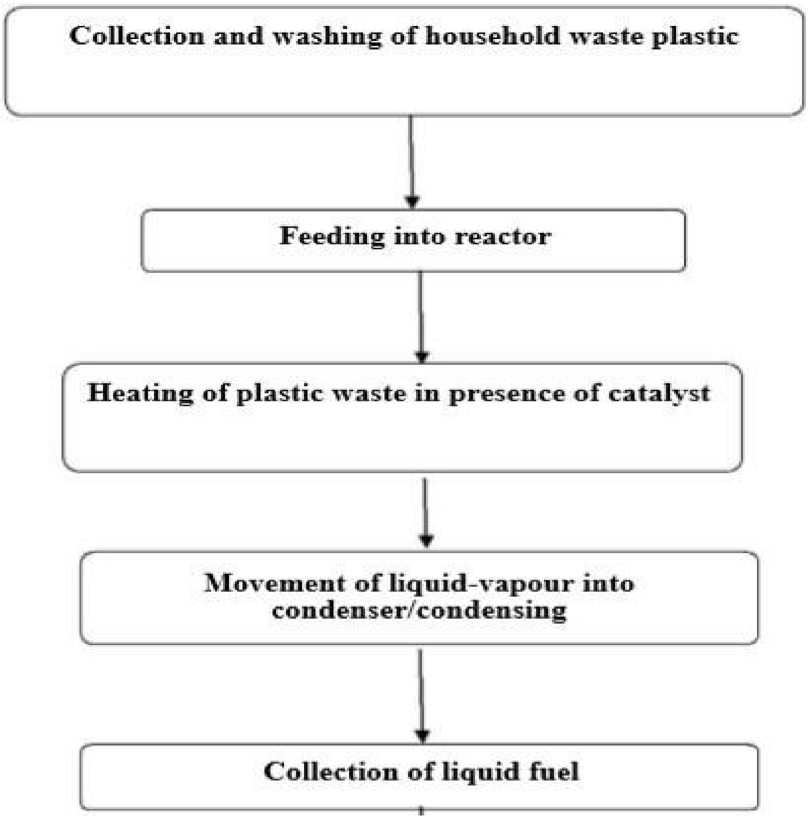
Following are the specification of the Equipment

- Reactor
- Condenser
- Heating Coil
- Temperature Indicator
- Pressure Indicator

Pyrolysis Reactor

Heating Coil

Temperature Indicator **Pressure Indicator**



Flow diagram for the conversion of plastic waste to liquid fuel

Chapter 4

Result

Result:

- About 60% fuel obtained from the pyrolysis is mixed fuel which can be used in industrial boilers, generators or can be further refined into diesel and gasoline.
- Total 99.98% of mass changes occurred from 448.5 K to 673 K.
- At the time of fractional distillation as we increase the temperature the quality of fuel will increase. The distillates were light yellowish at 180^0C and colourless at 150^0C in the early stage of distillation. This pyrolytic oil has similar properties to gasoline
- From Literature review We found out that most of the commonly used plastics we pyrolyzed produced mostly liquid and gas very less amount of solid was produced. For three most commonly used plastics PET, LDPE and HDPE results are as follows. **Polyethylene Terephthalate (PET)** produced around 52% gas, 39% oil and 9% solid when pyrolyzed at 500 degrees Celsius.

  Low-density Polyethylene (LDPE) produces around 10% gas, 89% oil and 1% solid when pyrolyzed at 400 degrees Celsius.

  High-density Polyethylene (HDPE) produces around 16% gas, 82% oil and 2% solid when pyrolyzed.

  Polyvinyl chloride when pyrolyzed produces 88% gas and 12% oil at 500 degrees Celsius.

  Polypropylene (PP) when pyrolyzed produces 29% gas, 69% oil and 2% solid at 300 degrees Celsius.

  Polystyrene (PS) when pyrolyzed produces 6% gas, 90% oil and 4% solid at around 400 degrees Celsius

Properties of liquid Fuel: -

1. **Density: -**

Density of fuel at different temperatures was measured by a standard 25 ml marked flask. Weight of the fixed volume of fuel (25 ml) was measured at different temperatures by an electronic balance which measures up to 0.0001 gm. The density values are reported in kg/m3.

2. **Viscosity:**

Viscosity is an important property fuel and it is fluid 's resistance to the flow (shear stress) at a given temperature. Fuel viscosity is specified in the standard for diesel fuel within a fairly narrow range.

Chapter 5

Conclusion

Conclusion:

From this work we can conclude that from the according to the current statistics, there is continuous rise of consumption and thus cost of petroleum oil, International Energy Outlook 2008 reports the world consumption of petroleum oil as 84 million barrels per day. The conversion of waste plastics to liquid hydrocarbon fuel was carried out in thermal pyrolysis unit. This method is superior in all respects (ecological and economical). By adopting this technology, efficiently convert weight of waste plastics into 75% of useful liquid hydrocarbon fuels without emitting any pollutants. It would also take care of hazardous plastic waste and reduce the import of crude oil. Depletion of non-renewable source of energy such as fossil fuels at this stage demands the improvements of this technique. Based on the properties of the Plastic fuel and Diesel fuel the all properties are nearer hence concluded that Waste plastic fuel represents a good alternative fuel for diesel engine and therefore it can be used for diesel engine vehicles for the transportation purpose. The conversion can further be increased by varying parameters such as temperature. From the literature survey we can observe higher conversion of fuel oil at higher temperature and lower residence time.

Plastic presents a major threat to today’s society and environment. Over 14 million tons of plastic are dumped into the oceans annually, killing about 1,000,000 species of oceanic life.

In this regard, the pyrolysis method is clean and very effective means of removing the debris that we have left behind over the several decades.

By converting plastics to fuel, we solve two issues, one is the environmental pollution due to plastic and the other of the fuel shortage.

This dual benefit, though will exist only as long as waste plastic last, but will provide a strong platform for us to build on a sustainable, clean and green future.

Chapter No: 6

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