Recycle Of Polymetric Waste to Diesel Fuel

Kalyani Funde[1], Suvarna Bhabad[1], Dhananjay Bendre[1], Dr. S. B. Magar[2]

1 UG Student of Department of Chemical Engineering and 2 Prof. of Department of Chemical Engineering, Pravara Engineering College, Loni, Ahmednagar - 413736.

ABSRACT

The processes like catalytic cracking, non-catalytic cracking (Pyrolysis, Gasification and Hydrogenation) steam degradation etc. are under industrial applications to produce energy from waste plastic/polymers. Pyrolysis is a thermal decomposition process with high temperature in the absence of oxygen. Pyrolysis process is proposed by many researchers since the process is able to produce large quantity of liquid oil up to 80-90 % at temperatures around 400-500 °C. Recycling of waste polymer/plastics to derive automotive diesel oil for use to power engines. Converting plastic or polymetric waste into transport fuel through a cleaner combustion process will contribute to saving environment. Pyrolysis is an advanced technology used in disposing waste plastics. Pyrolysis is the convert plastic to oil which is environment friendly technology for disposal of plastic waste. The pyrolysis can able to converting all types of plastic/polymetric waste in to fuel like petrol, diesel, kerosene and LPG. The yield range around 85-90 % weight of the plastic converted into hydrocarbon liquid and 10-15 % of into gas product. Thermal pyrolysis of waste plastic/polymetric waste has advantages over other alternative recycling methods. Diesel produced from plastic pyrolysis oil could be economically used in diesel engine combustion. High density polyethylene (HDPE) was pyrolyzed in a self-designed stainless steel laboratory reactor to produce useful fuel products. HDPE waste was completely pyrolyzed at 330– 490 ∘ C for 2-3 hours to obtain solid residue, liquid fuel oil and flammable gaseous hydrocarbon products. The maximum oil yield up to 77 % at 2 hr at 425∘ C. The liquid product yield is up to 80-85 % at 550 °C. LDPE has been used as a raw material in the pyrolysis processes which are in a fixed-bed reactor at 500 °C liquid product yields up to 95 %. Pyrolysis of waste plastic grocery bags at temperatures of 420-440 °C obtained a 74% yield of liquid product. Polypropylene (PP) at 425 to 600°C the liquid yields between 85 and 97 %.

Keywords – Pyrolysis, Polymetric Waste, Fuel Oil, Gases Hydrocarbon Product, Solid Residue, Diesel Oil, LPG, Thermal Pyrolysis.

Introduction

The polymers are the backbone of four major industries as plastics, elastomers, fibers and paints and varnishes. The term polymer is defined as very large molecules having high molecular mass. Pyrolysis is an advanced technology used in disposing waste plastics. Pyrolysis is the convert plastic to oil which is environment friendly technology for disposal of plastic waste. Pyrolysis or thermal cracking involves thermal degradation of long chain polymer molecules into less complex smaller molecules. The process takes place in the absence of oxygen at increased pressure and temperature for a short duration. Pyrolysis process able to produce liquid oil up to 80 % at temperatures around 500°C. A polymer is a large molecule or macromolecule, composed of many repeated subunits. Because of their broad range of properties both synthetic and natural polymers play an essential and ubiquitous role in everyday life. Polymers range from familiar synthetic plastics such as polystyrene to natural biopolymers such as DNA and proteins that are fundamental to biological structure and function. Polymers both natural and synthetic are created via polymerization of many small molecules known as monomers.

Various Methods of Waste Plastic Treatment

1. Primary Method

Plastic scrap can be re-introduced in the heating cycle of plastic processing line itself to increase production.

2. Mechanical Recycling (Secondary Methods)

Mechanical (physical) treatment to re-extrude, process and convert plastic solid waste to new plastic products blended with virgin polymers to reduce production cost.

3. Chemical (Tertiary) Methods

Chemical alteration in the polymer structure of plastic material can be performed through chemical or thermo-chemical means to utilize it as a monomer feedstock in industrial recycling loops.

4. Energy Recovery

Which entails recovery of steam, heat and electricity from waste plastic through combustion.

Properties of Polymers

1. Chemical Properties

The attractive forces between polymer chains play a large part in determining polymer's properties. Because polymer chains are so long, these inter chain forces are amplified far beyond the attractions between conventional molecules. Different side groups on the polymer lend the polymer to ionic or hydrogen bonding between its chains. These stronger forces result in higher tensile strength and higher melting points.

2. Optical Properties

Polymers are used as matrices in the gain medium of solid-state dye lasers that are also known as polymer lasers. These polymers have a high surface quality and are also highly transparent so that the laser properties are dominated by the laser dye used to dope the polymer matrix. These types of lasers also belong to class of organic lasers which are useful for spectroscopy and analytical applications. Important optical parameter of polymer used in laser applications which change refractive index with temperature.

3. Thermal Properties

A true workhorse for polymer characterization is thermal analysis, particularly Differential scanning calorimetry. Changes in the compositional and structural parameters of the material usually affect its melting transitions or glass transitions and these in turn can be linked to many performance parameters. For semi crystalline polymers it is an important method to measure crystallinity. Thermo gravimetric analysis can also give an indication of polymer thermal stability and the effects of additives such as flame retardants. Other thermal analysis techniques are typically combinations of the basic techniques and include differential thermal analysis, thermo mechanical analysis, dynamic mechanical thermal analysis, and dielectric thermal analysis.

4. Mechanical Properties

The characterization of mechanical properties in polymers typically refers to a measure of the strength of a polymer film. The tensile strength and Young's modulus of elasticity are of particular interest for describing the stress-strain properties of polymer films as in figure below. Dynamic mechanical analysis is the most common technique used to characterize this viscoelastic behavior. Other techniques include viscometry, rhinometry and pendulum hardness and stress-strain behavior is similar to that of metals.

Applications of Polymers [7]

A variety of polymers have been used for medical care including preventive medicine, clinical inspections, and surgical treatments of diseases. Among the polymers employed for such medical purposes, a specified group of polymers are called polymeric biomaterials when they are used in direct contact with living cells of our body. Typical applications of biomaterials in medicine are for disposable products.

1. Polyolefins

The polyolefins polyethylene (PE) and polypropylene (PP) are very inert and hydrophobic materials which do not degrade in vivo. its main applications are sliding surfaces of artificial joints. The artificial joint has a sliding interface using a combination of hard material Metallic femoral head, Soft material Polytetrafluoroethylene (PTFE) and acrylic cement polymethyl methacrylate to fix components and transfer stress uniformly.

2. Polytetrafluoroethylene (PTFE)

PTFE (Teflon's) has an ethylene backbone with four covalently bound fluorine molecules. It is a highly hydrophobic-degradable material. It's applied as vascular graft.

3. Polyvinyl Chloride (PVC)

PVC has an ethylene backbone with one covalently bound chlorine. Its fabrication and application requires stabilizers and plasticizers, which are the main reason for medical concerns against this polymer. Plasticizers, most frequently phthalates, turn the rigid PVC to a soft polymer, which is used for extra corporeal tubing or blood storage bags.

4. Silicone

Silicones consist of an –Si–O– backbone with different chain lengths and cross links, which determine mechanical properties from liquid oil via a gel structure to rubber elastomer. The biological response differs for various applications. There is high tolerance in ophthalmologic applications.

5. Methacrylate's

Methyl methacrylate polymerize to very rigid polymers (PMMA) by radical polymerization and therefore find application in dentistry and in orthopedics. Due to the optical properties (Plexiglas's) and inertness in the eye.

6. Polyesters

Biostable and biodegradable polyesters are used in biomedicine. Biostable polyesters containing aromatic groups are poly carbonates (PC), poly (ethylene terephthalate). They are used inform of membranes, filaments and meshes.

7. Polyether's

Ether bonding are bio stable. Poly ether ketone (PEEK) as hard material for orthopedic applications and polyether sulfone(PES) for dialysis membranes are main representatives of this polymer class in biomedicine.

8. Polyamides

Naturally all proteins consist of units liked by amide bonds and highly repetitive proteins like collagen or silk fibroin can be classified here. The synthetic polyamide with clinical application is nylon. For its high tensile strength and use for suture materials.

9. Polyurethanes

Poly urethanes are synthesized with multiple chemistries and properties. Polyester-polyether-, and polycarbonate- based polyurethanes with aromatic or aliphatic components are in medical use, where aromatic formulations have the better bio stability. Poly ether based poly urethanes specially aliphatic formulations show rapid softening in the body and making them more comfortable for the patient.

Literature Reviews

Beltran et al. have also conduct pyrolysis of HDPE plastics at 550°C the liquid oil yield obtained was 84.7 weight % and gaseous product was found to be 16.3 weight %. This results show that higher liquid oil yield is possible from HDPE at higher temperature. 93.1 Weight % of liquid oil was obtained when the same experiment was conducted in a batch reactor at a temperature of 550°C by **Marcilla et al.. From the** research conducted by Koizumi et al. 75.6 Weight % of liquid oil was obtained in a batch reactor at 400°C. **Aguado et al.** have obtained 74.7 Weight % of liquid oil when using the same type of reactor at a temperature of 450°C. **Pyrolysis of PP was conducted by Sakata et** al. on PP at temperature of 380°C and was obtained a liquid yield of 80.1 Weight %, gas yield of 6.6 Weight % and obtained a 13.3 Weight % solid residue. **Demirbas conducted pyrolysis** of PP at 740°C in a batch reactor and 48.8 Weight % liquid, 49.6 Weight % gas and 1.6 Weight % char yield were obtained. This experiment inferred a reduction in liquid yield with increasing temperature. [2] **The pyrolysis rate and yield should** be promoted by a catalyst, like silica–alumina catalyst. Before the catalyst and plastic waste is mixed within the pyrolysis reactor the plastic waste must be cleaned. The total yield of fuel oil is 50–65% relying on the composition of plastic waste during pyrolysis. [11] **HDPE took 220** minutes to react. The mixed plastic reaction time was 260 minutes. The differing temperatures that resulted in decomposition reactions provided hydrocarbons of different chain lengths. Pyrolysis of waste plastic grocery bags at temperatures of 420-440 °C obtained a 74% yield of liquid product. [12]. **In the pyrolysis the oil will be collected** at different temperature. At the 130 ^{0}C 20% oil, at 210 ^{0}C 30% oil, at 250 ^{0}C 40% oil, at 300 ^{0}C 60% and at 430 ^{0}C 90% oil will be collected. Thermal Pyrolysis of polyolefin is a high energy, endothermic process requiring temperatures of at least 350– 500 °C. From this crude oil various products petrol, diesel and kerosene etc. can be obtained by distillation. This process can convert all HDPE to different grade fuels and specially jet grade fuel. [13]

MATERIAL AND METHODOLOGY

Pyrolysis Process for Polymer [9]

Waste to Fuel this thermal process occurs in absence of oxygen and the generated gases possess higher calorific value to be alternatively used in various gas engines for electricity generation without any further treatment. The bio-oil derived from condensation of pyrolytic gases possesses almost similar properties of the solid feedstocks. It has vulnerable stability for long-term storage as it is intricately mixed with oxygenated compounds. Besides hydrocarbon oil is immiscible with the conventional hydrocarbon petroleum fuels. This bio-oil can be further processed to obtain polymer derived gasoline, diesel as crude oils are refined in the refineries. If the purpose is to optimize the yield of liquid hydrocarbon products from the pyrolysis of polymer feedstocks a lower temperature, higher heating rate and shorter gas residence time based operating process should be required. Fast pyrolysis process in a circulating fluidized bed (CFB) reactor could meet the requirement for this purpose the parameter can controlled.

EXPERIMENTAL ANALYSIS

Diesel Fuel from Polymetric Waste by Pyrolysis Process

Waste to Fuel this thermal process occurs in absence of oxygen and the generated gases possess higher calorific value to be alternatively used in various gas engines for electricity generation without any further treatment. There are different types of pyrolysis process

1. Conventional pyrolysis (slow pyrolysis) proceeds under a low heating rate with solid, liquid and gaseous products in significant portions. It is an ancient process used mainly for charcoal production. Vapors' can be continuously removed as they are formed.

2. Fast or flash pyrolysis at high temperatures with very short residence time. Fast pyrolysis (more accurately defined as thermolysis) is a process in which a material such as biomass is rapidly heated to high temperatures in the absence of oxygen. Fast pyrolysis is associated with tar at low temperature (850–1250 K).

Experimental Process of Pyrolysis

1. Feeding

Feed the feedstock's to reactor through feeder and closes the feeder inlet. Reactor can fabricated of iron metal or S. S. can also use. Reactor consists of Feeder, Outlet for vapor generated by burning of polymetric waste and heating arrangement.

2. Heating

To increase the temperature of reactor heat the product of reactor inside by using heating source. Polymetric material can directly heat by using flame.

3. Condensing

The plastic get evaporated at high temperature and vapor is condensed at atm temperature by using straight and spiral tube condensers. Condenser connected to the outlet of reactor with the help of hose which between outlet and inlet of condenser.

4. Liquid Collection

Out coming product from the condenser is collected at liquid collector. At the end of condenser provide a cyclone separator to separate the plastic liquid fuel and non-condensable gases. These non-condensable gases are reuses to heat the pyrolysis unit.

5. Water Wash

Purification and pH test- This involves many purification processes. In this method we take equal proportion of plastic fuel and water in a container and shake well, allow it for 5-7 hours to settle down. Now water along with some crystals is collected at bottom and pure plastic fuel is collected at the top container.

6. Purification

Purify the plastic fuel by using filter papers and filters.

7. pH Test

After purification measure the pH value of plastic fuel by using pH meter. If the pH is less than 7 fuel is acidic in nature. Wash with water for maintain pH value oil to 7.

8. Calculation of Various Properties

After pH test and purification the various properties of fuel oil to calculated. Also the % yield of fuel oil to be calculate.

RESULTS AND DISCUSSIONS

Yield of Fuel Oil and Gases Product From Polymetric Waste

Temperature Range	Polymetric Waste	% Yield of Fuel Oil	% Yield of Gases
400- 450 °C	Plastic Grocery bags	70-75	25-30
425- 600 °C	Polypropylene (PP)	85-90	10-15
425- 550 °C	High Density Polyethylene	80-85	15-20
450- 500 °C	Low Density Polyethylene	90-95	5-10
450-500 °C	PET	70-75	25-30

From various literatures the yield of liquid and gases fuel product at various types of polymetric waste at different temperatures shown in above tables. Plastic Grocery bags product yield as liquid fuel oil and gases up to 75 and 25 % at temperature 400- 450 °C . Polypropylene product yield as liquid fuel oil and gases up to 90 and 10 % at temperature 425- 600 °C . High Density Polyethylene product yield as liquid fuel oil and gases up to 85 and 15 % at temperature 425- 550 °C High Density Polyethylene product yield as liquid fuel oil and gases up to 85 and 15 % at temperature 425- 550 °C . PET product yield as liquid fuel oil and gases up to 75 and 25 % at temperature 450- 500 °C .

CONCLUSIONS

Pyrolysis is a thermal decomposition process with high temperature in the absence of oxygen. Pyrolysis process is proposed by many researchers since the process is able to produce large quantity of liquid oil up to 80-90 % at temperatures around 400-500 °C. Recycling of waste polymer/plastics to derive automotive diesel oil for use to power engines. Converting plastic or polymetric waste into transport fuel through a cleaner combustion process will contribute to saving environment. Pyrolysis is an advanced technology used in disposing waste plastics. Pyrolysis is the convert plastic to oil which is environment friendly technology for disposal of plastic waste. The pyrolysis can able to converting all types of plastic/polymetric waste in to fuel like petrol, diesel, kerosene and LPG. The yield range around 85-90 % weight of the plastic converted into hydrocarbon liquid and 10-15 % of into gas product. Plastic Grocery bags product yield as liquid fuel oil and gases up to 75 and 25 % at temperature 400- 450 °C . Polypropylene product yield as liquid fuel oil and gases up to 90 and 10 % at temperature 425- 600 °C . High Density Polyethylene product yield as liquid fuel oil and gases up to 85 and 15 % at temperature 425- 550 °C High Density Polyethylene product yield as liquid fuel oil and gases up to 85 and 15 % at temperature 425- 550 °C . PET product yield as liquid fuel oil and gases up to 75 and 25 % at temperature 450-500 °C .

FUTURE SCOPE AND BENEFITS

Benefits

1. Sustainability

Recycling plastics can reduce waste plastics greatly. The generated oil can save energy and natural resources. On the other hand, as the technology improved, secondary pollution has been controlled. The entirely sealed reactor can reduce the polluted gas emission.

2. Replace Landfill

To manage plastic wastes, landfill is the most common method in most countries. However, landfill is not a sustainable method to deal with the solid waste including plastic wastes. It can not only waste large land area, it can also emit large amount of greenhouse gases to cause the air pollution. Besides, leachate from landfills is a significant environmental hazard as well. What's more, as land sources are more precious, the gate fee for landfill was increased which makes it no longer a cheap way to manage wastes. Thus, pyrolyzing plastic wastes offer a good choice to replace the landfill compared with landfill disposal.

3. Valuable Outputs

Oil, carbon black and non-condensable gas are three main products during the process. Oil, as one of the fuel sources, it can be applied in many fields. Moreover, since oil is non-renewable, transforming plastics back into oil can save resources. As for carbon black, it is more economical to be produced from tires than that from petroleum. While non-condensable gas has higher calorific value as compared to natural gas which can be used as a source of energy for the pyrolysis process. It has an enormous energy potential since the total amount of recycled waste plastics are huge.

4. Offer Job Opportunities

Pyrolysis technology can be commercialized. Once it is put into market, it can activate the local economy. Not only for the oil and carbon black market, it can also create job opportunities and lower the unemployment rate.

Existing Problems For Polymetric Waste Recycle

1. Large Variation

For a Polymer/plastic to oil facility oil is the main source of profits. While oil quality and oil yield rate are highly related to the plastic wastes composition. Like polystyrene will increase the content of aromatics in products while PET will influence oxygen atoms. Due to the large variation of plastics the quality of oil is unstable and floated.

2. Unpredictable Moisture Content & Impurities

Though there is sorting system to separate plastic wastes from others and it is unavoidable that collected plastic wastes are mixed with some impurities like metals. Those impurities that add difficulties in pretreatment of feedstock and impact the quality of products. Moisture content is the other unpredictable factor no matter caused by rains or human behaviors. High moisture content in fuel will lower the heating efficiency.

3. Residence Time and Temperature Control

Temperature and reaction rate are the key parameters for pyrolysis process but they are hard to control. Different types of plastics have different thermal behaviors under different temperature. Temperature controls the reaction rate which has impacts on the composition of products. It is necessary to make tests repeatedly to choose the most appropriate temperature for mixed plastic wastes. Same as temperature, residence time can influence the distribution of outputs. But it is temperature dependence factor which only has potential impacts when temperature is low. When temperature is under limitation which is significant to have a good control of residence time.

4. Incomplete Regulations

Plastic Recycling Plant was a quite outstanding liquefaction plant had large capacity of mixed plastics and owned a high oil yield rateIf cost on collection can be reduced and government can increase the price for such pyrolyzed oil or give some preferential price for fuels to lower the operation cost and then the plant may not be closed. The development of plastic to oil pyrolysis technology needs the support of regulations. No matter from the production of plastics or the management of plastics and each process should be normalized. The process of production pyrolysis will be much easier and more efficient if the utilization of PVC and PET can be reduced. For the process of plastic management and the plastic collection should be formalized which can offer a stable source of feedstock with good qualities.

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NOMENCLATURE

CFB - Circulating Fluidized Bed

DETB - Diesel Engine Test Bed

EGR - Exhaust Gas Circulation

HDPE - High-Density Polyethylene

MSW - Municipal Solid Waste

LDPE - Low-Density Polyethylene

Low - Density Polyethylene LDPE

PVC - Poly Vinyl Chloride

PET - Polyethylene Terephthalate

PP - Polypropylene

PS - Polystyrene

PTFE - Polytetrafluoroethylene

TCC - Thermochemical Conversion

WPPO- Waste Plastic Pyrolytic Oil