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AN OVERVIEW ON PYROLYSIS OF PLASTIC TRASHES

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ABSTRACT

Due to the many uses of plastics in a variety of industries, worldwide plastic manufacturing has grown throughout time. The constant demand for plastics resulted in the buildup of plastic trash in landfills, which took up a lot of space and contributed to the environmental issue. Because plastics are a petroleum-based substance, increased demand for plastics resulted in the depletion of petroleum as a non-renewable fossil fuel. Recycling and energy recovery methods are two options for managing plastic trash that have been explored. However, the recycling technique had several disadvantages, such as high labor costs for the separation process and water pollution, which made the practice less sustainable. As a result of these flaws, researchers have shifted their focus to the energy recovery technique to offset the high energy consumption. Plastic waste conversion to energy was created after significant study and technological development. Because petroleum was the primary source of plastic, the conversion of plastic to liquid oil via the pyrolysis process had enormous potential, as the oil produced had a high calorific value comparable to commercial fuel. The pyrolysis process for each type of plastic was reviewed, as well as the main process parameters that influenced the final end product, such as oil, gaseous, and char. Temperatures, reactor type, residence time, pressure, catalysts, fluidizing gas type, and flow rate were among the key parameters discussed in this study.

KEYWORDS: *Energy recovery, Fuel, Liquid product, Plastic wastes, Pyrolysis.*

INTRODUCTION

For much more than 50 years, plastic has played an important part in improving people's quality of living. It is essential for the development of numerous goods in a variety of industries, including construction, healthcare, electronics, automotive, packaging, and others. The increasing expansion of the global population has raised the need for commodity plastics. Plastic output peaked at about 299 million tons in 2013 and has continued to rise. The ever-increasing demand for plastic has resulted in an annual increase in trash buildup[1]. This demonstrates that the proportion of plastic trash that ended up in the landfill was still extremely high, occupying a significant amount of space. Plastics may take billions of years to naturally breakdown. They disintegrate gradually because plastic is made up of molecular bonds including hydrogen, carbon, and a few additional elements like nitrogen, chlorine, and others that make it extremely durable. Continuous landfill dumping of plastic would undoubtedly pose a significant environmental threat.

Pyrolysis is the process of using heat and pressure to break down long chain polymer molecules into smaller, less complicated ones. The procedure requires high heat for a brief period of time in the absence of oxygen. Oil, gas, and char are the three main products generated during pyrolysis, and they are important in sectors such as production and refineries. Many researchers selected pyrolysis because it produces a large quantity of liquid oil, up to 80 weight percent, at a modest temperature of 500 degrees Celsius. Furthermore, pyrolysis is very adaptable, since process parameters may be tweaked to maximize product yield depending on preferences[2]. The liquid oil generated may be utilized in a variety of applications, including furnaces, boilers, turbines, and diesel engines, without the need for further treatment or upgrading. Pyrolysis, unlike recycling, does not pollute water and is considered a green technology when the pyrolysis waste, which is gaseous, has a significant calorific value that may be utilized to offset the pyrolysis plant's total energy demand. Because it does not need an expensive sorting procedure, the process handling is also simpler and more flexible than traditional recycling methods.

1.1 Pyrolysis of plastics

Various kinds of plastics feature different compositions, which are often described in terms of their proximate analysis. Proximate analysis is a method for determining the chemical characteristics of a plastic composite using four specific elements: moisture content, fixed carbon, volatile matter, and ash content. The main variables that affect the liquid oil output in the pyrolysis process are volatile matter and ash content. High volatile matter promoted liquid oil production, while high ash content reduced liquid oil production, resulting in higher gaseous output and char formation. These features suggest that plastics have a great potential for pyrolysis to generate significant amounts of liquid oil. Because the findings of the plastics proximate analysis are so compelling, the next discussion will concentrate on the pyrolysis process factors that have a significant impact on liquid output[3].

PET (polyethylene terephthalate) has emerged as a popular plastic packaging material for a variety of food items, including drinks such as mineral water, soft drink bottles, and fruit juice containers. This is owing to its inherent characteristics, which make it ideal for high-capacity, lightweight, and pressure-resistant containers. Electrical insulation, printing sheets, magnetic tapes, X-ray and other photographic film are some of the additional uses for PET. The widespread usage of PET would result in a build-up of PET trash in landfills. The current practice for dealing with accumulated plastic waste was to recycle PET waste. However, the bulkiness of the containers results in frequent collections, which raises transportation expenses. PET trash must be separated into various grades and colors to facilitate recycling, which makes recovery inefficient and uneconomical[4]. As a result, additional options for PET recovery, such as the pyrolysis method, have been investigated, and the product yield has been evaluated by a number of researchers.

Polyethylene with a high density

HDPE is defined as a long linear polymer chain with a high degree of crystallinity and little branching, resulting in great strength. HDPE is extensively utilized in the production of milk bottles, detergent bottles, oil containers, toys, and other items because to its high tensile characteristics. The different uses account for approximately 3% of the plastic waste category, which is the third most common kind of plastic found in municipal solid trash. HDPE wastes have a lot of promise for pyrolysis since they may generate a lot of liquid depending on the setup conditions. Many research on HDPE pyrolysis at various operating settings have been performed to determine the product yield[5].

1.2. Polyvinyl chloride (PVC) is a kind of plastic.

PVC is unique because it is made up of 57 percent chlorine and 43 percent carbon, unlike other thermoplastics such as polyethylene, polystyrene, and polypropylene, which may be softened by heating and are exclusively produced from oil. PVC has a high fire resistance due to its chlorine content, making it ideal for electrical insulation. PVC is a versatile material since it may be combined with a variety of additives. Wire and cable insulation, window frames, boots, food foil, medical equipment, blood bags, automobile interiors, packaging, credit cards, synthetic leather, and other uses of PVC are common. Despite its broad range of uses, research on PVC pyrolysis has been limited in the literature owing to the hazardous chemical that it tends to produce when heated to high temperatures[6].

1.3. Polyethylene with a low density

LDPE has greater branching than HDPE, which leads in a weaker intermolecular force and therefore lower tensile strength and hardness. LDPE, on the other hand, has greater ductility than HDPE because the side branching makes the structure less crystalline and easier to shape. It has high water resistance and is therefore extensively used in plastic bags, packing foils, garbage bags, and other applications. All of these products are ubiquitous in our everyday lives, and as a result, LDPE trash has accumulated to the point that it is now the second most frequent plastic waste in MSW, behind PP. Pyrolysis of LDPE to oil product has recently garnered a lot of interest from researchers as a method to recover energy and minimize waste.

- *Polypropylene*

PP is a chemically and thermally resistant saturated polymer having a linear hydrocarbon chain. PP, unlike HDPE, does not melt at temperatures below 160 degrees Celsius. It has a lesser density than HDPE, but it has a greater hardness and stiffness, making it a better choice for the plastics sector. PP accounts for approximately 22% of the plastic wastes category, which contains the most plastics in MSW. Flowerpots, office files, vehicle bumpers, pails, rugs, furniture, storage boxes, and other items are among the many uses. Because of the increasing need for PP in everyday life, the quantity of PP wastes grows each year, pyrolysis of PP is one of the energy recovery techniques available. Several studies have looked at the pyrolysis of PP at different temperatures and pressures to determine the liquid oil production and characteristics.

- *Polystyrene*

PS is composed up of styrene monomers derived from petrochemical liquids. A lengthy hydrocarbon chain with phenyl groups linked to every other carbon atom makes up the structure. PS is colorless by nature, but it may be tinted using colorants. Its heat resistance, as well as its acceptable durability, strength, and lightweight, make it suitable for a wide range of applications, including food packaging, electronics, construction, medical, appliances, and toys. The enormous quantity of PS in MSW collected each year is reflected in the broad variety of uses. PS is unfortunately not accepted in the roadside recycling program, which only accepts glasses, papers, cans, and certain plastics[7]. Despite the fact that there is a plastic category, most individuals do not place foam food packaging in the plastics recycling bin and instead place it in the general trash. Because of its low density polystyrene foam, PS is usually not separated and is difficult to collect for recycling. As a result, the only option to completely use PS waste is to use the pyrolysis process to convert it into a more valuable oil product rather than letting it sit in landfills indefinitely.

- *Mixed plastics*

As noted previously, the pyrolysis process offers an advantage over recycling in that it does not need a thorough sorting procedure. Most plastics are incompatible with one another in the recycling process and cannot be processed together. For example, a little quantity of PVC contamination in the PET recycling stream would damage the whole PET resin, turning it yellow and brittle, necessitating reprocessing. This demonstrates that the recycling process is so sensitive to contamination that all plastics must be separated by resin type, color, and transparency. However, since liquid oil can still be generated from the mixed polymers in the feedstock, the pyrolysis method seems to be more sustainable. Several researchers who studied the pyrolysis of mixed polymers have run across this problem.

1.4. The condition of the process parameters

In every process, parameters play a critical role in maximizing product yield and composition. The generation of ultimate end products such as liquid oil, gaseous, and char may be influenced by critical process factors in plastic pyrolysis. Temperature, reactor type, pressure, residence duration, catalysts, fluidizing gas type, and rate are some of the most significant factors. Controlling the parameters at various levels may result in the desired product. The subsections that follow go through the operational settings in more detail.

- Temperature

Temperature was among the most important operational factors in pyrolysis since it affects the polymer chain's breaking response. The Van der Waals force attracts molecules together, which prevents them from collapsing. When the temperature of a system rises, the vibration of molecules within the system rises, and molecules prefer to evaporate away from the object's surface. When the energy generated by the Van der Waals force along polymer chains is higher than the enthalpy of the C–C bond in the chain, the carbon chain is broken.

1.5. Reactors' types

The kind of reactor has a significant effect on the mixing of polymers and catalysts, residence duration, heat transmission, and reaction efficiency in producing the desired end product. In the lab, most plastic pyrolysis was done in batch, semi-batch, or continuous-flow reactors such fluidized bed, fixed-bed reactor, and conical spouted bed reactor. In the next subsections, the benefits and drawbacks of each reactor will be addressed.

- *Reactors, both batch and semi-batch*

During the reaction, a batch reactor is essentially a closed system with no input or outflow of reactants or products. One of the benefits of batch reactors is that they may obtain high conversion by keeping the reactant in the reactor for a long period of time. Batch reactors, on the other hand, have the drawbacks of product unpredictability from batch to batch, high labor costs each batch, and difficulties in large-scale manufacturing.

- *Reactors with fixed and fluidized beds*

Although it is simple to construct, there are certain limitations, such as the uneven particle size and form of plastics used as feedstock, which may create problems during the feeding process. Furthermore, the reaction's access to the catalyst's accessible surface area is restricted. Several studies, however, opted to utilize a fixed-bed reactor for plastic pyrolysis.

- *Reactor with a conical spouted bed*

The CSBR (conical spouted bed reactor) offers excellent mixing and can handle a wide particle size range, bigger particles, and different particle densities. CSBR was utilized by several researchers in their plastic catalytic cracking studies. When treating sticky materials, it also had a significant heat transfer between phases and a slight DE fluidization issue. However, a number of technical issues have arisen during the operation of this reactor, including catalyst feeding, catalyst entrainment, and product collection, making it less desirable.

- *Microwave-assisted technology*

Microwave technology has recently gained popularity, and it now provides a new method for waste recovery through the pyrolysis process. A microwave-absorbent substance, such as particulate carbon, is combined with the waste products in this procedure. The microwave absorbent absorbs microwave radiation to provide enough thermal energy to reach the temperatures needed for extensive pyrolysis. Microwave radiation has many benefits over traditional pyrolysis, including faster heating, higher manufacturing speed, and cheaper prices. Microwave energy is delivered directly to the material via molecular interaction with the electromagnetic field, unlike traditional techniques, thus no time is spent heating up the surrounding region.

1.6. By-products of the plastic pyrolysis

As a by-product of the pyrolysis of plastics, char and gas are produced. In pyrolysis, many factors such as temperature, heating rate, pressure, and residence duration have a significant impact on the percentage of by-product. The following is some information on the by-products produced:

In the pyrolysis process, char production is aided by a slow heating rate at a very low temperature and a lengthy residence period. Even though char production in the rapid pyrolysis process is often minimal, the characteristics and uses of the char should be considered to fully realize the promise of plastic pyrolysis. The char characteristics produced from the pyrolysis of

HDPE plastic waste were investigated. The major components of the char were determined to be volatile matter and fixed carbon, whereas moisture and ash were minority, according to the proximate analysis.

The optimum conditions for maximizing gas generation in the pyrolysis process were gas, high temperature, and extended residence time. These circumstances, on the other hand, are diametrically opposed to the characteristics that optimize oil output.

LITERATURE REVIEW

J.F. Mastral et al. studied the scientific life at the moment bed reactor was used to catalytically breakdown high density polyethylene in order to achieve a high yield of gas fractions at moderate temperatures between 350 and 550 C. Nanocrystal line HZSM-5 zeolite was employed as the catalyst. The gas fractionation, which were mostly made up of olefins, had high yields of butanes. Waxes were entirely made up of linear and branched paraffin with C10 to C20 components. The impact of temperature and the polymer-to-catalyst proportion on product yield was investigated. When the operating temperature was modest or the polymer to catalyst ratio was high, gas conversion was significantly reduced. The gas as well as wax compositions substantially changed, indicating that a portion of the HDPE was thermally decomposed, increasing the olefin content in the waxes. Experiments with high polymer to catalysis ratios, achieving a 50 percent olefin content in the waxes, revealed the similar variance. Thermal and catalytic degradations may both be blamed for the variations in product distributions[8].

MochamadSyamsiro et al. studied the goal of this study was to look into the manufacture of fuel oil from municipal plastic trash using a series of pyrolysis and catalytic reforming methods. In Yogyakarta, Indonesia, three types of municipal plastic trash were collected from the ultimate disposal site and a small recycling business. In this research, commercial Y-zeolite and natural zeolite catalysts were utilized. The findings indicate that feedstock types have a significant impact on product yields and quality of liquid and solid outputs. The liquid percentage from HDPE trash was the highest. The addition of catalysts decreased the liquid fraction while increasing the gaseous fraction. In addition, pyrolysis of municipal plastic wastes generated greater heating value solid products than biomass and relatively low level coal[9].

Yusaku Sakata et al. studied the thermal decomposition of polymeric polymers into fuel oil in the presence of a mesoporous silica accelerator has been studied. The yields, composition, frequency rate of degradation of polyethylene using KFS were compared to those obtained using a solid acid catalyst and non-catalytic heat degradation. PE degraded just as quickly over KFS, which has no acid sites, as it did over silica–alumina, and the output of liquid products was greater. These results indicate that the mesoporous enclosed by the silica sheet may serve as a flask for keeping radical species for a long period, and that long-lived radicals therefore accelerate the breakdown of polymers[10].

DISCUSSION

This analysis revealed that many studies have been conducted to examine the possibility of the plastic pyrolysis process for producing valuable goods such as liquid oil, with promising findings. This method has many benefits, including improving waste management, decreasing reliance on fossil fuels, expanding energy sources, and preventing environmental pollution. The method may be used with a variety of settings, resulting in a variety of liquid oil production and quality. Aside from that, this method provides more flexibility and economic feasibility in terms of process management and product variability. At various circumstances, summarized the optimal temperature needed to maximize liquid oil production in thermal and catalytic pyrolysis. The kind of reactors, pressure, heating rate, and pyrolysis time for each form of plastic are also impacted. The fluidizing media used in all of the tests was nitrogen gas.

CONCLUSION

This study offered a brief overview of plastic pyrolysis for each kind of plastic, as well as a discussion of the key influencing factors for optimizing liquid oil production. According to studies in the literature, most researchers selected the pyrolysis process because of its ability to convert the most energy from plastic trash into useful liquid oil, gaseous, and char. As a result, it is the greatest option for converting plastic waste and is also the most cost-effective in terms of operating. Adjusting the settings to obtain the flexibility it offers in terms of product choice is possible. Pyrolysis may take place in a thermal or catalytic process. With the appropriate catalyst selection, the catalytic process offered a lower operating temperature and a higher output of liquid oil for most polymers. The process's long-term viability is clear, given that the quantity of plastic trash accessible in each nation is in the millions of tons. Waste management becomes more efficient using the pyrolysis technique, which requires less landfill capacity, produces less pollution, and is also more cost effective. Furthermore, because of the availability of the pyrolysis technique for decomposing plastic into useful energy fuel, the reliance on non-renewable energy sources such as fossil fuels may be decreased, thus alleviating the increase in energy demand.

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